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Integretad solutions for Sustainable and Smart Buildings & Cities

SBE16 ISTANBUL

International Conference on Sustainable Built Environment

Organized by

TÜRKİYE İMSAD
İNŞAAT MALZEMESİ SANAYİCİLERİ DERNEĞİ
ASSOCIATION OF TURKISH CONSTRUCTION MATERIAL PRODUCERS

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Preface

As Türkiye İMSAD, we are undersigning an important event on behalf of our country and our industry. We are pleased to be organizing the International Sustainable Built Environment Conference, held in more than 50 countries across the world since 2000, for the first time in Turkey.

During the SBE16 ISTANBUL Conference that we organized to discuss and share the ideas, solutions, methods and techniques for a sustainable future, we talked about international vision of Turkey within the context of climate change.

As Türkiye İMSAD, we emphasize the importance we attach to sustainability on every platform. We support this not only verbally but also with our actions. As you know, in 2014, we shared our Sustainability Report with public. It is the first report around the world which has been prepared according to GRI4 format by a non-governmental organization. During the SBE16Istanbul Conference, we launched our second Sustainability Report.

On the other hand, to bring a common understanding and discourse to the industry on the concept of sustainability, we prepared the "Sustainable Construction Materials Glossary" in 2015. Each year, during the International Quality in Construction Summits which has been one of the largest meeting platforms for the industry for the last 7 years, we made sure to held sessions and presentations emphasizing sustainability. In the 7th International Quality in Construction Summit that we held in 2015, as members of Türkiye İMSAD, we made a "Sustainability Promise" by disclosing our Sustainability Parameters. We took the initial steps for the subjects that will be addressed in the conference we held this year with the theme "Changing World Emerging Materials".

In the conference, which we set the main theme as "Smart Metropoles - Integrated Solutions for Sustainable and Smart Buildings & Cities", we talked about the structures and the cities of tomorrow. A wide range of participants ranging from private sector representatives to academics, from non-governmental organizations to representatives of public had the opportunity to present 113 papers in 30 the sessions as well as presentations of 40 invited speakers. Studies done abroad and in our country on many subjects like sustainable future, climate change, smart and green buildings / cities, our present situation as a country, our problems and solution proposals were discussed and deliberated. In the workshop that was organized to determine the issues that the industry, public and universities should focus on regarding Sustainable Built Environment, all the parties came together and made an open discussion on the subject and presented their solution proposals in the Closing Session.

The International Sustainable Built Environment Conference that was held for the first time in our country also contained many firsts for our industry in many ways. Taking the opportunity, I would like to express my gratitude towards all who contributed to the conference, the authors who contributed with their papers, and our invited speakers.

We, as Turkiye İMSAD, look confidently to the future of our country. We are working for the development of the economy of our country and our industry. In the coming period, we will always continue to do our part.

F. Fethi Hinginar
President of the Organizing Committee SBE16 ISTANBUL
Chairman of the Board of Directors Türkiye İMSAD

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Speaker Profiles

Dr. Ahmet Çıtıpıtıoğlu

TAV Construction, Engineering and Design Director

TAV İnşaat, Mühendislik ve Tasarım Direktörü

Dr. Çıtıpıtıoğlu has been involved in the design, construction and technical operations of several high performance facility structures, from nuclear power plants, airport terminals, and high-rise buildings around the world. While working on several large airport projects at TAV, he has been leading the implementation of advanced design and construction coordination tools used at all phase of the built environment - design through facilities management. His experience at all phases of large projects gives him a unique perspective at the very start of a project with knowledge and foresight of the needs of operation. With more than 20 years of industry and consulting experience, Dr. Çıtıpıtıoğlu is a Registered Professional Engineer in the State of California. Having lectured engineering courses for several years he continues to give lectures on Design and Engineering and actively publishes technical papers.

*****

Dr. Ahmet Çıtıpıtıoğlu, geniş bir coğrafyada nükleer santral, havalimanları ve yüksek yapılar gibi performanslı yapıların tasarım, yapım ve teknik işletmelerinde rol almıştır. TAV İnşaat firmasında çok sayıda havalimanı projelerinde tasarım ve yapımında rol alırken, projelerin bitiminde teknik işletmelerinde deneyim sahibi olmuştur. Bu deneyim ile projelerin erken evrelerinde işletme ihtiyaçlarını da gözetebilecek özgün bir bakış açısı kazanmıştır. Bu sayede tasarım, inşaat ve işletmeye uzanan tüm evrelerde ileri tasarım ve koordinasyon araçların kullanımı ve iş-akışların kurgulanmasında öncülük etmiştir. ABD'nin California eyaletinde Yetkin Mühendis olan Dr. Çıtıpıtıoğlu'nun 20 yıldan fazla endüstri ve danışmanlık deneyimi bulunmaktadır. Halen deneyim sahip olduğu alanlarda aktif olarak akademik ve profesyonel çalışmaları devam etmektedir.

Birgit Rusten

FutureBuilt Program Manager

FutureBuilt Program Yöneticisi

Birgit Rusten is the program manager of FutureBuilt. FutureBuilt is a program with the aim of developing 50-100 pilot projects with at least 50 percent reduced climate footprint. The pilots are different kind of building typologies and city areas. Birgit Rusten initiated FutureBuilt together with her colleague Stein Stoknes in 2008, when they worked for The National Association of Norwegian Architects. The program was formally established in 2010 and will run until 2020. The pilot projects are meant to inspire and change practice in both the private and the public sector. FutureBuilt is a collaboration between 10 partners: the city of Oslo and 3 neighbouring cities, 4 national authorities, the developer organization the Green Building Alliance and the National Association of Norwegian Architects. Birgit Rusten has worked with architecture, sustainability and pilot projects since 2003 and she has worked with sustainability within public sector since 1986. Birgit Rusten has a masters degree in biology and planning from the University in Trondheim in 1986.

*****

Birgit Rusten 1986'da Trondheim Universitesi'nde biyoloji ve planlama alanında master derecesini almıştır. Bu dönemde kamuda sürüdülebilirlik alanında çalışmıştır. 2003 yılından beri ise mimarlık, sürdürülebilirlik ve ilgili pilot projeler üzerinde çalışmaktadır. Birgit Rusten FutureBuilt'in program yöneticisidir. Future Built, iklim dostu binaları ve şehirleri geliştirmek için 50-100 pilot projeyi tasarlamayı ve iklim ayakizini %50 oranında azaltmayı amaçlamaktadır. Söz konusu pilot projeler, farklı bina tipleri ve şehirlerde gerçekleştirilecektir. Birgit Rusten FutureBuilt projesinin temellerini 2008 yılında Ulusal Norveç Mimarlar Birliği'inden çalışma arkadaşı Stein Stoknes ile birlikte oluşturmuştur. Proje 2010 yılında başlamış olup 2020 yılına kadar devam etmesi planlanmaktadır. Projede hedeflenen pilot projelerin temel amacı, gerek özel sektörde gerekse kamuda binaya ve şehirlere karşı konvansiyonel bakış açısını değiştirmektir. Projenin ortakları; Oslo şehri ile birlikte komşu diğer 3 şehir, 4 adet yerel otorite, Yeşil Binalar Birliği ve Ulusal Norveç Mimarlar Birliği'dir.

Gordon Falconer
Schneider Electric Global Director, Smart Cities
Schneider Electric Akıllı Şehirler Global Direktörü

Gordon is Director of Smart Cities for Schneider Electric and is a former Director of Cisco, Urban Innovation and also the former Head of Masdar City Real Estate & Strategy. He is a smart city expert, city consultant, global thought leader in cities, technology clusters, property & infrastructure developer, city developer, and chartered surveyor.

He has more than 20 years of experience in urban innovation, smart city consulting, innovation cluster creation, smart city pilots, urban development, sustainable property development, utility and infrastructure development.

Gordon has worked heavily in the urban environment on cities and city scale projects globally for the last 4 years with Cisco Systems as a trusted advisor to both the public and private sectors, NGO's, government leaders with including World Bank and European Commission. In Singapore, he is an advisor to Government agencies & R&D panels and in the UK he is an advisory board member of University College London's City Leaders programme. He is also on the Advisory Board for the Barcelona Institute of Technology & Habitat.

Gordon brings a strategic understanding and economic development perspective to smart cities and urban development given his background in property development and city / urban development. He was formerly head of strategy and real estate for Masdar City, one of the world's most innovative Greenfield and sustainable city projects in Abu Dhabi. During this time, he was heavily involved with strategy for both sustainable real estate and sustainable utility integration in the areas of clean energy, water, infrastructure, information and communications technology, (ICT), and ICT financing. In particular, he was involved with the development of Masdar City as an economic cluster to drive foreign direct investment and economic diversification.

Gordon was also Vice President, Asset Management Real Estate, at The National Investor, a leading Abu Dhabi Investment Bank. He also held executive positions at Jones Lang Lasalle and CB Richard Ellis in Australia. In 2013 he was ranked No.47 by UBM Future Cities in their Top 100 City Innovators index. Based in Singapore, Gordon is also engagements with cities, governments, and corporations in South East Asia, India, and internationally. He is a member of both The Australian Property Institute and the Royal Institute of Chartered Surveyors.

*****

Gordon Falconer, Schneider Elektrik bünyesinde Akıllı Şehirler Direktörü olarak çalışmaktadır. Daha önce, Cisco, Kentsel Innovasyon Direktörlüğü'nün yanısıra Abu Dabi'de bulunan ve dünyadaki sayılı yeşil, innovatif ve sürdürülebilir şehir projesi olan Masdar Şehri Gayrimenkul ve Strateji Bölümü yöneticiliği de yapmıştır. Bu dönemde, temiz enerji, su, altyapı, bilgi ve iletişim teknolojileri (ICT) ve finansmanı alanları ve bu alanların birbirleri ile bütünleşik olarak ele alınması üzerine çalışmıştır. Böylellikte Masdar şehrinin yabancı yatırımcılar ile ekonomik portfolyosunun geliştirilmesi ve çeşitlendirilemesi hedeflenmiştir. Ayrıca, Abu Dabi Yatırım Bankası'nda yerli yatırımcıların gayrimenkül varlık yönetimi ile ilgili biriminde Başkan Yardımcılığı görevinde de bulunmuştur.

Gordon Falconer, akıllı şehir uzmanı, şehir danışmanı, altyapı ve şehir geliştiricisidir. kentsel innovasyon, akıllı şehir danışmanlığı, sürdürülebilir emlak/malk-mülk yönetimi, kamu ve altyapı gelişimi alanlarda 20 yılı aşkın tecrübesi bulunmaktadır.

Son 4 yıl içinde, aralarında Dünya Bankası ve Avrupa Komisyonu'nun bulunduğu birçok kamu/özel sektör kurumlarında Cisco Sistemleri ile kent ölçekli küresel projelerde danışmanlık yapmıştır.

Singapur'da çeşitli kamu ve AR-GE ajanslarında, İngiltere Kolej Üniversitesi Londra Şehri Liderleri programında ve Barselona Teknoloji ve Habitat Enstitüsü'nde danışmanlık yapmaktadır.

2013'te UBM Gelecek Şehirler Top 100 Şehir İnnovatörü arasında 47. Sırada yer almıştır. Ayrıca, Avusturalya Emlak ve Yeminli Araştırmacılar (mimar ve mühendis) Kraliyet Enstitüsüleri'nde üyelikleri bulunmaktadır.

Gökhan Yıldırım

WSEIN - World Sustainable Energy Institute - President

Dünya Sürdürülebilir Enerji Enstitüsü (WSEIN) Başkanı

After graduating from Yıldız Technical University Istanbul, Turkey, Gokhan Yıldırım got his master's degree from Technical University Vienna, Austria.
He is an expert on Integrative Traffic Planning and Sustainable Municipality Management, i.e. Zero Emission Cities, Green Buildings, Intelligent City Planning, Waste Management and Efficient Energy Solutions with Renewable Energy. He believes he is a bridge between West and East, supports companies all over the world in the area of renewable energy and environmental technologies.
Gökhan YILDIRIM was selected to represent Turkey in Austria with DEIK - DTIK World Turkish Business Council - Member of Europe Region from Austria in 2012 and in 2013 he established WSE - INITIATIVE with more than 70 countries. In 2014 he was selected to be the president of the WSEIN - World Sustainable Energy Institute based in Vienna.

*****

Lisansını Yıldız Teknik Üniversitesi'nde ve yüksek lisansını Viyana Teknik Üniversitesi'nde tamamlayan Gökhan Yıldırım, bütünleşik trafik planlaması, ulaşım planlaması ve yerel yönetimlerin bu konularda desteklenmesi gibi alanlarda çalışmalarını yürütmektedir.
2010 yılında Dünya Türk İş Konseyi (DEIK-DTIK) Avrupa Bölgesi üyesi olduktan sonra, sırasıyla 2013 yılında Dünya Sürdürülebilir Enerji Girişiminin (World Sustainable Energy Initiative – WSEI) ve 2014 yılında da Dünya Sürdürülebilir Enerji Enstitüsü'nün (World Sustainable Energy Institute – WSEIN) kurulmasında görev almıştır. Halen WSEI Küresel Direktörü ve WSEIN Başkanı olarak görev yapmaktadır.

Mahir Tosun

Siemens Wind Power and Renewables, Technical Sales Manager

Siemens Rüzgar Enerjisi ve Yenilenebilir Enerji, Teknik Satış Müdürü

Mahir Tosun was graduated from the Department of Mechanical Engineering, Dokuz Eylül University in 2002 and having a Master of Science degree in Energy Engineering from Izmir Institute of Technology. He started his career as Research Assistant and focused on Renewables. Afterwards he has worked as Project Coordinator in an Energy Investment company. Since 2010 he joined Siemens, and still working as Technical Sales Manager in Siemens Wind Power and Renewables.

*****

Mahir Tosun 2002 yılında Dokuz Eylül Üniversitesi Makina Mühendisliği bölümünden mezun olduktan sonra İzmir Yüksek Teknoloji enstitüsünde Enerji Mühendisliği yüksek lisansını tamamlamıştır. Araştırma görevlisi olarak başladığı çalışma hayatında yenilenebilir enerji alanına odaklanmış sonrasında Enerji yatırımları yapan bir şirkette proje koordinatörlüğü yapmıştır. 2010 yılında katıldığı Siemens Rüzgar Enerjisi ve Yenilenebilir Enerji Bölümünde halen Teknik Satış müdürü olarak çalışmaktadır.

Right after having studied at Waseda University in Tokyo, Japan, he began his professional career at Agence Candilis in Paris (1973) as a French Government Scholarship Intern, and co-founded his own architectural design office "AG5" in Darmstadt, Germany (1977). Then, after returning home, he founded IWAMURA Atelier Inc. in Tokyo, (1980), specialized in the holistic sustainability of architectural and urban design.
He received many awards so far including UN World Habitat Award 2001, AIJ Prize 2003 and JIA Environmental Architecture Prize in 2003 and 2014. Also he wrote 17 books of related themes to date.
He has been serving as Professor at Tokyo City University since 1998, and became Professor Emeritus in 2014, contributing in-between to numerous other universities and professional organizations world-wide including UIA, ARCASIA, WGBC, JIA etc., as vice-president, councillor or director.
Currently he is CEO of IWAMURA Atelier Inc., and Visiting Professor at Chu Hai College of Higher Education in Hong Kong. Contact: iwamura@iwamura-at.com

Kazuo Iwamura

IWAMURA Atelier Inc. - CEO

IWAMURA Atelier Inc. - Kurucu

*****

Kazuo Iwamura, Tokyo'da Waseda Üniversitesi'nden mezun olduktan sonra Fransız hükümetinin verdiği bursla Paris'te Agence Candilis'de 1973 yılında kariyerine başlamıştır. 1977 yılında Almanya'da Mimari tasarım ofisi A65'i kurmuştur. 1980 yılında ise Tokyo IWAMURA ATEILER şirketini kurmuştur.
Mimari ve kentsel bütünsel sürdürülebilirlik konusunda uzmanlaşmıştır. 2003 yılında Dünya Habitat ödülü, AIU 2003 Ödülü, JIA Çevre Mimarlık ödülleri de dahil olmak üzere birçok ödül almıştır. Ayrıca 2014 yılına kadar 17 kitap yazmıştır. 1988-2014 yılları arasında Tokyo CITY Üniversitesi'nde Profesör olarak görev yapmıştır. Bu dönem boyunca, diğer üniversiteler ile birlikte UIA, ARCASIA, WGBC, JIA dahil olmak üzere birçok organizasyonda çeşitli pozisyonlarda görev yapmıştır. Halen IWAMURA ATELIER'in Yönetim Kurulu Başkanlığı görevini sürdürmektedir.

Since 2011, Oliver Rapf is Executive Director of BPIE, the Buildings Performance Institute Europe, a Brussels based think-tank with a focus on energy and the built environment. Before joining BPIE, Oliver worked for the global conservation organization WWF in various roles, including as Head of the Climate Business Engagement unit of WWF International, managing strategy and partnership development with the private sector. Leading an international team, he advised multinational companies on climate change and energy issues.

*****

2011 yılından beri, Avrupa Bina Performansı Enstitüsü'nün Direktörü olarak görev yapmaktadır. Enerji ve yapılı çevre odak konuları arasında bulunmaktadır. BPIE bünyesine katılmadan önce, Dünya Doğayı Koruma Fonu (World Wildlife Fund – WWF)'nda iklim değişikliği ile ilgili birimin başkanı olarak çalışmıştır. Almanya konut şirketleri ile birlikte çeşitli detaylı iyileştirme projelerinin yürütücüsü olmuştur. Ayrıca, Birleşmiş Milletler İklim Değişikliği Çerçeve Sözleşmesi (United Nations Framework Convention for Climate Change – UNFCCC) çalışmalarında Almanya sivil toplum kuruluşlarını temsilen katkıda bulunmuştur. Halen çevre ve sürdürülebilirlik alanlarında jüri üyeliği yapmaktadır.

Oliver Rapf

BPIE, The Buildings Performance Institute Europe – Executive Director

Avrupa Bina Performansı Enstitüsü (BPIE) - Direktör

Murat Sungur Bursa

Sustainability Academy Chairman

Sürdürülebilirlik Akademisi Yönetim Kurulu Başkanı

Free-lance consultant in the fields of sustainability, environment, environmental impact assessment, renewable energy, energy strategy and investments. Presently conducting a study to identify measures in order to minimize seismic risks to ensure business continuity in Istanbul after an earthquake. Bsc - Mechanical Engineering; MBa -Production Management. He worked as founding manager at Small and Medium Enterprises Development Organization and Ministry of Environment during early years of their establishment. He served at the State Planning Organization of Turkish Prime Ministry. He was the Director of Marmara Earthquake Rehabilitation Projects. Between 2006 and 2012 he was the CEO of Zorlu Energy Group of Companies.

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Sürdürülebilirlik, Çevre, Çevresel Etki Değerlendirmesi, Yenilenebilir Enerji, Enerji stratejileri ve Yatırımları alanlarında serbest danışmanlık yapmaktadır. Halen olası bir depremde İstanbul'daki İş Devamlılığı konusundaki risklerin azaltılmasına yönelik bir çalışma yürütmektedir. ODTÜ Makina Mühendisliği eğitimi sonrasında, KOSGEB (Küçük ve Orta Ölçekli Sanayii Geliştirme İdaresi Başkanlığı) ve Çevre Bakanlığı'nda kurucu dönem yöneticiliği yaptı. Bir dönem Devlet Planlama Teşkilatı'nda çalıştı. Başbakanlık'ta Marmara Depremi Rehabilitasyon Projeleri Direktörlüğü yaptı. Daha sonra 2006-2012 arasında özel sektörde Zorlu Enerji Grubu Başkanlığı görevini yürüttü. 2008-2012 döneminde Dünya Bankası Global Afet Riski Azaltma Sonuç Yönetimi Kurulu üyeliği yaptı.

Rıfat Ünal Sayman

Regional Environmental Centre (REC) Country Office Turkey – Director

Bölgesel Çevre Merkezi (REC) Türkiye – Direktör

Since 2002, Sayman has built broad knowledge on various environmental topics, including nature protection, climate change, and sustainable cities through active involvement in more than 50 international and national projects. He developed sound decision-making and strong leadership skills; as well as profound skills in analysis of key points and numerical information. He acts as national coordinator for various environmental initiatives. He wrote several reports and articles. Since 2013, Sayman is Director of the Regional Environmental Center (REC) Country Office Turkey. In this position, he led and oversee staff, projects and operations of the office.

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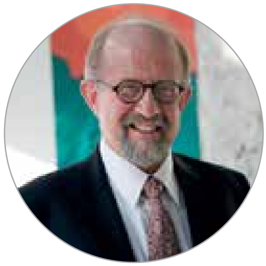
Rıfat Ünaal Sayman, Kamu Yönetimi lisans eğitimini Hacettepe Üniversitesi'nde, Uluslararası İlişkiler yüksek lisansını ODTÜ'de tamamlamıştır. REC Türkiye Direktörü olarak, kuruluşun yürüttüğü projelerin geliştirme, uygulama ve değerlendirme aşamalarına liderlik etmektedir. Çevre ve sürdürülebilirlik konularında 50'den fazla projenin yürütülmesine aktif dahil olmuştur. "Politika Analizi" ve "Etki Analizi" konularında uzmanlık geliştirmiştir. 2 sene Macaristan'da çalışan Sayman'ın, Avrupa'nın birçok ülkesinde katıldığı proje ve etkinlikler olmuştur. Sayman, AB tarafından finanse edilmiş "Türkiye'de Çevre Yönetimi için Kurumsal Kapasitenin Geliştirilmesi" (ÇEKAP) projesi direktörü, Avrupa Birliği Çevre Ödülleri (ABÇÖ) programının Ulusal Koordinatörü ve REC Türkiye ile Boğaziçi Üniversitesi Yaşamboyu Eğitim Merkezi'nin ortaklaşa yürüttüğü Kurumsal Sürdürülebilirlik Sertifika Programı'nın (KSSP) direktörüdür.



Pınar Mengüç

Özyeğin University - Center for Energy, Environment and Economy Director

Özyeğin Üniversitesi - Enerji, Çevre ve Ekonomi Merkezi Direktörü

Professor Mengüç has completed his BS and M.S. degrees at the Middle East Technical University (METU), in Ankara, Turkey. He has received his PhD in Mechanical Engineering from Purdue University, Indiana, USA in 1985. He joined the faculty at the University of Kentucky the same year, and was promoted to the ranks of associate and full professor in 1988 and 1993, respectively. In 2008, he was named as the Engineering Alumni Association Professor at the University of Kentucky.

Professor Mengüç was a visiting professor at the Universita degli Studi "Federico II," in Napoli, Italy in 1991, and at Massachusetts General Hospital/Harvard University in Boston during 1998-1999 academic year. In 2006, he was recognized as an Honorary Professor at ESPOL (Escuela Superior Politécnica del Litoral'), Guayaquil, Ecuador. He served as the founding director of the Nano-Scale Engineering Certificate Program at the University of Kentucky.

Prof. Dr. Mengüç authored/coauthored more than 115 refereed journal articles and more than 170 conference papers, and two books. He has four assigned and three pending patents, and has guided more than 50 MS and Ph.D. students and post-doctoral fellows. He is the Editor-in-Chief of Elsevier Journal of Quantitative Spectroscopy and Radiative Transfer.

Since early 2009, Mengüç is at Ozyegin University in Istanbul as the Founding Head of Mechanical Engineering Program and the Director of Center for Energy, Environment, and Economy. Professor Mengüç has received the Knowledge Transfer Award and the Outstanding Researcher Award from Ozyegin University in 2014 and 2015, respectively. He is a fellow of the American Society of Mechanical Engineers and the International Center for Heat and Mass Transfer, and a Senior Member of Optical Society of America.

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Makina Mühendisliği lisansını ve yüksek lisansını ODTÜ'de, doktorasını ise 1985'te Purdue Üniversitesi'nde Makina Mühendisliğinde tamamladı. Aynı yıl Kentucky Üniversitesi'nde yardımcı doçent olarak göreve başladı, 1988'de doçent ve 1993'te profesör oldu, 2008 yılında da Engineering Alumni Association profesörlüğüne getirildi.

1991'de İtalya'da Universita degli Studi "Federico II"de ve 1998-1999 arasında da Boston'daki Massachusetts Hastanesi/ Harvard Üniversitesi'nde ziyaretçi profesör olarak görev yaptı. 2006'da Ekvator'daki Escuela Superior Politécnica del Litoral'den (ESPOL) şeref profesörlüğü ünvanını aldı. Kentucky Üniversitesi'nde Nanoteknoloji Şemsiye Programı'nın (UPoN) koordinatörlüğünü ve Nanoboyut Mühendisliği Sertifika Programı (NECP) direktörlüğünü yürüttü.

Prof. Dr. Mengüç'ün dört patenti, üç patent başvurusu, 115 de fazla uluslararası hakemli dergi makalesi, 170'den fazla konferans bildirisi, ve ortak yazarlı iki kitabı bulunmaktadır. Journal of Quantitative Spectroscopy and Radiative Transfer dergisinin asil editörü olan Prof. Dr. Mengüç, bugüne kadar 50'den fazla yüksek lisans, doktora ve doktora sonrası araştırmacı ile çalışmıştır.

Makina Mühendisliği lisans programı kurucu profesörü olarak 2009 yılı başında Özyeğin Üniversitesi'ne katılan Prof. Dr. Mengüç, aynı zamanda Enerji, Çevre ve Ekonomi Merkezi Direktörlüğü'nü yürütmektedir. 2014 ve 2015'de Özyegin Üniversitesi Bilgi Transferi ve En İyi Araştırmacı ödüllerini kazanan Prof. Dr. Mengüç, Amerikan Makina Mühendisleri Odası (ASME) şeref üyesi (fellow), ve Optical Society of America özel üyesidir.

Prof. Robert Lowe

University College London (UCL) Energy Institute – Director

UCL-University College London Enerji Enstitüsü–Direktor

Robert Lowe is a physicist with a broad interest in the field of buildings, energy and sustainability, and in the role of research in the transformation of building energy performance. He joined UCL as Professor of Energy and Building Science in 2006. In 2009, with Prof Tadj Oreszczyn, he established the UCL Energy Institute, which he now directs. Since 2008 he has been Director of the London-Loughborough Doctoral Research Centre in Energy Demand, and from 2012-14 he chaired the SAP Scientific Integrity Group. Among his other projects, he is a co-investigator on UCL-Energy's Centre for Energy Epidemiology, one of six EPSRC-funded Energy End-use Demand Centres, and Director of a DECC funded project on the field performance of domestic heat pumps. He sits on the Board of the BBA, and the Advisory Council of the National Energy Foundation

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Robert Lowe bir fizikçi olarak bina fiziği, enerji sistemleri, sürdürülebilirlik ve özellikle bina enerji performansı, enerji ekonomisi ve yaratıcı inşaat konularında çalışmalarını sürdürmektedir. 2006 yılında Profesör olarak çalışmaya başladığı University Collage London (UCL)'da 2009 yılında Prof. Tadj Oreszcyn ile birlikte Enerji Enstitüsü'nün kurulmasına öncülük etmiştir ve halen Enstitü'de Direktör olarak görev yapmaktadır. Aynı zamanda, Mühendislik ve Fizik Bilimleri Araştırma Konseyi tarafından desteklenen UCL Enerji Epidemolojisi Merkezi'nde araştırmacı ve İngiliz Ulusal Enerji Kurumu'nda üyelik görevlerini de yürütmektedir.

Sven - Olof Ryding

Eco Platform – Chairman

Eco Platform – Yönetim Kurulu Başkanı

Sven – Olof Ryding is an Associate Professor in System Ecology at the University of Uppsala. He has held several positions with regard to scientific work such as Associate Professor at the University of Linköping and Head of Research and Head of Department at the Swedish Environmental Research Institute, IVL. He has been leading operational work as Senior Environmental Advisor at the Confederation of Swedish Enterprises and Managing Director for the Swedish Environmental Management Council. He has been engaged in several international co-operations with regard to sustainable development within EU, UN and bilateral work around the world. At the moment he is the chairman of the ECO Platform. The objective of ECO Platform is the development of verified environmental information of construction products, in particular type III declarations called EPD (Environmental Product Declarations)

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Sven – Olof Ryding, Uppsala Üniversitesi'nde Sistem Ekolojisi alanında doçent olarak görev yapmaktadır. Aynı Şekilde Linkoping Üniversitesi'nde doçentlik ve İsveç Çevre Araştırma Enstitüsü'nde Araştırma Başkanlığı ve Bölüm Başkanlığı görevlerinde bulunmuştur. İsveç Çevre Yönetimi Konseyi'nde Direktör, İsveç Şirketler Konfederasyonu'nda ise kıdemli çevre danışmanı olarak çalışmıştır. Gerek Avrupa Birliği gerekse Birleşmiş Milletler'de sürdürülebilir kalkınma ile ilgili birçok uluslararası işbirliği çalışmaları gerçekleştirmiştir. Halen inşaat malzemelerinin çevresel etkileri ile ilgili belgelendirmelerin gelişimini amaçlayan Eco Platformun Yönetim Kurulu Başkanıdır.Rüzgâr Enerjisi ve Yenilenebilir Enerji Bölüm yöneticisi olarak görev yapmaktadır.

He was born in Erzurum, in 1971. He graduated from high school, He was entered the university exams and earned a place in Atatürk University of Medicine. After his graduation from medical school,He started a life as a doctor. In 1997, He opened the Tuzla Diagnostics and Treatment Center.He was also a part of the founding of Turkey's Justice and Development Party. He started his life in politics as the first mayor of Tuzla district of Istanbul, and acted as the head representative of Justice and Development party for 7 years. He has been the mayor of Tuzla since 2009.

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1971 yılında Erzurum'da doğdu. Atatürk Üniversitesi Tıp Fakültesi'nden mezun oldu. Mezun olduktan sonra, doktor olarak meslek hayatına atıldı. 1997 yılında Tuzla'da kurduğu Tuzla Teşhis ve Tedavi Merkezi ile özel sektörde hizmete başladı. Adalet ve Kalkınma Partisi'nin kuruluş çalışmalarında yer aldı. İstanbul Tuzla Kurucu İlçe Başkanı olarak siyasete ilk adımını attı ve 7 yıl AK Parti Tuzla İlçe Başkanlığı görevini yürüttü. 2009 yılından beri 2 dönemdir Tuzla Belediye Başkanı olarak görev yapıyor.

Şadi Yazıcı

Tuzla Municipality - Mayor

Tuzla Belediye Başkanı

Daniel Kazado is graduated from Istanbul Technical University Mechanical Engineering Department at 1998. He has worked at Ekin Project firm from 1999 to 2012 as Project Manager, Project Coordinator, and BIM Manager, respectively. Kazado, who has done many significant projects such as Doha International Airport (Qatar), Sofia International Airport (Bulgaria), Palm Island Shoreline Apartments (Dubai), and Zorlu Center (Istanbul), is currently working at ProCS Professional Construction Solutions as Managing Partner & BIM Consultant.

Daniel Kazado approved himself at BIM system and also has Construction Contracts and Dispute Resolution Certificate and Contract Administration Certificate (FIDIC).

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Daniel Kazado, 1998 yılında İstanbul Teknik Üniversitesi Makina Mühendisliği bölümünden mezun oldu. 1999 yılından 2012 yılına kadar Ekin Proje firmasında sırasıyla Proje Müdürlüğü, Proje Koordinatörlüğü ve BIM Müdürlüğü yaptı. 13 yıllık Ekin Proje kariyerine Doha Uluslararası Havalimanı (Katar), Sofya Uluslararası Havalimanı (Bulgaristan), Palm Island Shoreline Apartmanları (Dubai) ve Zorlu Center (İstanbul) gibi birçok önemli projeyi sığdıran Kazado, iş hayatına ProCS Professional Construction Solutions firmasında Yönetici Ortak ve BIM Danışmanı olarak devam etmektedir.

İnşaat Sözleşme ve Uyuşmazlık Çözümü ile İnşaat Sözleşme Yönetimi sertifikaları bulunan Daniel Kazado kendisini BIM sistemleri alanında da kanıtlamıştır.

Daniel Kazado

ProCS -Professional Construction Solutions Partner & BIM Consultant

ProCS -Professional Construction Solutions Yönetici Ortak & BIM Danışmanı

Selçuk Avcı

Avcı Architects

Avcı Mimarlık

Born in 1961, Selçuk Avcı is the founder of Avci Architects, which has offices in London and Istanbul, and founding partner of Urbanista Real Estate Consultancy Co. The first company privately owned by him was established in the year of 1989 in London, with the name of Avci Jurca Architects which later on was turned into a multidisciplinary design-leading studio with offices in London, Istanbul, Budapest and Belgrade.

Having gained vast personal experience in the design and management of wide-ranging programs related to housing industry, business sector, offices, retail, arts, sports, airport design, health services and higher education institutions, Avcı put his signature to many projects driven by an architectural understanding that gives particular importance to ecologic design and energy saving.

Avcı has thought architecture lessons at Architectural Association of London, at TU of Delft and at Fakulteta za Arhitekturo of Ljubljana. He directed a studio at Architecture Department of Bilgi University in Istanbul and thought studio lessons at Istanbul Technical University. Currently, from time to time, he gives workshop lessons and conferences on ecological design.

With the projects it managed and with his compositions executed, he has won numerous national and international prizes. His works have been published in several journals. The most notable one among these publications is that his company, Avcı (Jurca) Architects, was listed in “England’s Most Promising 50 Companies Guide”. In the year 1989, Avcı won his first grand prize as design director in the European Union Energy Saving Architecture competition. In 1998, he won the RIBA Regional Award with the projects he completed during his position as design director at Energy Conscious Design Architects in London. The Turkish Contractors Union Building in Ankara conceptualized by Avcı was awarded as the “Best International Project” by Building Magazine in London. The same project was elected as the “Best Architectural Project” at Sign of the City Awards in 2014. The Turkish Contractors Union Building also won the “Construction Award” at 11th Architecture Awards organized by the Turkish Association of Architects in Private Practice. Later on, with its sustainability properties, the project qualified to receive LEED Platinum Certification.

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1961 yılında doğan Selçuk Avcı, Londra ve İstanbul'da yerleşik olan Avcı Architects'in kurucusu ve Urbanista Gayrimenkul Danışmanlık Şirketi'nin kurucu ortağıdır. Ekolojik tasarım ve enerji tasarrufunu ön planda tutan mimari anlayışıyla birçok projeye imza atan Avcı, Londra'da Architectural Association'da, Delft'de TU'da, Ljubljana'da Fakulteta za Arhitekturo'da mimarlık dersleri verdi. Avcı, İstanbul'da Bilgi Üniversitesi Mimarlık Bölümünde stüdyo yürütmüş, İTÜ'de stüdyo dersleri vermiş ve halen zaman zaman ekolojik tasarım üzerinde atölye dersleri ve konferanslar vermektedir. Yürüttüğü projeler ve uygulanan yapıtlar uluslararası ve ulusal birçok ödül kazanırken, bunlardan en dikkate değer olanı, şirketi Avcı (Jurca) Architects'in "İngiltere'nin 50 En İyi Genç Mimarlar Rehberi'nde yer almasıdır. Avcı, tasarım direktörü olarak 1989 yılında Avrupa Birliği Enerji Tasarruflu Mimari Yarışmasında ilk birincilik ödülünü kazandı ve Londra'da Energy Conscious Design Architects tasarım direktörü iken yaptığı projelerle 1998 yılında RIBA Bölgesel Ödülü'nü aldı. Avcı tarafından projelendirilen Ankara'daki Türkiye Müteahhitler Birliği Binası Londra'da Building Magazine tarafından "En İyi Uluslararası Proje", 2014 Sign of the City Ödülleri'nde ise "En İyi Mimari Proje" seçildi. Türkiye Müteahhitler Birliği Binası aynı zamanda 11.Türk Serbest Mimarlar Derneği (TSMD) Mimarlık Ödülleri'nde "Yapı Ödülü" ve sürdürülebilirlik nitelikleriyle de LEED Platinum Sertifikası almaya hak kazandı.

Arzu Tekir

WRI Ross Center for Sustainable Cities Director

WRI TÜRKİYE Sürdürülebilir Şehirler Direktör

Arzu Tekir is the Country Director of WRI Turkey Sustainable Cities in Turkey. She joined WRI's EMBARQ team as the Operations Manager in January 2011 and was appointed as the Country Director in December 2011. As the new Director she restructured the organization and managed the process of establishing the Sustainable Transportation Association in Turkey.

Arzu joined EMBARQ with more than ten years of work experience in strategic planning, project coordination, and fundraising for large projects in both the public and private sectors. Her prior work experience includes two years as a market research and strategy consultant living in New York City, where she wrote business plans and reports for diverse companies ranging from telecoms to baths products to IT.

Earlier in Arzu's career she worked for several Turkish IT companies in primarily business development or management roles. As an External Relations Director for Sampass Information and Communication Inc. she secured financing for R&D projects, raised the firm's public profile, and enabled the company's participation in several key European Union organizations. At Bilkent Holding/ Meteksan IT Group, she worked in two parallel roles including serving as the Business Development Director for the company's European Innovation Technology Centre Europa and as European Union Project Manager for its Meteksan IT Group. Finally, as the General Manager at Babspag Strategic Planning R&D Inc., a subsidiary of BABGROUP, she re-launched the firm's consulting business, rebuilding both its team and service offerings.

Arzu earned her Master's degree in Econometrics from Dokuz Eylul University and holds a Bachelor's degree in Statistics from Ege University.

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Arzu Tekir, kentlerde yaşam kalitesini yükseltmek için ulaşım, kentsel planlama ve enerji verimliliği üzerine projeler geliştiren, yerel, ulusal ve uluslarası düzeyde çalışmalar gerçekleştiren WRI Ross Center for Sustainable Cities (WRI Sürdürülebilir Şehirler)'in Türkiye Direktörü'dür.

Türkiye'deki operasyonel çalışmaları yönetmek için 2011 yılı başında World Resources Institute'ta (Dünya Kaynakları Enstitüsü) Operasyon Müdürü unvanıyla çalışmaya başlayan Tekir, 2011 yılı Aralık ayında EMBARQ Türkiye Direktörü olarak atandı ve Sürdürülebilir Ulaşım Derneği'nin kuruluş sürecini yönetti.

WRI'dan önce New York'ta ve İstanbul'da yatırım planları olan şirketlere danışmanlık yaparak, pazar araştırması projelerini yürüttü ve iş planlarını hazırladı. Bilgi ve iletişim sektöründe faaliyet gösteren şirketlerde Avrupa Birliği Projeleri Koordinatörü ve Dış İlişkiler Direktörü olarak çalıştı.

Kariyerine bir yönetim danışmanlığı şirketinde Kalite Yönetim Sistemleri Uzmanı olarak başlayan Arzu Tekir, Kadir Has Üniversitesi Sosyal Bilimler Fakültesi'nde MBA öğrencileri için Toplam Kalite ve Risk Yönetimi alanlarında bir dönem boyunca dersler verdi. Başka bir yönetim danışmanlık şirketini yeniden yapılandırdı ve yaklaşık üç yıl boyunca bu şirketin yöneticiliğini üstlendi. Ege Üniversitesi Fen Fakültesi İstatistik Bölümü'nden mezun olduktan sonra, yüksek lisansını Dokuz Eylül Üniversitesi'nde Ekonometri dalında yaptı.

Prof. Dr. Can Erkey

Koç University Tüpraş Energy Center, Director

Koç Üniversitesi Tüpraş Enerji Merkezi Direktörü

Professor Can Erkey got his B.S. in Chemical Engineering from Boğaziçi University in Istanbul, Turkey in 1984 and his Ph.D. in Chemical Engineering from Texas A&M University in Texas, USA in 1989. He started his academic career in the Chemical Engineering Department at the University of Connecticut in 1995 as an Assistant Professor. He was promoted to Associate Professor in 2001 and to Full Professor in 2006. He then joined the Chemical and Biological Engineering Department at Koç University in Istanbul, Turkey in 2006. He is serving as the director of the recently established Koç University Tüpraş Energy Center. His research interests are in nanostructured materials, supercritical fluids and energy. Prof. Erkey has 110 refereed journal publications with 4200 citations and a h-factor of 39. He holds 6 patents and is the author of the book titled "Organometallic Compounds and Supercritical Fluids: From Synthesis of Nanostructured Materials to Extraction of Trace Metals". He has made 200 presentations in technical meetings, universities and companies.

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Prof. Dr. Can Erkey Boğaziçi Üniversitesi Kimya Mühendisliği bölümünden 1984 yılında mezun oldu. Doktorasını Texas A&M Üniversitesi Kimya Mühendisliği bölümünde yaptı ve 1989 yılında mezun oldu. Akademik hayatına 1995 yılında University of Connecticut'da Kimya Mühendisliği bölümünde yardımcı doçent olarak başladı. Burada sırasıyla 2001 yılında doçentliğe, 2006 yılında profesörlüğe terfi etti. Daha sonra 2006 yılında Koç Üniversitesi Kimya ve Biyoloji Mühendisliği Bölümüne katıldı. Şu anda Koç Üniversitesi Tüpraş Enerji Merkezinin direktörü olarak görev yapmaktadır. İlgi alanları nanoyapılı malzemeler, enerji ve süperkritik alkışkanlardır. Hakemli dergilerde 4200 tane atıf almış 110 tane makalesi yayınlanmıştır. 6 tane patenti olan Prof. Dr. Can Erkey'in Organometalik Bileşenler ve Süperkritik Akışkanlar adlı bir kitabı basılmıştır. Şimdiye kadar bilimsel toplantılarda, şirketlerde ve üniversitelerde 200 kadar sunum yapmıştır.

Erdal Çalıkoğlu

**Deputy of General Director
Ministry of Energy and Natural Resources
General Directorate of Renewable Energy**

**Genel Müdür Yardımcısı V.
Enerji ve Tabii Kaynaklar Bakanlığı
Yenilenebilir Enerji Genel Müdürlüğü**

He was born in 1963 in Bartın. He graduetd from Hacettepe University Zonguldak Engineering Faculty Department of Mechanical Engineering in 1986. He started to work for the General Directorate of Electrical Power Resources Survey and Development Administration in 1986. He has been working on energy efficiency and renewable energy since 1986. He has experinece on differant kind of national and international studies and projects on energy efficiency, energy managementa nd renewable energy. He has experience also on development and implementation of strategies, policies, legislation, programs and projects on energy efficiency and renewable energy, energy audits, energy management etc. He studied on development of Energy Efficiency Strategy for Rurkey, Laws on energy efficiency and renewable energy and their secondary legislation in Turkey. He is married and he has 2 soons. He had been worked as engineer, expert, head of divison and he was the Deputy of General Director of General Directorate of Electrical Power Resources Survey and Development Administration between 2008 and 2011. He appointed as Deputy General Director of General Directorate of Renewable Energy in Ministry of Energy and Natural Resources in 2011.

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1963 yılında Bartın'da doğdu. 1986 yılında Hacettepe Üniversitesi, Zonguldak Mühendislik Fakültesi'nden Makina Mühendisi olarak mezun oldu. Aynı yıl Elektrik İşleri Etüt İdaresi Genel Müdürlüğü'nde göreve başladı. Enerji yönetimi ve verimliliği konularında Hollanda'da ve Japonya'da eğitim programlarına katıldı. Sanayide ve binalarda çok sayıda enerji etüdü çalışmalarını yürüttü. Enerji verimliliği alanında yürütülen ulusal ve uluslararası projelerin tasarımından yönetimine her kademesinde değişik görevler aldı. Enerji verimliliği ve yenilenebilir enerji konularında strateji, mevzuat ve politika geliştirilmesi çalışmalarını yürüttü. Türkiye için Enerji Verimliliği Stratejisi, 5346 sayılı Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına İlişkin Kanun ve 5627 sayılı Enerji Verimliliği Kanunu Tasarısı ve yönetmeliklerinin taslaklarının hazırlanması çalışmalarını yürüttü. Elektrik İşleri Etüt İdaresi Genel Müdürlüğünde 2008-2011 yılları arası Genel Müdür Yardımcısı olarak görev yaptı. Elektrik İşleri Etüd İdaresi Genel Müdürlüğü'nün 2011 yılında kapatılması ile Enerji ve Tabii Kaynaklar Bakanlığı bünyesinde kurulan Yenilenebilir Enerji Genel Müdürlüğünde Genel Müdür Yardımcısı görev yapmaya başladı. Halen bu görevini sürdürmektedir. Evli ve iki çocuk sahibi, İngilizce biliyor.

Han Tümertekin

Architects and Han Tümertekin

Mimarlar ve Han Tümertekin

Han Tümertekin is a practicing architect based in Istanbul and Stasbourg. He is the founder of Mimarlar + Han Tümertekin and Atelier Han Tümertekin. Tümertekin's work includes projects primarily in Turkey, as well as in Netherlands, Japan, United Kingdom, France, China, Mongolia and Kenya.
Tümertekin was trained as an architect at Istanbul Technical University and completed his M.Arch at the University of Istanbul. In addition to his built work, he has a strong presence in the academic world and has been teaching architecture since 1992 at various universities such as; Harvard University Graduate School of Design; Ecole Polytechnique Fédérale de Lausanne; Ecole Spéciale d'Architecture, Paris. He is also among the founders of the graduate programme in architecture at Bilgi University, Istanbul.
Han Tümertekin's work has been widely published in international architectural journals and a monograph of his work was published by Harvard University Press in 2006.
Recipient of several architectural prizes, Tümertekin was presented a 2004 Aga Khan Award for Architecture for the B2 House. He served on the Aga Khan Awards as a master jury member for 2004-2007 cycles and a steering committee member from 2007 till 2015.

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Han Tümertekin, mimari etkinliğini İstanbul'da kurduğu Mimarlar ve Han Tümertekin ve Strabourg'da kurduğu Atelier Han Tümertekin çerçevesinde yürütmektedir. Tümertekin, Türkiye başta olmak üzere, Hollanda, Japonya, Birleşik Krallık, Fransa, Çin, Moğolistan ve Kenya'da projeler gerçekleştirmiştir.
Mimarlık öğrenimini İstanbul Teknik Üniversitesi'nde tamamlayan Tümertekin, İstanbul Üniversitesi'nde tarihsel çevreyi koruma konusunda yüksek lisans yapmıştır. Mesleki çalışmalarına ek olarak 1992 yılından bu yana mimarlık öğrenimine de katkıda bulunan Tümertekin, Harvard University Graduate School of Design, Ecole Polytechnique Fédérale de Lausanne ve Ecole Spéciale d'Architecture-Paris'te konuk öğretim üyeliği yapmaktadır. İstanbul Bilgi Üniversitesi Mimarlık Yüksek Lisans programının kurucu ve yürütücülerindendir.
Çeşitli uluslararası mimari yayınlar Tümertekin'in çalışmalarına yer vermiştir. Ayrıca seçilmiş projeleri Harvard University Press tarafından bir monografi olarak yayınlanmıştır.
Çeşitli ulusal ve uluslararası ödüllere layık görülen Tümertekin, 'B2 Evi' ile 2004 Ağa Han Mimarlık Ödülü'nü kazanmıştır. 2007 Ağa Han Mimarlık Ödülü jürisinde yer alan Tümertekin, 2004-2015 yılları arasında Ağa Han Mimarlık Ödülleri Yönetim Kurulu üyesi olmuştur.

Ümit Deveci

Channel Director
Schneider Electric
Schneider Elektrik
Kanal Direktörü

He joined Schneider Electric in 2002. Until 2009, he has held a number of operational functions in Turkey and France, mainly in Project and Services business. In 2009, he was appointed Services Manager. He restructured and grew the organisation and business volume, improved both EBIT and DSO as well.
In 2013, he was appointed Strategy and Business Development Manager, created Company's 5-year Strategic Plan and deployed commercial transformation program to boost channel cross-selling and end-user coverage. Since 2015, he leads an emerging partner channel acting in building market. He cares about integrity, motivation and accountability in the work space, don't believe in one man show but team play. He is married with two daughters, enjoy life through traveling, spends time with his family and friends.

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Schneider Electric'e 2002 senesinde katılan Ümit Deveci, 2009 yılına kadar hem Türkiye'de hem de Fransa'da özellikle servis ve proje yönetimi alanlarında farklı fonksiyonlarda görev almıştır. 2009'da Servisler Müdürü olarak atanarak, servis organizasyon yapısının yeniden kurulmasında ve iş hacminin arttırılmasında görev almıştır. Deveci, 2013 senesinde görev değişikliği ile Strateji ve İş Geliştirme Müdürü olarak atanmış ve şirketin 5 yıllık stratejik planının oluşturulmasında ve çapraz satışı arttırmak için ticari dönüşüm programının geliştirilmesinde görev almıştır. 2015'ten beri, bina sektöründe gelişmekte olan bir partner kanal aksiyonunu yöneten Deveci'ye göre iş ortamında, motivasyon, güvenilirlik ve takım oyunu önem taşımaktadır. Evli ve iki kız babası olan Deveci, boş zamanlarımı seyahat ve ailesiyle zaman geçirerek değerlendirmekten hoşlanıyor.

İbrahim Yıldırım

Kordsa Global Chief Technology Officer and Composites

Kordsa Global Teknolojiden sorumlu Genel Müdür Yardımcısı

He received his BSc degree from Middle East Technical University, Chemical Engineering Department and his MBA degree from Sabancı University in 1993 and 2005 respectively. He started his professional career at Rafine Chemicals in 1994 and worked in different manufacturing companies. Between 1998 and 2007, he served in Sakosa as Technical Engineer and Production Engineer.
He was appointed as Technical Manager at Kordsa Turkey in 2007. In 2008, he was transferred to Global Technology Center as New Product Development Manager.
In 2009, he was appointed as New Product and Process Development Director.
In 2011, he was appointed as Technology Development Director.
In October 2013 he was appointed as the Chief Technology Officer. Since July 2015 he has been working as the Chief Technology Officer and Composites Business Unit Leader.

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1993 ve 2005 yıllarında ODTÜ Kimya Mühendisliği ve Sabancı Üniversitesi İşletme Bölümü'nde lisans ve yüksek lisans derecesini aldı. İş yaşamına 1994 yılında Rafine Kimya'da başladı; çeşitli üretim şirketlerinde çalıştı. 1998-2007 yılları arasında Sakosa'da Teknik Mühendis ve Üretim Mühendisliği görevinde bulundu.
2007 yılında Kordsa Türkiye Teknik Müdürlüğü görevine atandı. 2008 yılında Küresel Teknoloji Merkezi'ne Yeni Ürün Geliştirme Müdürü olarak transfer oldu. 2009 yılında Yeni Ürün ve Proses Geliştirme Direktörü pozisyonuna getirildi.
2011 yılında Teknoloji Geliştirme Direktörü olarak atandı. Ekim 2013'te Chief Technology Officer pozisyonuna getirilen Yıldırım, Temmuz 2015'de Teknolojiden sorumlu Genel Müdür Yardımcısı ve Kompozit İş Birimi Lideri olarak atanmıştır.

Murat Mustafa HARMAN

ISBAK INC. Transportation Planning Manager

İSBAK A.Ş. Ulaşım Planlama Müdürü

Murat Mustafa Harman was born in Güneysu district of Rize in 1974. He graduated from Güneysu Yavuz Selim High School In 1996, graduated from Mimar Sinan University Department of City and Regional Planning 2000 – 2005, worked as Technical Staff in Istanbul Metropolitan Municipality Transportation Coordination Directorate, 2005-2013, worked as Transportation Specialist in Isbak Inc. and has worked many transportation projects. During this time period in Istanbul and other cities in Turkey, worked as Project Head on Transportation Arrangement, Simulation Studies, Traffic Impact Analysis and Signal Optimization, and many of similar projects. Between May 2015 and November 2013 in ISBAK Inc., worked as Survey and Project Chief, and since then, he was Director of Transportation Planning.

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Murat Mustafa Harman, 1974 yılında Rize'nin Güneysu ilçesinde doğdu. Lise öğrenimini Güneysu Yavuz Selim Lisesi'nde tamamladı. 1996 yılında Mimar Sinan Üniversitesi Şehir ve Bölge Planlama Bölümünden mezun oldu. 2000- 2005 yılları arasında İstanbul Büyükşehir Belediyesi Ulaşım Koordinasyon Müdürlüğü'nde Teknik Eleman olarak görev yaptı. 2005-2013 yılları arasında İSBAK A.Ş. de Ulaşım Uzmanı sıfatıyla birçok ulaşım projelerinde görev yapmıştır. Bu süre zarfında İstanbul ve İstanbul dışında, Ulaşım Düzenleme Çalışmaları, Simülasyon Çalışmaları, Trafik Etki Analizleri ve Sinyal Optimizasyonu gibi birçok projenin proje yöneticiliğini yapmıştır. 2013 Mayıs ayından 2015 Kasım ayına kadar İSBAK A.Ş. de Etüt ve Proje Şefliği yapmış olup o tarihten itibaren Ulaşım Planlama Müdürlüğü görevini yürütmektedir.

Tuncer Cakmakli is founder and principal of TCA-TUNCER CAKMAKLI ARCHITECTS. In 1992 he transferred his architectural and urban design office to Istanbul. Cakmakli is an internationally recognized architect and educator who has designed and built award winning large-scale urban and commercial design projects and innovative educational and diplomatic institutions. Additionally, he also designed and built furniture and interior design projects.
Cakmakli was a full-time associate professor of architecture at RWTH Aachen Germany from 1986 to 1992. From 1992 to 2009 he gave lectures in architectural design at the Mimar Sinan University Istanbul as well as design and construction at the Barcelona-Girona /Eskisehir /Skyros/Plovdiv. Cakmakli was educated in architecture at the Technical University Karlsruhe, Germany.
2013 he start teaching at CORNELL University (AAP) –ITHACA NEW YORK
He has offices in Istanbul and Stuttgart

Tuncer Çakmaklı

Tuncer Çakmaklı Architects

Tuncer Çakmaklı Mimarlık

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Tuncer Çakmaklı, TCA –TUNCER CAKMAKLI ARCHITECTS kurucu ve yöneticisidir. Mimari ve Kentsel tasarım bürosunu 1992 yılında İstanbul'a taşımıştır.
Haydarpaşa lisesinden mezun olduktan sonar Karlsruhe Teknik Üniversitesin'de (KIT) lisans ve yüksek lisansını tamamlamıştır.
Uluslarası mimari ve kent tasarımları üreten ve öğretim üyeliği yapan Cakmaklı büyük ölçekli kentsel ve ticari projeleri ,eğitim ve diplomatik yapıları ile ödüller almıştır.
İç mimari ve mobilya tasarımları yapmaktadır.
1986-1991 yılları arasında RWTH -Aachen Teknik Üniversitesi Mimarlık Fakültesi'nde .1992-2009 yılları arasında Mimar Sinan Üniversitesi Mimarlık Fakültesi'nde mimari proje dersleri, Barcelona-Girona, Eskişehir, Yunanistan ve Bulgaristan'da mimari proje dersleri vermiştir. 2013 Bahar Dönemi'nde Cornell Üniversitesi'nde (AAP-Ithaca,New York) yüksek lisans mimari proje dersleri vermeye başlamıştır.
İstanbul ve Stuttgart ofisleri ile üretim vermektedir.

Murat Oral is the Deputy General Manager of General Directorate Of Vocational Services of Ministry of Environment and Urbanisation since 2014. He graduated from Blacksea Technical University in 1993. He worked in the private sector in structural design works and as site chief. In 1997 he worked in General Directorate of Highways as highway construction control engineer. Between 2000-2009 respectively he worked as an infrastructure and superstructure control engineer, branch manager and deputy regional manager in Samsun Regional Directorate of Bank of Provinces. Between 2009 and 2011 he worked as consultant and Head of Department in Ministry of Public Works and Settlement. Between 2011-2013 he was the Head of Department and Deputy General Manager respectively in the General Directorate of Infrastructure and Urban Transformation.

Murat Oral

Ministry of Environment and Urbanization, General Directorate of Occupational Services
Deputy of General Director

Çevre ve Şehircilik Bakanlığı
Mesleki Hiz. Gen. Müd.
Genel Müdür Yardımcısı V.

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Çevre ve Şehircilik Bakanlığı Mesleki Hizmetler Genel Müdür Yardımcısı olan Murat Oral, Karadeniz Teknik Üniversitesi İnşaat Mühendisliği bölümünden 1993 yılında mezun olmuştur. 1995-1997 yılları arasında Samsun'da özel sektörde, statik-betonarme proje yapımı ve şantiye şefliği görevlerinde bulundu. 1997 yılında Karayolları Genel Müdürlüğünde yol yapım kontrol mühendisi olarak memuriyete başladı. 2000-2009 yılları arasında Samsun İller Bankası Bölge Müdürlüğünde sırası ile altyapı ve üstyapı kontrol mühendisi,Şube Müdürü ve Bölge Müdür Yardımcısı olarak görev yaptı. 2009-2011 yılları arasında Bayındırlık ve İskân Bakanlığında Müşavirlik ve Daire Başkanlığı görevlerinde bulundu. 2011- 2013 yılları arasında Çevre ve Şehircilik Bakanlığı Altyapı ve Kentsel Dönüşüm Hizmetleri Genel Müdürlüğünde sırası ile Daire Başkanlığı ve Genel Müdür Yardımcılığı görevlerini vekâleten yürüttü. 24 Nisan 2014 itibariyle Genel Müdür Yardımcılığı görevini vekâleten yürütmektedir.

Burcu Başer

YEM Exhibitions General Manager

YEM Fuarcılık Genel Müdürü

Burcu Başer, having graduated from Department of Architecture of ITU Faculty of Architecture, did her master's degree in 1999 at ITU Faculty of Sciences – Department of Building Materials. Following her entry to the professional business life in 1995, Başer worked in various projects in the construction sector and became the Technical Manager of ITE Group Plc.'s affiliate company EUF – E Uluslararası Fuar Tanıtım Hizmetleri A.Ş. in 2012. She became the COO in 2004. Başer performed her duties of General Manager and Board Member at EUF A.Ş between 2005 and 2013 and also at Ekin Fuar A.Ş starting from 2012. In 2009, Başer received the "Exhibition Management Degree" which is given by UFI (The Global Association of the Exhibition Industry). Burcu Başer has been the General Manager of ITE Group Plc.'s affiliate YEM Exhibitions, since 2013 and a Board Member of ITE Turkey since May 2015.

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İTÜ Mimarlık Fakültesi Mimarlık Bölümü mezunu Burcu Başer, yüksek lisansını 1999 yılında, İTÜ Fen Bilimleri Fakültesi Yapı Malzemesi Ana Bilim Dalı'nda tamamladı. 1995 yılında profesyonel iş hayatına atılan Başer, inşaat sektöründe çeşitli projelerde çalıştıktan sonra, 2002 yılında ITE Group Plc. şirketi olan EUF – E Uluslararası Fuar Tanıtım Hizmetleri A.Ş.'de Teknik Müdür olarak göreve başladı, 2004 yılında Operasyonlar Direktörü oldu. Başer 2005 -2013 yılları arasında EUF A.Ş. ve beraberinde 2012'den itibaren de Ekin Fuar A.Ş.'de Genel Müdürlük ve Yönetim Kurulu Üyeliği görevlerini yürüttü. Başer, 2009 yılında, UFI (Uluslararası Fuarlar Birliği) tarafından verilen "Exhibition Management Degree"ye (Fuar Yönetim Derecesi) sahip olmuştur.2013 yılından bu yana ITE Group Plc. şirketlerinden biri olan YEM Fuarcılık'ın Genel Müdürlük görevini yürüten Burcu Başer, Mayıs 2015 itibarıyla ITE Turkey – Yönetim Kurulu Üyeliği görevini de yürütüyor.

Assoc. Prof. Dr. Hediye Tüydeş Yaman

ODTÜ

With a BSc degree in Civil Engineering from Middle East Technical University (METU), I received my MS and PhD degrees in transportation at Northwestern University, USA. Joining the faculty of METU CE Department in 2005 as a full-time member, I have been teaching and researching different aspects of transportation and traffic engineering, including network traffic management and traffic safety. I have taken part in the development of Intelligent Transportation Systems (ITS) applications and task force within the METU-BİLTİR Research Center and been appointed as the Head of ITS Unit in 2014. Recently, I am working on walkability and signal optimization.

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Orta Doğu Teknik Üniversitesi İnşaat Mühendisliği Bölümü'nü bitirdikten sonra ulaşım alanında yüksek lisans ve doktora derecemi ABD'de Northwestern Üniversitesi'nden aldım. 2005 yılında ODTÜ İnşaat Mühendisliği Bölümü'nde öğretim üyesi olarak göreve başladıktan sonra trafik ağı modellemeleri ve trafik güvenliği başta olmak üzere ulaştırma ve trafik mühendisliğinin farklı alanlarında çalışmalar yaptım. ODTÜ-BİLTİR Merkezi kapsamında yapılan Akıllı Ulaşım Sistemleri (AUS) çalışmalarına destek verdim ve 2014 yılında kurulan AUS Birimi Başkanı olarak atandım. Aktif olarak yürünebilirlik ve sinyalizasyon optimizasyonu konularında çalışmalar yürütmekteyim.

A.Faruk Göksu is a urban planner who gives advisory services to the public and private sectors especially for urban regeneration projects. He has several implemented public-private partnerships projects in Turkey. He was a general director of first public-private partnership company which was organized Orange Blossem Valley Project. He is a negotiation specialist to bring landowners, developers and public sector for the project basis. He is dealing with the new urban instruments such as the transfer of development rights, negotiation and community participation models and methods for the pilot projects especially in Anotolian cities in Turkey. He also gives lectures about urban regeneration at the university.

He is also founder partner of TAK Kadıköy, TAK Kartal and Vision Atelier.

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Şehir plancısı A.Faruk Göksu, kamu ve özel sektöre özellikle Kentsel dönüşüm konularında danışmanlık hizmeti vermektedir. Göksu, Türkiye'nin ilk kamu-özel sekör işbirliği ile Portakal Çiçeği Vadisi Projesini gerçekleştiren PORTAŞ A.Ş'nin yöneticiliğini yapmıştır. Göksu, yerel halk, belediye ve özel sektörü proje bazında bir araya getirilmesi konunda uzlaşma yöneticiliği yapmaktadır. Ayrıca, yenilikçi yaklaşımlar olan İmar Hakları Transferi, toplulaştırılması, halk katılımı, uzlaşma konularında özelikle Anadolu kentlerine model ve yöntemler geliştiren Göksu, üniversite de kentsel dönüşüm konusunda ders vermektedir.

TAK Kadıköy, TAK Kartal ve Vizyon Atölyesi kurucusudur.

A.Faruk Göksu

Urban Strategy Consultancy Founding Partner

Kentsel Strateji Kurucu Ortağı

Born in 1973 in Istanbul, graduated from Yıldız Technical University, Department of Electrical Engineering. Due to his intense interest in lighting, he started working in the lighting sector during his undergraduate studies. After having experienced different aspects of lighting and its professional uses in the leading production, import, export and design companies that he has worked for over 10 years, he started his own company, Seven Lights, in the light of these experiences. In a context where 'lighting design' and 'lighting designer' concepts have not been fully established, he contributed in the formation of this sector through his works and efforts. Meanwhile he had the opportunity to work on important projects both in Turkey and abroad. He's giving Architectural Lighting Design Lectures since 2013 at İstanbul Bilgi University.

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1973 İstanbul doğumlu Mustafa seven Kabataş Erkek Lisesini bitidikten sonra
Yıldız Teknik Üniversitesi Elektrik Mühendisliği Bölümünden mezun oldu.
1992'de üniversite hayatının başlamasıyla aydınlatma sektöründe teknik departmanlarda çalışmaya başladı. Sektördeki 13 yılının ardından 2005 yılında Türkiye'deki ilk aydınlatma tasarım ofisi olan Seven Lights'ı kurdu. O yıllarda pek bilinmeyen bir meslek olan mimari Aydınlatma
Tasarımcılığı'nın Türkiye'de tanınması adına yoğun uğraşlar verdi. Günümüze dek yerli yabancı bir
çok projenin aydınlatma tasarımını yapan Mustafa S. Seven 2013 yılından bu yana Bilgi Üniversitesi çatısı altında Mimari Aydınlatma Tasarımı dersleri vermektedir.

Mustafa S. Seven

Seven Lights

Prof. Dr. Lütfullah Gündüz

İzmir Katip Çelebi University

İzmir Katip Çelebi Üniversitesi

He was born in Istanbul at 1966. He finished his high school in Izmir at 1984 and he was graduated as a mining engineer from Mining Engineering Department in Istanbul technical University at 1988. He was also graduated as a PhD degree (Doctor of Philosophy) from University of London (U.K.), Imperial College of Science, Technology and Medicine, at 1992. During his research work in University of London, he was awarded a scholarship by the university. He was also attended to three different international Projects as a researcher supported by The Commission of the European Communities. After PhD studies, he returned back to Turkey. He worked in a short time period in Etibank institution as a Dr. Engineer in Ankara. Then he began to work as a lecturer in Mining Engineering Department, Faculty of Engineering and Architecture in Suleyman Demirel University, Isparta, Turkey. He became a professor at 2002 at the same department of Suleyman Demirel University. His research area is basically on lightweight concrete techniques, composite mortars, lightweight aggregates, masonry units, expanded and exfoliated natural and/or artificial aggregates, cement based boards and insulation properties of construction materials. He followed so many research works on these subjects in his academic life.
He was appointed at 2013 as a professor in Material Construction Division of Civil Engineering Department, İzmir Katip Çelebi University, İzmir, Turkey. He is now still working in this department as a lecturer. He speaks English very well. He is married and has two children.

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1966 tarihinde İstanbul`da doğdu. 1984 yılında orta öğrenimini İzmir'de tamamladı. İ.T.Ü. Maden Fakültesi Maden Mühendisliği Bölümünden 1988 yılında mezun oldu. 1992 tarihinde Londra Üniversitesi, Imperial College of Science, Technology and Medicine'de doktora tezini tamamlayarak doktor (Ph.D.) ünvanını aldı. Doktora çalışmalarını tamamladıktan sonra, 1992 yılında Imperial College`da aynı bölüme bir süre "Dr. Research Assistant" olarak görev yaptı. 1993 yılında Türkiye`ye dönerek, bir süre Etibank Genel Müdürlüğü Proje – Tesis Dairesi Başkanlığında "Dr. Mühendis" unvanı ile görev yaptı. 1994-1995 tarihleri arasında Süleyman Demirel Üniversitesi, Mühendislik-Mimarlık Fakültesi'nde Yardımcı Doçent Dr., 1995-2002 yılları arasında Doçent Doktor ve 2002-2013 yılları arasında da aynı üniversitede "Profesör Doktor" olarak görev yaptı. Doktora eğitim süreci ve sonrasındaki tüm akademik çalışmalarında doğal, yarı suni veya suni endüstriyel hammaddelerin yapı malzemesi üretimlerinde değerlendirilmesi üzerine çalışmalar yaptı ve yayımladı. Üniversite-sanayi işbirliği destekli çok sayıda projelerde yer aldı ve yapı malzemeleri tekniklerinde enerji verimliliği, yalıtım amaçlı kompozit harç üretimleri, yapı kimyasalları vb. konularda engin bir deneyime sahip oldu.
Halen İzmir Kâtip Çelebi Üniversitesi Mühendislik Mimarlık Fakültesi İnşaat Mühendisliği Bölümü Yapı Malzemeleri Anabilim Dalı'nda öğretim üyeliği görevini sürdürmektedir. İyi derecede İngilizce bilmekte olup, evli ve 2 çocuk babasıdır.

Asisst. Prof. Dr.
Berat Zeki Haznedaroğlu

Bosphorus University

Boğaziçi Üniversitesi

Dr. Berat Zeki Haznedaroğlu is an assistant professor at The Institute of Environmental Sciences at Bogazici University (BU). He received his Ph.D. from the Chemical and Environmental Engineering Department of University of California, Riverside. Dr. Haznedaroğlu holds a B.Sc. in Biology from the Middle East Technical University in Ankara, Turkey. Prior to joining Bogazici University, Dr. Haznedaroğlu completed his postdoc at Yale University working on enhanced production of biodiesel from microalgae.
Dr. Haznedaroğlu's research group focuses on Food:Energy:Water nexus. Current projects include systems level investigation of algae for nutritional supplements, biofuels, value-added chemicals, and wastewater treatment applications. He is currently the director of Istanbul Microalgae Biotechnologies Research and Development Center (IMBIYOTAB).

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Teknoloji; tasarım, inşaat ve işletme alanlarında müthiş bir etki yaratıyor. Kişisel teknoloji kullanımı birçok şekilde işimizdeki kullanımı aşmış durumda. Endüstri olarak yeni teknoloji ve uygulamalarını benimseyip iş yapış şeklimizi dönüştürmeyi hedeflemek amacında olmalıyız. Getirilerinden faydalanabilmek için yapılacak çok iş var. Yapı Bilgi Modellemesi (İngilizce'deki kısaltması BIM) gibi uygulamalar çalışanlarımızın eğitiminden iş yapışımıza kadar her şeyi başta düşünmemizi zorluyor. Artık tüm verilerin bütünleşebileceği, bilgiye dönüşüp - daha evvel hiç yapılamadığı gibi analiz edilebilmesi mümkün hale geldi. BIM ile derlenilebilen verinin ayrıntısı ve hacmi, yapılmış çevremizin adeta Google gibi bir arayüzün kapılarını açıyor. Bu işletme, enerji, iş ve ötesi için daha iyi analiz ile performans anlamına geliyor…

Prof. Dr. Celal Abdi Güzer

CAG Architectural Workshop-Architect

CAG Mimarlık Atölyesi, Kurucu

Born in Ankara, C. Abdi Güzer graduated from the Department of Architecture at Middle East Technical University in 1982. He received a British Council research grant and made studies on 'Architectural Criticism' at the University of Newcastle upon Tyne. Güzer received his doctoral degree on the same topic from METU where he is currently delivering courses on architectural criticism and leading one of three groups in the 4th year architectural design studio. He acted as the vice chair of the Department of Architecture, director of the Program on Architecture, Vice Dean of the Faculty of Architecture at Middle East Technical University and the General Secretary of Architects' Association 1927. Güzer has been a jury member in several architectural competitions and received many awards and mentions in national and international competitions including three first prizes. He realizes most of his projects through Middle East Technical University and has several completed projects including Middle East Technical University MATPUM Research Center, which received YEM (The Building Information Center) Design Award in 2008. Among his research interests are architectural criticism, concepts and applications in contemporary architecture, housing and mass-housing design, urban design and transformation projects, environmental design and sustainability. He is the founder of CAG Architectural Workshop which is a medium of discussion, research and production on architecture and design.

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1960 yılında Ankara'da doğan Celal Abdi Güzer, mimarlık eğitimini 1982 yılında Orta Doğu Teknik Üniversitesi Mimarlık Bölümü'nde tamamladı. Bir süre İngiliz Hükümeti bursu ile Newcastle upon Tyne Üniversitesi'nde "Mimarlıkta Eleştiri" üzerine çalışmalar yapan Güzer aynı konuda ODTÜ'den doktora derecesi aldı. Halen ODTÜ Mimarlık Bölümü'nde mimarlık eleştirisi üzerine ders vermekte ve dördüncü sınıf tasarım stüdyosu yöneticiliği yapmakta olan Güzer ODTÜ Mimarlık Bölümü Başkan Yardımcılığı, Bina Bilgisi Ana Bilim Dalı Başkanlığı, Dekan Yardımcılığı, Mimarlar Derneği 1927 Genel Sekreterliği ve Başkanlığı görevlerinde bulunmuştur. Mimari proje yarışmalarında çeşitli jüri üyeliklerinin yanısıra, üçü birincilik olmak üzere çok sayıda ödül ve mansiyon kazanan Güzer'in çok sayıda uygulanmış projesi bulunmaktadır. Bunların arasında tasarımını ve kurucu başkanlığını yaptığı ODTÜ MATPUM yapısı 2008 yılında son beş yılın yapıları arasında yapılan değerlendirmede YEM tasarım ödülü kazanmıştır. Güzer'in araştırma konuları arasında Mimarlık Eleştirisinin yanı sıra Yakın Dönem Mimarlık Kavram ve Uygulamaları, Konut ve Toplu Konut Yapıları, Kentsel Tasarım ve Kentsel Yenileme Projeleri, Yapılarda Çevre Duyarlılığı ve Sürdürülebilirlik gibi konular yer almaktadır. Projelerinin çoğunu ODTÜ Dönersermaye İşletmesi aracılığı ile gerçekleştiren Güzer, mimarlık ve tasarımla ilgili araştırma ortamı oluşturmayı ve proje üretimini amaçlayan CAG Mimarlık Atölyesi'nin kurucusudur.

Aydan Volkan

Kreatif Arcitects, Architect

Kreatif Mimarlık, Mimar

Aydan Volkan was born in 1969 in İstanbul. She received her Bsc degree in Architecture at İstanbul Yildiz Technical University in 1992. She worked in Ertem Ertunga Architectural Office until 1995 and she attended English courses at King's College in London for a year afterwards. She continues her practice with Kreatif as founding partner and principle architect since 1996. She is a member of the Istanbul Freelance Architects Association where she also served as one of the Board of Directors of the same association between 2013 and 2015. Apart from her professional studies Aydan Volkan frequently attends conferences, panels and interviews on related fields and takes place as a jury member of various awards and competitions.

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1969'da İstanbul'da doğan Aydan Volkan 1992'de İstanbul Yıldız Teknik Üniversitesi Mimarlık Fakültesi Mimarlık Bölümü'nü bitirdi. 1995 yılına kadar Ertem Ertunga Mimarlık'ta çalıştıktan sonra 1995–1996 yılları arasında King's College - Londra'da dil eğitimi gördü. 1996 yılından beri Kreatif Mimarlık'ta çalışmalarını sürdüren Volkan, aynı zamanda İstanbul Serbest Mimarlar Derneği üyesidir.

Papers

Building - Policy

Paper No: 51

Importance of Integrating Green Building Certification Requirements into Design, Construction and Consultant Contracts

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ABSTRACT: The paper aims to raise awareness in order to mitigate the emerging risks in Turkey by showing the lack of needed provisions in the existing contracts for green building projects. The green building process is summarized by identifying the services provided by stakeholders to design and build a green building. A critical literature review is done on the guides provided by professional organizations to make the sustainability community aware of existing international agreements where green building practices are almost becoming mainstream practices. The sustainability/certification consulting contracts used in Turkey for certification of green buildings have been examined to find out how contracts are modified to incorporate sustainability. Based on 38 contracts reviewed for this research, the findings indicate that, in Turkey, the contracts used for projects aiming to be certified with green building certification systems require performance specific services and goals related to certification drafted into them as well as the consequential damages and limitation of liability provisions.

Key words: Green buildings, law, contracts, liability, LEED, BREEAM

1. INTRODUCTION

Green building is a holistic concept that starts with the understanding that the built environment can have profound effects, both positive and negative, on the natural environment, as well as the people who inhabit buildings every day. Green building is an effort to amplify the positive and mitigate the negative of these effects throughout the entire life cycle of a building. While there are many different definitions of green building out there, it is generally accepted as the planning, design, construction, and operations of buildings with several central, foremost considerations: energy use, water use, indoor environmental quality, material section and the building's effects on its site [1]. The top sector for green building growth globally is commercial construction, with nearly half (46%) of all respondents to World Green Building Trends 2016 survey expecting to do a green commercial project in the next three years. In Turkey, commercial construction is playing a critical role in driving a commitment to green building, providing needed green experience that may eventually encourage green building in other sectors.

2. CERTIFICATION SYSTEMS

2.1 Building Certifications

Building Research Establishment's Environmental Assessment Method (BREEAM), the first green building rating system in the U.K. emerged in the beginning of 1990s. In 2000, the U.S. Green Building Council (USGBC) followed suit and developed and released criteria also aimed at improving the environmental performance of buildings through its Leadership in Energy and Environmental Design (LEED) rating system for new construction. BREEAM and LEED followed by many others, have continued to grow in prominence and to include rating systems for existing buildings and entire neighbourhoods [2]. The process of achieving certification adds a layer of accountability and integrity for the building project team. These systems are incorporated into building codes or statutes of some jurisdictions in the countries they emerged. There are a wide range of economic and environmental benefits to sustainable design and construction, often achieved through the use of green building certification systems. The percentage of firms expecting to have more than 60% of their projects certified green is anticipated to more than double from 18% currently to 37% by 2018 [10]. Their continued growth of use for many different types of buildings and communities make our research even more important for the real estate market.

Turkey was number nine on 2015's Top 10 Countries for registration for LEED certification. [8]. 23,74 gsm were registered to be certified only for LEED certification along with 2.95 gsm certified in 2015. With this recent paradigm shift in real estate development in Turkey, new issues and risks are coming for all stakeholders.

This paper does not endorse any particular green building certification system but aiming to improve the current contracts which are lacking sustainability requirements. Owners who undertake the green building certification process should familiarize themselves with the rating systems and allocate responsibilities under the system to the various project members. In selecting a system, it is general practice that the owner and the architect/sustainability consultant consider the options available. For new and existing buildings, there are variety of certification systems to be used. Time and effort to certify a project varies and parameters like; project type, massing, site conditions, the timing for the decision to certify the project, the form of the building, location, the rating level, the number of buildings to certify have effect on the efforts. These parameters have effect on fees of professionals involved in the project and liabilities too.

Regardless of the project type some of the most critical construction contract provisions emanate out of the parties' choices in allocating the risk of consequential damages [7].

2.2 Product Certifications

There is a diverse range of tools used to quantify green buildings. The intent of green building certification systems is to encourage the use of products and materials for which life-cycle information is available and that have environmentally, economically, and socially preferable life-cycle impacts in green buildings. Project teams are rewarded for selecting products for which the chemical ingredients in the product are inventoried using an accepted methodology and for selecting products verified to minimize the use and generation of harmful substances [1].

Concept of disclosure is the reporting of information pertinent to the environmental and health impacts of products and materials used in buildings. There are over 100 product certifications developed to identify sustainably designed, built or resourced products today. These tools may focus on a number of key aspects of the rated product. An EPD (environmental product declaration) is an independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products. While there are a range of disclosure tools that have evolved over the years, this paper focuses on Environmental Product Declarations (EPD) and a newer tool, Health Product Declarations (HPD). HPD Open Standard has become established as the leading industry standard for the reporting of building product content and associated health information. It is incorporated as a reporting tool in many leading certification programs and is also the foundation for industry harmonization efforts to establish a single method that can simplify reporting – and also improve the accuracy, consistency and reliability – of information about building products and health [3].

EPDs/HPDs are statements about a product's environmental and health impact based on an ISO compliant life cycle assessment (LCA). LCAs evaluate product environmental and health impacts over the product's entire life, from raw materials extraction, transportation, manufacturing, use, and final disposition or reuse. The liability associated with materials including the new largely untested EPDs and HPDs in the market still needs to be researched.

HPDs focus on compositional disclosure and hazard information and HPDs do not require third-party verification. Disclosure is legally required in many sectors and HPDs focus on compositional disclosure and hazard. But there is a lack of clarity in HPD protocol regarding reporting of chemical transformation and/or consumption in a manufacturing process. The HPD Open Standard has been criticized -- the approach was developed by a coalition of building advocates with no formal public process [4].

The fact today in real estate industry is that disclosure is a legal requirement in many cases but it is also becoming a commercial tool through the use of green building certification systems. HPDs are more relevant to liabilities than that of EPDs since they are directly linked to human health. In EPDs, on the other hand, environmental performance is measured and declared. There is no direct consequence of declaring such information wrong. However, the quality of EPDs should reflect the environmental performance of building. As such, EPDs are developed according to ISO 14025 guidelines. In the EU, in order to be able to compare the results of EPDs for the construction products, EN 15804 norm is in use. This norm provides the baseline for comparability and prevent manufacturers from potential trade barriers for the misuse of such declarations. There is no abuse of the system reported up to now. It is difficult for manufacturers to give assurance on the numbers they declare apart from the fact that such declarations are in line with the relevant standards. Such information, i.e. any EPD should be in line with ISO 14025 AND EN 15804 for Turkey, would be sufficient to include in the contracts. Such addition would give assurance to building contractor and manufacturers when environmental impact of buildings are assessed as part of any certification schemes that relied on life cycle data.

3. SUSTAINABLE DESIGN AND CONSTRUCTION: Architect/Engineer/Contractor/Consultant/Commissioning Agent

Sustainable design and construction continues to be a rapidly evolving area of importance to the construction industry [5]. The necessity of integrated design teams to create a green building project created new roles and responsibilities. But new roles and new expectations from the projects also brought new risks for owners, architects, contractors and consultants. In order to cover the risks the new information to be included in the contracts varies depending on the building function, LEED/BREEAM certification level, and the service level if it is a design and simulation and/or construction/commissioning contract.

The green building market continues to grow, but so do the corresponding legal risks which are only now being explored by scholars and practitioners. Behind any green building risk management strategy is how consequential damages should be allocated among the project stakeholders and may emanate from a party's breach of a design, construction, or consulting contract. This allocation is particularly critical on green building projects, whose unique and nonstandard nature can create an increased potential for consequential damages [6].

For example, green building tax credits, premium rents, and even energy savings might fall within the definition of consequential damages, creating disproportionately large liability for parties that fail to protect themselves by contract [7].

In Turkey, in majority of green building projects, the owners prefer to use certification consultancy firms in order to certify their buildings. These firms are either hired under architect/project management firms or directly by the client. The consultant (either a LEED or BREEAM accredited professional) generally serves as the overall coordinator of the certification process. It is becoming more and more important to develop the right contracts for these consulting firms since the number of certification applications in Turkey has been increasing steadily [8].

- The LEED/BREEAM consultants manage the overall certification efforts. They also provide specifications for green products and construction practices.

- The architect and his team of engineers are responsible for the sustainable design. This team is generally assisted with the LEED/BREEAM consultant in the implementation of certification strategies.

- The Commissioning Agent completes the commissioning of the building and commissioning is a prerequisite for receiving green building certification. An agent independent of the design team and hired by the owner coordinates the commissioning during design, prepare the commissioning specs and plans and review the construction documents.

- The contractor builds the project. On sustainable projects the contractors must be knowledgeable on certification process. They are also responsible from trade contractors submitting the requested information on the materials used. Their involvement continues until the certification is obtained.

3.1 Sustainable Project Documents

The publicly available resource for drafting contracts on green building projects is the American Institute of Architects (AIA) Document D503 Guide for Sustainable Projects. This guide has standard form of agreement between Owner and Contractor, for use on a sustainable project where the basis of payment is a Stipulated Sum; similar documents like General conditions of the Contract for Construction, standard form of agreement between Owner and Architect, standard form of agreement between Contractor and Subcontractor, standard form of agreement between architect and consultant exist to be used on a sustainable project.

AIA document B214-2012, Standard form of Architects Services: LEED Certification was updated in 2012 to incorporate the new concepts developed in the sustainable projects documents and establishes the Architect's scope of services for LEED certification.

These services among other issues take care of LEED workshop, score card formation based on the targeted green rating, preparing a LEED certification plan, monitoring the LEED certification process and providing LEED specifications for the inclusion in the contract documents.

There is also Associated General Contractors of America ConsensusDocs *"Green Building Addendum"* where the parties designate a Green Building Facilitator to coordinate or implement identified objectives, which can be a project participant or consultant. This addendum identifies unique and additional services necessitated by sustainable projects.

Engineers Joint Contract Documents Committee (EJCDC) created E-500 Standard Form of Agreement between Owner and Engineer for Professional Services. The E-500 does not directly cover damages in the body of contract and makes the waiver optional through a separate exhibit. EJCDC takes no actions to consider the unique situations that arise as a result of building green [12].

US Construction Industry produced ConsensusDOCS in 2007. Endorced by 22 different organizations, the systems aims to distribute the risk among parties. A contract involving green buildings either includes a waiver of consequential damages or a partial allowance coupled with or without a liquidated damage clause [13]. Later on 2009, ConsensusDOCS released a green building Addendum. This is supposed to use as an appendix to design and construction agreements. So far this is the most flexible work up to now with an entire section devoted to risk allocation. The addendum also is rating system-neutral.

The Design Build Institute of America (DBIA) has created a green building exhibit [14]. Although the document is intended to be annexed to a design-build contract, the ways through which specific risks are allocated between the owner and design-builder have implications for general contractors, construction managers, design professionals, and consultants alike.

Despite all the differences and/or limitations of the above documents, they are useful tools for project teams.

4. REVIEW OF AVAILABLE CONTRACTS

In a comprehensive review of 38 LEED/BREEAM consultant, design and contractor contracts for projects where all building owners rendered the third party green building certification and consulting services independent from professional design services, it is found that none of them had properly drafted provisions governing the disputed green building issues. The contracts belong to projects which are all certified with green building certification systems in Turkey from 2010-2016. Of all those contracts, none of them had any other meaningful sustainable project specific language i.e. tying the performance to fees.

In Turkey, the contractual agreements do not have provisions that will encompass services for LEED or BREEAM certification as part of Architect's Sustainability work. There is also no negotiation clause on indemnities in the context of certification or other Green Building goals and any related post-completion reporting or bonding requirements. There is no period of time that tells the owner and service providers the five year reporting period for utility bills (required by USGBC).

On the other hand USGBC Liability limitations exist in contracts signed between USGBC and the building owner. As the parties consider how to allocate liability for the risk of not obtaining LEED certification, or obtaining it and later being decertified (as well as the failure to achieve the planned environmental or energy benefits), they should be mindful of the fact that the Project Registration Agreement (the "PRA") and the Project Certification Agreement (the "PCA") entered into with the USGBC as part of the LEED certification process contain various limitations of liability and disclaimers in favour of the USGBC [1].

5. CLAIMS AND DISPUTES:

If the project does not meet the sustainability goals, the owner may claim to have sustained damages arising from failure to realize these added benefits [7]. If the contracts don't have any liabilities, it is very difficult to prove the damages.

Because receiving a green building certification is the result of a collective effort and has many stakeholders involved, drafting the contracts with right clauses become even more important for these projects aiming to receive green building certification.

The contractor's liability for damages can be limited by use of a limitation of liability provision if the certification goal fails. AIA document has detailed discussions on limitations of liability under section 15.

There are many unconsidered risks in green building projects. Considering the fact that, many clients decide to build green or receive green building certifications at a late stage of the design process, there is a possibility of failure to achieve the desired rating or certification. Such a failure may create loss of financing, buyer's confidence loss, losing tax incentives, lawsuits from tenants who rented because the building was supposed to be green. Design professionals should strongly consider insisting upon a waiver of consequential damages clause to mitigate unknown liabilities in their contracts [11].

Reviewing the 38 contracts for completed projects which received green building certification in Turkey, there was no waiver of consequential damages clause to mitigate unknown liabilities related to green in design contracts. For 3rd party certification contracts the provision "failure of the Project not to satisfy or obtain such level of LEED/BREEAM certification is not the fault of the consultant" existed in all contracts.

6. CONCLUSIONS

Based on the literature survey completed, the global construction industry clearly perceives risks arising out of green building projects. To push the local organizations, developing and promoting similar consensus documents with risk management provisions in Turkey is becoming more crucial as the green building industry grows with its current rate.

In order to set a benchmark for the existing situation, the content of reviewed contracts is analysed. The findings indicate that none of the contracts have clauses embedded into them protecting the owner, in case a particular rating or certification is not obtained. Because Turkey does not have public funding, tax credits, incentive programs for green buildings yet, not obtaining a LEED or BREEAM rating or particular rating did not create a financial loss for the owners nor a law suit.

Lack of clear definition of the sustainable measures included in the contracts for which each stakeholder is responsible for, may create disputes if the sustainability goals are not met. Because the owner, contractor and the architect each need to perform the services identified in their contracts to achieve the goals of a sustainability project, model forms like AIA Documents D503 Guide, EJDC or ConsensusDOCS can be developed for local use in Turkey with respect to consequential damages and limitation of liability clauses.

The industry professionals need to look into standard contracts for possible claims related to sustainability goals. Payment of fees can be tied to performance of specific services during the design and construction process can be tailored into the contract. The enforcement of contractual obligations to perform the services requested can also be tied to fees based on these contracts. The role of consequential damages and limitation of liability provisions as applied to green building contracts is an area that requires attention of the local construction law community as well as following of the best practices and understanding the critical importance of continuously changing standards in the product world.

For products, the necessary ISO and EN standards need to be placed in the contracts in order to be able to follow the compliance.

REFERENCES:

[1] http://www.usgbc.org/articles/what-green-building 6.6.2016

[2] https://www.wbdg.org/resources/gbs.php 6.6.2016

[3] http://www.hpd-collaborative.org/about/, 1.6.2016

[4] Lynn L. Bergeson, Stewardship 2015 Conference, June 1-3, 2015 Legal and Stewardship Issues associated with EPDs

[5] AIA document D503-2013 by the American Institute of Architects.

[6] Kenneth Block, New York Law Journal. © 2007 ALM Properties, Inc. All rights reserved. Can be ordered from: www. almreprints.com. #070-11-07-0017

[7] Darren A. and Del Percio, Stephen, Green Building Contracts: Considering the Roles of Consequential Damages & Limitation of Liability Provisions (2011). Loyola Consumer Law Review, Vol. 23, No. 2. 2010. SSRN: http://ssrn.com/abstract=1632079

[8] http://www.usgbc.org/2015top10countries 2015

[9] http://www.lexology.com/library/detail.aspx?g=4a4cd39c-acb8-4035-9ba1-c5b8f5f6b227, 5.5.2016

[10] World Green Building Trends 2016: Developing Markets Accelerate Global Green Growth Smart Market Report, Dodge Data and Analytics, 2016

[11] G. William Quatman , R. M. Manies, White Paper, Managing the Risks and Embracing the Benefits of going green, The AIA Trust, Feb 2008

[12] Engineers Joint Contract Documents Form E-500 (2002)

[13] ConsensusDOCS Contract Catalog (2007)

[14] Design-Build Institute of America, Sustainable Project Goals Exhibit (2009)

Paper No: 111

On-Site Energy Generation Potential of Turkey Existing Building Stock

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ABSTRACT

Recent years in Turkey, for reasons such as rapid development of building sector, population growth and the strengthening of the service sector; housing and services sector has become the sector with the highest share in final energy consumption surpassing the industry sector. For Turkey, having high energy import dependency ratio and high share of fossil fuels in power generation increase the importance of energy efficiency and on-site energy generation in the building sector. Under this study; it has been tried to obtain data on the potential energy savings that can be achieved when using on-site energy generation technologies in 6 different building types in the existing building stock of Turkey and the impacts of different climatic zones and building types on the applicability of the on-site energy generation technologies have been evaluated in the context of energy efficiency.

Keywords: On-site energy generation in buildings, Energy Efficiency, Renewable Energy, Housing and Service Sector, Public Policy.

1. INTRODUCTION

Because of expansion of use of the machine in industrial and agricultural sector, industrial revolution has increased the need of energy sources. At the same time, as a result of mechanization; production has increased, comfort conditions have been improved and urban life has begun to strengthen. Need for building has increased together with the increase in urban population. That is why the industrial revolution has led to increase energy consumption in service sector due to the increasing population and improve comfort conditions, also in the manufacturing sector due to the accelerating mechanization. Building related energy consumption has increased rapidly in recent years due to increase in the number of buildings and home appliances and also better living conditions. The difficulty in access to fossil fuels, the shortage of reserves and environmental factors make use of renewable energy sources in buildings more environmentally, friendly and economical. In the coming years, it is estimated that renewable energy usage and energy generation on buildings will be increased and will have widespread implementation.

Under this study, it has been tried to obtain data on the potential energy savings that can be achieved when using on-site energy generation technologies such as solar energy, wind energy, heat pump and cogeneration in six different building types as residential, hospital, office, mall, hotel and school buildings in the existing building stock of Turkey. And also, the impacts of different climatic zones and building types on the applicability of the on-site energy generation technologies have been evaluated in the context of energy efficiency. In this context, on-site energy generation analyses were performed for selected sample buildings of 6 different typology in 4 different climate zones. As a result of these analyses, average savings and net energy generation capacities per determined indicators for each building typology have been calculated. By the use of calculated indicators and current statistics, total on-site energy generation capacity and net saving potential of Turkey existing building stock with the use of on-site energy generation technologies has been investigated and policy recommendations to realize this potential are given.

2. RESIDENTIAL AND SERVICE SECTOR PROFILE OF TURKEY

In Turkey, building sector has a significant share in total energy consumption due to having high population growth rate and being a developing country. The building sector with 34,1% share of final energy consumption in 2014 had the biggest share among the other sectors [1]. Building sector, which is defined as residential and service sector in the official energy statistics, contains many kind of building typologies. According to current legislation in Turkey, buildings are generally classified as residential buildings, office buildings, educational buildings, hotels, health facilities and shopping centres regarding their usage purpose. In the year of 2000, total building number of Turkey has been identified as 7.838.635 according to TURKSTAT Building Census [2]. Between the years 2001-2015, a total of 1.305.667 buildings received occupancy permit [3]. By using these data, total number of buildings in Turkey is calculated as 9.144.342 in 2016. By the same way, total number of residential building is calculated as 7.944.301 and total number of houses as 22.606.906 in these buildings. It is noted that these values are calculated by using TURKSTAT Population And Housing Census--2011 and occupancy permit statistics between 2011-2015. According to the results of Address Based Population Registration System, as the end of the 2015, Turkey total population is 78.741.153, average household size is 3,5 and total household number is 22.497.472 [4]. According to these data % 86,8 of total building stock are consist with residential buildings. Regarding other building typologies, according to the Building Census conducted in 2000 data and occupancy permits statistics between 2002-2015, total construction area of office building is estimated as 172.042.261 m² as the end of 2015 [2,3]. In Turkey as the end of 2014, total number of educational buildings is 83.294 with 22.699.458 student capacity, total number of hotel is 4248 with 530.102 room capacity and total number of hospital is 1493 with 200.101 bed capacity [5,6,7]. And also Turkish shopping malls have more than 9,83 million m² rentable area as the end of 2015[8].

3. UNIT SAVING AMOUNTS OF SAMPLE BUILDINGS

According to on-site energy generation analysis conducted on 24 buildings in 6 different typology from 4 different climatic region of Turkey, for each building on-site electricity generation capacities, on-site heat generation capacities, net saving amounts and simple pay back periods are calculated by the scenario of using efficient capacities of PV panels, solar panels, micro wind turbines, heat pumps and cogeneration/tri generation systems. Two different scenarios were used to calculate total on-site energy generation capacity of each building. In first method, only the technologies which have shorter than 10-year payback period were considered and on-site electricity generation capacities, heat generation capacities, average simple payback periods were calculated of these technologies. In second method, all of on-site energy generation technologies are considered and same indicators were calculated similar in first method.

According to scenario of using on-site energy generation technologies of which pay pack period shorter than 10 years on sample residential buildings; annual average electricity generation capacity per house is calculated as 2.328 kWh, average fuel saving per house is calculated as 498 kWh. If payback period is not considered and all technologies that are analysed are considered annual average electricity saving per house will be 2.086 kWh, average fuel saving per house will be 1.923 kWh [9]. Because of using heat pumps in second scenario, electricity saving is decreased but heat saving is increased.

For sample office buildings in first scenario, annual average electricity generation capacity per square meter is calculated as 35,8 kWh/m², average fuel saving per square meter is calculated as -33,4 kWh/m². İf we consider the second scenario, net electricity saving per square meter will be 37,6 kWh/m², average fuel saving square meter will be -17,6 kWh/m² [9]. The reason of negative fuel saving is that cogeneration/tri-generation systems may increase fuel consumption. However, if we consider primary energy saving which contains both electricity and fuel savings total saving will be positive.

For sample educational buildings in first scenario, annual average electricity generation capacity per student is calculated as 260,9 kWh, average fuel saving per student is calculated as -67,7/kWh. İf we consider the second scenario, average electricity saving per student will be 275,5 kWh, average fuel saving per student will be 230,5 kWh [9].

For sample hotels, pay back periods of analysed systems are nearly or shorter than 10 years. So, all systems are considered for sample hotels. According to this assumption annual average electricity generation capacity per room is calculated as 10.893 kWh and average fuel saving per room is calculated as -7.881 kWh [9].

For sample hospitals in first scenariov, annual average electricity generation capacity per bed is calculated as 11.336 kWh, average fuel saving per bed is calculated as -8.560 kWh. İf we consider the second scenario, average electricity saving per bed will be 11.400 kWh and average fuel saving per bed will be -6.769 kWh.

Finally, for sample shopping malls in first scenario, average electricity generation capacity per square meter is calculated as 118 kWh/m², average fuel saving per square meter is calculated as -115 kWh/m². İf we consider the second scenario, electricity saving per square meter will be 119 kWh/m², average fuel saving square meter will be -93 kWh/m² [9].

For each building a proper indicator has been selected and on-site electricity generation capacities and fuel saving per selected indicators have been calculated which are given above. The reason of negative fuel savings in some buildings is that cogeneration/tri-generation systems may increase fuel consumption. But if we consider total primary energy saving which contains both electricity and fuel savings, total saving will be positive. Difference between first and second scenario is generally heat pumps and micro wind turbines. Simple payback period of these systems are nearly or longer than 10 years. Heat pumps increase fuel saving but may decrease electricity saving because of initial consumption.

4. ON-SITE ENERGY GENERATION POTENTIAL OF TURKEY EXISTING BUILDING STOCK

For Turkey existing building stock in 6 different typology, annual total on-site electricity generation potential, increase/decrease in total on-site fuel consumption and total investment needs have been calculated by using savings per selected indicators and current official statistics. And also assuming that the amount of electricity generated on-site is not generated by natural gas power plants, net natural gas saving potential have been calculated by considering transmission and conversion losses. It is assumed that transmission and distribution loss ratio is % 10 and average conversion efficiency of natural gas power plants is % 51 [10,11]. Results for first scenario are given in Table 4.1.

Table 4.1 Total Saving Potentials of Existing Buildings Stock According to First Scenario [9]

Building Typology	For First Scenario				
	On-site Electricity Saving Potential (kWh)	Increase/Decrease in Fuel Consumption (kWh)	Net Natural Gas Saving Potential (Sm3)	Average Payback Periods (Year)	Total Investment Need (Billion TRL)
Residential	52.635.839.623	-11.262.932.170	11.884.947.799	6,2	123,30
Offices	6.152.600.233	5.750.078.371	718.775.273	4,8	7,65
Educational	5.923.187.430	1.535.657.747	1.071.482.433	7,4	13,49
Hotels	5.774.539.356	4.177.535.977	790.283.536	4,1	5,70
Hospitals	2.344.722.152	1.770.524.044	313.845.335	3,6	2,19
Malls	1.155.064.830	1.129.175.446	130.226.698	5,6	1,65
TOTAL	**73.985.953.625**	**3.100.039.414**	**14.909.561.074**		**153,98**

According to the first scenario it is possible that 73,9 billion kWh electricity can be generated on-site by using on-site energy generation technologies on existing building stock of Turkey. This amount of electricity is % 72,9 of residential and service sector electricity consumption in 2014. If this amount of electricity is not generated by natural gas power plants and decrease/increase in total fuel consumption is considered, it is possible that 14,9 billion Nm^3 natural gas could be saved in a year. This amount of natural gas is % 30,2 of Turkey total natural gas import in 2014. Total CO2 emission reduction is calculated as 31,8 million Tonne CO2 for a year which is % 6,92 of Turkey total emission in 2013 [12]. Total investment need is calculated as 153,9 billion TRL. If we consider second scenario calculated saving potentials and related values are given in Table 4.2.

Table 4.2 Total Saving Potentials of Existing Buildings Stock According to Second Scenario [9]

Building Typology	For Second Scenario				
	On-site Electricity Saving Potential (kWh)	Increase/Decrease in Fuel Consumption (kWh)	Net Natural Gas Saving Potential (Sm3)	Average Payback Periods (Year)	Total Investment Need (Billion TRL)
Residential	47.153.707.064	-43.480.910.726	13.815.135.703	6,7	138,50
Offices	6.466.205.021	3.025.213.271	1.041.745.331	6,0	10,70
Educational	6.254.568.848	-5.232.915.064	1.781.758.967	9,2	19,78
Hotels	5.774.539.356	4.177.535.977	790.283.536	4,1	5,70
Hospitals	2.357.991.071	1.400.145.527	351.712.297	3,8	2,36
Malls	1.173.412.722	909.996.631	154.792.037	6,0	1,86
TOTAL	**69.180.424.082**	**-39.200.934.384**	**17.935.427.871**		**178,90**

According to the second scenario it is possible that net 69,1 billion kWh electricity can be generated on-site by using on-site energy generation technologies on existing building stock of Turkey. This amount of electricity is % 68,2 of residential and service sector electricity consumption in 2014. If this amount of electricity is not generated by natural gas power plants and decrease/increase in total fuel consumption is considered, it is possible that 17,9 billion Nm^3 natural gas could be saved in a year. This amount of natural gas is % 36,3 of Turkey total natural gas import in 2014. Total CO2 emission reduction is calculated as 38,3 million Tonne CO2 for a year which is % 8,34 of Turkey total emission in 2013 [12]. Total investment need is calculated as 178,9 billion TL. The main reason of decrease in on-site electricity generation potential in second scenario is that electricity consumption of heat pumps. Even electricity saving is decreased, net natural gas saving is increased due to fuel saving for heat pumps. If the renewable energy usage on buildings is increased, total saving potential will be increased too.

Simple payback period of photovoltaic panels on the building roofs considering operating cost is calculated between 6 and 8 years varies according to climatic zones. According to scenario of photovoltaic panel implementation on the efficiently usable area of existing residential buildings' roof, 48,9 billion kWh electricity can be generated in a year. It is assumed that average efficiently usable area of a building is 40 m^2 for a building and existing residential building number is 7.944.301 according to TURKSTAT statistics. If natural gas power plants do not generate this amount of electricity, it is possible that 10 billion Nm^3 natural gas could be saved in a year. The amount of required investment is calculated as 158.8 billion TL considering the current market prices [9]. In similar way, required solar panel area is calculated as 72,2 million m^2 to meet hot water demand of existing residential buildings. With this amount of solar panel it is possible to save 3,99 billion Nm^3 natural gas equivalent [9].

5. CONCLUSION

Existing buildings in Turkey have huge potential regarding on-site energy generation. The feasibility of on-site energy generation technologies for buildings varies according to technology type, building type and climatic region. Generally, active solar technologies are feasible for all building types with the payback period shorter than 10 years. Cogeneration/trigeneration systems are feasible for large buildings such as hotels, hospitals, malls and mass housing with the payback period shorter than 5 years. Heat pumps are feasible for hotels, hospitals and malls, which have both heating and cooling loads. In this context, some policy recommendations are given below to increase the implementation of on-site energy generation technologies on buildings in Turkey.

- First of all, Turkey should produce on-site energy generation technologies such as photovoltaic panels, wind turbines, heat pumps, energy storage technologies, and cogeneration and trigeneration systems locally with own sources.
- Turkey needs to start deep renovation programs for existing buildings regarding energy efficiency and on-site energy generation.
- If renewable technologies built on roofs are documented that they are statically acceptable, they should be exempt from permission of municipalities.
- Heat sale regulation should be published to create heat market and to allow heat sales among buildings.
- Micro cogeneration, cogeneration and trigeneration systems should be analysed for existing and new large buildings such as hotels, hospitals, malls and mass housing. If feasible, they should be implemented in a short period.
- Turkey should develop pellet industry especially in areas where wood product industry are developed. In this way, it is possible to distribute biomass cogeneration systems among Turkey.

- Turkey should develop new support mechanism to allow sales of stored heat and electricity in peak times.

It is possible to meet large portion of electricity and heat demand of buildings by using renewable energy technologies and cogeneration systems. Thus, with on-site electricity generation it is possible to decrease transmission, distribution and conversion losses. Turkey needs to develop new policies to produce these technologies locally and to increase implementation of these technologies on buildings.

REFERENCES

[1] ETKB (Enerji ve Tabii Kaynaklar Bakanlığı), "2014 Yılı Genel Enerji Denge Tablosu", 2015a

[2] TÜİK (Türkiye İstatistik Kurumu), "2000 Yılı Bina Sayımı" 2001, s.27

[3] TÜİK (Türkiye İstatistik Kurumu), "Yapı Kullanma İzni İstatistikleri", 2015a, (http://www.tuik.gov.tr/PreTablo.do?alt_id=1055)

[4] TÜİK (Türkiye İstatistik Kurumu), Adrese Dayalı Nüfus Kayıt Sistemi, 2016, (http://www.tuik.gov.tr/PreTablo.do?alt_id=1059) (erişim tarihi: 08.05.2016)

[5] TÜİK (Türkiye İstatistik Kurumu), "İstatistiklerle Türkiye 2014", 2014a, s. 25

[6] Kültür ve Turizm Bakanlığı, "Turizm Belgeli Tesis İstatistikleri", 2014 http://www.ktbyatirimisletmeler.gov.tr/TR,9860/turizm-belgeli-tesisler.html

[7] TKHK (Türkiye Kamu Hastaneleri Kurumu), "Genel Sağlık İstatistikleri", 2014, s. 23

[8] MİLLİYET, 2016, http://www.milliyet.com.tr/kac-avm-daha-yapiliyor--konut-2040797/ (erişim tarihi: 21.02.2016)

[9] KABAKÇI O. Kürşat, "Türkiye'de Bulunan Farklı Bina Tipolojilerinde Yerinde Üretim Potansiyelinin Enerji Verimliliği Çerçevesinde Değerlendirilmesi", Enerji ve Tabii Kaynaklar Uzmanlık Tezi, 2016, s.145, 146, 150, 151, 154, 155, 157, 159, 163, 166, 167, 168, 169.

[10] DUZGUN Bilal, "Fosil Yakıtlı Termik Santrallerde Mevcut Durum Değerlendirmesi Ve Enerji Verimliliğinin Artırılmasına Yönelik Bir Alan Araştırması", Enerji ve Tabii Kaynaklar Uzmanlık Tezi, 2015, s. 181

[11] TERIIN (The Energy and Resources Institute), "Transmission and Distiribution Losses", 2015 http://www.teriin.org/upfiles/pub/papers/ft33.pdf

[12] TÜİK (Türkiye İstatistik Kurumu), "Seragazı Emisyon Envanteri 2013", 2015c, http://www.tuik.gov.tr/PreHaberBultenleri.do?id=18744 (erişim tarihi: 23.04.2016)

Paper No: 181

Public Projects on Energy Efficiency in Buildings – Sample on Promoting Energy Efficiency in Buildings "Integrated Building Design Approach"

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ABSTRACT

The significance of studies on R&D about energy efficiency in countrywide is not clearly recognized yet and there are not adequate works carried out on project development. A need for design approach suggesting co-work of multi-disciplines during the construction process of buildings to improve energy performance in buildings by increasing awareness on energy efficiency in buildings is recognized. This approach is called "Integrated Building Design Approach". There are international funds benefited by United Nations member states to eliminate deficiency on consciousness on this approach in Turkey and to provide an environment sufficient for investments on energy efficient buildings and support for building sector development progress in terms of energy efficiency. This approach is implemented in Turkey with the support of Global Environment Fund (GEF).

This notice targets to provide information on preparation process of "integrated building design approach" studies and its outputs under the scope of "Promoting Energy Efficiency in Buildings in Turkey" Project implemented by support of Global Environment Facility (GEF), together with Ministry of Energy and Natural Resources General Directorate of Renewable Energy (GDRE) and United Nations Development Programme (UNDP) Turkey under the cooperation with Ministry of Environment and Urbanization and Ministry of National Education.

INTRODUCTION

"Promoting Energy Efficiency in Buildings in Turkey" Project, subject to this notice, is recognized valuable to be explained as it is a good sample. It is good sample for understanding how the co-work of state, funding institutions and university is done in public projects and how to spread the outputs of this work and form adequate consciousness on benefiting from funded projects.

Project has started on March 2011 and targeted to promote energy efficiency in building sector. It is a five-year period project supported by GEF executed by General Directorate of Renewable Energy (GDRE) of Ministry of Energy and Natural Resources under the cooperation with Ministry of Environment and Urbanization and Ministry of National Education. Under the scope of project, in order to promote energy efficiency in building sector, it is aimed; to introduce integrated building design approach, develop a design criteria indigenous to Turkey, apply integrated building design approach to sample projects (to apply on energy efficient demo building providing at least %50 energy saving), including "Regulation on Energy Performance in Buildings", to improve the regulation on energy use and to prepare and apply capacity building programmes for actors effective in the

sector. Total budget of the project is 17,580,000 $. [1]
One of the justifications during targeted commencement date of the project and a year earlier than it is on inadequacy of law and regulations on providing energy efficiency in buildings. While it is a true justification, revised adjustments made in 2011 on Regulation on Energy Performance in Buildings cannot be a solution. However, while subjected regulation, whole discussions, conferences and academic works up to today are taken into consideration; it is a significant step for bringing consciousness to architectures and engineers on mentioned subject.

Table 1 Energy efficiency codes and regulations implemented on buildings in Turkey [2]

Code / Regulation Name	Subject of the Revision	Latest Revision Date
Rules of Thermal Insulation National Standard	Insulation Standards for Buildings	May 2008 (small revision); June 2000
Energy Efficient Rule 5627	Energy Efficiency in Buildings	May 2007
Renewable Energy Resources Law 5346	Use of Renewable Energy Resources for Electric Energy Manufacture	May 2005
Regulation on Energy Efficiency	Calculation of Building Energy Performance, Renewable Energy use and Heating, ventilation and acclimatization systems	December 2008 December 2009 will be replaced with Heat Insulation Regulation.
Regulation on Thermal Insulation in Buildings	Insulation-based thermal performance	It has been revised on August 2008, and BEP regulation will be replaced with it on August 2009.
Revision on Energy Performance Regulation in Buildings	Settling disputes by major law and sharing central heating expense	01.04.2010 – 19.02.2011 and 20.04.2011 Revised regulation is published.

In this context, the reason behind inadequate legislation on energy efficiency in buildings is lack of academic approachs, re-de works, public and private sector collaboration, information of technical team constructing the building and user of the building and lack of improving awareness. The only way to approach to the target is uniting whole these facts.
Actually, under BEP regulation [3] Turkey conditions, which is not given so much importance but affecting energy efficiency decisions, is the 3rd section called **"Architecture Project Design and Architecture Implementation in terms of Building Energy Performance"**. It states in 1st paragraph of 7th article under this section that "*Architectural design of buildings, zoning and taking into consideration square / parsel situation, heating, cooling, natural ventilation, lightening need is kept in minimum level. Taken into consideration solar, damp and wind; natural heating, cooling, air condition and enlightening is benefited in minimum level.*" During this paragraph and architectural design phase even it is said that 'pay attention to criterias bounded to environment', there isn't any information or architectural detail on how to embrace these criterias on building design.
Under paragraph 2 of article 7 mentioning important matters to be considered during architectural design is mentioned as: "*While orienting indoor and buildings, holding undesired heating gain and loss at minimum level with architectural solutions found by taking into consideration solar, damp, wind, snow or similar meteorological data; placing living space, solar heat and light and natural air-condition in most appropriate way for taking advantage of; providing unity between architectural implementation project, system details and whole material and important*

details in thermal insulation project, preparation of roof-wall, wall-window, wall-base and wall-furniture-base details; using renewable energy resources upon the place where the building will be constructed, searching and reporting opportunities". However, in this paragraph, there is no information on how to prepare and design mentioned data.

Once again, it is indicated under section 3, article 8 on existing architectural implementations, possible estimates on heating gain and loss and already known important matters to be remembered by engineers - which actually should be known by architecture during heating calculations. The concepts under architectural practices are advisory articles, and don't require any mandatory implementation in terms of providing energy efficiency. In this case, arranging it in energy efficient way during design process is led to the preference of architecture.

Actually, promoting energy efficiency in buildings during architectural design process, aspects such as; direction of the building, land conditions, windward, sun's angle of incidence, existing surrounding trees, soil structure, underground energy resources, local and technological material considered to be used, building typology, user habits in building need to provide solutions for geometry and function of the building. Solution is using passive design principles. In case of ineligibility of passive design, artificial / mechanic system or active design support should be provided.

INTEGRATED BUILDING DESIGN PREPARATION STUDIES

Urban environment and construction process, while having similarity with international experiences and continuous, on the other hand, this process holds genuine differences caused by cultural, historical, political, physical and geographic dynamics and priorities. Therefore, while reflecting these practices to Turkey, numerous method and model intended for project and building manufacture should be discussed by considering geographical differences and they should be functionalized. IBDA, is a design model valid all around the world. It is more than 1/50 Implementation Project provided only in paper during design phase and detailed drawings made for providing its energy efficiency. There is a need for harmonizing it with Turkey conditions. Together with this project, 15 different experts revealed introduction of integrated building design approach, its principles, implementation samples (Figure 1 and 2).

Figure 1 First meeting (kick-off meeting) hold with experts - morning session

Figure 2 First meeting (kick-off meeting) hold with experts - afternoon session

Preparation of Sample Public Buildings and Implementations (Demo Buildings)

Integrated Building Design Approach is not only preparation limited to books, but also new building projects on this approach are prepared. Design phase, implementing projects and tender documents prepared under demo buildings by "Promoting Energy Efficiency in Buildings", implementation of best design is provided by modeling energy performance, lifecycle and life cycle cost assessment since the beginning. During the preparation phase of demo buildings, detailly provided phases in IBDA implementation guide is implemented with such method;

- Identifying functional and architectural needs,
- Identifying sustainability goals,
- Preparation of architectural preliminary design optimal to needs,
- Identification of passive, mechanic and electric systems of the building and integration to architecture,
- Implementation of energy modeling of suggested structural and mechanic solutions and similar analysis,
- Research on cost assessments of the construction and its benefits,
- Revised, improved architectural design.

Projects and instruction of demo buildings, as a sample to public buildings, are started as Ministry of Environment and Urbanization Sincan General Directorate of Land Registry and Cadastre Service Building (Figure 3), Ministry of Education Ankara Eryaman - Cezeri - Green Technology Technical and Industrial Vocational School (Figure 4). Experience gained through demo buildings and preparation process of the books is supportive and supplementary for each other.

Figure 3 General Directorate of Land Registry and Cadastre Service Building

Figure 4 Green Technology Technical and Industrial Vocational School

WHAT IS INTEGRATED BUILDING DESIGN APPROACH?

Integrated Building Design Approach (IBDA) is a process- driven method for improving energy and environment performance of buildings. IBDA provides a framework for efficient cooperation of initial actors on building development, design, construction and management. This approach provides an opportunity synergy in studies and system performance and improves performance levels considerably. While providing a work environment for investors and design team to work together and in coordination, IBDA provides early intervention opportunity to problems. This methodology adopts integrated building design approach. While it gives priority to individual performance subjects, on the other hand it also contains interaction between (for instance benefiting from energy and daily light and indoor standard etc.) performance fields. (Figure 5) [4].

IBDA also a process contains whole phases of building lifecycle starting with location determination and functional programming, it includes design, construction, execution and future dissemble / destruction. A decision take in a phase will affect the decisions going to be taken in continuing phases; therefore; in order to maximize successful chance, decision makers need to know possible phases in lifecycle and foreseen their impacts on other phases [4].

Existing buildings are holding the significant amount of total building stock among numerous countries. Therefore, IBDA is suggested not only as a method used for construction process, but also a method that can be implemented in alterations projects. However, different design and construction methods used in different methods, additionally previous alternations and changes of each building should be taken into consideration. (Figure 6) [4].

The purpose of IBDA is finding solutions to whole problems of buildings that are going to be constructed nowadays and under project phase so that to create a common work principle between stakeholders which desire to reach to intended performance targets.

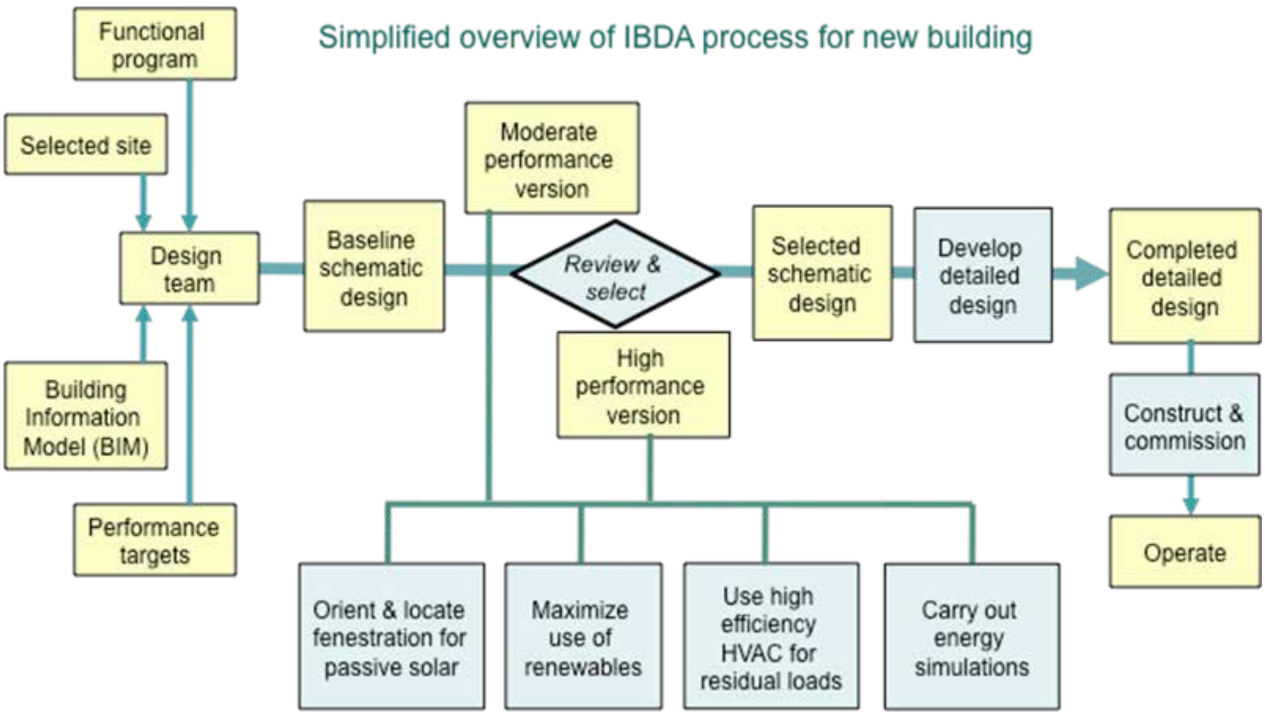

Figure 5 Phases that can be followed to achieve high performance in new buildings and relations between these phases [4]

As given in figure 5, following the architectural and engineering schematic design, by using information modeling analysis are done to provide optimum conditions. However, Building Information Model (BIM) analysis that show high performance according to the location of the building (for example: if solar energy gain is taken into consideration and valuable increase in energy performance is provided) are the ones need to be take into consideration between the available values. This situation is up to the working style and initiative taking of the design team.

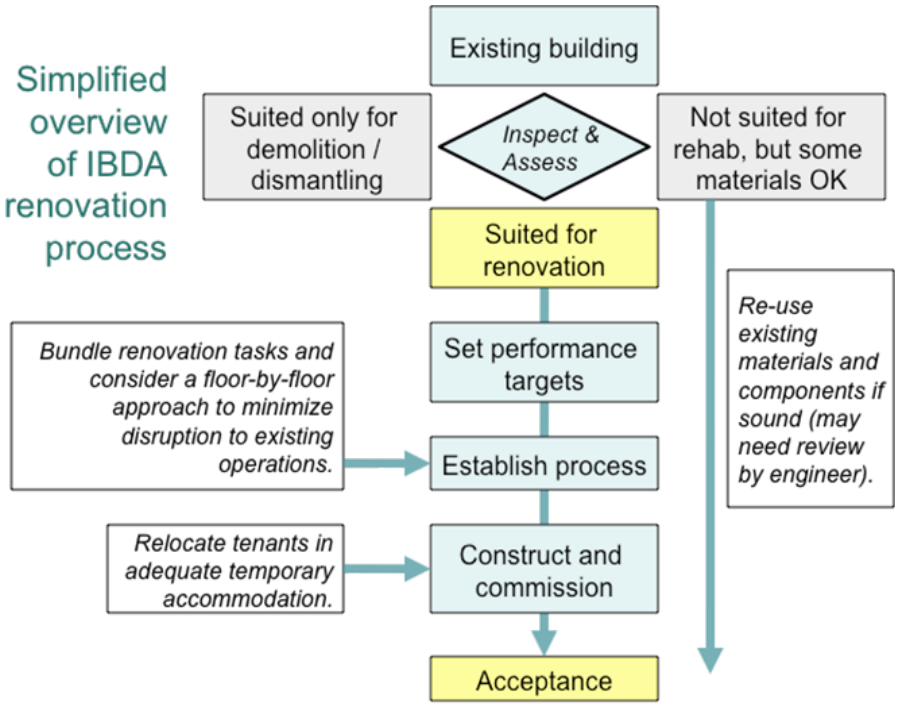

Figure 6 Phases that can be followed to achieve high performance in new buildings and relations between these phases [4]

In figure 6, in order to provide energy efficiency for IBDA application, current building decision depends on design – repair team investigation on building strength to earthquake and fire for alternation. If current building is suitable for retrofiting, energy and environment analyses are done as by modelling as in the way applied to new building. Also, performance target special to current building will be determined by paying attention to climate, location, early function.
Phases belong to suggested process model for applying special to each project for IBDA are subsidiary to each other and they can provide feedback for reasonable performance values of the building. Phases belonging to the model are as following [4];

Development Phase of Preliminary Project (Concept Project)

1. Identification of environment factors effecting design and construction process
2. Land choice and evaluation of field features
3. Evaluation of current construction in the land
4. Development of functional programme and management process
5. Development of priorities and targets oriented towards performance
6. Selection of design and design development team members
7. Organizing Preliminary Project brainstorming / information sharing meetings
8. Development of schematic design(s)
9. Selection of one schematic design to develop in advanced way
10. Development of settlement plan

Detailed Design Development Phase

11. Development of Building Information Model (BIM)
12. Development of requirements for schematic indoor design
13. Development of building static construction design
14. Development of building envelope design
15. Development of preliminary strategy for utilization from day light and lighting system
16. Development of preliminary design of power system
17. Development of ventilation, heating and cooling system designs
18. Evaluation of soil or water source-based thermal storage options
19. Development of specifications for building management control system
20. Practicing detailed energy simulations
21. Deciding design options
22. Selection of non-structural materials
23. Completion of project documentation before building construction process
24. Development of quality assurance strategies for construction and activities.

Construction Phase, Activities and Monitoring

25. Preparation and management for performing construction and activities
26. Deliver and preparation of land, completion of major works
27. Demolishing incompatible constructions in the land
28. Evaluation of use of detached materials possibilities
29. Use of recycled materials
30. Management of construction wastes aside
31. Completion of building construction
32. Performing energy simulations on constructed building
33. Application of commissioning process
34. Training execution personnel
35. Training lessees using the building for commercial purposes for efficient management process
36. Training building resident for fruitful management process
37. Building Management
38. Monitoring performance and development of management performance
39. Evaluation following the housing

* In case applications on energy efficiency of existing buildings done applied to these phases, steps under dissemble / destruction phases can be added.
Clues, detailed explanations, sample drawings developed under the scope of Promoting Energy Efficiency in Turkey Project on how to create this model in building design and path going to be followed for improving energy performance during building design is reflected to the readers via IBDA books.

INTEGRATED BUILDING DESIGN APPROACH STUDY OUTPUTS

Integrated Building Design Approach (IBDA), is subcomponent of project and composes of two phases within itself. One of these phases is to understand problems while functionalizing Integrated Building Design Approach in Turkey and prepare a report determining suggestions for application. The second phase is to prepare "Project Development Process Implementation Guidebook with IBDA" in line with these findings and data (Figure 7).

Figure 7 Book cover pages related to IBDA

First book called "Integrated Building Design Approach – Adaptation Report" contains problems, discussions, findings, evaluations and suggestions that will be framework during IBDA's adaptation to Turkey conditions. This report contributed to both development phase of research and determination of priorities and headings during preparation of IBDA Project Development Process Implementation Guidebook. [5].

Second book called "Integrated Building Design Approach - Implementation Guidebook" emphasizes the mail resource of numerous problems including sub-products such as tender order, implementation capacity of construction sector, material standards in the market, project standards. It determines models for process management to be a solution for problems occurred due to lack of project stakeholders' simultaneous or in coordination presence on providing feedback and knowledge sharing in project phase. On the other hand, it is a path finder for material choice, implementation details and process priorities which are other components of the problem [4].

In third book called "Integrated Building Design Approach – Priorities and Targets for Building Performance"; in order to determine performance problems, priorities and targets in buildings and constructed environment in Turkey, process from project phase of constructing a building to the process of building destruction is investigated for improving energy efficiency in constructed environments. Within this scope, problems and solution suggestions taking into consideration different phases from simulation programmes to design processes, from material choice to details, from construction phase to use process are emphasized in continuity that observe their impacts on each other [6].

Actually, integrated building design approach demo buildings and guidance books are contributed to these subjects;

- Improving energy efficiency and constructed environment quality in building scale,
- To develop qualified environment and building construction standards country-wide,
- Updating already existing standards,
- To develop continuity which is open for feedbacks between design, manufacture and utilization phases of the buildings,
- To support construction sector applying the designs,
- To develop a framework for manufacture standards on energy efficiency and environmental awareness subjects.

An Information Meeting on books has been held on 30 May 2016 in Ankara Rixos Grand Hotel with the involvement of leading media organizations such as Anadolu Ajansı. The meeting was a significant step for improving awareness on energy efficiency and dissemination of use of books (Figure 8 and 9).

Figure 8 Integrated Building Design Approach Introduction – Briefing Meeting

Figure 9 Experts from Integrated Building Design Approach Introduction – Briefing Meeting

CONCLUSION

Integrated Building Design Approach is forming a basis for impact of energy efficiency and construction on the environment before the building is constructed and feedback on the information gained from whole stakeholder disciplines and directing the design process. Performance of the building during life cycle, precautions contributing to this performance will be taken. Experience gained through functionalization of this process might provide reference assets for preparing regulation. Reference buildings for different building typologies can be obtained. By making new buildings obliged to perform above reference building values, a contribution can be provided on construction sector experiencing renewable building.
IBDA will reveal sustainable criteria, shortly can be defined as rationalism, article by article. Actual aim is to refresh rational habits that sunk into oblivion and societal memory and to reveal details on building construction with more modern approaches with facilities of modern days. Main lines of IBDA will be formed in the virtue of uniting previous experiences and present technology under production principles.

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Throughout 2 years, in order to adopt Integrated Building Design Approach to Turkey construction building conditions, make it ready for implementation and determine performance priorities, works with team consist of 15 experts had begun. We would like to share our, as ministry personnel, thankful to; Team Leader Prof. Dr. C. Abdi GÜZER, Team Manager Asst. Doc. Dr. İlker KAHRAMAN, Energy Efficiency and Sustainability Expert Nils LARSSON, Energy Efficiency and Sustainability Expert Prof. Dr. Birol KILKIŞ, Ventilation Expert Dr. İbrahim ÇAKMANUS, Building Acoustics Expert Prof. Dr. Arzu Gönenç SORGUÇ, Building Information Modelling Expert Hasan Burak CAVKA, Building Materials and LCA Expert Dr. Hüdai KARA, Lighting Expert Research Asst. Dr. Feride Şener YILMAZ, Water Usage and Management Expert Asst. Doc. Dr. Gülten MANİOĞLU, Building Structure Expert Dr. Özgür BOZDAĞ, Software Programs for Sustainable Buildings Design Expert Michael Carter WAKEFIELD, Solid Waste Management Expert Mahmut Özgür ŞAKI, Traditional Buildings Expert Dr. And AKMAN, Legislation Expert Dr. Selin Zağpus YİGİOĞLU for their contributions. Additionally, we would like to share thankful to our sincere managers Deputy General Manager of General Directorate of Renewable Energy Erdal ÇALIKOGLU and recent Energy Efficiency and Store Equipment Bureau of General Directorate of Vocational Services Head of Department Murat BAYRAM for their faith on us and continuous support.

REFERENCES

[1] http://www.eie.gov.tr/verimlilik/document/Binalarda_Enerji_Verimliliginin_Artirilmasi_Projesi.doc
[2] Promoting Energy Efficiency in Buildings Project, Project Application Document, p.8-9. http://www.surdurulebilirbinalar.net/index.php/tr/belgeler/category/11-proje-ile-ilgili-belgeler
[3] Energy Performance Regulation in Buildings, http://www.mevzuat.gov.tr/Metin Aspx?MevzuatKod=7.5.13594&MevzuatIliski=0&sourceXmlSearch
[4] Ministry of Energy and Natural Resources, General Directorate of Renewable Energy, "Integrated Building Design Approach Project Development Process Implementation Guidebook', Uzerler Matbaası, ANKARA, 2016, ISBN: 978-605-5310-87-5
[5] Ministry of Energy and Natural Resources, General Directorate of Renewable Energy, "Integrated Building Design Approach Turkey Environment and Conditions Adaptation Report", Uzerler Matbaası, ANKARA, 2016, ISBN: 978-605-5310-88-2
[6] Ministry of Energy and Natural Resources, General Directorate of Renewable Energy, "Integrated Building Design Approach Building – Priorities and Targets for Building Performance", Uzerler Matbaası, ANKARA, 2016, ISBN: 978-605-5310-89-9

Paper No: 206

The Story of Implementing Calculation Methodology of BEP into A Software Program (BEP-TR2)

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ABSTRACT

In the light of the introduction of the Energy Performance of Building Directive of the European Union, a big step was taken in Turkiye with releasing "Building Energy Performance (BEP) Regulation" in 2009. Moreover, the related national calculation methodology and its tool (BEP-TR) became mandatory in 2010. Regarding several issues occurred during the practice, national calculation methodology was renewed in 2014 and related software has been updated.

This paper aims to draw a general picture of the renewed methodology in the light of the scope of BEP regulation. A deep review of national calculation methodology and its implementation into the software is going to be done by means of module by module analysis. Each module and their sub-modules listed in calculation methodology are going to be examined and critical issues of implementation are discussed.

The first part of the paper is dedicated to discuss the steps of implementation process of the methodology. The story behind the challenge of implementing theoretical requisites into user friendly and practical tool is going to be revealed. The second part is directly related with applicability of graphical interface and drawing environment of the tool. Developing a drawing environment and integrating relevant necessities of building components into the tool with a user-friendly way are the hardest challenge of the tool developing process.

By this paper, the experiences gathered from implementation process has been shared and practical approach to emergent issues of implementation has been discussed.

INTRODUCTION

Energy performance in buildings issue has become one of the most important subject matters in Turkiye, especially regarding the procedure of accreditation within European Union. There are many studies conducted in the context varying from developing standards and regulations to inventory of buildings in the frame of energy performance parameters.

In the light of the introduction of the Energy Performance of Building Directive of the European Union, a big step was taken in Turkiye with releasing "Building Energy Performance (BEP) Regulation" in 2009. Moreover, the related national calculation methodology and its tool (BEP-TR) became mandatory in 2010 [1, 2]. There were several problems announced by the users of BEP-TR many of whom are mechanical engineers. Based on the critics related with national calculation software (BEP-TR), Ministry of Environment and Urbanization was decided to renew the methodology and release a second version of the software (BEP-TR2). The process of developing the new methodology was finalized on May 2014. Shortly after, the implementation process was started for BEP-TR2. Actually, developing a methodology was only one angle of this process. Implementation of methodology into a software has been another, very critical process that should be carried out very attentively.

With this study the implementation process of calculation methodology into software is being discussed in two basic stages. First stage covers the implementation course of methodology into code as modules. The other simultaneous stage is including the definition of required drawing platform and user interface of the software.

CONTENT OF BEP-TR2 SOFTWARE

The first version of the calculation methodology which has its framework defined on Official Journal (Gazette) of Republic of Turkey dated 05.12.2008 is in use for issuing energy identification certificates to buildings. With BEP-TR2 version which is completed by TUBITAK Marmara Research Center Energy Institute at May 2014, the calculation methodology was renewed and development of a new software according to this version was approved by Ministry of Environment and Urbanization. From November 2014 to April 2015, the BEP-TR2 software was prepared according to "Building Energy Performance National Calculation Methodology" in force and its implementation was completed.

There are four application consisting of multi layered architecture in the technical specification describing the implementation of methodology. These application are defined as below. (Figure 1):

- **BEP-BUY:** The desktop application belongs to the Ministry, working offline and online to generate the data file in XML format and transmit it to the BEP-MY
- **BEP-IS**: BEP Operating System,
- **BEP-MY**: The application performing calculations according to National Calculation Methodology.
- **BEP-ONAY**: EKB (Energy Identification Certificate) approval application

Among these applications BEP-IS runs completely web based and forms the administrative control mechanism of the Ministry as authorization, user information, reports etc. Whereas BEP-BUY can run entirely on desktop and offline as a user interface for the end user to develop complete building models and information inputs. BEP-MY provides results by transmitting the data from user interface to calculation algorithm. Calculation takes place on web based online system in the control of Ministry. The result obtained after calculation is used for issuing the Energy Identification Certificate for related building. This application is also included in the online system.

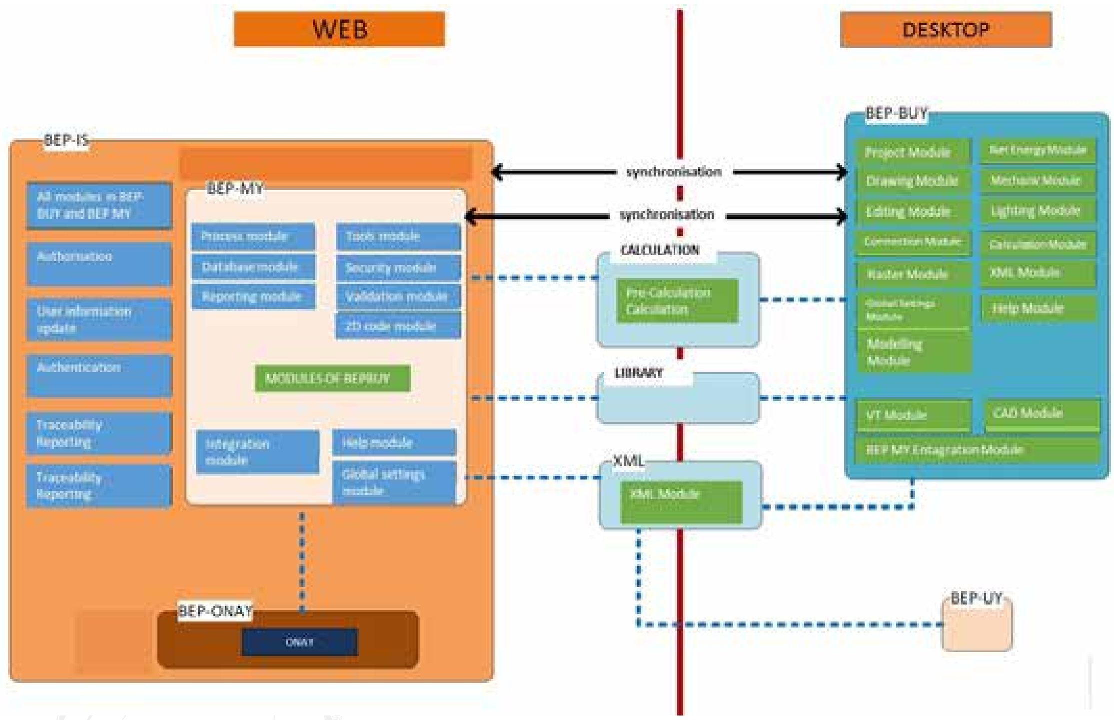

Figure 1 BEP-TR2 Definition of applications consisting of multi-layered architecture.

The most critical structure here is BEP-MY. The entire algorithm of the calculation methodology is needed to be implemented in this module in an accurate way. Besides, forming the BEP-BUY and establishing the coordination accurately between the two applications, defines another critical situation.

BEP-MY CALCULATION METHODOLOGY IMPLEMENTATION

Basically, the calculation module should provide the ability of identifying all parameters have effect on building, for determination of net energy consumption of building in the most possible approximate way. This requires the involvement of all parameters which have energy transfer between themselves. Since any possible complicacy here will cause the calculation turn out mistaken results, it has to be treated in utmost care.

For the calculation module, the accurate definition of net energy relation is essential. In the net energy relation; the net energy need for heating and cooling of the building creates data for the energy balance of building systems. Energy balance is divided into two, as energy at building level and energy at system level. The definition of hourly heat loss and heat gain ratio belongs to each zone determines the energy amount needed for that zone. Hence, in the calculation of net energy, to avoid the possible complicacy that interacting systems can cause and to add an operability compatible with calculation methodology, it is agreed that the calculation methodology is to be divided into sub-modules and assessed step by step.

Three basic sub-modules defined in the calculation module.

- Architectural Module
- Mechanical Module
- Lighting Module

Architectural module forms the basis for the net energy calculation can take place. Within itself, the architectural module includes geometry module, solar gains module, ventilation module, internal gains module and heat transfer module.

Geometry module is important for the accurate definition of the geometric data of the building. In this module zones composed of rooms with similar functions should be defined for each floor of the building separately. Area and volume of the each room; direction and area of the each surface from the room (wall, door, window); definition of horizontal and vertical adjacency conditions for each surface; the dimensions of horizontal and vertical shades (if applicable); angle value required for the calculation for dimensions of outside obstructions will be calculated in this module. The geometric data (area, volume, proportion, angle) belong to each component of the room (wall, floor, ceiling, roof etc.) are some essential data used frequently during calculation.

Solar Gains Module is a sub-module must operate with the values gathered from climate data and required hourly calculation for sure. The definition of the locations of earth and sun once for each day of the year should be enough. While, the data related to sunshine duration will be determined in hourly basis and take place in the climate data. The intermediate result obtained by solar gains module produces direct data for net energy as sun originated heat gain.

Ventilation module defined as two phases. Phase-1 includes air exchange rates depending on air leakage. The result obtained by this phase provides the definition of ventilation caused heat transfer coefficient. This value is also used in the Phase-2. Phase-2 defines the ventilation calculation of zones with air conditioning systems operated and ventilated mechanically. As a result it gives the ventilation caused heat transfer coefficient in hourly basis and creates another input required for net energy calculation.

Inner gains module requires the involvement of all components producing heat into the calculation hourly. In each zone, there are heat gain originated from human defined according to activity level. Lighting and equipment existing in the zone (computer, photocopy machine etc.) are included in heat gain calculation as heat sources as well. In the calculation of inner gain, a distinction is made according to the building types also. For each building type, number of persons in each zone, lighting and equipment information definition are added to calculation one by one, since the number of users are not the same for residential, office and educational buildings; just as the hours of operation differs. For the information regarding the lighting, the output from lighting module is used.

Heat transfer module requires the calculation of heat transfer coefficients of opaque and transparent components separately for the heat transfer calculation. During the calculation for transparent surfaces, definition of shading components and use of solar gain hourly angles that calculated in solar gain module are necessary. Heat transfer module is also defined as two phases. Second phase includes the calculation of the heat gain/loss ratios caused by heat bridges as well. The result obtained by this module gives the hourly heat transfer coefficient values of opaque and transparent components for each zone, and takes place in the net energy.

Mechanical module, is the definition of the mechanical system design required for sustaining the energy balance for each zone. Here, together with the calculation of the energy amount needed for air conditioning system, heating system and domestic hot water; definition and calculation is made for the renewable energy (solar energy, heat pump). With the renewable energy calculation, the ratio of energy supply will be met by renewable ways is in the determination of net energy need is calculated. Mechanical module uses the intermediate results obtained by all sub-modules included in architectural module during the calculation. Because, the results obtained by architectural module are necessary for the system design mechanical module and definition of its capacity.

Lighting module, includes the calculation of the energy consumed for interior lighting purposes in buildings. The result obtained by this module does not present any information only by itself. This sub-module can give independent result if related data input is provided. Yet, the heat gain obtained by lighting devices is expected to produce inputs for total hourly gains belong to each zone.

The procedure followed in implementation of these modules in software is shown in Figure 2. According to that procedure, in the coding process of each module, first, the parameters required for calculation are defined and calculation steps are determined. Existence of any mistake or deficiency is detected. Possible shortcomings are conveyed to authorized persons in Ministry and required corrections are made. Calculation algorithm is written on code and the calculation belonging to that module is run. Obtained result is compared by a result given by third party software with the same data and become validated.

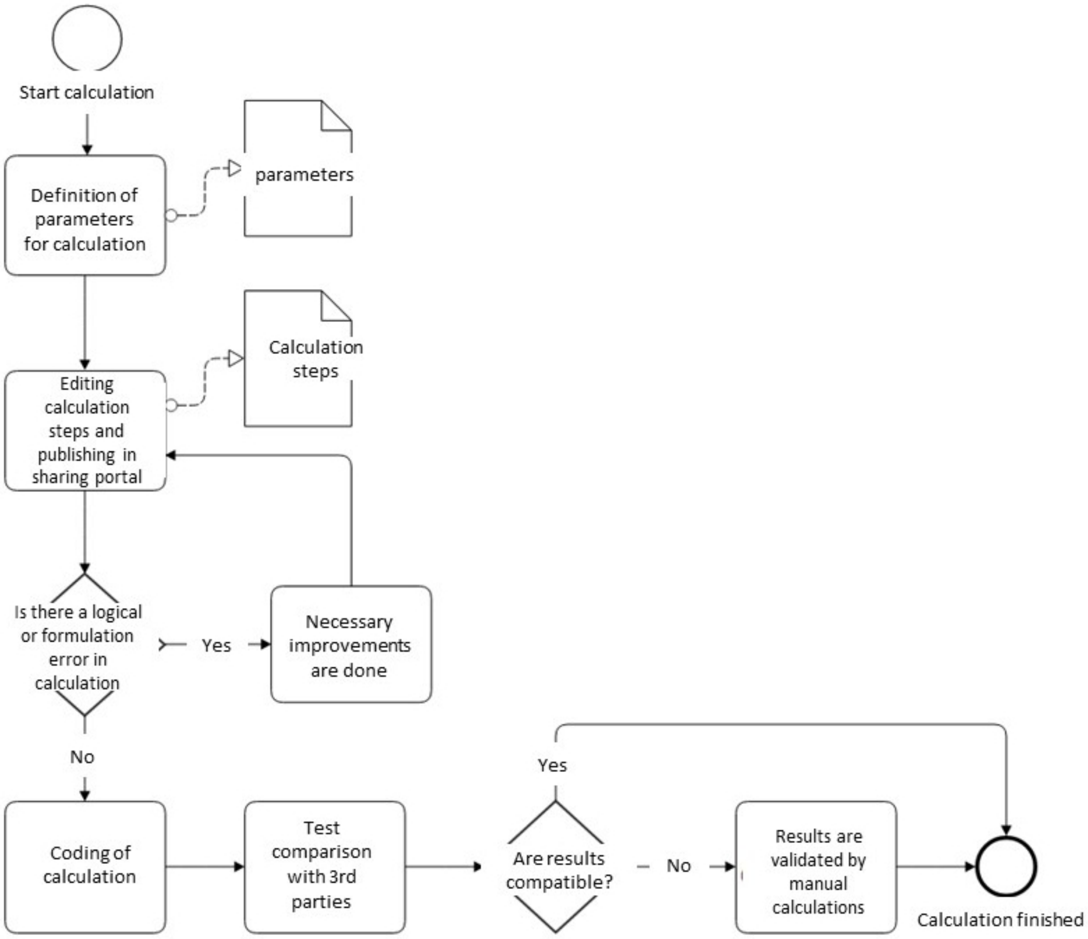

Figure 2 The procedure followed in implementation of these modules in software.

For the validation tests, one of the three essential methods appreciated in literature are decided to be used. One of these three methods is empirical validation (with the real building or lab configuration). However, since the empirical validation is not able to be set up with the real building or appropriate lab conditions, it cannot be used in this practice. Second method, analytic validation (analytic analysis based on mathematical facts). For testing the accuracy of some of the calculation algorithms this method is applied. Though, in this method which requires hand calculations, validation of a single calculation may take hours or days when complicated processes are in discussion. Therefore, each sub-module is validated based on the third method, comparative test (the comparison of the software with itself and other software). Also, this method is developed in IEA SHC Tasks 8, 12 and 22 and approved as a valid test procedure by becoming a standard with the name of ANSI/ ASHRAE Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs. Most of the validation tests are provided by this method.

USER INTERFACE AND BEP-BUY

BEP-BUY application, constitutes the user interface which is the desktop application where the modeling of the building and data input is done. By this application the geometry is defined as well as entire information of building components related with the calculation are entered.

In the BEP-TR calculation methodology, it is stated that the hierarchical definition of building geometry is required. As shown in the Figure 3 describing that hierarchy, the building is defined in tree order. Every component included here, carries all necessary parameters required for the energy calculations together with geometry information. (material, dimensions, climate etc.) In order to define the calculation flow accurately, the relation among components must be defined clearly.

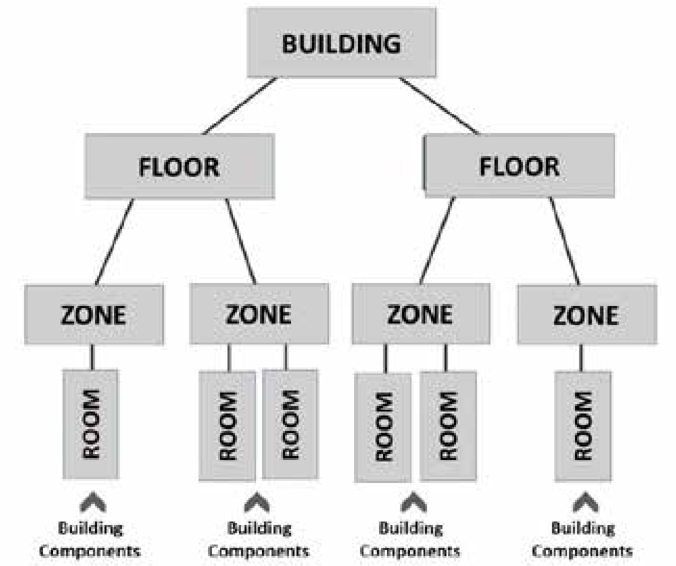

Figure 3 The hierarchical definition of building geometry.

In calculation methodology this hierarchic order described as below:
"Before creating any geometry in the methodology, the objects which will hold the geometries together should be created. As shown in Figure 3; a "building" object should be created to begin with when a project has been started. "Floor" objects are defined as sub components of building object. "Zones" mean the group of spaces which are air conditioned differently in a floor. After the zones are created, "room" objects are created ant the components constituting the building are defined as sub components of these rooms. Thanks to this hierarchic definition, all relations among the all components in buildings become defined."
In this hierarchic order, the "zone" and "room" terms included in the hierarchy are combined and the calculation is enabled to be operated only with zones defined on floors to relieve the data input and provide ease in modeling. The accuracy of the BEP-TR calculation module is directly related with the accurate definition of the building to be analyzed in the BEP-BUY. One of the mostly criticized parts of the first version of BEP-TR still in use is the insufficiency of the geometric definition. There are international drawing norms in architectural expression for the correct understanding and construction of a building. Drawings as plans, sections and elevations are required to define a three dimensional structure (object) in two dimensional plane (like paper). Plan is indeed a horizontal section drawing of a structure, showing the space organization from bird's eye, dimensioned and scaled. Whereas, section is used for showing the vertical dimensions and material components of a structure in scale with dimensions. Thus, only the plan or section is not enough to define any place. Coordinated use of both drawings is among the minimum requirements to define a place.
In the related part of documents including the calculation methodology about geometry module, there is no information about the three dimensional modeling of the building. However, in the related parts of calculation methodology (especially the module related with heat transfer) inconveniencies appears because of the building defined only in plan plane. In particular, for shared walls/floors and adjacency definitions there is need for

information in third dimension. Furthermore, not only for very complicated buildings, but also for the definition of many ordinary buildings, this is a must.
To be able to make the issue more comprehensible, beginning from the BOX model which is used for testing the calculation methodology is necessary. The BOX model is composed of a single room and single zone (Figure 4). With this model, solar gains, lighting, inner gains etc. calculation methods can be calculated and tested based on simple information. However, when the subject is heat transfer and ventilation, the heat transfer between adjacent spaces must be calculated. It is impossible to test it in a single zone building.

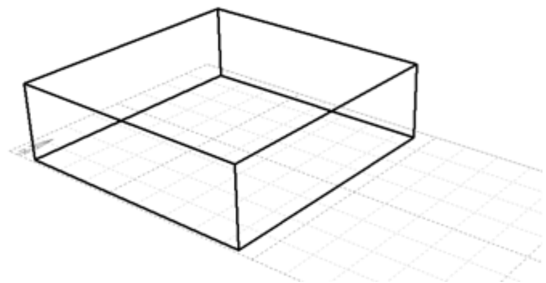

Figure 4 BOX model.

To make the BOX model two zoned, zone addition can be made either horizontally or vertically. When we add a same size zone to the model horizontally, defining the walls between adjacent spaces might not be very hard since we can recognize it easily in plan.

For example when we add a same size space to the beginning model in Figure 4 horizontally, we can get the Figure 5. Here, there won't be a change related with walls or floors under and above. But if the second zone added has a different size from the previous, the part of the wall shown with red color here is adjacent with the exterior while the other part is adjacent to other zone (Figure 6). Here, there is a need for a separated definition in geometry since there will be a need for calculations for wall parts in two different conditions. However, it is easy to know and define the different zone sizes even if we only have the plan plane.

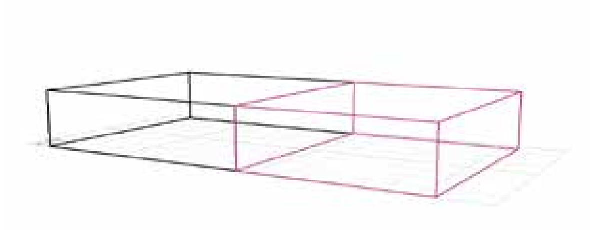

Figure 5 Adding the second zone horizontally

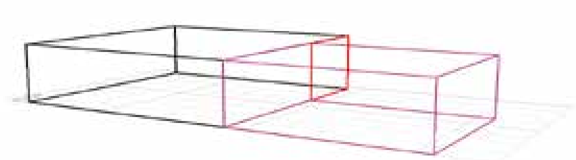

Figure 6 When a different sized zone is added the red part of the wall is adjacent to exterior.

If the second zone will be defined vertically instead of horizontally, then the clarification of the floor separating zones will be needed. Especially on this matter, it will be understood more clearly why the plan plane mentioned above will not be enough for the definition. In Figure 7, a second floor level (zone) added to the model is defined. This newly added space is a single zone and its floor is projecting out from the zone below, creating a cantilever. Here, the floor separating the two zones from each other must be defined. As shown in the Figure 8, one part of the floor (green) is between two zones, while the other part (red) is adjacent to outside environment. Within the architectural drawing setting, each time the independent definition of a floor is made, it won't be possible to add the zones with different sizes and adjacency relations between two floor levels and it will cause inaccurate calculation.

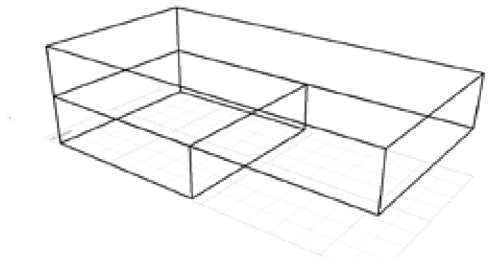

Figure 7 The second floor level added to the BOX model.

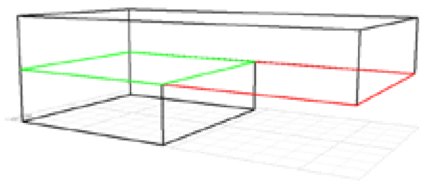

Figure 8 Different floor parts defining the adjacency relations with the other floor level.

Another reason of the necessity of using the section in architectural expression is that every wall part may not have the same elevation. If exemplifying requires, one of the zones from the model given above with two zones might have designed with a pitched roof. As it can be seen in Figure 9, the upper zone might have been designed as its ceiling is sloped and side walls are angled. The view of this in plan plane has no difference with the view of the one in Figure 7, yet it defines a different volume in third dimension and this difference must be included in calculations. Walls shown in red in Figure 10 have different areas, the level height belongs to that zone is variable, therefore the volume is different. This can not be expressed by only drawing the floor plan and defining floor level height. Besides, the green wall in Figure 10 is a angled wall not perpendicular wall, so it also changes the geometry of that space and this cannot be expressed sufficiently with only plan plane and level height.

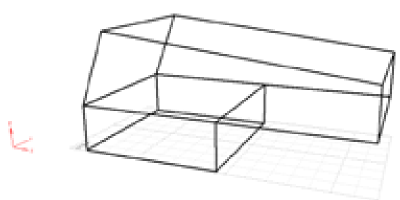

Figure 9 Zones might have different wall geometry.

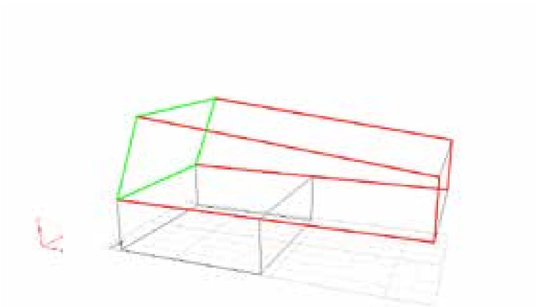

Figure 10 Because of the different wall geometry, wall areas and space volumes varies.

Because of all these necessities, even if the definition of geometry will be made only in two dimensions and each floor plan will be drawn separately; coordinate values connecting every surface to each other should not be left as only (x,y), but defined as (x,y,z) coordinate definition assuredly. So, since for each wall or floor part, a

complete definition will be provided in space; both the adjacency definitions and the wall or floor parts designed in different geometries can be included in calculations with correct dimensions.
The nodes which the coordinates to be defined at are shown in red in Figure 11.

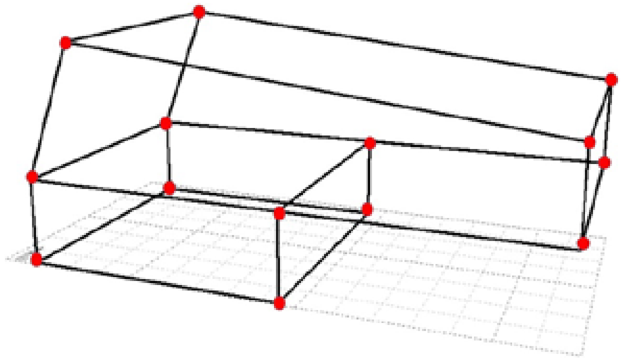

Figure 11 Nodes which the three dimensional coordinates needed to be defined at.

CONCLUSION

With this study, a review of the renewed calculation methodology in the implementation process to the software with its general outline and some important points based on the Building Energy Performance (BEP) Regulation is done.
In the implementation process of the software there are two critical applications. One of these is the BEP-MY in which the calculation algorithm is transferred into code, the other one is then the BEP-BUY, forms the user interface, where the building geometry is defined. The content of BEP-MY was step by step implemented to the code in sub-modules as defined in methodology and progressed with validation tests applied in each stage.
With the BEP-BUY application, the geometric information entry that the methodology described was provided. Some requirements mentioned in methodology and some of the convenience presented by BEP-BUY are listed below:

- Providing the data belonging the building components by easily accessed menus.
- Either the building geometry is drawn in BEP-BUY from beginning, or the existing CAD drawing used as base within the software and above it the architectural components are created in BEP-TR format, or after the building geometry is drawn in BEP-TR2 format in any CAD environment, geometries are introduced as architectural components by importing in BEP-TR2.
- After the entire data input is completed, the validation is run as offline for missing or mistaken data.
- Although it is not included in the methodology, creating the three dimensional view and user is supported visually in data input.

The implementation of the calculation methodology into the software has been a rather challenging, demanding and iterative process. It is intended that the resulting software can become user friendly and have a solid background as well. After presenting the software to public, gaining acceptance as a user friendly, preferred software and developing it in time based on the feedbacks will come from real users, is the shared wish of all contributors involved in this process.

REFERENCES

[1] BEP, Binalarda Enerji Performansı Yönetmeliği, Bayındırlık Bakanlığı, Ankara, 2010.
[2] Yılmaz, Z., “Bina Enerji Performansı Ulusal Hesaplama Yöntemi (BEP-tr) ile Isıtma ve Soğutma Enerjisi İhtiyacının Hesaplanması”, X. Ulusal Tesisat Mühendisliği Kongresi, 13-16 Nisan, İzmir, 2011.

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Next Generation Building Technologies of Hospitality

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ABSTRACT

Hotels are the buildings where the comfort stands in the forefront, correspondingly where new technologies are applied at first and most. Similar to aviation, with the new technologies, improvement on the comfort level is expected. Nevertheless, it is so difficult to use energy efficiently while reforming the comfort standards. It is crucial not to affect customer experience adversely, when reducing energy costs because on these 24-hour living buildings, energy costs have huge share in total costs. Hotel chains and local investors make investments in hotels every day, which increase the rivalry. There are 3 very important methods to stand in this rivalry: Increase the comfort level, reduce the energy consumption and increase the operational efficiency.

New technologies facilitate access services, high quality lighting and air conditioning to reform comfort level. In addition, managing divergent areas and systems of hotel buildings in one hand, reduces operational costs while increasing the energy efficiency.

In this report, some examples of new technologies used in hotel buildings with their positive effects to comfort and efficiency will be surveyed.

INTRODUCTION

Hotel investments are increasingly continuing in many countries, with the exception of seasonal economic fluctuations. United Kingdom faced with 90% increase in hotel investments in 2014 [1]. This is acceptable for all European countries too, based on the 30% growth of investment from 3.318M to $4,726M [2]. Rising internet usage, concordantly rising websites of tourism agency and falling the prices of airlines, are the advances which encourage the vacationers. Number of tourists travelling with airplane has reached to 4,7% growth in 2014, which is 51 million more than the number in 2013. This is the fifth consecutive year of above average growth since the 2009 economic crisis [3]. Adding decreasing petrol prices, it is positive outlook for next years [4]. These growing numbers of both tourist and hotel investments, show that the competition is getting harder in hospitality. The ways of staying in the competition are increasing customer experience, decreasing energy and operational costs are enable at the same time with new building technologies.

NEXT GENERATION HOTEL TECHNOLOGIES

There are a lot of new building technologies, used in the hospitality sector, which can support the investor in the competition. In case usage of technologies together, hotels become more profitable, manageable and sustainable. In Section 1 of this article, real occupancy detection is presented. In Section 2, the payment for the usage of energy is explained. In Section 3, the zoning of the building is described and system monitoring and predictive maintenance is discussed in Section 4. Some easy-to-use technologies and their different areas of usage is described in Section 5. The article is concluded in Section 6.

1. REAL OCCUPANCY DETECTION

Customers don't prefer to cut energy of their room generally, when they leave the room for a while. In the classic hotel rooms, presence of the guests is detected by the energy savers (card holders).
There are three type of energy savers; mechanical type, magnetic type, rfid/chipped type.
Mechanical energy saver which is the most used type in hotels is very easy to deceive by the customers, with using another card having the same dimensions, such as credit cards or identity cards.
Mechanical and rfid/chipped types of energy savers are specialized for one room. This means guests can't use another card to set their room occupied. But when guests want another key card for their roommate or for children, reception has to give second card. It is an easy way to set room occupied when leaving room for a while. This is not the most favourite way for energy consumption for hotels.
Instead of energy savers, using presence sensors to detect occupancy has been applied for a long time in the hotels and it is ever increasingly applied method. Basically, systems start to scan the room by the sensors, when the door is opened by someone.
"Door is opened" information can be transmitted with the simple dry contact from the switch. If the door-lock system is interconnected, detailed door status information can be collected from the door. In this case, different scenarios can be applied for guests and housekeepers and in case of emergency too.
Furthermore, not only door switches, but window switches with dry contact or zigbee can be used to stop the fancoil, when window is opened, for prevent redundant energy consumption.
However, if the process is not running well, customers sometimes may be left in the dark or in undesirable room temperature.
It is difficult to predict the occupancy if two or more guests enter the room and after a while, one of them opens door for leaving. When the door switch gives command to sensors to scan room, the sensors cannot sense the presence, if one of the guests is sleeping in the room, without any motion.
There are three common ways to detect the occupancy;
Room thermostats with the Passive Infrared (PIR) sensors are the way of detecting occupancy. For limited service hotels, it is simple, common method and also PIR is hidden into thermostat. However, PIR is not very effective to sense sleeping people.
Thermal sensors can predict the occupancy with a fair degree of accuracy. New thermal sensors, powered with PIR and thermal image processing aren't mistaken by kettles, TV's and other heat dissipating devices. These types of sensors don't need motion for detecting occupancy. Generally used thermal sensors in hotels, have to direct view with the guest. This means, thermal sensor cannot hide, being suspected as a hidden camera by the customers, which is a disadvantage.
The other technology is using microwave sensors. These type sensors can predict the occupancy with a fair degree of accuracy too and no need to direct view with the guest. This means microwave sensors can hide in the ceiling or wall. On the other hand, it is very hard to set up microwave sensors in a hotel building. If the range of sensors is not adjusted well - all new types are adjustable- microwave types can sense the other rooms too. This means all rooms must be set up with studiously, which cause long installation times and prone to error.
This infers that, every type of occupancy detection has its own advantages and claiming one of these methods as a best is not true.
Fundamentally, occupancy detection can support with other simple implementations. Independent sockets for charging mobile phones and other electronical devices, which work even if room is unoccupied, make guests more satisfied. In case of occupancy system fault, one master on/off light socket can avoid the guests staying in the dark.
This occupancy detection methods without energy saver is the method reducing energy consumption when enhancing customer experience. The guest, whose hands are full of luggage or shopping bags, never be satisfied for searching key cards. Therefore, hotel customers feel more comfortable without using key cards and cardholder.

2. PAY AS AMOUNT OF USAGE

Most of hotels don't ask anything except minibar usage to customers, when the guests are leaving.
As the nature of human, the hotel guest prefers consume energy, water and the other things free of charge. Switched-on left lightings, irons, TVs, hot waters and fancoils have significant influence of energy bills of hotels.
It is easy to measure consumption of a guest with simple energy meters, pulse water meters and Building Management System (BMS) integrated room thermostats. Heating and cooling costs are more than half of total energy consumption of hotel.

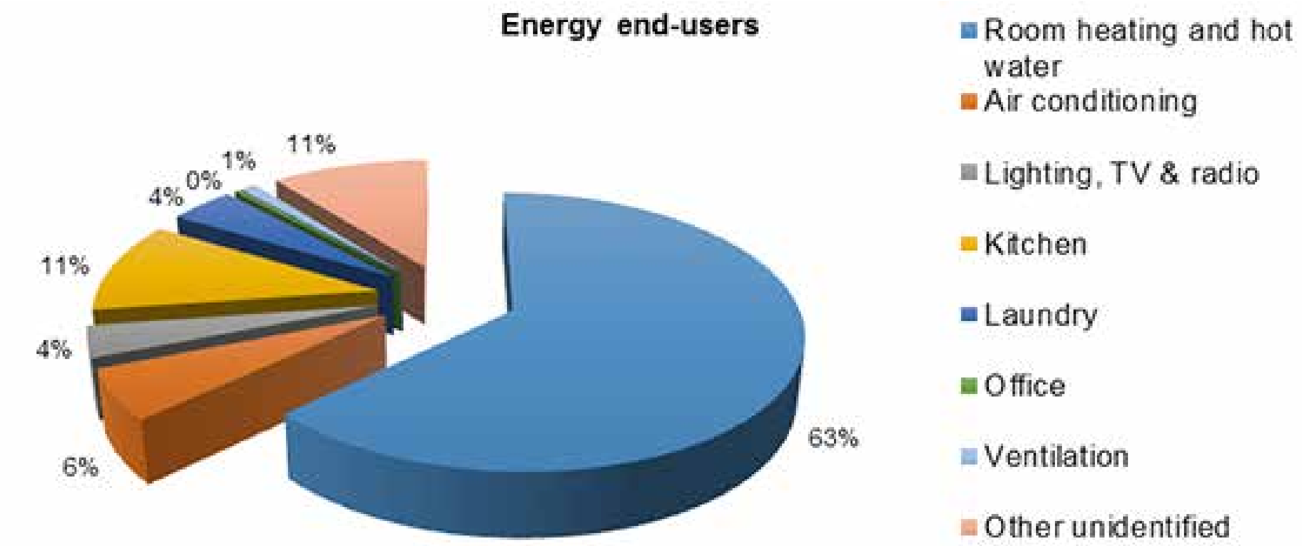

Figure 1: Energy End Users In Hotel Buildings [5]

Pay as amount of consumption system can become more profitable for hotel operators. By this method on the one hand energy bills are reducing, on the other hand revenue per room can be increased.
Amount of used electricity can be determined by simple energy meters, but adding minibar and fancoil consumption is not equitable. Therefore minibar, fancoil and other devices which are not under the control of the guest must be fed from another line and fuse.
Water consumption is generally determined by pulse generator water meter. If necessary, hot and cold water can be priced individually. Thus, filling a bathtub with water becomes difficult for a standard room in a limited service hotel.
Another usage which may be charged to customers is air conditioning. Ideal temperature level is 23'C-25,5'C in summer and 20'C-23'C in winter for rooms. Most of guests adjust the temperature unconsciously. Generally thermostats set up 30'C in winter and 18'C in summer. It is neither efficient nor healthy [6].
If room thermostats are connected to BMS, it is easy to see how long time and which speed level it used. This means air conditioning can be charged to customers with respect to their usage.

3. ZONING THE BUILDING

Occupancy rate of the hotels is different in seasons of the year. In hotels, when the occupancy decreases 50%, it is difficult to decrease energy cost 50% too. Therefore, when the occupancy rate is decreasing, revenue per room will decrease dramatically.
One of the ways for preventing the downfall of profitability is zoning the building based on occupancy rate

and season. In the seasons that chiller runs, firstly north side of the hotels must be rent out and opposite of this in heating seasons firstly south side must be rent out. Furthermore, it is not necessary to condition all building when it is not occupied completely. Arranging these conditioning scenarios for hotel rooms can reduce the burden of the chillers or boilers.

- Occupied – Checked in (Guest is in the room)
- Unoccupied – Checked in (Guest is out)
- Unoccupied – Not Checked in (May hire out in shortly after)
- Unoccupied – Not Checked in (Will not hire out in shortly after)

Zoning the hotels with mechanical automation integrated with BMS is most effective way of increasing energy efficiency. Rooms on the top floor of the hotels, are generally rent out last. For this reason it is not necessary to climate these rooms.

If any room waits for the next customer, this room must be conditioned to a close degree to preferred room temperature. It is difficult for a receptionist to guess which room is most effective for renting out. At the same time, it is difficult for technical responsible to be sure about how the hotel must be zoned.

Property Management System (PMS) integrated mechanical automation is the best way of zoning. When the PMS helps receptionist about renting out the efficient room, BMS manage the room temperatures automatically.

4. SYSTEM MONITORING AND PREDICTIVE MAINTENANCE

Hotels are the buildings where many of system are running together. It is not always easy to be sure that these systems running with harmony and without any problems. In the complex buildings such as hotels, facing with faulty equipment is very normal. Response time to faults is the most important issue for system sustainability. Detecting faults immediately or before it happens by monitoring remotely, is the key of minimum response time. Thanks to new technologies we can monitor all systems in buildings;

- Mechanical systems,
- Lighting systems,
- Electrical distribution equipment,
- Fire systems & Emergency Lighting
- Access control,
- UPS's

By monitoring mechanical systems, all needed water temperatures, chillers, boilers, valves, fans, pumps, thermostats can be under control in case of fault.

It is important that, the main controllers of the mechanical automation must be able to communicate with field devices of different brands, which means open system and available to communicate with most used protocols such as Bacnet, Lonworks and IP directly, without no interface.

For instance, detecting a faulty fancoil before the guest enters the room is big advantage. This is the way to improve customer experience.

Detecting remotely faulty lighting equipment on the corridor is a way of avoiding accidents. It is possible with addressing armatures, part of Dali – KNX integration. By using this system, different scenarios can be applied in different time of the days and armatures can be dimmed by measuring sun light in the room.

All security equipment must be controlled periodically in case of fault, for working properly in case of emergency. This is a workforce, which is inconvenience for the operation and can be avoided with remote monitoring of

emergency lighting and fire systems. This is possible with addressable field equipment.
Similar with the all electronic devices that we use, electrical distribution panels become smart too. This means we can both monitor the position of the breakers and fuses and we can control them remotely. By monitoring the position of fuses, the technical crew can notice the fault immediately. In addition to that controlling, the breaker is the way of reenergizing dead spaces.

5. EASY TO USE TECHNOLOGIES FOR COMFORT

As we can control all systems in the hotel building, similarly it is possible to control all systems in the room in one screen. The screen can control lighting and room temperature, which make customers use this screen. Therefore this screen is very convenient place to advertising and selling offers such as dinners, special offers, traditional gifts, etc.
These screens on the TV or iPad or customers owned devices are very modern ways of carrying customer experience to level up and way of selling customers different offers from the hotel room.

6. CONCLUSION

If we analyse the total costs of hotels for all lifetime, 25% of the costs are about construction, and the %75 of these costs are operational.
Designing and constructing hotel buildings sustainable and manageable with new technologies and designs from the ground up, is the way for shorten the time of Recovery of Investment (ROI).
These technologies increase the energy efficiency and operational efficiency, which cover the big amount of total costs.
Besides, it should not be forgotten that, customer remember the good experiences more than the price they pay.

REFERENCES

[1] Michael Gerrity, U.K. Enjoyed 90 Percent Increase in Hotel Investment in 2014, January 30, 2015 8:20 AM ET, http://www.worldpropertyjournal.com
[2] http://www.cbrehotels.com/EN/Research/Pages/European-Hotels-Investment-Snapshot-Q3-2015.aspx
[3] http://media.unwto.org/press-release/2015-01-27/over-11-billion-tourists-travelled-abroad-2014
[4] Graham Rapier, Cheap oil is finally having an impact on expensive air travel, Aug. 21, 2015, http://www.businessinsider.com/
[5] Vadam C., How to reduce energy consumption in hotels, April 22, 2015, http://hotelnewsnow.com/Articles/25821
[6] Burroughs, H. E.; Hansen, Shirley, Managing Indoor Air Quality, 2011

Paper No: 162

Business Benefits of Intelligent Technology Infrastructure in Healthcare

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ABSTRACT

Healthcare lags behind other industries when it comes to the implementation of information technology. The World Health Organization (WHO) estimates that 20-40% of resources spent on healthcare are wasted. However, new advances in technology make it possible to integrate previously separate facility systems to form an "intelligent" hospital infrastructure. As a result, significant improvements in patient care and reductions in operational costs are possible. One of the main challenges facing healthcare organizations around the world is the ageing population. The United Nations (UN) predicts that by the year 2100, the number of persons aged 60 or over is expected to more than triple, which will necessitate new healthcare facilities or more effective ones. Healthcare costs will continue to rise as treatment and care costs are high for the diseases of this old population. Another challenge is that, by the usage of new technological devices in healthcare, the energy expenditure is more important; which brings the need of energy efficiency. Furthermore, operational costs are high in hospitals so systems and solutions to increase the operational efficiency are required. In this article, initiatives that promote both the energy and operational efficiency in healthcare facilities are presented and some examples and references are given.

1. INTRODUCTION

In a challenging healthcare environment, facilities need to increase their margins and patient experiences in order to have a sustainable business model. There are barriers to achieve this model including financial budgets, time, cyber security and inefficiencies in the processes. These barriers are also waste incubators and give damages to the targets of the business. Inefficiencies should be analyzed to create funding opportunities for the facility. WHO estimates 20–40% of resources spent on healthcare are wasted with the inefficiencies [1]. It is also estimated that in the United States alone $335 billion a year is wasted in healthcare due to the lack of interoperability of information systems [2]. Therefore, it is a clear opportunity to invest in intelligent infrastructure with efficient return of investment (ROI) ratios.

In order to reduce the inefficiencies and to achieve a better financial performance and competitiveness, healthcare facilities need a hospital intelligent technology infrastructure.

The main idea of the intelligent infrastructure is integrating the physical infrastructures such as power infrastructure, HVAC, lighting, security with information technologies in order to create a platform to manage the data with operations efficiently. When there is a single platform that communicates multiple systems, it builds the intelligence for improving resource efficiencies.

Today, with the technological improvements in the areas of internet of things (IoT), mobile applications and big data, it will be more effective and fast to achieve the single intelligent infrastructure that integrates separate sub-systems. Wireless hardware and business intelligence software can decrease the cabling, software engineering, commissioning, and installation costs. Intelligent hospital infrastructure removes the barriers of mobile applications. Portio Research estimates that 1.2 billion people worldwide were using mobile apps by the end of 2012. Their analysts forecast that number to grow nearly 30%, to 4.4 billion users, by the end of 2017 [3]. Research2Guidance

forecasts that 1.7 billion people will have downloaded healthcare-related mobile apps by 2017 [4].
Although mobile apps for healthcare facilities are still considered a novelty, industry analysts at Ernst & Young predict that within the next five years, usage of mobile apps within facilities will be mainstream [5]. As patients gain increased control over their healthcare decisions at home, they're also beginning to expect the same level of control during their stay in hospitals and their homes at senior living facilities.

To effectively analyze the benefits of intelligent technology infrastructure, the potential improvements are divided into 5 main groups which will be deeply analyzed in this paper. In Section 2, the financial performance of HITIP will be explained. In Section 3, patient satisfaction is analyzed and patient health protection is discussed in Section 4. In Section 5, the importance for these systems to be future proof is presented. In Section 6, integrated security management is described. Finally, this paper is concluded in Section 7.

2. IMPROVE FINANCIAL PERFORMANCE

2.1 Operating Expenditures (OPEX) Savings

Productivity is a key to achieve OPEX savings. In the hospitals, the data transfer is one of the main challenges. In the traditionally managed hospitals, there is a significant paperwork and substantial amount of time of people is spent for this basic operation; which means a huge operational expenditure. The digital infrastructure creates a possibility to install wireless communications for transferring digital data such as digital imaging and medical results. Network connectivity is the main infrastructure of the transferring technologies to be more productive. By the developments in the smart phone and applications technology with network enhancements, medical staff can track their patient's results remotely to take faster actions to enhance productivity.

2.1.1 Staff and Patient Tracking Productivity with Real Time Location System (RTLS)

According to a recent study by Transparency Market Research1, of all the applications where RFID is used in a healthcare setting, tracking medical hospital equipment accounts for the largest revenue generating application [12]. The processes should be analyzed with the business analytics software with algorithms for optimization, the bottlenecks can be defined and the solutions can be generated. Better productivity means more patients to care. In a study released by Centers for Disease Control and Prevention (CDC), for 275 beds hospital, reducing average stay by four hours is equivalent to increasing physical capacity by 10 beds [21]. In a 372-bed hospital in United States, Birmingham, software with RTLS implemented for tracking and analyzing patient flows and operations. As a result, bed-cleaning response time is reduced from 30 minutes to 10 minutes, observation time is reduced from 50 hours to 24 hours, two to seven new beds is created by the bed control staff, patient volumes have increased of 6.88 bed turns per month to 8.2 bed turns per month in first 5 months which is estimated 5.5M$ increase in revenue [22].

2.1.2 Integrated Power Monitoring System

Another opportunity of increasing financial performance is preventing unplanned power outages in a hospital. According to a study made by Schneider Electric, average 1 day cost for unplanned power outage is 1M$ [7] To avoid unplanned outages, energy monitoring system which is integrated to healthcare infrastructure will be a cost effective solution. It will give right information to right people in right time with a proactive way. Using power monitoring system in the hospital will provide a predictive maintenance system as all the electronic products such as breakers, transformers, medium voltage switchgears and low voltage panels will be monitored and abnormal situations will be discovered before the outage. Also this integrated monitoring system will provide the capacity reports and financial performances of equipments. It will be an opportunity to catch the inefficiencies to take right actions for financial benefits.

2.1.3 Operating Theatre Energy Optimization

Operating Theatre (OT) monitoring is another opportunity to gain financial efficiencies. With integrating BMS with healthcare information management system (HIMS) with HL7 interface, BMS can decrease the air flow rate in the operating theatres, which is allowed in DIN1946/4-2008 standards, to 8 air change per hour when there is no operation. This operation can decrease the OT energy levels estimated 25%.

2.2 Capital Expenditures (CAPEX) Savings

Intelligent technology infrastructure decreases the labor cost which is related to time spent on commissioning and cable costs. Also in network systems, each system will not need different network switches and mutual switches will decrease the number of total switches which will lead to cost decrease in network systems.

2.2.1 Decentralized Architecture

Decentralized approach with Variable Air Volume (VAV) control units, smart thermostats and frequency drives can reduce the number of MCC and BMS modules. In this system, mechanical, electrical equipment will have its own control panels and control units on or near itself. This solution will decrease the labor costs with decreased commissioning time period. This model creates opportunities of offsite prefabrication with “plug n play” model. Integrated solutions will be installed in integrated equipment such as direct digital control (DDC) panels, VAV controllers and frequency drivers at the plant manufacturer (mainly air handling unit manufacturers, pump manufacturers, VAV manufacturers) with tests and commissioning. When these units are sent to the site, with a single network cable, all the systems become “plug and play”. It will increase the time of commissioning, speed of delivery, efficiency of project management, environmental benefits and quality of the system. It will also decrease the waste, disruption, labor costs, and construction carbon footprint.

2.2.2 Inventory Optimization and Preventing Lost/Theft of Medical Equipment/Assets

In an average hospital, there is an initial investment of approximately 200k$ for each bed. The cost of discharges per patient is 3k$ [8]. Tracking the hardware with RTLS and intelligent analytics software integrated with the inventory system will optimize the inventories which will account for financial savings.
Without tracking the assets in real time with integrated security system, a 300 Beds Hospital can lose 1.2M$ with the stolen and lost equipment [9]. Asset monitoring with real time location system will track the assets and give alarms to CCTV, access control and emergency systems which will prevent the thefts and staff can easily find the lost or inefficient equipment.

2.2.3 Integrated Project Approach

The other suggestion of the organizations like LEED®, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE’s) to reduce wastes and increase the project management financial performance is integrated project approach. Integrated project approach integrates systems, designs, businesses and operations for optimizing the results by optimizing design and construction phases. Early engagement of the integrated project approach is crucial for better financial results. Integrated technology can prevent the wastes and inefficiencies. NIST has a study that interoperability is costing the industry of 15.8B$ each year in US alone [10]. Integrated project approach results in great efficiencies. The United Kingdom’s Office of Government Commerce (UKOGC) shows that in constructions, employing integrated supply teams can save of 2-10% in the cost [11].

3. IMPROVE PATIENT SATISFACTION

Patient satisfaction is one of the most important parameters in hospitals to have a better financial performance and differentiation. In order to increase the patient satisfactions intelligent hospital infrastructure creates several opportunities.

3.1 Workflow optimization

Decreasing the waiting time and increasing the quality of care is one of the biggest changes in a hospital. To analyze and have an idea to increase this performance, hospitals need to find the bottlenecks and take actions to prevent waiting times of patients. Cleaning, equipment searches, transports, patient information processes should be automatically tracked with the integration of RTLS and HIMS systems to send data to integrated business analytics software to optimize the processes. According to California Healthcare Foundation, patient satisfaction score gets higher with RTLS solution. Besides, decreasing the length of stay leads to better revenue generation [13]. Nurses lose time to find the related equipment to serve patient. In an RTLS software nurses can easily find the nearest related equipment to serve faster.

3.2 Decreasing Noise Levels with Integrated Noise Monitoring System

WHO declared a report for Europe that the night noise level is harming patient health which can cause hypertension, depression and increasing stress levels [14]. Night noise increases heart rates with the interrupted sleep. Noise levels should be maximum 30dB at night and 35dB during the day in patient rooms [15]. This problem slows down the care time and leads to patient dissatisfaction. Noise is also increasing the stress level of staff and it reflects to patients by mistakes or negative behaviour of staff. A study of ASHRAE shows that 42% of patients have negative feedback of noise problem and decreased satisfaction [15]. There are several options to decrease noise levels in hospitals and the most cost effective way to decrease the noise levels is monitoring with the integrated hospital software, taking alarms and analyzing them to take actions. In a research of 156 operations, sound levels were measured before and after a noise-reduction program on the basis of education, rules and noise monitoring devices. Surgical complications were recorded. The surgeon's stress levels were measured and correlated with mission protocols and individual noise sensitivity. It resulted with reduced postoperative complications by 50% and reduced surgeon stress by 60% [16].

3.3 Mobile Applications

American Society for Healthcare Engineers declared that in a more relaxing, customized environment patient recovery time is decreased by 2.5 days. Mobile applications are getting important in whole healthcare and patients will search for applications for healthcare facilities. Ernst & Young predict that within the next five years, usage of mobile apps within facilities will be mainstream [5]. Mobile applications also create opportunities to get in contact with practitioners continuously and make the care process quality better. According to a study, 88% of health workers in 17 healthcare organizations lack performing better for patients because of the lack of mobile solutions [17].

4. PROTECT PATIENT HEALTH

4.1 Preventing Healthcare Acquired Infections (HAIs) with Integrated Ventilation Control

One of the biggest problems for patients in a hospital is infection. For WHO, ventilation is crucial for preventing healthcare acquired infections (HAIs) and air flow should be designed with respect to the number of patients. The air volume should be 60 liters per second per patient in general wards and outpatient departments [18]. With integrated healthcare infrastructure, it can be achieved easily with integrating HIMS, RTLS and BMS to design a control system for preventing HAIs.

4.2 Hand Hygiene System with RTLS and Nurse Call

Integrated technology infrastructure can also decrease the effects of healthcare acquired infections. Most of the HAI's spread from doctors or nurses hands. Hand hygiene systems will be a very important solution to decrease the number of HAI's. By integrating nurse call and RTLS systems with hand hygiene units, doctors and nurses can't get in touch with patients without checking in at the nearest hand hygiene unit. RTLS tags will match the healthcare personnel's tags with the tag in hand hygiene unit before getting interaction with the patient. In a study released in United States, average HAI's can cost is 415k$ per bed [23]. In a medical publication, the savings per bed with hand hygiene solution is 25% [24], then 103.8k$/bed savings made in this case.

4.3 Energy Availability

Energy availability is critical for patient's health in hospitals. A power outage is a huge risk for patient life and safety. According to the IEC standards, in hospitals, energy should be continuous in critical areas. Integrated hospital infrastructure ensures the energy availability by integrating power monitoring system with power supply system to monitor the tanks and batteries of generators and uninterruptible power supplies (UPSs). In the operating theatre monitoring of the UPS battery remaining time benefits the operating staff to avoid stress in case of power outages to manage their time efficiently. Also the stress of the unknown battery remaining time in a power outage causes stress and difficulties in managing time that can lead to mistakes which can result the lost of patient. Monitoring the whole electrical and environmental events will minimize the liabilities. Furthermore, automatic generator tests can be conducted remotely. Integrated technology infrastructure also gives opportunities for predictive maintenance and service opportunities in right time.

5. BECOMING FUTURE-PROOF

It is important to be open and adaptable for future technologies with the integrated infrastructure. Healthcare technologies are changing its shape to become fully electronic but in a study it has shown that in hospitals it is very slow to adapt new technologies [20]. The integrated technology is a key proactive vision to stay current.

6. INTEGRATED SECURITY MANAGEMENT

In a hospital environment the security is vital for the staff and patients. It is a need for business sustainability. Especially in private sector with competitive environment, patients are choosing the hospitals with better security. For obtaining better security, integrated security solutions will be a key opportunity. By integrating video surveillance with megapixel camera technology, access control, fire alarm, staff/patient tracking and asset monitoring, hospitals can benefit more for security systems. Besides, in a single network and integrated systems, security personnel can monitor different security systems to decrease the possibility of mistakes.

6.1 Infant Protection

Baby tagging systems can monitor the location of babies and match them with their mothers' tags in order to prevent baby theft or mixing. When there is a theft alarm with the integrated security systems, related doors can be locked, lifts can be managed not to stop at that level of building, CCTVs begin to record and send alarm to security personal to take fast actions.

6.2 Preventing Violence Against Health Workers

RTLS offers a good solution to decrease the violence against health workers besides law enforcement. There is a panic button on the tags of health workers and when the risk of violence occurs, health staff can send alarm to RTLS and integrated security system to avoid the violence by sending security personnel next to the health staff.

6.3 Preventing Theft of Medical Equipment and Pharmaceutical Assets

Without tracking the assets in real time with integrated security system, a 300 Beds Hospital can lose 1.2M$ with the stolen and lost equipment [9]. Asset monitoring with real time location system will track the assets and give alarms to CCTV, access control and emergency systems will prevent the thefts and also staff can easily find the lost or inefficient equipment.

7. CONCLUSION

The developments in mainly communication technologies create new opportunities. IoT and big data will lead the opportunities with the development of communication and software systems. People can make mistakes naturally but with the solid data coming from high quality sensors and good analytics can change the equation to almost zero mistake in hospitals which is desirable for both patients and healthcare businesses. In searching for better business opportunities, business leaders should employ staff with healthcare and hospitals knowledge, and make the most of the technology to operate. In most countries including Turkey, facility managers for healthcare should be trained to adapt these technological advances and operate the facilities more efficiently. ROI analyses are crucial for healthcare projects to be getting funded and there are big opportunities to focus on this area. Choosing right solution provider will be a key for success.

REFERENCES

[1] WHO. “World Health Report 2010: Health Systems Financing: The Path to Universal Coverage.”

[2] Bradley Sokol, Fast Track Technologies, Ltd. “RFID & Emerging Technologies Market Guide to Healthcare.”

[3] Portio Research, “Mobile Applications Futures 2013-2017” (2013)

[4] Reseach2Guidance, “Mobile Health Market Report 2013-2017” (March 4, 2013)

[5] Ernst & Young, “mHealth: Mobile technology poised to enable a new era in healthcare” (2012)

[6] Darling Michael and Sandy Wise (April 2010). Not Your Father’s Supply Chain. Materials Management in Healthcare. vol. 19 no. 4.

[7] Schneider Electric, http://www2.schneider-electric.com/documents/support/white-papers/wp_healthcare-how-unreliable-power.pdf

[8] Wang, B.; Eliason, R.W.; Richards, S.M.; Hertzler, L.W.; Moorey, R., “Financial impact of medical technology,” Engineering in Medicine and Biology Magazine, IEEE , vol.27, no.4, pp.80,85, July-Aug. 2008

[9] Darling Michael and Sandy Wise (April 2010). Not Your Father’s Supply Chain. Materials Management in Healthcare. vol. 19 no. 4.

[10] National Institute of Standards and Technology, 2004, NIST GCR 04-867 http://nvlpubs.nist.gov/nistpubs/gcr/2004/NIST.GCR.04-867.pdf

[11] Office of Government Commerce, Achieving Excellence in Construction Procurement Guide, Vol. 5, at p. 6 (2007) www.ogc.gov.uk

[12] Radio Frequency Identification (RFID) In Healthcare Industry - Global Market Size, Share, Growth, Analysis and Forecast, 2012 – 2018. Transparency Market Research. Published November 16, 2012.

[13] California Healthcare Foundation. Using tracking tools to improve patient flow in Hospitals, 2011 http://www.chcf.org/~/media/MEDIA%20LIBRARY%20Files/PDF/PDF%20U/PDF%2 UsingPatientTrackingToolsInHospitals.pdf

[14] WHO. Night Noise Guidelines for Europe, 2009, ISBN 978 92 890 4173 7 http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf

[15] American College of Physicians, “Sleep Disruption due to Hospital Noises. A Prospective Evaluation.” It is in

the 7 August 2012 issue of Annals of Internal Medicine (volume 157, pages 170-179). The authors are O.M. Buxton, J.M. Ellenbogen, W. Wang, A. Carballeira, S. O'Connor, D. Cooper, A.J. Gordhandas, S.M. McKinney, and J.M. Solet. http://annals.org/article.aspx?articleid=1305527

[16] Ann. Surg. A noise-reduction program in a podiatric operation theatre is associated with surgeon's benefits and a reduced rate of complications: a prospective controlled clinical trial. Ann Surg 2014 May;259(5):1025-33 http://www.pubfacts.com/detail/24394594/A-noise-reduction-program-in-a-pediatric-operation-theatre-is-associated-with-surgeons-benefits-and-

[17] TorontoMobile, 2014. http://www.ehealthnews.eu/industry/3964-lack-of-real-time-information-affects-88-of-community-healthcare-workers-ability-to-do-their-jobs

[18] http://apps.who.int/iris/bitstream/10665/44167/1/9789241547857_eng.pdf

[20] "The Use of Electronic Health Records in U.S. Hospitals," Ashish K. Jha, Catherine M. DesRoches, Eric G. Campbell, Karen Donelan, Sowmya R. Rao, Timothy G. Ferris, Alexandra Shields, Sara Rosenbaum, David Blumenthal, New England Journal of Medicine, online March 25, 2009

[21] CSC Calculation based on CDC data on U.S averages for inpatient care (Non-federal short stay hospitals) http://www.cdc.gov/nchs/fastats/hospital.htm

[22] CDC/NCHS National Hospital Discharge Survey, 2010 http://www.cdc.gov/nchs/fastats/hospital.htm

[23] Johns Hopkins University School of Medicine, Electronic monitoring and voice prompts improve hand hygiene and decrease nosocomial infections in an intermediate care unit, Crit Care Med. 2004 Feb;32(2):358-63. http://www.ncbi.nlm.nih.gov/pubmed/14758148

[24] Journal of Medical Economics, Volume 16, Issue 12, 2013, Economic burden of healthcare-associated infection in US acute care hospitals: societal perspective, DOI: 10.3111/13696998.2013.842922, pages 1399-1404 http://www.tandfonline.com/doi/abs/10.3111/13696998.2013.842922

"Material - Production Technics & Technologies"

Paper No: 69

Aluminium Curtain Wall Systems: Standards for Production of Components, System Design and Performance

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ABSTRACT

Preventing buildings premature failures is significant in term of sustainable construction. To avoid premature failures, correct design, construction, use and maintenance-repair are needed. Hence, technical specifications are prepared to define design and construction of components and their assemblies. There are missing information concerning standards for production of components, design and performance of aluminium curtain wall façade systems in technical specifications. Component production, system design and performance standards of aluminium curtain walls have not been studied in Turkey. Aim of this paper is to put forward existing standards that can be used by companies that are in business in Turkish construction industry for production of component, design and performance of aluminium curtain walls. Scope of this paper is aluminium stick system curtain walls. Two different data collecting method were used. Literaturewise; technical specifications, national and international standards were reviewed. In meetings in person; production, system design and system execution/design companies were interviewed about production standards, system design and performance standards, respectively. Literature review revealed that standards for low tolerance and high tolerance aluminium profile production were both specified in technical specifications. DIN standards are preferred by the gasket manufacturers according to face to face meetings. Face to face meetings revealed that there were not any standards for design of aluminium curtain walls and performance standards were defined according to requirements of each project.

Keywords: Aluminium curtain wall, Facade, Performance, Standard

INTRODUCTION

Building life cycle consists of processes such as planning, design, construction, use, maintenance, reuse and disassembly. To be termed as sustainable, premature failures should not occur in buildings. To prevent premature failure in building element systems and components; correct design, construction, use and maintenance-repair processes of the components and their assemblies are required. Hence, technical specifications, which define correct processes for the components and their assemblies, are important at the duration of building service life. In recent years, developments of construction technology have influenced facades considerably and modern curtain wall façade systems have been adopted for the exterior walls of buildings instead of traditional load bearing walls. Nowadays, aluminium curtain wall systems are preferred for nearly all types of buildings [1].

Aluminium curtain walls are preferred in many projects by architects because of increasing demand for these type of facades. Number of facade companies in the market and type of aluminium curtain wall facade system have increased depending upon this growing demand. As a consequence, architects may have difficulties in choosing right materials and system types. Therefore, specification of performance criteria concerning materials is required and the materials, which fulfil specified criteria should be chosen to make correct material selection. The decision makers can do accurate selection of product and system type by help of national and international standards, which include performance criteria. Review of several architectural projects and their documentation of buildings has revealed that either there were no technical specifications of aluminium curtain wall systems or adequate standards concerning production of the relevant components, design and performance of the systems were not specified in the technical specifications. **Fig1a** shows a construction plan of a building as an example, which aluminium stick system with cover cap has been designed as the external wall system and **Fig 1b** demonstrates that there was missing information regarding the standards for the aluminium profiles and there was not any standards for thermal break component in the technical specification. Lack of standards may lead to the occurrence of some defects and, therefore, damages during the use of aluminium curtain wall systems. In other words, premature failures occurs in buildings

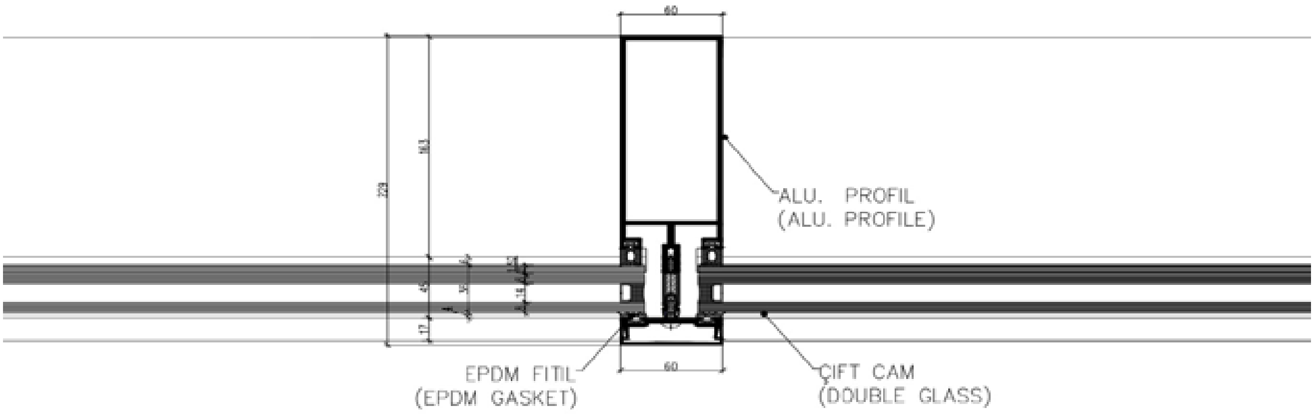

Fig 1a. Sample project (plan)

Alüminyum profillerdeki ısı bariyerleri, düşük ısı yayılma oranı olan ve rutubetten etkilenmeyen malzemelerden oluşmalıdır. Ek olarak, minimum -40°C'den +220°C (cam lifleri ile kuvvetlendirilen poliamid PA66) arası sıcaklıkta sağlam kalabilmelidir.

Fig 1b. Part of text of the relevant technical specification for the project given in Fig 1a. The text given above is in Turkish. It does not include any specific standards except the material name.

Currently, there is not any study which includes all the standards for production of aluminium curtain wall components, system design and system performance of aluminium curtain walls in Turkey. Therefore, such a study is needed in Turkey. A dissertation is being conducted at Istanbul Technical University Graduate School of Science Engineering and Technology Environmental Control and Construction Technologies Master Program to compose a guide including standards for production of components, design and performance of aluminium curtain wall systems.

Aim of this paper is to put forward existing standards that can be used by companies that are in business in Turkish construction industry for production of component, design and performance of aluminium curtain wall with stick systems. In this study, glazing and thermal break are excluded.

Literature review and face to face meetings are conducted to achieve the aim. National and international standards and the technical specifications of architectural projects have been examined as literature review. Face to face interviews have been made with the producers regarding production standards, with system design companies about system design and with system execution/design companies about performance standards. The existing standards used by these companies have been specified as a result of these interviews and literature review.

ALUMINIUM CURTAIN WALL FAÇADE SYSTEM

Definition and classification

"Curtain wall" is mostly a vertical building element, which separates interior space from exterior, provides all the required expected performance criteria from exterior walls, carries and transfers wind, earthquake loads and its dead load to the structural system of the building with anchorages and is hanged in front of the structural system [2-7].

Yeun and others classified curtain walls according to materials as follows [8]: Metal curtain wall, polymer concrete curtain wall, prefabricated panel wall system. Aluminium curtain walls fall into the category of metal curtain walls based on the above given classification. Aluminium curtain walls can be classified according to construction method as follows [8]: Stick construction, unitised construction, semi-unitised construction. Aluminium curtain walls can be classified according to fixation type of infill panel as follows [9]: Cover cap system, structural silicone system. Stick construction with cover cap system is designated as the scope of this paper.

Components

Aluminium curtain wall-stick system with a cover cap consists of vertical and horizontal structural framing members named mullion and transom, which carries and transfers loads to the structural system of the building; exterior and interior glazing gaskets, which provides tightness and resilience; thermal break that reduces heat flow; insulating glass unit, which provides an improved performance of thermal and acoustic insulation; pressure plate, which provides structural restraint and compresses the glazing gasket and cover caps to provide an architectural finish, **Fig 2** [7].

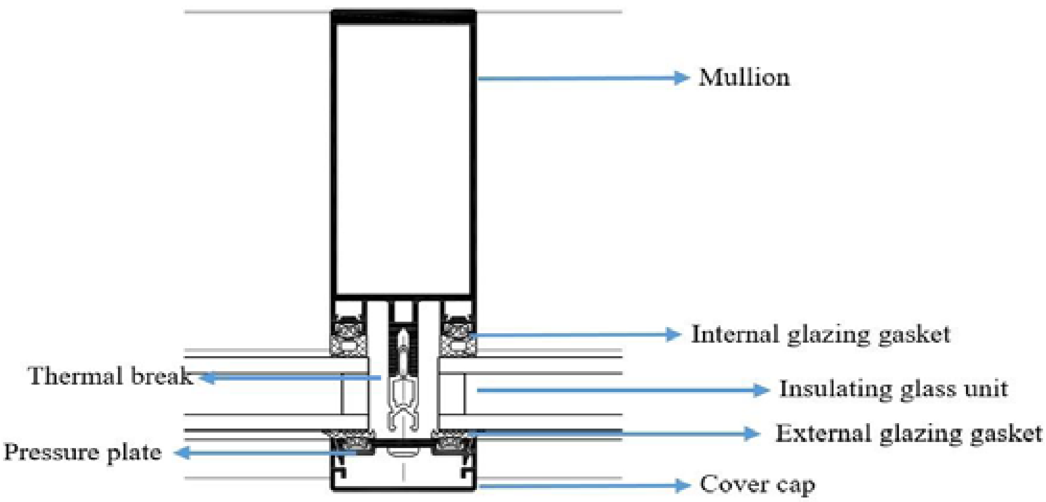

Fig 2. Components of aluminium curtain wall stick construction system (plan) [10]

NATIONAL AND INTERNATIONAL STANDARDS FOR PRODUCTION OF COMPONENTS, SYSTEM DESIGN AND PERFORMANCE

Standards related to the production of components

Mullion and transoms: aluminium profiles

Most appropriate form of aluminium for construction is extruded profiles. Extrusion is defined as the process of shaping material, such as aluminium, by forcing it to flow through a shaped opening in a die. To manufacture extruded aluminium profiles, there are certain processes that needs to be followed. First of all, alumina is produced from the bauxite by using the Bayer Method and the aluminium is obtained with electrolysis of alumina. Then, aluminium billets are produced by casting. After defining the shape of die at the design stage, billets are heated approximately 420-470 °C and preheated billets are pushed through to heated die. Extruded aluminium profiles are cut after cooling. Surface treatment like anodic oxidation or painting should be executed to extruded aluminium profiles for corrosion resistance, longevity and aesthetic reasons.

Initially companies, which produced aluminium profiles in Turkey, were determined through literature review. Subsequently, one of the companies was visited, where the process involved in the production of the aluminium profile was observed. Afterwards, Turkish Standards Institute (TSE), European Standards (EN), German Institute for Standardization (DIN) Norms, International Organization for Standardization (ISO), British Standards Institution (BSI) were searched to determine the existing standards that were available for the companies to be used in the production of the aluminium profile. Additionally, representatives of 4 companies out of 10 were contacted to enquire the standards that they were using for the production of the aluminium profile.

Table 1 gives the standards, which are used for the production of raw material, profile and the coating of the profile as well the companies that use the relevant standard and demonstrates which company utilizes which standard during the production of aluminium profile. For example, Company A is only the company that stated to be using TS EN 12258-1: Aluminum and aluminum alloys - Terms and definitions - Part 1: General terms. All the companies stated that they used TS EN 573-3: Aluminum and aluminum alloys-Chemical composition and form of wrought products-Part 3: Chemical composition. Interestingly, Company C stated to be still using the standard DIN 1725: Aluminum alloys; Wrought alloys, which has been replaced by DIN EN 573-3: Aluminum and aluminum alloys-Chemical composition and form of wrought products-Part 3: Chemical composition. Company A stated that as a raw material standard, TS EN 573-3 should be used by the manufacturers for these processes during face to face meetings at the date of May, 2016.

Company A and D stated that they do not use TS EN 755-9: Aluminum and aluminum alloys- Extruded rod/bar, tube and profiles – Part 9: Profiles, tolerances on dimensions and forms because of high tolerances on dimensions and they prefer to use TS EN 12020:2 Aluminum and aluminum alloys - Extruded precision profiles in alloys EN AW-6060 and EN AW-6063 - Part 2: Tolerances on dimensions and form at the date of May, 2016 and November, 2015. Additionally, Company B and C still use TS EN 755-9: Aluminum and aluminum alloys- Extruded rod/bar, tube and profiles – Part 9: Profiles, tolerances on dimensions and forms.

Company A, B, C and D stated that they use QUALANOD-Quality Label for sulphuric acid-based anodizing of aluminum. Besides Company A, C, and D stated to be still using the standard TS 4922: Anodic oxidation coatings on aluminum and wrought aluminum alloys. It has been suggested that manufacturers which have QUALANOD and QUALICAOT certification should be chosen for the surface treatment by the Company A.

Table 1: National and international standards used in the aluminium profile production

	Standard Number	Company A	Company B	Company C	Company D
Raw Material	TS EN 12258-1 [11]	x			
	TS EN 573-1 [12]	x			
	TS EN 573-2 [13]	x			
	TS EN 573-3 [14]	x	x	x	x
	TS EN 573-4 [15]	x			
	TS EN 573-5 [16]	x			
	TS EN 515 [17]	x			
	TS EN 15088 [18]	x			
	TS EN ISO 6892-1 [19]				x
	DIN 1725 [20]			x	

	Standard Number	Company A	Company B	Company C	Company D
Profile	TS EN 12020-1 [21]	x	x	x	x
	TS EN 12020-2 [22]	x	x	x	x
	TS EN 755-2 [23]	x	x	x	x
	TS EN 755-9 [24]		x	x	

	Standard Number	Company A	Company B	Company C	Company D
Coating	TS 4922 [25]	x		x	x
	TS EN ISO 7668 [26]				x
	EN 12373-1/18 [27]		x		
	BS 6161-18:1991 [28]				x
	QUALANOD [29]	x	x	x	x
	QUALICOAT [30]	x	x	x	x
	DIN 17611 [31]		x		x
	EN 12371-1 (QUALANOD) [32]		x		
	EN ISO 2360 [33]		x		
	DIN 50018 [34]		x		
	EN 12373-5 [35]		x		
	ISO 3210 (TS 2676) [36]		x		
	EN 12373-4 [37]				x
	EN ISO 2409 [38]		x		
	EN ISO 1519 [39]		x		
	EN ISO 6272-1 [40]		x		
	EN ISO 2815 [41]		x		

Internal and external gaskets

Rubber compounds are prepared in accordance with the tolerances and properties which are indicated in technical specifications by using banbory-mixer. After this process, gaskets are produced by extrusion or pressing. TSE, EN, DIN, ISO were searched to determine the existing standards that were available for the companies to be used in the production of the gaskets. Literature review revealed 5 companies, which produced gaskets for aluminium curtain wall. Representatives of three companies were contacted to enquire the standards that they were using for the production of the gaskets. Representatives of companies that produced gasket were unwilling to share information; hence, limited information was obtained.
Table 2 shows the standards, which are used for the production of the gasket and the three companies that use the relevant standards. Table 2 indicates that companies use various standards for the production of the gaskets and mostly DIN standards are used. Additionally, Company A still uses the standard TS 7510: Rubber building gaskets - Materials in preformed solid vulcanizates used for sealing glazing and panels , and TS 2827 ISO 2781: Rubber, vulcanized; determination of density, which have been withdrawn at the year of 2015 and 2015, respectively. It has been suggested that DIN 7863 and DIN 7715-3 class E2 should be used for the EPDM gasket production by the system designers. Also, Company C stated that they use DIN 7863 and TS 7510 unless costumer demands or technical specification includes any other standards.

Table 2: National and international standards of EPDM gasket production

Standard Number	Company A	Company B	Company C
TS 7510 (withdrawn standard) [42]	x		x
TS ISO 48 [43]	x	x	
TS 2827 ISO 2781(withdrawn standard) [44]	x	x	
TS 4595 ISO 815 [45]	x	x	
TS ISO 37 [46]		x	
DIN 7863-1 [47]	x		x
DIN 7863-2 [48]	x		x
DIN 7715-1 [49]	x		x
ISO 3302-1 E2 [50]		x	

SYSTEM DESIGN AND PERFORMANCE STANDARDS

TSE, EN, DIN, ISO, BSI, ASTM, AAMA were searched to determine the existing standards that were available for the companies to be used in the evaluation of the performance of aluminium curtain walls. Literature review revealed 15 companies in Turkey, which design aluminium curtain wall and 17 companies, which install curtain wall systems.
Literature review revealed that there were no standards describing the system design of aluminium curtain walls. Face to face interviews indicated that each system design companies developed their own know-how.
Representatives of 2 system design companies and 1 system design/execution company were interviewed to learn the standards that they were using as the performance standards. After literature review and meetings in person, collecting data was compiled in Table 3. For example Company C is only the company that stated to be

using ASTM E283 - 04(2012): Standard test method for determining rate of air leakage through exterior windows, curtain walls, and doors under specified pressure differences across the specimen. Company A and company B stated that they use EN 12152: Curtain walling - Air permeability - Performance requirements and classification.

Table 3: National and international standards concerning performance of aluminium curtain wall façades

Standard Number	Company A	Company B	Company C
EN 12152 [51]	x	x	
EN 12153 [52]			x
EN 12154 [53]	x	x	
EN 12155 [54]			x
EN 12179 [55]	x		x
EN 12211 [56]			x
ENV 13050 [57]			x
EN 13051 [58]			x
EN 13947 (withdrawn standard) [59]	x		
EN ISO 10077–1 [60]	x		
EN 12600 [61]	x		x
EN 1026 [62]			x
EN 1027 [63]			x
EN ISO 717–1 [64]	x		
EN V 1627 [65]	x	x	x
EN V 1628 [66]			x
EN V 1629 [67]			x
EN V 1630 [68]			x
EN – 13501 [69]			x
EN 13829 [70]			x
EN 14019:2004 [71]	x		x
EN 12412 [72]	x		
EN 13049 [73]			x
EN ISO 16283-1 [74]			x
EN ISO 12567-1 [75]			x
EN ISO 8990 [76]			x
ISO 10140 [77]			x
ISO 10848 [78]			x
ISO 140 [79]			x
AAMA–501–94 [80]	x		
AAMA–501–01 [81]			x
AAMA–501–02 [82]			x
AAMA–501–05 [83]			x
AAMA–501–06 [84]			x
AAMA–501–07 [85]			x
ASTM E283 – 04 [86]			x
ASTM E330 / E330M – 14 [87]			x
ASTM E 331 – 00 [88]			x
ASTM E 783 [89]			x

CONCLUSION

This paper presents existing standards used by the companies in Turkey for components production, design and performance standards of aluminium curtain wall façades with stick construction method. Results concerning each part is given below.

All the companies which were interviewed stated that they use TS EN 573-3: Aluminum and aluminum alloys-Chemical composition and form of wrought products-Part 3: Chemical composition to define raw material. The standard for high tolerance aluminium profile production (EN 755-2: Aluminium and aluminium alloys-Extruded rod/bar tube and profiles-Part 2: Mechanical properties) is still used by some companies for the aluminium profile production. The standard for high tolerance aluminium profile production and low tolerance aluminium profile production (EN 12020-2: Aluminium and aluminium alloys - Extruded precision profiles in alloys EN AW-6060 and EN AW-6063 - Part 2: Tolerances on dimensions and form) are both specified in technical specifications. It is suggested that only EN 12020-2 standards should be used for aluminium curtain walls because of low tolerances. It can be seen from the table that these 4 companies have QUALANOD and QUALICOAT certificates.

For the gasket production, various standards exist and withdrawn standards are used by some of the producers. In technical specifications, DIN standards were specified concerning gaskets but these standards have not been defined in European Standards (EN) and Turkish Standards (TSE). All the companies stated that they produce gaskets in accordance with technical specifications and on demand of their clients. But Company C particularly stated that they use TS 7510 and DIN 7863 for the production unless indicated otherwise. As it seen in the Table 2 that companies still use withdrawn standards for the gasket production.

It is observed that aluminium curtain wall façades are designed with the know-how of system design companies due to absence of design standards. Literature review reveal that performance standards should be specified according to project except resistance of air permeability, watertightness and resistance to wind load.

As a consequence, face to face interviews and literature reviews have revealed that there are still inadequate information concerning standards for production of components, system design and performance of aluminium curtain walls. To achieve sustainable design, premature failure of buildings should not occur. Hence, material selection and design should be done correctly and technical specification should include all information concerning component production, system design and performance.

REFERENCES

[1] Mostaedi, A. Facades (2002). Michigan: Charles Broto & Josep Ma Minguet.
[2] Technology, C. f. Standard and Guide to Good Practice for Curtain Walling (1993). Centre for Window and Cladding Technology.
[3] Brock, L. Designing the Exterior Wall: An Architectural Guide to the Vertical Envelope (2005). Wiley.
[4] Brookes, A., & Meijs, M. Cladding of Buildings (2008). Taylor & Francis.
[5] Hasol, D. Mimarlık Cep Sözlüğü (2009). İstanbul: YEM.
[6] BS EN 13119. Curtain walling- Terminology (2007). British Standards, London.
[7] BS EN 13830. Curtain walling- Product standard (2015). British Standards, London.
[8] Yeun, K. W., Han, G. H., Lee, Y. W. and Kim, J., A study on the sustaining capability of the curtain wall system for the attached cleaning robot (2001). The 28th International Symposium on Automation and Robotics in Construction, Seoul.
[9] Kazmierczak, K. Review of Curtain Walls, Focusing on Design Problems and Solutions. https://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/BEST/BEST2_008_EE4-1.pdf
[10] http://www.schueco.com/web2/de-en (2016)

[11] BS EN 12258-1. Aluminium and aluminium alloys. Terms and definitions. General terms (2012). British Standards, London.
[12] BS EN 573-1. Aluminium and aluminium alloys. Chemical composition and form of wrought products. Numerical designation system (2004). British Standards, London.
[13] BS EN 573-2. Aluminium and aluminium alloys. Chemical composition and form of wrought products. Chemical symbol based designation system (1995). British Standards, London.
[14] BS EN 573-3. Aluminium and aluminium alloys. Chemical composition and form of wrought products. Chemical composition and form of products (2013). British Standards, London.
[15] BS EN 573-4. Aluminium and aluminium alloys. Chemical composition and form of wrought products. Forms of products (2004). British Standards, London.
[16] BS EN 573-5. Aluminium and aluminium alloys. Chemical composition and form of wrought products. Codification of standardized wrought products (2007). British Standards, London.
[17] BS EN 515. Aluminium and aluminium alloys. Wrought products. Temper designations (1993). British Standards, London.
[18] BS EN 15088. Aluminium and aluminium alloys. Structural products for construction works. Technical conditions for inspection and delivery (2005). British Standards, London.
[19] BS EN ISO 6892-1. Metallic materials. Tensile testing. Method of test at ambient temperature (2009). British Standards, London.
[20] DIN 1725. Aluminium alloys. Wrought alloys (1983). German Institute for Standardization, Berlin.
[21] BS EN 12020-1. Aluminium and aluminium alloys. Extruded precision profiles in alloys EN AW-6060 and EN AW-6063. Technical conditions for inspection and delivery (2008). British Standards, London.
[22] BS EN 12020-1. Aluminium and aluminium alloys. Extruded precision profiles in alloys EN AW-6060 and EN AW-6063. Tolerances on dimensions and form (2008). British Standards, London.
[23] BS EN 755-2. Aluminium and aluminium alloys. Extruded rod/bar, tube and profiles. Mechanical properties (2016). British Standards, London.
[24] BS EN 755-9. Aluminium and aluminium alloys. Extruded rod/bar, tube and profiles. Profiles, tolerances on dimensions and form (2008). British Standards, London.
[25] TS 4922. Anodic Oxidation Coatings On Aluminium and Wrought Aluminium Alloys (1986). Turkish Standards Institute, Ankara.
[26] BS EN 7668. Anodizing of aluminium and its alloys. Measurement of specular reflectance and specular gloss of anodic oxidation coatings at angles of 20 degrees, 45 degrees, 60 degrees or 85 degrees (2010). British Standards, London.
[27] BS EN 12373-1. Aluminium and aluminium alloys. Anodizing. Method for specifying decorative and protective anodic oxidation coatings on aluminium (2001). British Standards, London.
[28] BS 6161. Methods of test for anodic oxidation coatings on aluminium and its alloys. Determination of surface abrasion resistance (1991). British Standards, London.
[29] QUALANOD. Specifications for the QUALANOD Quality Label for Sulphuric Acid-Based Anodizing of Aluminium (2010). http://www.qualanod.net/
[30] QUALICOAT. Specifications for a Quality Label for Liquid and Powder Organic Coatings on Aluminium for Architectural Applications (2015). http://www.qualicoat.net/main/home.html
[31] DIN 17611. Anodized products of wrought aluminium and wrought aluminium alloys (2011). German Institute for Standardization, Berlin.
[32] BS EN 12371:2010. Methods of test for anodic oxidation coatings on aluminium and its alloys. Determination of surface abrasion resistance (2010). British Standards, London.

[33] BS EN ISO 2360. Non-conductive coatings on non-magnetic electrically conductive basis materials. Measurement of coating thickness. Amplitude-sensitive eddy current method (2003). British Standards, London.
[34] DIN 50018BS 6161. Methods of test for anodic oxidation coatings on aluminium and its alloys. Determination of surface abrasion resistance (1991). British Standards, London.
[35] BS EN 12373-5. Aluminium and aluminium alloys. Anodizing. Assessment of quality of sealed anodic oxidation coatings by measurement of admittance (1999). British Standards, London.
[36] BS EN ISO 3210. Anodizing of aluminium and its alloys. Assessment of quality of sealed anodic oxidation coatings by measurement of the loss of mass after immersion in phosphoric acid/chromic acid solution (2010). British Standards, London.
[37] BS EN 12373-4. Aluminium and aluminium alloys. Anodizing. Estimation of loss of absorptive power of anodic oxidation coatings after sealing by dye spot test with prior acid treatment (1998). British Standards, London.
[38] BS EN ISO 2409. Paints and varnishes. Cross-cut test (2013). British Standards, London.
[39] BS EN ISO 1519. Paints and varnishes. Bend test (cylindrical mandrel) (2011). British Standards, London.
[40] BS EN ISO 6272-1. Paints and varnishes. Rapid-deformation (impact resistance) tests. Falling-weight test, large-area indenter (2011). British Standards, London.
[41] BS EN ISO 2815:2003, BS 3900-E9:2003. Paints and varnishes. Buchholz indentation test (2003). British Standards, London.
[42] TS 7510(Withdrawn standard). Rubber building gaskets - Materials in preformed solid vulcanizates used for sealing glazing and panels (1989). Turkish Standards Institute, Ankara.
[43] TS ISO 48.Rubber, vulcanized or thermoplastic-Determination of hardness (Hardness between 10 IRHD and 100 IRHD) (2015). Turkish Standards Institute, Ankara.
[44] TS 2827 ISO 2781(Withdrawn standard). Rubber, vulcanized; determination of density (2005). Turkish Standards Institute, Ankara.
[45] TS 4595 ISO 815. Rubber, vulcanized or thermoplastic; determination of compression set at ambient, elevated or low temperatures (1997). Turkish Standards Institute, Ankara.
[46] TS ISO 37. Rubber, vulcanized or thermoplastic - Determination of tensile stress-strain properties (2015). Turkish Standards Institute, Ankara.
[47] DIN 7863-1. Elastomer glazing and panel gaskets for windows and claddings - Technical delivery conditions - Part 1: Non cellular elastomer glazing and panel gaskets (2011). German Institute for Standardization, Berlin.
[48] DIN 7863-2. Elastomer glazing and panel gaskets for windows and claddings - Technical delivery conditions - Part 2: Cellular elastomer glazing and panel gaskets (2011). German Institute for Standardization, Berlin.
[49] DIN 7715-1. Rubber products; dimensional tolerances, ebonite products (1977). German Institute for Standardization, Berlin.
[50] ISO 3302-1. Rubber -- Tolerances for products -- Part 1: Dimensional tolerances (2014). International Organization for Standardization, Geneva.
[51] BS EN 12152. Curtain walling. Air permeability. Performance requirements and classification (2002). British Standards, London.
[52] BS EN 12153. Curtain walling. Air permeability. Test method (2000). British Standards, London.
[53] BS EN 12154. Curtain walling. Watertightness. Performance requirements and classification (2000). British Standards, London.
[54] BS EN 12155. Curtain walling. Watertightness. Laboratory test under static pressure (2000). British Standards,

London.
[55] BS EN 12179. Curtain walling. Resistance to wind load. Test method (2000). British Standards, London.
[56] BS EN 12211. Windows and doors. Resistance to wind load. Test method (2000). British Standards, London.
[57] BS EN 13050. Curtain Walling. Watertightness. Laboratory test under dynamic condition of air pressure and water spray (2011). British Standards, London.
[58] BS EN 13051. Curtain walling. Watertightness. Site test (2001). British Standards, London.
[59] BS EN 13947 (Withdrawn standard). Thermal performance of curtain walling. Calculation of thermal transmittance (2006). British Standards, London.
[60] TS EN ISO 10077-1. Thermal performance of windows, doors and shutters. Calculation of thermal transmittance. Numerical method for frames (2012). British Standards, London.
[61] BS EN 12600. Glass in building. Pendulum test. Impact test method and classification for flat glass (2002). British Standards, London.
[62] BS EN 1026. Windows and doors. Air permeability. Test method (2000). British Standards, London.
[63] BS EN 1027. Windows and doors. Watertightness. Test method (2000). British Standards, London.
[64] BS EN ISO 717-1. Acoustics. Rating of sound insulation in buildings and of building elements (2013). British Standards, London.
[65] BS EN 1627. Pedestrian doorsets, windows, curtain walling, grilles and shutters. Burglar resistance. Requirements and classification (2011). British Standards, London.
[66] BS EN 1628. Pedestrian doorsets, windows, curtain walling, grilles and shutters. Burglar resistance. Test method for the determination of resistance under static loading (2011). British Standards, London.
[67] BS EN 1629. Pedestrian doorsets, windows, curtain walling, grilles and shutters. Burglar resistance. Test method for the determination of resistance under dynamic loading (2011). British Standards, London.
[68] BS EN 1630. Pedestrian doorsets, windows, curtain walling, grilles and shutters. Burglar resistance. Test method for the determination of resistance to manual burglary attempts (2011). British Standards, London.
[69] BS EN 13501. Fire classification of construction products and building elements. (2014). British Standards, London.
[70] BS EN 13829. Thermal performance of buildings. Determination of air permeability of buildings. Fan pressurization method (2001). British Standards, London.
[71] BS EN 14019. Curtain walling. Impact resistance. Performance requirements (2004). British Standards, London.
[72] BS EN 12412-2. Thermal performance of windows, doors and shutters. Determination of thermal transmittance by hot box method. Frames (2003). British Standards, London.
[73] BS EN 13049. Windows. Soft and heavy body impact. Test method, safety requirements and classification (2003). British Standards, London.
[74] BS EN ISO 16283-1. Acoustics. Field measurement of sound insulation in buildings and of building elements. Airborne sound insulation (2014). British Standards, London.
[75] BS EN ISO 12567-1. Thermal performance of windows and doors. Determination of thermal transmittance by the hot-box method. Complete windows and doors (2010). British Standards, London.
[76] BS EN ISO 8990. Thermal insulation. Determination of steady-state thermal transmission properties. Calibrated and guarded hot box (1996). British Standards, London.
[77] BS EN ISO 10140. Acoustics. Laboratory measurement of sound insulation of building elements. (2010). British Standards, London.
[78] BS EN ISO 10848. Acoustics. Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms. (2010). British Standards, London.

[79] BS EN ISO 140. Acoustics. Measurement of sound insulation in buildings and of building elements. (2006). British Standards, London.
[80] AAMA 501-94. Methods Of Test For Exterior Walls (2004). American Architectural Manufacturers Association, Illinois.
[81] AAMA 501-01. Standard Test Method for Water Penetration of Windows, Curtain Walls and Doors Using Dynamic Pressure (2005). American Architectural Manufacturers Association, Illinois.
[82] AAMA 501-02. Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls and Sloped Glazing Systems (2015). American Architectural Manufacturers Association, Illinois.
[83] AAMA 501-05. Test Method for Thermal Cycling of Exterior Walls (2007). American Architectural Manufacturers Association, Illinois.
[84] AAMA 501-06. Recommended Dynamic Test Method For Determining The Seismic Drift Causing Glass Fallout From A Wall System (2009). American Architectural Manufacturers Association, Illinois.
[85] AAMA 501-07. Recommended Static Test Method for Evaluating Windows, Window Wall, Curtain Wall and Storefront Systems Subjected to Vertical Inter-Story Movements (2011). American Architectural Manufacturers Association, Illinois.
[86] ASTM E283-04. Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen (2012). ASTM International, Philadelphia.
[87] ASTM E330/E330M-14. Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference (2014). ASTM International, Philadelphia.
[88] ASTM E331-00. Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference (2009). ASTM International, Philadelphia.
[89] ASTM E783-02. Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors (2010). ASTM International, Philadelphia.

Paper No: 91
Hot dip Galvanization; Sustainable Protection for Steel

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ABSTRACT

Corrosion is the inevitable fate of metals and metal alloys whose surfaces are not protected. Corroded products become unusable and they compromise the building that they are used in. It doesn't only give harm to the subject steel; it is also dangerous for all livings. It also badly affects the national economy. Corroded steel is the loss of national wealth and also waste of natural resources.

Unfortunately we are not able to eliminate it but we can get it under control by using some methods. Hot-dip galvanization (HDG) is the most advantageous, economic, long-lasting and sustainable of them. Sustainability is the key word here, because in all sectors it became a necessity in conditions of today's world.

Key words: Hot-dip Galvanizing, General Galvanizing, Eco-friendly Coating, Corrosion Protection, Steel Protection, Sustainability, Sustainable Steel Protection

INTRODUCTION

When an engineer starts to design a new bridge, he/she has to design "the most economic" structure possible, but "the most economic" doesn't always mean the cheapest choice. Initial cost, long term cost for maintenance and environmental affects should have been taken into account. Otherwise maybe the cheapest material used at the beginning, can cost excessive in the following years.

In our century, structures are built from concrete or steel. Steel is generally preferred by being constructed faster, which saves time on site, and with its strength to weight ratio. However, it has to be protected against corrosion.

Corrosion is the physical interaction between a metal and its environment which results in changes of the metal's properties. Corroded products become unusable and they compromise the building that they are used in. Corrosion doesn't only do harm to the subject steel, more over it badly affects the nature. It runs the living things' lives in danger and causes environmental pollution. Corrosion also causes waste of raw material, energy, labor, capital and knowledge. For this reason it affects to national economies. In 2013, corrosion lost total of the world was almost 5 trillion dollars. [1]

Corrosion is a natural event. Unfortunately we are not able to eliminate it but we can take it under control by using some methods. Hot dip galvanization (HDG) is the most advantageous, economic, long-lasting and environment-friendly of them. By hot-dip galvanized coating it is possible to extend steel's lifetime, without compromising its performance and built sustainable structures. In this paper, you will get detailed information on hot-dip galvanizing and its performance compare to alternative methods in terms of economy, lifetime and sustainability.

HOT-DIP GALVANIZED COATING

Concisely, HDG is the coating which is made by dipping the steel products into zinc liquid, melt at nearly 450 °C, after the surface preparation steps. Thus, all surfaces of the product, even the closed volumes, are covered with zinc. Zinc, who has durable structure, makes a metallurgical bond with steel. It sacrifices its self to corrosion and for this reason it extends the lifetime of the steel. Unlike the other corrosion protection techniques, steel never effected by corrosion even though the coating peeled by an impact, because zinc keeps on defending the product by cathodic protection.

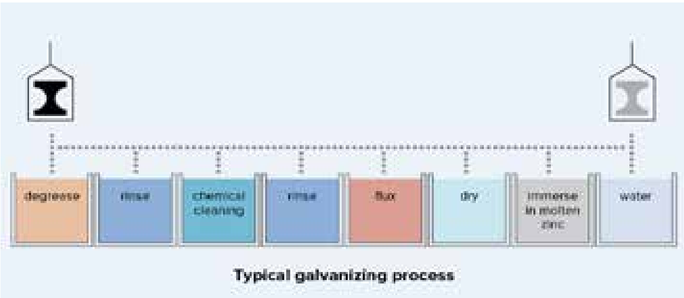


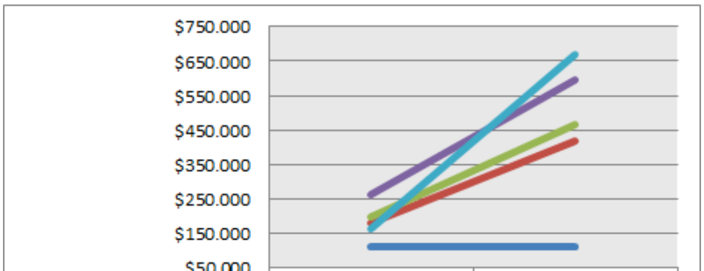
Figure 1 Typical Hot-dip Galvanization Process [2]

Hot dip galvanized coating is used to protect steel in energy, building and construction, street furniture, utilities, agriculture and horticulture, transport, fasteners, industrial equipment and marine. It also inspires artists for sculptures.

WHY HDG COATING?

There are many reasons to choose hot-dip galvanized coating for steel protection, but the featured advantages are being economic, ensuring long-term protection and being environmental-friendly.

1. Economic: Many people think that HDG is a more expensive choice according to alternative corrosion protection solutions. However, as it is seen in the Figure 2, the truth is completely the opposite of this idea.



	Initial Cost	30 years service life cost
Galvanized Steel	$110.000	$110.000
IOZ / HB Epoxy	$178.375	$416.875
Epoxy Zinc/Polyurethane	$197.750	$465.625
IOZ/Epoxy/Polyurethane	$260.625	$597.500
Epoxy/Epoxy	$163.250	$668.125

Figure 2 Initial and Life-Cycle Cost Analysis [3]

This figure represents a practical maintenance cycle of expected service life in an industrial environment. It also represents a 250-ton project of typical size/shape, and a 30-year service life. The paint costs are based on a conventional spray, SP6 surface preparation in eastern U.S. exposure. In the first application, the cost of HDG coating is the cheapest. In 30 years of service life, by being a maintenance free protection, HDG didn't add even a penny to its cost. However, painting options had to be repaired in 30 years and it increased the lifecycle costs.

2. **Longevity:** HDG coating ensures long term protection, which is proven by case histories. Its life time is also predictable depending on its environmental conditions and coating thickness, according to EN ISO 1461. As it is seen in Table 1 lifetime of HDG coating is determined in all conditions and coating thickness. Thus, Project owners can guess the maintenance time of the products. It eliminates frequent controls and decreases service costs.

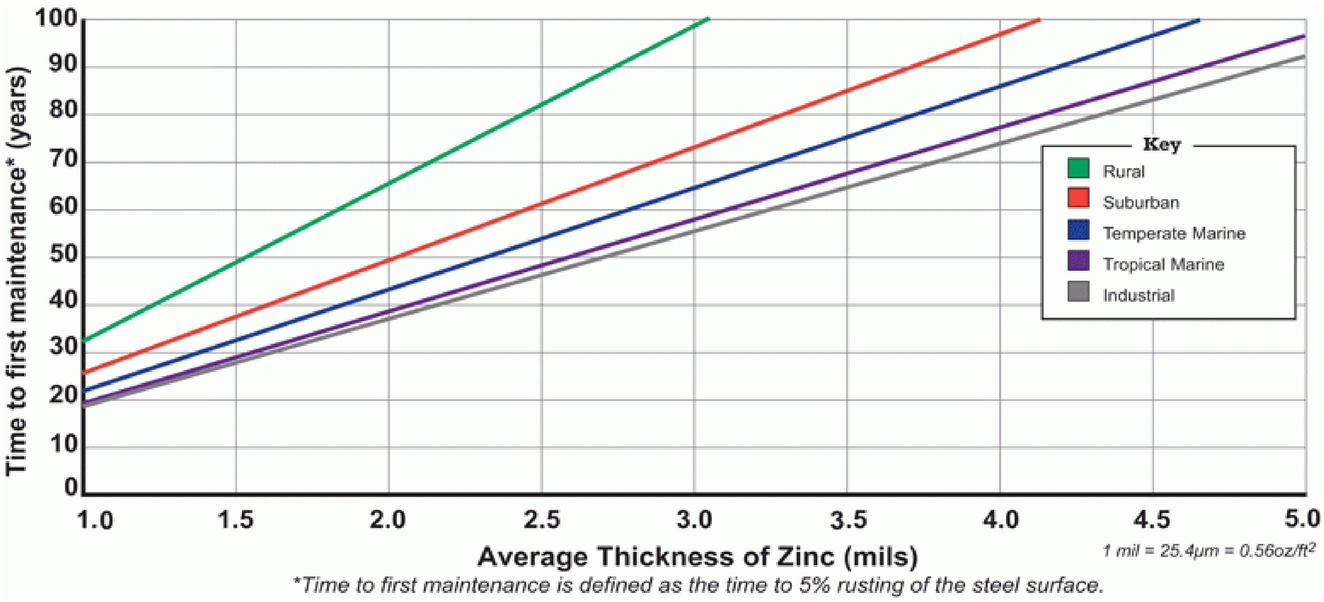


Figure 4 HDG Coating Service Life According to ASTM 123 / A 123M / DIN EN ISO 1461 [4]

Sample Project: Leaside Bridge, Toronto

Figure 4 Leaside Bridge [6]

The Leaside Bridge (Figure 4) is one of the good examples for HDG's performance in steel bridges. It was built in 1927 and the structural steel painted. After 42 years, it was decided to extend the 4 lanes bridge by 2. In this case 3 choices review. (Table 1) The first one was "Blast clean and paint all structural steel" the second one was

"Galvanizing the new steel in the widened section and blast clean and paint the bridge's original steel on site" and the last choice was "Galvanizing the new steel and blast clean and metal spray the original steel with zinc."

Tablo 1 Cost of 3 choices reviewed for Leaside Bridge in 1969 [7]

	Choice 1 **All painting**	**Choice 2** **Galvanizing & Painting**	**Choice 3** **Galvanizing & Zinc Spray**
Initial Costs	**294.000 $**	**230.000 $**	**270.000 $**

Second choice is preferred as it was "the lowest initial cost" option.

After 20 years of usage, galvanized parts of the bridge were still excellent despite of the moderately industrial atmosphere of Toronto. The readings taken in May of 1988 show a minimum coating thickness of 178 um of zinc which allows a maintenance free life for over a 50 years for all galvanized steel on the bridge. On the other hand the painted half had to be repainted in 1981 and after 7 years, the paint job was already displaying edge corrosion, caused by variations in coating thicknesses and would probably need repainting in next 3 to 5 years.

These readings proved that maintenance free lifetime of the galvanized side of the bridge was 5 times more than the painted portion's. When we looked closer to the real cost story. It is much more interesting because painted part has to be repainting in every 10- 12 years term. As a result of this, it is obvious that "the most economic" choice is not the cheapest choice in long term.

3. **Environment Friendly:** Hot dip galvanizing is an environment friendly method because:
   - Proses wastes such as acid, can be recycled
   - Zinc, used for the coating, is a recyclable metal by 100 % (Figure 6)
   - HDG coating dissolves at the end of its lifetime and doesn't leave any deposit unlike the other corrosion protection methods.

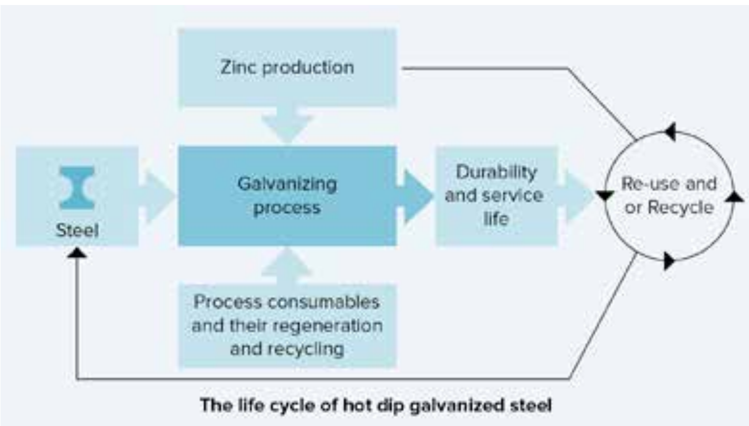


Figure 6. The lifecycle of hot-dip galvanized steel [8]

Galvanized metals are not been effected by corrosion till all coating dissolves. Thus, lifetime of iron and steel products extend and for this reason natural resources are protected. In 2012 preventable corrosion loss of Turkey was 17 billion USD. In another words, if all the steel produced in Turkey in 2012 were galvanized, 37 % of the total corrosion loss could be avoided. [9].

It is a burden for national economies to repair harms given by the unprotected steel to buildings. Moreover it causes waste of natural resources, which has a limited amount, and time. It also causes waste of work force, time and money. For this reason, it is a social responsibility of architects, engineers, constructors and suppliers to prefer galvanized steel.

Case Study 1: Parking Garage

The Institute for Environmental Protection Technology at the Technical University of Berlin conducted life-cycle assessments (LCAs) comparing a hot-dip galvanized parking structure to a painted one [10]. The results of the study demonstrate the significant impact the coating plays in the overall environmental impact of the parking garage.

The following parameters were used in the parking structure study:

- 60-year service life
- 1 m2 steel part (20m2/metric ton)
- Galvanized coating corrosion rate of 1 micron per year (ISO 1461, C3 environment)
- Paint system: 3-coat system, 240 microns thick
- Paint Maintenance: year 20 and 40 (ISO 12944)

This study also examines the PED, GWP, AP, and POCP values for each system. The results for each impact area are much less for the hot-dip galvanized garage than for the painted one. Similar to the painted balcony, the two maintenance cycles required for the painted garage significantly increase the resource and energy consumption of the painted garage. As galvanizing requires no maintenance during the 60-year life, the total energy and resource consumption for the galvanized structure is only 32% of that required for the painted garage, and the GWP is 38% of paint. Furthermore, the AP is 15% less than paint, and the POCP 33% less (Figure 7).

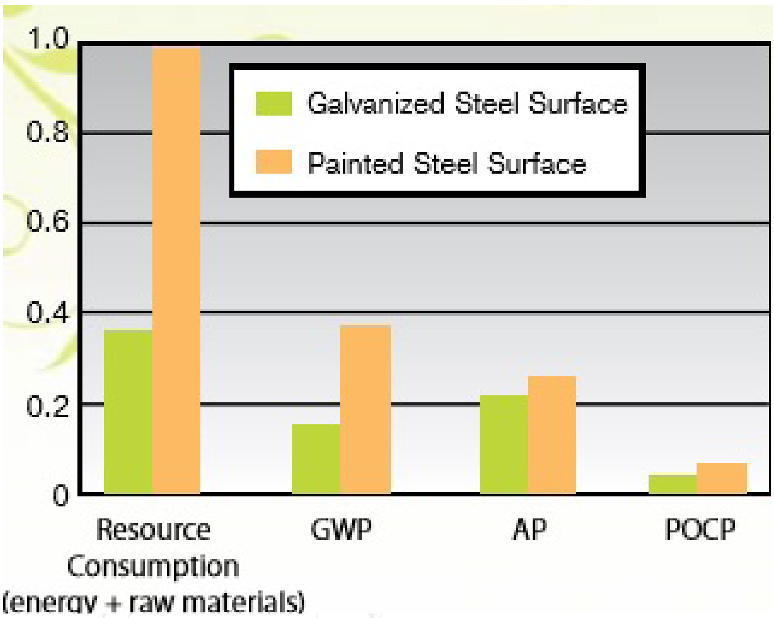


Figure 7 Galvanized Steel Surface and Painted Steel Surface Comparison [11]

Case Study 2: Balcony Structure

VTT Technical Research, renown for establishing environmental product declarations (EPDs) for building products, conducted lifecycle assessments (LCAs) comparing a hot-dip galvanized balcony to a painted balcony of identical design [12]. The goal of the study was not only to measure the sustainability of hot-dip galvanized steel, but also to establish a baseline for future improvements. The study demonstrates although the steel comprises the majority of both balconies, the coating is a significant part of the LCA profile.

The environmental assessments of the balconies were based on the following parameters:

- 60-year service life
- 1,715 lbs (778 kg) galvanized steel; 420 ft2 (39 m2) painted steel
- Galvanized coating corrosion rate of 0.5 – 1.0 microns per year (ISO 14713)
- Paint system: zinc-rich epoxy primer (40 microns), epoxy intermediate (160 microns), polyurethane topcoat (40 microns)
- Paint Maintenance: year 15, 30, and 45 (ISO 12944)

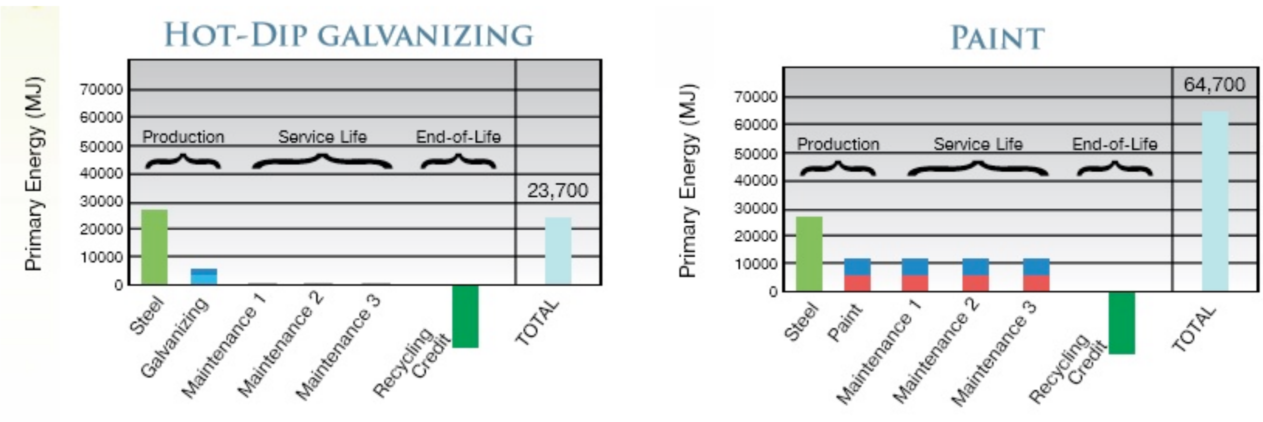


Figure 8 Life-cycle Energy: HDG vs Paint [13]

The environmental impact criteria examined were the same as the LCI/LCA study: primary energy demand (PED), global warming potential (GWP), acidification potential (AP), and photochemical ozone creation potential (POCP). The results show the durability of the coating plays a huge role in the overall environmental impact. The three maintenance-cycles required for the painted balcony account for almost half of the energy requirement for the painted structure, while the galvanized balcony required no additional material or energy inputs. T h e following graphs illustrate the total PED of each phase of the LCA, the percentage of the PED consumed by the coating, and the GWP, AP, and POCP values.

Figure 9 shows the total primary energy demand (PED) for the hot-dip galvanized balcony is 23,700 MJ (30.5 MJ/kg), or just 37% of the 64,700 MJ (83.2 MJ kg) required for the painted balcony. Keep in mind, if the painted balcony is left in service for even one more year, an additional maintenance-cycle would be required and more energy demand and emissions would be added to the values shown, while the galvanized balcony will remain untouched.

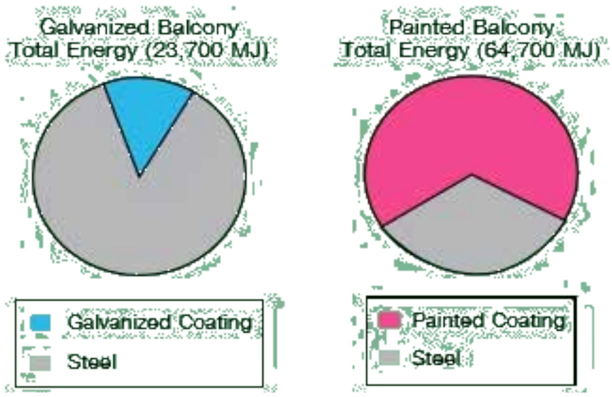


Figure 9 Coating Energy Consumption HDG vs Paint [14]

The difference in the energy demand for each balcony structure is even more striking when you consider the percentage of the total energy attributed to the coating. Galvanizing only contributes 16% of the total energy demand, where paint contributes 69% by the end of the 60-year life (Figure 9).
According to the study, each paint maintenance cycle consumes an amount of energy equal to that used in the original production, while galvanizing protects the steel throughout the entire 60-year life without maintenance. In addition to the energy savings, there are significant differences in GWP, AP, and POCP. For each indicator, galvanizing has a fraction of the environmental impact of the paint coating Figure 10).

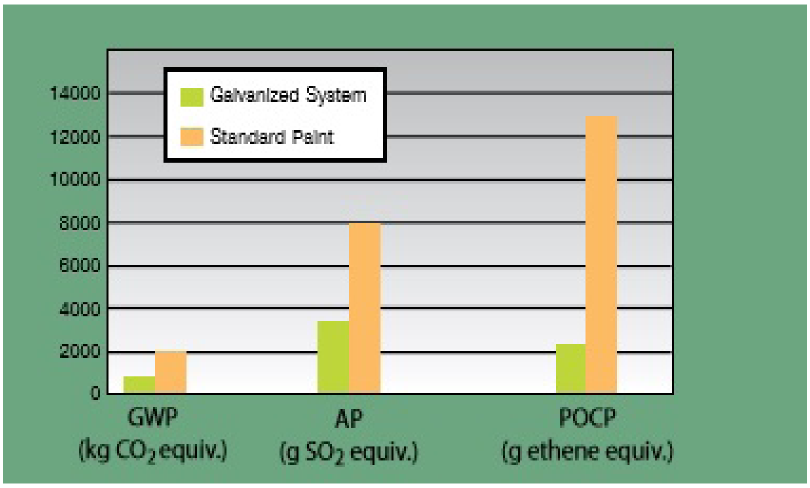


Figure 10 Emissions HDG vs Paint [15]

CONCLUSION

In conclusion, steel is one of the most preferred and advantageous material for structures, but it has been protected against corrosion to increase lifetime of the building, decrease its service costs. We shouldn't forget that only in 2013, corrosion lost total of the world was almost 5 trillion dollars. Corroded steel is the loss of national wealth and also waste of natural resources. It is a threat for all living things' health and for the nature. In this case, hot dip galvanized coating, the environment friendly corrosion protection method, is the best solution for sustainable buildings. In another words, to save the planet and to save the economy, HDG is a must for steel protection.

REFERENCES

[1] Prof. Dr. Ali Fuat Çakır, "Türkiye'de Genel Galvanizin Korozyon İle Mücadelesi", Hot-dip Galvanization Conference, Istanbul (2014)

[2] http://www.egga.com/galvanizing/the-process/

[3] NACE Paper C2014-4088 Expected Service Life and Cost Considerations for Maintenance and New Construction Protective Coatings Work (2014)

[4] http://www.galvanizeit.org/hot-dip-galvanizing/how-long-does-hdg-last/in-the-atmosphere/time-to-first-maintenance

[5] Steel Bridges, Galvanizing in Action GA, A National Industrial Journal in UK (1998 June)

[6] https://www.galvanizeit.org/project-gallery/gallery/leaside-bridge

[7] Source: Steel Bridges, Galvanizing in Action GA, A National Industrial Journal in UK (1998 June)

[8] http://www.egga.com/galvanizing/sustainability/

[9] Prof. Dr. Ali Fuat Çakır, "Türkiye'de Genel Galvanizin Korozyon İle Mücadelesi", Hot-dip Galvanization Conference, Istanbul (2014)

[10] Woolley, Tom B. Arch. PhD, Galvanizing and Sustainable Construction: A Specifiers' Guide (2008)

[11] Hot-dip Galvanizing for Sustainable Design, American Galvanizers Association (2009), 18

[12] Vares, S., Tattari, K., Hakkinen, T. 2004. Life-Cycle Assessment study for hot-dip galvanized balcony system compared with painted balcony system. Results. Research report No. RTE1324/4 (confidential), VTT, 57 pages

[13] Hot-dip Galvanizing for Sustainable Design, American Galvanizers Association (2009), 18

[14] Hot-dip Galvanizing for Sustainable Design, American Galvanizers Association (2009), 17

[15] Hot-dip Galvanizing for Sustainable Design, American Galvanizers Association (2009), 17

Building - Design

Paper No: 157

Investigation of Some Design Decisions on Energy Efficiency: A Case Study of Bornova Municipality Service Building

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ABSTRACT

The phenomena of production and consumption refer to an integrated system that contains both conflict and interaction. If this system is interpreted as a whole of equilibriums, all of the processes that focus on production need to deal with the concept of consumption. In this sense, when the amount of resources and energy consumed during the production and utilization of the built environment is considered, the practice of architecture dominantly intervenes with the natural environment. The simplest and the most efficient method for long term energy efficiency in buildings can be termed as the consideration of environmental inputs in the design phase. In this context, the problems of ensuring long term energy efficiency and integrating this thought with design become evident when the lifetime, frequency of use, and scale/size of a building, especially for the local governance buildings in Turkey, is considered.

In parallel with the aforementioned statements, this work aims to systematically evaluate and express the inherent potentialities, which can be integrated with technological solutions, of the design methodology that incorporates rational energy use via passive design decisions in the case of Bornova Municipality Building, which won the first prize in the national architectural project competition in 2015.

Key Words: Passive Design, Energy Efficiency, Municipality Buildings

INTRODUCTION

The phenomena of production and consumption refer to an integrated system that contains both conflict and interaction. If this system is interpreted as a whole of equilibriums, all of the processes that focus on production need to deal with the concept of consumption. In this sense, when the amount of resources and energy consumed during the production and utilization of the built environment is considered, the practice of architecture dominantly intervenes with the natural environment. It is a known fact that natural environment and energy resources are suffering/have suffered especially as a result of the consumption pattern associated with the increasingly rapid construction/production practices without regard for any environmental sensitivity. While the practice of architecture has an inherent nature of design and construction as its domain of action, it is continuously examining its intrinsic behaviors against the aforementioned factuality and it has been re-discussing and transforming its position within the concept of “sustainability” for a long time.

This transformative approach contains much diversity, from the basic decisions in the design process to the solutions in the construction process that contain technical-technological relationships. Although the technological solutions in question cannot be used in all designs when the building type, scale, and economical constraints are considered, it is possible to keep passive design principles in mind during the design process. Thus, the simplest and the most efficient method for long term energy efficiency in buildings can be termed as the consideration of environmental inputs in the design phase. In this context, the problems of ensuring long term energy efficiency and integrating this thought with design become evident when the lifetime, frequency of use, and scale/size of a building, especially for the local governance buildings in Turkey, is considered,.

In addition to passive design principles' being related to sustainability concept which is a contemporary discourse; in fact, sustainability, which is new as a concept, has been an ongoing approach since the ancient period especially within the context of the deliberation of local data and the utilization of climatic data in design [1]. The basis of passive design principles can be expressed as the consideration of dominant climatic data from the environment in which the building exists and the usage of this data as strategies of natural-passive climatization at the design stage. Passive design strategies can dramatically affect building energy performance. These measures include building shape and orientation, passive solar design, and the use of natural lighting [2]. In this sense, protection from basic environmental factors such as solar radiation and wind movements or gaining maximum benefit from this data becomes important in design process. By that means, it is necessary to make the most of the wind effects by increasing ventilation and to avoid thermal effects by reducing solar heat gain under cooling circumstances, whereas a total opposite strategy should be targeted under warming circumstances in the sense of passive climatization strategies [3]. The integral consideration of the decisions which increase energy efficiency such as natural ventilation, natural lighting, building envelope efficiency, shading/heat protection, orientation in design process is aimed at the reduction of the energy which the building consumes in its life cycle and long term usage periods, rather than energy generation of the building. When it is taken into consideration that construction activities consume 40% of globally used energy every year and energy is mostly consumed [4] for heating-cooling, ventilation and lighting systems in service, the importance of passive design principles can be obviously seen in terms of energy efficiency. In this sense, considering the firm ground decisions observed in close environment relations such as building scale, intensity in the number of stable and unstable users, typologic characteristics of the mass and the site, consumption values in the production and usage processes and yard-square, the necessity of using passive design principles in long-term energy efficiency obtainment becomes evident as a value that should be cared about in cases of local governance buildings in Turkey.

When the building envelope and spatial solution characteristics belonging to aforementioned buildings are surveyed, atrium usages that provides vertical volume sustainability in the interior and solar shading usages in facade implications as the fundamental component of building envelope are frequently observed. Especially under cooling circumstances, atrium is effective in enabling natural indoor air ventilation and increasing the quality of inside air. However, as the atrium sizes increase and there is not adaquate efficiency, these volumes can transform into spaces which need heating and cooling and therefore increasing the energy consumption in the long term. Solar shading elements used in facade implications establish control over solar radiation in especially cooling periods. Solar shading is an effective energy saver all year round. In summer it can cut the amount of heat entering a building and in winter it can decrease heat loss. In both cases, the need for additional climate control measures is substantially reduced [5]. Particularly, design approaches such as the differentiation in north-south facade characterization, deaf-transparant facade usage, sectional or monoblok mass decisions, canopy, inner yard and street can be rated as passive design strategies that affect mass and place composition depending on environmental data and settelement spesifications. Besides, the relations between open spaces and indoors, which are seen in local governance buildings, are effective in building and close environment design decisions. By the same token, open/semi-open place implications such as square, yard, parade ground, terrace, etc. can be observed in this building typology which is predominantly shaped by public usages. In order heat reflections created by the firm ground around the building to be reduced and shading in user areas to be increased, green spaces shoud be used in a balanced way in the design. Moreover, formation of floor gardens and green terraces gain importance in climatization and offering usage comfort in the buildings which are designed under cooling circumstances.

In parallel with the aforementioned statements, this work aims to systematically evaluate and express the inherent potentialities, which can be integrated with technological solutions, of the design methodology that incorporates rational energy use via passive design decisions in the case of Bornova Municipality Service Building design. In this sense, the project, which won the first prize in the national architectural project design in 2015 and is planned to begin construction in 2017, will be discussed within the parameters of form, placement decisions, building elements, material usage, orientation-façade characteristics, climatic conditions, etc…

CASE STUDY

The basic expectation of the competition in 2015 is not only limited to the obtainment of a qualified local governance building but also the production of personified common living spaces which will also enrich the daily life of the city. Consequently, the ultimate building of the competition is expected to take a place in the collective memory of the city and to be an examplary solution for the future works which will contribute to a more qualified environment of Bornova. [6] It is targeted that the ultimate building in this direction becomes an important part of the urban space and the municipal building, which is in the appearance of the locomotive of this urban part, includes the spatial sequences that describes a setting within the modern city life which is integrated with the city centre, easy to reach, embraced and exists in an urban sustainability. Hence, it is intended that the newly built architectural language makes contribution to the city culture, modern architecture and art environment. One of the significant topics of the competition is that the open space described in the area is rebound to the city life, transformed into a social site and integrated with the municipal building.

A building group including Underground Parking and New Municipal Services Building is expected to be designed instead of Bornova Stadium which is 1 km away from Bornova Square, 600 m from Metro Station and Ege University Hospital. There exists a zoning plan made in this sense. Municipal Services Building is depicted as a parcel that owns averagely 50 m depth on the northwest side of the area. As for Mustafa Kemal Street side, it is reserved as an area with underground parking and its upper part to be a public space. Namely, constructional borders are clearly indicated in the zoning plan. Accordingly, 27.555 m^2 for the Municipal Building, 15.000 m^2 for the underground parking and 17.500 m^2 for the open spaces, totally 60.055 m^2 construction area composes the amount of m^2 on which the project is expected to be designed.

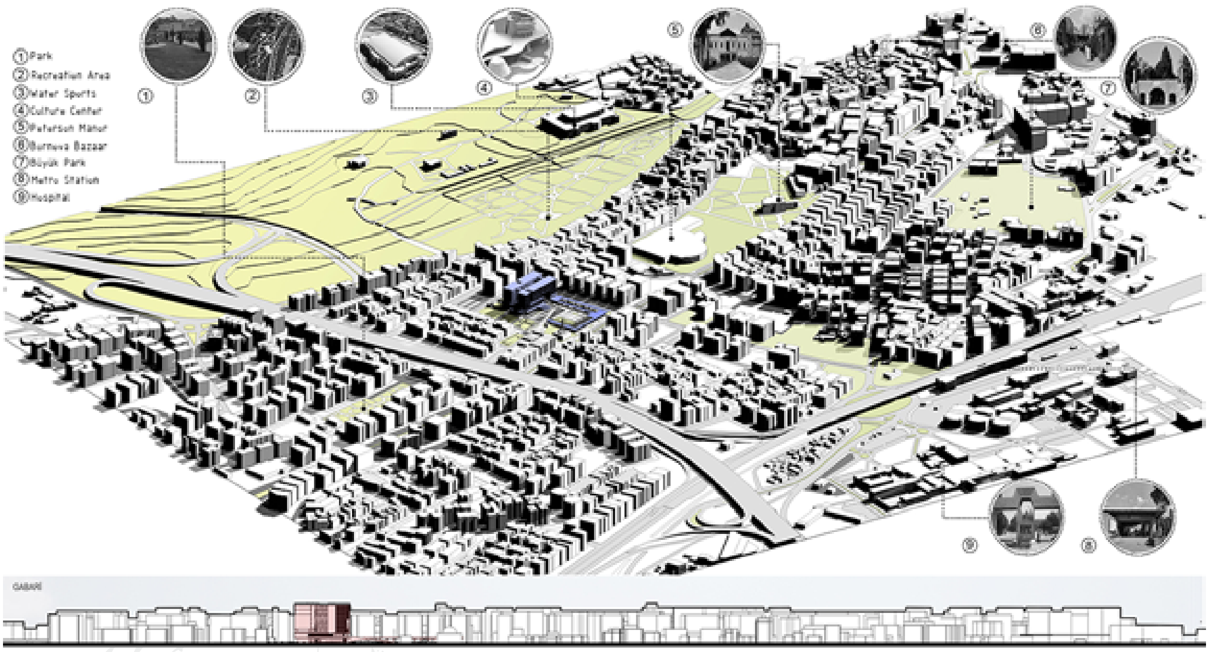

Figure 1 General view of area where the project is expected to be designed.

Design Decisions

A series of research questions about the constructional forms to be attached to the environment in the light of zoning plan data constitutes the main approch of the design. How Municipal Services Building and the public area on the front would be linked, the relation between Municipal Building, which fatefully would create an intense structuring due to its program, and the environment, arising public open space would have a new quare scale as of the size of the area and its relation with the scale of Bornova, the potential of transforming open public space into an active recreation area and night utilization, the relation between the surrounding streets and the structuring in the area are the outstanding primary questions of these research questions. Apart from these research questions, the qualification of an possible intervention in the situation which will occur along with the attachment of the area resulting from a huge inward space becoming an outward space is also an essential problem. As a result, the new situation created by possible solutions which are to be found within architectural scale, has become a set of architectural decisions and solution offers that direct design.

Tectonic/Formation/Form Implication

Forming an intermediate space in Municipal Services Building: The area is restricted by Mustafa Kemal Street on the southwest side, by Gediz Street on the southeast side. Intense pedestrian and vehicle trasportation are provided on Mustafa Kemal Street and the intensity on Gediz Street follows this. Although the transportation from the area including Bornova Square and the historical bazaar is provided via Mustafa Kemal Street, 555 Street occurs as a pedestrian centre line that reaches directly to Municipal Services Building. The revival of this centre line with urban fittings and partial pedestrianization exhibit a significant urban decision that will link Municipal Building and from historical Bornova bazaar, St. Peterson mansion and Bornova Culture Centres.

The division of the intense program of Municipal Building into two parts on the ground floor and upper floors along 555 Street centre line provides the centre line, which continues as an inner street, with an ending where exists a forum area enriched with cultural functions. The connection of thoroughly divided building mass with steel bridges with green roof means saving in the climatizaion of the building, rather than a 7-floor atrium. It is aimed that the surfaces obtained by the articulation of the mass composition brought by formation implication will create elements in order to increase spatial and living richness.

Consequently, floor gardens, terraces and balconies are designed with an approach that questions public space notion by means of the semi-open space usages which enable living richness and are open to the city and the citizens, rather than strict, monumental, public, not containing clues of life, empowering the administrative position effects that are the general characteristics of administrative buildings. This architectural formation implication used to increase the intensity of public usage has also made the inputs such as natural air, light or wind parts of design in the light of climatic data.

Figure 2 General view of the project settlement.

Open Space Implication

Identifying the open public space with a canopy: Strengthening the problems occured at the handling the area with an urban canopy. Regardless of the fact that open public space and its surroundings are being structured with a low-qualified commercial perception, the emergence of some small commercial units (bookstores, boutiques, etc.) under the canopy which has pedestrian open spaces and a strong relationship with the municipality provides opportunity for the enhancement of the active usage of the area during day and night. The idea of historical Bornova bazaar joining with a new bazaar here, the accession of 555 Street reaching the area to the historical bazaar and a pedestrian way suggestion reaching to the municipal square from Bornova centre have improved its vision. It is surely beyond doubt that this vision is a suggestion to be evaluated in the long term. Another solution that the urban canopy provides is the contribution it makes to the softening the scale of the aforementioned space. People may establish a relationship with a space they have never seen thanks to this canopy. A canopy, which can be described as a brink, is actually a permeable border that protects from climatic circumstances and hosts parking exits and kiosks.

Figure 3 Canopy, relation with the open space and mass organization

Section Implication

To create urban sustainability: Sections of a building forms the best design characteristics describing the building. Street formation starting from historical Bornova bazaar implicated along the pedestrian centre line; the formation activity which creates the building mass with sustainability of the canopy which is surrounding the urban green area and scaling the main road; theatres, social fittings and city assembly describing public area usages are the products of this section design. When the sections of a design examined, it is seen how loaded empty mass formations become organized in the light of urban sustainability; it gives clues about the implication of a building not only with fullness but also with the design of the emptiness.

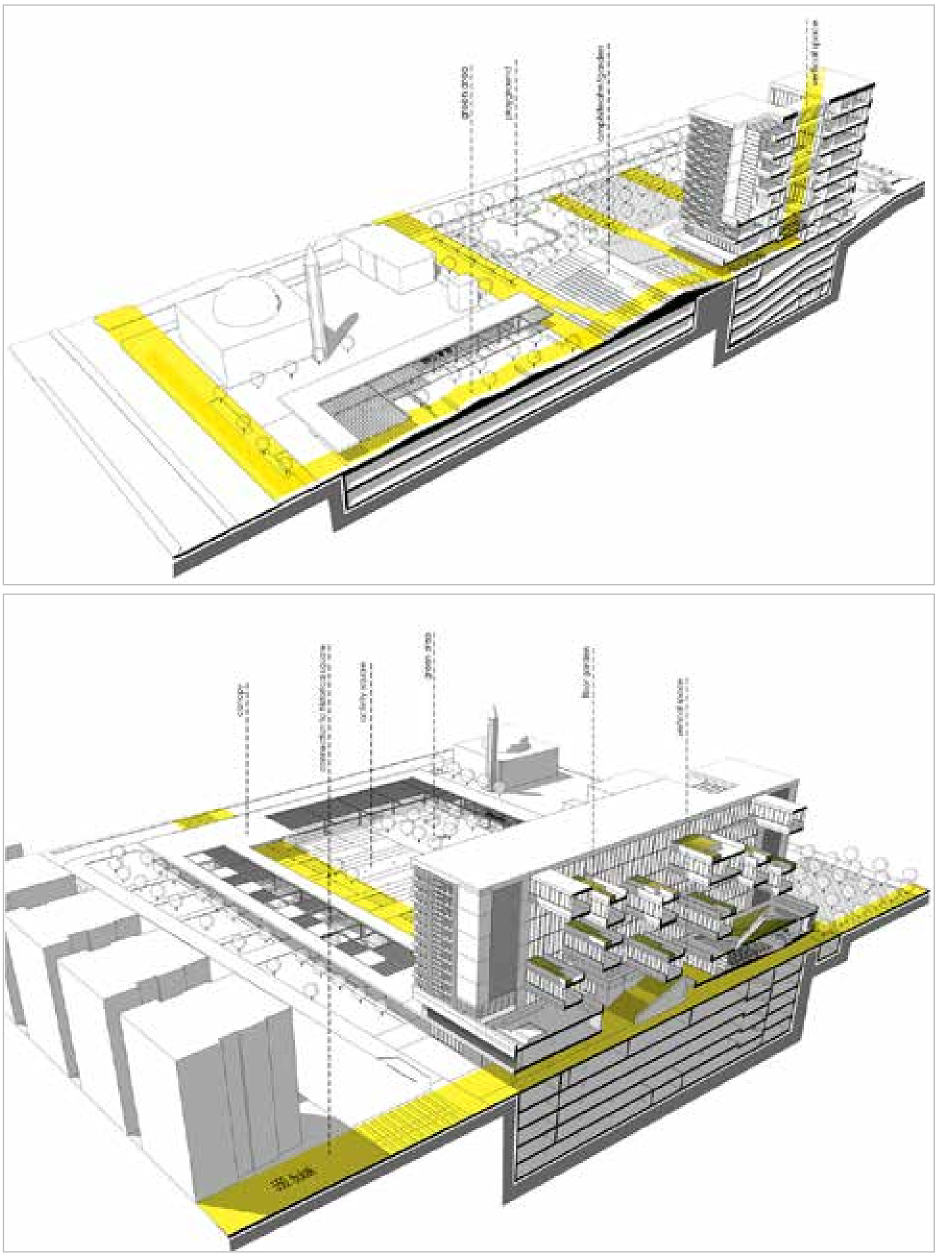

Figure 4 Shematic sections, describing the building and open space design characteristics

Planimetric Implication

To form new and alive bases: Doubtlessly, the loci which are the most intensely used and requiring a higher sensitivity in its relation with the environment of public buildings are ground floors. At this point, getting the maximum efficiency from the ground floor usage is a very important thing for a Municipal Services Building. The ground floor of a Municipal Services Building should embody the surrounding pedestrian movements, feed its entrances with these places, and direct its users with the intermedite places created. In this sense, the centre line coming from 555 Street and the centre line coming from the open activity area are embodied within the intermediate place with a culture street; cafeteria, multi-purpose hall, exhibition hall and main entrances are provided from this place The entrance to Financial Services Desk, which is the busiest unit of the municipality, is also independently provided here; waiting areas on the street are taken into account. A second ground is created at + 4.50 elevation. Access to the assembly hall is provided from this elevation which is accessed via ramps and the theatres facing the activity area. This solution creates an advantage for the municipalities where the public attendance to the assembly meetings and encourages assembly halls to be designed as city assemblies. The differentiation of the circulation inside the bulding and a good analysis depending on public and staff use intensity (document circulation between the units and archive, the differentiation of protocol, assembly hall, exhibition hall and public entrances, the freight lift necessary for the services, etc.) are important point taking place in the planimetric implication of the bulding. The suitable design of the structure for people with disabilities is also among the important topics.

To create flexible, changable, transformable places: Another significant notion for municipal buildings is flexibilty. In modern-day Turkey, where the political conjuncture is in a continuous motion, local governance buildings receive their share from this change. Especially the changes in law regarding local governance buildings and closure of municipalities in small towns, neighbourhoods, etc. have led to an increase in duties and powers of metropolitan, provincial and district municipalities, and this is reflected in spatial arrangement. In the meantime, local government administrations' modi operandi being different from each other; make several offices' location, settlement and working principles different. At this point, it is targeted that places have flexible usages and an implication that can be changed and transformed when needed in the design of Bornova Services Building. At this point, it is targeted that transparent, open office systems that have the potential to change are implicated and all the closed systems that can be included in this open system such as archive, store, etc. are fixed set with the cores. This implication means that the directorates that may be transformed-changed in the future meet their service possibilities with the minimum cost.

Socializing Municipality, Socializing Staff: It is aimed that the office structure template which is seen in the structures of management positions is broken for the staff and instution and transforms into an implication being able to include citizens. At this point, new spatial arrangements, which Municipality staff may need during the day, socialize, and increase their efficiency at work with this socializing, are created. By creating resting areas, terraces, floor terraces, floor gardens which will provide an opprtunity for socializing and taking a break on each floor; it is aimed that the building becomes a social centre for both the staff and the citizens.

Ecology/Economy/Sustainibility Implication

Today's developing engineering technologies, the importance given by the construction sector in ecology and recycling, along with the sensitivity to them that public have in this regard, will include sustainability solutions which have reached certain standards for a building of this scale to be built in Bornova. At this stage, what we need to talk through design is how the translation of sustainability criteria into architecture, above material, detail and engineering solutions proposals, will actualize via the place. In our view, determining the location of a structure, the creation of the requirements program, defining the areas of use and their functionality are also an important part of this process.

Sensitivness in Material: The correct choice of materials to be used in a structure, starting from that structure's constructional continuity; in terms of costs, future heating, cooling, ventilation, etc. has gained extreme importance. Material selection in Bornova Municipality Services Building is the concrete skeleton system which is easily obtained in the Turkish construction sector and has practical applications and ready-mixed concrete coating covering this system was chosen. Canopy, which describes the public space implication of design, is implicated with ready-mixed concrete and wooden elements along with steel carrier system.

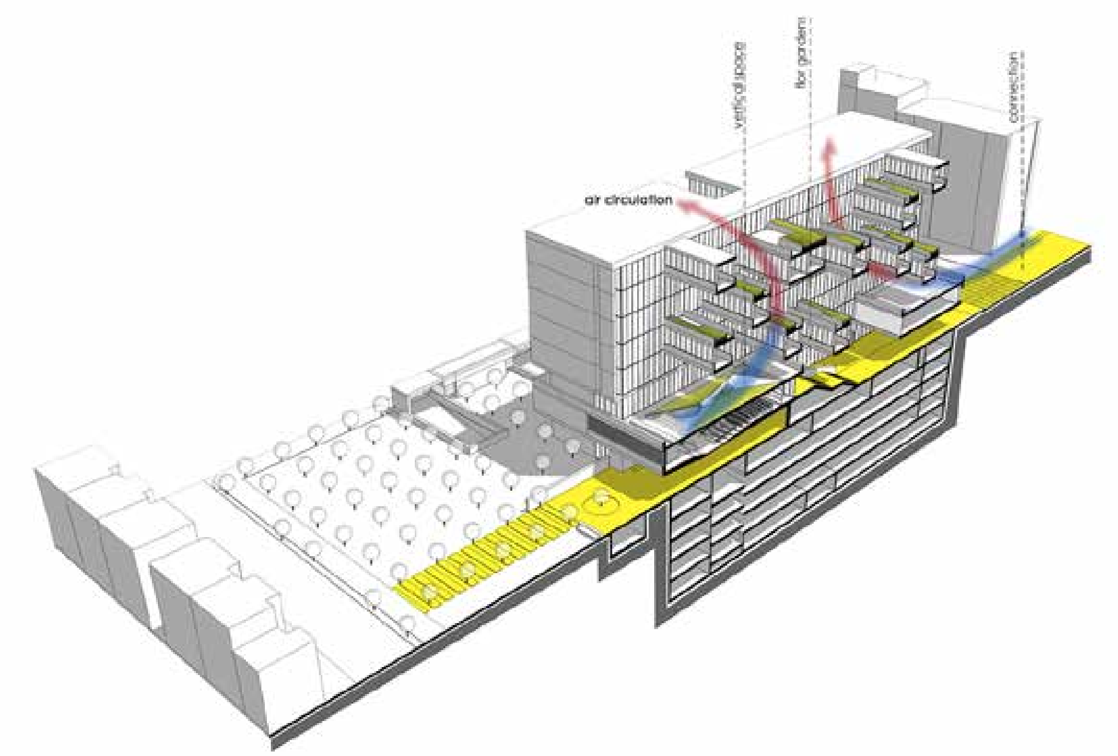

Figure 5 Shematic section describing the vertical space, floor gardens and air circulation

Figure 6 Mass organization, expressing the horizantal-vertical space and facade characteristics

Orientation decisions and facade studies: In building design, facade design constitutes the most prominent, the most effective point in perceptual context, which also gives the building its identity. The settlement of the structure towards the north-south orientation, which is the most opposite orientation in the context of climatic data, leads to important criteria in facade decisions. The constant sunshine in the southern direction, while the northern direction is exposed to the effects of wind and does not contain direct light have caused the differentiation of the southern and northern facades of the building But when the reflection of this difference to the general mass plastic of the building is thought, an arrangement including the design decisions has been implicated. According to this, the refractive design located on the southern facade which comforts the interior with different refractions of light, is treated vertically on the Northern facade, therefore creating a set against the north wind, and southern and northern facades of the building are studied to differentiate in the light of climatic data in the same design integrity. The translucent and transparent facade logic of the building emphasizing the publicity on ground elevations, has prepared a welcoming ground to the building; particularly the big frame, which rolls people in from the main Street and directs them towards Street elevation, aims to gather people with an iwan effect. Canopy design proposed for urban open space, encompassing the large urban green space that faces the building and with its shaded areas surrounding it, embraces the green area which nearly provides the city an opportunity to take a new breath.

Figure 7 Design characteristics of South and North elavations

CONCLUSION

In order to achieve green, sustainable and smart building, not only with automation systems but also with achitectural design this qualification should be provided. A good design is able to offer opportunities to use alternative clean energy sources with its main decisions within the frame of sustainable construction concepts such as natural lighting, heating-cooling, acoustics, and interior comfort. Another ignored point is functional implication of the building. Dissoiation of arc circulating density of the building on the ground and first floors and ensuring as little circulation as possible to the upper floors by taking the building into consideration with proper functioning, also gain value in terms of criteria for use of the building automation systems. Again, flexible usages of the places, structural cores meeting all wet areas criteria such as store, tea house, archive, etc. , lead places to be volumes enabled to be transformed with minimum intervention and increase building lifetime. This flexibility and transformativeness enables the building to use sustainable, natural sources.

REFERENCES

[1] Oktay, D., "Sürdürülebilirlik Bağlamında Planlama ve Tasarım: Kuzey Kıbrıs'ta Yöresel Mimarinin Geleneklerinden Çağdaş ve Duyarlı Çevrelere", Mimarist Dergisi, Sayı:6, s 67-71, 2002, İstanbul
[2] Kahraman, İ., "Green Building Design Guideline", Sustainable Construction, Proceedings of International Symposium, p 33-39, 23-25. July 2010 –Malta
[3] Ok, V., " Sağlıklı Kentler için Pasif İklimlendirme ve Bina Aerodinamiği", VIII.Ulusal Tesisat Mühendisliği Kongresi Bildiriler Kitabı, s 213-227, 2007, İzmir
[4] Sev, A., " Sürdürülebilir Mimarlık", YEM Yayınları, 2009 İstanbul
[5] Kahraman, İ., "Green Building Design Guideline", Sustainable Construction, Proceedings of International Symposium, p 33-39, 23-25. July 2010 –Malta
[6] Bornova Belediyesi ve Çevresi Mimari Proje Yarışma Şartnamesi, 2015

Paper No: 224

Sustainable Social Development Strategies of an Urban Renewal Project in Gaziemir, Izmir

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ABSTRACT

Urban transformation of Aktepe and Emrez districts, located in the provenience of Gaziemir, İzmir (Turkey), is the subject of a considerable debate for the last ten years' agenda of the city of Izmir. Although, Aktepe and Emrez were once respected as areas located in urban periphery, due to the urban growth, they have turned out to be places more central, but less connected with the city. In the area mentioned above, there is an informal urban setting within insufficient facilities giving service to inhabitants who came partly through migration. In 2015, an urban renewal project competition has been organized and opened by Izmir Metropolitan Municipality with the aim of transforming the site into a healthy urban living space and an urban renewal process has been initiated.

The implementation process of urban renewal projects in Turkey are realized in three different means of management under the control of the Ministry of Environment and Urbanization of Turkey. First type of the renewal projects are handled by investor-contractors. Second type renewals that occupy larger urban areas that are undertaken by Turkish Governmental Institutions and Housing Development Administration of Turkey (TOKİ). And thirdly, there are renewal projects that are carried out by metropolitan municipalities of cities that have population more than 750.000 citizens. Gaziemir Urban Renewal Project can be evaluated within the scope of the third category.

Purchasing renewal projects through a nationwide competition process brings about a new participatory model in contrast with the conventional approaches. The municipality in this sense has targeted a healthy and sustainable renewal program for the site within a competition process.

Sustainability is not a fixed process, in contrary, it is a dynamic process associated with economic, social and environmental dimensions. In contrast, in Turkey, mostly economic factors come into prominence and components of social sustainability are being ignored. However, social sustainability creates the provision of participation and equality, protects harmonious coexistence of social groups and intends the sense of social cohesion.

Therefore, in this paper, the urban renewal process in Gaziemir where 15,000 residents are living, will be discussed through the key concepts of social sustainability such as participation (program organization), variety according to the user's profile (spatial variations), place-making (sustainable community and neighbourhood development) and equal opportunity (access to common key services). Spatial equivalents of these concepts have been searched for the competition project and questionnaires are used as sources for determining user's profile and expectations.

Key words: social sustainability, community development, urban renewal, Gaziemir, Izmir.

INTRODUCTION

This paper discusses social sustainable strategies on an urban renewal project that was proposed in August 2015 for Izmir Metropolitan Municipality in Gaziemir, Aktepe Emrez. In the first part, brief information about the process of urban transformation projects that are accomplished in Turkey will be summarized. Then sustainability issues and social sustainability will be defined regarding to references, which will illustrate circumstances and settings about main approaches and strategies of sustainable developments. Thirdly sustainable approaches and strategies of a winning proposal on Gaziemir Urban Renewal project in context of social sustainability will be exposed. And finally, in the conclusion key ideas of physical interventions targeting social sustainability for such kind of urban renewal projects will be revealed and concluded.

Process of Urban Transformation Projects in Turkey

Implementation process of urban renewal projects in Turkey are realized in three different means of management under the control of the Ministry of Environment and Urbanization of Turkey. First type of the renewal projects are handled by investor-contractors. Second type of renewals that occupy larger urban areas are undertaken by Turkish Governmental Institutions and Housing Development Administration of Turkey (TOKİ). And thirdly, there are renewal projects that are carried out by metropolitan municipalities of cities that have population more than 750.000 citizens. "Gaziemir Aktepe –Emrez Urban Renewal Project" can be evaluated within the scope of the third category.

Urban transformation of Aktepe and Emrez districts, located in the provenience of Gaziemir, İzmir (Turkey), is the subject of a considerable debate for the last ten years in agenda of the city of Izmir. Although, Aktepe and Emrez were once respected as areas located in urban periphery, due to the urban growth, they have turned out to be places more central, but less connected with the city. In the area mentioned, there is an informal urban setting within insufficient facilities giving service to inhabitants who came partly through migration.

Figure 2 Gaziemir- Emrez Aktepe Region

Figure 1 Izmir plan and Gaziemir region

Gaziemir, Aktepe Emrez Competition

In 2014, an urban renewal project competition has been organized and opened by Izmir Metropolitan Municipality with the aim of transforming the site into a healthy living urban space and an urban renewal process has been initiated. After an 8 month preparation and data gathering, the municipality opened a nationwide urban design competition which can be counted as the biggest in its kind, inviting the teams including architects, landscape architects, planners and engineers. The competition was organized in two phases (steps). Phase 1 was open to all professionals while the selected 10 finalist groups have been invited for the second and final stage of evaluation.

What mainly municipality was asking in this competition was justifying the needs of people with a healthy urbanization with a participatory process. A list of questions, aiming a sustainable living environment and requirements which municipality was demanding from the participants of the competition have been listed and redefined by the jury of the competition justifying the needs of sustainable development (1):

- The demand of social and cultural facilities for a social sustainable development and economically sustainable community.
- The demand of urban spaces and zones initiating social and cultural diversities.
- Integration with the environment and urban neighbourhood in context of rational and convenient solutions for the competition area.
- Generating human scale and human oriented urban design solutions for the area.
- Generating an economic sustainable development by providing rant which will support the project and shall be shared by the land and stake holder residents.
- Providing a richer and diverse commercial environment by purchasing a diverse of retail and commercial spaces.

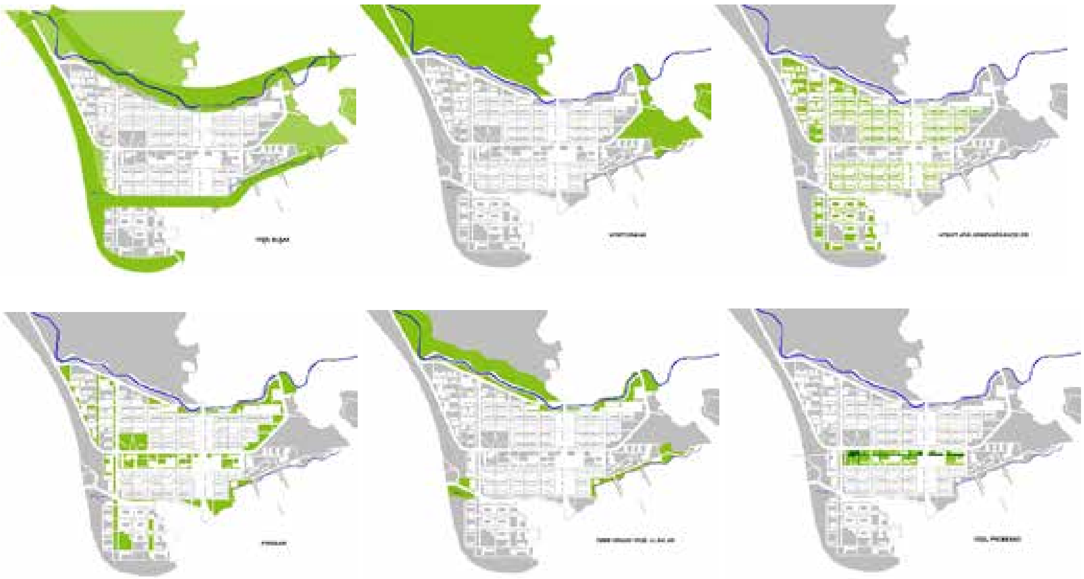

Figure 3. Urban Infrastructure, Urban Configuration, Pedestrian and Traffic Networks, Green Network strategies of Gaziemir Aktepe_Emrez Urban Renewal Project

Figure 4 Existing Urban configuration- Solid-Voic Map of Gaziemir Urban Renewal Proposal

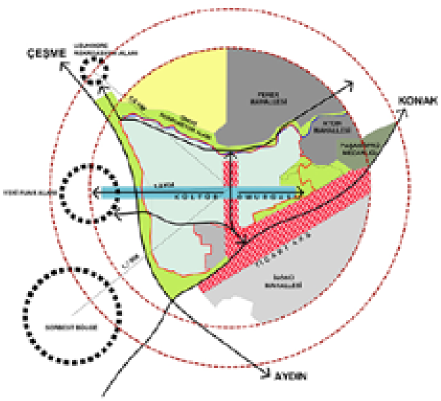

Figure 5 Urban Planning Strategy of Gaziemir Aktepe-Emrez Urban Renewal Proposal

3. Sustainable Development: SLIDE 10

When we refer to the requests of the jury committee on the behalf of Metropolitan Municipality of Izmir, there is a certain demand for a sustainable development. On the other hand, what is a sustainable development? How can it be accomplished?

In general, a sustainable development can be accomplished only by reaching the thresholds achieving a balance between economical, ecological and social sustainability goals.

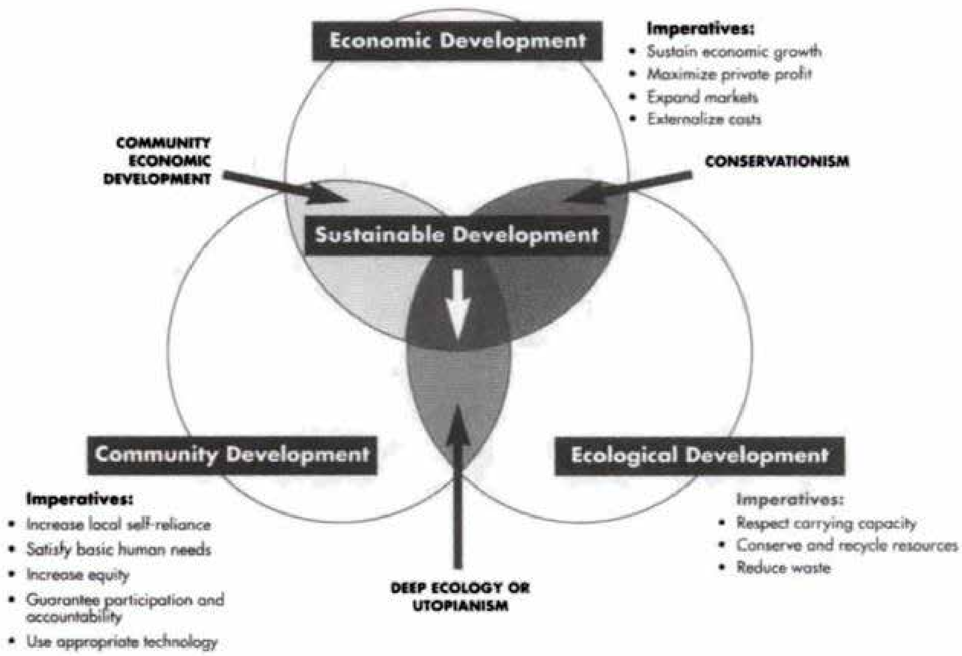

Figure 6. Sustainable Building Process (2)

These three phases of sustainability asked to be woven and having an interaction. According to Newman and Kenworthy "development is not to be perceived as a permanent state or a static image, but rather as a continuing process that implies the integration of the three essential and inseparable aspects of development: Environmental, Economic and Social dimension." (2) Thus, what are definitions for each aspect (dimension) of sustainability and what can we say about the goals or the thresholds for a sustainable development?

a. Environmental dimension

Environmental dimension of sustainability is the capability to increase the value of the environment and its features, while ensuring the conservation and renewal of the natural resources and the environmental heritage. (2)

b. Economic dimension

Economic sustainability is usually defined as the capacity to create income and employment in order to maintain the populations. But there is another mean for an urban renewal projects in Turkey. This is economic sustainability of a project can also be defined as a capacity which brings extra value of real estate to continue for funding construction.

c. Social dimension

An finally when we are to talk about Social dimension , social sustainability is the capability to assure of welfare, security, health, education and providing all of these issues equally without separating any social classes and gender. According to Hurol "Within a territory, social sustainability means the capacity of the different social actors (stakeholders), to interact efficiently, to aim towards the same goals, encouraged by the close interaction of the institutions, at all levels."(3)

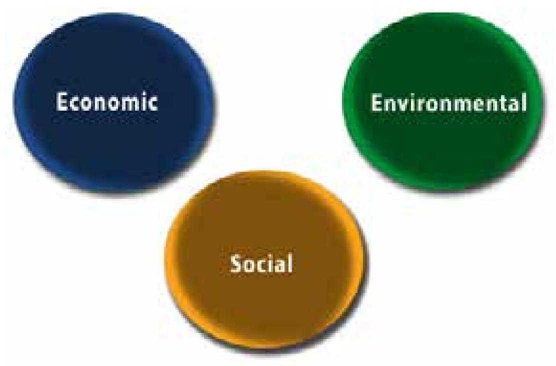

Figure 7 Dimensions of Sustainability (3)

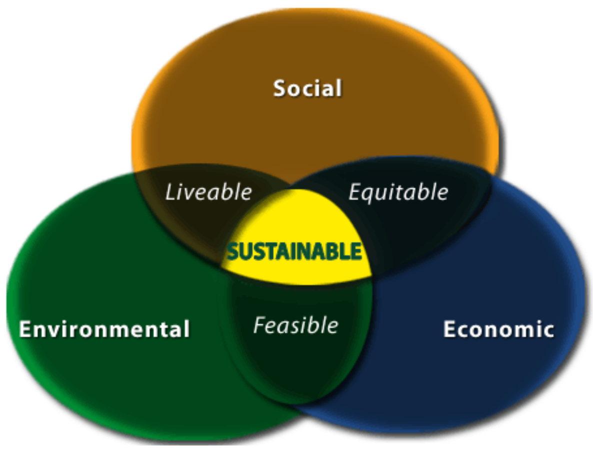

Figure 8 Three E's balance rule, Environment, Equity, and Economy (3)

According to Edwards there is a three E's balance rule. The First E is between Ecology and Environment There are significant problems in the first E as: short-range vs. long-range time projection; for the survival of human existence piece by piece versus systemic understanding of ecosystem necessity; and the concept that ecosystems built-in limits on the nature and human impact that can be sustained. In this sense, environmental sustainability gives up the short-term acquisition philosophy in return for the long-term viability of our source use -particularly in spaces like extraction of resource, agriculture, manufacturing, materials of building and transportation. (4)

The Second E is between Economy and Employment Economic sustainability deals with the connection between the needs of employment and protection of the environment. Economic sustainability is separated from environmentalism with its acknowledgement of the significance of ensuring safe, long-term deploy without putting ecosystems health at risk. At the same time providing the requirements of dynamic economy based on an extended period and having an environment which is healthy without toxic wastes and pollution are seen in sustainability as supplementary, but rather conflicting, initiatives. (3)

The Third E is between Equality and Equity on a basic level, sustainable community members recognize that individual's wellbeing is connected with the well-being of larger community, for sure vice-versa. (3)

According to McKenzie, Social sustainability is marked by strong sense of social cohesion and access equality to key services (as health, education, housing and recreation, transportation) as a positive condition.(5) At nation-state level, righteous distribution of resources as nutrition and food, healthiness, affordable housing, education, training for job and professional opportunities will be addressed by this equality.

"Social sustainability occurs when the formal and informal processes, systems, structures and relationships actively support the capacity of current and future generations to create healthy and liveable communities. Socially sustainable communities are equitable, diverse, connected and democratic and provide a good quality of life."(3) Communities are affected by urban renewal both in a physical and social manner.

Figure 9: Principles of social sustainability (6)

4. Strategies in Gaziemir Urban Renewal Project for a Social Sustainable Development

Four concepts has been identified in this study to understand a sustainable development which can be turned into physical urban spaces with architectural and urban renewal scale solutions:

1. participation (program organization),
2. variety according to the user's profile (spatial variations),
3. place-making (sustainable community and neighbourhood development) and
4. Equal opportunity (access to common key services).

Figure 10 Site Plan of Gaziemeir Aktepe-Emrez Project

4.1. Public Participation

Expectations of the residents for the future of their living environment and neighbourhood have been asked and gathered by the municipality in an analytical survey of pre studies for the competition. The data collected then has been shared with the project groups in the competition process. The questions asked to the residents for further development of the urban renewal program are briefly listed below as:

- Opinions of the residents about the environment, the neighbourhood and the housing type that they would like to live in.
- Opinions of the residents about urban transformation process that they would like to be part of it.
- Expectations about the qualities of the living spaces of outdoor and indoor environments.
- Expectations about recreational, social, cultural, educational, health care facilities and physical infrastructures

4.2. Variety

Different user profiles exist among residents. The varieties of users do need variety of housing units regarding to their needs and wishes. Referring to the questions related with the housing types 44% of the residents would like to live in 100-125 m2 apartment flats, 21% of the residents would like to live in 125-150 m2 apartment flats, 19% of the residents would like to live in 150 m2 and above size apartment flats, 14%of the residents would like to live in 50-100 m2 apartment flats. According to expectations of the residents and collected data, a variety of housing unit in different clusters of communities have been designed and proposed. Moreover, a diversity of arrangement in types of housing units has been proposed in different areas in the competition area.

4.3. Place-Making

Referring to the questionnaires and studies made with the local residents of Aktepe and Emrez, most of the residents would like to continue their living in their home neighbourhood and they realize their home district as the most liveable environment among other districts in Izmir. They do not wish to migrate to another town or district in the city. One of the reasons is the location of the neighbourhood. It is appealing for many people besides all the deficiency of infrastructure and unhealthy buildings and environmental problems, the location is quite close to the İzmir city centre and just next to Gaziemir centre. The second reason is that, 64% of the residents have been living in neighbourhood for more than 15 years, with a long time of inhabiting the location, sense of belonging to the place has been increased among the longer settled residents. Consequently a social community knowing and interacting with each other has been shaped. Streets are the places that have been spatialized for the interaction of the community in Aktepe and Emrez where residents meet and interact with each other at the doorsteps of their homes.

In the light of the analyses mentioned above, inner courtyards and gardens have been proposed for communal usages, interacting, for 4 or 5 storey housing developments of Gaziemir Aktepe-Emrez. These communal spaces are proposed to be used only by a block of housing units, not the entire neighbourhood. Accordingly, community awareness has been extended due to the variety scales of housing clusters and developments.

Figure 11 Proposed Housing Types and Mixed Use Clusters

All the religious, educational and cultural and health facilities have been kept still and preserved in their location. This preservation process brings a tie between people and place, and highlights the sense belonging to the place for the local residents. Moreover, gathering all the preserved public buildings with the new ones on a cultural and social facilities zone enriches and strengthens the sense of place.

4.4. Equal Opportunity

Proposed urban renewal project of Gaziemir Aktepe-Emrez has been projected on the equality of all the inhabitants. The cultural, social, educational and religious buildings and infrastructure have been situated on an axis of east-west direction where all the local residents could easily reach and have access to all the social and cultural facilities in equality. Users of all ages and diverse social groups can interact and benefit all along this social-cultural spine of communal usages. Where accessing to all facilities gets easy for everyone, sense of place and sense of community get stronger, and successively social sustainability is to be achieved.

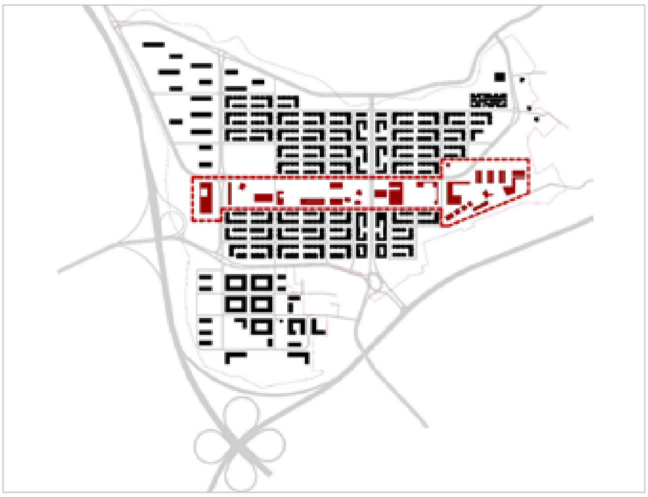

Figure 12 Social-Cultural spine of Gaziemir Aktepe-Emrez Project

Figure 13 Social-Cultural spine of Gaziemir Aktepe-Emrez Project

Figure 14 Perspective of Social-Cultural spine of Gaziemir Aktepe-Emrez Project

Figure 14 Perspective of Mix use building cluster

Figure 15 Perspective of the general view of the Gaziemir Emrez –Aktepe Project (winner)

5. CONCLUSIONS

Urban Renewal is a process inhabiting many actors ranging from politicians to professional, users to residents. So, the whole transformation process should be kept as open as possible to make all the actors comprehend and appreciate each other to grasp a sustainable development. Besides, for the sake of inhabitants they should get more involved into urban renewal project process with an enhanced participation. In Turkey, however agreements are being made between habitants and the authorities in areas where projects are being carried out only on economic negotiations. Local governments are acting like stakeholders and they take share in the development areas in order to provide funding for the construction. These kind of partnerships do not provide benefit to the social results of urban transformation projects. Instead, governments and authorities should consider determination of socio-cultural and economic conditions of people living in the district. Moreover, physical qualifications of renewal area and thoughts of residents about renewal project have to be clarified beforehand with previous studies which employed in-situ questionnaires.

Social sustainability means life-enriching condition in communities along with a process inside of communities, which can reach to success in that condition.

- Providing social infrastructure
- Availability of open spaces
- Creating meeting point for social communication
- Accessibility
- Creation of harmonized living environment and preservation of local features
- Ability to satisfy psychological requirements
- Affordability and being fair for everyone
- Public participation are the main issues to be handled for community development.

As a conclusion physical space and planning is needed to reach the goals of a social sustainability of a development strategy listed above;

Another important issue is the "***Equality***" between generations, which means that future generation should not be affected negatively due to the activities of the present generation. Sufficient amount of green areas, cultural heritage and open spaces with resources have to be preserved.

Urban renewal is not just an action of physical renewal. More sensitive approach in renewal of residential areas should be needed to carry out with in the process of collapse from other urban land uses.

Another important social issue is community identity and mechanism of gathering, integration and interaction. A sustainable environment requires a conscious society and in creating the conscious society, local scale has a big indisputable importance. Furthermore neighbourhoods (as a basic unit of local scale) emerge as the most important scale in social change process. For this reason, the concept of sustainability discussed in different scales with its many aspects cannot expand to the large scales due to the fact that it gets behind in environmental concerns of organization size and social cohesion of the society in practice, and as the most important unit of the society, the neighbourhood scale is undefined.

Neighbourhood is a unit not only with its physical but also with social characteristics as well. In this context, certificate systems used in measurement of sustainability in neighbourhood scale should include criteria reflecting local characteristics with a holistic perspective for each country.

With the aim of orienting place-making, some special references over people, place, events and community based organizational actions are investigated by place-framing. For the evaluation of social sustainability, culture, identity and sense of place terms are important. It is claimed that establishing a sense of place and socially sustainable communities by the way of urban renewal should contain effective public connection of the community.

REFERENCES

1. Gaziemir Aktepe Emrez Kentsel Fikir Tasarım Yarışması Şartnamesi (2015): İzmir Büyük Şehir Belediyesi,

2. Newman, P., & Kenworthy, J. (1999). Sustainability and cities: overcoming automobile dependence. Island Press.

3. Hürol, H. Y. (2014). A Study On Social Sustainability: The Case Of Doğanbey Urban Renewal Project In Bursa (Doctoral Dissertation, Middle East Technical University).

4. Edwards, A. R. (2000). Sustainability today: A compass for the future.

5. McKenzie, S. (2004). Social sustainability: towards some definitions.

6. Barron, L., & Gauntlet, E. (2002, March). WACOSS housing and sustainable community indicators project. In Sustaining our Communities International Local Agenda 21 Conference, Adelaide (pp. 3-6).

7. Chiu, R. L. (2003). 12 Social sustainability, sustainable development and housing development. Housing and social change: East-west perspectives, 221.

8. Darchen, S., & Ladouceur, E. (2013). Social sustainability in urban regeneration practice: a case study of the Fortitude Valley Renewal Plan in Brisbane. Australian Planner, 50(4), 340-350.

9. Colantonio, A., Dixon, T., Ganser, R., Carpenter, J., & Ngombe, A. (2009). Measuring Socially Sustainable Urban Regeneration in Europe.

10. Edwards, A. R. (2000). Sustainability today: A compass for the future.

11. Edwards, A. R. (2005). The sustainability revolution: Portrait of a paradigm shift. New Society Publishers.

12. Forrest, R., & Kearns, A. (2001). Social Cohesion, Social Capital and the Neighbourhood. Urban Studies, 38(12), 2125-2143.

13. Friedmann, J. (2010). Place and place-making in cities: A global Perspective. Planning Theory & Practice, 11(2), 149-165.

Smart Talks

Paper No: 4

Ecological Citizenship as the New Dimension of the Ecological City: A Survey Study in Famagusta, N. Cyprus

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ABSTRACT

Ecological city, being one of the most prevailing and also promising paradigms within the sustainable urbanism discourse, suggests that the implementation of ecological principles to urban planning, design and management is essential in order to be environmentally and economically sustainable. This paradigm is generally categorized in four dimensions as 'sustainable urban form', 'sustainable transportation', 'urban ecology and biodiversity', 'energy use and waste management'. Today, in an era of environmental deterioration, 'Ecological citizenship' emerges as a new addition to these dimensions as a non-physical aspect of 'ecological city'. It is hypothesized in this paper that adopting ecological citizenship as a lifestyle among urban residents has a potential effect on the ecological quality of the city, and is therefore worth investigating. This study, in line with this, focuses on Famagusta, a city with rich traditional values, and tries to measure the potential for ecological citizenship among the local residents. Within this context, environmental attitudes and environmental behaviours of the residents were investigated carrying out a user survey among 165 local residents.

KEYWORDS: Ecological City, Ecological Citizenship, Environmental Behaviour, User Survey, Famagusta

INTRODUCTION

Ecological city is one of the most prevailing and also promising paradigms within the sustainable urbanism discourse. With the knowledge of cities having a crucial role, 'ecological city' as a concept suggests that the implementation of ecological principles to urban planning, design and management is essential in order to be environmentally and economically sustainable. This paradigm is generally categorized in four dimensions as 'sustainable urban form', 'sustainable transportation', 'urban ecology and biodiversity', 'energy use and waste management'. Today, in an era of environmental deterioration, 'ecological citizenship' emerges as a new addition to these dimensions as a non-physical aspect of ecological city.

Famagusta, a city with rich traditional values, has been on a path of unsustainable urban development especially since the 1980's. Therefore constituting the ecological city dimensions seems to be a crucial need for the city. Within this context, besides seeking to improve the physical urban environment of the city, adopting ecological citizenship as a lifestyle among residents of Famagusta is worth investigating. On that ground, environmental attitudes and environmental behaviour of the residents are eligible to be investigated.

In this paper accordingly, first, the concept and understanding of 'ecological city' is evaluated; second, ecological citizenship as a newly concept is discussed; third, a user survey is done to measure the environmental worldview of Famagusta residents and the environmental behaviours in three categories; fourth, the results of the user survey carried out among 165 local residents are displayed and discussed; and finally, conclusions are drawn.

With the knowledge of cities having a crucial role, 'ecological city' as a concept suggests that the implementation of ecological principles to urban planning, design and management is essential in order to be environmentally and economically sustainable. The main principles structuring 'ecological city' can be proposed to be categorized in five dimensions as follows:

Sustainable Urban Form

Urban form generally encompasses a number of physical features and non-physical characteristics including size, shape, scale, density, land uses, building types, urban block layout and distribution of green space [1]. There is an ongoing debate for more than two decades, beginning from the late 1980's, about the type of urban form which best facilitates sustainable development. According to [2], there are those who emphasize the high density development and those who highlight garden city or garden suburban forms. In this context, the first view suggests that compact urban form with mix uses is essential for a city to prevent urban sprawl, to reduce car use and to obtain more land for urban open space, urban agriculture and forestry. Many planning theories like New Urbanism and Smart Growth have emerged that support higher density development, in housing areas in particular. According to the second view, higher densities introduce congestion, crime and reduction of open space in the neighbourhood and whereas low density development can give a chance for better quality of life, environment and facilities. It can be argued that the best solution can be found according to the local dynamics and characteristics of the urban environment. In some cases, garden suburban form, and in some others compact development achieving high densities would be appropriate; and sometimes the solution would be a mixture of both.

Sustainable Transportation

Transportation is reported to account %27 of total worldwide energy consumption and particularly in developing countries it is based on fossil fuel burning, mainly oil as a finite resource. Consequently, a considerable amount of the manmade carbon dioxide ($CO2$) in the globe's atmosphere arises from transport sector (automobiles and so forth) as advocated by many researchers. As reported by the Centre for International Climate and Environmental Research in Oslo, 15 percent of the carbon dioxide ($CO2$) in the atmosphere is released from transport sector and the remaining 85 percent (of atmospheric $CO2$) originates from agriculture, industry and buildings. These pollutants released by transportation not only cause global warming because of the 'greenhouse effect', but they additionally degrade directly the natural resources including forests, farmlands and wetlands as the sources contributing to the ecology of urban environments. And because of the urban sprawl, urban open spaces are also wasted resulting in loss in ecological diversity.

Within these consequences, one of the basic concerns of ecological urban planning is to achieve sustainability in urban transportation by promoting walking, cycling, public transportation and innovative technologies that are less dependent on fossil fuels increasing greenhouse gas emissions. Hence, urban design and planning movements focusing on the sustainability handle the urban transportation as a core issue. The most influential ones among these movements can be suggested to be Smart Growth, New Urbanism and the Dutch Woonerf system. All these movements aim to increase more sustainable modes of transportation within the city such as walking, traffic calming, cycling and light railway trains and buses etc.

Urban Ecology and Biodiversity

Protecting and enhancing natural environment, biodiversity and food producing areas is another basic concern of ecological cities. The natural and semi-natural green spaces provide multi-dimensional benefits [3-6] Dean et al. (2011; (Kim and Kaplan, 2004, De Vries et al., 2003; Takano et al., 2002. Especially in some developed countries where the city policy and management is evaluated within an ecologically based point of view, the concept of 'green infrastructure' has been introduced into the urban management policies. According to [7], green infrastructure can be determined to comprise of all natural, semi-natural and artificial systems of multifunctional ecological systems within, around and between urban areas, at all scales. It can be suggested that in general, green infrastructure in a city refers to all parks, public green spaces, green corridors, street trees, urban forests, farms, native spaces, wetlands, roof gardens, vertical greenings and private gardens. So it can further be suggested that the layout of the green system is as much significant as the amount of the green spaces, because the needed integrity of habitat systems can be obtained if only the green layout is comprehensive, coherent and well organized. In other words, the main aim of a green infrastructure in a city is to achieve a green network connectivity which is capable for the biodiversity of habitat systems. Such connectivity can be achieved by linking different size of green patches together. Hence in an ecologically based city, having an adequate green infrastructure, all built environment as a whole is surrounded by natural, semi natural and/or man-made greenery within a system and without any fragmentations, resulting in biological integrity achieving biodiversity

Energy Use and Waste Management

As cities are places where the highest amount of energy consumptions and CO2 emissions are taking place, it is vital to deal with the issues of reducing energy use and finding alternative renewable sources of energy in cities. Such that, according to UN Department of Economic and Social Affairs report in the year 2007, 'climate change' and 'energy' are core focuses, within the scope of sustainable development.

As a result of the increase in the population of the world, rapid urbanization and changes in the way of life, there has been a huge quantity of waste being generated daily in cities. Cities demand large amounts of water and energy and release large quantities of waste. Usually, the greater the economic wealth and higher the percentage of urban population, larger is the amount of solid waste generated [8].

The solid waste and wastewater generated in cities can be the reason of serious health hazards if not managed with the help of appropriate systems. It may pollute the air, soil and water. Briefly management of the waste generation has become one of the urgent concerns of sustainable urban development. And for ecologically based cities it can be suggested to be a must. Consequently within ecological cities, innovative infrastructure systems are operated in order to reduce, re-use and recycle solid waste and wastewater.

ECOLOGICAL CITIZENSHIP

Ecological citizenship can be proposed to be the new dimension of ecologically responsive cities. According to the international cases, i.e. Freiburg, Bogota and Portland, it is obvious that the role of ecological citizenship is both the reason and result of the sustainability efforts of the cities which can be described as ecologically responsive. It can accordingly be suggested to be the fifth new dimension of the Ecological City. On that ground, further investigation is necessary to understand the dynamics of ecologically responsive living.

If we evaluate the historical background of sovereign political systems, it can be easily recognized that it was the vast majority of ordinary people of the communities coming together and forcing the change. So, if we target to create a new sort of citizenship, as Ref. [9] suggests, we cannot make it possible without shaping the lives of the ordinary individuals. Then urban dwellers coming together and making more and more political bounds day by day will create the politics giving chance to live as ecological citizens in green states.

Otherwise within the democratic states, it can be perilous and even useless to force them with compulsory work of legislations and laws. Because merely focusing on to make a political ground within state-based solutions for defining a new form or a new notion of citizenship can cause us to obtain a weak structure having no strong base of democratic participation and public approval.

This suggestion would not be misunderstood that related laws and legislations are insignificant or redundant. On the contrary, they are one of the main dynamics of the whole process. However, achieving the individuals' contribution and participation and at least making the proposed green political structure familiar and harmonious with the lifestyle change within their daily lives, can make the greening of the states more concrete and strong.

Based on this approach, a concrete behavioural change is eligible in order to achieve communities perceiving and recognizing their individual environmental activities as duties and obligations for the conservation of the universe against global warming and so on. They are just requested to do their bit to protect the universe and to reduce their impact on the environment [10].

Within these circumstances in this research, ecological citizenship can be proposed to be based on daily activities and actions. These activities performed daily, make the difference between the ecological and the traditional citizen. Therefore, what are these activities and actions in and around home as the duties, responsibilities of an ecological citizen? How can we define the ecological practices, activities of a contemporary, modern citizen making him/her an ecological one in an urban environment? What are the characteristics of these activities and actions as duties and obligations?

Although it diverges according to the focus of the researchers, briefly it can be argued that these activities constructing the ecological citizenship can be grouped in six behavioural categories [11].

i. *Energy saving*: keeping heating low to save energy, using double glazed windows for buildings, using energy efficient appliances and whitegoods, reducing hot water temperature, using more clothes instead of more heating, switching lights off in unused rooms, reducing heat in unused rooms, using high efficiency bulbs, using building isolated.

ii. *Water conservation*: using a shower instead of a bath, turning tap off when soaping up, turning tap off when washing dishes, turning tap off when cleaning teeth, using plants that need less water, reducing the number of baths/showers, reducing toilet flushes etc.

iii. *Waste management:* recycling plastic bottles, composting garden waste, recycling cans, recycling glass, recycling newspaper, reusing glass, donating furniture and clothes to charity, reusing paper, reducing battery usage, composting kitchen waste etc.

iv. *Public participation:* involving in environmental decision making process, involving in environmental campaigns, being an environmental activist etc.

v. *Sustainable transportation*: using public transportation instead of car, walking in short distances, carpooling, using bicycle rather than car etc.

vi. *Green consumption:* buying locally produced foods, using own bag for shopping, buying recycled toilet paper, less packaging, buying organic products, avoiding aerosols and toxic detergents, buying recycled writing paper, buying from a local store etc.

RESEARCH CONTEXT

Research Design

A survey was designed in order to measure the environmental worldview and to understand the dimensions of environmental behaviour in three categories among Famagusta residents in N. Cyprus. On that ground, the research framework was closely related to that of Famagusta Area Study (FAS), which was directed by the second author of this paper and aimed to measure the quality of community life in Famagusta based on a comprehensive survey research carried out in 2007. As a study of environmental research, FAS [12] involved several findings which are strongly useful to be evaluated in order to recognize the existing situation of the Famagusta citizens as a case study and to determine the appropriate framework of the research measures.

In this context, the aspects of this research were part of a questionnaire including a set of questions which were answered under four important titles. These titles were as follows: environmental concern; environmental attitudes; environmental behaviour; socio-demographic data.

The Sample

A random sample of 165 residents between 16 and 75 years old within the territory of Famagusta Municipality including all 16 quarters were chosen for the user survey. The number of participants from each of the 16 quarters was decided according to the ratio of the quarter's population to the city's whole population. The respondents were selected randomly in each sample area for filling out a questionnaire form. The details are shown as follows:

Gender: 37.6% of the 165 participants were female and 62.4% were male;

Table 1 Participants' gender profile (%)

Gender	Frequency	Percent (%)
Female	**62**	**37.6**
Male	**103**	**62.4**
Total	**165**	**100**

Age: 30.9% of the participants in the study were between the ages of 26~40. 28.5% were between 16~25 and 24.8% were between 41~55 years old. The rest 9.7% were between 56~65 years old and 6.1% were between 66~75.

Table 2 Participants' age profile (%)

Age	Frequency	Percent (%)
16~25	**47**	**28.5**
26~40	**51**	**30.9**
41~55	**41**	**24.8**
56~65	**16**	**9.7**
66~75	**10**	**6.1**
Total	**165**	**100**

Education: The largest portion (48.5%) among the participants had a high-school degree. 16.4% had a university degree, 13.3% had a secondary school degree, 12.7% had a primary school degree and 7.9% had a master or Ph.D. degree. A non-significant portion of 1.2% was without a degree.

Table 3 Participants' education profile (%)

Education	Frequen-cy	Percent (%)
None	**2**	**1.2**
Primary school degree	**21**	**12.7**
Secondary school degree	**22**	**13.3**
High school degree	**80**	**48.5**
University degree	**27**	**16.4**
Postgraduate degree	**13**	**7.9**
Total	**165**	**100**

Household income: 42.4% of the respondents had a monthly household income of 1,200~2,499 TL (Turkish lira), 28.5% had a monthly household income of 2,500~3,999 TL. 12.7% refused to answer and 8.5% had a monthly household income of 600~1,199 TL.

Table 4 Participants' household financial situation profile (%)

Financial situation	Frequency	Percent (%)
600~1,199 TL	**14**	**8.5**
1,200~2,499 TL	**70**	**42.4**
2,500~3,999 TL	**47**	**28.5**
4,000~5,999 TL	**9**	**5.5**
6,000 TL+	**4**	**2.4**
Refuse to answer	**21**	**12.7**
Total	**165**	**100**

Measures

Environmental worldview: The environmental attitudes were measured with the help of NEP (New Environmental Paradigm) scale including 15 items [13] in the second section of the questionnaire. These NEP scale items were used to measure the ecocentric and anthropocentric attitudes. According to the NEP scale design, one of the statements refers to an ecocentric attitude and the other refers to an anthropocentric attitude. In total, eight items refer to ecocentric attitude and the other seven items refer to anthropocentric attitude. Likert type five point scale (strongly disagree to strongly agree) was used to record the participants' responses for each item.

Environmental behaviour: Environmental behaviours were measured in three categories as energy saving, water conservation and green consumption, with the help of 15 items. Five items were used for each environmental behaviour category in order to understand how often the respondents are experiencing these environmental behaviours in and around home in their daily lives. Five point frequency scale (from never to always) was used to record the participants' responses for each item.

Procedure

After participants were briefly informed about the research, environmental awareness and concern about general environmental issues were measured in the first part of the questionnaire's first section. Awareness and concern about environmental problems of Famagusta in particular, was measured in the second part of the first section. Ecocentric and anthropocentric attitudes were examined in the second section in order to provide data for the existing value orientations. In the third section, environmental behaviours were examined in three categories: energy saving, water conservation and green consumption. In the last section, socio-demographic data was collected in order to obtain information about the issues such as age, gender, education, marital status and housing type of the respondents.

The administration and application of field study was carried out with the help of the survey firm "The Management Centre of the Mediterranean", a fully resourced support centre. The field study was undertaken starting from the second week of April 2013 until the first week of June 2013, in a time period of seven weeks (10th April~03rd June). After the data was collected, the research results were analysed with the help of SPSS (Statistical Package for Social Sciences) and displayed in the following section.

RESULTS

The mean score of the NEP scale was calculated as 3.52, in total. As it is accepted that a NEP mean score of 3 is the boundary between an anthropocentric and ecocentric worldview [14-15], the result showed that the respondents had a medium level of ecological worldview.

When the findings of questionnaire's third section which involves 15 items about environmental behaviours in and around home were evaluated, it can be argued that the highest percentages replied 'always' or 'usually' for each of the first 10 items which were about energy saving and water conservation.

Table 5 Participants' responses to the items about 'energy saving' (%)

Items about 'Energy Saving'	Always	Usually	Sometimes	Rarely	Never
I wait until there is a full load for washing.	**58,8**	**23,0**	**11,5**	**3,6**	**3,0**
I switch lights off in unused rooms.	**70,9**	**24,8**	**1,2**	**1,8**	**1,3**
I wear more clothes instead of heating more.	**26,1**	**29,1**	**21,2**	**14,5**	**9,1**
I use energy efficient white goods at home.	**15,8**	**32,7**	**29,1**	**15,2**	**7,3**
I use high efficiency bulbs at home.	**46,1**	**31,5**	**9,1**	**7,9**	**5,5**

Such that among these items, the highest percentages replied 'usually' only for two items: For the statement 'I use energy efficient white goods at home', %32,7 of the respondents suggested 'usually' and secondly %29,1 suggested 'sometimes'. And for the statement 'I wear more clothes instead of heating more', %29,1 replied 'usually' and %26,1 replied 'always'. For another item 'I reduce the number of baths/showers' %27,3 replied 'always' and another %27,3 replied 'usually'. For the rest of the seven items of these first two behavioural categories, the highest percentages replied 'always'.

Table 6 Participants' responses to the items about 'water conservation' (%)

Items about 'Water Conservation'	Always	Usually	Sometimes	Rarely	Never
I reduce the number of baths/showers.	**27,3**	**27,3**	**16,4**	**9,7**	**19,4**
I turn tap off when cleaning teeth.	**53,9**	**28,5**	**9,1**	**3,6**	**4,8**
I prefer to have shower rather than bath.	**61,2**	**27,9**	**4,2**	**1,2**	**5,5**
I reduce toilet flushes.	**40,6**	**28,5**	**10,3**	**5,5**	**15,2**
I turn tap off when washing the dishes.	**53,9**	**28,5**	**9,1**	**5,5**	**3,0**

However when the responses of the last five items which are about green consumption were evaluated, the results differ. It can be suggested that the highest percentage replied 'always' for merely two items: %44,8 suggested 'always' and %31,5 'usually' for the statement 'I prefer to give my unused clothes'. And %33,3 replied 'always' and % 24,8 'usually' to the item 'I prefer buying locally produced food'. For the rest three items the highest percentages suggested 'rarely' or 'never'. Such that for the item 'I use my own bag while shopping', %48,5 replied 'never' and %32,7 'rarely'. For the item 'I prefer to buy recycled paper and toilet paper', %24,8 replied 'rarely' and %23 'never'. And %28,5 replied 'sometimes' and %23 'rarely' to the item 'I choose to buy less packaged products'.

Table 7 Participants' responses to the items about 'green consumption' (%)

Items about 'Green Consumption'	Always	Usually	Sometimes	Rarely		Never
I prefer to buy recycled paper and toilet paper.	**13,3**	**18,8**	**20,0**	**24,8**		**23,0**
I choose to buy less packaged products.	**7,3**	**18,8**	**28,5**	**23,0**		**22,4**
I use my own bag when shopping.	**2,4**	**3,6**	**12,7**	**32,7**		**48,5**
I prefer to give my unused clothes.	**44,8**	**31,5**	**10,9**	**10,3**		**2,4**
I prefer buying locally produced food	**33,3**	**24,8**	**28,5**	**8,5**		**4,8**

As green consumption items (a behavioural category that needs a high level of environmental awareness) had the least agreement, it can be easily evaluated that the respondents do not achieve an adequate level of environmental awareness. However according to the findings of the NEP scale, they have a medium level of environmental worldview. In other words, they somehow have a potential for the requirements of being ecologically based citizens but they do not achieve a commitment reflecting as a lifestyle with their daily environmental activities and practices.

DISCUSSION AND CONCLUSION

Ecological city is one of the definitions emerged in relation to the sustainable urbanism attempts and in this study the main principles characterizing an 'ecological city' are proposed to be categorized within five dimensions including 'ecological citizenship' as a new dimension after 'sustainable urban form', 'sustainable transportation', 'urban ecology and biodiversity', and 'energy use and waste management'.

As the dimensions of the ecological city for Famagusta city seems to be a crucial need, ecological citizenship is evaluated for the theoretical background of the study. It is proposed that, there are activities and actions in and around home as the duties of an ecological citizen. And these activities and actions define the ecological practices of a contemporary citizen making him/her an ecological one in an urban environment. These activities constructing the ecological citizenship are grouped in six behavioural categories: 'energy saving', 'water conservation', 'waste management', 'sustainable transportation', 'green consumption', 'public participation.

Within this framework, a survey study has been carried out in the city of Famagusta. Within this study two main measures are evaluated: environmental worldview and environmental behaviour in three categories. On the basis of the findings, it can be suggested that Famagusta residents have a potential to be ecological citizens without having a concrete commitment of environmentally based living. Such that even though there is the lack of social, economic and environmental dynamics of sustainability, they somehow intend to live ecologically based (mean sore of NEP: 3,52). Further, when we evaluate the findings about the green consumption items -as a behavioural category that needs a high level of environmental awareness and concern- it is obvious that the respondents do not achieve a strong commitment.

As concluding remarks, the findings imply that there are disparate components and dimensions in relation to ecologically based living. Therefore further investigation is essential about these dynamics of the environmentally based living both in Famagusta and in other cities. This scientific base would be eligible to be used as a guide for making the ecological type of citizenship as it is the traditional one.

REFERENCES

[1] Dempsey, N., Brown, C., Raman, S., Porta, S., Jenks, M., Jones, C. & Bramley, G. (2010). Elements of urban form. In: Jenks, M., & Jones C. eds. Dimensions of the Sustainable City 2, Netherlands: Springer, 21-51.

[2] Oktay, D. (2001). Planning Housing Environments for Sustainability: Evaluations in Cypriot Settlements, Yapı Endüstri Merkezi Yayınları, ISBN: 975-8599-12-7, Istanbul.

[3] Dean, J., van Dooren, K., & Weinstein, P. (2011). Does biodiversity improve mental health in urban settings? Medical Hypotheses, 76, 877-880.

[4] Kim, J., & Kaplan, R. (2004). Physical and psychological factors in sense of community. New Urbanist Kentlands and Nearby Orchard Village, Environmental Behaviour, 36, 313-340.

[5] De Vries, S., Verheij, R. A., Groenewegen, P. P., & Spreeuwenberg, P. (2003). Natural environments-healthy environments? Environmental Planning, 35, 1717-1731.

[6] Takano, T., Nakamura, K., & Watanabe, M. (2002). Urban residential environments and senior citizens' longevity in mega-city areas: the importance of walkable green space, J. Epidemiol, Community Health, 56 (12), 913-916.

[7] Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kazmierczak, A., Niemela, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review, Landscape and Urban Planning, 81, 167178.

[8] Hassan, M. N. (2000). Policies to improve solid waste management in developing countries: some insights in Southeast Asian Countries, In: Chang EE, Chiang PC, Huang CP, Vasuki NC, editors. Proceedings of the 2nd international conference on solid waste management, 191-207.

[9] Dobson, A. (2007). Environmental citizenship: Towards sustainable development, Sustainable Development, 15, 276-285, Wiley InterScience.

[10] Melo-Escrihuela, C. (2008). Promoting ecological citizenship: Rights, duties and political agency, collection at ACME Editorial Collective, UK.

[11] Asilsoy B., & Oktay D. (2016). Environmental Attitudes as Predictors of Ecological Citizenship: Findings from a Survey in Famagusta, North Cyprus, Open House International (Special Issue on Transformations of Architecture and Urbanism of Cities in the Global South, Eds: A. Salama & D. Grierson), Volume 41, Issue 2 (accepted for publication).

[12] Oktay, D. (2010). Gazimağusa'da Yaşam Kalitesi: Araştırma, Planlama ve Yönetim için Göstergeler. EMU Press, Famagusta.

[13] Dunlap, R. E., Van Liere, K., Mertig, A., & Jones, R. E. (2000). Measuring endorsement of the New Ecological Paradigm: A revised NEP scale, Journal of Social Issues, 56, 425-442.

[14] Rideout, B. E., Hushen, K., McGinty, D., Perkins, S., & Tate, J. (2005). Endorsement of the environmental paradigm in systematic and e-mail samples of college students, Journal of Environmental Education, 36 (2), 15-23.

[15] Van Petegam, P., & Blieck, A. (2006). The environmental worldview of children: A cross-cultural perspective. Environmental Education Research, 12, 625-635.

Paper No: 10

Keys for Eco-friendly Architecture

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ABSTRACT

Following the industrialization period, the environment in cities which have developed, has devastated and in order to draw the line for this devastation, an approach of sustainability is put forward. When it is considered that approximately half of the energy consumption in the world arises from buildings, significance of sustainability approach in architecture is comprehended once again.

With the sustainability approach in architecture, it is possible to build structures with zero consumption of energy or even able to generate and store its own energy. Usage of sustainable energy resources and designing structures those do not harm the environment have become a necessity for maintaining the natural environment in today's conditions.

In this paper and within this context, examples of design which can be regarded as eco credential, environmentally sound or in other words; eco-friendly are reviewed and answers to questions such as "what is eco-friendly architecture?", "how to achieve eco-friendly architectural design" are sought through these examples. Answers achieved by analysis of examples of literature, have the characteristics of a guide for works to be performed on the subject of eco-friendly architecture and include easily applicable solutions.

Keywords: Architecture, Eco-friendly design, Sustainability.

INTRODUCTION

With the first oil crisis first escalated in 1970's, the issues regarding energy utilization in buildings were taken into consideration. The human - nature relationship and the consequences of this relationship is being discussed up to this day. "The issue of global warming as a result of the damages inflicted by the human race to the nature and the issue of sustainability taken into agenda following up the political process regarding the global warming have become a field of interest in building design, thus became a project criteria in Europe, United States and currently increasingly in Asia" [2].

As relevant studies are reviewed, although the practices are similar, some differences in definitions are seen. The terminology is constantly changing and new popular classifications are being produced. The "environmental design" in 1970's, "green design" in the 1980's, late 1980's and 1990's "ecological design" and from 1990's up to today the "sustainable design" concepts can be considered as examples. In 1970's several studies were conducted in order to achieve a high standard and comfort in architecture, in 80's the green thinking and recycling have become increasingly significant. Furthermore, from the mid 1980's, an eco-centric approach is developed that takes nature as an inspiration, encourages to use passive energy systems, considers the humans as a part of the ecosystem and the building as a healthy and a biological organism [5]. In 1990's a total "eco-conscious" practices aimed to "form a balanced bond with nature" can be recognized. Based on this approach the first criterion in building design is to adopt an 'eco-centric' attitude regarding the design approach. Constructing a building based

on these criteria require an eco-friendly design approach from the conceptualization phase.
Although the regulations are slow to react to recognize these criteria and adopt them as rules to impose on the community, ongoing positive practices are worth mentioning. Recently designing the buildings based on sustainability criteria and certification via accreditation systems such as LEED (Leadership in Energy and Environmental Design) are trending. However the issue here is not only abiding certain accreditation systems but to develop an eco-friendly design approach. For this, the eco-friendly environmental design criteria should be reviewed. In this context, this article will provide "eco-friendly architecture" criteria that are commonly seen in literature and examples of buildings designed based on the said criteria. Eco-friendly design criteria elaborated through the provided examples are believed to encourage the architects, applicators and architecture pupils to design quality, environmental friendly buildings.

ECO-FRIENDLY DESIGN

"Design is created with a holistic structure formed of a series of facts" [9]. The most prominent issue regarding the human - nature relationship challenging the designers is to design a built environment that will not damage and be in harmony with the natural environment. With this in mind, eco-design requires the consideration of both architecture and the built environment.
Eco-design is a multi-disciplined practice. In short, it is defined as designing the built environment in aligns with the ecological design principles and strategies to bond built and natural environment in perfect harmony. For an eco-friendly architectural design, efficient utilization of energy sources, providing the right to live to all organisms and taking responsibilities regarding the environmental sustainability are required.
Today there are many misconceptions regarding the definition of eco-design. Many designers think that by installing solar panels, wind turbines and building automation systems an eco-friendly building can be designed. This is a wrong perspective. Architect Ken Yeang defines this approach as "eco-device architecture" and criticizes this approach [9]. Based on Yeang the primary goal of eco-friendly design should be adapting to nature, instead of adopting an approach based on efficiency similar to engineering designs.
The foundation of eco-design is ecosystem. The concept of ecosystem is used in 1935 by British botanist Arthur George Tansley and defined by Eugene P. Odum as a "stable system that is formed by the organic and inorganic substances in nature interacting with each other in nature" [9]. The eco-friendly design can be summarized as a design based on the ecosystem example, i.e. eco-copy. The adopted approach at this point shall be to elaborate the design criteria underlying the theoretical infrastructure of eco-design.
The first step is to determine the priorities and deciding on designing based on these priorities. At this stage the conceptual works should include determination of spatial requirements and the life cycle of the designed system and minimizing the footprint of the building. The main goal here is to decide on the characteristics of the system and its harmony with the environment. In order to make this decision, the designer should contemplate on the project draft, ecological aspect of the project and costs. In later stages a strategy regarding whether the design to be permanent, land specific and stable or temporary. The design in question whether to be a product or a structure shall be clarified. Furthermore, deciding on the building's level of interaction with the environment is important. The designer shall contemplate on unification with the environment physically, systematically and temporally and if required, limit certain applications that will not be practical in reaching the goal. Locating a land suitable for the designed building and investigating the ecological history of the land are other subjects that should not be overlooked [9].
Another criterion to be considered is to make planning decisions to improve the current ecosystem of the design area. For this, the topography of the land in question should be reviewed, land should be mapped, and the climate, topography, vegetation and the living environment should be evaluated [9]. Therefore the characteristics

of the designed system are ensured to operate in harmony with the field's ecosystem. The end products would be less mechanic and inorganic.

One can say that: the design will undoubtedly affect the environment. It is important to minimize the effects of the urban micro climate effects and not generating light and noise pollution in the ecosystem. This consideration should not be overlooked when handling issues such as transportation and access to the built environment. Furthermore the design should comply with the large scale planning criteria in long term and should be integrated with the urban infrastructure. In a smaller scale the interior comfort should be emphasized, certain designs should be adopted to enhance the interior conditions.

The most significant factor affecting the building design is the land climate. Passive methods should be prioritized when designing, passive systems with renewable energy sources should be preferred when deciding on building form, plan schematics, land utilization. Planning and designing should be in line with the climate to provide energy efficiency by reducing energy usage. And it must be environment friendly with less co2 emission.

In this context, traditional buildings are good examples of energy saving and using passive systems in architecture [8]. Therefore these examples must be analysed about eco-friendly architecture concept for designing contemporary and sustainable new built environments.

When looked at traditional architecture examples, today's known sustainable design criteria can be seen at mostly housing examples [4]. Examples of traditional architecture, which are the rules of ecology, are situated in the most appropriate solution which is the nature principle in light of members of the public's life experiences and over the years the concept of master-apprentice with trial / lapse method have been created as examples of ecological buildings [6]. Local sources are usually being preferred to form the characteristic texture of this type of settlements. For example in the Eastern Black Sea Region in Turkey, "this characteristic texture that have been completely formed with local sources including from construction material to labour force takes on a value, significant in terms of ecology" [1].

In this context, issues such as recycling and waste management should also be taken into consideration. Materials, furniture, fixture and product choices should be based on their ability to be recycled. The basic principle of reusing, recycling and recovery is utilizing "dismountable design components".

Another criterion to comply is to spread the permaculture and encourage food production [9]. The criteria regarding recovery and recycling above are not solely adopted by Yeang. The concept of "cradle to cradle" defined in literature and studied by architect William Mcdonough is still significant in today's world [10].

As much as the application of these criteria, the outcomes should be evaluated. The designer should adopt a holistic approach when applying these criteria, instead of a partial adoption and is should be noted that these evaluations will provide important outcomes for future designs. On the other hand the specified concepts above should be taken into consideration and applied prior to designing.

However when a building is reviewed, it is not possible to see the tangible reflections of these criteria. The features that are tangible and distinguishable with naked eye are the location of the building based on land data, climate-conscious outer shell and roof design, the utilization of vegetation and material choices. In this article, the "eco-friendly architecture" approach of some of the designers with a few examples and the theoretical knowledge is supported with tangible examples.

CASE SAMPLES

Environmentally sustainable, eco-friendly, bioclimatic and efficient houses are primarily aimed to be in harmony with the environment. In this context **"villa langbo"** in Finland can be elaborated as an example. It is known that the mentioned house on the edge of the forest is designed to minimally affect the ecosystem [3]. The house can be accessed via marine vehicles through the sea in the summer and via skis or on horseback in winter. By resolving the issue of transportation naturally, the nature is not affected by artificial means and thus not harmed. The same approach is adopted for material selection and building method. The building is constructed manually; heavy machinery was not utilized. All materials used for the building are locally gathered wood and recyclable materials.

The building is erected on the ground without damaging the soil. The roof and overhang width are designed with sun and the rain in mind. The building components are designed especially to be dismounted in order to facilitate the indoor-outdoor interaction.

Figure 1 "Villa Langbo" general view [3]

Another example may be Spain's **"wood and steel house"**. The house connecting the ground solely on four locations consist a prefabricated carriage system. Traditional construction method and local wood materials are utilized for the building. All the materials used are recyclable. The orientation of the sun is taken as a basis for locating the building and glass is preferred on the southern façade. The building includes bioclimatic features and passive methods are preferred for heating, cooling and ventilation instead of mechanic systems [3].

Figure 2 "wood and steel house" construction process [3]

Another functional construction except residential areas may be the Sportplaza Mercator designed and constructed with the request of the Amsterdam municipality. The building designed claiming to be eco-friendly consists many features such as a swimming pool, fitness and gym and saunas. The building is fully integrated with the park that it is located due to its green roof and became a part of the landscape [2].

Figure 3 Sportplaza Mercator, interaction with the landscape [2]

Another example from Amsterdam shows that eco-friendly design criteria are applied not only for small scale buildings but greater buildings with hybrid functionality. **De Zuidkas,** emphasized by its environmental goals is a building consisting many diverse functions such as residential areas, office, restaurant and park. Features such as reduced CO2 emission, saving energy, providing human health and comfort are prioritized.

The primary goal with the design is to create an intelligent and a self-sufficient building. The most important ecological feature of the building is to consist a glazed facade to project the outdoor conditions in the building without compromising the indoor comfort. This interface includes green houses, CO greenhouses hybrid green houses and an atrium. This interface area ensures air conditioning and prevents heat loss in winter, keeps the interior cool in the summer. Furthermore natural ventilation is ensured in the building due to this flexible glass system

“Besides vegetable waste and biomass from the greenhouse, the building also collects black water and leads it to the co-fermentation plant, where all biomass is converted into biogas. This gas serves as a sustainable fuel for the chp power installation. The heat that is released in this process used to heat tap water as well as the various building areas. Besides generating heat, the chp power installation produces high quality energy in the form of electricity” [2].

Figure 4 De Zuidkas [2]

The other example is Japan's **House C**. House C, similar to Sportplaza Mercator in Amsterdam, is a building that stands out by utilization of materials that is designed to be integrated with the natural environment. The main idea behind the building is to design an indoor area as an extension of the garden. The soil on which the building is constructed, is a characteristic and homogeneous soil seen in the area. The soil is being utilized for production of tools such as pottery for hundreds of years, thus the soil stands out as the substance that feeds the bio system and the culture of the region.

The architect primarily aimed to integrate the building with the soil and by covering the building with the soil, created a living, breathing system. First the location of the building and the openings are located in order to allow the air flow coming from the sea goes through the building and natural ventilation criterion is met. For building insulation, the roof insulation is established by covering the roof with local soil and growing vegetation. Thus the costs regarding an additional insulation coating for the roof are avoided. The soil is mixed with seaweed and resin and the walls are coated with this blend. Covering the building with soil is done with the home owners themselves and thus got involved in the design and production process. As seasons pass by and even with the wind, the design process is being regenerated, the seeds reaching the roof of the house, the inclusion of new organisms the design and natural evolution of the house is ever changing [7].

Figure 5 House C elevation and section [7]

Figure 6 House C walls and roof [7]

CONCLUSION

As seen above, with the recognition of ecological approach in architecture, example practices regarding the concept are applied at an increased rate. Further examples may be provided, however within the context of this article; to reach a conclusion with the examples and theoretical knowledge provided: As defined by Ken Yeang who identifies himself as **"**I am an ecologist first, and architect second", the "eco-friendly design" issue requires integration and harmony with the natural environment.

As seen in the examples shown, the criteria prioritized in application may vary and all criteria is not reflected on the final products. Furthermore, application of the criteria as a whole on the design may not be required. As specified in the beginning, providing solutions as required, i.e., in align with the eco-friendly concept is important. The goal of this article is to emphasize that the eco-friendly design approach is prominently an environmental issue, by referring architects such as Yeang and Mcdonough. For this reason, this issue should be considered with the precision of an ecolog and with interdisciplinary works. The primary goal in eco-friendly design is not to enhance efficiency but to be in harmony with the environment, for this reason it is important to be in an environment friendly mind set from the outset.

REFERENCES

[1] Aydın, Ö and Lakot Alemdağ, E. (2014). Sustaınable Materıals In Black Sea Vernacular Archıtecture; Wood And Stone, *The Journal of International Social Research 7* (35).

[2] Broto, C. *Eco Friendly Architecture*. (Barcelona: Links, 2011).

[3] Costa , S., Paredes, C., Farras Perez, L. *Visual Tips for Eco Living. A Practical and Inspirational Guide*. (Barselona: Booq Publishing, 2014).

[4] Çetin, S.(2010). Geleneksel konut mimarisin ekolojik yansımaları: Burdur örneği, 5. Ulusal Çatı & Cephe Sempozyumu 15-16 Nisan 2010.

[5] Durmuş Arslan, Zeynep. "Türkiye'de Sürdürülebilir Mimari". *Mimarlık 340* (2008).

[6] Keskin, K. and Erbay, M. (2016). *Learnings to Sustainable Architecture from the Anatolia Traditional Houses*, http://www.ierek.com/wp-content/uploads/2015/08/the-last-word-.pdf

[7] Krauel, J. *Sustainable Houses*. (Barcelona: Links, 2014).

[8] Radhakrishnan, S., Shanthi Priya Assi , R. (2014).Eco Friendly materials used in traditional buildings of Chettinadu in Tamil Nadu, India, *American Journal of Sustainable Cities and Society 3* (1), 336-344.

[9] Yeang, K. *Ekotasarım, Ekolojik Tasarım Rehberi*. (İstanbul: Yem Yayınları, 2006).

[10] Westerlo, V. D. B., Halman, J. I., & Durmisevic, E. Translate the cradle to cradle principles for a building. CIB (2012).

Paper No: 12

A Methodology for an Active and Sustainable Earthen Construction Sector

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ABSTRACT

From ancient times to the middle of the past century, earthen construction was one of the leading construction methods. However, earthen material has become uncompetitive within the last two centuries as a result of industrialized building sector. Although the new industrial products were supported with the standardization institutes, due to failing researches a proper standardization method of earthen materials could not be developed. On the other hand earthen was called as a primitive material, which should be replaced with modern materials. As a result, the traditional skilled workmanship has almost disappeared. However, only after the world wars at the beginning of the 20th Century earthen constructions begun to be subject of researches. The human and nature oriented ecological aspects of 21th century make it necessary to develop or support the environmentally friendly sectors. Earthen constructions and contemporary earthen products comply not only with the environment but also with human and construction biology based needs. Therefore a down-to-earth and sustainable earthen construction sector is necessary. For this purpose this paper focuses on a methodology, which can be applicable for countries, where despite a longstanding earthen culture, an active and sustainable earthen construction sector does not exist.

INTRODUCTION

The discovery that soil can easily be formed and that it can serve as an effective building material responding to the requirements of habitability led to the development of mankind's oldest building culture. While we often talk about the environmental problems caused by very energy-intensive sectors, earthen architecture needs to be as stronger as it has been in the past. At present, there are a few countries, where environmentally friendly architecture is getting more and more popular. This popularity is due to a recently growing construction sector, which offers contemporary earthen products and completion methods to the planners and costumers. Earthen construction culture is a global value. We are responsible for making sure that many other local earthen construction sectors can sustainably occur and be competitive with other types of building products and methods. For that reason the aim of this paper is to present a roadmap for the initiatives with the above stated responsibility. The paper is structured into four parts. First, the general main problem is defined. Second, both the historic and the current situation of earthen architecture are analyzed. Based on the results of this analysis, the methodology for this paper is developed. As such, the expected result is a detailed method, which can be applied for establishing an active and sustainable earthen construction sector in different countries.

1. PROBLEM STATEMENT

Earthen buildings are not permitted in several countries. Although in some countries standards or guidelines on earthen buildings can be found (*see 3.3 Standards, Guidelines*), the building an earthen house without any problems is still not possible.

Even a country like Mali, world-renowned for its earth-built cities, does not allow the construction of modern earth buildings. This is a significant problem facing potentially billions of people across the globe [1]. For instance in Turkey, where the earthen building tradition dates back to 8000 BC, some important Standards (such as TS-2514 Adobe Blocks and Production Methods and TS-2515 Adobe Buildings and Construction Methods [2]) have unfortunately been withdrawn.

Moreover, there are still a limited number of educated people in general and both the legal infrastructure (standards, regulations, and educational programs) and a compatible earthen building sector are the main lack. As today's building material producers are restricted by standards and as the earthen construction regulations are insufficient, building permissions cannot be obtained for the planned projects. Therefore, buildings made of earth cannot be sustainable and secured. Inexperienced people in rural areas tend to erect houses, which are do not comply to basic principles earthen construction. The more our society sees insufficiently erected, poor quality earthen houses; the lower will be the interest in using this thousand of year's old material.

2. UNDERSTANDING THE HISTORY

Ancient civilizations all around the world used earth by many building types as a main construction material. From Sumerians, Babylonians, Assyria, Hittites to the Persian, Greeks and Romans the earth always dominated the character of the ancient cities.

The Egyptians constructed the pyramids and palaces with earth: In the Tel el-Amarna center, built in the new Kingdom (1552-1070 BC), we find the homes of artisans and nobles, palaces and temples, all built in sun-baked bricks [3]. Medean centers of religion and administration were girt with thick, sharply intended unbaked brick [3]. The Persian style of architecture reached its peak with the mastery of the techniques for building vaults and domes [3].

The Hittites, which were settled in today's Turkey, erected wide and high earthen walls surrounding their cities (see reconstruction of Hattusa city walls in Figure 01). As Vitruvius observed, the Greeks built temples and chapels made of earth. The Ottoman's two-storey *Safranbolu houses* (timber frame construction filled with adobe and plastered with clay) in Anatolia and the *ksar*, a group of earthen buildings surrounded by high walls [4] in southern Morocco are the well-known UNESCO world heritages.

Clearly, in history, earth was not only used by poor people, but was a prominent material for military and other public buildings due to its availability and easy workability. This made earth an admired material across human history. In addition, the earthen architecture has a reasonable diversity all around the world, which is based on its vernacular character. Every culture formed its own specific earthen architecture, indicating both geographical and climatic factors. For that reason it is a necessity to look back to the history of the region, of which's earthen architecture is subject matter.

Figure 01 Reconstruction of Hattusa City walls, erected by Hittites (in Turkey) [5]

2.1 Summary of historic basis

The use of earth showed a significant improvement in the ancient period. We understand from diverse sources that different types of additives were used in order to improve physical properties of earth against water. The variety of additives such as, straw, animal hair, lime, puzzolan or ground burned bricks or bitumen, which were used in different regions shows that using of earth was already innovative for that age. For instance using bitumen for increasing the water resistance of adobe bricks was already known from Babylonians in 5th Century BC [6]. These developments could take place, because earth was a favored and legal material in those civilizations. The experiments and knowledge concerning building with earth were passed through the recognized social structures from generations to generations. This deep know-how and experiments allowed earth to be used for erection of huge and complex structures with arches, vaults, domes and high walls. In this context, it is necessary to summarize the approach of all these civilizations to earth:

- Earth was used in various building types and it was one of the major construction activities.
- Experienced and skillful architects were working for states and a skilled workmanship existed continuously in communities.
- Constructing military and religious buildings made necessary to develop stable structures made of earth.
- Many experiments to improve the properties of the material were conducted: For instance, Egyptians and Persians used lime as a stabilizer; the Romans discovered that tuff and lime can serve as a stabilizer, and Ottomans used pulverized ceramics and bricks as additives.
- Physical protection solutions developed both for outer and inner surfaces: For this, plant and animal oils were used in outer surfaces. *Stucco* was developed as a significant technique as art and protection of facades. *Tadelact* (a two-thousand years old story in Morocco), earth colors or different mixtures (For instance: asbestos, fine straw, water mixture) were used for interior surfaces.
- Variety of construction types based on local conditions: rammed earth was used in less earthquake-risk regions (North Africa, southwest Europe). Masonry adobe structures with horizontal (wooden) ring anchors were used in areas with high earthquake-risk (Anatolia, Asia). Earthen domes, arches (Iran, Khorassan). Wooden structures with earth as filling material in rainy regions (north-west Europe, North-Anatolia etc.).

3. OVERVIEW OF TODAY'S APPROACH

Since the world was threaten by long wars causing an incomparable destroy of cities with the power of modern weapons and since the immigration balance between rural and urban areas were damaged due to enormous need for man power in highly mechanized production, the solutions are being discussed for buildings offering healthy life conditions. People let down the vernacular architecture, sustainability and eco-friendliness as main targets for our habitat. 'The truth of material', that has been forgotten within the last two centuries is being discussed more often.

Millions of people still suffer from hastily and in terms of health and comfort insufficiently erected houses. The problem based on unhealthy conditions lie not only on industrial materials and new way of constructing but also failing or insufficient experiences about using these materials. So while experiments and experiences about modern products and construction methods were still at the beginning, the traditional knowledge concerning the use of common materials began to disappear.

Earthen buildings, the legacy of that old culture that knew how to perfectly match materials, climate and functional requirements, translating them into "appropriate" building techniques and accurate architectural and typological choices, now find a reason for redemption in this sense as well (Bollini 2008) [7]. Over the last thirty years, most of the dimensions of earthen building have been explored (technology, performance, cultural and social), and the results have filled hundreds of pages, videos and now, even, Internet websites (Bollini 2008) [7]. Contemporary earthen building projects with ecology related mottos have become more popular in architectural magazines. But the number of these projects is still insufficient in compare to those project planned with highly industrial materials.

3.1 Education & Congress:

Since the adoption of Agenda 21 at the Conference on Environment and Development in Rio de Janeiro sustainability has become a central concept of international environmental policy [8]. Following to this many conferences and meetings have been arranged in order to discuss the subject in a global scale. Hereby ICOMOS-ISCEAH (International Scientific Committee for Earthen Architectural Heritage) played a central role to build a global network through a number of conferences, which brought the scientists, researchers and interested people together. ICOMOS is an NGO of professionals working on heritage and CIAV consists of members with established expertise in the field of Vernacular Architecture [9].

On the other hand, a number of institutions (such as CRATerre from Grenoble, ICCROM from Rome, DACHVERBAND LEHM from Weimar, Green Lines Institute from Barcelos, Getty Conservation Institute from Los Angelos, etc.) and PROTERRA (Iberian-American Network on Earthen Architecture and Construction) with its experts and institutions from Iberian-American countries have significantly contributed to re-strengthen the earthen culture both in a local and a global scale.

There has been a significant exchange of knowledge at international conferences or programs, such as VerSus: Lessons from Vernacular Heritage to Sustainable Architecture within the frame of European project (ICOMOS-CIAV congress) and World Heritage Earthen Architecture Programme (The UNESCO-WHEAP program). This has led to many other national symposiums, panels and research projects.

3.2 Today's Earthen Market

The earthen construction market has to be understood both as design and planning services and as products currently available on the market for constructional use. Therefore, these two points are discussed separately in the following:

3.2.1 Earthen Architecture and Expertise

Contemporary earthen architecture has begun with understanding of the earthen heritage of our world. Engaged architects or planners summarized their experiences on earth in several books. In the last few years these experienced architects organized many workshops under different themes and brought the interested students, potential investors and eco-friendly people together. Especially, the well-preserved earthen heritage of North Africa (Morocco, Lebanon), Iran, Peru, etc. became a model for contemporary planning approaches. There are already ecological planning offices offering the design, renovation or restoration services of earthen buildings. In India many masonry buildings have been constructed with new types of adobe (variety of form, stabilized blocks) manufactured through mechanized methods. Between different methods, the rammed earth is one of the most popular construction type applied by many projects, due to its uncomplicated way of completion and good experiences on using modern molds, commonly used by concrete sector. In America and Australia a number of cement stabilized rammed earth houses have existed, reflecting a high contemporary character. In Turkey, Gypsum and lime stabilized earth *(Alker)* houses have been erected. It is important to underline that the seminars for sharing the experiments and new applications particularly in the western countries increased the quality of available literature about earthen architecture. Although insufficient on its own, every kind of individual initiative plays an important role by reducing the lack of skilled workmanship.

3.2.2 Earthen Products

Due to increasing tendency on green buildings and environmentally friendly products, a contemporary earthen building sector has grown within the last few decades. The aim of this sector is to replace the primitive completion methods with the modern production and application techniques. The contemporary earthen building sector allows for realizing projects efficiently both in terms of time and budget. Prefabrication minimizes the mistakes and applies the material expertise to the entire production process. Especially in Germany the earthen panels and boards became an important part of dry wall constructions. These board and panels can be provided in various sizes and thicknesses. However currently there is no standard for these products. Earth blocks can be found in different formats. In Germany, earth blocks are produced in standardized dimensions as given in DIN 4172 "Modular Co-ordination in Building Construction" and DIN 18945 [10]. Clay plasters are also available in standard packages on the market both as undercoat and finish coat, offering different surface pattern and appearances. A significant reference for clay plaster culture is Japan. *Sakan* is the name given the crafter in Japan who descends from the tradition which uses the earth for his material and a trowel for his tool [11]. Traditional *sakan* skills continue to be used to maintain temples, castles, tea houses (see Figure 03) and farmhouses should their owners [...] maintain the original structure [11].

Figure 03 A Japanese tea-house with clay walls at RWTH-Aachen [Credits: Author]

Furthermore, prefabricated rammed earth elements, wall heating and cooling elements and in accordance with special needs of earthen building restorations further earthen products, such as hollow earth blocks or inserted panels, are offered from different producers.

3.3 Standards, Guidelines

Thousands of years ago Vitruvius described the kinds of clay suitable for sun-dried bricks. He mentioned the optimal seasons for sun-dried brick productions and explained fundamental reasons of that. He also described the kinds of bricks. This information in Vitruvius's *The Ten Books on Architecture* can be seen today as guidelines. In global terms construction is very much controlled by regulation, and regulation in turn has become the guardian of industrial products and process [1]. In Countries like Germany, France, New Zealand, Peru, Australia, earth construction is strongly regulated and supported by appropriate policies and actions [12].
The oldest preserved written building standards for earthen buildings in Germany and Austria is to find from 1760 on the issue of royal forest agencies "forest regulations". These are mostly short excerpts from provisions, which were published since the beginning of 18th-century for fireproof buildings after the ban to build in wood [13]. National DIN standards for earth blocks and earth mortars (DIN 18945, 18946 and 18947) were introduced in Germany in 2013. These national standards follow the general and basic requirements for the formulation of European regulations for building products defined in the European Regulation No. 305/2011 concerning harmonized conditions for the marketing of construction products in the EU (Construction Products Directive CPD) [10].
In the USA, the current edition of earthen building standards E2392/E2392M were approved in 2010 and called as "Standard Guide for Design of Earthen Wall Building System" [14]. The ASTM used New Zealand Standards as reference. In New Zealand, Engineering Design of Earth Buildings (NZS 4297:1998), Materials and Workmanship for Earth Buildings (NZS 4298:1998) and NZS 4299:1998 are the current standards. In India Specification for Soil-Cement Blocks (IST 715) is published by Indian Standards Institute. Standards Australia published "Australian Earth Building Handbook (HB 195-2002)" as unofficial guidelines.
Also for instance in Italy, where the regulations seem to be not sufficient, researchers begun to define new guidelines for rammed earth restoration (Terra Battuta: Technica construttiva e recupero. Linee guida per le procedure d'intervento).

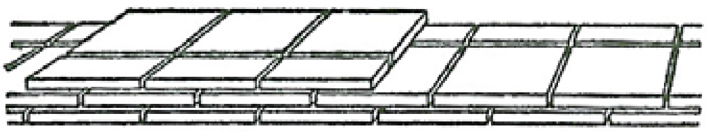

Figure 04 Vitruvius' brick bond according to Reber [15]

4. METHODOLOGY

A method how to establish or strengthen the earthen construction activity and how to repair the mistakes which damaged this ancient culture and its image is developed in the light of the overviewing the past and today.

4.1 Understanding the use of earthen as a construction material

The modern research techniques made it possible to understand the physical properties of the construction materials. The practical experiments and knowledge related the use of common materials can today be scientifically clarified. Standardization of every kind of materials on the market is one of the results of this development.
Clarification of the physical and chemical nature of materials brought along the question "how does a material affect the environment in which we live?". Therefore the expectations related to properties of the building

materials are focused not only on their chemical impacts (to be non-poisoning, non-radioactive, non-cancerogen, etc.) but also on the embodied energy by their production. These both aspects mirror in a macro-scale how environmentally friendly the chosen materials are or how they affect the environmental biology. In a micro-scale every kind of building material plays an important role on the quality of the artificial environment in which we dwell. In other words they determine the performance of the building biology.
In accordance to this the earthen materials or constructions came in to prominence. Numerous researches, done within the last half-century have proven the importance of earthen as a building material. The high is the embodied energy of a material; the worse is its environmental impact due to a higher CO_2-Emission. For instance the primary energy content (PEC) of adobe is distinctively low. Following table shows a comparison of different building materials in terms of PEC.

Table 01 Primary energy content of building materials [6]

Building material	PEC (kWh/t)	PEC (kWh/m³)
Adobe	3-6	5-10
Rammed earth	20	44
Earthen plaster (industrially prod.)	139	236
Hochlochziegel, porous	722	541
Solid brick	750	1350
precast concrete		800
Reinforcement steel	3.611	28.166
Aluminum plate	72.500	195.000
OSB-Plate	2.058	1-276

Moreover, in terms of a building biology the earthen constructions provide significant advantages. For instance, earthen can shield the high-frequency electromagnetic radiations of the mobile phones, cordless phones, UMTS and GPS network. Especially allergy sufferers can profit the climate in the earthen buildings, because earthen works as de-polluting and antistatic so don't energize the smallest dust-particles. Furthermore this building material caters for balanced air moisture of 50 to 60 Percent [16].
Together with this, the socio-economic aspects are also to take into account. For almost two hundred years ago Cointereaux [17] mentioned that by using earthen we can show how easily or successfully we can replace stone or brick with earthen if they are rarely or expensive. Also Çelebi [18] pointed out "U-Value", "economic viability" and "availability" as important factors for the solution of housing problems by preferring adobe.

4.2 Supplying a public infrastructure

The standards, regulations and other legal infrastructural arrangements should be updated or newly arranged referring the current diversity of applications on the world, but in respect to ecological aspects and sustainability policies. Establishing a strong governmental infrastructure is the base of a sustainable earthen construction sector. Today, without standards and regulations none of construction activities is legal. On the other hand past experiences have shown us that, institutions or chambers specialized on earth can be more effective and successfully support the government in supplying the information and methods required for constructing the legal and governmental infrastructure. For instance, Dachverband Lehm in Germany worked on updating the German Earthen Construction Standards in 2013 (See above 3.3 Standards and Guidelines) and published a guideline book (Lehmbau Regeln). It is also a platform where its members (architects, manufacturers and experts) can meet or simply communicate on any kind of exchange.

4.1.1 Updating the Standards

Building and material standards are being used as an efficient marketing strategy. Today's production and marketing is strongly connected with the local standards and guidelines. On the other hand, the standardization can be done after numerous tests and/or analyses. Passing these tests is a proof of quality and suitability. However, there is also a need on standards, which should precisely describe these tests. At present very few countries have developed standards for analyses and tests specifically suited to soil [3]. A research and working commission with experts or preferentially – a specialized institution or chamber can easily summarize currently existing standards in order to arrange new country-specific standards both for material testing and/or analyzing and construction. Furthermore, every country-specific standard should strongly take the vernacular and local data in to account.

4.1.2 New Regulations

Except from updated or newly formulated standards, new regulations should be arranged. Earthen building regulations will facilitate building and construction permissions for planned earthen building projects. Through the legal regulations, every kind of earthen construction or planning activities will be secured. Moreover the regulations should take the site-specific data (climate region, earthquake zones, geological structure, etc.) in to account, which are decisive by determination of the earthen construction type.

4.2 Educational infrastructure

The governments have to follow concrete policies focused on educating and supporting new generations. Understanding the importance of a better arranged environment and continuing to prefer the use of ecological materials can be achieved through education.

Education is most efficient tool to strengthen the awareness about environmentally-friendly life and culture. Since the French architect François Cointeraux's book Pisé (1803), in which he summarized the rammed earth techniques, a number of academic and practice oriented publications have been occurred. However, the global awareness on this literature is very limited. A global data-network can provide access to an inventory list of this literature. Additionally, the translation of these data-sources in various languages is important as the earthen architecture is a vernacular culture. The availability of this literature in different languages will contribute to composing the local educational programme.

Moreover, a proposal program for educational purposes has been developed and is provided in the following table:

Table 02 A proposal educational program for primary and higher education [Credits: Author]

A.	**The History of the Earthen Architecture**
B.	Earth as a Construction Material
-	Its chemistry
-	Physical improvement and stabilization of constructional soil
-	Additives and their effects
C.	**Earthen Building Components**
-	adobe types and forms
-	earthen building fundaments
-	earth walls
-	earth arches and domes
-	earth floors and roofs
-	earth plasters and paints
D.	**Restoration and Renovation of Earthen Buildings**

E.	**Earthen Construction Types (Traditional and Modern techniques)**
-	Adobe buildings
-	Daubed earth houses
-	Cob on posts
-	Rammed earth buildings
-	Cob houses
-	Shotcrete technique
F.	**Modern Applications and new earthen products**
-	New adobes and earth blocks
-	Hybrid earthen structures
-	Precast earth products (earth wall blocks, earth panels)
-	Ready earth plasters and paints
-	Earth equipments (fireplaces, benches, counters)

4.2.1 Programme for public and private schools:

In general the educational schedules of schools should include lessons offering basic knowledge about the sustainable and environmental aspects of our time. Hereby not only the earthen but also every kind of ecological construction cultures based on a long history should be transmitted to the students. The negative image on traditional earthen houses (material of poor people, not resistant against weather conditions and earthquake, primitive and old-fashion), which has existed since the lifestyle constructed via modern materials came in to prominence, can efficiently be changed through primary education. Particularly the vocational schools can play an important role by teaching the skills for producing masonry walls, plastering and painting with earth. This can be seen as a solution to the lack of skilled workmanship that is often found within contemporary generations.

4.2.2 Programme for universities, colleges and academies

Through significantly structured higher education programme, qualified experts (architects, engineers) will instate a multi-dimensional (structural, material technique, cultural, scientific etc.) improvement of earthen building tradition. Research about both material structure and behavior will help for improving the features of earth in terms of minimizing its common deficits (weakness against water, weather conditions or earthquake loads, etc.). "Earthen Construction" should be mentioned as one of the most comprehensive and useful source books. It summarized the most important aspects of earthen and can be a significant source for developing an educational program.

4.3. Organizing postgraduate trainings

Postgraduate trainings include every kind of further educational, scientific and practical activities supported, organized or offered from institutions, foundations and for all chamber of architects/engineers. Courses, seminars and workshops are important postgraduate trainings. Junior architects, engineers and interested people can deepen their knowledge and obtain an expertise certificate through completing these trainings. These trainings make possible to strengthen theoretical education through practical exercises and applied methods.

5. CONCLUSION

The current high tech analyze methods can help to understand the structure of earth and earthen products better than ever. For that reason, if more investigations could be carried out on physical and chemical structure of earth, significant information could be gained about its features. Through new knowledge gained from modern analyses, fair and environmentally friendly improvements related to well-known deficits of earth can be achieved. However, these high-tech methods alone are not sufficient in ensuring a sustainable and well-established earthen sector. What is additionally required is support from the government through a well-structured educational program, new standards and regulations for strengthening earthen culture. Therefore, the important factors, which should be taken into account, have been discussed within the methodology of this paper. Especially the proposal program for education needs to be more specific in regard to different stages of the education.

Finally, the immortality of buildings and structures is often discussed, but actually trying to make them immortal, via using non-recycling materials is an activity against the natural recycling and regeneration process of our world. For that reason the sustainability of our common culture "the earthen architecture" is more important now than before.

6. NOTES

The quotations from German references have been translated in to English by the author himself.

7. REFERENCES

[1] Keable, J., Keable, R.: Rammed Earth Structures. *A Code of Practice*. Practical Action Publishing. Reprinted in 2014. p. preface to second edition.

[2] [Online]. Available: https://intweb.tse.org.tr/standard/standard/standardara.aspx [Accessed: 18-Apr-2016]

[3] Houben, H., Guillaud, H.: Earth Construction. *A Comprehensive Guide. CRATerre-EAG*. Practical Action Publishing, (reprint 2014). ppp. 9-12-133

[4] [Online]. Available: http://whc.unesco.org/en/list/444 [Accessed: 02-May-2016]

[5] [Online]. Available: http://www.bogazkale.gov.tr/resim/hattusa/sur/sur01.jpg [Accessed: 05-May-2016]

[6] Minke, G.: Handbuch Lehmbau. *Baustoffkunde, Techniken, Lehmarchitektur*. Ökobuch Verlag. 8. verbesserte Auflage 2012, Freiburg, p. 38-42

[7] Bollini, G.; Parodi, I.: The first Italian Rammed earth restoration guidelines. From the book; Earthen Architecture. *Past, Present and Future*. CRC Press/Balkema. (2015). pp. 49-50

[8] Neufert, E.: NEUFERT. *Bauentwurfslehre.* 41. Auflage, Springer Vieweg Verlag (2016), p. 55.

[9] Correia, M.; Carlos, G.; Rocha, S.: Vernacular Heritage & Earthen Architecture: Contributions for Sustainable Development. CRS Press (October 2013) Foreword, p. xxi

[10] Schröder, H.: Clay boards and panels. *An innovative earth building product for drywall construction.* From the book; Earthen Architecture. *Past, Present and Future*. CRC Press/Balkema. (2015). p.344

[11] Reynolds, E.: Japan's Clay Walls. *A Glimpse into their Tradition of Plastering.* Peace Street Publications. Second edition (2009), p. 3-4

[12] Achenza, M.; Cocco, C.: A web map for Italian earthen architecture. From the book; Earthen Architecture. *Past, Present and Future*. CRC Press/Balkema. (2015). p.11

[13] Schneider, U.; Schwimann, M.; Bruckner, H.: Lehmbau für Architekten und Ingenieure. *Konstruktion, Baustoffe und Bauverfahren, Prüfung und Normen, Rechenwerte*. Verner-Verlag GmbH. 1. Auflage (Düsseldorf, 1996), p. 198.

[14] ASTM International. *Standard Guide for Design of Earthen Wall Building Systems.* Designation: E2392/E2392M-10$^{\varepsilon 1}$ May 2010

[15] Vitruvius. The Ten Book On Architecture. Translated by Morris Hicky Morgan. 68 Illustrations. Dover Publications, INC New York (2015), p. 44

[16] Zogler, O.; Wohnhäuser aus Lehm. Moderne Einfamilienhäuser aus Lehm. Neubauten und Renovierungen. Deutsche Verlags-Anstalt München 2004, p. 6

[17] Cointereaux, F.; Der Lehmbau, Pisé-Baukunst. Reprint-Verlag-Leipzig. Reprintauflage der Originalausgabe von 1803 nach dem Exemplar des Verlagsarchives, p.6

[18] Çelebi M.R.; Anadolu Kerpiç Mimarlığı; T.C. İstanbul Kültür Üniversitesi, Golden Medya Matbaacılık ve Tic. A.Ş. August 2012, p.XXI

Paper No: 15

The Role of Rating Systems in Providing Sustainability-High Rise Buildings

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ABSTRACT

After reaching the maximum size with the energy crisis in the last quarter of the twentieth century, the period that begins today awareness and sustainability and sustainable practices it has emerged as a solution. Methods of application of sustainability concepts to everyday life, are applied in the field of architecture, as in many other disciplines.

Prepared by various international organizations, there are many sustainable rating systems. Sustainable rating system with the evaluation and scoring methods are determining sustainability performance of buildings and building materials. Similarities and differences of these systems have tried to determine an effective and focused on the development of cultural and environmental factors. The purpose in assessment of rating and points systems for sustainability performance of buildings is: To clarify the evaluation parameters for sustainability standards and the grading system is to determine to what extent they are effective. In this context, sustainability practices of high rise buildings and rating systems like LEED, BREEAM which have accepted from many of the Member of World Green Building Council-WGBC have been studied. These two rating system categories, distribution of performance ratings system with assessment rates of parameters was studied and transferred the resulting inferences with charts created.

Sustainability rating systems, how sustainable they are evaluating the buildings systems. However, these systems are more design decisions of the building construction and building systems in the design of high rise buildings to examining their performance and sustainability standards, we could say that this is not an adequate tool in determining.

Keywords: Sustainability, Rating systems, The role of rating systems in sustainability

INTRODUCTION

In the twentieth century the industrial revolution and developments and be seen nature as a source to meet the growing energy needs depending on the development and renewal of the use of irresponsible possible non-fossil fuels is the source of environmental problems. Natural disasters, environmental pollution, global warming, after reaching a large size with a short time will be depleted and loss of biodiversity, such as environmental issues, particularly the energy crisis in the last quarter of the twentieth century to the present energy sources, began today awareness period, and the concept of sustainability and sustainable practices have emerged as a solution. Methods of application of sustainability concepts to everyday life, are applied in the field of architecture, as in many other disciplines.

Prepared by various international organizations, there are many sustainable rating systems. Sustainable rating system with the evaluation and scoring methods are determining sustainability performance of buildings and building materials. In this paper, which is widely used throughout the world for two rating system, it was examined. Similarities and differences of these systems have tried to determine an effective and focused on the development of cultural and environmental factors. The purpose in assessment of rating and points systems for sustainability performance of buildings is: To clarify the evaluation parameters for sustainability across the high rise buildings sustainability standards in determining and the grading system for this type of building is to determine to what extent they are effective. In this context, in this study sustainability practices of high rise buildings and rating systems like LEED, BREEAM which have accepted from many of the Member of World Green Building Council-WGBC have been studied (Figure 1). These two rating system categories, distribution of performance ratings system with assessment rates of parameters was studied and transferred the resulting inferences with charts created.

Figure 1 Countries using the four predominate ranking systems in the world map

EFFECTS OF BUILDINGS

The concept of sustainability; the most common definition of the World Commission on environment and development in 1987, published "Our Common Future" Brundtland produced a report called "Sustainable development which is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Begeç, 2015).

The buildings, the life cycle (life-cycle) energy are used at every stage. It consumes energy and resources from the production stage, producing waste and harm to biodiversity. According to recent studies; buildings across the globe, 17% of water use, 25% of the wood utilization of 33% of carbon dioxide emissions and the use of materials and energy were determined to constitute 40%. Only buildings in the United States; power consumption of 71% of the, from 30% of waste production, 39% of carbon dioxide emissions' of flour and water consumption since it is responsible for 12% [12].

A cost of sustainable building provides several advantages along with being more than the other buildings. The initial investment cost of building a sustainable rate of 2-5% is more than the other building. However, it is 20-50% savings in operating costs of the building's life cycle. This means that in order to meet the cost of the initial investment made 10-15 years (Begeç, 2012).

In addition to lifecycle savings, building green creates other economic, environmental, health and community benefits.

Economic Benefits

- Reduced operating costs of 9% on average
- Improved employee productivity and satisfaction
- Increased building value by an average of 7%
- Increased rent values by a 3% average .

Environmental Benefits

- Decreased fuel use
- Decreased fresh water use
- Decreased waste output
- Decreased raw material use
- Decreased greenhouse gas emissions

Health and Community Benefits

- Improved air quality
- Improved thermal comfort
- Improved overall quality of life

SUSTAINABIILITY RATING SYSTEMS IN BUILDINGS

In order to reduce the harmful effects on the environment of the last thirty years building sustainable building production and related industries supporting independent, non-profit, run by a third party and occurred too many organizations attended. Independent outside organization forming Rating Systems; The United Nations Environmental Programme (UNEP), Sustainable Development Department (UNDP), the European Union within the "Transport and Energy Directorate", "Sustainability Research" and "Energy Systems Director for" their research published by the pilot applications, there are strategies they have developed (Çelik, 2009).

Supported by the Clinton-Al Gore in the United States and the United States Environmental Protection Agency (EPA) was created in 1992 by the "Energy Star" products for the consumer; "energy consumption" is engaged in studies. American Society of Heating, Refrigeration and Air Conditioning Society of Engineers (ASHRAE) for building components and products is determined by the mechanical standards (Demir, 2011). Especially ASHRAE 90.1 energy standard for buildings are widely used.

With regard to the determination of sustainability of structures at the international level, there are several organizations that are currently running. In the UK, Building Research Establishment – BRE and the United States Green Building Council – USGBC these organizations is leading. In addition, buildings and building components were rated and what level of sustainable certification body has many systems. At the beginning of the certification of these systems emerged in the UK in 1990, BREEAM (Building Research Establishment

Environmental Assessment Method), in 1998 the United States emerged in the LEED (Leadership in Energy and Environmental Design), adapted from Australia in 2003, BREEAM GREEN STAR and created in Japan in 2004, resulting in CASBEE (Comprehensive Assessment for Building Environmental Efficiency). This system, outside of the SBTool (Sustainable Building Tool-Canada), BEES (Building for Environmental and Economic Sustainability), EcoProfile (Norway), Promise (Finland), Green Mark for Buildings (Singapore), HK-BEAM and CEPAS (Hong Kong), GBC (Green Building Challenge), SBAT (South Africa) and Environmental Status (Sweden), as well as numerous reviews system (Begeç, 2015).

LEED

Leadership in Energy and Environmental Design
www.usgbc.org/LEED

The U.S. Green Building Council (USGBC) was established as a nonprofit organization in 1993. The council is made up of construction industry stakeholders including owners, contractors, architects, engineers, product manufacturers, and environmental groups. The U.S. Green Building Council established LEED in 1998 under a pilot version to transform the way buildings and communities are designed, built and operated. By being environmentally and socially responsible LEED enables a healthy and prosperous environment that improves quality of life. After extensive revisions by the council, LEED New Construction and Major Renovation version 2.0 was released in 2000. Since then, development of different LEED assessment categories has occurred along with version revisions (Say, Wood, 2008).

Assessment Categories

LEED currently has eight different assessment categories. These categories "New Construction and Major Renovation", "Core and Shell", "Schools", "Retail", "Data Centers", "Warehouses and Distribution Center", "Hospitality", "Healthcare".

Building Statistics

LEED rating system is one of the most widely used worldwide in more than 150 countries / regions has made a total of 72 000 project applications. So far, over 4.2 billion square meters, it is made up certified. To support and facilitate the process of LEED accredited professionals has more than 50 000.Receiving LEED certification; which have positive impacts on the environment, healthier, more productive, efficient use of energy and resources, means and structures with high rental rates have reduced operating costs. In addition, 88 of the Fortune 100 companies are using LEED.

Assessment Process

The assessment process for LEED begins with building registration by the design team. The team submits info at two stages, design submittal and construction submittal. A review by the USGBC occurs after each submittal. After the final submittal, a LEED certified designation is issued to the building (Figure 2).

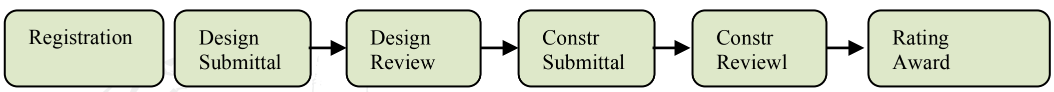

Figure 2 LEED Assessment Process

Breakdown in Categories

LEED New Construction and Major Renovation points are broken down into eight categories: These categories:

1) Location and Transportation
2) Sustainable Sites
3) Water Efficiency
4) Energy and Atmosphere
5) Materials and Resources
6) Indoor Environmental Quality
7) Innovation
8) Regional Priority

Each category scores and percentage distributions are different (Figure 3).

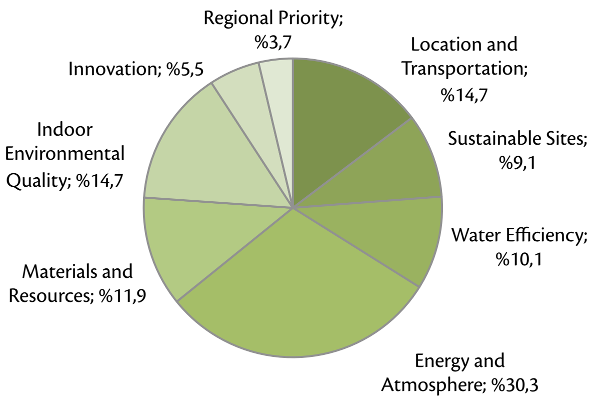

Figure 3 LEED V4 New Construction

Calculation of Scores

Based on a simple system it is implemented. Under each category, there are several criteria corresponding points specified. Make the sum of scores from the fulfillment of the criteria or the project will determine the certification level. Structure / project receive a total of at least 40 points to receive LEED certification is required. Other certificate level is shown below (Figure 4).

LEED	Certificate	40-49 points
LEED	Silver	50-59 points
LEED	Gold	60-79 points
LEED	Platinum	80 +points

(U.S. Green Building Council, 2016)

Figure 4 LEED Rating System **BREEAM**

Building Research Establishment Environmental Assessment Method
www.breeam.org
www.breeam.com

BREEAM was developed in the United Kingdom in 1990 by Building Research Establishment Global Ltd., a division of the larger research charity, Building Research Establishment Trust. The board is comprised of stakeholders in all aspects of the construction industry. The goals of BREEAM are to reduce environmental impact, ensure the best environmental practices in design, operation-management, and to increase awareness of the impacts of buildings on the environment (Say, Wood, 2008). For evaluation to be made in countries outside the UK, BREEAM International and BREEAM Gulf and BREEAM Europe it has been developed.

Assessment Categories

BREEAM currently has nine different assessment categories. These categories:
“Courts”, “Education”, “Industrial”, “Healthcare”, “Offices”, “Retail”, “Prisons”, “Multi-residential”, “Data Centers”. Organized by quite a wide range of assessment panels assess the environmental performance of the building, according to various categories. On-demand (bespoke) evaluation criteria as may be determined by the institution-specific building types.

Building Statistics

From 1990 until today, the BREEAM within the 73 countries in the world, there are 539 400 registered certified, including 2.2329 million project [13]. The certification is used in approximately 80% of buildings in Europe. Regional and climatic characteristics are considered in the evaluation. Today, there are about 1,200 licensed world-wide assessment authority (Julien, 2009). BREEAM new building in the UK has 25% of market share.

Assessment Process

The BREEAM assessment process begins with registration and completion of the necessary documents by the design team. The project is then reviewed by a BREEAM assessor. The assessment report is filed and then reviewed by a member of the BREEAM team. Upon successful completion, certification is issued (Figure 5).

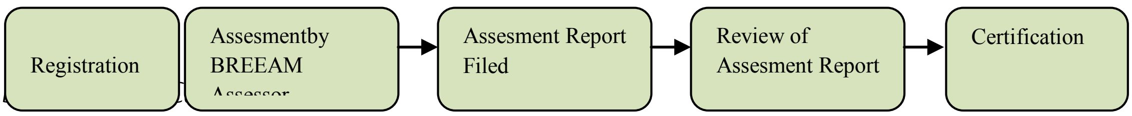

Figure 5 BREEAM Assessment Process

BREEAM are broken down into categories like LEED. These categories:

1) Management
2) Health & Wellbeing
3) Energy
4) Transport
5) Water
6) Materials
7) Waste
8) Land Use & Ecology
9) Pollution
10) Innovation

Each category scores and percentage distributions are different (Figure 6)

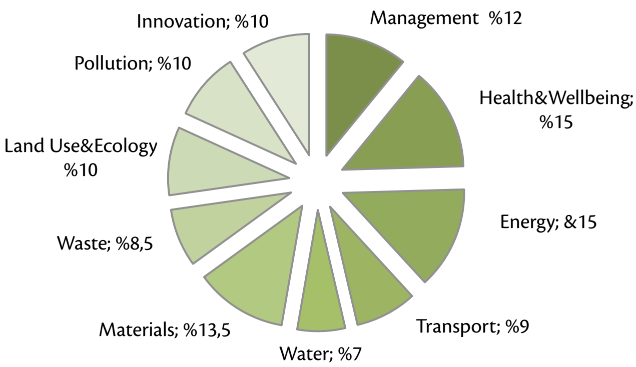

Figure 6 Breakdown in BREEAM

Calculation of Scores

A BREEAM score is compiled by category. A predetermined weighting is subsequently applied to each category score. The sum of the category scores then determines the final score and the BREEAM Rating. BREEAM ratings are determined by achieving a set percentage of the benchmark points (Figure 7). Buildings must achieve at least 30% of the benchmark to qualify (Say, Wood, 2008).

Unclassified	%30 below
Pass	%30-%44
Good	%45-%54
Very Good	%55-%69
Excellent	%70-%84
Outstanding	%85 above
(Building Research Establishment Ltd, 2016)	

Figure 7 BREEAM Rating System

EVALUATION OF RATING SYSTEMS -HIGH RISE BUILDINGS

Rating systems, it is important that the attention will be on how sustainable buildings and wishes of the community in terms of the increase. Progressive project developers and building market leaders, those who prefer the certified production Overall, it is observed that innovative companies. In this sense, the certification process, in high-rise buildings can be seen as a prestige building said mostly preferred.

Today, there have been certified five buildings in the lists of first twenty world's tallest buildings. There have been certified four building are also available in the Europe (excluding Russia) and in the United States in the highest 10 building built in between 2010-2015. In the same period, the Far East, in the highest area of 10 buildings on the certificate has 3 buildings [15].

The purpose of the exanimate rating system;

- The general and current measurement standards and to identify sustainable buildings,
- Develop a holistic building design method,
- Recognize environmental leadership in the building industry,
- To encourage widespread competition in the sustainability of the building,
- To increase consumer awareness about the benefits of sustainable building
- To transform the building market (Ding, 2008).

The certification of the high rise building rating agencies that they are perceived as a factor that increases the initial investment costs. This constitutes the challenges in order to direct investors. Receive a certificate in building construction; the rate of 2-5% depending on the type of certification is an additional cost. Despite this increase in initial investment cost of the building it has increased and decreased the market value of the building operating costs. Sustainable high rise buildings are seen as they meet the initial investment costs in an average of 10-15 years (Begeç, 2012).

BREEAM and LEED rating system of the present structure provide a separate certificate for conversion. This is important in terms of improving the environmental impact of the existing building stock.

Rating systems, today criticized the transformation of marketing tool. Some investors by brand value of the certificate system are highlighted. This brings together the vision of certification systems as marketing tool. In this case ignored by some of the certification criteria can be taken to collection points can be taken by way of easy points. A building, even if they are not points of some of the main factors such as energy efficiency to reach the target score high points total by other criteria and can receive certificates (Curwell 1996). This performance they provide the same certificate, building reasons may be different from each other.

Rating systems have been criticized as not taking into account local characteristics. The criteria applied in the world of construction in regions with different properties bring problems along with the attempt to evaluate the sequence. Regional diversification studies; climatic conditions, economic and cultural values, the structure of the construction industry, the differences in materials and techniques, integrating essential to differences in political approaches are necessary elements rating system. In recent years the rating system has made arrangements for it.

CONCLUSION

Today the work of rating system, sustainability and the increased interest in and knowledge of sustainable architecture concept has an important role.

Rating systems, which lower the parameters of sustainability; environmental, economic and social parameters is seen that inclusion of economic and social factors. The basic principle of a financial investment for investors recycles. The construction costs of a project may not be much attractive for investors (Larsson and Cole 2001). Therefore it must be considered as economic criteria as environmental impacts. Economic criteria for sustainability practices in buildings with high initial investment costs much more than other types of buildings are decisive. In addition to design a sustainable building excessive cost is incompatible with the concept of sustainable building.

REFERENCES

[1] Begeç, H., "Yüksek Yapılarda Sürdürülebilirlik One Bryant Park Binası Örneği", *Sürdürülebilir Yapı Tasarımı Ulusal Konferansı*, İzmir, (2012).

[2] Begeç, H., "Rating Systems as a Tool for the Determination Sustainability Standards in High Rise Buildings", *12th International Conference "Standardization, Protypes and Quality: A Means od Balkan Countries Collaboration*, Kocaeli, (2015).

[3] Say, C., Wood, A., "Sustainable Rating Systems around the World", *CTBUH Journal* (2008) Issue 2

[4] Ding, G.K.C., "Sustainable construction—The role of environmental assessment tools", *Journal of Environmental Management*, (2008), 86, 451–464.

[5] Julien, A., "Assesing The Assesor: Breeam vs Leed", *Sustain Magazine*, 6, 33, http://www.breeam.org/filelibrary/BREEAM _v_ LEED_Sustain_Magazine.pdf, (2009).

[6] Larsson, N.K., Cole, R.J., "Green Building Challenge: The Development of An Idea", *Building Research and Information*, 29(5), (2001), 336–345.

[7] Crawley, D., Aho, I., "Building Environmental Assessment Methods: Application and Development Trends", *Building Research and Information*, 27 (4/5), (1999), 300–308.

[8] Curwell, S., "Specifying For Greener Buildings". *The Architects' Journal*, January, (1996). 38–40.

[9] Çelik, E., "Yeşil Bina Sertifika Sistemlerinin İncelenmesi Türkiye'de Uygulanabilirliklerinin Değerlendirilmesi", *İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü Yayınlanmamış Yüksek Lisans Tezi*, (2009).

[10] Zinzade, D., "Yüksek Yapı Tasarııinda Sürdürülebilirlik Boyutunun Irdelenmesi", *İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü Yayınlanmamış Yüksek Lisans Tezi*, (2010).

[11] Demir, N., "Yüksek Yapılar ve Sürdürülebilir Enerji", *Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü Yayınlanmamış Yüksek Lisans Tezi*, (2011).

[12] http://www.worldgbc.org/index.php?cID=1 January 2016

[13] http://www.breeam.com/index.jsp January 2016

[15] http://skyscrapercenter.com/interactive-data/ January 2016

Paper No: 21
The Effects of Daylighting and Solar Energy in High Rise Buildings

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ABSTRACT

A global movement of green skyscrapers is upon us. Architects, engineers, developers, and clients are pioneering this shift towards eco-towers. These towers are shaping the future of high rise buildings, and utilizing green technologies on an entirely new scale. In sustainable high rise buildings especially, an integrated process is necessary because of their scale and the fact that green design affects so many different elements of a building, such as daylighting, which in turn concerns siting, orientation, building form, facade design, floor to-floor heights, interior finishes, electric lighting controls, and cooling loads, among other things.

This paper presents summary information from a noncritical literature review on daylighting and solar energy in high rise buildings. This paper summarizes the benefits and defects of daylighting and solar energy effects on high rise buildings. High rise buildings are seemingly well-tuned to their climate; and they provide a major portion of their own energy requirements through integrated passive design, daylighting, and intelligent control systems. Daylighting has been associated with higher productivity, lower absenteeism, fewer errors or defects in products, positive attitudes, reduced fatigue, and reduced eyestrain. Good daylighting strategies and concepts are also discussed in the guide on building systems.

Keywords: Daylighting, High rise building, Solar Energy Energy Efficiency

INTRODUCTION

Legislation concerning solar access protection has been known since the Roman Empire in the 2nd century AD, when Ulpiano created the Heliocaminus: the sun path. At this time, Rome had 1 million inhabitants and the lack of space forced vertical expansion, with buildings ranging from 6 to 12 storeys.

Daylighting is a technique that brings natural daylight into a building, through openings so that the day's natural light provides effective internal lighting (Fontoynont et al., 2004). Daylight is the total light from the sky dome which is affected by attenuation, due to the absorption and scattering in the atmosphere and it consists of direct (or beam), diffused and ground-reflected components (Zain-Ahmed et al., 2002a).

The daylighting studies involve a great number of cross-disciplined design factors intertwined between the site planning, architecture, interior design, lighting design, electrical engineering and mechanical engineering (Phelan, 2002). All these factors have to integrate with occupants' characteristics, owner's operating requirements, task lighting requirements and the daily and seasonal solar cycles. There are three major developments that contribute to interests on the aspect of daylighting in building designs namely; the impact of light on human health, the growing influence of green building rating schemes and progress at lower cost, along with reliable, integrated control technologies to provide the responsiveness needed for comfort and energy savings (Reinhart and Selkowitz, 2006; Franzetti et al., 2004).

In today's world, the rate of energy usage is growing rapidly in accordance with the industrial development, and the population growth is becoming greater. Thereby, as few studies have been done by architects such as Ken Yeang on the amount of energy consumed in high-rise buildings, the author attempts to make viewpoints of some architects, construction builders and also users more clear about the influences of using passive solar strategies and active solar technologies on high rise buildings. Therefore, by considering the use of solar passive strategies and active technologies as an alternative in high-rise buildings, this study tries to fill some of the current gaps as much as possible and its proposed fundamental message is changing architects' and construction builders' view in dealing with the subject. This research is mainly based on a theoretical approach, which is supported by the outcomes of a literature review and case study analysis.

THE HIGH-RISE BUILDINGS AND SUSTAINABILITY

These days, "Buildings are the main destination for the nation's power supplies and hence the main sources of carbon dioxide emissions" and high-rise buildings are an inevitable part of our society building forms. Furthermore, skyscrapers are becoming more necessary, according to the effective use that they make of the available limited land. Ecological design and sustainability of high rise buildings are in fact more crucial than those of ordinary buildings. Constructing these buildings are inevitable, because of their scale and their huge amount of energy and material usage. Therefore, high rise buildings have a great potential for maintaining and recycling resources. Moreover, high-rise building design is complicated and requires more experience. So, for many reasons, the sustainable design of skyscrapers needs to be addressed.
Some advantages of high rise buildings are as follows:

- Material saving because of repetitive type plans.
- Observing standards and efficient contractors, especially in large quantities, lead to lower costs.
- More potential to reduce energy and material waste by using sustainable materials in elevations.
- High rise buildings occupy less land.
- Better use of daylight and thermal mass.
- Prepare better horizontal access for its inhabitants.

EFFECTS OF DAYLIGHTING AND SOLAR ENERGY IN HIGH RISE BUILDINGS

The right application of daylighting in buildings can reduce electricity usage for room illumination by more than 50% (Lechner, 2009; Ihm et al., 2009), while Zain-Ahmed et al. (2002b) proved that the adaptation of daylighting as passive solar design strategy in tropical buildings can help to conserve up to 10% of the energy used. Lowering the usage of electric lighting in buildings, it can reduce the energy demand for cooling requirements resulted from the internal load from the artificial light (Leslie, 2003). The electricity from an incandescent lamp heats up a wire filament causing it to glow and emit the light, where 90% of the energy produced is heat, not light (Mahlia et al., 2005). According to Leslie (2003), capturing day light in the buildings is capable to;

- improve the human performance and well-being through daylighting's impact on their aesthetics, vision, and photobiology, where experimental work indicates that the suppression of melatonin, the hormone responsible for regulating the body's internal clock or circadian rhythm is influenced by the exposure to light levels typical of daylight.

- possibly improve productivity, increase job satisfaction or reduce absenteeism.
- create interesting lighting effects that modulate throughout the day and year, while also providing a broad electromagnetic spectrum with excellent colour rendering.
- allow buildings to be lit at higher levels than those with electric lighting alone. This will allow people to continue working on certain given tasks during power shortages or breakdown.

The effectiveness of daylighting depends on several factors, including the building architectural features (shape, window area, glazing type), the building locations (Ihm et al., 2009), the surrounding climate and the requirements of lighting for specific purposes (Kischkoweit-Lopin, 2002). In the window design, it can include the size, location, orientation, external condition and the use of light diffusers which directly control the light level, daylight qualities and internal luminance (Jughans, 2008). Thus, improving the visual comfort while reducing the heat gain caused by light penetration (Yeang, 2008), can be conclusive in four daylighting strategies, as mentioned by Omer (2008),

- Penetration: collection of natural light inside the building,
- Distribution: homogeneous spreading of light into the space focusing,
- Protect: reducing, by external shading devices, the sun ray penetration into the building,
- Control: control light penetration using movable screens to avoid discomfort.

For high rise buildings, the most appropriate zones for active human activities should be located within the daylight zone, typically about 5 meter deep from the window wall or the top floor of a building with skylight (Leslie, 2003). Additionally, the critically visual tasks need to be placed near the building parameter, and light color interior surfaces should be used towards reducing the luminance contrast between the windows and surrounding surfaces while increasing the visual comfort (Jamaludin, et all, 2015).

Therefore, the opening size of a window is the most important aspect that affects the penetration of daylighting in the high rise building. The solar gains as the window to wall ratio (WWR) increase while the peak gains occur in the southwest-facing windows (Zain-Ahmed et al., 2002a).

The daylighting is not only an energy efficient technology but also an architectural discipline that improves the performance of the building and occupants. Daylighting stands in prominence as the major factor in occupants' perceptions and acceptance of spaces in buildings. Successful energy saving through daylighting can only be realized when the building and system design support broader occupants' needs for comfortable and healthy indoor environments (Reinhart and Selkowitz, 2006). Unfortunately, the effectiveness of implemented bioclimatic design strategies, particularly daylighting in a building is rarely assessed once they are handed over to their users. The buildings normally do not fit the ecological and cultural contexts and do not answer to programmatic, practical and functional needs (Al-Kodmany, 2014). Indirectly, this indicates the adequacy of daylight in achieving comfortable space as a habitat indoor environment, as prescribed by international and local standards.

Solar Energy

Solar radiations can be considered as the primary source of renewable energy. Although it can take part as a direct energy source, it impacts the earth's climate (Lotfabadi, 2015). Energy opportunities are developed from waves, tides and wind, which are also a host of biological sources. This kind of energy can specifically be used in building sector as an energy source. However, this source of energy is considered as two parts:

1) *Passive Solar Design*: For many decades, passive solar energy gain has been used as environmental factors. Anyway, the more the global warming debate has been put forward, the more pressure has been put into designing buildings, which causes the maximum use of free solar gains for heating, cooling and lighting. Passive solar design configurations itself can be separated into five sections as follows:
    - Direct solar gain
    - Indirect solar gain
    - Isolated solar gain
    - Thermal storage mass
    - Passive cooling
2) *Active Solar Design*: This item focuses on obtaining usable heat from the solar radiation. For instance, in case of temperate cli-mates the most suitable application of solar radiation is using solar radiation to supplement a conventional heating system or to generate power (Lotfabadi, 2015).

1) Passive Solar Design

Direct solar gain: Direct gain concentrates on controlling the amount of direct solar radiation reaching the living space. This direct solar gain is a critical part of the passive solar house designation as it imparts to a direct gain. Thus, it is a kind of design technique that mainly concentrates on the sun-facing facade. Solar radiations are directly admitted into the space concerned. The main design attributes are as follows:

- Opening for solar radiation should be placed on the solar side. The angle is about ±20εof south in the Northern Hemisphere.
- West side facing windows might increase the risk of summer overheating.
- It is better to use double or triple glazed windows with low emissivity glass.
- In design, the most occupied living spaces should be considered on the solar side.
- In order to absorb the heat and set thermal inertia that decrease the temperature fluctuations inside the building, the floor should be constructed from high thermal masses (Lotfabadi, 2015):

In order to obtain solar protection in summer, lift cores are located at the west and northeast facades of the building and in winter southeast units and central landscaped circulation area have a maximum solar gain. Meanwhile, each facade contains vast trans-parent windows that can provide better air ventilation and help to achieve maximum daylighting (Lotfabadi, 2015).

Indirect solar gain: In this case, a heat absorbing element is added along with the incident solar radiation and space to be heated. Therefore, the heat transfer is in an indirect form. This is often a wall, which is placed behind glazing facing toward the sun. This thermal storage wall controls the flow of heat into the construction. Thus, the most important factors contributing to the design function are as follows:

- The wall heat flow can be modified by its thickness and materials. For instance, for the residential spaces, this amount is between 20and 30 cm in order to make some delay for this heat transaction and its thickness depends on the occupancy periods.
- In order to prevent heat loss, glazing is used on the outdoor space. It also helps to retain the solar gain by taking advantage of the greenhouse effect.
- Approximately 15–20% of the floor area, which emits heat, should be dedicated to the thermal storage area.
- To derive more instantaneous heat benefit, air can be circulated from the construction through the air gap among glazing and wall, and back into the room. Heat reflecting blinds should be inserted between the thermal wall and the glazing to limit heat build-up in summer (Lotfabadi, 2015):

Isolated solar gain: This means benefiting solar energy in living areas through using a fluid like water or air by forced or natural convection. Heat can be gained through solarium, sunspace or solar closet. Generally, this item can be considered as an extension space, which is added to the living area. It can be used as a solar heat store, a preheated for ventilation or also as an adjunct greenhouse for plants. As conservatories are often heated, they are a net contributor to global warming, sunspace should be completely insulated in order to pre-vent the building from getting cold in winter and being too hot in summer (Lotfabadi, 2015).

In ideal conditions the amount of heat absorbed in summer should be stored to be used in winter and finally there should be controlled spaces between the building and the conservatory for the air to flow. In order to benefit the local natural energy reserves appropriately, apart from global radiation, the temperature, humidity and wind, specific climate data corresponding to the geographical location are the most considerable factors (Lotfabadi, 2015).

Thermal storage mass: The solar radiations cannot be benefited all day, so that it has to be applied for heat storage, or thermal mass to keep the buildings warm. This is designed for only one or few days, which is possible through indirect solar energy gain, such as; trombe wall, glass X facades, a cistern, water wall or roof pond, a ventilated concrete floor (Lotfabadi, 2015).

Passive cooling: The efforts done to minimize energy consumption and improve indoor thermal comfort, which mostly focus on heat dissipation and heat gain control in buildings, are referred to as passive cooling. This is possible in case we prevent heat from entering the interior (heat gain prevention) or remove heat from the building (natural cooling). Architectural design of building components together with natural environment use natural cooling to dissipate heat. However, in this case an innovative passive cooling system is not applied (Lotfabadi, 2015).

2) Active Solar Design

This type of solar technologies is mainly used in order to produce other useful types of energy from solar radiations. This new energy type is a kind of thermal energy to provide power generation, cooling, heating and hot water supply. Therefore, in the conversion process, one type of mechanical or electrical equipment is used and this is happening in order to maximize the effect of solar energy in buildings. To achieve more sustainable design, gallium arsenide photo-voltaic cells combined with a rainwater catchment or a rain-screen in south-east facade are used. PV panels are utilized in order to obtain more energy self-sufficient building and sustainability (Lotfabadi, 2015).

SHANGHAI TOWER

Shanghai Tower is located in Pudong Financial District in Shanghai, China. The 121-floor tower was topped out recently rising to 557m (1,826 ft.). The 121-storey tower is divided into nine vertical zones, with retail at the bottom and hotels, cultural facilities and observation decks at the top. The zones in between will contain offices. Designed by the architectural firm Gensler, the tower features numerous green design elements including: the façade's taper, texture and asymmetry work in partnership to reduce wind loads on the building by 24 percent, offering significant savings in overall building materials. The building's transparent inner and outer skins admit maximum natural daylight, thereby reducing the need for electric light. The tower's outer skin also insulates the building, reducing energy use for heating and cooling. The tower's spiraling parapet collects rainwater, which is used for the tower's heating and air conditioning systems (Kheir Al-Kodmany, 2014).

Figure 1. Shanghai Tower

Figure 2. Doha Tower

DOHA TOWER

Doha Tower is a 46-story (231 m/ 758 ft.) high rise located in West Bay (Doha), Doha, Qatar, and was completed in 2012. Designed by Jean Nouvel, the cylindrical form of the tower was decided upon for its efficiency in floor-to-window area and relative distances between offices and elevators. Additionally, the core of the building has been shifted off-center to allow more flexible floor area for the office spaces. The cladding system is a reference to the traditional Islamic "mashrabiya," a popular form of wooden lattice screen found in vernacular Islamic architecture and used as a device for achieving privacy while reducing glare and solar gain. The design for the system involved using a single geometric motif at several scales, overlaid at different densities along the façade. The overlays occur in response to the local solar dynamics: 25% opacity was placed on the north elevation, 40%

on the south, and 60% on the east and west. The overall façade system is estimated to reduce cooling loads by 20%. The building received the CTBUH Skyscraper Award for the Best Tall Building Worldwide from the CTBUH in 2012 (Kheir Al-Kodmany, 2014).

AL BAHAR TOWERS

Al Bahar Towers house the new headquarters for the Abu Dhabi Investment Council and occupies a prominent site on the North Shore of Abu Dhabi Island, in UAE. The project comprises two 150m (490 ft.) tall towers that share a common podium and a two-level basement. Similar to the case of Doha Tower, Al Bahar Towers took inspiration from a traditional Islamic motif to design an innovative and visually interesting external automated shading system for the building. The dynamic façade has been conceived as a contemporary interpretation of the traditional Islamic "mashrabiya." However, the "mashrabiya" at Al Bahar Towers comprises a series of transparent umbrella-like components that open and close in response to the sun's path. Each of the two towers comprises over 1,000 individual shading devices that are controlled via the building management system, creating an intelligent façade. Each unit comprises a series of trenched PTFE (polytetrafluoroethylene) panels (Kheir Al-Kodmany, 2014).

Figure 3. Al Bahar Tower

Figure 4. Torre Cube

TORRE CUBE

Designed by the Catalan architect Carme Pinos, the 58m/190 ft. tall, 16-sotry Torre Cube is a landmark tower in the city of Guadalajara, capital of Jalisco, Mexico. The city is an area of high seismic intensity, and hence the tower's structure, shape and geometry had to count for that. The tower's design takes advantage of the mild and sunny climate to bring natural ventilation and light to the building. The building's double skin and central atrium enable 100% natural ventilation. Also, wooden-latticework outer skin reduces solar gain; collectively obviating the need for air conditioning. Interior spaces also enjoy abundance of natural light. Construction was completed in 2005. This is a rare example of a high rise building that relies entirely on natural ventilation and light year round which significantly reduce energy consumption and eliminates the spaces needed to house mechanical HVAC equipment (Kheir Al-Kodmany, 2014).

CONCLUSION

Eventually, by considering today's global warming and world's economy, no one doubts that current energy sources are not inter-minable. So, the necessity of sustainable design for the future is inevitable. Moreover, in theory, this potential is available by energy efficient design, which can cause the design to change from being uncertain into a confident science. This kind of energy conservation might be meaningfully reached in high-rise building design.

Finally, high-rise buildings have great potential to gain solar radiations because of their vast façade. Applying solar energy and daylighting strategies in high-rise buildings have a meaningful effect on reducing the total annual cooling and heating energy demand. These strategies can be applied and adapted to high-rise buildings by using direct solar gain, indirect solar gain, isolated solar gain, thermal storage mass and passive cooling systems. On the other hand, considering active solar technologies can also add extra potential by providing part of the building necessary energy demands. Although this amount is not huge amount in the case study, it can be improved by integrating PV panels and other solar active technologies in the high-rise building facades.

REFERENCES

[1] Al-Kodmany, K.., Green towers and iconic design: Cases from three continents. *ArchNet-International Journal of Architectural Research*, 8(1), (2014), 11-28.

[2] Fontoynont, M., Tsangrassoulis, A., & Synnefa, A., SynthLight handbook. *France: European Commission*, (2004)

[3] Franzetti, C., Fraisse, G., & Achard, G. (2004). Influence of the coupling between daylight and artificial lighting on thermal loads in office buildings. Energy and Buildings, 36(2), 117-126. doi:10.1016/j.enbuild.2003.10.005

[4] Ihm, P., Nemri, A., & Krarti, M., Estimation of lighting energy savings from daylighting. *Building and Environment*, 44(3), 509-514. (2009), doi: 10.1016/j.buildenv.2008.04.016

[5] Jughans, L., Design, elements and strategies: Daylighting. In R. Hyde (Eds.), *Bioclimatic housing: Innovative designs for warm climates* (pp. 345-365), (2008). UK: Earthscan.

[6] Jamaludin, Adi Ainurzaman; Hazreena Hussein; Nila Keumala; Ati Rosemary Mohd Ariffin, The Dynamics of Daylighting at a Residential College Building with the Internal Courtyard Arrangement, *Archnet-IJAR*, Volume 9 - Issue 3 - November 2015 - (148-165) – Special Issue

[7] Kheir Al-Kodmany, Green Towers And Iconic Design: Cases from Three Continents, *Archnet-IJAR*, Volume 8 - Issue 1 - March 2014 - (11-28) – Section: Original Research Articles

[8] Kischkoweit-Lopin, M., An overview of daylighting systems. *Solar Energy*, 73(2), 77-82, (2002), doi: 10.1016/S0038-092X(02)00036-1

[9] Lechner, N., Heating, cooling, lighting: Sustainable design methods for architects, 3rd ed. *New Jersey: John Wiley & Sons*, (2009).

[10] Leslie, R. P., Capturing the daylight dividend in buildings: why and how?, *Building and Environment*, 38(2), 381-385, (2003), doi: 10.1016/S0360-1323(02)00118-X

[11] Lotfabadi, P., Solar considerations in high-rise buildings, *Energy and Buildings* 89 (2015) 183–195, http://dx.doi.org/10.1016/j.enbuild.2014.12.044

[12] Mahlia, T. M. I., Said, M. F. M., Masjuki, H. H., & Tamjis, M. R.,Cost-benefit analysis and emission reduction of lighting retrofits in residential sector. *Energy and Buildings*, 37(6), 573-578, (2005)., doi:10.1016/j.enbuild.2004.08.009

[13] Omer, A. M., Renewable building energy systems and passive human comfort solutions. *Renewable and Sustainable Energy Reviews*, 12(6), 1562-1587, (2008), doi: 10.1016/j.rser.2006.07.010

[14] Phelan, J. P. E,. Commissioning lighting control systems for daylighting applications, (2002).

http://resources.cacx.org/library/holdings/178.pdf, Access Date, 4/12/2014.

[15] Reinhart, C., and Selkowitz, S., Daylighting - Light, form and people. *Energy and Buildings*, 38(7), 715-717, (2006), doi: 10.1016/j.enbuild.2006.03.005

[16] Yeang, K., Ecodesign: A manual for ecological design. London, UK: *John Wiley & Son Ltd*, (2008).

[17] Zain-Ahmed, A., Sopian, K., Othman, M. Y. H., Sayigh, A. A. M., & Surendran, P. N., Daylighting as a passive solar design in tropical buildings: a case study of Malaysia. *Energy Conversion and Management*, 43(13), 1725-1736, (2002a), doi: 10.1016/S0196-8904(01)00007-3

[18] Zain-Ahmed, A., Sopian, K., Abidin, Z. Z., & Othman, M. Y. H., The availability of daylight from tropical skies–a case study of Malaysia. *Renewable Energy*, 25(1), 21-30, (2002b), doi: 10.1016/S0960- 1481(00)00209-3

Paper No: 23

Experimental Investigation of Thermal Comfort Performance ofthe Radiant Heating System: Comparison of Different Heating Surface Configurations

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ABSTRACT

Radiant heating is a well-known technology for space heating which has many advantages such as thermal comfort and energy efficiency. However, radiant heating systems are not commonly used in Turkey in spite of its ability to use low heating energy sources. The aim of this study is to evaluate thermal comfort in terms of Fanger's Thermal Comfort Model (PPD-PMV). Test Chamber is designed for experimental testing of different panel locations. Wall and ceiling heating panels are applied as heating surfaces within the room.The motivation is to estimate how thermal comfort is affected by changing the active radiant heating surface such as different wall/ceiling surface heating configurations. This study is just a preliminary study of the experimental research. In this paper, experimental setup and experimental methodology for thermal comfort evaluation of radiant heating systems is described. In the following activities thermal comfort tests will be performed.

Keywords: Thermal Comfort, Radiant, Heating, Cooling, Experimental, Energy Efficiency

1. INTRODUCTION

The energy efficiency has become a big issue because of the increasing energy consumption and decreasing of non-renewable energy sources. Human being's life is also threatened by global warming. In many countries, global warming considerations have led to efforts to reduce fossil energy use and to promote renewable energies in the building sector. Energy use reductions can be achieved by minimizing the energy demand, by rational energy use, by recovering heat and cold and by using energy from the ambient air and from the ground [1].

Buildings are major consumers of the world's energy. Building sector has a considerable impression over the natural resource consumption. Currently, energy consumption of the buildings account for approximately 40% of global energy demands and the energy requirement for space heating, ventilation and air conditioning (HVAC) of a building is approximately 60% of the total energy consumed in buildings, which accounts for the largest percentage of energy usage. Lowering the buildings' energy consumption could be the main point of saving energy. People need to improve the buildings efficiency by using more efficient systems and sustainable sources for heating and cooling operations [2–8].

Thermal comfort is one of the most important subjects that effects directly on people's quality of life and wellness. In the other hand, thermal comfort also effects on people's performance [9]. Recently, hydronic radiant heating and cooling panels have been started to be a common solution for building heating and cooling operations because of their advantages which are thermal comfort and low energy consumption.

Panel heating and cooling systems use temperature-controlled indoor surfaces on the floor, walls and/or ceiling; surface temperature is maintained by circulating water through a circuit embedded to the panel. A temperature controlled surface is called as radiant panel if 50% or more of the heat transfer on the temperature-controlled surface takes place by thermal radiation [10]. In this respect, Miriel et al. [11] that the radiant component involves around 66% of the total heat transfer in cooling operation and 80% in heating operation experimentally. Radiant heating systems have been a well-known HVAC solution for providing thermal comfort. Radiant heating systems are different from typical HVAC systems because they heat surfaces rather than air and can save large amounts of energy while providing higher levels of comfort. It is a proven technology carries out the requirements which are explained in related standards [12, 13].

Radiant systems provide better thermal comfort levels than other HVAC systems by means of using lower supply temperatures for heating and higher supply temperatures for cooling. This permits small vertical temperature gradient, few air movements and reduced local discomfort for occupants [14]. The study that has been done by Ghaddar et al. [15] is the effect of the heater's position on energy consumption in a room while providing the same level of thermal comfort. Myhren et al. [16] had a research study was how different heating systems and their position affect the indoor climate.

Nagano and Mochida [17] analysed the thermal comfort of five subjects in an experimental test room equipped with cooling ceilings. They concluded that the mean radiant temperature for a supine human body should be used in the design of ceiling radiant cooling. Kitagawa et al. [18] investigated the effect of humidity and small air movements on the thermal comfort of subjects in a climatic chamber equipped with radiant cooling panels. Catalina et al. [19] analysed the indoor thermal comfort using PMV using the results obtained from experimental and CFD studies. A field assessment of thermal comfort was conducted in subtropical region of Pakistan by Memon et al [20] The results show that people of the area were feeling thermally comfortable at operative temperature 29.31°C.

The mean radiant temperature is one of the six main variables responsible for the thermal sensation of the man exposed in a particular thermal environment (indoor and outdoor). Its measurement is not direct and is usually carried out by means of different methodologies and instruments whose general details and accuracy requirements are reported in the ISO Standard 7726 [21]. Alfano et al. reviewed typical measurement methodologies and compared the experimental results obtained from real-sized test room [22]. Kalmar et al.investigated influence of room geometry on the mean radiant temperature for similar heating systems [23]. De Carli et al. developed a numerical model able to perform the detailed simulation of the dynamic behaviour of water based surface embedded heating and cooling systems. Numerical model was validated with the result of measurements. Measured and simulated values of surface, air, operative and mean radiant temperatures were compared for different cases [24].

As it was shown in the literature above, there are manystudies were submitted about radiant systems and their effect on thermal comfort. Beyond the research has been done in the literature; this experimental studywill be fulfilling the gap that how thermal comfort is affected by changing the location of the radiant panels inside the room (wall/ceiling).Furthermore, the comparison of radiant system and conventional heating systems will be studied in terms of thermal comfort. This paper is a preliminary study of all experimental research will be done in near future. In thispre-study the experimental setup and evaluation methodology will be described briefly. After that it is planned to present the ongoing result in the conference.The study has the aim to provide further information for better understanding the thermal comfort of radiant and conventional heating systems clarify the vague conceptions in heating operations.

2. EXPERIMENTAL SETUP

2.1. Description of test chamber

The test chamber was constructed to get realistic test results for different heating applications under different controlled climatic conditions which are listed in Table 1. The test chamberwill be used in this study was built in such a way to reproduce as accurately as possible the structure and characteristics of a real size room which is presented in Fig.1. This chamber, which is composed of 5zones which are the "Test Room" which is characterized by a floor area of 16 m^2 (4.00 m × 4.00 m) and an internal height of 3.00 m, façade volume (1), inner zone volume (2), floor volume (3), ceiling volume (4).The wall types are chosen as the sandwich type with polyurethane insulation between two layers made out of sheet steel which has engagement and locking mechanism to increase the strength. The insulation thicknesses and the coefficient of thermal transmittance of walls for different zones were determined according to Turkish Standard TS 825 (thermal insulation requirements for buildings), presented in Table 2 [25]. Internal wall surfaces are characterized by an emissivity value of 0.9.

Table 1Controlled parameters in zones

	Ceiling	Floor	Facade Room	Interior Room
Temperature Range	-10˚C / +40˚C	+0˚C / +30˚C	-10˚C / +40˚C	+0˚C / +30˚C
Temperature Tolerance	± 0.5 ˚C	± 0.5 ˚C	± 0.5 ˚C	± 0.5 ˚C
Humidity Range	n/a	n/a	%35 / %85 RH	n/a
Humidity Control Steps	n/a	n/a	%1	n/a
Humidity Tolerance	n/a	n/a	± % 0.5 RH	n/a
Air Velocity	n/a	n/a	0.5 – 5 m/s	n/a

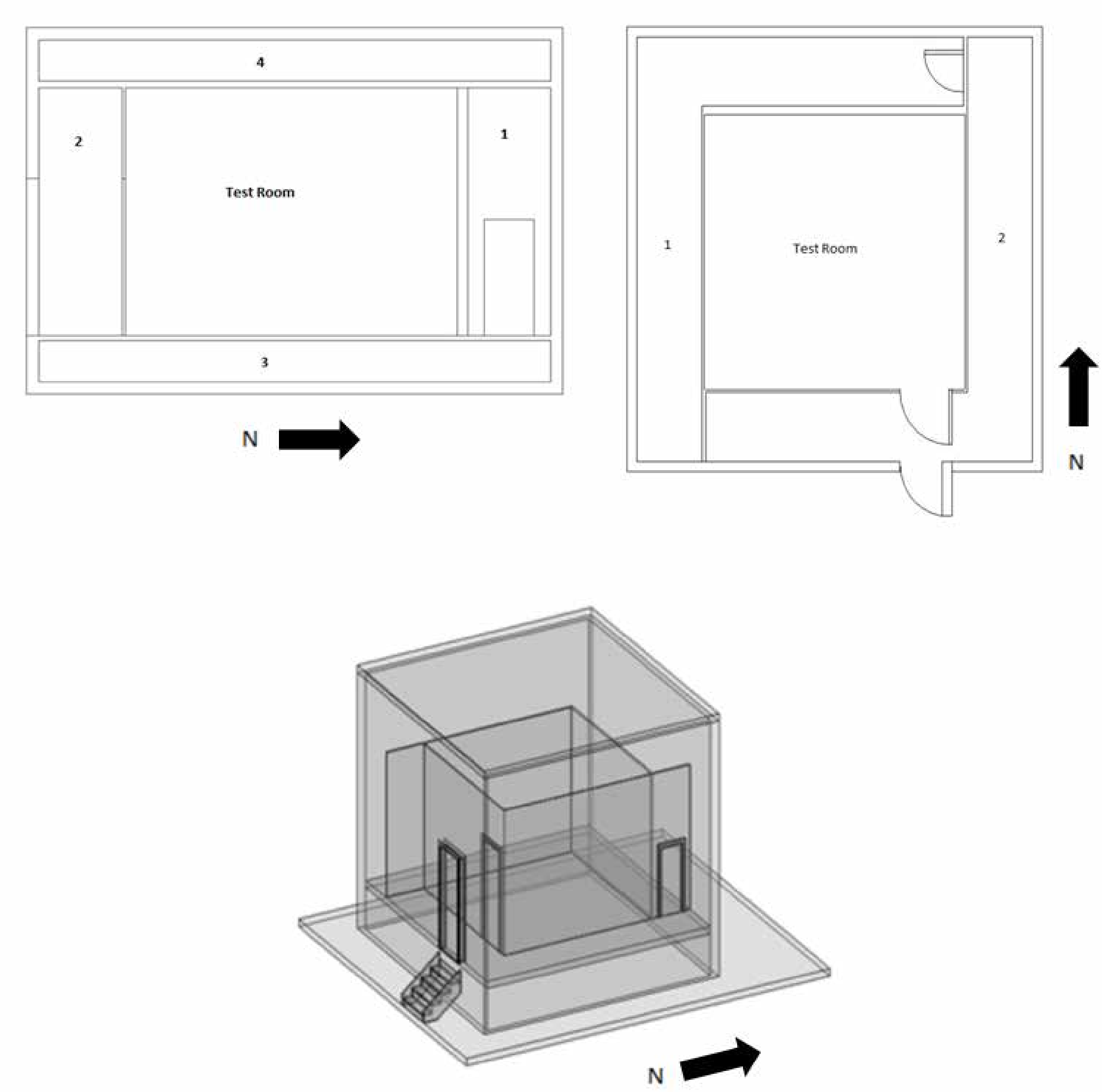

Figure 1General view of the climatic test room in 2D and 3D perspective

Table 2 Coefficient of thermal transmittance of surfaces

Surfaces	U (W/m²K)
Ceiling	0.3
Floor	0.4
North Wall	0.4
West Wall	0.4
East Wall	0.8
South Wall	0.8

2.2. Hydraulic circuit andradiant panels

The temperature of the water pumped to the radiant panels may differ according to the heating season for different climatic conditions. A water conditioning system was used in the test chamber to circulate the water in the panels for all the case studies in order to get more reliable results at the end of this research.

As shown in Fig. 2, the inlet water, which accesses to the system through the tank (the water temperature is obtained by means of a chiller for the cooling case and by means of electric resistances for the heating case), firstly comes to a four-way valve. Here, the four-way valve provides a mixture through a return pipeline. The mixed water temperature leaves the four-way valve so as to be equal to the water inlet temperature and enters the pump to supply the needed pressure. After the pump, the water comes to a three-way valve. The purpose of the three-way valve is to return excess of the fluid back so as to be equal to fix the flow rate when the water which comes from the pump has a higher flow rate than required. Then, the fluid passes through the flow meter, where the volumetric flow rate was measured. The data for the flow rate control is provided from electromagnetic flow meter. In the sequel, the water goes to manifolds and then the panel facility to activate the heat transfer mechanism. After finishing the cycle in the panels, the water comes to the four-way valve again through the return line and it is mixed with the water that comes from the tank if needed (to adjust the required temperature of the fluid).

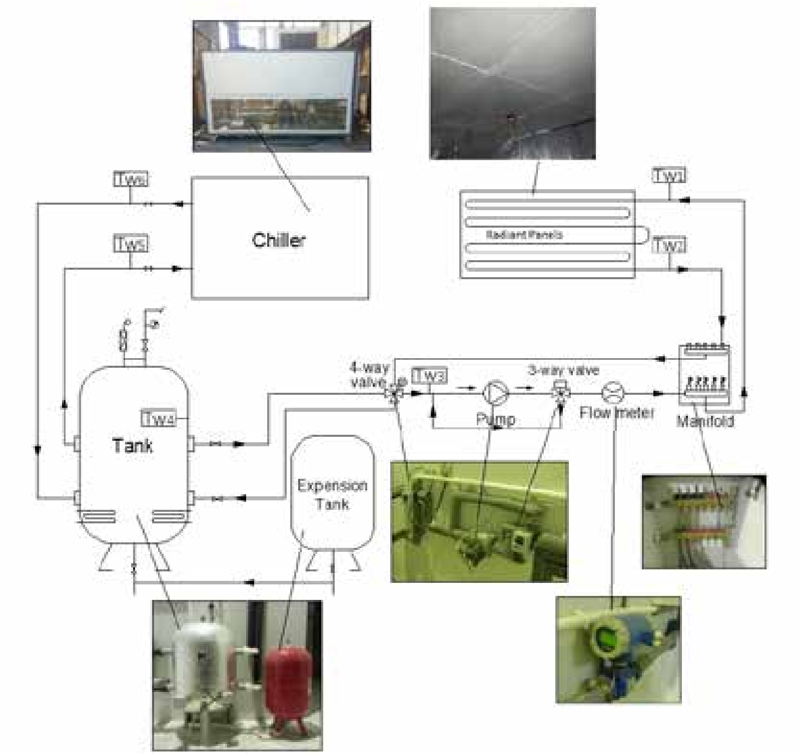

Figure 2. Hydraulic system

Radiant wall/ceiling panelsweredesignedwhich consist of three layers are drywall, heating pipe serpentine and insulation; from inner to outer layers.The thickness of the drywall layer is 15 mm while the panel insulation thickness is 30 mm. The serpentine has cross-linked polyethylene (PEX) pipes with a 10.1 mm external diameter and 150 mm pipe spacing. Expanded polystyrene (EPS) is used as an insulation material which has a coefficient of thermal transmittance value of 0.035 W/mK (at 10˚C).

2.3. The Measurement Equipment

The indoor air temperatures of the test chamber will be measured by using K-type thermocouples (chromel-alumel), which are located vertically 10 cm, 110 cm, 170 cm and 250 cm above the floor and placed in two different positions symmetrically with respect to the centre of the room. In this way, uncertainty of the temperature distribution can be decreased.When measuring air temperature, it is important to use a transducer which is shielded against thermal radiation. This ensures that the air temperature is measured and it is not an undefined combination of air and radiant temperature.

The relative humidity will be measured from two points which are at the same location with thermocouples. The indoor humidity will be measured by using a sensor with a relative uncertainty of ±3.5%. The temperature of each surface will be measured from the middle point of the walls by type K thermocouples. Four thermocouples is located on the west façade wall cross section on the same line (the radiant wall surface T_1, the insulation layer T_2, the inner surface of the façade room T_3 and the exterior surface of the volume1 and volume 2) at 1.5 m. In Fig.3 the cross-section of wall is shown. The temperature distribution of the panel surfaces will be detected by a thermal camera.

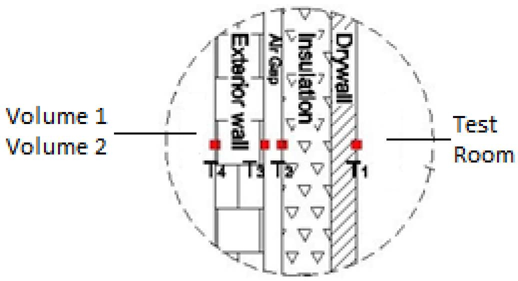

Figure 3Cross-Section of Test Room Wall

Four PT100 sensors will be used to measure the water temperature in the inlet and outlet of each of the two hydronic circuits, while electromagnetic flow meter, with a relative uncertainty of ±0.5%, are used to regulate the water flow. Thermal comfort parameters will be measured with thermal comfort measuring equipment which has four module slots, each module with three input sockets. Operative temperature, air velocity, radiant temperature asymmetry, air temperature, humidity, surface temperature, WBGT and dry heat loss will be measured with transducers connected to input sockets. These instruments will be used to evaluate thermal comfort conditions attached to a tripod located in the centre of the room at 1.1 m height as shown in Fig.4.

Figure 4 Thermal Comfort Measurement Equipment

The data from the sensors will be transmitted to the respective signal conversion panels on PXI and stored in a personal computer. The data will be recorded at every minute. The LabVIEW software, which allows the graphs of the data values to be viewed in real time, will be used to process the data. The software also provides the opportunity to set parameters and automation.

3. METHODOLOGY

The main study on the thermal comfort conditions is able to determine the conditions for achieving human internal thermal neutrality with minimal power consumption. For this purpose, the know-how of a human body's response for different environmental and air conditioning situations is needed. The present experimental set up prepared to show that how thermal comfort is effected by changing the heating surface locations in a real-sized test room. The radiant wall panels and ceiling panelswill be used for this experimental study, and the thermal comfort rates will be taken from the measurement system.

3.1. Basic theory

The heat transfer process between the surface heating panels and the room depends on the temperatures of the surfaces and the temperature characteristics of the indoor environment. Total heating capacity of the panels will be calculated from experimental measurements of water mass flow rate and water temperature difference between the inlet and the outlet of the panels.The total heat capacity of the radiant panels will be calculated from Eq. (1)$Q_{loss}Q_{loss}$ is the backward heat transfer through radiant panel to facade wall and calculated with using measured surface temperatures offacade wall layers via Eq. (2)The heat flux between the wall panel and the room was calculated subtracting from the total heat flux the backward heat transfer toward the facade room.

$$Q_{total} = \dot{m}c_p(T_i - T_o)\ (W) \tag{1}$$

$$Q_{loss} = UA(T_3 - T_4)\ (W) \tag{2}$$

$$q_{net} = \frac{Q_{total} - Q_{loss}}{A}\ (W/m^2) \tag{3}$$

The heat flux between the radiant surface and the room is transferred by both convection and radiation. The summation of the radiative and convective heat transfer values gives the net heat transfer amount as in Eq. (4)

$$q_{net} = q_r + q_c (W/m^2) \tag{4}$$

In order to calculate the radiative heat transfer through Eq. (5), the view factors can becalculated numerically by integrating of Eq.(6).

$$q_r = \sigma \sum_{j=1}^{n} F_{\varepsilon_{s-j}} \left(T_s^4 - T_j^4\right)(W/m^2) \tag{5}$$

$$F_{\varepsilon_{s-j}} = \frac{1}{[(1-\varepsilon_s)/\varepsilon_s] + (1/F_{s-j}) + (A_s/A_j)[(1-\varepsilon_j)/\varepsilon_j]} \tag{6}$$

The emissivity of the chamber surfaces and radiant floor surfaces, which will be used for radiant heat transfer calculations, will be estimated by the use of an infrared thermal imaging camera and calibrated thermocouples. The surface temperature will be measured by using temperature sensors. Then, the surface emissivity must be changed in the pyrometer setup in order to get the same temperature of the analysed surface as obtained before by the use of the temperature sensors [26].

Taking into consideration the net heat flux emitted from the heating panels (q_{net}) and the radiative heat flux (q_r), the convective heat flux (q_c) may be calculated on the basis of Eq. (7)

$$q_c = q_{net} - q_r (W/m^2) \tag{7}$$

3.2. Thermal comfort

The thermal comfort is, by definition, a subjective sensation; different people will express different preferences and it is preferable to use real persons to evaluate this notion. However, thisestimation method requires the use of a representative largenumber of subjects and hence can become expensive and timeconsuming. The approach used in this article study is based onexperimental data in order to obtain results on the parameters that influence thethermal comfort.
General thermal comfort is mainly related to PMV-PPD index can be expressed as mathematically and occupant's thermal sensation temperature by the whole body called as operative temperature. Fanger's PMV model [27] which is very common to calculate general thermal comfort depends on thermoregulation and heat balance theories. PMV consists of six comfort variables (metabolic rate, clothing insulation, ambient air temperature, mean radiant temperature relative humidity and air velocity) and is expressed Eq. (8) [13].

$$PMV = \left(0.303 \cdot e^{-0,036 \cdot M} + 0.028\right) \begin{bmatrix} (M-W) - 3.05 \cdot 10^{-3} \cdot \left\{5733 - 6.99 \cdot (M-W) - p_a\right\} \\ -0.42 \cdot \left\{(M-W) - 58.15\right\} - 1.7 \cdot 10^{-5} \cdot M \cdot (5867 - p_a) \\ -0.0014 M (34 - T_a) - 3.96 \cdot 10^{-8} f_{cl} \left\{(T_{cl}+273)^4 - (T_r+273)^4\right\} \\ -f_{cl} \cdot h \cdot (T_{cl} - T_a) \end{bmatrix} \tag{8}$$

PPD is expressed via Eq. (9) using PMV index value [13] :

$$PPD = 100 - 95 \exp\left(-0.03353 PMV^4 - 0.2179 PMV^2\right) \tag{9}$$

Operative temperature is not equal the ambient air temperature and is affected by surfaces and objects temperatures of indoor environment. As suggested by Olesen et al. [9], the operative temperature would be a convenient solution as reference for thermal comfort analysis. Furthermore, in EN Standard 12831 [29], the use of operative temperature is suggested also for heat load calculations. The operative temperature is measured experimentally.

3.3. Experimental programme

The most reliable analyses are those based on measurements performed in full scale test chambers. In this paper, several cases which are wall heating, ceiling heating, wall-ceiling combined heating; conventional-radiator heating will be studied experimentally. The aim of this study is to estimate how thermal comfort is affected by different heating locations for radiant heating. In addition to that radiant system and radiator heating system which is one of the most common conventional systems will be compared.

The PMV and PPD express warm and cold discomfort for the body as a whole. But thermal dissatisfaction can also be caused by unwanted cooling or heating of one particular part of the body. This is known as local discomfort [13]. Vertical air temperature profile and percentage of discomfort caused by vertical temperature difference will be investigated for each heating cases.

Water set point temperatures will be the range of 30 °C to 45 °C. In all heating scenarios, the heat output of radiant surfaces will be equalised by inlet water temperature. Furthermore a conventional heating device will be applied into one surface of the room to compare radiant and conventional heating systems.

The outside conditions of the test room will be settled at a certain temperature (3ºC) which is a winter day in Istanbul and the effect of the inlet water temperature will be investigated by changing the inlet water's properties. This test will be done for different locational configurations of heating panels.
The thermal comfort rates will be investigated for different thermal conditions and heating panel configurations. The test room which has been fulfilled with advanced test chamber measuring devices will be providing all local and general thermal comfort prerequisites to prepare the ambient conditions for experimental programme.
In accordance with the test to be performed, the façade room and ceiling set at 3ºC while the interior room and floor will be set at 20ºC for all the cases. Hence, the simulated heating load for all the cases will be kept constant. Thus, indoor air temperature varies with changing supply water temperature for all cases.

4. RESULTS AND DISCUSSION

In this part of study the concepts will be evaluated after the experimental programme is given. The main idea of this paper is clarify the preliminary study. Therefore there are not any performed results; however the following concepts will be evaluated after a set of experimental study.

4.1. Heat flux and uncertainty analysis

The measurements which will be taken for each case study is going to be used to carry out the heat fluxes and will be presented after the experimental programme.
To verify the accuracy of the measurements, EN 15377 [28] standard will be followed. The EN 15377 series is applicable to water-based embedded surface heating and cooling systems in residential, commercial, and industrial buildings, and it is applicable to systems integrated into the wall, floor, or ceiling. The recommended heating output for wall heating systems is given as follows:

$$q = 8(T_s - T_{op}) \tag{10}$$

4.2. Thermal comfort

The desired thermal environment for the real sized test room is category B as defined in ISO 7730 [13].

4.2.1. PMV and PPD

The PPD is an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people who feel too cool or too warm. The PMV and PPD for all cases will be presented.

4.2.2. Vertical Air Temperature Profile and %PD

A high vertical air temperature difference between the ankle and the head (0.1 and 1.7 m above the floor) can cause discomfort. Vertical indoor temperature distributions will be presented for all supply water temperatures.

PD% is the percentage of people dissatisfied by the vertical temperature difference which is estimated by a function given in ISO 7730. PD can be determined by using equation (12)

$$PD = \frac{100}{1 + \exp\left(5.76 - 0.856\, \Delta T_{a,v}\right)} \qquad (12)$$

Percentage dissatisfied will be introduced for all heating cases and scenarios will be compared as well.

4.2.3. Mean Radiant Temperature

Panel heating systems provide an acceptable thermal environment by controlling surface temperatures as well as indoor air temperature in an occupied space. With a properly designed system, occupants should not be aware that the environment is being heated. The mean radiant temperature (T_{mrt}) has a strong influence on human thermal comfort. When the temperature of surfaces comprising the building (particularly outdoor exposed walls with extensive fenestration) deviates excessively from the ambient temperature, convective systems sometimes have difficulty counteracting the discomfort caused by cold surfaces. Heating panels neutralize these deficiencies and minimize radiation losses or gains by the human body.

Mean radiant temperature is defined as the temperature of a uniform, black enclosure that exchanges the same amount of thermal radiation with the occupant as the actual enclosure. Mean radiant temperature will be determined by Eq. 13 which is used for operative temperature calculations normally [21].

$$T_{op} = \frac{(h_c T_a) + (h_r T_{mrt})}{h_c + h_r} \qquad (13)$$

Mean radiant temperature (MRT) is the most importantparameter governing human energy balance, with the strongest influence on PMV.

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NOMENCLATURE

A	Area (m^2)
c_p	Specific heat at constant pressure ($J\ kg^{-1}\ K^{-1}$)
f_{cl}	Clothing area factor
F_{s_s-j}	Radiation interchange factor
F_{s-j}	View factor between radiant surface and j-surface
h_c	Total heat transfer coefficient ($W\ m^{-2}\ K^{-1}$)

h_r	Radiation heat transfer coefficient (W m-^{2} K^{-1})
h_{tot}	Convective heat transfer coefficient (W m-^{2} K^{-1})
$\dot{m}$	Mass flow rate (kg m^{-3})
M	Metabolic rate
p_a	Water vapor pressure in the air
PMV	Predicted Mean Vote
PPD	Predicted percentage of dissatisfied (%)
Q_{total}	Total heat transfer (W)
Q_{loss}	Backward heat transfer (W)
q_c	Convective heat flux (W m^{-2})
q_{net}	Net heat flux (W m^{-2})
q_r	Radiation heat flux (W m^{-2})
T_a	Air temperature (°C)
T_{cl}	Clothes surface temperature (°C)
T_i	supply water temperature (°C)
T_j	j-surface temperature (°C)
T_{mrt}	Mean radiant temperature (°C)
T_o	return water temperature (°C)
T_{op}	Operative temperature (°C)
T_s	Surface temperature (°C)
T_w	Water temperature (°C)
U	Coefficient of thermal transmittance of surfaces (W m^{-2} K^{-1})
WBGT	Wet bulb globe temperature
ε	Emissivity
σ	Stefan-Boltzmann constant (W m^{-2} K^{-4})

REFERENCES

[1] A.M. Omer, Energy, environment and sustainable development, Renewable and Sustainable Energy Reviews, 2008; 12,2265–2300.

[2] Sharma A, Saxena A, Sethi M, Shree V, Varun. Life cycle assessment of buildings: a review. Renew Sustain Energy Rev 2011; 15, 871–5.

[3] Xiao F, Wang S. Progress and methodologies of lifecycle commissioning of HVAC systems to enhance building sustainability. Renew Sustain Energy Rev 2009;13:1144–9.

[4] Lollini, Barozzi, Fasano, Meroni, Zinzi, Optimisation of opaque components of the building envelope, Energy, economic and environmental issues, Building and Environment, 2006; 41, 1001–1013.

[5] Hepbasli A., Low exergy (LowEx) heating and cooling systems for sustainable buildings and societies, Renewable and Sustainable Energy Reviews, 2012, 16, 73-104

[6] Stetiu, C. Energy and peak power savings potential of radiant cooling systems in U.S. commercial buildings, Energy and Buildings 30 (1999) 127-138.

[7] Franc S. Economic viability of cooling ceiling systems, Energy and Building 30 (1999) 195-201.

[8] Imanari, T, Omori, T, and Bogaki, K. Thermal comfort and energy consumption of the radiant ceiling panel system: Comparison with the conventional all-air system, Energy and Buildings 30 (1999) 167-175.

[9] B. Olesen, Radiant floor cooling systems, ASHRAE J. 50 (9) (2008) 16–22.

[10] ASHRAE Handbook—fundamentals. Panel heating and cooling. ASHRAE: Atlanta; 2008 (Chapter 6) ASHRAE

[11] Miriel, J., Serres, L., and Trombe, A. 2002. Radiant ceiling panel heating-cooling systems: experimental and simulated study of the performances, thermal comfort and energy consumptions. Applied Thermal Engineering 22 (2002): 1861–1873.

[12] ANSI/ASHRAE Standard 55-2004: Thermal Environmental Conditions for Human Occupancy.

[13] EN ISO 7730, Moderate thermal environments - determination of the PMV and PPD indices and specification of the conditions for thermal comfort. Geneva: ISO; 1994

[14] D. Saelens, W. Parys, R. Baetens, Energy and comfort performance of thermally activated building systems including occupant behavior, Building and Environment 46, (2011) 835–848.

[15] Ghaddar N, Salam M, Ghali K. Steady thermal comfort by radiant heat transfer: the impact of the heater position. Heat Tran Eng 2006;27(7):29-40.

[16] Myhren JA, Holmberg S. Flow patterns and thermal comfort in a room with panel, floor and wall heating. Energy Build 2008;40(4):524-536.

[17] Nagano K, Mochida T. Experiments on thermal environmental design of ceiling radiant cooling for supine human subjects. Building and Environment, 2004;39:267–75.

[18] Kitawaga K, Komodo N, Hayano H, Tanabe S. Effect of humidity and small air movement on thermal comfort under a radiant cooling ceiling by subjective experiments. Energy and Buildings June 1999;30(2):185–93.

[19] Catalina T., Virgone J., Kuznik F., Evaluation of thermal comfort using combined CFD and experimentation study in a test room equipped with a cooling ceiling, Building and Environment 44, (2009), 1740-1750.

[20] Memon R. A., Chirarattananon S., Vangtook P., Thermal comfort assessment and application of radiant cooling: A case study,Building and Environment 43, (2008), 1185–1196.

[21] ISO 7726. Ergonomics of the thermal environment - instruments for measuring physical quantities. Geneva: International Standardization Organization; 2002.

[22] d'Ambrosio Alfano FR, Marco Dell'Isola, Palella BI, Riccio G., Russi A.,On the measurement of the mean radiant temperature and its influence on the indoor thermal environment assessment, Building and Environment 63, (2013), 79-88.

[23] Kalmar F., Kalmar T., Interrelation between mean radiant temperature and room geometry, Energy and Buildings 55, (2012), 414–421

[24] De Carli M., Scarpa M., Tomasi R., Zarrella A., DIGITHON: A numerical model for the thermal balance of rooms equipped with radiant systems, Building and Environment 57, (2012), 126-144.

[25] TSE 825, Thermal insulation requirements for buildings, Turkish Standards, May 2008.

[26] T. Cholewa, M. Rosinski, Z. Spik, M.R. Dudzinska, A.Siuta-Olcha, On the heat transfer coefficient between heated/cooled radiant floor and room, Energy and Buildings, 66(2013) 599-606

[27] Fanger PO. Thermal comfort. NY: McGraw-Hill; 1972

[28] EN 15377-1, Heating Systems in Buildings – Design of Embedded Water Based Surface Heating and Cooling Systems – Part 1: Determination of the Design Heating and Cooling Capacity, 2008.

[29] BS EN 12831, Heating systems in buildings — Method for calculation of the design heat load, 2003

Paper No: 26

Assessment of Summertime Thermal Comfort in University Classrooms

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ABSTRACT

One of the most fundamental issues affecting the learning efficiency for students is comfortable working environment. There are two main factors affecting thermal comfort. One of them is indoor environmental factors such as air temperature, humidity, air velocity and radiant temperature. Another is personal factors: clothing insulation and metabolic rate. Environmental factors are closely related to the design of buildings. The aim of the study was to analyze the summer thermal comfort conditions in university classrooms in Balikesir – Turkey. A faculty building in Balikesir University was selected as the case study representing an educational center which is a naturally ventilated building. DesignBuilder-v4 simulation program was used to model and perform simulations. Results were evaluated by using discomfort hours calculated based on ASHRAE-55-2004 throughout the year. Different strategies were applied on current model then results were compared to examine its effect on the thermal comfort. The selected strategies were energy efficient glazing and shading device. The results showed that it is very important to understand interactions of glazing and shading to optimize summer thermal comfort conditions in classrooms. It was also observed that the combinations of Double Solar-Low-e Clr-4mm/12mm. Air and shading (louvre) is the best strategy to reduce discomfort hours.

Keywords: Thermal comfort, university building, simulation

1. INTRODUCTION

Today, the most important tool for development, which is accepted as the primary function of education is to provide improvements to people based on their ability [1]. Universities is a spaces for vocational training which is mainly given to young people and provide undergraduate and postgraduate education [2]. Besides the need for the program, special requirements should be taken into account in universities. Thermal comfort is one of the special requirements. General comfort which is the significant factor affecting body balance and business efficiency can be achieved by ensuring the all proper conditions related to humidity, temperature, illuminance, and acoustic [3].

All living things perform heat exchange between them and with their environment. Thermal comfort is a mental process indicating satisfaction with environment. It is one of the major factors affecting human performance and productivity because level of basic conditions for good and efficient working of the human body is to keep body temperature at normal level. For example, weariness, inattention, inefficiency may occur in people when air temperature increased above thermal comfort value. These problems can affect the learning capacity of the students.

Factors determining the thermal equilibrium of the human body; the physiological mechanisms of body heat balance, personal and environmental factors can be grouped under three headings. Personal factors are regulated by the individuals themselves. Clothing and metabolic rate are the personal factors. Environmental factors are air temperature, humidity, air velocity, and radiant temperature [4]. They should be met by buildings.

To feel comfortable in the environment energy produced in the body should be equal energy excreted from the body to the environment. The body to keep the deep temperature at 36.8 °C has complex physiological control mechanisms [5].

This study focuses on classrooms in university building as they represent a significant part of naturally ventilated educational building stock in Turkey. Thus, this research gives an insight into summer thermal comfort for public university classrooms in Balikesir through a series of building simulation because classrooms do not have an air conditioning system for cooling. The primary aim of this study is to assess summer thermal comfort conditions and is to investigate impact of glazing and shading device on thermal comfort.

2. METHODOLOGY

2.1. AREA OF STUDY

Balıkesir University is an institutional campus in the rural region of Balikesir experiencing a hot summer Mediterranean climate. The maximum air temperatures during summer (May and August) varies between 24.6 °C and 31.4 °C and the minimum air temperatures during winter (November and February) varies between 1.3 °C and 5.8 °C [6]. All the studied classrooms are naturally ventilated. Windows are double clear glazing and window to wall ratio is 0.43. There is no solar protection in windows.

2.2. MODELING AND SIMULATION

The analysis of this research is mainly concerned with evaluating the existing status of thermal comfort condition, according to discomfort hours within classrooms which belong to Balikesir University. Discomfort hours show the time when the combination of zone humidity ratio and operative temperature is not in the ASHRAE 55-2004 [7] summer or winter clothes region. A typical faculty building was selected to act a case study. It has a total area of 4100 m^2, is four-store height. Modelling and simulations were made by using DesignBuilder v4 software [8]. It is a kind of interface of EnergyPlus [9]. Overall heat transfer coefficients of all building components were showed in Table 1. The building is occupied from 8:30 to 17:30 during summer season. It was assumed a total of 50 students and one lecturer in each classroom. All simulations are performed between May and August. There is no air-conditioning system in classrooms.

Table 1 Overall heat transfer coefficients of construction layers

Component	Layers	U value (W/m^{2}K)
External wall	Plaster, aerated concrete, plaster	0.86
Internal wall	Plaster, brick, plaster	1.58
Flat roof	Plaster, concrete floor, glass wool, roof covering	0.83
Ground floor	Covering, cement finish, ground floor, water insulation, lean concrete	1,9
Internal floor	Plaster, concrete floor, plaster	2,45

Two window types and one solar control equipment were selected in order to assess the thermal comfort in classrooms. Window types are Double Low-e Clr 4mm/12mm Air and Double Solor Low-e Clr 4mm/12mm Air. They were chosen as a representative selection of available windows on Turkish market. The shading devices adopted in this study were external fixed louvers used on the west and east windows. Table 2 describes the parameters of windows at standard conditions.

Table 2 The properties of studied window types [10]

Window type	U-value	SHGC	g-value
Double Clr 4mm/12mm Air (Current)	2.761	0.761	0.812
Double Low-e Clr 4mm/12mm Air	1.6	0.56	0.79
Double Solor Low-e Clr 4mm/12mm Air	1.6	0.44	0.71

The first step for constitute model is to determine thermal zones of the building. Each floor was divided into 14 thermal zones, representing 8 classrooms, 1 circulation area, laboratory, store room, computer lab and 2 toilets. The final model is composed of 42 thermal zones. Figure 1 indicates the thermal zones divisions, which are the same for each floor. Hourly weather data of Balikesir, in TMY form was created by using METEONORM [11].

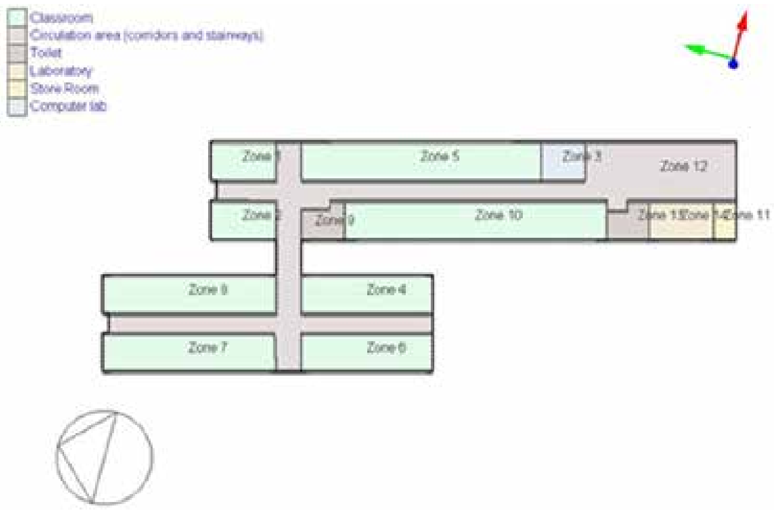

Figure 1 Thermal zones in the model

3. RESULTS AND DISCUSSIONS

All results are presented in Fig. 2. It can be observed that Ground-z5 with double clear window has 916.5 discomfort hours. It corresponds to 31% of total hours. This zone is located on the ground floor and is east oriented. The zone that has the maximum numbers of discomfort hours is Second floor-z5 with double clear window, representing 919.5 discomfort hours during the summer season. z7 in all floors has approximately 880 discomfort hours. Ground, first and second-z10 achieved an average of 2083 comfort hours against 869 of discomfort hours. These results indicate the actual building. It is clear that there is no important difference between floors in terms of discomfort hours. In addition, the difference based on orientation is only 1%.

The average discomfort hours in z5-ground-first-second floors decreased 3% when replacing the glazing with double low-e glazing. This glazing has 0.56 SHGC (solar heat gain coefficient) value. It directly affects gain from solar radiation. Thus, comfort hours increased. In z7i increased rate is only 1.3%. They are 3.2% and 1.7% in z8 and z10 respectively.

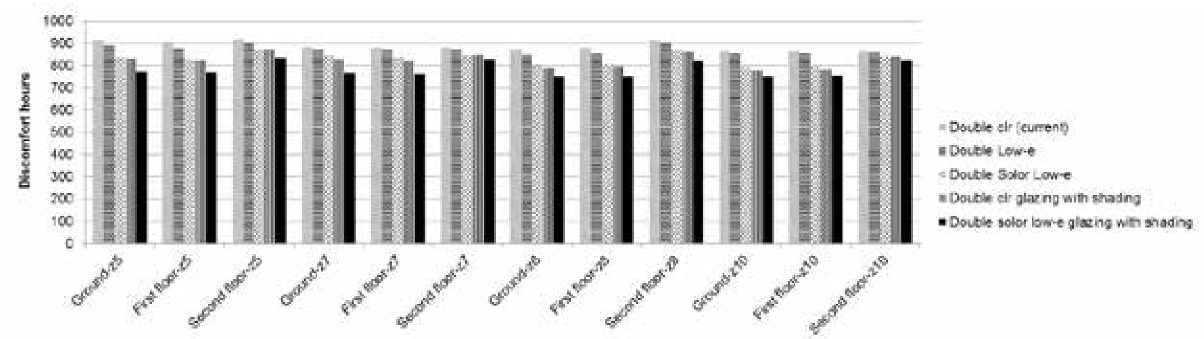

Figure 2 Discomfort hours based on energy efficient strategies

By using the double solar low-e glazing in windows of the same base case, the discomfort hours for z5, z7, z8 and z10 decreased 9%, 4.7%, 8.8% and 8.7% respectively. And the average discomfort hours decreased 7.8%. SHGC value of this glazing is 0.44.

Combinations of glazing and shading were investigated. These combinations are double clr glazing with shading and double solar low-e glazing with shading. In these cases, the shading includes only 0.5m louvers for east and west windows. The combination of double clr glazing with shading achieves a 9.2%, 6.5%, 9.7% and 10.3% average reduction in discomfort hours for z5-7-8-10 respectively. Double solar low-e glazing with shading is the best combination. This case reduces discomfort hours to 771 (15.8%), 765.5 (13.3%), 750.5 (14.5%) and 750 (13.5%) for z5-7-8-10 respectively. Shading has greater effect on increasing comfort hours in classrooms. It is clearly a significant measure to increase summer comfort conditions. Its positive impact can be increased with suitable glazing usage.

4. CONCLUSIONS

This study analyzed the thermal comfort of naturally ventilated classrooms located in the city of Balikesir, Turkey. The evaluation based on simulations using DesignBuilder v4 and ASHRAE 55-2004. The results are summarized below;

1. Floor level does not have an important impact on thermal comfort in classrooms.
2. Usage of glazing having low SHGC value may reduce the number of discomfort hours in summer season in classrooms, but it may also decrease solar heat gains in winter.
3. Classrooms on East and West orientations showed insignificant difference in terms of comfort conditions.
4. Shading plays an important role in reducing the number of discomfort hours. Based on the combination of glazing type and shading, the possible reduction could easily be more than 15% too high.

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REFERENCES

[1] Özbulut, H., (1999), 1980 Sonrası Dönemde Ortaöğretim (Lise) Tip Binalarının Ankara'da Uygulanmıs Üç Örnek Aracılığı ile Değerlendirilmesi, Gazi Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, Ankara.

[2] MEB, (1998), Ilköğretim El Kitabı, Ankara.

[3] Yüksel, N. (2005) "Günümüz kamu kurumlarında yapısal konfor koşullarının tespit edilmesine yönelik bir çalışma" Uludağ Üniversitesi Mühendislik-Mimarlık fakültesi Dergisi, 10 (2) 21-31.

[4] Öngel, K ve Mergen, H. (2009) "Isıl Konfor Parametrelerinin İnsan Vücudundaki Etkilerine Yönelik Literatür Taraması" Süleyman Demirel Üniversitesi Tıp Fakültesi Dergisi, 16 (1) 21-25.

[5] Atmaca, İ ve Yiğit, A. (2009) "Isıl Konfor İle İlgili Mevcut Standartlar ve Konfor Parametrelerinin Çeşitli Modeller ile İncelenmesi" IX. Ulusal Tesisat Mühendisliği Kongresi. 6-9 Mayıs, İzmir.

[6] Turkish State Meteorological Service. http://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=BALIKESIR [02.02.2016].

[7] ASHRAE, 2004. ANSI/ASHRAE Standard 55-2004: Thermal Environmental Conditions for Human Occupancy. Atlanta, 2004.

[8] DesignBuilder documentation, DesignBuilder user manual, version 1.2. UK: DesignBuilder Software Limited; 2006.

[9] EnergyPlus software, U. S. Department of energy, http://apps1.eere.energy.gov/buildings/energyplus [01.01.2016].

[10] SİSECAM Flat Glass Company. http://www.isicam.com.tr/isicam_sinerji [22.12.2015].

[11] Meteonorm, http://meteonorm.com/products/meteonorm/ [12.06.2016].

Paper No: 65

Optimal Municipality Building Program Parameters in Turkey for Having Performance Based Design Approach

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ABSTRACT

According to energy demands, the distribution shows that the buildings have 35% percentage of total energy consumption and causing roughly 25% of the global CO2 emissions. In the highlight of this knowledge, the Covenant of Mayors' projects is implementing in all the world by municipalities to reduce CO2 emissions at least by 20% by 2020 since 2007. Also, Turkey aimed to reach and exceed the 20% of CO2 reduction objective in the boundaries of their districts by 10 municipalities; 2 of them as metropolitans and 8 of them as districts recently. The importance of municipal buildings are obvious, they will be the best case example for citizens living in that district. Therefore the main focus of this study is the municipal buildings as working office type building which designed by architectural competitions in Turkey. The aim of this study is to find the optimum program of buildings by assessing of 22 municipal building architectural competitions in order to create a guide of the design stage. Furthermore, this study will be the first investigation about the performance-based municipal building design to achieve energy efficiency level for office type buildings. The significance of the study is to set a frame related to municipal building program during the design stage.

Keywords: *municipal building, performance-based design, program parameter*

1. INTRODUCTION

Increasing of energy consumption and CO2 emission became a global problem all over the world recently. Therefore the local and regional authorities are volunteers to reduce CO2 emissions at least by 20% by 2020 based on European Council (Directive 2002/91/EC) like as Covenant of Mayors projects [1]. Turkey has also participants in Covenant of Mayor via 10 municipalities as 2 metropolitans and 8 districts [2]. Moreover, the number of Energy Cities projects are increasing and applying in Turkey as a part of more than 1000 local authorities from 30 countries. Principally municipalities support this project, but also inter-municipal structures, local energy management agencies, municipal companies and groups of municipalities are participants. 6 municipalities are supporter and practitioner from Turkey [3].

In this regard, the municipalities have a key role in building sector to authorize influentially by controlling building energy performance in the boundaries of their districts. Also, a municipality should be a sample for building sector as a role model via their buildings. So many studies are related to the government buildings. One of these about the government office buildings in China case, government office buildings, and private offices are just two of the major objectives. Xu, et al. examined that how much energy these are consuming. Finally, they achieved that government offices are more wasteful than private sector offices. Although all of this kind of studies are related to the material and mechanical system design alternatives, there are not any research regarded the program design for municipal building [4]. For this reason, the main problem is the absence of guide for building programs which belong municipal buildings. Besides that, creating performance-based buildings needs initially creating an optimum program. After the program optimization, designs can be developed to reach energy efficiency level. Therefore the main focus of this study is creating municipal buildings' program with adequate areas by using architectural competitions in Turkey.

As explained below, generally the departments of the program are set by rules and regulations in Turkey, in the fact that show some distinctions depend on population, culture, location etc. However, some program deficiency can cause designing unnecessary spaces at municipal buildings. In other words, unnecessary spaces mean unnecessary energy consumption and low performance-based design. Because of that, requirements of the program are searched on municipal buildings which designed by architectural competition in this study. So, the main goal of this study is to obtain the guide for new Municipal buildings in order to prevent designing dispensable spaces and consuming dispensable energy. Further research may be reached to design sustainable municipal building in terms of energy efficiency approach.

Municipal building is a public office building. So, the design principles of municipal buildings are mainly based on a literature review by describing office buildings and regulations. Finally, the assessment of results is given by comparing program between standards and specifications of competitions on the existing situation. Totally 22 municipal buildings are investigated which are classified as metropolitan (5), provincial (5), and district (12) municipal buildings.

The comparison will give information about the optimum area needs for each department, which ones are mandatory or optional departments for each kind of municipalities, how many square meters municipal building needs on an average, what the differences are between each municipal level.

1.1 Optimization Building Program for Performance-Based Approach

Energy efficiency is studied in the highlight of creating a sustainable program guide. So the parameters of energy efficiency should be investigated from beginning of design to the end of construction application. In this context, program design is the starting point as a guide for future works based on designing energy efficient & performance-based municipal buildings.

According to previous studies, creating optimum building program as a sort of design stage parameter is the main precaution for energy efficiency which may be taken at the design stage, rather than during construction stage. Some of these studies attend to energy reduction strategies; but just as Lobato's (2011) main approach, the most effective intervention is at the beginning of the design stage [5]. For another example, the China Building Energy Standards examine buildings with two main topics as design stage and post occupancy. "Design Stage" includes *design standards* for commercial buildings (office buildings, hospitals etc.), for daylighting design of the building, for lighting design of building and evaluation standard for green buildings. "Post-Occupancy" includes a standard for building energy performance certification, standard for consumption of buildings [6].

This study will be the first part of a master thesis about creating parameters for sustainable municipal building design in İzmir case, Turkey. The thesis is trying to create a guide for achieving optimum energy consumption by simulating a real case municipal building based on energy performance. So this study is examining the building program as a parameter of the early design stage.

2. MUNICIPALITY BUILDINGS

In the literature, the office is a general term which has the same meaning as bureau term. Nowadays the office term is using in contemporary bureau approach [7]. In this study, the main description of the bureau is working places where are editorial and administrative departments; the builds of the bureau are satisfied the expectations of bureau necessities, office builds [8]. According to the economic or managerial classification of office buildings, there are two main branches as administrative office buildings and commercial office buildings. Administrative office buildings service for commerce, industry, cultural or political jobs. Also, administrative office buildings are dividing into two as public and private buildings [9]. According to Varlı's table of office classification, municipal buildings are under the public office buildings branch as a local government building [7]. We are using the "office" term to explain municipal buildings

By the way, the main aim of office buildings is giving a sustainable work life with comfortable, humanist, and healthy circumstances. As one of the main objectives, this study is trying to achieve office's aim investigated by sustainability issue upon municipal buildings.

2.1. Necessity Department Analysis

The municipal building program just exists as units name in literature. Meanwhile, there is not an adequate source to find optimal area needs of buildings for municipalities. On the other hand, Akbulut (2005) have searched and classified municipality service departments based on the other studies about the municipality [10]. Akbulut's study is examined the real case municipal buildings and after decided this classification which divided into main 6 units like below explanation:

1.Administrative Departments:

- Mayor of Municipality
- Vice-Presidents of Municipality
- Private Secretariat

2.Developmental Departments:

- Local Planning Authority
- Directorate of Cartography
- Built Control and Housing Department
- Directorate of Real Estate
- Searching, Planning, Coordination Department

3.Productive and Applied Departments:

- Public Works and Engineering
- Cleaning Service

- Park and Gardens Department
- Woodworking department
- Machine Repair and Maintenance Department

4.Management Departments:

- Editorial Department
- Human Resources Department
- Department of Legal Affairs
- Information Processing Department
- Council Department
- Financial Service (accounting) Department

5.Social-Cultural, Educational Departments:

- Civil Defense Department
- Kindergarten Department
- Handicapped Department
- Department of Marriage
- Department of Health and Social Affair
- Veterinary Department

6.Consultancy and Controller Departments:

- Traffic and Municipal Police Department
- City Council [8].

3. REGULATIONS and COMPETITION's SPECIFICATIONS

By means of the comparison between regulation and competition programs, optimum municipal building programs included area square meter details will be attainable. In this chapter will be given information about municipality rules, regulations, and architectural competition programs. The main focus of this is to understand the existing situation and limitations of municipality power and building's requirements.

Just as explained Rezessy (2006) review study about municipality and energy efficiency in Bulgaria, Hungary, and Macedonia, municipalities have a power with their statutory obligations dealing with an energy-related task:"*1. Ownership and operation of municipal institutions,2.Ownership and operation of district heating, 3.Ownership and operation of street lighting systems, 4.Urban planning *Elements of local government finance: 1.Stability and predictability of budgetary revenue: taxes and state subsidies, 2.Ease of access to non-budgetary sources*" [11]. By the help of knowledge about "*Ownership and operation of municipal institutions*" by municipalities, this paper is interested in that task.

Municipalities have a power and a design maker position in also Turkey. When we check the Turkey municipality definitions, you may see more detailed responsibility tasks below. According to 1580 code of legislation about municipalities; the municipality is a legal entity who is in charge of arranging and providing the necessities of the population located in its boundary. Therefore, municipalities have some tasks and authorities;

- To build or get bazaar place, pier, bridge built
- To give approval and permission for all built, maintenance, restoration etc.
- To establish the educational and cultural built such as theater, library, and concert hall.
- To build shops for wholesale and retail sale
- To build municipality guest house, hotels, wedding hall, car parking, cold storage house, bakery, gas station etc. in qualifying conditions
- To build municipality service buildings and similar buildings
- To determine water, natural gas, and electric bills producing by municipalities

Aforementioned by regulations, municipalities are responsible for build their administrative buildings likewise the other kind of buildings in their boundaries [12,13]. Obviously, the influence of municipalities is extremely important for public awareness to be a sample in the highlights of energy efficiency.

Moreover, the given services may be various by municipalities. Because the classification of municipalities is in 6 main groups depend on the inhabitants how many these have. Within this study just consists of 4 of them as metropolitan municipalities (Group A), provincial municipalities (Group B), metropolitan district municipalities (Group C), and district municipalities (Group D) [13] due to 22 total municipal buildings.

3.1 Regulations of Municipality Types

In the regulations, municipality standards and regulations depend on norms and employees. These standards contain mandatory and optional staff details such as numbers and positions according to municipality class. This employee information shows essential departments in municipal building due to arranging population and their needs. While assessing, these departments are used to compare with specifications of architectural competitions [14].

Metropolitan Municipality

According to norms and staff about the municipality, the class of metropolitan municipalities are named as A (A1 to A6). The main differences are numbers of staff and some department needs of municipalities changing due to population ratio. [14]. According to Appendix of the source this regulations, you may reach all details about department norms.

Provincial Municipality

The provincial municipalities are in B class based on norms and staff regulations (B1 to B8). These municipalities differ than metropolitans in terms of mandatory departments such as editorial, environmental protection, and veterinary etc. [14].

District Municipality

The district municipalities are in C and D group, because of the Group C is metropolitan district municipalities, Group D is district municipalities [14].

Summarizing of regulations; from metropolitan to district municipality regulation details show that the mandatory department number is decreasing despite increasing number of optional departments. According to that, needs of inhabitants influence program design in terms of standards and regulations. Below tables, you may see the detailed departments for each municipality.

3.2 Architectural Competition Specifications of Municipal buildings

The architectural competitions are using in a widespread manner to find the best approach in a case and build it. If we look through the municipality programs, architectural competitions help to find proposed area needs. Furthermore, the architectural competitions are usual in Turkey to design and to build municipality built environment.

Therefore this study is investigating 22 municipal buildings programs chosen by competitions in between 1985-2015. Based on the previous chapters, total 22 buildings are distributed like as; 5 of them are metropolitan, 5 of them are provincial and 12 of them are district municipal buildings [15].

Metropolitan Municipal buildings

According to the investigation, metropolitan municipal buildings are Tekirdağ (2015), İstanbul (2001), Ankara (2000), Gaziantep (1986), Ankara (1985). Ankara is the capital of Turkey and also one of the 3 biggest cities in Turkey, likewise İstanbul. So that Ankara and İstanbul became a metropolitan city in 1984 by 3030 code of legislation. And then Gaziantep became a metropolitan city in 1987 depends on 3398 code of legislation. The last city Tekirdağ became a metropolitan city by 6360 code of legislation in 2011. Therefore these all cities are investigated in this branch of classification [16].

Provincial Municipal buildings

The population data of cities are determined by TUIK (Turkey Statistic Corporation) in 2011 and the new legislations were accepted about the approval of being new metropolitan cities in 2012. According to that; Manisa, Trabzon, and Aydın became metropolitan municipalities in 2012. However, the competitions of these municipalities were done before 2012. So that, these municipalities are assumed as in provincial municipality table. If we put the line under 2012, the chronological range looks like that Manisa (2011), Manisa (2005), Karabük (2005), Trabzon (1996), Aydın (1992) respectively [17].

District Municipal buildings

The district municipalities have 2 main branches as metropolitan district municipalities and district municipal buildings. According to standards, there are two groups which are C and D group of municipalities. In this study, 12 district municipal buildings are investigated which are İzmir-Konak (2015), İzmir-Bornova (2015), Antalya-Gazipaşa (2013), Adana-Çukurova (2011), Osmaniye-Kadirli (2009), Diyarbakır-Yenişehir (2005), İstanbul-Pendik (2005), Eskişehir-Tepebaşı (2004), Kocaeli-Derince (1997), Ankara-Çankaya (1995), Kayseri-Kocasinan (1991), Ankara-Altındağ (1986) [18].

4. ASSESSMENT OF COMPARISON

Assessment results demonstrate that the regulations match with specifications in terms of the mandatory and optional department, although the names of departments have variety between in regulations and specifications. Moreover, the results show the mandatory departments are almost half of the specification programs. The main reason is that on the contrary common obligatory needs, specifications may differ regional differences dependent on the social and cultural needs of the local population.

Except the mandatory,

- Metropolitan municipal buildings have general archive, dining hall, prayer room, blueprint & copy room, multi-purpose hall and close parking area in the rate of 80%-100%;
- Provincial municipal buildings have general archive, dining hall, canteen & café, blueprint & copy room, kindergarten, commercial service area and close parking area in the rate of 80%-100%;
- District municipal buildings have a general archive, reserve department, blueprint & copy room, multi-purpose hall and close parking area in the rate of 60%-100%.

Considering all, we may obtain each type of municipal building needs on average 34404 m^2 area for per metropolitan municipal building, 10500 m^2 area for per provincial municipal building, 11587 m^2 area for per district municipal buildings as given below Table 1,2 and 3. These tables give a chance to attain all departments/ units square meters. Therefore, when municipalities need program requirements during the design stage, they may use this study as a guide for their new design in order to achieve energy efficient/ performance-based design approach.
In addition, this study is able to reach the average square meters per person who is living in the region of each municipality types by means of using population number. The municipal buildings have 0,33 m^2 area per capita for metropolitan; 0,02 m^2 area per capita for provincial; 0,07 m^2 area per capita for the district who are living in their boundaries. As a result, district municipalities have more space per person in their buildings despite having less population. According to the area of responsibility in metropolitan regions which is wider than others and also containing other's area of responsibility, these results make sense as districts are in the lowest level in terms of municipal hierarchy. And also, the worldwide energy is comparing per capita energy use. So the results of per capita usage are significance for further studies' energy use per capita.
When looking toward from metropolitan to districts by examined mandatory and optional spaces, the number of department increases. The main reason is increasing and changing of the requirements depends on the area of municipal responsibility and social life of the population. The metropolitan municipalities should have more general responsibility than districts by keeping some boundaries against to more detailed requirements. And also, metropolitan municipalities have a responsibility of province and regions. The optional departments ought to be more in the small scale municipalities in order to solve problems and to serve better. Even if the department variety is less, the required space areas are larger in metropolitan because of the needs of the employee to serving the crowded population.

Table 1. Metropolitan Municipal Building Program *

Metropolitan Municipal Buildings		**Total Area**	**Evaluate Building**	**Average Area**
***Standard Departments**	**Specification Program Departments**	17202	5	**34404,40**
Directorate	Directorate	1499	5	**299,80**
Private Secretariat	Private Secretariat	862	5	**172,40**
Office of Secretary	Office of General Secretary	2108	5	**421,60**
Supervisory Board	Supervisory Board	2539	5	**507,80**
Human Resources	Human Resources	3572	5	**714,40**
Public Information Agency	Public Information Agency	2192	5	**438,40**

Municipal Police	Municipal Police	5810	5	**1162,00**
Environmental Protection	Environmental Protection	5242	5	**1048,40**
Works & Engineering	Public Works & Engineering	12918	5	**2583,60**
Editorial Department	Editorial Department	2610	5	**522,00**
Legal Affairs	Legal Affairs	3057	5	**611,40**
ICT	Information and Communication Technology	3507	5	**701,40**
Local Planning	Local Planning Authority	13803	5	**2760,60**
Financial Services	Financial Services	10856	5	**2171,20**
Support Services	Support Services	5684	5	**1136,80**
Cultural & Social Affairs	Cultural &Social Affairs	5624	5	**1124,80**
Plan And Project	Plan And Project	2850	5	**570,00**
Strategy Development	Searching-Planning-Coordination	3264	5	**652,80**
Real Estate	Directorate Of Real Estate	6884	5	**1376,80**
Urban Design	Urban Renewal	2918	5	**583,60**
Traffic And Accessibility	Road Maintenance And Repair	2519	4	**629,75**
Municipal Health Services	Municipal Health Services	9502	5	**1900,40**
Fire Department	Fire Department	6059	5	**1211,80**
	General Facilities	30459	4	**7614,75**
	General Archive	9360	4	**2340,00**
	Dining Hall	10166	5	**2033,20**
	Prayer Room	850	4	**212,50**
	Blueprint And Copy Room	1202	4	**300,50**
	Technical Room	20097	4	**5024,25**
	Social And Cultural Spaces	18204	5	**3640,80**
	Multi-Purpose Hall	10446	5	**2089,20**
	Close Car Parking	61900	5	**12380,00**
	Shelter	23213	2	**11606,50**
	Municipal Council Hall	6448	5	**1289,60**
	Committee Hall	1420	5	**284,0**

**based on the regulations of standard employee needs*

Table 2. Provincial Municipal Building Program *

Provincial Municipal Buildings		**Total Area**	**Evaluate Building**	**Average Area**
***Standard Departments**	**Specification Program Departments**	52503	5	**10500,60**
Directorate	Directorate	1205	5	**241,00**
Private Secretariat	Private Secretariat	1084	4	**271,00**
Office of Secretary	Office of General Secretary	650	5	**130,00**
Consultancy	Consultancy	337	4	**84,25**
Supervisory Board	Supervisory Board	296	5	**59,20**
Human Resources	Human Resources Department	557	5	**111,40**
Public Information Agency	Public Information Agency	560	5	**112,00**
Municipal Police	Municipal Police	1188	5	**237,60**
Environmental Protection	Environmental Protection	420	4	**105,00**
Works & Engineering	Public Works And Engineering	2228	5	**445,60**
Editorial Department	Editorial Department	664	5	**132,80**

Legal Affairs	Legal Affairs	507	5	**101,40**
ICT	Information and Communication Technology	828	5	**165,60**
Local Planning Authority	Local Planning Authority	2836	5	**567,20**
Financial Services	Financial Services (Accounting)	3387	5	**677,40**
Support Services	Support Services	1268	5	**253,60**
License And Supervision	License And Supervision	155	1	**155,00**
Cultural Social Affairs	Cultural, Educational &Social Affairs	727	5	**145,40**
Plan And Project	Plan And Project	1706	4	**426,50**
Strategy Development	Searching-Planning-Coordination	318	4	**79,50**
Directorate of Real Estate	Directorate of Real Estate	1096	3	**365,33**
Urban Design	Urban Renewal	136	1	**136,00**
Traffic and Accessibility	Road Maintenance and Repair	467	4	**116,75**
Municipal Health Services	Municipal Health Services	1210	5	**242,00**
Veterinary	Veterinary	165	3	**55,00**
Cemeteries	Cemeteries	96	2	**48,00**
Water And Sewerage	Water And Sewerage	2135	5	**427,00**
Gardens	Gardens	339	4	**84,75**
General Facilities	General Facilities	3432	2	**1716,00**
Library	Library	1206	3	**402,00**
Kindergarten	Kindergarten	1126	4	**281,50**
Sport Hall	Sport Hall	900	2	**450,00**
	General Archive	1782	4	**445,50**
	Canteen & Cafe	641	4	**160,25**
	Blueprint And Copy Room	378	4	**94,50**
	Technical Room	6679	5	**1335,80**
	Circulation Areas	16394	4	**4098,50**
	Commercial Service Spaces	25500	4	**6375,00**
	Close Car Parking	56700	5	**11340,00**
	Municipal Council Hall	2492	5	**498,40**
	Committee Hall	576	5	**115,20**

*Table 3. District Municipal Building Program**

District Municipal Buildings		**Total Area**	**Evaluate Building**	**Average Area**
***Standard Departments**	**Specification Program Departments**	139048	12	**11587,33**
Directorate	Directorate	2336	12	**194,67**
Private Secretariat	Private Secretariat	3334	11	**303,09**
Office Of Secretary General	Office Of Secretary General	1351	12	**112,58**
Supervisory Board	Supervisory Board	916	9	**101,78**
Human Resources Department	Human Resources Department	2551	11	**231,91**
Public Information Agency	Public Information Agency	2283	12	**190,25**
Municipal Police	Municipal Police	3123	12	**260,25**
Cleaning Service	Environmental Protection	1424	12	**118,67**
Public Works & Engineering	Public Works And Engineering	3868	12	**322,33**
Editorial Department	Editorial Department	1944	12	**162,00**

Legal Affairs	Legal Affairs	1812	12	**151,00**
ICT	Information Communication Technology	2027	12	**168,92**
Local Planning Authority	Local Planning Authority	7126	10	**712,60**
Building Control	Building Control	2101	5	**420,20**
Financial Services	Financial Services (Accounting)	9749	12	**812,42**
Support Services	Support Services	5916	10	**591,60**
License And Supervision	License And Supervision	949	4	**237,25**
Cultural Social Affairs	Cultural, Educational & Social Affairs	2325	8	**290,63**
Plan And Project	Plan And Project	1455	4	**363,75**
Strategy Development	Searching-Planning-Coordination	1325	9	**147,22**
Real Estate	Directorate of Real Estate	1739	7	**248,43**
Urban Design	Urban Renewal	517	3	**172,33**
Traffic and Accessibility	Road Maintenance and Repair	355	5	**71,00**
Municipal Health Services	Municipal Health Services	2437	9	**270,78**
Veterinary	Veterinary	650	6	**108,33**
Water And Sewerage Services	Water And Sewerage Services	2200	12	**183,33**
General Facilities	General Facilities	5087	4	**1271,75**
Library	Library	800	9	**88,89**
Social Studies and Projects	Social Studies and Projects	613	2	**306,50**
Kindergarten	Kindergarten	932	5	**186,40**
	Consultancy	1034	7	**147,71**
	General Archive	11412	11	**1037,45**
	Dining Hall	5594	9	**621,56**
	Blueprint And Copy Room	1541	10	**154,10**
	Technical Room	6640	12	**553,33**
	Multi-Purpose Hall	4968	8	**621,00**
	Close Car Parking	43425	12	**3618,75**
	Municipal Council Hall	7620	12	**635,00**
	Committee Hall	1386	11	**126,00**

5. CONCLUSION

Turkey has minimum 1443 municipal buildings those which are 30 metropolitan, 51 provincial, 534 metropolitan districts, 795 district, and 33 subsidiary municipalities in source "Union of Municipalities of Turkey" [12]. Considering all, municipalities may be a sample for public and private built environment by significant influence on all over Turkey in terms of creating sustainable & energy efficient buildings. Aforementioned, this study recommends optimal area needs for municipal buildings in order to use in early design stage. Based on this study, sustainability issue will be studied in terms of energy consumption reduction by a master thesis in order to create a framework as a guide. By the help of the optimum program, sustainable municipal building design will be developed in energy performance approach. Therefore this study is the first step to achieving energy efficient municipal buildings. Further studies will be an investigation of energy performance belongs real case studies and to create alternatives by simulating a municipal building in order to achieve optimum energy performance. In the highlight of all, perhaps this program guide may be accepted as standards by municipalities for future new municipal buildings.

REFERENCES

[1] Official Journal of the European Union- Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. European Parliament, 2010, 26.6.2015. Can be downloaded at: www.eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0031&from=EN

[2] Covenant of Mayors committed to local sustainable energy. Can be downloaded at: www.covenantofmayors.eu/+-Covenant-of-Mayors-+.html

[3] Energy Cities Project, Can be downloaded at: http://www.energy-cities.eu/-Members-

[4] Xu, P., Huang, J., Shen, P., Ma, X., Gao, X., Xu, Q., *Xiang, Y. Commercial building energy use in six cities in Southern China*. Energy policy, 2013, vol.53, pp.76-89.

[5] Lobato, C., Pless, S., Sheppy, M., & Torcellini, P. *Reducing plug and process loads for a large scale, low energy office building: Nrel's research support facility*, In ASHRAE Winter Conference, 2011,February, Vol. 29, pp. 1-2

[6] Hong, T., Li, C., Yan D., *Updates to the China Design Standard for Energy Efficiency in public buildings*. Energy Policy, 2015, vol 87, pp. 187–198

[7] VARLI, E., *Büro Tasariminda Kullanici Standartlari Ve Teknoloji Kullaniminin Değerlendirilmesi*, Master Thesis, Advisor: Prof. Dr. Veyis ÖZEK, Edirne-2004, Trakya University Institute of Science and Technology

[8] Hasol, D., *Ansiklopedik Mimarlık Sözlüğü*. Vol. 2. YEM, 1979.

[9] Eldem, N. *İdari ve ticari büro binaları*. İstanbul Technical University, 1950.

[10] Akbulut, M. A., *Kamu Yapılarında Iç Mekan Düzenlemeleri: Belediye Binları Ve Izmit Saraybahçe Belediyesi Örneği*, Master Thesis, Interior Architecture, Advisor: Assist. Prof. Dr. Deniz Demirarslan, Kocaeli University, Institute of Social Sciences, pp. 105-106

[11] Rezessy, S., Dimitrov, K., Urge-Vorsatz, D., & Baruch, S. *Municipalities and energy efficiency in countries in transition: Review of factors that determine municipal involvement in the markets for energy services and energy efficient equipment, or how to augment the role of municipalities as market players*. Energy Policy, 2006, Vol. 34(2), pp. 223-237

[12] Çamas,E., *Geçmişten Günümüze Kamu Yönetim- Belediye Hizmet Binalarının Mimari Değişimi*, Master Thesis,2000, Istanbul Technical University Institute of Science and Technology, pp.11-14

[13] Anonymous, *Belediyelerimize rehber, türk belediyecilik derneği-konrad adenauer vakfı*, 1994, Ankara, pp. 25-66

[14] Union of Municipalities of Turkey, *Belediye Ve Bağlı Kuruluşları Ile Mahalli Idari Birlikleri Norm Kadro Ilk Eve Standartlarına Dair Yönetmelik*, May, 2014, Ankara, Sarıyıldız Ofset, ISBN:978-975-6311-87-5

[15] Aykutlar, P., *The Spatial Analyses of Public Spaces in Municipal buildings in Context Of Architectural Competitions Between 1984-2013*, 2016, Master Thesis, Yasar University Institute of Science and Technology

[16] Municipality Regulations. Can be searched at: http://www.ekanun.net/3398-sayili-kanun/index.html

[17] Municipality Regulations. Can be searched at: https://www.tbmm.gov.tr/kanunlar/k6360.html

[18] Competition Specifications. Can be searched at: http://sartname.arkitera.com/

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Implementation of Carbon Marginal Abatement Cost Curves in Household Sector

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ABSTRACT

A MAC Curve (Marginal Abatement Cost Curve) is a graph that represents the extra (or marginal) carbon reduction (or abatement) potential of different alternative technologies relative to a baseline and enables decisions makers to decide the most cost-efficient emission reduction technology, easily. They are important tools while the global warming and emission limits have been being discussed for a considerable period.

They became popular with Mc Kinsey&Company's global cost curves, the first of which is published in 2007, showing the emission abatement technologies and their abatement costs globally.

In the event of Turkey has a quantitative international or national emission reduction target, it will be essential to reduce emissions in building sector, which has %35 share of energy sector, and has essential reduction potential to meet the targets.

So, in this study, an expert based MAC curve is formed for an assumed existing residence in İstanbul, Turkey, in order to visualize the emission reduction potentials of possible emission reduction technologies for the so-called residence. Primarily, the baseline scenario for the study is determined and energy consumption spots are specified. Later, energy saving potentials of each spot is examined. Finally a MAC curve is formed by calculating different alternative technologies' reduction potentials and costs in ten years period.

INTRODUCTION

McKinsey&Company's global marginal abatement cost curves is an inspiration to this study. The aim of this study is, from a simple point of view, to present and compare few different easily applicable widely-used simple emission reduction technologies' potentials and their unit carbon reduction prices in Turkey's building sector, which has a very-high energy consumption percentage, correspondingly very-high greenhouse gas emission reduction potentials, on a simplified graph.

In the event of building sector has legal reduction obligations on greenhouse gas emissions and also in the event of carbon market exists, detailed marginal abatement cost curves could give the owner the most cost efficient emission reduction idea and the chance to decide if it is more feasible to buy extra carbon emission right from market or to invest in another reduction technology. Baseline technologies were chosen according to the mostly used and the recommended abatement technologies are chosen according to the mostly used or mostly preferred.

CARBON MARJINAL ABATEMENT COST CURVES IN HOUSEHOLD SECTOR

Rapid rising of greenhouse gas emissions and climate change, has led countries to reduce emissions [1]. According to this, in the scope of UNFCCC, The Kyoto Protocol was adopted at the third session of the Conference of Parties (COP 3) in 1997 in Kyoto, and member states set quantitative goals to reduce and limit the emissions.

These targets and legal commitments to reduce greenhouse gas emissions require policy makers to find cost-efficient ways to meet the obligations. Marginal abatement cost (MAC) curves have frequently been used in this context to illustrate the economics associated with climate change mitigation and to illustrate the technological feasibility [2,3].

The earliest cost curves are developed after the two oil price shocks in the 1970s with the aim of reducing crude oil consumption and later electricity consumption. Then they became popular with Mc Kinsey&Company's global cost curves. Mc Kinsey published its first MAC curve in 2007. That curve shows the emission abatement technologies and their abatement costs globally. In that study, they assumed three emission limits which of them is the highest limit for their advocates to stop global warming [4,5]. Later, McKinsey updated their cost curve in 2009 in a more detailed and extended way. In 2010, McKinsey updated the curve to reflect a more realistic reduction in emission according to global financial crisis and higher fuel price expectations. Afterwards, McKinsey published cost curves for 14 different countries [3].

A MAC curve is a graph which shows the marginal costs of the various emission abatement alternatives. A MAC curve represents the extra (or marginal) carbon reduction (or abatement) potential of these alternative technologies relative to a baseline [6]. Typical technology options in a MAC curve are improvement of energy efficiency and clean energy usage.

To start with, the first important thing in MAC curve design is to make a decision about the emission baseline. In order to design a reliable MAC curve, it is essential to indicate the assumptions underlying the calculations.

There exist different kinds of approaches to generate MAC curves with different strengths and weaknesses. They are called expert-based MAC curves and model derived MAC curves [1].

Expert-based MAC curves assess the cost and reduction potential of each single abatement technology based on educated opinions individually, while model-derived curves are based on the calculation of energy models. They have different advantages and disadvantages because of their different formation approaches. To give an example; expert based MAC curves contain technological detail, while model-based MAC curves don't. Nevertheless, since expert-based MAC curves evaluate the emission reduction technologies individually and are not based on a model, they might not assess the real total reduction potential. Although, both expert-based and model-derived MAC curves possess important disadvantages that limit their usefulness for policy makers, they are very useful tools for policy makers to have vision about carbon abatement technology investments, in the end. [1].

Although, Turkey is Annex I Parties, because of its special conditions, it does not have first-round Kyoto targets. [7]. However, by developing new policies, regulations and strategies, Turkey sets its own targets in order to improve energy efficiency and reduce greenhouse gas emissions.

In the event of Turkey has quantitative international or national emission reduction targets, it will be essential to reduce emissions in building sector, which has %35 share of energy sector, and has essential reduction potential to meet the targets [8]. In such conditions, using MAC curves enables decisions makers to decide most cost-efficient emission reduction technology, easily.

In this study, an expert based MAC curve is formed for an assumed residence in order to visualize the emission reduction potentials of possible emission reduction technologies for the so-called residence.

Since according to TUIK's household survey, 80% of household live in multistory buildings [9], the curve is formed for a residence in İstanbul, Turkey, which has specific conditions, according to assumptions. Primarily, the baseline scenario for the study is determined and energy consumption spots are specified. Later, energy saving potentials of each spot is examined.

The assumptions are suitable to the assumed location of the residence, to the surveys, to the sale rates of the devices and materials. The existing aforementioned residence is located in İstanbul, on the ground floor of an uninsulated building, over basement. The building construction materials are mainly brick on walls and reinforced concrete on post-and-beam. Heating is provided by natural gas. The windows are wooden window. For cooling needs in summer, an air conditioner is located in living room in an energy class of B. According to AC companies advices, an air conditioner with a 22000Btu cooling capacity is sufficient for a 45m^2 room. No renewable energy system is located for electricity generation. Lightning system is based on incandescent lamps. The refrigerator, which has the highest energy consumption rate of a residence, is chosen as B energy class, according to sale rates and surveys.

Projections are made for year 2025. Therefore, electricity and natural gas price forecasts are made according to the past prices. Monthly electricity prices between 2005-2015 are obtained from TEDAŞ, a firm which is responsible for the distribution of electricity in Turkey. Monthly natural gas prices between 2010-2015 are obtained from İGDAŞ, a local natural gas supplier. Accordingly, price forecasts are made for 2025 by linear regression method. In regard to the predicted prices, the average assumed prices between 2015-2025 are calculated in order to use in MAC curve calculations for ten-year period.

For the uninsulated building, the use of EPS (expanded polystyrene) and rock wool is investigated, according to the selling rates. In accordance with TS 825 Standard for Thermal Insulation Requirements in Buildings in Turkey in Terms of Solar Radiation, an insulation board with 5cm board thickness is enough for external thermal insulation application. Also, it is assumed that an insulation of 3 cm thickness EPS will be implemented over basement in both calculations, since the residence is located over basement floor. The assumptions over insulation thicknesses have been decided according to widely sold thicknesses in the market. The assumptions for investment costs such as material costs and implementation costs have been made over market prices. Electricity savings and greenhouse gas reduction potential is calculated accordingly and added in final MAC curve and stated in the table below.

Table 1 TS825 calculations of the flat and the savings

	Uninsulated	**EPS**	**Rockwool**
Energy consumption (kJ/year)	92.059.967,7	48.103.769,7	49.045.331
Energy consumption (kWh/year)[1]	25.572,2	13.362,2	13.623,7
Natural gas saving (kWh/year)[2]		12.210,1	11.948,5
Average gas price according to 2025 projection (TL/kWh) (VAT included)	0,169	0,169	0,169
Consumed natural gas Cost (TL/year)[3]	4.316,56	2.255,52	2.299,67
Cost of the saved natural gas (TL/flat.year)[4]		2.061,05	2.016,90
Cost of the insulation for a unit area (TL/m^2)		45	65
Total outer wall insulation per flat (m^2)5		95,95	95,95
Basement ceiling insulation cost (TL/flat)		675	675

Insulation investment cost (TL/flat)		4.992,75	6911,75
Payback period (year)6		2,42	3,43
Natural gas unit conversion (kWh/m^3)	10,64	10,64	10,64
Saved natural gas amount (m^3/year)		1.147,56	1.122,98
Natural gas emission factor for (kg eq CO_2/m^3)	1,922	1,922	1,922
Abated eq CO_2 emission (kg eq CO_2/ year)		2.205,61	2.158,36

For windows, energy savings and emission reductions with the use of PVC frame with double-glazed windows, with a better thermal transmittance value (U value), is investigated. The assumptions for investment costs such as material cost and implementation costs have been made over market prices. Natural gas savings and greenhouse gas reduction of the measure is calculated accordingly and added in final MAC curve.

Table 2 Savings that is achieved by changing windows

Energy Consumption (kJ/year)	92.059.967,72	79.996.801,00
Energy Consumption (kWh/year)	25.572,21	22.221,33
Natural gas Saving (kWh/year)		3.350,88
Average Gas Price according to 2025 projection (TL/kWh) (VAT included)	0,169	0,169
Consumed Natural gas (TL/year)	4.316,56	3.750,94
Window screen+window glass implementation cost included application cost(TL/flat)		3.634,75
Payback period (year)		6,426
Natural gas unit conversion (kWh/m^3)	10,64	10,64
Saved natural gas amount (m^3/year)		314,932
Natural gas emission factor for (kg eq CO_2/m^3)	1,922	1,922
Abated eq CO_2 emission (kg eq CO_2/ year)		605,300

Refrigerators, lightning systems and air-conditioners are the most energy consuming systems in a residence; therefore, improvements are investigated in these systems as well. For refrigerator and air-conditioner, savings from the utilization of a better energy class, hence less energy-consuming devices are calculated. For the lightning system, by using Dialux program electricity savings with the use of compact fluorescent light bulbs and LED lamps instead of incandescent lamps are investigated. Electricity savings and correspondingly greenhouse gas reduction of all the measures are calculated accordingly and added in final MAC curve.

Table 3 Savings that is achieved by changing refrigerator

Average yearly saving (kWh/year)	415,603
Electricity price (10 year average) (TL/kWh) (VAT included)	0,507
Average yearly saving (TL/year)	210,877
Investment cost (TL)	3000
Electricity emission factor (ton eq CO_2/MWh)	0,660
Emission abatement (ton eq CO_2/year)	0,274
Payback period (year)	7,21

Table 4 Savings that is achieved by changing lightening

	Incandescent	KFL	LED
Total power (W)	4080	804	420
Lamp operating time (h/year)	713,67		
Electricity consumption (kWh/year)	2.911,77	573,79	299,74
Saving (kWh/year)		2.337,98	2.612,03
Electricity unit cost (TL/kWh)		0,43	0,43
Electricity unit cost (VAT included) (TL/kWh)		0,507	0,507
Average yearly saving (TL/year)		1.186,29	1.325,34
Investment cost (TL)		554,59	1.370,75
Electricity emission factor (ton eq CO_2/MWh)		0,66	0,66
Emission abatement (ton eq CO_2/year)		1.543,07	1.723,94
Payback period (year)		0,935*	1,034

Table 5 Savings that is achieved by changing AC

Energy Class	B	A++
Model	A* brand V-Fashion	S* brand AR24JSFNCWK/SK
Cooling capacity (Btu)	24.000	23.000
Cooling consumption (W)	2.300	2.060
Investment cost (TL)		3.299
Operating period (h/year)	440	440
Electricity consumption (kWh/year)	1012	906,4
Electricity unit cost (VAT included) (TL/kWh)	0,507	0,507
Electricity consumption (TL/year)	513,49	459,91
Average yearly saving (kWh/year)		105,6
Average yearly saving (TL/year)		53,58
Electricity emission factor (ton eq CO_2/MWh)		0,66
Emission abatement (kg eq CO_2/year)		69,696
Payback period (year)		61,6

Finally, electricity generation by the implementation of solar PV panels on the roof of the building is investigated. It is assumed that a part of the consumed energy will be supplied from these mentioned panels. Investment costs such as device costs and implementation costs are assumed according to market prices. Natural gas savings and correspondingly greenhouse gas reduction of the measure is calculated accordingly and added in final MAC curve.

Table 6 Saving that is achieved by PV panel

Consumed Energy	Saving (TL/year)	Abated CO_2
3,37 kWh/day	622,95 TL/year	2,22 kg eq CO_2/kWh 0,81 ton eq CO_2/year

Tabel 7 PV panel installation cost

Equipment	Feature	Price (TL)
PV cell	250W*6 mono-crystalline panel	7.800
Inverter	4.300W on-grid inverter	3.800
Labor cost+installation+burocracy		3.500
Total cost		15.100

In Table 8 and Table 9, the existing situation and the assumed renovation details are summarized.

Table 8: MAC data assumptions– existing situation

Area:	150m^2
Flat information:	2 flats on a floor, 10-storey building
Flat Location:	Over basement
Story Height:	2,8m
Façade Directions:	North-East-South
Insulation Information:	Uninsulated building
Building Construction Materials:	%85 brick-%15 reinforced concrete
Wall area:	North:42m^2, South:42m^2, East:28m^2
Windows:	Wooden, single glazed (U=5,1 W/m^{2}K)
Window area:	North: 3,95m^2, South:6,3m^2, East:5,8m^2
Internal Lightening:	Incandescent (60W)
Refrigerator:	B Class (628,234 kWh/year)
Air-Conditioning:	B Class (2.190W)

Table 9: MAC data assumptions – efficiency renovations

Insulation	- exterior insulation: 5cm ε:0,035 W/mK EPS + basement ceiling 3cm ε:0,035 W/mK EPS - exterior insulation: 5cm ε:0,040 W/mK rockwool + Basement ceiling 3cm ε:0,035 W/mK EPS
Window renovation	Usage of PVC (4+16+4) (U=1,3 W/m^2 K)
Lightening systems renovation	Usage of CFL(Compact Fluorescent Lamp) (12W) Usage of LED Lamps (8W)
Refrigerator renovations	Usage of A+++ Class Refrigerators (212,634 kWh/year)
Air Conditioner renovation	Usage of A++ Air Conditioner (2.060W)

RESULTS AND CONCLUSION

Table 10 shows the MAC curve data. To illustrate one of the reduction technology, for example the investment cost of KFL usage is 555TL. The life time of the project is 10 years since the projection is made for 2025, however the lifetime of KFL is 8,5 years so the investment cost in 8,5th year is added to today's investment cost by present value calculation. This technology usage will cause in average 1186,29TL saving, yearly, considering the electricity price rise between 2015-2025. Reducing the electricity consumption will cause reduction of 1,543tonnes CO_2 in average, annually. Net Present Value of changing the KFL is a negative value, since the saving is higher than the investment in 10-year period. The price of unit CO_2 emission reduction cost is calculated according to net present value per project lifetime per annual tones of CO_2 abatement.

In the formed curve by this data, KFL and LED usage, exterior insulation and window changing practices stayed on the left side and negative part of the curve which means reduction of one unit of emission saves the investor money in the determined projection time with these abatement technologies. Other technologies such as, change of refrigeration and air-conditioner and solar panel implementation are the projects in which one unit of emission abatement is expensive, relatively. In case CO_2 emission limit and CO_2 market price exist, the reduction technologies whose marginal abatement cost of CO_2 are under the CO_2 price of the market, would be feasible to implement. In the event of emission reduction limits exist, this final MAC curve will give the householder –or building sector- a broad perspective to limit the emissions in an economically efficient way.

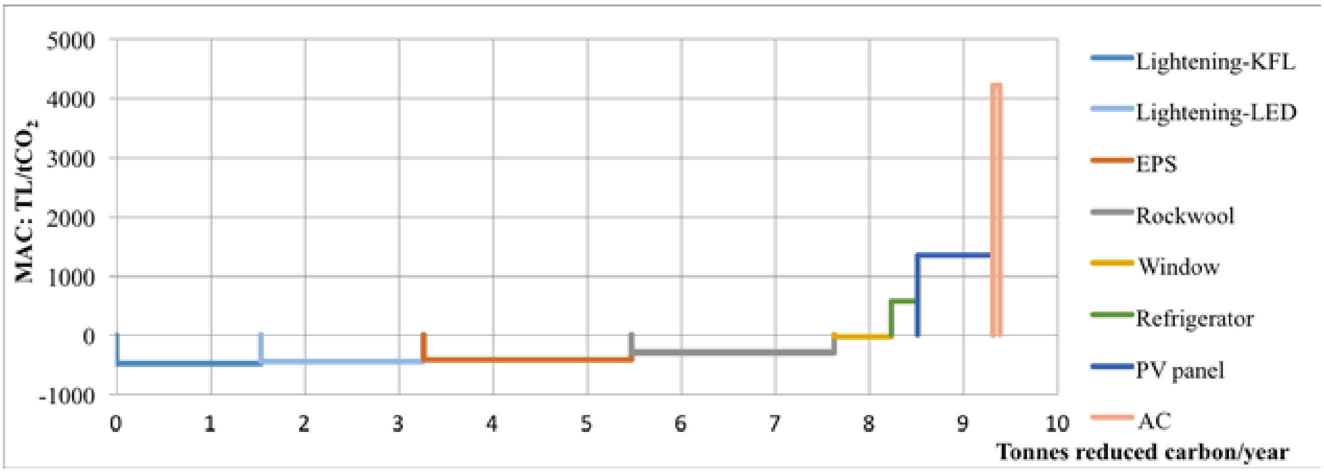
As a conclusion, it is important to remark once more that, the aforementioned formed expert-based MAC curve, does not give the total emission reduction potential since it is an expert-based MAC curve and does not based on energy models but shows each emission reduction technology's abatement potential and abatement cost individually in a way which may cause duplicate count of unit CO_2 abatement.

As a first step, easily understandable expert based MAC curve is formed for the investor, with a more detailed data a model-based MAC curve could be formed based on different strategy models as a next step which may overwhelm the weaknesses of expert-based MAC curves.

Tablo 10 MAC Data of carbon abatement projects.

Proje		Lightening-KFL	Lightening-LED	EPS	Rockwool	Windows	Refrigerator	Solar Panel	AC
Investment Cost	(TL)	555	1.371	4.993	6912	3.635	3.000	15.100	3.299
Saving/Cost	(TL/ year)	1.186,29	1.325,34	2.061,05	2.016,90	565,63	210,88	622,95	58,58
Yearly Average CO_2 Saving	(tonnes/ year)	1,543	1,724	2,206	2,158	0,605	0,274	0,810	0,070
Project Life	(year)	10	10	10	10	10	10	10	10
NPV*	(TL)	-7.286	-7.726	-9.154	-6.932	-248	1.553	10.824	2.931
Marginal Abatement Cost	(TL/ tonnes)	-472,2	-448,19	-415,0	-321,2	-40,9	565,7	1336,3	4206,1
Payback Period	(year)	0,935	1,034	2,42	3,42	6,424	7,21	24,24	61,6
Cumulative CO_2 Saving	(tonnes/ year)	1,543	3,267	5,473	7,631	8,236	8,510	9,320	9,390

*NPV: Net present value



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REFERENCES

[1] Senatla, M., Merven, B., Hughes A. & Cohen, B. (2013). Marginal Abatement Cost Curves: Mitigation Decision Tools, Can be downloaded at: http://www.mapsprogramme.org/wp-content/uploads/Final_Paper_MACC_130624.pdf

[2] Kesicki, F., Marginal abatement cost curves for policy making – expert-based vs. model-derived curves, 2011. Can be downloaded at: http://www.homepages.ucl.ac.uk/~ucft347/Kesicki_MACC.pdf

[3] Ekins, P., Kesicki, F., & Smith, A.Z.P. Marginal Abatement Cost Curves: A call for caution, *Climate Policy*, *12*, 219-236.

[4] http://www.somar.co.uk/tools/excel/MAC-Calculation.xls

[5] Food and Agriculture Organization of the United Nations, Using Marginal Abatement Cost Curves to Realize the Economic Appraisal of Climate Smart Agriculture Policy Options . 2012., Can be downloaded at: http://www.fao.org/docs/up/easypol/906/ex-act_macc_116en.pdf

[6 Tilburg, X., Würtenberger, L. & Tinoco, R. Marginal Abtement Cost Curve Policy Brief, 2015. Can be downladed at: https://www.ecn.nl/fileadmin/ecn/units/bs/IEC/ECN_Low_Carbon_TA_Brochure_.pdf

[7] http://iklim.cob.gov.tr/iklim/AnaSayfa/BMIDCS.aspx?sflang=tr

[8] Enerji ve Tabii Kaynaklar Bakanlığı.. Ulusal Enerji Verimliliği Eylem Planı Taslak versiyon No.7, 2015. Can be downladed at: http://www.eie.gov.tr/duyurular_haberler/document/UEVEP_TASLAK.pdf

[9] http://www.tuik.gov.tr/PreHaberBultenleri.do?id=15843

(Footnotes)

1 Calculated with TS825 for 1 flat.
2 Difference between insulated and uninsulated condition.
3 Amount of natural gas in present conditions.
4 Difference between insulated and uninsulated condition.
5 Total outer wall area except window area.
6 Calculated with simple payback period. The rate of investment cost to natural gas cost.

Paper No: 76

Evaluation of Energy Efficient Urban Planning Approach

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ABSTRACT

Due to the increase in energy need with urbanization as a result of industrialization and rapid population growth, preservation of natural resources has become impossible. As the energy generated particularly from non-renewable natural resources in danger of depletion, such as coal, natural gas, petroleum is limited, and as environmental issues caused by energy resources increase, means of safe and continuous access to energy are searched in the world. Owing to the limited energy resources and energy dependence on foreign sources in the world, and particularly in European Union countries, efforts of increasing the share of renewable energy sources in energy consumption increased in all industries, including urban planning as well. Likewise, energy resources in Turkey are limited, and by reason of rapidly increasing energy demand, large amount of energy is imported. Concordantly, it is necessary to develop policies and approaches that enable utilization of domestic resources, comply with the country's conditions, and monitor developments in energy. Such policies and approaches, which must be implemented in urban planning as well, have great importance in terms of not deteriorating habitable environments of future generations while utilizing present-day energy resources, prevalence of utilization of renewable energy sources, and utilization of energy effectively. For that purpose, this study puts forward the principles, strategies and methods on energy efficient urban planning approach, and discusses the energy efficient urban area examples within this context.

Key Words: Energy Efficiency, Urban Planning, Eco City, Energy Efficient Urban Planning.

INTRODUCTION

Increased migration from rural to urban areas associated with industrialization and developments in knowledge and technology in the 19th century caused rapid urbanization. Consequently, utilization of nonrenewable natural resources with limited reserves increased. Therefore, the entire world is after finding the means of safe and continuous access to energy. The risk of depletion of nonrenewable energy resources and their damage on environment at high levels, on one hand, and the need to develop alternative and renewable energy sources, and to expand their domains of application, on the other hand, led to emergence of new approaches in planning of cities as part of sustainability, environmental consciousness, and energy efficiency approaches [1].

With the environmental awareness that started to awaken in the world as of 1970s, and adverse effects of environmental problems on all living creatures, including humans, that were revealed in 1980s, discussions started on utilization of renewable energy sources, and the notion of energy efficiency attracted great interest. Due to the limited energy resources and the 55% dependence on foreign sources for energy in the world, and particularly, in European Union (EU) countries, efforts of increasing the share of renewable energy sources in energy consumptions increased [2]. It may be argued that on this subject, no sufficient studies are conducted in Turkey, although 28% of the consumed sources in Turkey is supplied from own resources and 72% is imported [3]. Concordantly, it is very crucial to develop policies and approaches that enable utilization of domestic resources, comply with the conditions in Turkey, and monitor studies pertaining to energy in the world. Such policies and approaches, which must be implemented in urban planning as well, are important in terms of not deteriorating habitable environments of future generations while utilizing present-day energy resources, prevalence of utilization of renewable energy sources and utilization of energy effectively. The objective of this study is to form the principles, strategies and methods pertaining to energy efficient urban planning and evaluate exemplary energy efficient urban areas in the world within this scope.

1. ENERGY EFFICIENT URBAN PLANNING

World's energy need increases 4-5% every year for such reasons as industrialization, rapid population growth and advancement in the standards of living [4]. Due to such reasons as rapid depletion of fossil fuel reserves, such as coal, petroleum and natural gas, providing for the energy need of the world; thinning of ozone layer as a consequence of increasing energy consumption; raising air pollution associated with the impact of greenhouse gases; climatic change and increasing environmental pollution; the issue of efficient utilization of energy gradually became crucial [5]. Because of ever-increasing energy demand and fluctuations in energy prices, energy became a strategic issue for countries, and efficient utilization of energy became one of the most important aims. In this context, new approaches emerged in recent years, taking energy efficiency in urban planning into consideration.

2.1. Energy Efficiency

Energy efficiency is the transformation of each unit of energy consumed to more service and product without any compromise on quality and comfort requirements [6]. The most important element in energy efficiency is energy saving, and one of the most important indicators is energy density [6, 7]. Energy saving is ensured by minimizing the amount of consumed energy without losing quality and performance by means of utilization of energy wastes and prevention of existing energy losses; the lowest-cost energy is the energy saved by efficient utilization. Energy efficiency may be increased by decreasing energy density, which is explained as the energy consumed per unit output [8]. The most important factor triggering energy efficiency policies in the world was the energy and petroleum crisis encountered in 1970s, and with environmental protection coming into prominence in 1980s, the concept of energy efficiency became the essential part of energy and development policies. Energy efficiency is one of the parameters affecting sustainable growth, which allows relaying present-day necessities to future generations without perishing natural resources. According to Brundtland Report, published by United Nations World Commission on Environment and Development, it has become necessary to take urgent, unyielding and grave measures for much efficient utilization of energy [9]. There are various measures and proposed solutions in each country in regards to energy efficiency, which is to minimize the amount of consumed energy without reducing quantity and quality in its generation, and without hindering economic growth and social welfare [8].

As the first country recognizing the importance of energy efficiency, United States of America (USA) has conducted studies on energy efficiency since 1970s. Finding the achievements from such studies insufficient, USA prepared a national action plan, named "Vision 2025", on energy efficiency in 2008 for such reasons as increasing security of energy supply and mitigating potential risks in carbon policies. Likewise, since early 1970s when the petroleum crisis was faced, EU countries started studies and set certain targets in order to minimize dependence on petroleum, increase supply security, reduce energy costs, encourage competition, reduce unemployment, preserve the environment and reduce greenhouse gases. With the concern that defined targets may not be reached, "Energy Efficiency Directive" was prepared in late 2012 [6]. Having experienced adverse impacts from 1970s petroleum crisis, Japan renewed "Law on Energy Saving" in 1999. In Japan, where the studies on energy efficiency are supported by the state by various financial models, such as tax incentive, long-term loans, industrial organizations and people support such studies voluntarily and urban managements apply various efficiency programs occasionally within their boundaries [10, 11]. In Turkey, a country being foreign dependent on energy, it is highly crucial to utilize energy sources efficiently because the investment costs of alternative energy sources are high, and the technology therefore depends mostly on imported materials. Consequently, targeting sustainable growth, supply security, energy generation at low cost, preservation of environment and protection of human health; energy efficiency policies must be taken as a process covering proper technologies, social consciousness and public and legal regulations. Table 1 shows the legislative steps on energy efficiency in Turkey.

Table 1. Legislative Steps on Energy Efficiency in Turkey [6, 12]

Date	Legislative Steps
April 2004	Energy Efficiency Strategy in Turkey
December 2006	Regulations on Energy Labeling of Household Air-Conditioners
December 2006	Regulations on Energy Efficiency Requirements for Household Electric Refrigerators, Freezers, and Their Combinations
December 2006	Regulations on Energy Efficiency Requirements for Ballasts for Fluorescent Lighting
May 2007	Energy Efficiency Law, No. 5627
June 2007	Regulations on Making Amendments to Regulations on Energy Labeling of Household Air-Conditioner
February 2008	Prime Ministry Circular on Energy Efficiency Year 2008
April 2008	Regulations on Sharing of Cost of Heating and Sanitary Hot Water in Central Heating and Sanitary Hot Water Systems
June 2008	Regulations on Efficiency Requirements of New Hot Water Boilers using Liquid and Gas Fuel
June 2008	Regulations on Procedures and Principles Regarding to Increasing the Energy Efficiency in Transportation
August 2008	Prime Ministry Circular on Replacing Incandescent Lamps in Public Sector
October 2008	Regulations on Increasing the Energy Resources and the Efficiency of Energy Utilization
December 2008	Regulations on Energy Performance of Buildings
January 2010	Regulations on Energy Labeling of Household Electric Refrigerators, Freezers, Refrigerators, Deep Freezers, and Their Combinations
May 2010	Regulations on Making Amendments to Regulations on Energy Labeling of Household Electric Refrigerators, Freezers, Refrigerators, Deep Freezers, and Their Combinations
October 2010	Regulations on Environment-Friendly Designs of Energy-Related Products
April 2011	Regulations on Making Amendments to Regulations on Energy Performance of Buildings
October 2011	Amendments in Regulations on Increasing the Energy Resources and the Efficiency of Energy Utilization
February 2012	Energy Efficiency Strategy Document
July 2012	Communiqué on Energy Efficiency Supports
July 2012	Communiqué on Certification of Institutions and Organizations to Conduct Energy Efficiency Services
September 2012	Communiqué on Training and Certification Activities for Energy Efficiency
January 2013	Communiqué on Certification of Institutions and Organizations to Conduct Energy Efficiency Services
April 2014	Regulations on Making Amendment to Regulations on Increasing the Energy Resources and the Efficiency of Energy Utilization

According to Table 1, Turkey does not have a legislation regarding energy efficient urban planning; however, "Urbanization Council - Climate Change, Natural Resources, Ecologic Balance, Energy Efficiency and Urbanization Commission Report" prepared by Ministry of Public Works and Settlement in 2009 [13] suggests development of new laws and regulations for sustainable cities since existing legislations are insufficient. Accordingly, in 2014, "Spatial Planning Construction Regulation [14]" and "Regulations on Certification of Sustainable Green Buildings and Sustainable Settlements [15]" were published.

2.2. Energy Efficient Urban Planning Approach

Owing to increased energy needs in cities, urban planners recently started to attach importance to the studies manifesting the energy and city relation in the process of urban planning, and studies on new planning approaches increased for livable cities. It became obvious that urban planning is not just to arrange and improve any physical domain; urban development must be taken together with economic, social, communal, environmental and physical dimensions, and that it is necessary to evaluate their interactions with each other and to develop policies [16]. In urban planning, spatial structure is generated by such variables as land use, principles for selecting location, urban macro-form, urban grandness, density, communication and transportation facilities. Any change in any of these variables has substantial impact on energy source requirements [17]. It is therefore necessary to take the variables in question into account in the principles of energy efficient urban planning in order to ensure energy efficiency.

Starting in early 1990s, city planning and design approaches were developed under the names, such as "Sustainable Cities", "Ecological Cities", "Green Cities", "Smart Growth", "Slow Cities", "Low Carbon Cities", "Livable Cities", "Digital Cities" and "Smart City Initiatives" in various cities and regions throughout the world. "Energy Efficiency in Settlements" is the most important subject that urban planning discipline must deal with primarily [18]. In other words, energy efficiency, being defined as efficient utilization of energy, must start with urban planning. Energy saved as result of efficient utilization is the least-cost energy, and the means to utilize the energy much efficiently by adopting certain habits, applying improvement methodology or making use of new technologies, by making no concessions on generation and quality, and maintaining standard of social life [19]. For provision of energy efficiency, city plans, which are sensitive to environmental issues, preserve ecologic balance, and fulfill the requirements of comfort and health necessary for human life, come into prominence.

Energy conservation, land conservation, water conservation, waste reduction and ensuring accessibility are the principles necessary to be taken into consideration for energy efficient urban planning. These principles will contribute to energy efficient urban planning in terms of economical, social and environmental dimensions. In this study, in consideration of the classifications proposed in the articles of Arzuhan Burcu Gültekin and Seda Yavaşbatmaz [20], Mustafa Yılmaz and Serkan Yıldız [21], Aslı Atıl, Bahriye Gülgün and İsmail Yörük [22], Mehmet Karaca and Çiğdem Varol [23] and Serkan Sınmaz [18] in Urbanization Council Commission Reports [5], principles, strategies and methods pertaining to energy efficient urban planning is presented in Figure 1

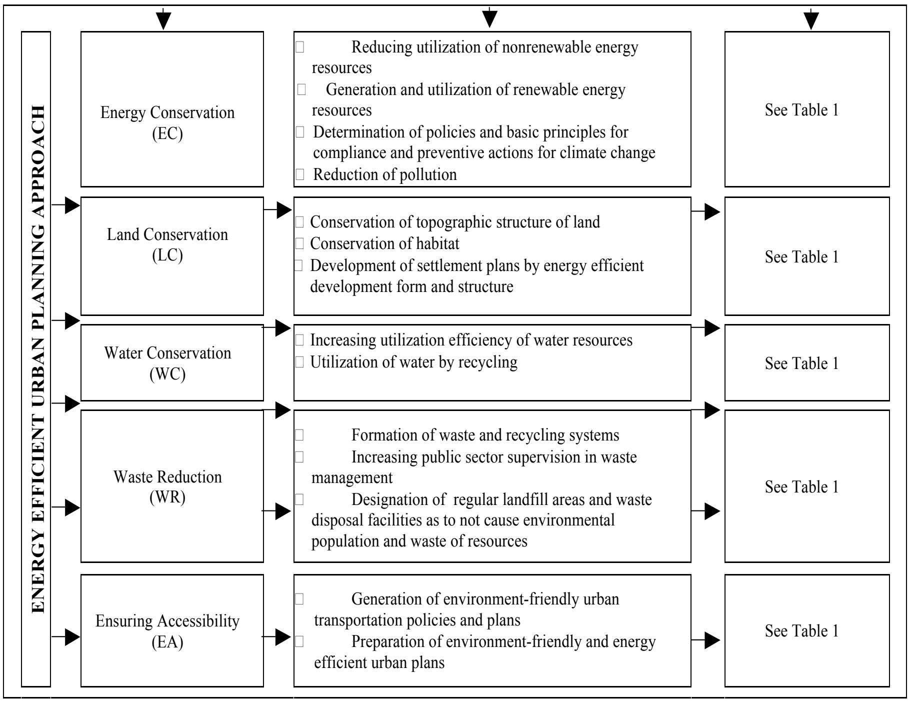


Figure 1. Energy Efficient Urban Planning Approach

In the process of energy efficient urban planning, where unique aims of cities differentiate and procedures are executed, it is required to determine the strategies and methods intended for having settlements and natural environment qualified and livable pursuant to the principles of urban planning. Principles, strategies and methods pertaining to energy efficient urban planning are given in Table 2.

Table 2. Principles, Strategies and Methods Pertaining to Energy Efficient Urban Planning

Principles	**Strategies**	**Methods**
EC	Reducing utilization of nonrenewable energy resources	Site selection and execution for settlement areas according to the sun
		Reduction in energy consumption
		Integration of energy technologies to city, elimination of the deficiency of renewable energy systems (solar, wind, bioenergy, waste energy, water and geothermal)
		Promotion of architecture suitable to local climate and utilization of local building materials
	Generation and utilization of renewable energy resources	Issuance and enforcement of the regulations of implementation for renewable energy generation in settlements
		Creation of aids and incentives for utilization of renewable energy sources
		Arrangement of spatial areas containing renewable energy utilization
		Development of social awareness and training on renewable energy
		Provision of city lighting by means of renewable energy systems
	Determination of policies and basic principles for compliance and preventive actions for climate change	Legislating and enforcement of the law on climate change
		Regulations for increase of energy efficiency and savings for controlling and mitigating greenhouse gas emissions
		Preparation of climate maps of settlements and keeping them updated
	Reduction of pollution	Balanced distribution, preservation and enhancement of green spaces within settlements
		Connection of existing outdoor and green spaces to each other and to pasture area
		Utilization of local vegetation suitable for climate
		Development of urban forestry
		Implementation of green wall and green roofing systems

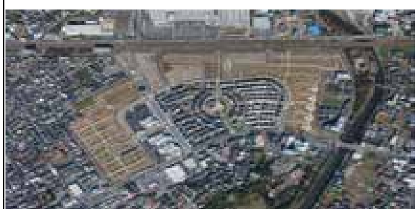
LC	Conservation of topographic structure of land	Provision of harmony between land usage and topographic structure
	Conservation of habitat	Formation of inventory for natural resources
		Formation of a basis in spatial planning by use of natural resource values as data
		Preservation and growth of agricultural areas
	Development of energy efficient development form and structure when preparing settlement plans	Selection of right location for upper-scale decisions based on climatic properties
		Mitigation of heat island impact
		Minimization of infrastructure and superstructure problems arising from land
WC	Increasing utilization efficiency of water resources	Utilization of systems allowing efficient usage of water
		Taking legal measures for efficient utilization and management of water resources and enforcement of the law on water management
		Reduction in water consumption
		Having environmental planning utilizing water efficiently and requiring less maintenance
		Renewal of sewage systems to prevent contamination of water resources
	Reuse of waste water	Developing proper technologies for storing and recycling of water
		Treatment and reuse of waste water
		Collection of rain water and reusing in suitable areas
WR	Formation of waste and recycling systems	Promotions to local administrations for waste systems and recycling
		Increasing public sector supervision in waste management
		Sorting of wastes on site, use of recycling technologies
	Designation of regular landfill areas and waste disposal facilities so as not to cause environmental population and waste of resources	Marking locations of such facilities on relevant plans
EA	Generation of environment-friendly urban transportation policies and plans	Drawing plans of transportation and land usage suitable for public transportation
		Developing the pedestrian/bicycle transportation systems and marking them in the physical plan
		Developing energy-efficient transportation means and systems
		Minimization of private vehicle ownership
	Preparation of environment-friendly and energy efficient urban plans	Establishing relationships between housing, working and required locations in such a way that they require minimum energy

3. EVALUATION OF EXEMPLARY URBAN AREAS IN THE WORLD WITHIN THE SCOPE OF ENERGY EFFICIENT URBAN PLANNING

For a better livable future, there are exemplary cities of urban planning approach in the world where energy is utilized efficiently and productively, where renewable energy resources are produced and utilized, where projects for reduction in water consumption are put into practice, where waste problem and environmental problems are taken in account. While some of these cities are built according to energy efficient urban planning approach, some are transformed to the cities utilizing energy efficiently. In this study, Dongtan Eco City, Fujisawa Sustainable Smart City, City of Masdar and Songdo Smart City were evaluated in the scope of newly-built energy efficient cities; City of Copenhagen, City of Gothenburg and City of Portland were evaluated under transformed cities. Practices of energy efficient urban planning performed in these exemplary cities are presented in Table 3 and Table 4 according to the principles, strategies and methods given in Figure 1.

Table 3. Evaluation of Cities Built According to Energy Efficient Urban Planning Approach

<table>
<tr><th colspan="2">Cities</th><th colspan="2">Energy Efficient Urban Planning Approach</th></tr>
<tr><td rowspan="5">Dongtan Eco-City [1, 24, 25]</td><td rowspan="5">


Country: People's Republic of China, Chongming Island
Intended Population: 500,000 people
Project Date: 2008-2050
Area: 3000 ha</td><td>EC</td><td>Renewable energy resources shall be used. While energy efficiency increases by minimizing the impact of energy on climate change wherever it is used, energy consumption and its costs shall be reduced. Zero-energy buildings with zero greenhouse gas emissions shall be built. Energy shall be generated from wind, sun and biologic domestic wastes. There shall be green roof practices on buildings.</td></tr>
<tr><td>LC</td><td>No high structuring shall be allowed in consideration of climatic properties. Housings shall not exceed 40% ratio and 60% of land shall be natural bird habitat. Organic agriculture shall be utilized.</td></tr>
<tr><td>WC</td><td>Agricultural irrigation shall be with rain waters. Waste waters shall be treated and reused.</td></tr>
<tr><td>WR</td><td>By treating and reusing 90% of wastes, a zero-waste city shall be created.</td></tr>
<tr><td>EA</td><td>Transportation shall be provided with vehicles running on hydrogen-based clean fuel. A pedestrian-based transportation system shall be promoted.</td></tr>
<tr><td rowspan="5">Fujisawa Smart-City [24, 27-32]</td><td rowspan="5"> 

Country: Japan, Kanagawa
Intended Population: 3,000 people
Project Date: 2008-2018
Area: 19 ha</td><td>EC</td><td>For utilization of solar energy, roofs of buildings shall be covered by solar panels. Renewable energy sources shall be increased minimum by 30%. Greenhouse gas emissions shall be reduced by 70%. City lighting shall be provided by using smart grid systems (self-sustained energy supply). The most advanced systems shall be employed in buildings for generation, storage and management of energy.</td></tr>
<tr><td>LC</td><td>Smart infrastructure systems shall be utilized. City shall be in harmony with the nature and shall not pollute environment. An organic city shall be built where solar battery placements are to be in harmony with the soil layer. An optimal smart infrastructure system shall be created.</td></tr>
<tr><td>WC</td><td>Domestic water consumption shall be reduced by 30%.</td></tr>
<tr><td>WR</td><td>No available data on this subject.</td></tr>
<tr><td>EA</td><td>Particularly transportation to health and public institutions shall be kept short and in walking distance. Electric bicycle, electric vehicle and pedestrian transportation shall be promoted.</td></tr>
</table>

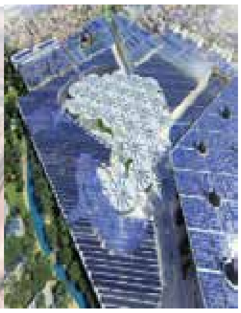
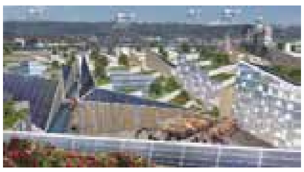
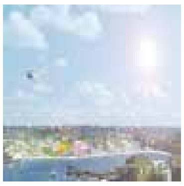
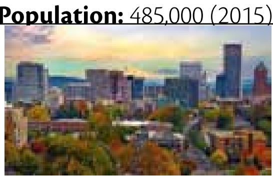
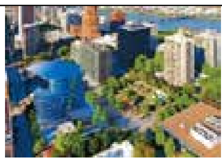
City of Masdar [1, 24, 26]	   **Country:** The United Arab Emirates (being built in desert nearby Abu Dhabi) **Intended Population:** 50,000 people **Project Date:** 2006-2025 **Area:** 600 ha	**EC**	Energy consumption shall be minimized in order to maximize energy efficiency. The aim shall be zero-carbon emission. Carbon dioxide generated by the city shall be buried underground. 80% of buildings shall fully have solar collectors, while solar panels shall be placed on rooftops. 99% of waste shall be used for energy generation.
		LC	Buildings shall be limited to 5 floors in order to effectively benefit from shadows and the sun.
		WC	Sea water shall be treated and utilized for meeting water needs in order to reduce water consumption; all the waste water and rain waters shall be utilized for irrigation. Solar energy shall be utilized for treatment process. Materials such as efficient fixtures, household appliances and smart counters shall be used in order to increase water efficiency.
		WR	All the waste shall be recycled in order to generate zero waste. A portion of wastes shall be utilized in generating energy, while another portion shall be used as fertilizer for landscaping.
		EA	Electric bus and electric rail system shall be installed throughout the city, and vehicles shall not be allowed to enter the city. Transportation shall be mainly pedestrians and bicycles. Electric taxis with one-person cabin and no drivers (Personal Rapid Transit) running on clean energy shall be utilized.
Songdo Smart-City [24, 33-37]	   **Country:** South Korea **Intended Population:** 252,000 people **Project Date:** 2003-2020 **Area:** 610 ha (replenished area)	**EC**	Wastes shall be used in energy generation. Energy consumption shall be reduced by utilization of LED lighting, air conditioning systems with water cooling and wind and solar energy. Green roof systems shall be applied using local vegetation. Greenhouse gas emission shall be reduced. Natural building materials shall be used. Green and smart growth has been aimed for the city with LEED certificates in 120 of its buildings. Traffic, public transportation system, energy consumption, heating and air conditioning of the city shall be managed from one center by means of sensors controlled by computers connected through a grid.
		LC	40% of the land shall be comprised of green areas and golf courses. Environment-friendly design shall be implemented.
		WC	Water consumption shall be reduced. Rain water shall be collected, and waste water shall be treated and reused.
		WR	A waste collection system eliminating garbage trucks shall be implemented. Domestic waste shall be transported directly from the buildings to waste processing centers and sorted.
		EA	Pedestrian and bicycle transportation shall be promoted. Public transportation shall be popularized. Electric vehicles shall be in use, and private vehicle ownership shall be reduced.

Table 4. Evaluation of Cities Transformed According to Energy Efficient Urban Planning Approach

Cities		Energy Efficient Urban Planning Approach	
City of Copenhagen [38]	    **Country:** Denmark **Population:** 1,213,822 people (2012)	**EC**	By the year 2020, 50% of electricity shall be generated by wind farms. The city's climate plan slogan for the year 2025 is "a green and smart city with zero-carbon emission", and it is anticipated to quit utilization of fossil fuels and nuclear energy completely. By the year 2050, 100% of energy need shall be met from renewable energy resources. The heating has been almost solved by utilization of geothermal energy. There shall be green roof practices on buildings.
		LC	No available data on this subject.
		WC	Rain water shall be recycled and used.
		WR	94% of wastes shall be recycled.
		EA	Bicycling is popularized, and the subway network and bicycling are combined optimally. Emphasize is given to public transportation.
City of Gothenburg [1, 24, 39-41]	    **Country:** Sweden **Population:** 485,000 (2015)	**EC**	Solar panels and wind turbines shall be installed on roofs to save energy and to provide heating and cooling for buildings. Green roof systems shall be utilized. Greenhouse gas emissions shall be reduced by reducing energy consumption. Energy generation shall be supported by wave-power and bio-gas generated by remnants of large-scale transportation sector. Green areas shall be preserved and enhanced.
		LC	Traditional materials (yellow bricks) shall be used in construction of buildings, and local architecture shall be maintained. A high-density decision shall apply.
		WC	Rain water shall be collected and reused. The sewer system shall be re-built. Waste water shall be treated and used.
		WR	No available data on this subject.
		EA	Zero-carbon emission transportation shall be provided by Personal Rapid System. Bicycling shall be promoted using bicycle roads covered with roofing. Emphasize shall be given to hindering the gas and oil consumption. Pedestrian and public transportation shall be promoted. Use of private vehicles shall be reduced. Transportation to housing, working and plant locations shall be provided by consuming the least energy.
Portland Green-City [24, 42-44]	   **Country:** USA **Population:** 609,456 people (2013)	**EC**	The city shall utilize hydroelectric plant, solar and wind energy at 70%. There are 175 buildings with LEED certificates. It is anticipated in the climate action plan to reduce carbon emissions by 80%.
		LC	No available data on this subject.
		WC	Water consumption shall be reduced. Rain water shall be collected and waste water shall be treated for reuse.
		WR	60% of waste is recycled.
		EA	Coordination shall be established between institutions related to transportation planning; the actors involved in transportation, meaning employers, transportation companies and city people shall take part in the planning process. Bicycling shall be promoted. Public transportation shall be popularized. Investments shall be made for light rail system and tramway lines.

There was not enough information available in the literature regarding to exemplary urban areas throughout the world in the scope of energy effective urban planning approach. It may be argued that constructed energy effective cities evaluated in the light of limited information in Table 3 are not sustainable economically. For this reason, completion dates of urban area projects implemented by both public and private sectors are postponed continuously. It may be stated that transformation of existing cities according to energy efficient urban planning approach is much better than building energy efficient new cities. It was determined that strategies and methods for energy efficient urban planning approach in Figure 1 were partly applied in exemplary cities examined, but no information was available particularly on regulations, supports and incentives for utilization of energy efficiently and effectively. In the exemplary urban areas examined, it is observed that such strategies and methods as utilization of energy generated from renewable energy sources and solid waste, integration of energy technologies into cities, reduction of greenhouse gas emissions, promoting pedestrian and bicycle transportations, reduction of private vehicle ownership by increasing electric vehicles and public transportation systems, and reusing rain water and waste water were prominent.

4. CONCLUSIONS AND SUGGESTIONS

In today's world, where most of the world population lives in cities, it is a rather expensive method to provide all of increasing energy need from renewable energy sources with today's technology and conditions. It is therefore necessary to utilize existing energy efficiently and productively, which is a much affordable practice for fulfilling the increasing energy need.

The principles, strategies and methods presented in this study may be adopted as a guideline in energy efficient urban planning, and consequently, may be used as a guide for different disciplines. Since constructing new cities according to energy efficient urban planning is not economically sustainable, for sustainable developments of existing cities, transformations must be performed, renewable energy sources must be utilized, wastes must be recycled, greenhouse gas emissions must be reduced, transportation must be pedestrian-based, and utilization of bicycles and public transport must be increased. Efficient and productive utilization of energy and renewable energy resources must be adopted as a government policy, and the public awareness must be increased. People shall be more selective as public awareness increases on efficient and productive utilization of energy, and investments of lesser energy consumption for less money shall be taken into consideration. In today's world, where economic growth and social welfare lead to more energy consumption, decrease in energy consumption, preservation of the environment and reduction the burden of energy costs on the economy shall be provided with the enforcement of laws and regulations for efficient and productive utilization of energy.

REFERENCES

[1] http://www.emo.org.tr/ekler/eaf4aa6261ad403_ek.pdf

[2] http://www.21yyte.org/tr/arastirma/avrupa-birligi-arastirmalari-merkezi/2015/02/26/8087/avrupa-enerji-birligi-ortak-enerji-politikasi-mumkun-mu

[3] Gültekin, Arzuhan Burcu and Alparslan Ersöz, Bengü. “Ecological Building Design and Evaluation in Ankara.” Journal of the Croation Association of Civil Engineers Gradevinar 65:11 (2013): 1004.

[4] Gültekin, Arzuhan Burcu and Farahbakhsh, Elnaz Bagheri. “Energy Performance of Glass Building Materials.” TÜBAV 9: 3. (2016), 52-65.

[5] Spatial Planning System and Institutional Structuring Commission Reports of Urbanization Council of Ministry of Public Works and Settlement (2009), 780.

[6] 42nd Period Energy Working Group. UCTEA Chamber of Electrical Engineers Energy Efficiency Report. (Ankara: EMO Publications, 2012), 21.

[7] Bayraç, H. Naci. “Effects of Energy Use on Global Warming and prevention Policies.” Eskişehir Osmangazi University Journal of Social Sciences. 11:2. (Dec 2010), 246.

[8] http://www.ibb.gov.tr/sites/aydinlatmaenerji/

[9] Aksoy, Soner. “Energy Management and Policies-Related Rules and Regulations on Energy Efficiency.” Anadolu University Publication No:2787. (Jan 2013), 3.

[10] http://www.enerjigazetesi.com/kose-yazisi-dunyada-enerji-verimliligi-japonya-abd-ve-ab/

[11] Kavak, Kubilay. “Energy Efficiency in the World and Turkey and Investigation of Energy Efficiency in Turkish Industry.” SPO-General Directorate of Economic Sectors and Coordination. Thesis for Planning Expertise. (Sep 2005), 68-71.

[12] http://www.eie.gov.tr/verimlilik/v_mevzuat.aspx

[13] Climate Change, Natural Resources, Ecologic Balance, Energy Efficiency, and Urbanization Commission Report” of Urbanization Council of Ministry of Public Works and Settlement (April 2009), 10.

[14] Ministry of Environment and Urbanization, “Spatial Planning Construction Regulation.” Date of Official Journal: 14.06.2014, Issue of Official Journal: 29030 (2014).

[15] Ministry of Environment and Urbanization, “Regulations on Certification of Sustainable Green Buildings and Sustainable Settlements”, Date of Official Journal: 08.12.2014, Issue of Official Journal: 29199 (2014)

[16] Yazar, Kadir Hakan. “A Proposal of an Urban Planning Method for the Medium Sized Cities within the Framework of Sustainable Urban Development.” Ankara University Graduate School of Social Sciences Department of Political Science and Public Administration PhD Thesis. (2006): 20.

[17] Erbaş, Erdem. “Local Energy Planning in New Development Areas.” UCTEA Chamber of City Planners Journal of Planning. (2008): 30.

[18] Sınmaz, Serkan. “Integration of the Energy Efficiency Theme into the Urban Planning System of Turkey: An Approach for the City of Lapseki” UCTEA Chamber of City Planners Journal of Planning. (2015): 196.

[19] http://www.emo.org.tr/ekler/4cd7a8f7f9f8512_ek.pdf

[20] Gültekin, Arzuhan Burcu and Yavaşbatmaz, Seda. “Sustainable Design of Tall Buildings.” Journal of the Croation Association of Civil Engineers Gradevinar 65:5 (2013): 452.

[21] Yılmaz, Mustafa and Yıldız, Serkan. “Sustainability Criteria for Military Buildings” Journal of Defence Sciences. 14:2 (2015): 169-170.

[22] Atıl, Aslı, Gülgün, Bahriye and Yörük, İsmail. “Sustainable Urbans and Landscape Architecture”. Journal of Agriculture Faculty of Ege University (2005): 221.

[23] Karaca, Mehmet and Varol, Çiğdem. “Energy Efficiency of Housing Areas; A Critical Review on Housing Development Projects of Housing Development Administration of Turkey.” METU JFA. (2012): 129-131.

[24] Joss, S., Tomozeiu, D. and Cowley, R. “Eco Cities – A Global Survey 2011.” University of Westminster (28,47,49,59,73 September 2011).

[25] http://www.yapi.com.tr/haberler/cin-dongtan-eko-city---arup_95743.html

[26] http://www.theguardian.com/environment/2016/feb/16/masdars-zero-carbon-dream-could-become-worlds-first-green-ghost-town

[27] https://iguneltr.wordpress.com/2011/06/02/japonlar-yuzunu-gunese-donuyor/

[28] http://www.panasonic.com/tr/corporate/surdurulebilirlik/sinirli-kaynaklardan-ve-enerjiden-en-iyi-sekilde-yararlanma.html
[29] http://panasonic.net/es/solution-works/fujisawa/
[30] https://medium.com/city-smarts/smart-cities-in-japan-fujisawa-sustainable-smart-town-519aa39a813e#.fw1x8xu06
[31] http://www.scmp.com/news/asia/article/1706185/japans-hi-tech-fujisawa-sustainable-smart-town-glimpse-future
[32] http://en.envirocitiesmag.com/articles/sustainable-smart-cities/panasonics-fujisawa.php
[33] http://www.wilderutopia.com/sustainability/land/songdo-south-korea-utopian-city-of-big-data-and-urban-sustainability/
[34] http://inhabitat.com/songdo-ibd-south-koreas-new-eco-city/
[35] http://www.theatlantic.com/international/archive/2014/09/songdo-south-korea-the-city-of-the-future/380849/
[36] http://www.newcitiesfoundation.org/cityquest-songdo-south-korea-conceptualized-ultimate-smart-sustainable-city/
[37] http://www.arkitera.com/haber/5604/spontane-sehirlerin-donemi-kapaniyor--songdo-ibd
[38] http://www.ekoyapidergisi.org/194-avrupanin-besinci-yesil-baskenti-kopenhag.html
[39] http://revolve.media/gothenburg-sustainable-showcase/
[40] http://www.goteborg2050.se/pdf%5Curbanstrukturfoldereng.pdf
[41] http://www.floraburada.com/flora-haber/1005/Super-Surdurulebilir-Kent-Gothenburg
[42] http://www.businessinsider.com/portland-green-city-infographic-2013-3
[43] http://thecityfixturkiye.com/ani-dasguptanin-kaleminden-cop21-sehirleri-iklim-gundemine-yerlestirmek-icin-bir-firsat/
[44] Beyazıt, Eda. "Evaluation of Pedestrian Spaces within the Intermodal Transportation System that Increase Urban Livability: Kabataş Case." İstanbul Technical University Graduate School of Science, Engineering and Technology, Department of Urban and Regional Planning, Regional Planning Graduate Program, Master's Thesis, (June 2007): 52-53.

Paper No: 93

Experimental Tests of the Wall with Carbonfiber Reinforcement

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ABSTRACT

Historic facts of design and construction of the region's first industrial tank for drinking water are given in article. For strengthening of a design use of carbon fiber tape and laminating superficial reinforcing on an epoxy basis was offered. Models of the walls strengthened by carbon fiber reinforcing were tested for tension and a bend. As a result of test linear deformations under loading are also defined necessary mechanical characteristics of composite material - the elasticity module, Poisson's coefficient, the tension resistance, a support angle of rotation during a bend. The tests are conducts in the experimental polygon of the building materials research institute.

Keywords: *bend, strengthening, carbon fiber, stretching*

INTRODUCTION

Constructed 100 years ago Shollar undergrond drinking reservoir in Baku is the unique hydraulic engineering construction. However during inspection need for strengthening of a design of a construction has come to light. Theoretical and experimental studies have shown weak stability of averages of the concrete not reinforced construction walls[1 - 2].Therefore the risk of destruction of a design is very big.It is in the same row located 13 currents of walls partitions.

Figure 1 Type of average walls of a reservoir

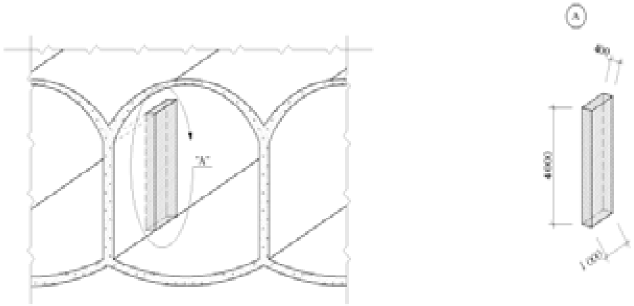

Figure 2Fragment of the average wall of a reservoir

Broad use of carbon fiber reinforcement demands recently new engineering methods of calculation.This material on the indicators has found application in construction of inhabited and hydraulic engineering constructions. Much easier than steel, it is steady against corrosion, the high durability of material is the main indicators. Durability on tension in comparison with steel reinforcement allows to save the area of reinforcing at 7-11 times. In comparison with classical reinforcement the carbon fiber reinforcement are released in a look by the laminate of sheets and a thin tape.However how to consider to the designer in engineering calculations indicators of reinforcing of surfacereinforcing in system (concrete + epoxy + carbonfiber) - the elasticity module, Poisson's coefficient, the tensionload can be defined only through experiment.

STATEMENT OF THEPROBLEM

In engineering calculations for determination of the necessary mechanical parameters operating on a wall virtually cut out 1 m of length of a wall and put all loadings operating on him. As wall height 4.0m virtually cut out fragment of a wall will have the size ***4.0×1.0×0.4m*** (figure 2). On a wall 1 m long the operating loading from soil, by P =2880 kN has been determined by the LIRA 9.6computer program [2]. From additional seismic loading of a wall of the tank were exposed to a bend.At this time in without reinforcing concrete flexural deformations and a set of cracks on a concrete body appear. Here the maximum tension load corresponding the 8th to ball seismic loading will be $R_{nt}=45tq$ [2].For check of a possibility of strengthening of walls it has been decided to carry out experimental tests of models of walls on tension and a bending.Fragments of walls have been covered with epoxy, sheathed by a carbon fiber bow and a laminate, and prepared for test as composite material.Thus it will be possible to obtain more reliable data - the elasticity module, Poisson's coefficient and the tensionloading for composite material.

MODELLING

We will show modeling of a weak link of the underground tank - an average wall.Therefore we will virtually cut out a wall 1 m long fragment.We will receive a fragment of a wall 4 m high and thickness 0.4m.In scale 1:4 we will receive model 1 m high, thickness 0.1m and width 0.25m.If at the rate on a fragment of a wall 1 m wide and thickness 0.4m loading P =2880kN works, then the operating load of model can be calculated.We will consider that the concrete wall works only for the central compression.Then normal stress from the operating loading can be calculated:

$$\sigma = \frac{P}{A \times E} = \frac{2880kN}{0.4m \times 0.1m \times 30 \times 10^6 kN/m^2} = 0.0024kN/m^2 \qquad (3.1)$$

Where *E-* elasticity modulus of concrete, for B25 class concrete $E=30\times10^3 MPa=30\times10^6\ kN/m^2$. Material of model can't be identical with nature material.Therefore it is necessary to determine similarity indicators by the theory of similarity.For this purpose we use the main formula of the theory of similarity [3]:

$$\frac{P_r}{E_r \times L_r^2} = 1 \rightarrow P_r = L_r^2 \times E_r \qquad (3.2)$$

If is to replace material (class B25 concrete) for elasticity with material (class B15 concrete) then for the elasticity module the similarity indicator:$E_r = \frac{E_n}{E_m} = \frac{30\times10^3 MPa}{18\times10^3 MPa} = 1.66$. Then the similarity indicator for the operating loading will be:$P_r = L_r^2 \times E_r = 4^2 \times 1.66 = 26.56$. The operating load of model can be calculated:$P_m = \frac{P_n}{P_r} = \frac{2880kN}{26.56} = 108.43kN$. Then normal stree will be:

$$\sigma = \frac{108.43kN}{0.1m \times 0.25m \times 18 \times 10^6 kN/m^2} = 0.00024kN/m^2 \qquad (3.3)$$

During an earthquake from action of seismic loading on average walls of the tank flexural deformations appear and therefore there are tension loading.As the concrete wall isn't reinforced on a surface of walls appears множетсво cracks.For each class of concrete there is a formula between resistance to compression $(R_b)$and resistance to tension (R_{bt}): $R_{bt} = 0.5\sqrt[3]{R_b^2}$ [4]. For concrete class B30 $R_{bt}=1.15MPa$. If maximum tension load from calculation $R_{nt}=45tq$, then we can to calculated tension indicator: $R_{rt} = L_r^2 \times E_r = 4^2 \times 1.66 = 26.56$

Now we will define the necessary tensionload for model:$R_{mt} = \frac{R_{nt}}{R_{rt}} = \frac{45q}{26.56} = 1.76tf$. If the weight of the concrete wall fragment for the nature is $W_n=4\times0.4\times1\times2.5=4tf$and for the model is$W_m=0.1\times0.25\times1\times2.5= 0.0625tf=62.5kgf$. The we can to calculate of normal stress: $\sigma_n = \frac{R_{nt}}{A_n} + \frac{W_n}{A_n} = \frac{45tq}{0.4\times1} + \frac{4tq}{0.4\times1} = 1.225MPa$. If this stress appears in nature for class B30 concrete then for model will be: $\sigma_m = \frac{R_{mt}}{A_m} + \frac{W_m}{A_m} = \frac{1.76tq}{0.1\times0.25} + \frac{0.0625tq}{0.1\times0.25} = 0.729MPa$. If to take a formula $\sigma_n = E_r \times \sigma_m$as a basis it is possible to specify the similarity indicator for the module of elasticity of model: $E_r = \frac{\sigma_n}{\sigma_m} = \frac{1.225}{0.729} = 1.68$. Then for model the elastic module can to calculate: $E_r = \frac{E_n}{E_m} = 1.68 \rightarrow E_m = \frac{E_n}{1.68} = \frac{30\times10^3}{1.68} = 17.8 \times 10^3 MPa$ $E_r = \frac{E_n}{E_m} = 1.68 \rightarrow E_m = \frac{E_n}{1.68} = \frac{30\times10^3}{1.68} = 17.8 \times 10^3 MPa$. From Normative Design Code it corresponds to class B12-B15 concrete durability [5-6].

TENSION TEST

After durabilities made of model class B10 concrete by the size 1×0.25×0.1m have been prepared for tests on tension and a bending.Previously models have been covered with brand CCS EP Grout epoxy.After drying of model have been strengthened in the following order:

1) Strengthened by one layer a carbon fiber tape with fibers on length of a model and metal caps for a holding strap-2 models
2) Strengthened from two parties by a carbon fiber laminate strip 8 mm wide in 3 rows on length of a model and metal caps for a holding strap-2 models
3) Strengthened from two parties by a carbon fiber laminate strip 8 mm wide in 3 rows on length of a modelwith steel reinforcing inside and metal caps for a holding strap

Carbon fiber tape and laminate are made and will be applied by ***Magnel Laboratory for Concrete Research Belgium Institute.***Tests were carried out on the test hall of Construction Materials Research and Design Institute after S.Dadashev named in Bakuon the ГРМ-2Аbrend tension installation press. The tension loading was put by an interval 0.5 tonf (5 kN). The scheme of tension of model is submitted in figure 3.On motel electronic sensors for measurement of deformations have been established.By means of these sensors relative deformations of tension and compression of composite material have been fixed. It has allowed to calculate Poisson's coefficient for these models.Placement of models on the press and process of test is shown in figure 4.During test relative deformations of longitudinal ε_2 and crossε_1 have been measured. On the basis of it Poisson's coefficient of composite material has been calculated $\mu = \frac{\varepsilon_1}{\varepsilon_2}$ $\mu = \frac{\varepsilon_1}{\varepsilon_2}$. During tension the maximum tension stress through the tensionloadis expressed by a formula$\sigma_B = \frac{P}{A}$$\sigma_B = \frac{P}{A}$, kN/cm^2.Results of test - the maximum tension load, Poisson's coefficient, strength on tension are presented in table 1.

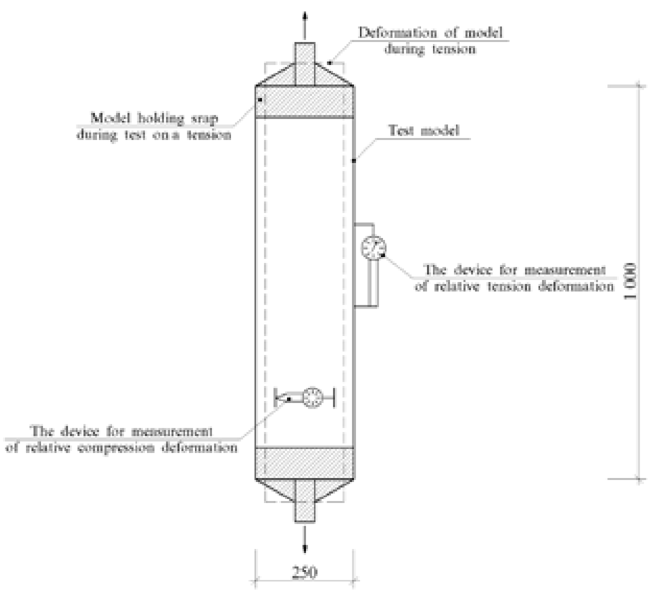

Figure 3The scheme of tension of model

Figure 4 View of the tension test of model

Table 1 Results of test of the concrete models strengthened by a carbon fiber tape and a laminate on tension.

N	Type of models	The maximum tension load P, *tf*	Relative deformation from the maximum tension load ε1	Relative deformation from the maximum comoression load ε2	Poisson coefficient $\mu = \frac{\varepsilon_1}{\varepsilon_2}$	Resistance of the tensile stain $\sigma_B = \frac{P}{A}$ kN/cm^2
1	Carbon fiber laminate concrete model	17	0.07	0.4	0.175	0.68
2	Carbon fiber laminate inside steel reinfircing concrte model	28.2	0.009	0.022	0.409	1.128
3	Carbon fiber laminate concrte model	21.6	1.139	0.4208	0.32	0.864
4	Carbon fiber tape concrte model	26.6	0.391	2.69	0.145	1.064
5	Carbon fiber tape concrte model	30.2	1.295	8.63	0.336	1.208

TENSION DURING BENDING TEST

Tests on tensionduring bend were carried out at the test bench of the ЦД-40 brand. The compression loading was put by an interval 1.0tonf (10 kN).Here tests were carried out on the basis of the interstate standard [6].According to the standard the model is established on the stand, distance between support is 80cm. At 1/3 lengths of model round support under a rigid steel plate are established by the size 30×30cm through which vertical loading was transmitted (figure 5).This scheme of test is widely used in tests on tension at a bending.As well as at test on tension, at test on bending a model strengthened by carbon fiber reinforcing were prepared for test in the following look:

1. 2 layers of a carbon fiber tape in the tension zone of concrete
2. Carbon fiber tape in the tension zone of concrete + inside steel reinforcement
3. Carbon fiber laminate in the tension zone of concrete
4. Carbon fiber laminate in the tension zone of concrte + inside steel reinforcement
5. 1 layers of a carbon fiber tape in the tension zone of concrete - 2 models

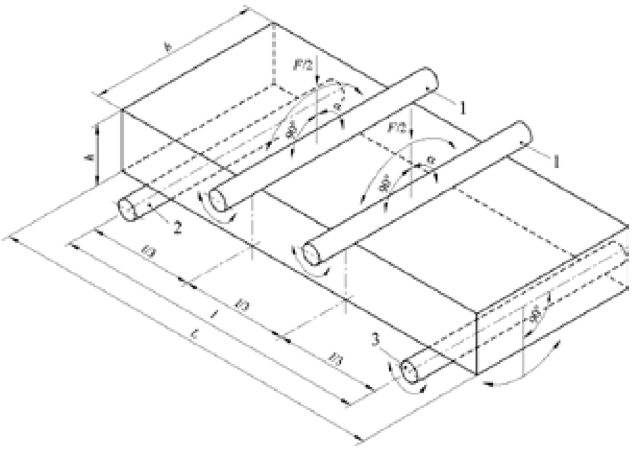

Figure 5 The scheme of model of tension by bending

Figure 6.View of the tension by bending test

During test from action of vertical loading deformations of a deflection were measured.For exact definition of a deflection of model electronic sensors were established in three points, on two support and in the middle of a plate.As edges of model freely lean on support and during loading are bent, the angle of rotation of a support needs to be defined.In this case use Maxwell-Mohr's method.According to this method movement of section of a beam is determined by the following formula:

$\delta = \int_0^l \frac{\overline{M_1} Mdz}{EI_x} \delta = \int_0^l \frac{\overline{M_1} Mdz}{EI_x}$. In this δ - displacement (deflection V are rotation angleθ); *l* - length of the beam; EI_x - bending stiffness of beam; *M* and $\overline{M_1 M_1}$ -the bending moments from the unit and operating loading.

For a case of rectangular section this integral can be calculated as: $\delta = \frac{1}{EI_x} \sum_{i=1}^{n} \omega_i \times \eta_i \delta = \frac{1}{EI_x} \sum_{i=1}^{n} \omega_i \times \eta_i$. In this ω_i- *i* area parts of the weight diagram; η_i -Ordinate under the center of gravity of the area of a weight diagram; *n* -number of division of a weightdiagram into a usual diagram.According to a method multiplication of a diagram is made by the rule$V_K = 2\frac{\omega_1 \times \eta_1}{EI_x} V_K = 2\frac{\omega_1 \times \eta_1}{EI_x}and\theta_A = \frac{\omega \times \eta}{-}\theta_A = \frac{\omega \times \eta}{-}$. These formulas can be simplified and written expression for movement and an angle of rotation: $V_K = \frac{Pl^3}{48EI_x} V_K = \frac{Pl^3}{48EI_x}$, $\theta_A = \frac{Pl^3}{16EI_x}$

$\theta_A = \frac{Pl^3}{16EI_x}$. If the angle of rotation θ_A is defined from test, the moment of inertia is calculated as $I_x = \frac{bb^3}{12}$ $I_x = \frac{bb^3}{12}$, having substituted vertical loading *P* and flight of *l* in a formula it is possible to calculate the elasticity module at a bend as$E_b = \frac{Pl^2}{16I\theta_x}E_b = \frac{Pl^2}{16I\theta_x}$, kN/cm^2.The technique of measurement of an angle of rotation is defined by a specular reflection of a point of support.On an end face of a concrete sample the small mirror is pasted and from distance (*L*) the horizontal laser beam goes to a mirror.The reflected beam from a mirror gets on the filled vertical platform at distance (Δ_S) from a vertical.Then it is possible to define a double angle of rotation$2\theta_A 2\theta_A$ through a tangent of angle$tan\, 2\theta_A = \frac{\Delta_s}{L} tan\, 2\theta_A = \frac{\Delta_s}{L}$. As an angle of rotation very small it is also possible to accept ($\tan 2\theta_A \approx 2\theta_A \tan 2\theta_A \approx 2\theta_A$), then it is possible to receive expression$\theta_A = \frac{\Delta_s}{2L}$ $\theta_A = \frac{\Delta_s}{2L}$ .Results of test - the maximum bending load, rotation angle, Young modulus by bending, tension load by bending, strength on tension are presented in table 2. The tension loadat the bending$R_{tf}$is less than tension load at normal tensionR_t.Therefore he is defined through transitional coefficient $R_t = R_{tf} \times k_1$, where $k_1 = 0.55$is a transitional coefficient.

Today there is a set of the chemical companies on production of carbon fiber tapes and laminate.Though mechanical characteristics of these materials have high rates directly to accept them when strengthening concrete and stone walls, crossbars, columns it is impossible.Because the new strengthened element of a design represents composite material.If resistance to tension of a carbon fiber tape and laminate at 10-20 times more than for steel reinforcement, then the module of elasticity isn't big.On a concrete surface under loading this material behaves as a composite and increases the tension resistance of concrete by 2-6 times.Analyzing results of test it is possible to see that the module of elasticity has grown by 2,5 times, Poisson's coefficient was left without change.

Figure 7.Rotation angle measurement of the tension by bending test

Table 1 Results of test of the concrete models strengthened by a carbon fiber tape and a laminate on tension by bending.

N	Type of model	Deflection, f, cm 1	2	3	Middle deflection, cm	Distance between lazer and miracle , L, cm	Vertical distance from reflected $\ddot{A}s$, cm	$\theta = \frac{\Delta_S}{2L}$ Angle rotation	Maximum bending P, kN	Tension load by $R_{tf}=Pl/bh^2$, kN/m^2	Transit tension $R_t=R_{tf} \times k_1$, $k_1=0.55$	Elasticity modulus $E_b = \frac{Pl^2}{16I\theta}$, *kN/cm^2*
1	2 layers carbon fiber tape	0.346	0.001	3.21	1.779	23.5	0.6	0.0127	44.5	1.424	0.7832	6727.2
2	Carbon fiber tape + steel inside reinforcing	7.8	0.04	7.05	7.465	21.5	1	0.023	39	1.248	0.684	325.56
3	Carbon fiber laminate	8.28	0.002	13.78	11.032	23.5	2.8	0.04	46	1.472	0.809	144.79
4	Carbon fiber laminate + steel inside reinforcing	2.801	0.003	2.83	2.818	29	1	0.0172	40.5	1.296	0.7128	452.09
5	Carbon fiber tape	0.016	0.001	0.27	0.144	38	1.3	0.0302	38	1.216	0.668	1207.9
6	Carbon fiber tape	9.114	0.005	5.02	7.07	26.5	0.3	0.0056	39	1.248	0.684	6685.8

CONCLUSION

1. Strengthening of engineering structures of especially concrete walls a carbon fiber tape and a laminate reduces emergence of superficial cracks. The tebsion resistance increases 8-10 times, and rigidity by 2-3 times.It allows to increase stability of a design at least twice;
2. The analysis of results of test allows to draw a conclusion that use of such materials when strengthening concrete and stone constructions is possible only after experimental tests on design models;
3. Advantage of such strengthening - without breaking structure of an element of a design by means of accidental elements it is possible to achieve the engineering decision;
4.Such experimental method gives the chance in similar ancient constructions to carry out strengthening of a design. It will allow to reduce seismic risk of destruction of such constructions.
5. Applied in a method it can be used not only in ancient constructions but also in modern underground strustures.

REFERENCE

[1] Mastanzade N., Rasulov Kh., Mirzoyev M. Assessment and retrofit project of an underground Shollar concrete reservoir for drinking water. ***Tandem: Cement & Construction. № 2.2013 Moscow. Russia***

[2] ***Mastanzade N., N.Sultanov.***Assessment, analysis and strengthening design of the underground reservoir. ***Soil-Structure Interaction. Underground Structures and Retaining Walls. Saint Petersburg, June 16-18, 2014***

[3] Yakitin G.S. Modelling of structures. Study guide. Khabarovsk. Russia. 2002 (in russian)

[4] State Standard 10180-90 Interstate Standard. Concretes. Methods for strength determination using reference specimens.(EN 123390-1-6 2009, NEQ). Moscow. 2013

[5] Construction norms and rules 2.03.01.84.Concrete and reinforcement concrete structures.

[6] Rules 52-101-2003.Rules by design and construction concrete and reinforcement concrete without press-strange. Moscow.

Paper No: 106

Assessing Manual Lighting Control in Offices

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ABSTRACT

Despite the widespread implementation of user behavior models in the field of lighting research, existing user profiles have not been based on extensive user involvement. To understand and enhance manual lighting control behavior data, office users' behavior is evaluated since they correspond to one group consuming energy of electric lighting in terms of multiplying high rates. This study examined the influence of interior layout design, illuminance level and occupancy rates on manual lighting control in offices.
Methodology involves a monitoring process to determine and understand interior layout, occupancy and illuminance levels' contributions to manual lighting control considerations. Monitoring process took place in single office building on Izmir Institute of Technology Block-C. The sample room was modified by 8 different interior layouts to see the change of manual lighting control. By the use of illuminance meter and occupancy-light sensors, manual lighting control behavior of the occupant were evaluated with relation to interior layout. Results were analyzed and discussed in order to understand the contribution of interior layout, illuminance and occupancy.

Keywords: Manual lighting control, monitoring, user behavior, interior layout

INTRODUCTION

Buildings play a role of accommodating user's organizations and activities. They provide users with indoor climate, technique services, and platforms for activities [1]. As Sattrup mentioned, "buildings and their designs can also be understood as devices that serve technical purposes, as technology in a more narrow sense of the word, which integrates a wide range of other technologies in the processes of fabrication and to achieve the desired performance of the design" [2]. Architecture can be used to trigger people towards sustainability, to awake their senses and lead them for being more responsible [3] . For instance, "employees can change their physical setting to satisfy their needs (e.g. changing the orientation of a workplace to prevent arousal by bright sunlight or using headphones to prevent distraction by noise" (V. Tabak 2009, 27). Besides, physical features like color, shape, texture may influence users' perception and energy consumption [4]. For example, the relation of desk and window can play a role on manual lighting control. If someone is having a seat in front of the window and his/her back is facing the window, his/her own body may obstruct and cause shadow; therefore, he/she may need to switch on the lights. Or on the contrary, if anyone is facing the window, even though illuminance is not sufficient, because of the luminosity, he/she may consider the room as well-lit and not switch on the lights.

Another parameter can be related with the distance between window and desk. Since illuminance decreased as it gets deeper in the room, the distance between the window and desk, because more important in terms of illuminance levels on the workplane. So a user, whose desk is located far from window, may need to switch on lights more frequently than with someone whose desk is near to window.
This study aims to observe the change of manual lighting control behavior according to desk position and distance to window. This study tries to understand the relation between the interior layout and users' artificial light usage. Here the hypothesis is that in a well-lit workplace the users may not turn on the lights while working. Therefore, in the observed sample rooms, lights off & occupied hour percentages were compared with each other. Though the users were not in the office for full day, the percentages only represent the amount of occupied without artificial light usage hours in 24-hour time.

METHODOLOGY

Within the monitoring phase, three measurements were carried out with two sensors, which will be described respectively.
For the monitoring process, three private office rooms in İzmir University of Technology, Faculty of Architecture were observed in terms of occupancy and manual lighting control. For monitoring process, sensors which have been used in various lighting and energy consumption research [5]–[8] were used to. To observe occupancy and manual lighting control for long terms and energy consumption evaluations, these types of sensors are very helpful and useful. The volunteers of the study were monitored by using two sensors; HOBO U12-O12, to record the horizontal illuminance on the desk and HOBO UX90-006 data loggers were used for to hold the records of both occupancy and light on-off conditions. Using these two sensor/data loggers, the following data were achieved:

- horizontal illuminance measurements on desks
- occupancy detection in the room
- artificial lighting operation

The monitoring phase took place during winter season (between November 2014 - February, 2015) because daylight penetration is limited and weaker in winter, which might trigger users' manual lighting control. Four basic directions of getting the daylight penetration (from left, right, back and front) have become the variants of the monitoring. In order to see the contribution of distance to window on the manual lighting control, these eight directions were tested with two different distances from the window for 10 days. Each direction was monitored with 1/1.5m (which is named as direction-A) and 2/2.5m (which is named as direction B) (Figure 1). To determine the relation between occupancy and illuminance, the manual lighting control behavior was analyzed for each interior layout for each day with each user. In these analysis the following results were obtained:

- illuminance during entrance
- average illuminance during occupancy
- artificial light usage
- occupancy

RESULTS

The occupancy and light percentages of each layout were analyzed to find out the relation between occupancy and artificial lighting usage. However, these results vary according to the interior layout and distance to window since different layouts affected users' manual lighting control. Results are discussed for each interior layout and user individually (Figure 1).

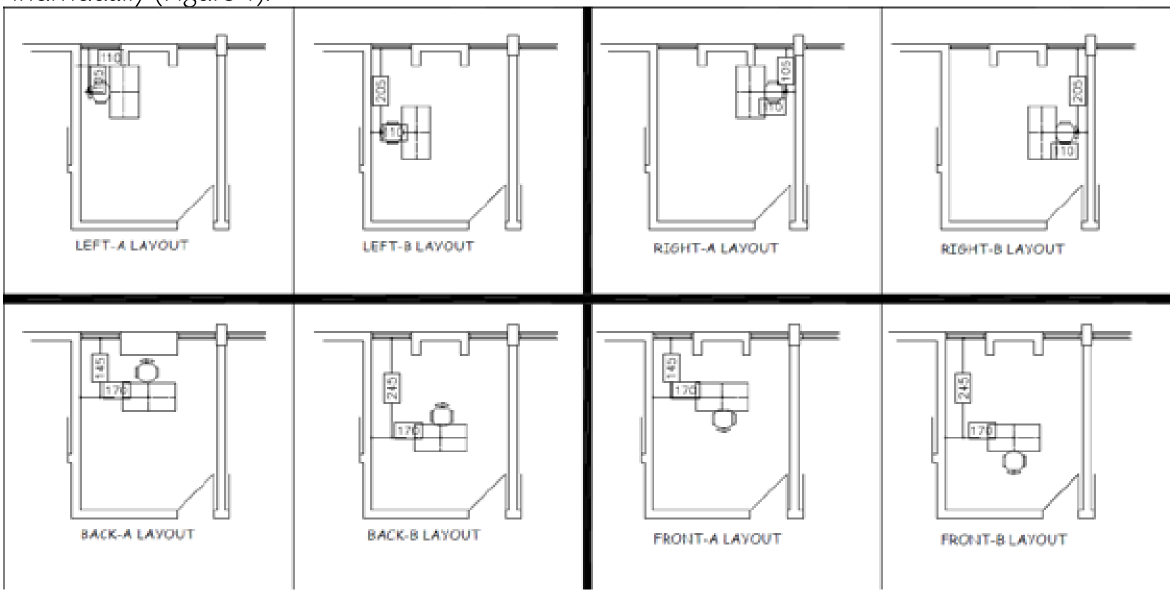

Figure 1 Eight determined interior layout schemes

A. Left Layout

Regarding the Left layout, User A's and User C's artificial lighting usage differs in Left A and B positions. For example, in Left B position, the overall percentage of occupancy without lights on (Light off&Occ) for all users is less compared to Left A (where the desk is nearer to window). Correspondingly, the Light on&Occ, (where the users occupy the room with lights on) percentage is higher for Left B compared to Left A. Both of the findings are a sign of higher lighting energy consumption during the occupancy intervals for User A,B and C (Figure 2).

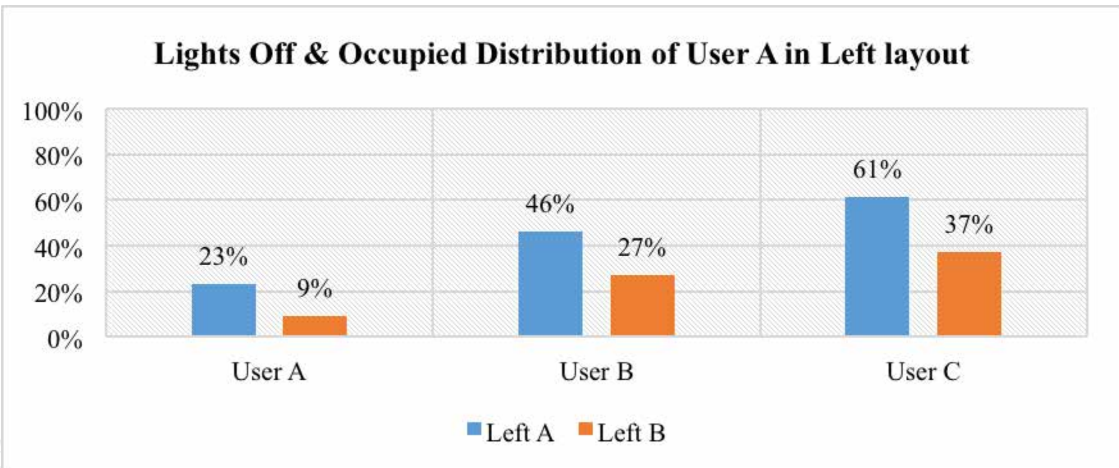

Figure 2 Lights Off& Occupied distribution of User A in Left Layout

B. Right Layout

Compared to Left layout, in Right layout, users' manual lighting control shows slightly changed. The most obvious difference from the Left layout, User B has longer periods of occupancy without artificial light usage (Light Off&Occ) and especially in Right B position. On the other hand, User A and User C do not show that much significant change in terms of artificial lighting usage between the Right and Left positions however percentages of Lights Off& Occupied is higher in Left Layout. Just like Left layout, again in Right layout, B position has more hours with artificial light usage compared to Right A position (Figure 3).

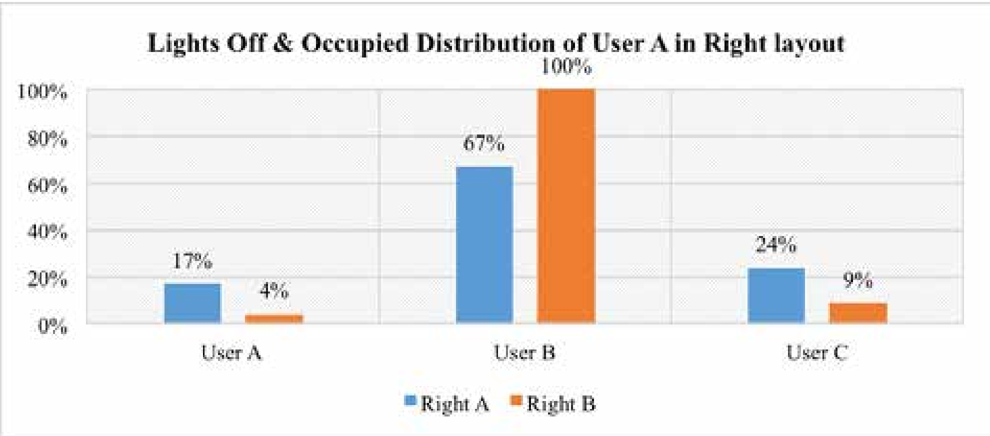

Figure 3 Lights Off& Occupied distribution of User A in Right Layout

C. Back Layout

In Back layout, User A and C's percentage of Lights Off& Occupied decreased significantly compared to Left and Right layouts yet again in compared to A, during B artificial lighting consumption was lower. On the contrary, User B never turned on the lights during the Back Layout, both A and B measurements. User C's was rarely at the office therefore the percentage of occupancy was very low for that user (Figure 4).

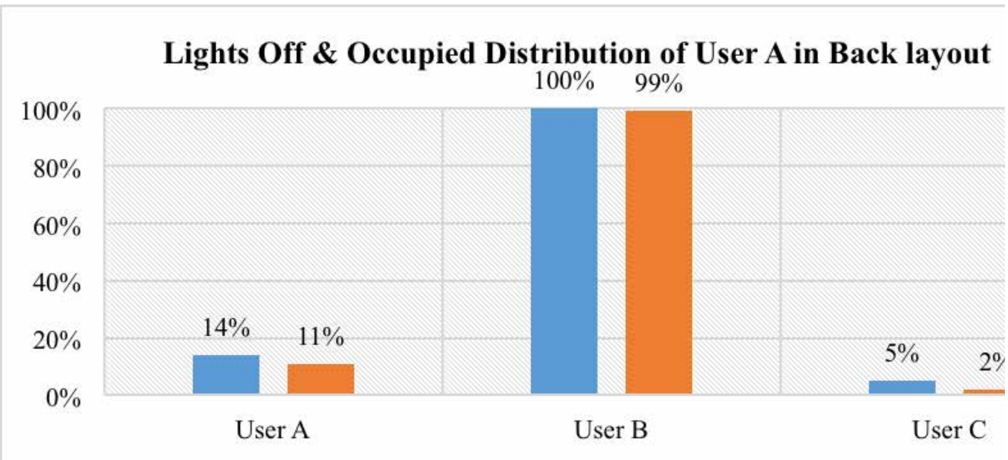

Figure 4 Lights Off& Occupied distribution of User A in Back Layout

D. Front Layout

In Front layout, users' manual lighting controls have little in common. Therefore, instead of common statements which includes all users, each user has to be analyzed individually. In Front layout, artificial lighting usage percentage was higher compared to other three layouts. Even User B, who generally prefers to work without lights on, worked with the lights on during Front layout. Similar to User B, also User A used artificial lighting more in Front A layout compared to Front B. However, in Front layout, User A preferred to switch on the lights more compared to the other three layouts. The increase in Light On & Unoccupied hours were higher especially for Front B position for User C (Figure 5).

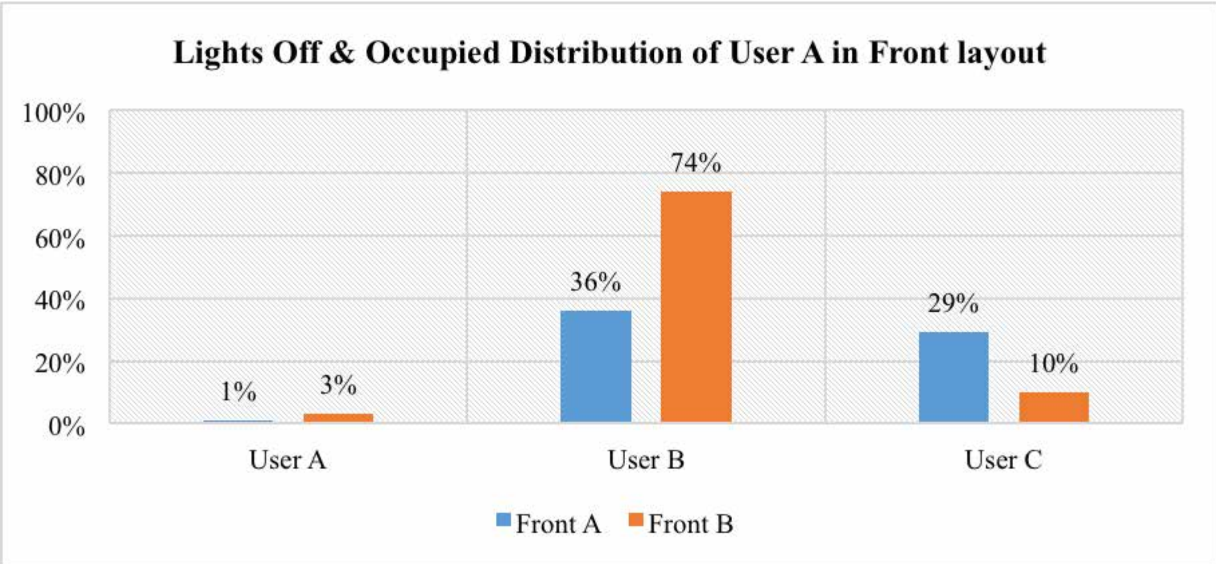

Figure 5 Lights Off& Occupied distribution of User A in Front Layout

E. User Manual Lighting Control Analysis

During the same time periods, weather conditions and orientation, three different users were observed in terms of manual lighting control behavior. Though the conditions were almost identical, the manual lighting control behaviors were not, during these two months of measurement. This fact underlines the importance of user's preferences, expectations and actions in manual lighting control behavior. Here each users' manual lighting control will be discussed by their own, and not compared with the other users.

When the measurement results of User A were evaluated, it was seen that in A position, the amount of time he preferred to work with daylight was higher compared to B position (except the slight difference in Front layout). Especially in Left layout, almost on the one fourth of the time User A did not turn on the lights while working.

Independently of the layout, User B has the least ratio of artificial light usage and generally prefers to work without the lights on. Besides this fact, User B's manual lighting control behavior does not show significant changes between A and B positions in any of the layouts. One another important point is that User B, generally does not stay in the office for long periods of time.

During the 2 months of measurement period, User C mostly preferred to work without artificial lighting energy in Left layout, which was followed by Front, Right and Back. However, independently of the layout User C, turned on lights fewer on A position compared to B. Actually User C show the greatest difference according to the change of layout and position in terms of manual lighting control.

F. Layout Comparison

Users' manual lighting control preferences showed variance according to different layouts. For example, when Back responses were compared to Front responses, User A and B used less artificial lighting. Though the distinctness is more clear among Left and Right layouts for User A and C. When compared to Back and Front, still in Left layout users switch on the lights less frequently.

CONCLUSION

This study aims to understand how the users' manual lighting control preferences change according to the interior layout. Though the manual lighting control behavior differs according to the layout, position and user, such an outcome is noteworthy not only in developing architectural design merits but also in enhancing technical ways to evaluate daylight performance and energy efficiency in working spaces. Users' desk layout can be involved as a certain affecting variable/or constant in performance and energy calculating tools. Additionally, personal issues can be integrated to get a deep understanding and insight. A further study can analyze in detail how a left-hand writer receiving daylight from the left side satisfies differently than a right-hand writer in the same layout; and how the lighting electricity is consumed or saved in both cases.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Q. Shen, W. Shen, "User Activity Simulation and Evaluation Model for the Improvement of Space Planning in Office Buildings," in *18th CIB World BUilding Congress*, 2010, p. 62.

[2] P. A. Sattrup, "Sustainability - Energy Optimization - Daylight and Solar Gains," Royal Danish Academy of Fine Arts School of Architecture, Design and Conservation Institute of Architectural Technology, 2012.

[3] G. Y. Yun, H. Kim, J. T. Kim, and H. J. Kong, "Effects of occupancy and lighting use patterns on lighting energy consumption," *Energy Build.*, vol. 46, pp. 152–158, Mar. 2012.

[4] P. Maleetipwan-Mattsson, T. Laike, and M. Johansson, "Factors Affecting Optimal Lighting Use in Shared Hospital Environments: A Case-Study," *Build. Environ.*, vol. 96, pp. 260–269, 2016.

[5] R. Athalye, H. Eckerlin, and W. M. Street, "Comparison Of Results From The Daylighting Simulation Of A Side-Lit Classroom Using Daysim With Actual Measured Annual Illuminances."

[6] C. Reinhart and K. Voss, "Monitoring manual control of electric lighting and blinds," *Light. Res. Technol.*, vol. 35, no. 3, pp. 243–260, Sep. 2003.

[7] G. Y. Yun, H. Kim, J. T. Kim, and H. J. Kong, "Effects of occupancy and lighting use patterns on lighting energy consumption," *Energy Build.*, vol. 46, pp. 152–158, Mar. 2012.

[8] V. Inkarojrit, "Multivariate Predictive Window Blind Control Models For Intelligent Building Façade Systems," in *Building Simulation 2007*, 2007, pp. 787–794.

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Sustainability of Historical Cultural and Environmental Heritage within the Scope of Tourism Management Plans: A Case Study for Talas

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ABSTRACT

Talas is a town in Central Anatolia and resides in almost at the center of Cappadocia. Talas is an ancient center of Kayseri which is one of the major cities in Turkey with a history of six thousand years. Ancient center of Talas is under protection as a 1st grade historic site by the Turkish Law. Talas was one of the provinces selected for the CEKUL Foundation's "7 Region 7 Cities" project in 1998 - a UNESCO founded initiative - and one of the cities in which a pilot implementation was made within the scope of that project. Since then not much has done to protect the existent heritage. There are unique opportunities for cultural and natural touristic activities within Talas and in nearby places. Today, Talas is under the threat of an heavy urban transformation in progress. In this research past "Urban Development Plans" for Talas are thoroughly analyzed, a draft inventory of the existent and "lost" heritage is made. A SWOT analysis for Talas is presented. The results shall be used to develop a rehabilitation and regeneration plan proposal and a policy development to enable a regenerative management model for Talas, mainly focusing on tourism opportunities.
Keywords: Urban transformation, Talas, Regenerative Tourism Management

INTRODUCTION

Collective consciousness is something built upon culture and heritage, and something which may decay fast if not fed by the built environment, memories, customs and traditions. It starts in the form of a family, extends to our neighborhood, then to a nation, and help to develop a social consciousness to realize ourselves as a world citizen. Tourism is a major driver towards "global collective consciousness" in that sense. Urban sustainability is essential to lead the path to such "total consciousness".

Heritage is a comprehensive concept that includes various cultural, natural, historical, architectural, archaeological, and geological values. It reflects different ways of lives and habits. In other words, different cultures and periods of societies [1]. However, there are many considerable social, environmental and economical repressions which threat the heritage ans so the collective consciousness of societies. Heritage is an nonrenewable source; therefore it should be conserved – or better – managed effectively.

Talas is one of the many settlements in Central Anatolia which survived for ages from neolithic times to present as a modern city. Talas is so unique as a settlement in the world - an unique city - which inherits natural, historical, cultural, economic and modern life values from «in itself» and «very» nearby places.

Problem Context

Heritage is ultimately important as anything that is considered important enough to be passed on to the future generations. Past experiences had shown that conserving a heritage is not efficient enough to maintain the value and sustainability. Instead it needs to be presented.

If a heritage is well managed, it is a source of tourism based economic growth. However there are side effects of heavy visiting. Talas is so unique that the place is a officially recognized as a historical, cultural and natural heritage.

Though, Talas is under threat of heavy construction activities as an output of current city transformation policy in progress all around Turkey.

Talas requires a development and tourism management plan for the sustainability of core values of the land. General character of the city and the fauna it was in had been widely deteriorated within the last decade.

Objectives and Scope of Research

This research aims to develop a tourism based regional development plan for Talas province in Kayseri Turkey. A Management template and a process model shall be output to enable social, economic, historic and environmental sustainability of the place with such an attitude to facilitate the prevention of side effects of the current modern transformation in progress and the proposed tourism based (city or region) development plan.

Within the scope of this paper, we focus on the basic terminology and will present the core values of Talas in terms of the society, architectural and urban values and patterns to develop an inventory of what should be protected and how.

Related Work

In spite of the importance of conserving heritage for many reasons, including tourism and economic development, there are a number of challenges associated with heritage conservation in the less-developed world. That pushed the academic efforts to develop a new approach for the conservation and management of inherited built environment, culture and nature.

This approach is called “Cultural Heritage Management”, which has been implemented since the 1970’s with an emphasis on the “sustainability” principle. It aims to conserve, use and develop the heritage and to sustain its values and significance by giving the heritage a compatible use. The most important innovation of the management approach involves the sustainability principle [1].

United Nations Educational, Scientific and Cultural Organization (UNESCO) is the most important international institution that is active in heritage conservation. The organization arranged a convention called “Convention Concerning the Protection of the World Cultural and Natural Heritage” (World Heritage Convention) in 1972 [2]. The convention paid a significant attention to reaching a common definition about heritage and thus it came up with definitions for both cultural and natural heritage.

Boniface and Fowler (1993) mention that urban heritage tourism provides a means to accentuate local difference and assert place identity in a rapidly globalizing environment [3]. Zeren & Erkut (1990) studied Relevance of Socio-Economic and Physical Data for the Conservation of Istanbul Historic Peninsula [4], Zeren Gulersoy also studied with Kukrer (1993) to investigate the Interaction of Conservation and Tourism in Historic Cities within the scope of Kayakoy [5].

Ataov (2007) analyses the relationship between social sciences and urban planning [6]. Beyhan Ş. G. developed an identity model to enable sustainable tourism whilst satisfying contemporary user requirements within the scope of urban sustainability [7]. UNESCO founded a “Chair in Cultural Heritage Management and Sustainability” in 2011 at the Institute for Social and European Studies Foundation [8]. The topic as an area of interdisciplinary research is quite new and more models for sustainable tourism management in heritage sites are required.

Methodology

Most of the content of this paper is based on literature research. First, within the scope of planning for urban heritage places the main terminology is introduced. Then tourism policies are discussed from a sustainability perspective. Third, we elaborate on research which introduces tourism management plans for heritage sites. Then a case study introduces Talas and underlying problems as in which we also identify / analyze the types of entertainment and tourism activities possible in Talas. It will be a good example for the deficiency of monitoring and review strategy of conservation plans, although they have a successful conservation and development approach. This research will present with practical, legal, and theoretical issues

PLANNING FOR URBAN HERITAGE PLACES

Within the context of planning in historic environments a dichotomy exists between preserving the past for its intrinsic value and the need for development in response to changing societal values. This conflict arises from the new sense of historicity and a romantic nostalgia for the past, which according to Lowenthal (1985), stems from a psychological need to know the past as a reference point although how we "know" the past varies from personal experience through fallible memory to learned history. Lowenthal shows clearly that we want old things to "seem" old, with antiquity valued and validated by decay and the patina of age [9]. Contribution of "modern" requirements to the existing old and merging both in harmony is a main focus of related research efforts.

Significance of Cultural Heritage and Concepts of Conservation

Conserving the heritage is beneficial for social and national identity, economical power, political power, educational aspect and according to urban context. In 1972, the UNESCO World Heritage Convention revealed the most important decision on establishing an intergovernmental committee to protect the natural and cultural heritage called "World Heritage Committee". The Committee determined a "World Heritage List (WHL)". According to the article 5(a) of the Convention, every state that has signatory is responsible of conserving the WHL that are appreciated by International Council on Monuments and Sites (ICOMOS) based on 'universal outstanding value'. The Operational Guidelines (2015) of the World Heritage Committee constitute the World Heritage list which conveys the universal outstanding value as:

"***Outstanding universal value means cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole. The Committee defines the criteria for the inscription of properties on the World Heritage List.***"

The Cultural Heritage Management has gained importance since the 1970's particularly in Europe. The management studies started in the 1970's, but the term was used first by the ICAHM (The ICOMOS International Committee on Archaeological Heritage Management) formally ICOMOS-Charter for the Protection and Management of the Archaeological Heritage. Also, ICOMOS Charter for the Protection and Management of the Archaeological Heritage gave some global principles of the Archaeological Heritage Management [10].

In 2001, the US/ ICOMOS made an international symposium under the theme "Managing Change: Sustainable Approaches to the Conservation of the Built Environment". This symposium emphasized the importance of the sustainability principle for heritage conservation. According to the 4th Annual US/ICOMOS International Symposium [11]:

"***Sustainability emphasizes the need for a long-term view. If conservation is to develop as a viable strategy, the economic dimension needs to be addressed, while at the local level community education and participation is central to sustaining conservation initiatives. Unless we understand how cultural heritage is being lost or affected and what factors are contributing to those processes, we will not be able to manage it, let alone pass it on. Effective heritage site management involves both knowing what is important and understanding how that importance is vulnerable to loss***".

The Management Guidelines for World Cultural Heritage Sites (1998) emphasizes that the definition of the heritage should be clear, so that the conservation process can be made in an efficient way. The Guideline adds :

"*Restoration and conservation should be based on a clear definition of the heritage resource and its relationship to its setting. This definition is part of the critical process aimed at cultivating an appreciation of the heritage as an integral part of present-day society by developing a framework for assessing resource values, establishing management objectives, and preparing presentation and interpretation policies*" [12].

OURISM AND SUSTAINABILITY

As the global economy evolves, cities restructure themselves to meet the new challenges and needs that arise. This negotiation between global and local processes has been articulated in a number of ways by different commentators. Urry expresses this relationship in geographic terms through the concept of the "global division of tourism" [13].

The basic proposition is that widespread deindustrialization, improved transportation and communication networks, the expansion of the service economy and the globalization of tourism have propelled different countries to emphasize certain tourism activities. This created "expert" or "special" cities of cultural heritage with unique characteristics which cannot be found elsewhere; therefore, entailing destination areas which capitalize on local resources and accentuate unique identities within the context of a globalized economic system. Local site factors {such as the (1) quality of attractions, (2) transportation infrastructure, (3) accessibility, (4) availability of media information and (5) competition from similar attractions} determine the success or failure of destination areas in attracting tourists. The unequal footing occurred because of local factors such as the inheritance of fine buildings, history and population characteristics, as well as mediating conditions like an unfavorable industrial image or social disorder, yield with different outcomes [13].

The emergent form of the industry is based around **flexibility, segmentation and diagonal integration**. At the global scale, the **diffusion of information technology**, worsening **environmental problems**, changing leisure and work patterns, and a number of other factors have forced local tourism systems to respond in ways that are markedly different from the past. This issue is the basis of the case study on Talas, which is subject to this paper.

Whilst in developing countries, disenchantment with mass tourism and the recognition of new market segments have encouraged local governments, host entrepreneurs and businesses to play a more proactive role in the tourism industry [14], in Talas we face the fact that urban transformation was based on temporary effortless income only and a big opportunity for sustained economic growth based on tourism activities was lost (but within the context of this research, that we assume possible to regenerate).

New, more imaginative and varied tourism products and services that are "unique" and which provide a more "meaningful" travel experience promise a potential for sustained economic growth. In Talas, various opportunities are existent including (but not limited to) "paragliding (Ali Dagi)", "Skiing (Erciyes Mountain)", "Tracking (Hisarcik & Erciyes)" as well as various historical heritage sites like an underground city, an ancient old town and traces of neolithic settlements. Heritage tourism, with its historical and cultural overtones, offers Talas an important avenue through which to develop and maintain economic and cultural growth.

Urban heritage development serves many objectives beyond the obvious economic goals of tourist attraction, employment generation and revenue creation. Heritage sites may be created to meet residents' demands for recreation and/or cultural enrichment, or they may be undertaken to fulfill certain political agendas. Although multiple motives underlie each project, the economic objectives are often given greatest prominence because they legitimize the substantial capital channeled into such an undertaking and provide tangible proof of returns on investment [13].

Financial constraints

Major financial bottlenecks are occurred as a result of the following factors: "Private ownership and human habitation"; "Unmanaged agriculture"; "Looting and illegal digging"; "Colonialism"; "Improper conservation"; "Random modernization"; "Too much of a good thing"; "Lack of cooperation and holistic management"; "Lack of social will"; "Local poverty and unawareness"; "Lack of political will". Unfortunately, Talas suffers from all these adverse effects. Revenue created by the current investments (as per the ongoing urban transformation process) is extremely limited and impossible to sustain.

Sustainability

Sustainability today expresses both theoretical and philosophical dimensions. Sustainability is a function of the negative impact of population growth and affluence. The aim and expected outcome of sustainability concept is to establish, control and manage the requirements of society with an attitude to guarantee that next generations would continue to benefit the same quality of life.

Sustainability enables the continued function of a society, an ecosystem or any system which maintains a sustained existence without decay, interruption, deterioration whilst preventing that system becoming extinct as a result of overuse or benefit from the vital resources that system depends on. This approach requires a paradigm and philosophy shift which requires new approaches, thoughts and attitude towards development [15].

In order to maintain sustainability of urban settlements, subsets of properties which makes a place an "urban place" must be preserved and/or improved to sustain relevant values. These subsets of properties include a variety of "core" values related with the environment, social structure and economy such as;

- Culture, social values, wisdom
- History and memorials, landmarks
- Natural resources(fauna, water resources, agricultural resources)
- Socio - economic structure

Culture is a function of history, nature and socio-economic dynamics of a society [16]. Cultural sustainability is essential to maintain sustainability of values as a product of that function, which requires a conservative attitude. Conservation alone usually interferes with ever-changing contemporary requirement of a society so, it is important to merge, model, adopt, plan and manage contemporary conditions and requirements with traditional values to enable continued benefit from such conserved values, built environment, artifacts, etc.

SUSTAINABLE TOURISM

Sustainable tourism is the concept of visiting a place as a tourist and trying to make only a positive impact on the environment, society and economy. Core values that define sustainable tourism are [17]:

- Optimum, long term, and effective use of natural and social resources
- Preservation of social settlement and relevant built environment
- Economic and social equity
- Cohesion to total quality
- Social participation

Tourism can involve primary transportation to the general location, local transportation, accommodations, entertainment, recreation, nourishment and shopping. It can be related to travel for leisure, business and what is called VFR (visiting friends and relatives). There is now broad consensus that tourism development should be sustainable; however, the question of how to achieve this remains an object of debate [18].

Sustainable tourism is about re-focusing and adapting. A balance must be found between limits and usage so that continuous changing, monitoring and planning ensure that tourism can be managed. This requires thinking long-term (10, 20+ years) and realizing that change is often cumulative, gradual and irreversible. Economic, social and environmental aspects of sustainable development must include the interests of all stakeholders including indigenous people, local communities, visitors, industry and government. [19] Tourism is a major economic activity in the European Union with wide-ranging impact on economic growth, employment, and social development. It can be a powerful tool in fighting economic decline and unemployment. Nevertheless the tourism sector faces a series of challenges. The European Commission works to address these with policies and actions [20].

Sustainable tourism is a form of tourism which involves being conscious of the potential economic, environmental, and cultural impacts of tourism. Sustainable tour companies and tourists who support the idea of sustainable tourism make extra efforts to ensure that their impact on the places they visit is positive, rather than simply neutral or negative. Several certification agencies inspect and accredit tour companies which offer sustainable touring packages, with the goal of creating an industry-wide standard which makes it easier for tourists to select companies to do business with.

The concept of sustainable tourism is closely related to ecotourism, a form of tourism which focuses on environmental and ecological issues associated with tourism, but sustainable touring is wider in scope. While sustainable tours are designed to address environmental issues related to tourism, other considerations such as the impact of tourism on the local economy are also incorporated into the sustainable tourism philosophy. In addition, this industry is very aware of the cultural impacts of tourism, especially on indigenous people [21].

Sometimes, sustainable tourism also involves an active contribution to the community. For example, tourists might volunteer with local organizations and help provide health care, housing, and other services to needy people in the community. Others might participate in environmental cleanups or donate to nonprofits and charities which serve the area.

Interoperability has a key role in establishing sustainable tourism. Major interoperability driver is communication tools and facilities. Such communication facilities include [22]:

- Advertisement
- Exhibitions (domestic and abroad)
- Knowledge maps
- Education
- Public awareness campaigns
- Involvement of local people to governance
- Incorporation of dedicated information models and Information and Communication Technologies (ICT)

Sustainable Tourism Policies

For tourism to be more sustainable, it requires a holistic, integrated perspective that takes into account all the industries and resources upon which tourism relies. Mass tourism will continue with or without alternative/eco/green/responsible tourism, therefore policies pertaining to environmental and social criteria as well as economic growth are required. The criteria recognized to make tourism more sustainable have led to the call for government intervention in the form of sustainable tourism policies [23]. The physical planning of tourism deals with environmental and social pressures which may be analyzed under the “Water”, “Energy”, “Transport”, “Urban Waste”, “Land use” and “Social” topics:

The synthesis of above factors shall be used for efficient operation of facilities, financing patterns and solutions and economic growth [24]. Similar research elsewhere yielded the following policy attributes:

- Touristic planning according to the supply rather than demand
- Giving priority to local citizens
- Enabling tourism for the whole year
- Public transport
- Social participation
- Renewable energy use
- Merging tourism activities into real life
- Use of existent building stock
- Preservation of social and local cultural identity
- Long term, flexible, tourism investments

Basic components of sustainable tourism policies include

- Ecological policies
- Cultural Policies
- Social policies
- Economics policies
- Institutional Policies
- Aesthetic policies
- Examples, success stories; Sustainable tourism policies from all over the world; a lessons learned database.

Examples of tourism management models on heritage sites

In contrast to the global culture approach, some commentators argue that urban heritage tourism provides a means to accentuate local difference and assert place identity in a rapidly globalizing environment [3]. The pervasiveness of heritage tourism in cities throughout the world is often explained as an outcome of global economic trends. According to Law, four factors have propelled cities toward tourism development: (1) the decline of long-established manufacturing activities; (2) the need to create new economic activities or face high unemployment; (3) the perception of tourism as a growth industry; and (4) the hope that tourism development will result in the regeneration and revitalization of urban cores [13].

The user approach addresses four related issues: (1) who the urban tourists are, (2) what they do in the city, (3) why they visit the city and (4) what their perceptions are. In "actor-centered" studies, the roles played by the state, local entrepreneurs, residents and community groups in Urban Heritage Tourism (UHT) development are investigated and the power relations between them are articulated. Employing such concepts as the "entrepreneurial city" and the "urban growth machine", various scientists have investigated the different ways in which "players" conflict and negotiate with one another in the collective goal of urban change. Unfortunately, little comparable research is available on these aspects of UHT development with a key reason being the independent agendas of scientists in the fields of tourism development, historic conservation and urban change [13].

While the acknowledgment of local conditions in shaping UHT development is vital, greater attention needs to be focused on the ways these conditions interrelate with global processes of change. An overemphasis on locality alone is unhelpful because of the inherent difficulty in drawing generalizations and comparisons between case studies. The local does not exist as an oppositional reality to the global, but rather constitutes a dynamic cultural negotiation with the changing structures of political economy, a negotiation in which dominant structures are mediated by individual agency [13].

Campbell (1996) believes that the romanticized past offers little to planning. He states that "our modern path to sustainability lies forward, not behind us" [25]. In his view, taking a historical perspective is not instructive; solutions to the problems of pre-industrial society are not transferable to those created by modern industrial and postindustrial society [26]. Although this is true at a general theoretical level, planning for sustainability in heritage places is significantly different because of their inextricable link to the past as a continuum.

Urban planners recognize the link to the past and its influence on the "sense of place as an important dimension of sustainable places, strengthening local identity, contributing to investment, and retaining communities. Any sustainable future for historic contexts therefore, must be intrinsically linked to its past, not just in the continuity of the built heritage and urban spaces but also in the living culture that created, and is still shaping, the distinct townscape, or genius loci, that characterizes heritage places [26].

The literature on urban conservation reflects the gap in integrating the social dimension. Factors of (1) selection, (2) restriction and (3) expansion, (4) efficient use, and (5) viability are rather more product focused, concerned with the physical attributes and their commercial potential, and not with the users', residents', property owners', and those who depend on the area for their livelihoods. Nevertheless, these factors merit discussion since they provide a guiding framework on how historical qualities and individual identities can be retained without unnecessarily inhibiting a reasonable degree of essential growth and modernization.

In a key contribution to the literature, Ashworth and Tunbridge's The Tourist-Historic City (1990) argues that authenticity as it is defined needs to be replaced by a more flexible concept. Their argument revolves around the idea that the existing stock of old buildings are a result of survival over time, dependent on such factors as building type, materials, districts and towns, natural catastrophes, and socioeconomic pressures. Hence, arrange of fundamental biases exist that distort authenticity of conservation as an accurate revelation of the past, before it has begun. In their words, if authenticity is the accurate reflection of the past through its architecture, then skillful reconstruction may be more authentic than scattered remnant relics. Most old urban structures are the result of much adaptive reuse. Restoration therefore faces the problem of choosing which past from many should be restored [26]. This concept is our base-point to propose "regenerative" solutions for Talas and somehow salvage the remnants of the existing heritage.

TALAS: A CASE STUDY

Talas is a town in Central Anatolia and resides in almost at the center of Cappadocia. Talas is an ancient center of Kayseri which is one of the major cities in Turkey with a history of six thousand years. Ancient center of Talas is under protection as a 1st grade historic site by the Turkish Law. The town is settled on two different elevations. On the higher level was a neighborhood in which Greeks and Armenians was living and on the lower level was a Muslim settlement. Each presenting the unique characteristics of their own culture and architecture. Talas was one of the provinces selected for the CEKUL Foundation's "7 Region 7 Cities" project in 1998 - a UNESCO founded initiative - and one of the cities in which a pilot implementation was made within the scope of that project. There are two significant archaeological sites within the boundaries of the town; remnants of a Hittite Castle on the top of Ali Mountain and an underground village built under the same mountain. Agricultural land surrounding the old town is also of significance because there are facilities built by the Greek population to prevent erosion and enable watering. Besides the historical and cultural values there are many natural beauties and unique sports facilities (i.e. paragliding and skiing resorts as well as various tracking routes). The complete list of all heritage and history shall be included in the incorporating presentation of our paper.
There are various (sustainable) tourism activities that are possible in Talas:

- Winter, Faith, Congress, Healthcare
- Nature & Nature Sports
- Trekking, paragliding
- Culture tourism

In order to develop a real sustainable and regenerative tourism management model we identified and analyzed the (either positive or adverse) effects of following tourism effects within the scope of our research:

- Political, Cultural
- Effects on preserved historical site
- Economic, Social, Physical
- Use of technology

An effective tourism management model, incorporating a dedicated tourism management information model is required to realize regenerative tourism management solutions which include (but not limited to) augmented reality applications, resource management, automation systems, security systems, early warning systems, etc. To develop such solutions and inventory of relevant «Information Society Technologies» are required.

- Materials, construction tools & techniques

There is a need for a major restoration and restitution activity. Besides new facilities are required to host tourists as per the initial tourism management plans. Construction activities should be planned in a way to prevent further damage to the environment whilst mending current damage. This requires innovative and contemporary construction tools and techniques incorporating new type of materials including but limited to 3D printing of new and old parts.

- Transformation of the city

Developing proposals to rehabilitate the negative effects of current heavy construction process in the town, revisions to the current masterplan in force are required. A better approach is to make a new masterplan to reshape the town and implement energy and resource efficient solutions for the new town.

RESULTS

This research requires interdisciplinary efforts to realize denoted outcomes. Talas is an excellent laboratory not only for Turkiye but also for the world to try regenerative solutions in order to "recall" damaged heritage. Talas with its climate, environment, modern life facilities and urban equipment, is a town in which a near perfect quality of life is possible. Tourism may play a key role to realize such vision. Details of our research and the case study itself is provided as a separate presentation incorporating to our paper.

REFERENCES:

[1] ÜNVER, E., 2006, Sustainability of Cultural Heritage Management, 'Keklik Street and Its Surrounding Conservation and Development Project', ODTÜ Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi.

[2] UNESCO 1972, World Heritage Convention, http://whc.unesco.org/en/convention/, Last access: September 07th ,2016

[3] BONIFACE P., FOWLER P. J., 1993, Heritage and Tourism in "The Global Village, Routledge, 1993, (2003ed. Ebook By Taylor & Francis e-Library), ISBN: 0-203-03368-X, pp.45-121, New York, USA

[4] ZEREN N., ERKUT G., 1990, "Relevance of Socio-Economic and Physical Data for the Conservation of Istanbul Historic Peninsula", Culture, Space, History, International Conference, 1990, 8-12 July 1990, METU, Ankara, Vol. 5, pp. 273-284

[5] ZEREN GÜLERSOY N., KÜKRER Ş., 1993, "Interaction of Conservation and Tourism in Historic Cities: A Case Study of Kayakoy (Levissi)", International Conference on the Impact of Tourism on Traditional and Historic Settlements in the Cou, 1993, Thessalonica, 22-24 October 1993, pp. 97-113

[6] ATAÖV, A., 2007. Planlamada sosyal bilimcinin değişen rolü: toplumdan biri olmak , METU Journal of Faculty of Architecture, vol.24 (no:1), Ankara, 2007, pp.139-152,
e-article: http://jfa.arch.metu.edu.tr/archive/0258-5316/2007/cilt24/sayi_1/139-152.pdf

[7] BEYHAN, Ş. G., 2004, Kültürel Süreklilik ve Çağdaş Gereksinimler Bağlamında Sürdürülebilir Turizm ve Kimlik Modeli : Pamukkale Örneği, İ.T.Ü Fen Bilimleri Enstitüsü, Danışman: PROF. DR. S. METE ÜNÜGÜR, Doktora Tezi, İstanbul, 2004

[8] UNESCO 2011, Jean Monet Centre of Excellence – UNESCO Chair in Cultural Heritage Management and Sustainability, http://www.ises.hu/en, Last access: September 07th ,2016

[9] LOWENTHAL,D, 1985, The past is a foreign country, Cambridge, Cambridge University Press, UK, 1985

[10] UNESCO, 2015, Rules of Procedure, United Nations Educational, Scientific and Cultural Organisation, Intergovernmental committee for the protection of the world cultural and natural heritage, July 2015, http://whc.unesco.org/document/137812, Last access: September 07th ,2016

[11] ICOMOS 2001, ICOMOS International Symposium, Managing Change: Sustainable Approaches to the Conservation of the Built Environment, 5-8 April 2001, Philadelphia, Pennsylvania, http://www.usicomos.org/past-symposia/2001-usicomos-international-symposium/
Last access: September 07th ,2016

[12] FEILDEN, B. M., JOKILETHO, J., 1998, Management Guidelines for World Cultural Heritage Sites, ICCROM, 1998

[13] CHANG, T. C., MILNE, S., FALLON, D., POHLMAN, C., 1996, Urban Heritage Tourism: The Global-Local Nexus, Annals of Tourism Research, Vol. 23, No. 2, pp. 284-305, 1996,Pergamon,Elsevier Science Ltd.

[14] POON A., 1988, The Future of Caribbean Tourism – A Matter of Innovation, Tourism Management, Vol.9, pp. 213-220

[15] KARAMAN, A., 1996. Sürdürülebilir Çevre Kavramı Çerçevesinde ekolojik Planlama Yaklaşımı : Bir Yöntem, Ekolojik Temele Dayalı Bölge Planlama, Uluslararası Sempozyum Bildirileri, Y.T.Ü Basım Yayın Merkezi, İstanbul.

[16] Report No. 36442 – GLB, 2006, Understanding Socio-economic and Political Factors to Impact Policy Change, The World Bank, Social Development Department, November 2006, http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1164107274725/3182370-1164107324437/Socio-Eoconomic-CSA-ESW-wb.pdf?resourceurlname=Socio-Eoconomic-CSA-ESW-wb.pdf Last access: September 07th ,2016

[17] HİMMETOĞLU, B., 1996. Turizmde Bugün Bulunulan Noktaya Nasıl Gelindi?, Türkiye'de 19. Dünya Şehircilik Günü Kolokyumu, MSÜ Mimarlık Fakültesi, Şehir ve Bölge Planlama Bölümü, İstanbul

[18] Wikipedia, 2016, https://en.wikipedia.org/wiki/Sustainable_tourism
Last access: September 07th ,2016

[19] Sustaining Tourism, 2016, http://www.sustainabletourism.net/ Last access: September 07th ,2016

[20] EU Commission, 2016, http://ec.europa.eu/growth/sectors/tourism/
Last access: September 07th ,2016

[21] WISEGEEK, 2016, http://www.wisegeek.com/what-is-sustainable-tourism.htm
Last access: September 07th ,2016

[22] NIJKAMP, P., VERDONKSCHOT, S., 1996. Sustainable Tourism Development: A Case Study of Lesbos, Sustainable Tourism Development, Avebury Athenaeum Press Ltd., Netherlands.

[23] DODDS R., 2007, Sustainable Tourism and Policy Implementation: Lessons from the Case of Calvia ´, Spain, Current Issues in Tourism, Vol. 10, No. 4, 2007

[24] ATABAY, S., 1998. 21. Yüzyılda Sürdürülebilir Turizm Politikaları, 1. Uluslararası Turizm Sempozyumu, Yıldız Teknik Üniversitesi, Basım yayın Merkezi, İstanbul.

[25] CAMPBELL S., 1996, Green cities, growing cities, just cities? Urban planning and the contradictions of sustainable development. Journal of the American Planning Association 62, 3: pp.296-312 (302).

[26] NASSER, N., 2003, Planning for Urban Heritage Places: Reconciling, Conservation, Tourism and Sustainable Development, Journal of Planning Literature, Vol.17, No.4 (May2003), DOI:10.1177/0885412203251149, Sage Publications

[27] AYRANCI İ., 2007, Koruma Alanlarının Yönetimi ve Yönetim Planı Sürecinin Değerlendirilmesi, Yüksek Lisans Tezi, İTÜ

[28] INHERIT, 2007, Investing in Heritage – A Guide to Successful Urban Regeneration, EU (Partly) Funded Project

[29] ZEREN GÜLERSOY N., ÖZSOY A., TEZER A., YİĞİTER GENLİ R.,GÜNAY Z., "Strategic Quality Planning in Historic Urban Environment", AIZ, ITU Journal of the Faculty of Architecture, 2009, Vol:6, No:1, 2009, pp.109-125, ITU, Faculty of Architecture, Istanbul

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A Sustainability Approach in Construction: Sustainability Management, Innovative and Eco-Friendly Products

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ABSTRACT

As the climate change and related social impacts increases globally, nowadays, the industries adopt their business models to a responsible, sustainable model. They redesign their processes, products and services in order to contribute to establish a sustainable future. In this perspective, construction material industry is a candidate to become in future a major solution provider for city managements and industries in terms of environmental impacts such as wastes, energy and emissions. Akçansa, one of the leading companies in Turkish construction material industry, envision its future sustainable management approach based on 6 pillars: Health and Safety, Sustainable Supply Chain Management, Tackling Climate Change, Sustainable Construction and Stakeholder Dialogue. Positioning itself in Sustainable Construction as a solution partner, Akçansa maintains a Life Cycle Assessment approach in production process and innovative approach in products. Our objective with this paper is to show the sustainability of building materials in Turkish construction industry through a case study analyzing the impact of the use of waste as an alternative energy source, waste heat power generation processes in cement production, and contribution of the innovative and eco-friendly products such as Akçansa Safkan Cement, A+ concrete and 100+ concrete.

Keywords: Sustainability, green building, cement, renewable energy, innovative concrete products, Turkey

INTRODUCTION

Construction sector is recognized as the largest source of carbon emissions worldwide and impacts of buildings on releasing CO_2 emission is 39% [1, 2]. Demands for minimizing the consumption of natural resources and energy, considering right building materials for more environmental friendly buildings force companies to improve the aspects of construction phases. The main objectives of these efforts are to preserve the natural resources as much as possible while providing benefits in environmental, social and economic perspectives. With the realization that economic development and the environment are linked, engineers, architects and project managers strive to avoid adverse impacts on society and the environment by adopting sustainable development during design and implementation of development projects [3]. As the interest in green buildings increase, the construction industry is more involved in "green" projects and many projects are actualized in different parts of the world. According to Kubba [4], the main benefits of building green include,

i) reducing energy consumption,
ii) protection of ecosystems and
iii) improved occupational health and safety

Production process of one particular building material, which is cement, has a huge impact on the environment because of releasing significant amount of CO_2 emissions. Concrete is by far the World's most consumed manufactured material. Therefore, cement is considered one of the most important building material since it is mainly used for the production of concrete. Cement plants already account for 5 percent of global emissions of carbon dioxide, one of the main causes of global warming [5, 6]. As pointed out in CEMBUREAU Environmental Product Declaration for Cement, 899 kg CO_2 is released during the production of 1000 kg cement [7]. According to Cement Sustainability Initiative [8], which was established in order to reduce CO_2 emissions from cement production by 23 major cement producers with operations in more than 100 countries, it is estimated that 80% of the future emissions from cement plants will take place in developing economies [8]. There is a tendency for decreasing the CO_2 emission of cement production, thus decreasing the environmental impact. CSI members pledged to work with stakeholders to develop a protocol for measuring and reporting CO_2 emissions from cement manufacturing. Working together with European Cement Research Academy (ECRA), The European Cement Association (CEMBUREAU) (2008) completed the Environmental Product Declaration (EPD) for Portland cement (CEM I) and defined their prime purpose is to provide measurable and verifiable input for the environmental assessment of construction works [7].

Turkey plays a major role in the production of cement. The production capacity of cement sector in Turkey was merely 20 thousand tons in 1911. In 2015 Turkish cement sector has reached a usable production capacity over 100 million tons. Turkey ranks first in Europe and 4th in the world after China, India and USA [9]. Turkey also holds the forth place in exports according to 2015 data [10]. Despite of the increasing cement production within the country, the environmental impacts and sustainability aspects are still less considered.

CASE STUDY: AKÇANSA APPROACH

Akçansa corporate sustainability policy is conducted in line with the goals set in the HeidelbergCement Sustainability Ambitions 2020, which are valid for all HeidelbergCement affiliates. According to the Sustainability Ambitions 2020, Akçansa Sustainability Committee is responsible for the annual company practices and performance measurement. Akçansa Sustainability Committee provides direct information for the Executive Board and submits risk reports to the Board of Directors on the practices implemented, goals reached and performance developments achieved regarding sustainability priorities.

The input provided through channels such as surveys and studies, satisfaction surveys, working group studies, OHS Committees, marketing communication studies, competitions, “Bridge Days” and “Neighbor Councils” are assessed in terms of the Sustainability Ambitions 2020 along with the local, international risks and opportunities. As a result of a workshop prioritization organized in the light of those assessments, a number of prioritized issues for the Akçansa Value Chain have been identified. The prioritized areas are covered within the scope of the following 5 links comprising the value chain: Raw material production, procurement, cement and ready-mixed concrete production, logistics and sales & marketing. Within the scope of the Sustainability Ambitions 2020 in March 2013, the Sustainability Committee updated the committee structure in line with the sustainability priorities set and by the approval of the Executive Board. Akçansa Sustainability Committee continues to function within the framework of the 6 thematic working groups updated in 2013. Chaired by the representative of the Akçansa Executive Board, Akçansa Sustainability Committee is composed of the members of the thematic working groups formed in parallel to the strategic goals besides a communication manager and a coordinator.

Sustainability Approach in Production

This study aims to express the sustainability of building materials in Turkish construction industry through a case study analyzing cement production and emphasizing the effect of using alternative fuels and raw materials (AFR) for sustainable environment. Effects of alternative fuels and raw materials in sustainable cement production are analyzed through one of the most prominent cement companies in Turkey. The company documented the first sustainability report (GRI B level) in the sector indicating its economic, environmental and social performance between 2007 and 2009 [11]. The third sustainability report disclosing 2012 and 2013 performances was recently published in 2015 [12]. The sustainability performance of Company's operations is conducted through 6 pillars:

1. Occupational health and safety.
2. Use of waste as a resource.
3. Climate change.
4. Reducing other environmental impacts.
5. Sustainable construction solutions.
6. Biodiversity.

Taking into consideration of "materials and resources" category in the certification systems, the Company aims to contribute higher ratings from this part. The improvements on sustainability approach can be listed as follows:

- Alternative fuels.
- Alternative raw materials.
- Reducing the rate of clinker usage in cement.
- Energy efficiency.
- Recycled and alternative materials usage in ready mixed concrete.
- Producing low carbon products both in cement and concrete business lines

Environmental Impact of Cement Production

Portland cement clinker is produced in a rotary kiln where the raw materials are melted at temperatures more than 1400ºC for the chemical reactions. By far the largest proportion of energy consumed in cement manufacture consists of fuel that is used to heat the kiln. More than 40% of the total CO_2 emission in cement production is caused by fuel consumption [11]. The required heat has been only obtained by fossil fuels such as lignite or petroleum coke until the last decades. Therefore, the replacement of fossil fuels with alternative materials derived from waste contributes to efficient resource management and to long-term cost savings for cement plants. This is why the use of alternative fuels plays a significant role in reducing CO_2 emissions and other pollutants, although care should be taken for high volatile elements as mercury and thallium [13]. The carbon emissions impacts of substituting miscellaneous waste fuels for coal vary based on their respective calorific values and carbon and water contents. Industrialized countries have over 25 years of successful experience to replace fossil fuels with alternatives in cement manufacturing. In the majority of European countries the percentage of using alternative fuels for manufacturing cement is above 35% [14]. The Netherlands and Switzerland, with respective national substitution rates of 83% and 48%, are world leaders in this practice [15]. In Turkey, the energy consumption in 2014 is supplied mainly by petroleum, coal and natural gas (26.2%, 31.5% and 32.5%, respectively) [16]. The structure of energy resources heavily rely on fossil fuels [17]. The share of the total CO_2 emissions of Turkey represented by the cement industry is 10% [11]. This is higher than the world average which is reported as 6% [18, 19]. This illustrates the importance of using alternative fuels in order to reduce CO_2 emissions in Turkey. Waste and industrial by-products (alternative fuels) can be used in cement kilns instead of carbon based fossil fuels such as lignite or petroleum coke. Thus, the energy requirement can be met by using wastes as an alternative to fossil fuels in cement kilns, this is also reducing the amounts of waste that needs to be handled through other disposal solutions such as landfilling incineration which are less preferable in terms of environmental protection. Another major advantage of burning waste materials in cement kilns is that no residues are generated, since the ash is completely incorporated in the clinker [20]. Turkey is a developing country and there is a high consumption of materials and resources. Although the legal authorities are promoting the use of waste materials by cement companies through strategy papers and regulations, it is still hard to reach alternative fuels [21]. The Company mentioned in this paper has a promising capacity to use alternative fuels but the main difficulty is to obtain alternative fuels in desired amounts. The main reason is that there is a deficiency in waste collection and recycling systems. It should be noted that cooperation with municipalities in sourcing alternative fuels and reuse/recycling of waste is of vital importance. The Company strives to create cooperation opportunities with municipalities to obtain refuse derived fuel and sewage sludge to use as a source of fuel. A campaign is also announced on the internet to collect waste for this purpose [22]. The alternative fuels consumed in one of the largest plants of the Company are used-tires, refuse derived fuel (RDF) plastic, contaminated waste (Fig. 1), waste oil, scrap paper, waste soil, husk, tank bottom sludge and sewage sludge. Establishing waste acceptance procedures and including waste and industrial by-products properly into the fuel system are the main steps of alternative fuels and raw materials (AFR) management system. Additionally, the physical and chemical properties of the waste sample are checked to ensure the waste's compliance with legal limits and specifications. In 2013, the Company has used 101.476 tons of alternative fuels thus saved 50,000 tons of coal. This amount gives a 6.67% calorific substitution rate, for 2020, 29% is targeted. According to the measurements obtained from several tests in their laboratory, consumed alternative fuels' calorific energy potentials are shown in Table 1 and compared with respect to most widely used fossil fuel namely pet coke which has approximately 7500 kcal/kg calorific value. Beside the advantages of using alternative fuels in cement kilns, their use can lead to some operational challenges. Therefore, some improvements and provisions should be considered to minimize the possible problems such as plugging in cyclones, fluctuation in cement quality and higher maintenance requirement and operational costs [23]. All fuel types have unique combustion characteristics that cement plant operators must adapt to in order for successful kiln operation. In addition, the quality of the cement must remain unchanged [15].

Figure 1 Contaminated waste as an alternative fuel source

Table 1 Wastes used for alternative fuel sources and their energy [24]

Wastes	**Energy (kcal/kg) (Petcoke ~ 7500)**
Used tyre	5500
Husk	4760
Industrial plastic	4350
Waste oil	3500
Scrap paper	3400
Contaminated waste	3400
RDF plastic	2800
Sewage sludge	2000

Refuse Derived Fuel (RDF)

The product of municipal solid waste (MSW) processing is typically referred to as "refuse derived fuel" (RDF), and is a common fuel alternative in many European countries. Italy, Belgium, Denmark and The Netherlands are among the nations that have at least one cement kilns processing RDF. MSW must be sorted to remove the recyclable and inert, and sometimes wet fractions before it is input into cement kilns. The remaining material accounts for approximately 20–50% of the original MSW weight can be incinerated directly or pelletized [15]. Using RDF as a supplemental fuel in cement production is an economically viable option to reduce fuel costs and landfill disposals. However, the effect of using RDF on economy is changing with the cost of capital, coal and landfill disposal prices. There are also several advantages of RDF such as decreasing CO_2 emission and ash residue, producing more homogeneous fuel, having higher calorific value content and a lower moisture content, etc. [25]. It is reported that for a net carbon offset through the replacement of coal with RDF, water content must be less than 15% and in this case net reduction in emissions is obtained as 0.4 tons CO_2/ton coal [15]. The main issue regarding the use of RDF by cement kilns is the chlorine content since chlorine weakens the cement and increase the risk of corrosion of steel bars in reinforced concrete structures [15, 25]. Therefore, alternative fuels that have high amount of chloride like PVC should be used in limited amounts and fuel mix optimization is very critical in terms of sufficient heat value in kiln and cement quality. The Company has cooperated with The Scientific and Technological Research Council of Turkey (TUBITAK) and Istac Co. to investigate the potential of alternative fuels derived from municipal solid waste. The first industrial plastic pretreatment facility in Turkey has been established to disintegrate and transform the nonhazardous and inert materials into RDF (Fig. 2). In this facility, nonhazardous waste from various industries is handled. The Company is targeting to reach approximately 100,000 tons of waste annually. By incinerating plastic waste with high calorific value in cement kilns, energy saving is improved significantly [11].

Figure 2 Use of refuse derived fuel plastics in RDF Plant

Tire Derived Fuel (TDF)

The environmental benefits of utilizing scrap tyres as a supplemental fuel in the Portland cement manufacturing process are multifold (Figure 3). When whole tyres are combusted in cement kilns, the steel belting which is the wire mesh supporting the rubber tyre becomes a component of the clinker, becomes a component of the clinker, replacing some or all of the iron required by the manufacturing process [26]. Since tires contain no component deleterious to the quality of cement and, as proven from long experience in checking the quality of the product, there is no change in the quality of cement caused by feeding tires. Combustion residues of both tyre and steel are not found in the finished cement [27]. None of the differences in the emission data sets between tyre derived fuel (TDF) versus non-TDF firing kilns for sulfur dioxide, nitrogen oxides, total hydrocarbons, carbon monoxide, and metals were statistically significant. Separate studies conducted by the U.S. governmental agencies and engineering consulting firms have also indicated that TDF firing either reduces or does not significantly affect emissions of various contaminants from cement kilns [26].

Figure 3 Used tires as an alternative fuel source

Sewage Sludge

The disposal of sewage sludge generated for sewage treatment plants is causing an important waste management problem. Cement companies are able to use sewage sludge with calorific energy potential as one of the alternative fuel sources. The Company is also using sewage sludge within the license of "using waste as an alternative fuel" from Ministry of Environment and City Planning. Thus, dried sludge is also used as an alternative fuel in its rotary kilns. Accordingly, cooperation has been started between the Company and the operators of Istanbul Water and Sewerage Administration (İSKİ) Ataköy Waste Water Treatment Plant to supply 45,000 tons of sewage sludge annually. In order to feed rotary kilns with dried sludge that are transported by silo buses from Ataköy Waste Water Treatment Plant, essential storage and feeding systems were constructed inside the plant. Mentioned system consists of storage of waste in closed silos and conveying to rotary kilns through feeding units. The facility is in compliance with environmental, health and safety regulations. The use of sewage sludge does not generate any additional emissions, also of all proven technologies; the co-processing of sewage sludge in a cement kiln offers the largest reduction of CO_2 equivalents per ton of dry sludge [28].

Alternative Raw Materials

The production of Portland cement starts with two basic raw ingredients: a calcareous material and an argillaceous material. The calcareous material is a calcium oxide, such as limestone, chalk or oyster shells. The argillaceous material is a combination of silica and alumina that can be obtained from clay or shale [29]. These compounds interact with one another in the kiln to form a series of more complex products. Major compounds are called as silicates and aluminates. The process of manufacture of cement consist essentially of grinding the raw materials, mixing them intimately in certain proportions and burning in a large rotary kiln at a temperature of up to about 1450°C when the material sinters and partially fuses into balls known as clinker. The clinker is cooled and grounded to a fine powder, with some gypsum added, and the resulting product is the commercial Portland cement which is widely used throughout the world [30]. The Company substitutes natural raw materials with alternative raw materials, wastes and industrial by-products in cement production. Grid has the largest share in the use of alternative raw materials for the Company. Grid is followed by pyrite ash, excavation soil and the blast furnace slag derived from iron–steel production respectively. Marble wastes containing minerals such as aluminum and iron as well as other wastes such as foundry sand, iron powder, scales, plaster chipping, bypass powder, volatile ash and iron dross are also utilized in the cement production process. Additionally, phosphogypsum, which is a pollutant residue obtained from the production of phosphoric acid in the phosphate fertilizers industry, is used as an alternative of gypsum. The

Reducing the Rate of Clinker Usage in Cement

Clinker is the most important component of cement. However, clinker production due to calcination process causes high level of CO_2 emissions. One way to reduce CO_2 emissions as well as the cost of cement is to use pozzolanic materials that do not require heat treatment, as a substitution to clinker in production. The pozzolanic materials containing minerals can provide the same properties in cement as clinker does. For example, blast furnace slag (a byproduct of iron and steel industry), fly ash (waste of fossil fuel thermal plants) and micro silica (a by-product of silicon and ferrosilicon alloy production) can show supplementary cementitious characteristics and can be partially replaced with clinker. Thus, it is possible to reduce CO_2 emissions in cement production by substituting clinker with other materials. The need to extract natural raw materials is reduced by using industrial wastes and by-products. This action contributes not only to the protection of natural resources and consequently the environment but also to the reduction of cost and to durability of concrete. The Company also produces ground granulated blast furnace slag (ggbfs) and CEM III type cement. The other cement factories of the Company use ggbfs in producing blended cements. Ggbfs is also used as a minor additive in cement production and as a mineral additive in concrete production. Total CO_2 emission during the production of cement can be reduced depending on the used ingredients by using less clinker as seen in Fig. 5. In addition, total energy consumption can be reduced from 121 kWh to 98 kWh for producing blended cements, resulting with approximately 20% energy saving. However, there are some problems in replacing clinker with other components such as availability of the materials, costs, chemical properties, conformity with the type of cement to be produced, applicability to national standards, and the demands and habits of the customer and/or market. Most importantly, the strength development is slower compared to a purely clinker-based cement of the same fineness. Because the vast majority of cement applications require certain strength of the finished product after a couple of hours or a few days, the industry is using different strategies to overcome these problems [31]. The so-called clinker factor (CF) is the proportion of clinker in cement. It can be derived for every cement product, but it is mainly used as an indicator of the average clinker substitution of a producer. In 2003, the world average CF was 0.85. The clinker factor in an area is affected by the type and volume availability of clinker substitutes, the cement standards, and also by the cement market itself. The current average clinker-to-cement ratio over all cement types in the EU27 is 73.7% [31]. In 2015, the Company has performed 87% clinker to cement ratio, and targeting to reach 79% in 2020.

Energy Efficiency

As cement production is an energy intensive process, the Company aims to decrease thermal and electric energy consumption through several improvement steps; some of the strategies addressed are replacing high energy consuming equipment with more efficient ones and installing energy recovery systems. In 2011, a waste heat recovery power generation (WHG) system of 15 MW is installed into one of the Company's plant (Canakkale plant), which produces yearly 105 million kWh energy and thus reduces 60,000 tons of CO_2 emission per year. The energy saved is equal to one third of the energy needed in production and the reduction of CO_2 emission is equal to the O_2 production of 2.7 million trees. In this facility, exchangers were installed in cooling exits of clinker production lines and preheater exits. With this modernization process, temperature is reduced to 70ºC from approximately 350–400ºC in cooling exits and the hot gas temperature is reduced to 230ºC from 300 to 350ºC in preheater. In addition, vapor at 1.25 MPa is generated which can be collected by pipelines and sent to the 15 MW power turbines to generate electricity there. Considering CO_2 emission reduction obtained, the Company is also targeting to take a position in the voluntary emission trading market. This project has been registered to be accredited as Gold Standard Project; the Voluntary Emission Reduction (VER) credits generated from this project would market as premium carbon credits. The project was also presented among the "best practices held in Turkey to combat climate change" at Rio+20 in 2012.

Microalgae Project

Microalgae are microscopic algae, typically found in freshwater and marine systems living in both the water column and sediment. They are unicellular species which exist individually, or in chains or groups. Unlike higher plants, microalgae do not have roots, stems, or leaves. They are specially adapted to an environment dominated by viscous forces. Microalgae, capable of performing photosynthesis, are important for life on earth; they produce approximately half of the atmospheric oxygen and use simultaneously the greenhouse gas carbon dioxide to grow photoautotrophically.

The project is basically industrially relevant R&D project aiming to consume CO_2 from stack by microalgae that will be continually harvested, dried by using waste heat from the plant, and then burned as a fuel inside the kilns. Alternatively, algae will be processed into vegetable oil and biofuels as in laboratory for the cost analysis.

The aims of the project are:
1. Reducing the amount of CO_2 emission by using it to produce microalgae.
2. Reducing the production cost of microalgae.
3. To obtain a valuable oil source from this production.

The innovative sides of this project are:
1. Using three different habitats at the same time (panel, tube and open pool).
2. Using flue gas to dry algal biomass. It is the first application in cement industry.
3. Applying a unique method in producing oil from microalgae at open pools (Figure 6).

Figure 6 Microalgae pool

Recycled and Alternative Materials Usage in Ready Mixed Concrete

In its simplest form, concrete is a mixture of paste and aggregates, or rocks. The paste, composed of Portland cement and water, coats the surface of the fine (small) and coarse (larger) aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to form the rock-like mass known as concrete. Within this process lies the key to a remarkable trait of concrete: it's plastic and malleable when newly mixed, strong and durable when hardened.

Concrete is a 100% recycled material and recycled materials can be used in its production. Water and aggregate which are obtained from returned concretes by recycling units can be reused in ready mixed concrete (RMC) production. The best performance that has been achieved by the Company till now is 50% of water and 5% of aggregate from recycling units. Fly ash and ground granulated blast furnace slag (ggbfs) are also used in concrete production as a supplementary material with less clinker usage (Figure 7). In addition to use of recycled materials, other initiatives are also considered for efficiency. Instead of transporting the aggregates by trucks with 20 tons capacity as it was before 2005, trailers are now used for transportation, resulting 200,000 tons fuel saving, annually.

Figure 7 Cement and mineral additive ratio in concrete [12]

Innovative and Eco-Friendly Products

In parallel with its operations to create a more livable world, Akçansa has provided high quality special ready-mixed concrete products for the Turkish market since 2003. In line with Akçansa customer demands, the special product portfolio essentially seeks to provide high performance solutions with reduced environmental impact especially in terms of greenhouse gas emissions, apart from helping the customers save on labor costs and time; offering them thermal and noise insulation as well as waterproofing and reducing risks to occupational health and safety. Thanks to the studies undertaken in collaboration with Betonsa Technology Centre and Istanbul Technical University (İTÜ) Building Materials Laboratories during the reporting period, new products were developed including "100+Beton" and "A+Beton". Thus the total number of special products by Akçansa rose from 15 in 2011 to 18 in 2013. While the share of the special products in total sales turned out to be 7.3%, the products highlighted for their reduced environmental impact enjoyed 28% share in special product sales.

Safkan Cement is a typical Portland cement including ground granulated blast furnace slag. The main properties of this cement are high strength and durability. It is much more eco-friendly compared to its alternatives. "Safkan Cement" product won the Second Prize in the Environmentally Friendly and Innovative Product Category of the 2013 ISO Environment Awards organized by the İstanbul Chamber of Industry (ISO).

Yeşilşap, an environmentally friendly and light ready screed product, reduces CO_2 emission by up to 35% through special additive blend cements used in its production process. Due to the special chemical additives used, Yeşilşap weighs 25% less when compared with conventional screed products and also contributes to thermal insulation on buildings.

100+Beton features superior durability and permeability qualities thanks to the special cement and various mineral additives used, and is developed for large infrastructure projects required to serve for over a century such as bridges, airports, subways and highways. High use of mineral additives instead of clinker in the product composition ensures a significant reduction in greenhouse gas emission values.

A+Beton is a durable and high performing concrete product with a significantly reduced $_{CO2}$ emission value due to the use of blast furnace slug for up to 70% in its composition, and is developed for environmentally friendly green buildings. Depending on the building type, the A+Beton product group is composed of three categories including A+Beton Basic, A+Beton Road and Coverage, A+Beton Structure.

Viskobeton is a self-landing concrete product developed for structures requiring strength and durability. Due to mineral additives used highly to replace clinker in its composition, the product's CO2 emission value has been reduced. Its high strength and durability enhance the durability of the structures thereby reducing their maintenance costs. Since it does not require any vibration, the product is especially suitable for being used on compact and narrow section forms, areas requiring high quality smooth surfaces, downtown building sites, aesthetic form designs and sites where it is not possible to use a vibrator. The product thus reduces safety and occupational health risks, noise impact and labor costs.

CONCLUSION

The companies producing the materials for constructions need to focus on sustainable development and produce more eco-friendly materials. The major objective of this study is to investigate sustainability approaches of a Turkish cement manufacturing company and emphasize the importance of lowering CO_2 emissions during cement and ready mixed concrete production. Methods such as using alternative fuels, raw materials and by-products in cement production as well as establishing a waste heat recovery generation system for sustainable development are helpful for obtaining following environmental benefits:

- Protection of natural resources by using alternative fuels and materials.
- Reduction in CO_2 emission.
- Providing post incineration zero waste.
- Obtaining energy efficiency.
- Reducing the rate of clinker usage in cement.
- Recycled and alternative materials usage in ready mixed concrete.
- Producing low carbon products both in cement and concrete business lines.

REFERENCES

[1] Environmental Information Administration; EIA Annual Energy Outlook; 2008.

[2] Environmental Information Administration; Emissions of Greenhouse Gases in the United States; 2006.

[3] L. Da Silva, J.Y. Ruwanpura. Review of the LEED Points Obtained by Canadian Building Projects, J. of Arch. 2009; 15(2): 38-54.

[4] S. Kubba. LEED Practices, Certification and Accreditation Handbook, Elsevier Inc., USA, 2010.

[5] Rosenthal, E. (2007). In booming economies, cement is crucial for growth but an enemy of green. New York Times. Retrieved from http://www.nytimes.com/2007/10/21/business/worldbusiness/21iht-cement.1.7979990.html

[6] Damineli, B.L., Fernanda, M.K., Patricia, S.A. and Vanderley, M.J. (2010). Measuring the eco-efficiency of cement use. Cement and Concrete Composites. Vol. 32, pp. 555–562.

[7] CEMBUREAU (2008). Environmental Product Declaration for Cement. Retrieved from http://www.ecocem.ie/downloads/CEM_EPD.pdf

[8] CSI (2011). Emerging economies. Cement Sustainability Initiative. World Business Council for Sustainable Development. Retrieved from http://www.wbcsdcement.org/index.php/about-cement/emerging-economies

[9] US Geological Survey (2011). Report on USGS Mineral Program Cement Report. Retrieved from http://minerals.usgs.gov/minerals/pubs/commodity/cement/mcs-2016-cemen.pdf

[10] http://www.worldstopexports.com/cement-exports-by-country/

[11] Akcansa Cement Company (2009). Akcansa 2007-2009 Sustainability Report. Istanbul: Turkey.

[12] Akcansa Cement Company, Akcansa 2012–2013 Sustainability Report, 2014; http://www.akcansa.com.tr/downloads/surdurebilirlik/surdurebilirlik_2014_en.pdf

[13] C.A. Hendriks, E. Worrell, D. de Jager, K. Blok, P. Riemer, Emission reduction of greenhouse gases from the cement industry, IEA Greenhouse Gas R&D Program, Cited December 19, 2012. Available from: http://www.moleconomics.org/files/sustainability%20documents/EmissionReductionofGreenhouseGasesfromtheCementIndustry.pdf

[14] I.Z. Bribian, A.V. Capilla, A.A. Uson, Life cycle assessment of building materials: comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential, Building and Environment 46 (2011) 1133–1140.

[15] A. Murray, L. Price, Use of Alternative Fuels in Cement Manufacture: Analysis of Fuel Characteristics and Feasibility for Use in the Chinese Cement Sector, Ernest Orlando Lawrence Berkeley National Laboratory Report No: LBNL-525E, 2008.

[16] Türkiye'nin enerji görünümü (in Turkish), TMMOB Makine Mühendisleri Odası raporu, 2016, http://www.odtumd.org.tr/dosyaArsivi/Etkinlik/TurkiyeninEnerjiGorunumu.pdf

[17] Ministry of Energy and Natural Resources General Directory of Energy Affair, Workgroup Report on Greenhouse Gas Reduction in Energy Sector, Ankara, Turkey, 2006, Cited December 19, 2012. Available from: http://ieahia.org/Activities/National-Documents/Task-18/Turkey/Workgroup-Report-on-GHG-Reduction-in-Energy-Sector.aspx

[18] E. Rosenthal, In Booming Economies, Cement is Crucial for Growth But An Enemy of Green, New York Times, cited December 19, 2012, 2007. Available from: http://www.nytimes.com/2007/10/21/business/worldbusiness/21iht-cement.1.7979990.html

[19] B.L. Damineli, M.K. Fernanda, S.A. Patricia, M.J. Vanderley, Measuring the eco-efficiency of cement use, Cement and Concrete Composites 32 (2010) 555–562.

[20] J.S. Damtoft, J. Lukasik, D. Herfort, D. Sorrentino, E.M. Gartner, Sustainable development and climate change initiatives, Cement and Concrete Research 38 (2008) 115–127.

[21] Atık Yönetimi Eylem Planı, Republic of Turkey Ministry of Forestry and Water Affairs, Ankara, 2008.

[22] Akcansa Cement Company, Cited December 19, 2012. Available from: http://www.atiginizibizegonderin.com

[23] M. Kara, E. Günay, Y. Tabak, S¸ . Yıldız, V. Enc, The usage of refuse derived fuel from urban solid waste in cement industry as an alternative fuel, in: 6th IASME/WSEAS International Conference on Heat Transfer, Thermal Engineering and Environment, 2008, pp. 172–177.

[24] Akcansa Cement Company, Environment and Quality (AFR) Laboratory Measurements, 2010.

[25] MVW, Session 5-Quality Management, in: Workshop Alternative Fuels for the Cement Industry in Turkey, Lechtenberg and Partner, Turkey, Ankara, 2010.

[26] Portland Cement Association Sustainable Manufacturing Fact Sheet, Cited December 19, 2012. Available from: http://www.epa.gov/osw/conserve/materials/tires/pubs/brochure5-08.pdf

[27] Y. Nakajima, M. Matsuyuki, Utilization of waste tires as fuel for cement production, Conservation & Recycling 4 (3) (1981) 145–151.

[28] J. Theulen, L. Szabo, CO2 beneficial sewage sludge recovery by cement kilns, in: 2nd European Conference on Sludge Management, ECSM 2010, Hungary, Budapest, 2010.

[29] M.S. Mamlouk, J.P. Zaniewski, Materials for Civil and Construction Engineers, 3rd ed., Pearson, New Jersey, 2011.

[30] A.M. Neville, Properties of Concrete, fifth ed., Pearson, England, 2011.

[31] http://lowcarboneconomy.cembureau.eu/index.php?page=clinker-substitution

Paper No: 124

The Effect of Waste Material Usage on Embodied Energy: An Experimental Study on Construction Material

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ABSTRACT

The basic goal of a sustainable construction industry is to protect the resources in the nature. Such production sector with sustainable approach/understanding performs the new products by using the wastes. The performance of the products used in construction sector are defined with their aesthetics, durability, and functionality qualities. Beside those indicators; being a recycled material itself, recycled material ratio in its content and low embodied energy are the other legend in production of sustainable construction material. The study is intended to share information about an originally produced construction material with low embodied energy. The material is a composite material produced by using iron-steel production wastes and polyethylene wastes. It has been proved by the performance tests and experiments that the product can be used as a flooring material. The embodied energy of the material was accounted by Method of Life Cycle Energy Analysis (LCEA) and it was compared with epoxy flooring material which is plastic in origin. The study proves that the new material included recycled materials have low embodied energy than those which do not include recycled material.

Keywords: embodied energy, construction product, iron-steel production wastes, polyethylene wastes, flooring materials

INTRODUCTION

An important goal for the building sector is to produce buildings with a minimum of environmental impact. Because, buildings are responsible for a huge share of energy, electricity, water and materials consumption globally. Buildings account for 18% of global emissions today, or the equivalent of 9 billion tons of CO_2 annually [1]. But, the building sector has the greatest potential to deliver significant cuts in emissions. So, green building practices aim to reduce the environmental impact of building.

Besides buildings, construction materials are used for 50% of global materials which extract from the ground [2]. The resources that are used in life cycles of construction products effect the environment and human health. So, the selection of correct construction product is very important in the context of sustainable architecture [3].

Construction products which interact with the environment throughout their lives, can give great damage to the environment and can be source of major environmental problems such as waste, toxicity, emissions and energy necessary [4]. Interactions with the environment throughout the life of the products can be determined by life cycle assessment method (LCA). LCA is a method of determining the real impact (emissions, toxicity etc.) over the lifetime of a product, from cradle to grave [5,6]. LCA is particularly helpful for comparing a number of options, that is, identifying the most effective option available [7].

For accounting energy necessary for an entire product life-cycle (embodied energy), can be also used life cycle energy analysis method (LCEA). This method determines the extent of energy into raw material extraction, transport, manufacture, assembly, installation, disassembly, deconstruction and/or decomposition as well as human and secondary resources. Energy consumption produces CO_2, which contributes to greenhouse gas emissions, so embodied energy is considered an indicator of the overall environmental impact of building materials and systems. Unlike the life cycle assessment, which evaluates all of the impacts over the whole life of a material or element, embodied energy only considers the front-end aspect of the impact of a building material. It does not include the operation or disposal of materials A summary flowchart detailing the elements required to estimate embodied energy was given in Figure 1. Most embodied energy figures for specific materials are quoted using a "cradle to gate" boundary (includes yellow boxes). Consumers must also consider transport, assembly, maintenance and demolition components of embodied energy [7].

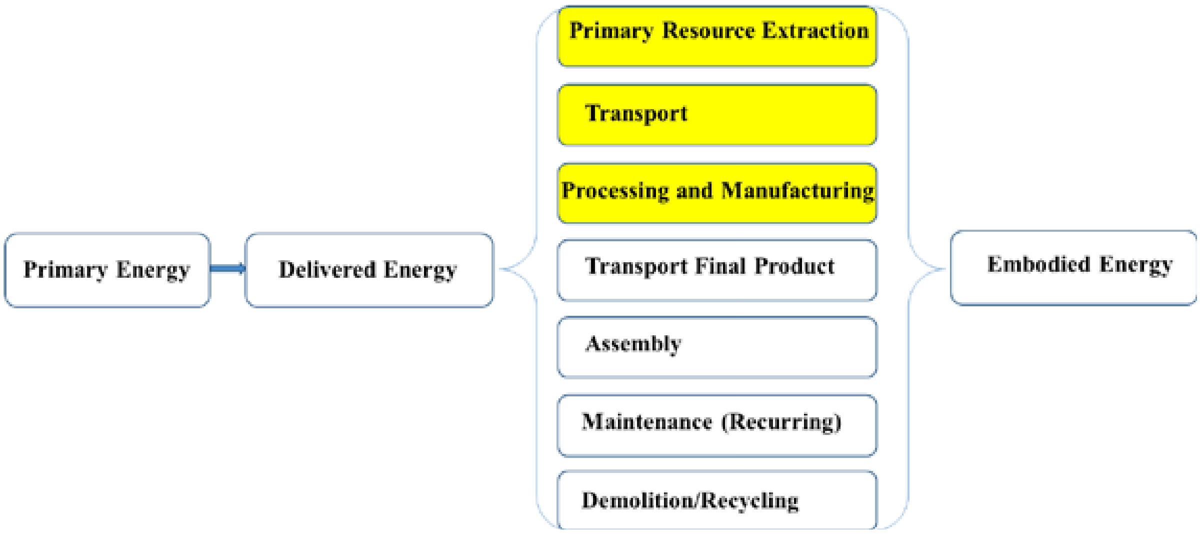


Figure 1 Breakdown of Embodied Energy Calculations [7]

In residential buildings, embodied energy represents between 30 and 100% of total life cycle energy consumption. Examples of embodied energy include: the energy used to extract raw resources, process materials, assemble product components, transport between each step, construction, maintenance and repair, deconstruction and disposal. As such, it is important to employ a whole-life carbon accounting framework in analyzing the carbon emissions in buildings [8].

When selecting building materials, the embodied energy should be considered with respect to: use of recycled materials, avoiding waste, how easily materials can be separated, use of locally sourced materials, the durability of building materials, specifying standard sizes of materials, selecting materials that are manufactured using renewable energy sources [7]. When reused materials were used in a one-family building, the embodied energy decreased about 45% [9]. In a study of recycling nationally produced building waste, the potential energy saving through recycling was about 50% of the embodied energy [10]

The one of the high-embodied-energy industries of construction sector is iron steel industry. Besides high embodied energy necessary, this industry extracts many wastes which are about 400 kg per ton steel production [11]. These wastes can be counted as blast furnace slag, dust and mill scales. These wastes effects environment and human healthy dangerously [4,12-13]. It could be said that blast furnace dust can recycle hardly and has most waste ratio than the others [14,15].

The other one of the high-embodied-energy industries of construction sector is plastic industry. This industry grows because of being resistant, insulating, lightweight, having feature highly able to give form. The growth of the industry also brings the increment of plastic wastes. Polyethylene has maximum utilization rate in Turkey, and therefore it has waste rate [16].

In this study, with the scope of proving the new material included recycled materials have low embodied energy than those which do not include recycled material, a composite construction material which includes blast furnace dust and waste low density polyethylene was produced. After the performance tests and experiments, it was decided that the product can be used as a flooring material. The embodied energy of the composite construction material is calculated by Method of Life Cycle Energy Analysis (LCEA) and it was compared with the epoxy which is produced raw plastic.

MATERIAL AND METHOD

For producing composite material, blast furnace dust and waste low density polyethylene (LDPE) was used. These waste products which have a large waste ratio was combined by using extrusion method and produced composite granules. Then, these granules were shaped in injection machine according to sizes generated for standards used in test methods. A picture showing the composite material was given in Figure 2. After the performance tests and experiments, it was decided that the product can be used as a flooring material.

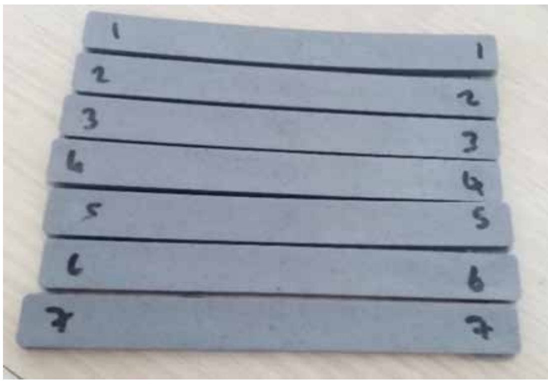


Figure 2 Composite Material Produced by Blast Furnace Dust and Waste Polyethylene

For accounting the embodied energy of this composite material was used life cycle energy analysis method (LCEA). The functional unit was determined as 1 kg of composite product. In the study, different ratios were tried for combining but embodied energy was calculated for 50% blast furnace dust and 50% LDPE waste. Data of energy for injection and extrusion of composite material (for polyethylene) was taken from Granta CES EduPack 2015 database and was given in Table 1.

Table 1 Energy and Emission Values for Extrusion and Injection Molding of Polyethylene

	Energy (MJ/kg)		CO_2 Emission (kg CO_2 eq/kg)	
Product	**Extrusion value**	**Injection value**	**Extrusion value**	**Injection value**
Polyethylene	6,2	22	0,46	1,60

Calculated embodied energy value of composite material for this study, includes that the waste products are taken from their landfills, the necessary for energy during the transportation of product to manufacturing area and for manufacturing. The system boundary of the study was given in Figure 3.

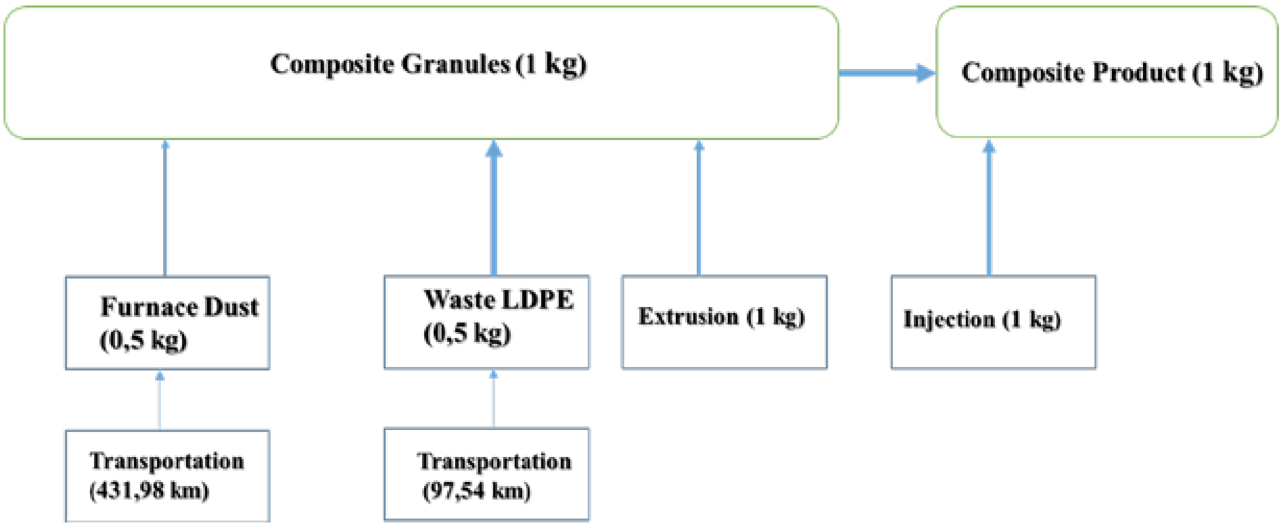


Figure 3 System Boundary for The Study of Embodied Energy

The manufacturing area was accepted as Ankara Gazi University, The Laboratory of Dust Metallurgy (GULDM). Blast furnace dust wastes were provided with Kardemir Iron-Steel Factory (KISF) and wastes of LDPE were provided with Industry Area of Kazan (IAK). For calculating energy necessary for the transportation of the wastes to manufacturing area was used Eco Transit World Tool (Ecological Transport Information Tool for Worldwide Transports) according to EN 16258 [16]. Transportation data which determined for the transportation dust and LDPE from landfill areas (KISF and IAK) to production area (GULDM) was given in Table 2. Transportation distances were determined by using Google Map Tool.

Table 2 Transportation Data

Interval	Device	Distance (km)	Tour	Total Distance (km)
GULDM-KISF	3,5-7 ton truck	215,99	2	431,98
GULDM-IAK	3,5-7 ton truck	48,77	2	97,54

After the embodied energy value of composite material was calculated, this value was compared with epoxy that is the other plastic based flooring material. Embodied energy value of the epoxy was provided from Granta CES EduPack 2015 database.

RESULTS AND COMPARISON

The embodied energy of the composite material which produced waste products was calculated by using LCEA within system boundary that was given in Figure 3. The necessary energy for the transportation was determined by using Eco Transit World Tool (Ecological Transport Information Tool for Worldwide Transports) according to EN 16258.

The transportation energy was calculated as 0,76 MJ/kg for the interval of GULDF-KISF and as 0,152 MJ/kg for the interval of GULDF-IAK. As the relation with them, the transportation emission was calculated as 0,054 kg CO_2 eq/kg for the interval of GULDF-KISF and as 0,011 kg CO_2 eq/kg for the interval of GULDF-IAK.

Energy necessary data for injection and extrusion of composite material (for polyethylene) was taken from Granta CES EduPack 2015 database. The energy necessary for the polymer extrusion was assumed as 22 MJ/kg and 6,2 MJ/kg for the polymer injection molding for LDPE. Then, as you can see Table 3, all energy inputs were gathered and the embodied energy of composite material was counted as 29,112 MJ/kg for 1 kg. Likewise, the embodied emission of composite material was detected as 2,125 kg CO_2 eq/kg for 1 kg.

Table 3 The embodied energy of composite material (for 1 kg)

Proses	**Embodied Energy (MJ/kg)**	**CO_2 Emission (kg CO_2 eq/kg)**
Transportation	0,912	0,065
Injection	22	1,6
Extrusion	6,2	0,46
Total	**29,112**	**2,125**

As you can see in Figure 4 and Figure 5, the embodied energy of composite material includes, transportation, injection and extrusion energy inputs. The most energy input and emission output were observed injection phase because injection method includes heating and cooling stages, although extrusion phase includes only heating stage.

To compare this composite material with epoxy, energy and emission values were taken from Granta CES EduPack 2015 database and were given in Table 4. The mean value was created by using average method.

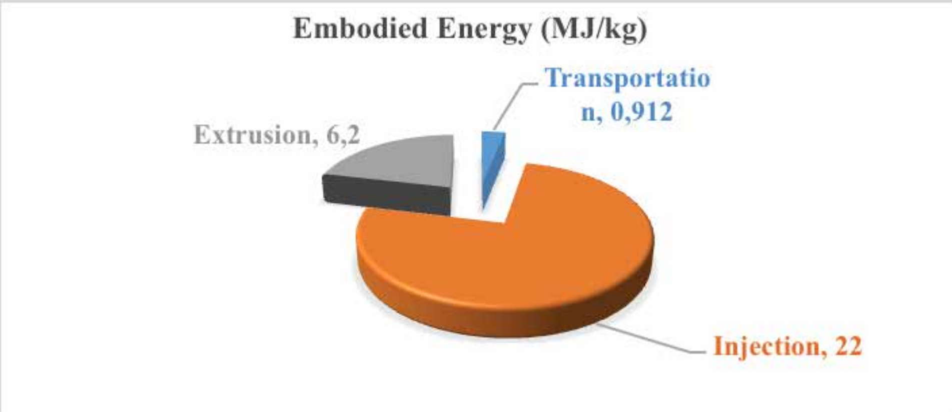


Figure 4 The Distribution of Energy Inputs

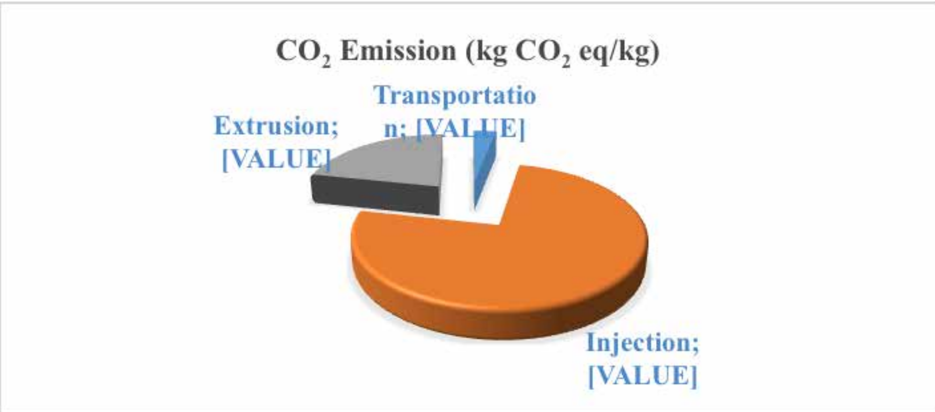
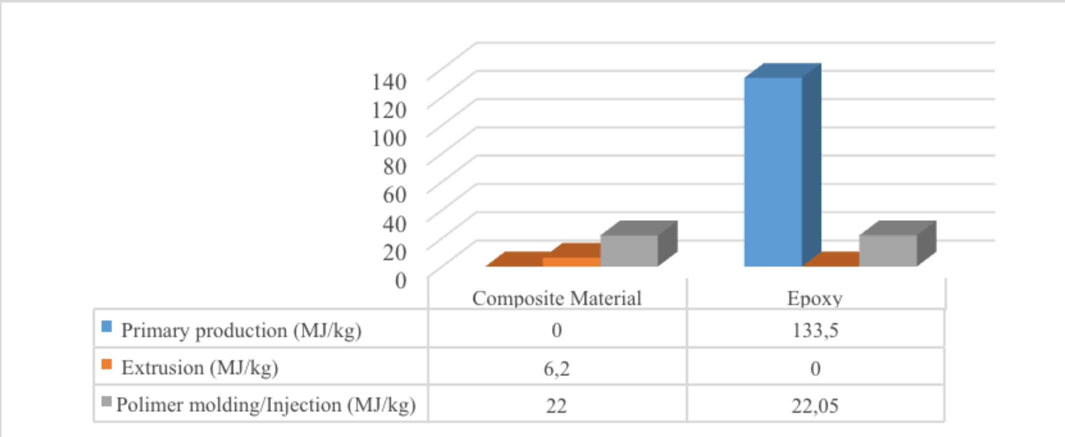


Figure 5 The Distribution of CO_2 Emissions

Table 4 Energy Input and Emissions for Epoxy Production

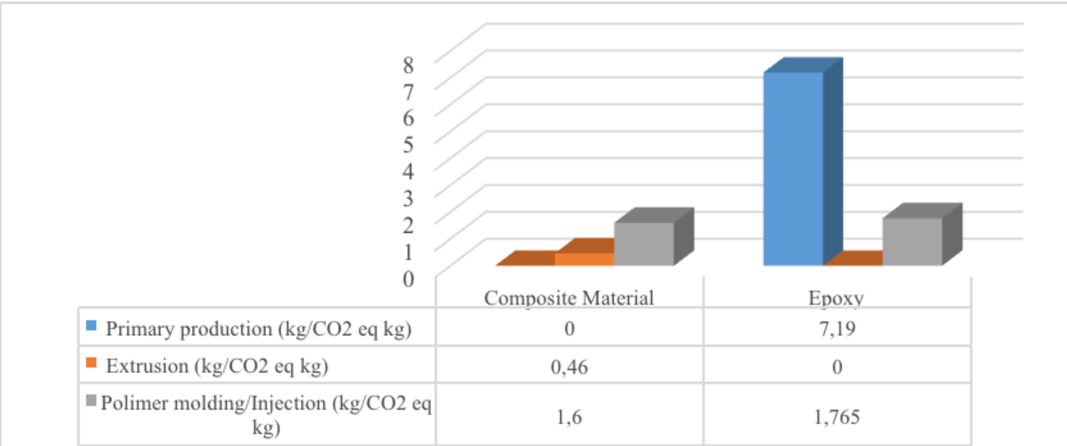
Product	**Primary Material Production**		**Material Processing**			
	Energy (Mj/kg)	**CO_2 Emission (kg CO_2 eq/kg)**	**Energy for Extrusion (MJ/kg)**	**Polymer Molding (MJ/kg)**	**CO_2 Emission for Extrusion (kg CO_2 eq/kg)**	**CO_2 Emission for Injection (kg CO_2 eq/kg)**
Epoxy	127-140	6,83-7,55	0	21-23,1	0	1,68-1,85
Mean value	133,5	7,19	0	22,05	0	1,765
Embodied Energy	155,55 MJ/kg			**CO_2 Emission**	8,955 kg CO_2 eq/kg	

As you can see in Figure 6 and Figure 7, it says that the most energy input and emissions for production of epoxy is in primary production stage. Raw material production increases the embodied energy due to the energy-intensive stage. When we compare the composite material which produced recycled materials, we can see that the energy for the primary production is zero. The embodied energy and CO_2 emission that is obtainable by producing epoxy is roughly five times and four times that which is obtainable by producing composite material respectively.
So, we can say that materials which produce recycled materials has low embodied energy and emission generally due to lack of necessary extra energy of primary production.



	Composite Material	Epoxy
Primary production (MJ/kg)	0	133,5
Extrusion (MJ/kg)	6,2	0
Polimer molding/Injection (MJ/kg)	22	22,05

Figure 6 Comparison of The Energy Inputs for Epoxy and Composite Material Production



	Composite Material	Epoxy
Primary production (kg/CO2 eq kg)	0	7,19
Extrusion (kg/CO2 eq kg)	0,46	0
Polimer molding/Injection (kg/CO2 eq kg)	1,6	1,765

Figure 7 Comparison of The Emission Outputs for Epoxy and Composite Material Production

CONCLUSION

In this study, the embodied energy of the composite flooring material which includes recycled materials is calculated by Method of Life Cycle Energy Analysis (LCEA) and it was compared with the epoxy flooring material which is produced raw plastic. It was observed that the embodied energy and CO_2 emissions of epoxy is bigger than composite material. The embodied energy of the composite flooring material is lower than five times through recycled material using. The emission for producing of the composite flooring material is lower than four times epoxy. It was proved that materials which produced raw materials needs more energy because of primary production energy. So, using of recycled of materials which have high embodied energy in the first life is very important because of providing the opportunity to reduce the embodied energy for sustainable buildings.

ACKNOWLEDGEMENT

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REFERENCES

[1] IPCC, Climate change mitigation in the buildings sector: the findings of the 4th Assessment Report of the IPCC, 2007.

[2] WGSC (2004). "Working group for sustainable construction", Working Group Sustainable Construction Methods and Techniques Final Report. Can be downloaded at: http://www.webcitation.org/query?url=http%3A%2F%2Fec.europa.eu%2Fenvironment%2Furban%2F++&date=2016-05-05, Son Erişim tarihi: 10.04.2010.

[3] Tuna, M., Bina Derecelendirme Sistemlerinde Çevresel Etki Sınıflarının Önemi, Yüksek Lisans Tezi, Gazi Üniversitesi Fen Bilimleri Enstitüsü, Ankara, (2010), 15.

[4] Tuna Kayılı, M. Yüksek Fırın Baca Tozu ve Atık Polietilen Kullanılarak Üretilen Kompozit Malzemenin Yapıda Kullanılabilirliğinin Saptanması, Doktora Tezi, Gazi Üniversitesi Fen Bilimleri Enstitüsü, Ankara, (2016), 23.

[5] Gültekin, A.B., "Yaşam Döngüsü Değerlendirme" Yöntemi Kapsamında Yapı Ürünlerinin Çevresel Etkilerinin Değerlendirilmesine Yönelik Bir Model Önerisi, Doktora Tezi, Gazi Üniversitesi Fen Bilimleri Enstitüsü, Ankara, (2006), 6-24.

[6] Menke, D. M., Davis, G. A. and Vigon, B. W. "***Evaluation of life-cycle assessment tools***". Canada: Environment, (1996), 20-120.

[7] Haynes, R. Embodied Energy Calculations within Life Cycle Analysis of Residential Buildings, 1-16, (2010). Can be downloaded at: http://www.etoolglobal.com/wpcontent/uploads/2012/10/Embodied-Energy-Paper-Richard-Haynes.pdf

[8] Ibn-Mohammed, T., Greenough, R., Taylor, S., Ozawa-Meida, L., Acquaye, A., ***"Operational vs. embodied emissions in buildings—A review of current trends",*** Energy and Buildings, 66 (2013): 232–24.

[9] Thormark, C., "***Environmental analysis of a building with reused building materials***", International Journal of Low Energy & Sustainable Building. 1999-2000. Can be downloaded at: http://www.ce.kth.se/bim/leas.

[10] Thormark, C., "***Conservation of energy and natural resources by recycling building waste",*** Resources, Conservation and Recycling, 33.2 (2001): 113-130.

[11] Robinson, R. Studies low temperature self-reduction of by-products from integrated from and steel making, Ph. D. Thesis, Lulea University of Technology, Department of Chemical Engineering and Geosciences, Division of Process Metallurgy, Lulea, Sweden, 1-46, 2008.

[12] Erünsal, E., Perçinel, S., Entegre demir çelik fabrikalarında oluşan katı atıkları değerlendirme teknolojilerindeki son gelişmeler, Demir Çelik Sempozyumu, Erdemir A.Ş, Zonguldak, 989-994,2005.

[13] Önkibar, G., Entegre demir çelik tesisi tufalinden doğrudan redüklenme yöntemi ile ham demir üretimi, Yüksek Lisans Tezi, Sakarya Üniversitesi Fen Bilimleri Enstitüsü, Sakarya, 4-31, 76-120, 2006.

[14] Doğantepe, G., ***Hematit karakterli demir cevherinden ve yüksek fırın baca tozundan sünger demir üretilebilirliğinin araştırılması***, Yüksek Lisans Tezi, Karabük Üniversitesi Fen Bilimleri Enstitüsü, Karabük, 34-35, 2014.

[15] Fleischanderl, A., Joseph, P. and Gebert, W., Aspect of recycling of steelworks by-products through the BOF, SEAISI Q., 28 April 1999, (2) 51–60.

[16] PETKİM (2014) Faaliyet Raporu. Can be downloaded at: http://www.webcitation.org/query?url=http%3A%2F%2Fwww.petkim.com.tr%2FSayfa%2F1%2F176%2FYATIRIMCI-ILISKILERI-OPERASYONEL-VEFINANSAL-VERILER-FAALIYETRAPORLARI.aspx+&date=2016-05-05

Paper No: 126

Clustering-based assessment for primary energy consumption allied to carbon dioxide emission and economic growth

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ABSTRACT

Although many investigations have been conducted in analyzing how climate change influences the natural environment and human society, the cause-and-effect connections are often complex and the timing uncertain. There is a close connection between the energy consumption and corresponding atmospheric carbon dioxide level. For identifying the trends and the periodic intervals of the primary energy consumptions in Turkey between 1990 and 2013, a clustering-based analysis was performed. First the amounts of consumed sources which are lignite, bituminous coal, oil, and natural gas, were identified and then a fuzzy clustering procedure was applied to classify the annual energy consumptions according to years. By this way, the relationships among the consumptions and development parameters in Turkey such as growth rate have been appraised. The results showed that the clustering approach provides some findings to evaluate the relationships between the periodic variations of energy consumption and the growth rates at different levels of generality.

INTRODUCTION

Since 1990, energy-related CO_2 emissions have more than doubled and are likely to continue to increase rapidly over the medium and long term, in parallel with energy demand since 1990 [1]. One of the main sources of the carbon dioxide emissions is the consumption of fossil fuels in industrial processes. Therefore to understand the main relationships among the level of growth, emissions and energy consumptions a reliable methodology should be used [2].

There are some studies in literature which focused on the energy consumptions/demands and their assessments using some statistical tools. One of these studies, the energy structure of Turkey for public and private sectors via some selected social and economical indicators which reflect the development and also the indicators reflecting the energy structures has been discussed [3]. Similarly, long-run equilibrium relationship between tourism, energy consumption, and environmental degradation as powered by carbon dioxide (CO_2) emissions in Turkey was appraised [4]. Recently, the relevance of the environmental Kuznets curve (EKC) hypothesis in Turkey using carbon dioxide (CO_2) emissions, energy consumption, economic growth, and foreign direct investment (FDI) variables by various statistical tests has been investigated [5].

In data mining, data clustering, also called unsupervised classification, is a method of creating groups of objects, in such a way that objects in one cluster are very similar and objects in different clusters are quite distinct [6]. A clustering algorithm can provide some opportunities to describe a data set and to visualise a system. In this study, a well-known fuzzy clustering method, the fuzzy c-means clustering (FCM) algorithm was utilized [7]. Because the parameters contain ambiguous and uncertain properties, instead of a conventional clustering algorithm, a fuzzy clustering-based methodology was preferred.

Energy consumptions and energy-related carbon dioxide emissions in Turkey began to increase rapidly during the 1990s. [8]. The annual consumptions of the fossil energy sources of Turkey, and connected carbon dioxide emissions were handled and analyzed with the economic growth rates. By this way, to gain a clear understanding the relationships between the economic growth and the amount of energy consumption which are also connected with the carbon dioxide emissions recorded in the same period, an effective tool has been examined.

METHODOLOGY

Problem statement

Since 1990, linked to rapid economic growth, Turkey's total emissions of greenhouse gases have strongly increased [1]. The amount of emissions is directly related with the energy consumption of Turkey. Therefore, based on the temporal data, the trend of the energy consumption should be determined.

Although many linear and nonlinear methods in literature have been practiced to analyze the energy trends, there are limited number of classification-based approaches have been used for this purpose. In fact, a clustering-based recognition can reveal the main properties of the trends in accordance with the data classification. Based on a similarity (or dissimilarity approach) potential connections and discriminations can be explored.

Clustering-based recognition

Clustering is employed to partition sample points into subgroups which are represented by cluster centers. In this study, as a well-known clustering method, Fuzzy c-means clustering (FCM) algorithm is considered to analyze the records.

FCM partitions a collection of n vector x_i, $i=1,\dots,n$ into c fuzzy groups, and finds a cluster center in each group such that a cost function of dissimilarity measure is minimized [9]. Each data point belongs to a cluster center with a degree which is determined by the membership grade. The fuzzy partition matrix is of probabilistic property as follows:

$$\sum_{i=1}^{c} \mu_{ij} = 1, \qquad \forall j = 1,\dots,n \tag{1}$$

The objective function for FCM is given by Eq. (2).

$$J_m = \sum_{i=1}^{c} \sum_{j=1}^{n} \mu_{ij}^m \, d_{ij}^2 \tag{2}$$

where μ_{ij} takes values between 0 and 1, c_i is the cluster center of fuzzy group i, $d_{ij} = \|c_i - x_j\|$ is the Euclidean distance between ith cluster center and jth data point and $m \in [1, \infty]$ is a weighting exponent. Cluster means and membership matrix are calculated as follows.

$$c_i = \frac{\sum_{j=1}^{n} \mu_{ij}^m x_j}{\sum_{j=1}^{n} \mu_{ij}^m} \tag{3}$$

$$\mu_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{d_{ij}}{d_{kj}} \right)^{2/(m-1)}} \tag{4}$$

RESULTS and DISCUSSION

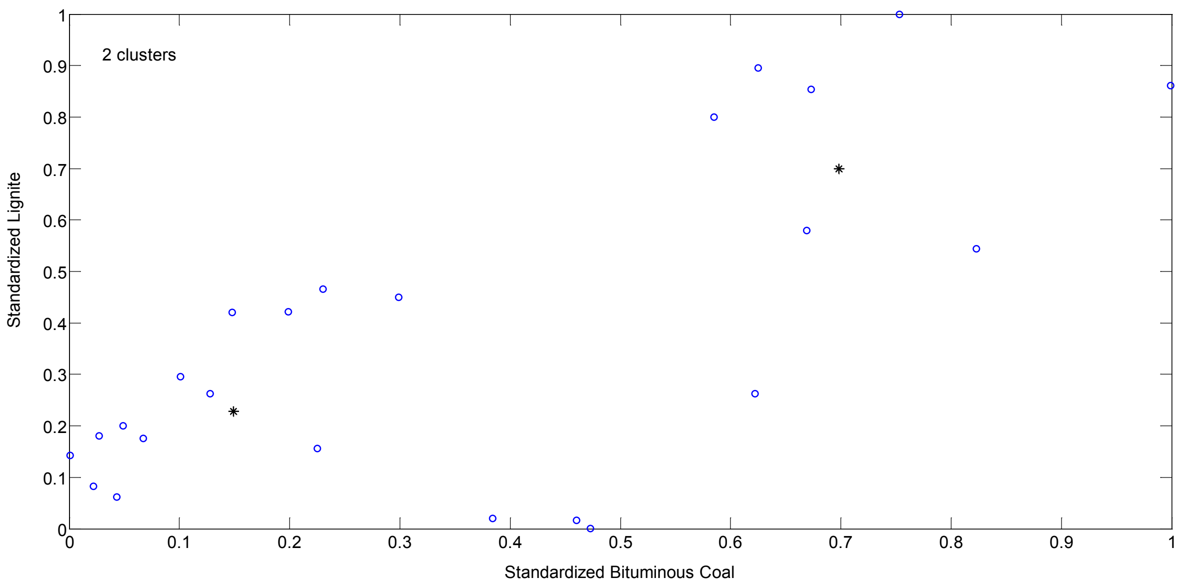
Applications

In order to analyse the mining-based energy consumptions and corresponding carbon dioxide emissions in Turkey, first the sources such as lignite, bituminous coal, oil, and natural gas were identified and their amounts of consumptions (Btep) between 1990 and 2013 were treated. A reliable clustering analysis is carried out under a data conditioning [10]. Therefore, before the starting of the applications, a data scaling was carried out between min (0.001) and max (0.999) values via a linear transformation.

By using the FCM clustering algorithm, a series of clustering applications have been performed. Figure 1 shows the classifications for 2, 3, and 4 clusters, respectively. To show the positions, standardized bituminous coal and lignite values have been used as axes, respectively. Because the number of data (24 years data) is limited, the clustering applications were conducted only for obtaining the general structures.

Discussion

The main motivation of this study is to explore the different levels of the consumptions and corresponding CO_2 emissions in the same pool. The FCM algorithm was considered as a strong indicator for providing the different periods. The results obtained from the clustering have been illustrated in Fig 2. The information collected from the applications indicated some findings.



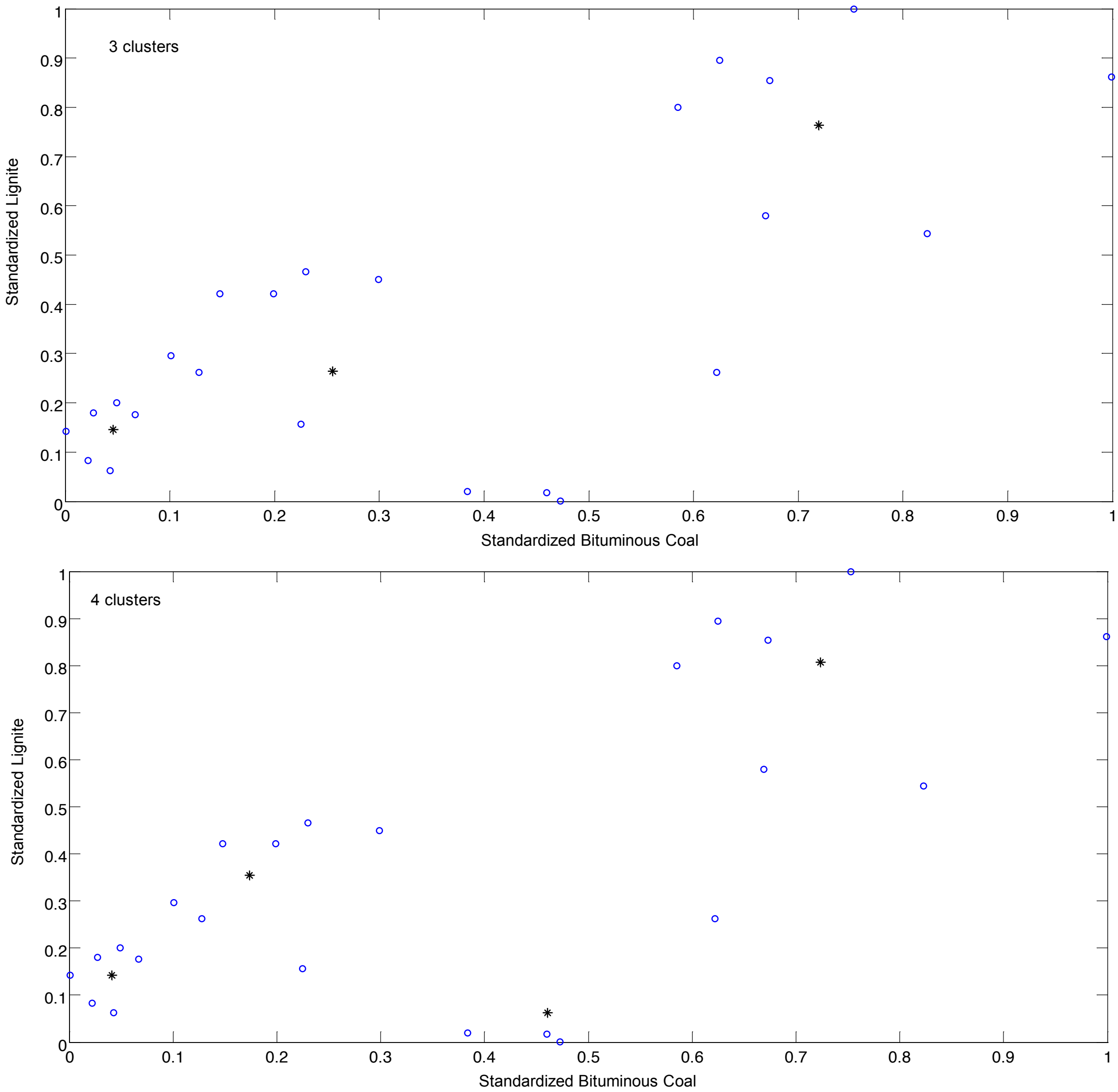


Figure 1. FCM clustering applications

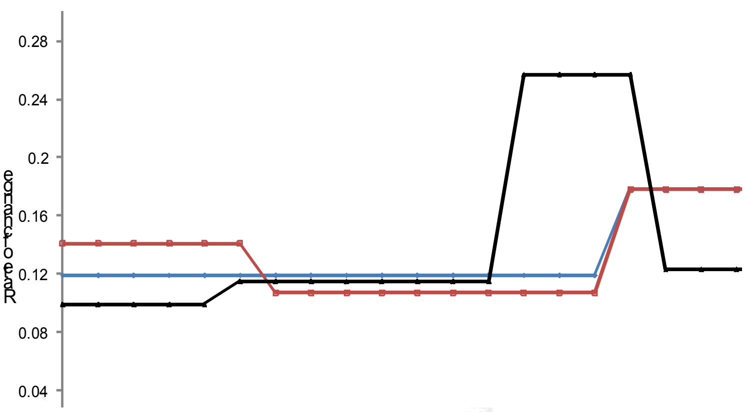


Figure 2. Consumption rates against clustering results at different periods.

To indicate the relative changes with the years, a relative measure expression, the rate of change ***(RoC)*** was described as follows:

$$RoC = \frac{\sum_{i=1}^{k} x_{i+1} - x_i}{k} \tag{5}$$

where ***i=1,2,..,k*** denote the years in a cluster, x_i represent the total energy consumption at the year ***i.*** Figure 2 shows that there are two breaking points for energy consumption: 1994-1996 and 2005-2007. These critical stages can be followed in three applications. The application performed for four clusters is the more detailed analysis which indicated that a high energy consumption between 2003 and 2006. From the public records, the economic growth rates of Turkey between the years 2003-2006 were actualized as 5.3, 9.4, 8.4, and 6.9, respectively [11]. All these values address high economic growth levels. These records have been identified by two and three clusters in general, and by four clusters in detail.

CONCLUSION

The energy consumption of a country and corresponding atmospheric carbon dioxide levels are directly connected issues. Therefore, in this study for identifying the trends and the periodic intervals of the primary energy consumptions in an efficient classification tool is utilised. Thus, the relationships among the energy consumptions and development parameters in Turkey such as growth rate have been appraised. The results indicated that the fuzzy clustering-based evaluation procedure can provide many findings for decision makers to interpret the consumption levels allied with carbon dioxide emissions in connection with the economic growth figures.

REFERENCES

[1] IEA. ***Energy Policies of IEA Coutries***, Turkey 2009 Review, Paris, OECD-IEA, 2010.

[2] Desideri U., Manfrida G., Sciubba E. ***ECOS 2012 - The int. conference on efficiency, cost, optimization, and simulation of energy conversion systems and processes***, Perugia, 2012.

[3] Cakir MT., Sozen A., Yucesu, HS. ***A multiple variables data analysis on the relationship between Turkey's Socio-economic and Energy Indicators***, Uluslararası İlişkiler-International Relations 5(20), 27-56, 2009.

[4] Katircioglu ST. ***International tourism, energy consumption, and environmental pollution: The case of Turkey***, Renewable and Sustainable Energy Reviews 36, 180-187, 2014.

[5] Gökmenoğlu K., Taspinar N. ***The relationship between CO_2 emissions, energy consumption, economic growth and FDI: the case of Turkey***, The Journal of International Trade & Economic Development 25(5), 706-723, 2016.

[6] Gan G., Ma C., Wu J. ***Data Clustering: Theory, Algorithms, and Applications***, SIAM, 2007.

[7] Bezdek JC., Ehrlich, R., Full W. ***FCM: The fuzzy c-means clustering algorithm***, Computers and Geosciences 10(2), 191-203, 1984.

[8] Tutmez B. ***Trend analysis for the projection of energy-related carbondioxide emissions***, Energy Exploration & Exploitation 24(1), 139-150, 2006.

[9] Höppner F., Klawonn F., Kruse R., Runkler T. ***Fuzzy Cluster Analysis***, Wiley, 1999.

[10] Jain AK., Dubes RC. ***Algorithms for Clustering Data***, Prentice Hall, 1988.

[11] TÜİK. ***Statistical Indicators 1923-2011, Turkish Statistical Institute***, CD-ISBN: 978-975-19-5571-5, December 2012.

Paper No: 132
Critical Misapplications in Energy Efficiency and Green Building Sectors in Turkey

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ABSTRACT
There are two main critical and common misapplications in energy efficiency sector. One of them is misunderstanding of the insulation principles and another one LED lighting misapplications. There have been hundreds of bad examples indicated during analyses and audits conducted on case study buildings in Turkey.
Getting aware about energy efficiency, most of the building owners are investing on refurbishment and building insulation in particular. Due to the lack of technical background most of efforts are being wasted into the unreliable and improper products (like insulated paint), which has been misleadingly suggested by irresponsible producers. In spite of the effort conducted by some organizations to improve situation and propose solutions, which in fact cannot be solved without proper regulations.
Lighting sector is continuously developing. Recent regulations are stated that lighting automation should be installed on all new hospitals. With the help of new advancements now it is possible to make hospitals more comfortable and efficient. There is a potential of 60-70% lighting efficiency in the hospitals even without automation system and LED. When energy efficiency is achieved by changing lighting fixtures only the outcome can be more expensive than predicted. The operation costs depend on the scenario rather than fixture.

Keywords: Smart Lighting, Energy Efficiency, Green Building, Hospital Dynamic Lighting, LED Applications.

INTRODUCTION

There are two common and very critical misapplications in energy efficiency sector that can evidently cause problems for the building and facility owners. The first one is thermal insulation and second 'assemble-disassemble' applications of LED lighting. Unfortunately in both misapplications there are hundreds of improper applications and failed examples that have been confronted during the analyses and audits in Turkey.

1. JACKETING OR THERMAL INSULATION?

Currently there are various amount of houses and buildings that have been insulated with pseudo materials like plaster and paint-oriented substances as the main thermal insulation materials. Being persuaded by the untruthful producers, hearsays from neighbors and relatives, building owners and moreover elderly people some with limited technical background about the issue are investing their budgets onto insulation without real technical expertise. The reason underlying this fraud is that there is no control and inspection mechanism as well as no reliable source about the problem available for public in Turkey. House retrofit implementations are mostly done without having any official contracts, technical specifications or legal guarantee, which does not work properly, as owners would expect. Moreover, when there is a failure about the insulation, home owners are usually faced with difficulties in finding a responsible for the work, due to that fact that "one-workman-companies" suddenly disappear in most of the problem cases. In spite of the İMSAD [1] and İZODER's [2] efforts to solve this vital problem, unfortunately it is not enough to cover entire market since it's too big that untruthful producers, which do not not care about İZODER-İMSAD or "TS-825 Heat Insulation Standard" [3] can survive through an illegal lobbies.

The suggestion to solve this problem is to establish 'energy efficiency office-call centers' in each and every province and district - by "Environment and Urbanization Ministry Provincial Directorates" and the sector associations like EYODER, ENVER, İZODER, İMSAD can help and support this development at the establishment stage - guiding the energy efficiency products, systems and applications in insulation, energy performance certificate, solar collectors, lighting, etc. The products conforming the standards should be listed in a national database and common specifications and application contracts should be prepared, while the end user will be accurately and technically informed. To illustrate, such a database example have been released for public access by Department of Consumer Affairs of State of California in 2016 (see figure 1). California law states that all insulation sold and installed in California must be certified to be in compliance with California insulation quality standards [4].

BEARHFTI - THERMAL INSULATION DIRECTORY Manufacturers Listing (click on manufacturer to go to product listing)		
Manufacturer	**Insulation Type**	**License Number**
ACH Foam Technologies	Polystyrene Board	T 1313
Advanced Foil Systems	Radiant Barrier	T 1436
Applegate Insulations Systems LLC	Cellulose Fiber Blanket	T 1496
Applegate Insulations Systems LLC	Cellulose Fiber Loose Fill	T 1496
Atlas EPS	Polystyrene Board	T 1472
Atlas Roofing Corporation	Polyisocyanurate Board	T 1231
BASF Corporation	Polyurethane Spray or Field Applied	T 1153
BASF Corporation (Spray-Applied PUF)	Polyurethane Spray or Field Applied	T 1423
Bayer Material Science LLC	Polyurethane Spray or Field Applied	T 1453
Bonded Logic	Cellulose Fiber Blanket	T 1367
Bonded Logic	Cellulose Fiber Water Heater Kits, Duct & Pipe Wrap	T 1367
Carlisle Coatings and Waterproofing	Polyisocyanurate Board	T 1501
Carlisle Syntec Inc	Polyisocyanurate Board	T 1418
Cell Pak LLC	Cellulose Fiber Loose Fill	T 1479
Certainteed Corporation	Mineral Fiber Blanket	T 1023
Certainteed Corporation	Mineral Fiber Board	T 1023
Certainteed Corporation	Mineral Fiber Loose Fill	T 1023
Certainteed Corporation	Mineral Fiber Water Heater Kits, Duct & Pipe Wrap	T 1023
Certainteed Corporation	Polyurethane Spray or Field Applied	T 1433
Convenience Products	Polyurethane Spray or Field Applied	T 1298
Covertech Fabricating Inc.	Aluminum Foil System	T 1354
Covertech Fabricating Inc.	Radiant Barrier	T 1354
DAP Products Inc.	Polyurethane Spray or Field Applied	T 1343

Figure 1 Thermal Insulation Directory [4]

Another example of this kind of suggestion is Erzurum Energy Consultancy Center project [5], which has been operated between 2002-2005 by the support of German Technical Cooperation Agency (GTZ) and Erzurum Municipality. However, this project was not sustained after financial grant was terminated.

1.1. BUILDING AIRTIGHTNESS IN TURKEY.

Airtightness, one of the Passivhaus design principles, is a decisive factor for energy efficiency. There has been many studies conducted abroad on different kind of the buildings. Nevertheless, there is limited number of studies on airtightness in Turkey. In most of the cases, airtightness tests have been performed merely for LEED or Passivhaus commercial certifications by invited experts from Europe, while for academic purposes this number remains dramatically low. On the other hand, the vast majority of local population is unaware of airtightness benefits.

"Building Airtightness is a flow rate of air required to pressurize or depressurize a building to 50 Pascal, divided by the surface area of the building" [6]. In other words, this concept indicates air leakage level of the building envelope. Figure 2 presents building airtightness rates in different countries in Europe. The values demonstrate that average air permeability value is 3 ACH.

Country	Max Air Permeability		Pressure difference (Pa)	Comments
UK	10	$m^3h^{-1}m^{-2}$	50	Area includes ground floor
Finland	4	ac/h	50	This is the default value
Norway	3	ac/h	50	less than 2 storeys
	1.5	ac/h	50	over 2 storeys
	4	ac/h	50	domestic
France	1.2 (1.7)	$m^3h^{-1}m^{-2}$	4	ALI: offices/apartments. Ref. Val., default in brackets
	2.5 (3.0)	$m^3h^{-1}m^{-2}$	4	ALI: Industrial. Ref. Val., default in brackets
	0.8 (1.3)	$m^3h^{-1}m^{-2}$	4	ALI: Single houses. Ref. Val., default in brackets
Belgium	3	ac/h	50	housing with mechanical ventilation
Germany	1.5	ac/h	50	mechanical ventilation
	3	ac/h	50	natural ventilation
	0.6	ac/h	50	Passivhaus standard

Figure 2 Comparison of air-tightness requirements across Europe [7]

According to UNDP in Turkey (2015), approximately 36% of the whole energy consumption of the country fall to the building industry [8]. In spite there was a major improvements through TS-825 (2008) Standard on air leakage regulations, building sector is still facing problems as well as many misapplication in practice since the 3rd part control and verification scheme are not yet obligatory. The precise airtight envelope design and highly qualified workmanship, which is the main issue in Turkey, can help to eliminate air leakage sources, which are commonly detected within thermal boundary (See Figure 3) [9].

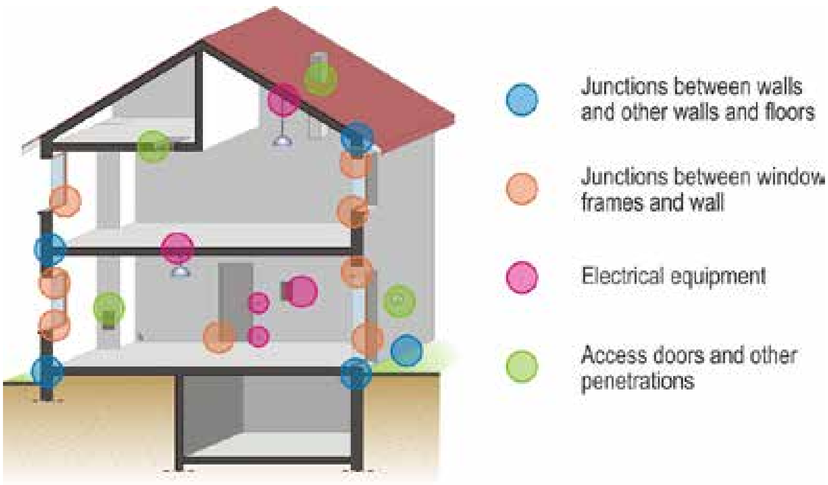

Figure 3 Common leakage sites classified in 4 categories [10]

The poor quality of workmanship is a central issue of the building sector within the Turkish Building Sector. One of that biggest portions of failures falls into building component assembly such a windows and doors installations. The most common problems have been occurred in prefabricated buildings like containerized and modular buildings.

The poor envelope airtightness may affect [10]:

- Indoor air quality: Hazardous gases and dust leaking into the building via cracks and leaky openings.
- Energy use: Air leakage may inadequately increase the total ventilation airflow rate; or it may not allow sufficient heat recovery.
- Building materials: Air leaking out of the envelope may cause condensation, mold and decay of insulation material.

The fan pressurization test is a common method to measure the airtightness of a building. The Blower Door [11] testing tool is mainly used to perform the tests on site. Pressurization method is applied during the test. This test can be conducted according to standards not limited to ASTM E-1827-11 [12], EN 13829 [13] and ISO-9972 [14]. The common goal of those standards is to measure airtightness level of the building.

During the tests, negative and positive 50 Pascal air pressure is applied onto the building envelope. All designed openings are temporary sealed, while interior ones remain open. The main task of the test is indication of the leakage rate and demonstrate unforeseen and undesired air passages through the building envelope. According to Potter (2001), Blower Door measurements have to be accompanied with infrared thermal imaging, which helps not only visually identify air leakage paths but also improperly insulated areas, thermal bridges and condensation, moisture trap within the building envelope. On Figure 4, there is a Passivhaus super insulated building in the foreground, while in background less insulated conventional building with visible thermal anomalies on its façade.

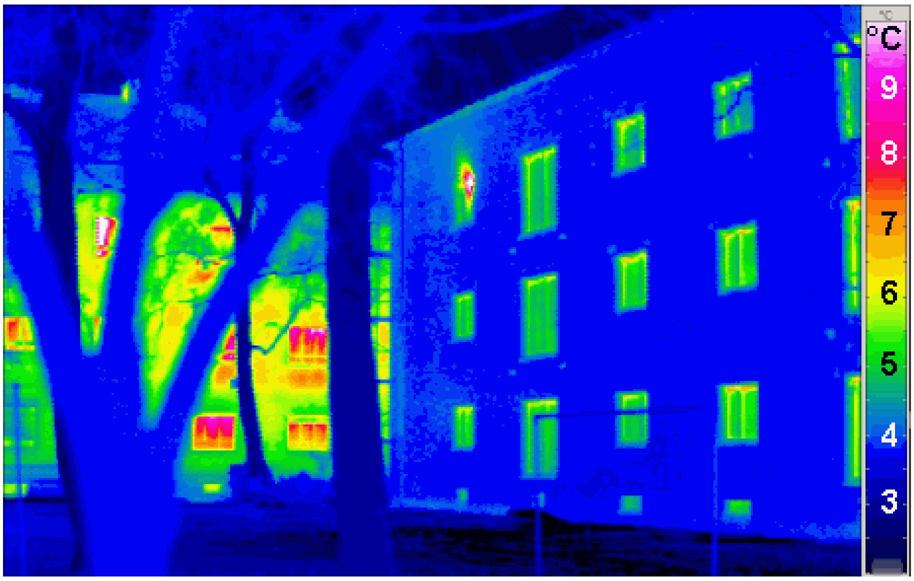

Figure 4 Infrared Thermal Imaging Example [15]

According to outcome of the thesis research conducted on containerized buildings, good airtightness accounts for 10% of energy improvements [16]. A combination with proper thermal insulation energy efficiency situation will improve significantly. In addition, in order to obtain a high quality workmanship with good airtight building envelope on-site, trainings related to airtightness strategies and Blower Door measurement workshops, showing common leakages points, are vital solution to raise awareness among builders and building owners to prevent future implementation failures and potential fraud.

IS LED LIGHTING A CURE FOR ALL?

Lighting systems and the lighting sector is continuously developing in Turkey. As a general saying energy efficient lighting systems, energy efficiency, sustainability, green building concept and green building evaluation-certification systems create a favorable demand to those products and give a priority to them among other market products.

Today 'efficiency and saving' is one of the most recent, significant and interrelated topics in engineering applications. However, it should be remembered that saving is achieved if it is established on efficient system basis. It is a comprehensive approach that consists of material and engineering and operation and maintenance implementations. To achieve this, related engineering activities and the use of the most appropriate technologies should be utilized.

It is possible to make hospitals more comfortable and more efficient by using recent advancement in lighting technologies. In this context, there is a potential of 60-70% lighting efficiency in the hospitals, especially which are operated more than 4000 hours annually and do not have any automation system [17]. However, when the efficiency activities are just done by changing lighting fixtures (mostly they are changed with any other inefficient ones) it results in more expensive outcomes.

In most cases a lighting fixture's annual energy consumption and all over life-time cost are more than its initial market price. This difference is more observable and dramatically increases in the facilities where long operational periods exist such as shopping malls or hospitals. For this reason, it should always be remembered that the important thing is not the initial cost of the fixture but the annual or life-long operational cost of it since cheap and inefficient products poses more expensive problems under continuous operations.

CONCLUSION

To conclude, in order to overcome insulation misapplications there should be regulatory mechanism or organ, which will increase awareness of people towards energy efficiency and at the same time perform verifications with further certifications for targeted standards. There are many examples, when not only standard buildings but also green buildings with good insulation failed post occupancy verification tests. Lighting applications for indoor and outdoor have to be measured as a quality control measures against potential failures and mismatches with required standards. People should address 3rd party experts in case when regulatory organization is unavailable. Those experts have to be formed from industry and academic experts as well as consist of representatives of municipality and departments.

REFERENCES

[1] Izoder. (2016). Izoder. [online] Available at: http://www.izoder.org.tr [Accessed 17 April. 2016].

[2] Imsad.org. (2016). TÜRKİYE İMSAD. [online] Available at: http://www.imsad.org [Accessed 03 May. 2016].

[3] TS 825. (2008) ***Thermal Insulation Requirements in Buildings***. Turkish Standards Institution. Ankara, Turkey.

[4] Paddock, J. (2016). Directory of Certified Insulation Materials. 1st ed. [ebook] California: Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation. Available at: http://www.bearhfti.ca.gov/consumers/ti_directory.pdf [Accessed 28 Jun. 2016].

[5] OECD. (2008), "Eco-Innovation Policies in Turkey", Environment Directorate, OECD.

[6] Potter, N., (2001). Air tightness testing. Technical Note 19, Building Services Research & Information Association.

[7] ETHICS WP 1: Air-tightness of buildings. Report on National and European Regulations and Requirements Regarding Air-Tightness. (2008). 1st ed. Aachen: RWTH Aachen University Institute for Steel Construction.

[8] UNDP in Turkey (2015). Promoting Energy Efficiency in Buildings in Turkey. [online] Available at: http://www.tr.undp.org/content/turkey/en/home/operations/projects/poverty_reduction/promoting_energy_efficiency_in_buildings_in_turkey.html [Accessed 08 Jul. 2015].

[9-j] Jaggs M, and Scivyer C. (2009). A Practical Guide to Building Airtight Dwellings. NHBC Foundation NF 16. Bucks, UK.

[10] Tightvent.eu. (2016). FAQs | TightVent Europe. [online] Available at: http://tightvent.eu/faqs [Accessed 28 Jun. 2016].

[11] BlowerDoor Gmbh (2014) MessSysteme für Luftdichtheit - BlowerDoor. [online] Available at: http://www.blowerdoor.de/ [Accessed 23 Apr. 2014].

[12] ASTM (2013) ASTM E1827 - 11 Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door. [online] Available at: http://www.astm.org/Standards/E1827.htm [Accessed 02 Nov. 2013]. West Conshohocken, USA.

[13] EN 13829 (2001) Thermal Performance of Buildings, Determination of air Permeability of Buildings, Fan pressurization Method. (Modified from ISO 9972:1996).

[14] ISO (2015) ISO 9972:2015 - Thermal performance of buildings -- Determination of air permeability of buildings -- Fan pressurization method. [online] Available at: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=55718 [Accessed 10 Aug. 2015].

[15] Passivhaus Institut, (2006). Thermogram of a traditional building in the background and a "passive house" in the foreground. [image] Available at: https://commons.wikimedia.org/wiki/File:Passivhaus_thermogram_gedaemmt_ungedaemmt.png#/media/File:Passivhaus_thermogram_gedaemmt_ungedaemmt.png [Accessed 28 Jun. 2016].

[16] Bekboliev, M. (2015). Assessing the Airtightness Performance of Container-Like Buildings in Relation to its Effect on Energy Efficiency. Master's Thesis. Middle East Technical University.

[17] Özenç S., Künar, A. (2013) "Verimlilik, Tasarruf, Konfor ve Performans", EMO Available at: http://www.emo.org.tr/ekler/ddb19bc08297670_ek.pdf [Accessed 10 April. 2016]

Paper No: 187

An Innovative Financial Business Model leading Stakeholders towards Energy Efficient Building Envelope Components

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ABSTRACT

Most green buildings cost a premium of <2%, but yield 10 times as much over the entire life of the building. The stigma is between the knowledge of up-front cost vs. life-cycle cost. The savings in money come from more efficient use of utilities which result in decreased energy bills.

As of necessity for creating successful model belonging to one of building envelope components, energy efficient window system is chosen as pilot project in Turkey. A private bank, company and property investment partnership are 3 main trivets of this business model.

Firstly, costs of traditional or "business-as-usual" window system and energy efficient window system, will be compared.

Secondly, financial savings on bills including water, natural gas and electricity etc. will be calculated by considering traditional and energy efficient window systems.

Lastly, a private bank will be responsible for financial model of the pilot project. The main idea of the pilot project is building energy efficient building envelope components with reasonable up front costs that will be paid back through bills over a period of time.

Keywords: Energy efficient building envelope components, financial business model, stakeholder partnership

INTRODUCTION

Buildings are at the centre of our economic and social lives, providing us shelter, work places and spaces for commerce and leisure. On the other hand, buildings also put a tremendous strain on our environment, being responsible for a significant share of global energy use (approximately 40%), resource consumption (more than 30% of materials use and 20% of water use) and waste generation (30% of solid waste, 20% of wastewater). The building sector is also the source of more than 30% of global greenhouse gas (GHG) emissions, therefore being a crucial sector in combat with climate change. [24]

The sustainable buildings agenda has gained considerable momentum through the development of flagship buildings, all over the world, showcasing the most efficient and innovative solutions found on the market. 2007 report of the Intergovernmental Panel on Climate Change (IPCC) highlighted that the building sector has the greatest potential for reducing GHG emissions at the lowest cost. With proven and commercially-available technologies, the energy consumption in both new and existing buildings, as well as the related GHG emissions, can be reduced by 30-50% without significantly increasing the investment costs of new construction or renovation projects ([14] IPCC, 2007). It is now crucial to mainstream sustainable building practices at a broader scale. Acting now can prevent locking in buildings' potential to contribute to climate change mitigation and sustainable development. Special attention shall be given to find appropriate solutions to target the building market in developing countries, where most of the new construction is taking place.

Countries with rapid population growth and urbanization have additional challenges to face. Housing shortages have lead to the launch of large-scale social housing programmes. Although these programmes deliver a high quantity of housing units at low-cost and provide shelter for millions of families, severe time and budget constraints often lead to low-quality, unsustainable and sometimes buildings harmful for human health. Furthermore, two main preconceptions tend to slow down investments in sustainability in social housing. First, it is often perceived that social housing units already have a low energy consumption, and thus investments in energy efficiency are not justified. Second, sustainable solutions are thought to be far too expensive to include in social housing, as they would increase the unit cost and make them unaffordable for both users and housing authorities. However, under current rapid construction conditions, the high rate of building defects leads to users having to face high operation and maintenance costs. Also, constraints in land use often result in units being located in remote areas, where users have little access to urban infrastructure, and even less to the social and economic opportunities of the city.

So while social housing's first and greatest priority should continue to be to provide housing for the low-income population, locally-appropriate techniques, solutions and practices exist that can support this objective and deliver sustainability improvements at low or no-cost. The most critical issue about constructing environmentally friendly buildings is the price. Photo-voltaics, new appliances, and modern technologies tend to cost more money. Most green buildings cost a premium of <2%, but yield 10 times as much over the entire life of the building ([16] Kats et al, 2008). The stigma is between the knowledge of up-front cost vs. life-cycle cost ([3] California Sustainability Alliance, 2010). The savings in money come from more efficient use of utilities which result in decreased energy bills. It is projected that different sectors could save $130 Billion on energy bills ([8] Fedrizzi, 2009). Also, higher worker or student productivity can be factored into savings and cost deductions. Studies have shown over a 20 year life period, some green buildings have yielded $53 to $71 per square foot back on investment ([19] Langdon, 2007). Confirming the rentability of green building investments, further studies of the commercial real estate market have found that certified buildings achieve significantly higher rents, sale prices and occupancy rates as well as lower capitalization rates potentially reflecting lower investment risk ([9] Fuerst and McAllister, 2010a; [20] Pivo and Gary, 2010; [10] Fuerst and McAllister, 2010b).

Developing a local project agenda and identifying priorities related to the local context will lead to the construction of more sustainable housing units without an increased life cycle cost and will even reduce the costs of housing for housing authorities and residents in the long-term. In fact, the long-term social, economic and environmental benefits of using sustainable solutions can strongly improve the quality of life of residents, reduce energy and resource consumption at the national level, improve the climate responsiveness and adaptation of buildings and deliver secondary benefits in terms of social integration, lower health costs and increased performance and productivity.

AIMS

The proposal focuses on issues of innovation in emerging economies that have the objective of invalidating the following preconceptions which slow down investments in sustainability in affordable housing components:

(1) social housing units have a low environmental impact, not justifying sustainable investments and
(2) sustainable solutions are far too expensive to include in social housing, as they would increase the cost of the unit and make it unaffordable for both users and developers.

Within this context, the research project aims to answer the following key questions:

- Within emerging countries, what are the processes driving innovation around sustainable social housing components?
- Are there regional differences in these drivers?
- What incentives are there for providing sustainable building products and components from the private sector's perspective?
- How can the governance of sustainable social housing components be harnessed so as to encourage such innovation?

METHODOLOGICAL FRAMEWORK

The methodological framework consists of the following components:

(1) pilot project and

(2) comparative study in order to implement the outcomes of the pilot project in emerging countries

GEOGRAPHICAL FOCUS

The geographical area proposed for the pilot project is Turkey due to the following reasons:

Turkey's geology and history of earthquakes provide incontrovertible evidence of the country's significant seismic hazard. The movement of Turkey's Anatolian block relative to the African, Eurasian and Arabian plates causes earthquakes to occur along the plate boundaries, or fault-lines ([21] Scawthorn and Johnson, 2000; USGS, 2000). The 1500 kilometer North Anatolian Fault is the most active fault zone in Turkey and 90% of the population live in seismically hazardous areas ([18] Özerdem and Barakat, 2000).

The propensity of seismic activity in Turkey to cause disaster is recently underscored by descriptions of destruction during the 17 August 1999 Marmara Earthquake. This magnitude 7.4 event is also known as the "Kocaeli" or "Izmit" earthquake. This quake ruptured 110 km of the North Anatolian Fault, shaking a highly developed region of the country and causing at least 18,000 deaths and almost 50,000 hospitalized injuries, mostly in Gölcük, Adapazarı and Yalova. In this earthquake, the majority of the deaths resulted from structural collapses of residential buildings. 77,000 homes and business structures were reported to be destroyed; many more were in need of significant repair ([18] Özerdem and Barakat, 2000; [21] Scawthorn and Johnson, 2000; [22]

Sezen et al, 2000; [5] Daley et al, 2001; [6] Durukal et al, 2002; [15] Kasapoglu and Ecevit, 2003).

Technical design flaws, poor engineering and "deficient engineering practice" are directly responsible for structural collapses ([23] Tankut, 2001, p180). The "technically responsible engineers" who must supervise on-site construction work are frequently employed directly by contractors and they are rarely a visible presence on the construction site. These supervisory engineers are moreover required only to report deviations from shop drawings in construction, and are not held responsible for construction problems unless there is evidence of premeditated malice ([11] Gülkan, 2001; [18] Özerdem, 2003). The contracting profession is popularly seen as an easy way to earn a good living; as the Turkish construction industry boomed in the 1980s anyone could easily start a contracting and construction business ([18] Özerdem, 2003).

Municipalities are responsible for supervising building construction projects under Turkish law, but most have inadequate personnel and resources to fulfill this task. In theory, the system of ensuring adherence to building codes and land use regulations works much as it does in the US and the UK; before a project begins, the architectural, structural and mechanical designs must be submitted to the municipal authority in order to obtain a construction permit. In practice, municipalities have insufficient resources to hire a significant number of technical staff ([23] Tankut, 2001; [11] Gülkan, 2002). As a result, most municipal planning offices employ no structural engineers and stamp plans as "received" without checking the technical considerations of the project ([11] Gülkan, 2001; [12] Gülkan, 2002). Local governments are permitted to shut down construction sites if these plans do not meet their regulations, but problems are more frequently met with an institutional "averting of eyes" ([12] Gülkan, 2002, p20). Furthermore, municipalities are not liable for omissions or mistakes in development, and no legal action against officials has ever been taken ([1] Balamir, 2001; [12] Gülkan, 2002). Municipalities and provinces are also responsible for zoning ordinances, new development and urban plans. Their influence, however, is rarely used to enforce planning regulations for environmental standards and disaster mitigation. Despite its intimate relation to development and urban planning, few local governments have explicitly considered disaster preparedness ([4] Coburn, 1995; [7] Erdik, 1995; [1] Balamir, 2001).

Turkey is a country with a population of 74,724,269 people according to 2011 counting. With an annual population growth over 1.35%, Turkey is expected to have 80.2 million people by 2020 ([17] Kick, 2011). Turkey's energy expenses vary between $55 billion and $70 billion, increasing by every year. With a gross domestic product (GDP) of $1.116 trillion in 2010, Turkey is the 15th largest economy in the world ([13] IMF, 2011). At the same time, the IMF predicts an average economic growth of 5.4% per year until 2015 ([17] Kick, 2011). For more than a decade, Turkey has enjoyed unprecedented growth that is in many ways unique to Europe. In return, the country's infrastructure and social services have improved drastically, and major business developments have taken place, especially joint investments with the EU.

In Turkey, around 14 million houses would fail to meet viability criteria and should be reviewed at the earliest possible convenience. The current government has shown its strength and political will on this vital issue and took a crucial decision to renew these buildings. After many heated discussions, the destruction and rebuilding of not only the urban zones but also all other areas from forests to military areas which are declared to be "under catastrophe risk" is at stake with Law No. 6306 on The Transformation of Areas Under the Catastrophe Risk, issued in May 2012. In the context of urban transformation it's planned to renew 6.5 million houses in Turkey within the next 20 years; only in Istanbul over 400.000 buildings are planned to be demolished and rebuilt.

However, the Turkish government is implementing urban transformation through sudden, top-down decisions that do not sufficiently account for environmental protection or consultations with citizens. In the process, the population's leanings are largely ignored, making it impossible to nurture civic consensus on the pace and nature of economic development. In addition, there is no systematic monitoring of urban transformation practices and abuses. Few national and international non-governmental organizations (NGOs) are allocating time to the subject, and most of the evidence of abuses comes not from academic or other dispassionate sources but from stakeholders in the process and commentators.

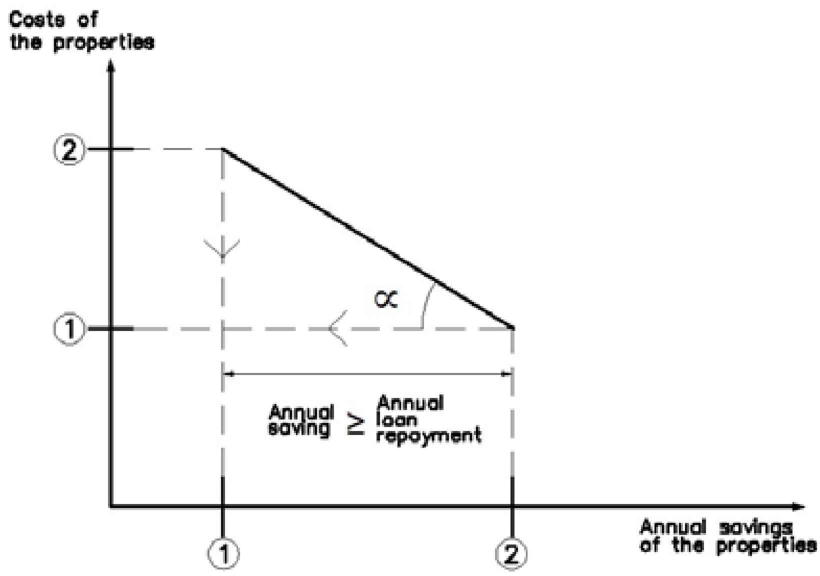
Turkey is not only the country as proposed for the pilot project but also my dissertation empirical research carried out. So the pilot study can be assumed as a continuation of my dissertation ([2] Bekiroğlu et al, 2011).

PILOT PROJECT

As shown in the following research model (Figure 1), firstly, costs of traditional or "business-as-usual" window system and energy efficient window system, will be compared

Secondly, financial savings on bills including water, natural gas and electricity etc. will be calculated by considering traditional and energy efficient window systems.

Lastly, a private bank will be responsible for financial model of the pilot project. The main idea of the pilot project is building energy efficient building envelope components with reasonable up-front costs that will be paid back through bills over a period of time. This is unlike a conventional loan because if you move out of the property the bill stays with the property where the savings are occurring and not with the bill payer. The expected financial savings must be equal to or greater than the costs attached to the bills.



1: Traditional or "business-as-usual" window system,
2: Energy efficient window system.
ROI = Return on Investment = Tangent alpha = (ΔCosts)/ (Δ Annual savings)

Figure 1 Research model

COMPARATIVE STUDY

Dissemination and publication of the pilot project outcomes will be reference study for other emerging countries such as China, India and Brazil. Comparative study of stakeholders between Turkey and other emerging countries will highlight the following consequences:

The pilot project is directly applicable in most of these emerging countries and some parts of the pilot project should be modified in order to apply it in the rest of these emerging countries.

REFERENCES

[1] Balamir, Murat, 2001, "Recent changes in Turkish disasters policy: a strategical reorientation," in Paul R Kleindorfer and Murat R. Sertel (eds.), Mitigation and Financing of Seismic Risks: Turkish and International Perspectives, Kluwer Academic Publishers, London.

[2] Bekiroğlu, Ç., Erdil, O., Alpkan L., (2011), "Variables perceived by managers as antecedents that lead firms to environmental management: An empirical research in the Turkish construction sector", Journal of Global Strategic Management (JGSM), December 2011, Volume 5, Number:1, ISSN:1307-6205.

[3] California Sustainability Alliance, Green Buildings. Retrieved June 16, 2010, fromhttp://sustainca.org/programs/green_buildings_challenges.

[4] Coburn, Andrew, 1995, "Disaster prevention and mitigation in metropolitan areas: reducing urban vulnerability in Turkey," in Ronald Parker, Alcira Kreimer and Mohn Munasinghe (eds.), Informal Settlements, Environmental Degradation and Disaster Vulnerability, World Bank, Washington.

[5] Daley, W Randolph, Adam Karpati, Mani Sheik, 2001, "Needs assessment of the displaced population following the August 199 earthquake in Turkey," Disasters, vol. 25, no. 1.

[6] Durukal, E, E Uskan, K Sesetyan and MB Demircioglu, 2002, Earthquake Risk Assessment for Industrial Facilities in Istanbul, Bogazici University.

[7] Erdik, Mustafa, 1995, "Istanbul: Emergency Action Plan," in Ronald Parker, Alcira Kreimer and Mohn Munasinghe (eds.), Informal Settlements, Environmental Degradation and Disaster Vulnerability, World Bank, Washington.

[8] Fedrizzi, Rick,"Intro – What LEED Measures." United States Green Building Council, October 11, 2009.

[9] Fuerst, Franz; McAllister, Pat. Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Property Values. 2009. [4] Retrieved: November 5, 2010a

[10] Fuerst, Franz; McAllister, Pat. An Investigation of the Effect of Eco-Labeling on Office Occupancy Rates. 2009.[6] Retrieved: November 5, 2010b

[11] Gülkan, Polat, 2001, "Revision of the Turkish Development Law no. 3194 governing urban development and land use planning," in Paul R Kleindorfer and Murat R. Sertel (eds.), Mitigation and Financing of Seismic Risks: Turkish and International Perspectives, Kluwer Academic Publishers, London.

[12] Gülkan, P, 2002, "Setting the stage for urban risk mitigation: seismic risks and compulsory insurance policy issues in Turkey," Second Annual IIASA-DPRI Meeting, Integrated Disaster Risk Management: Megacity Vulnerability and Resilience, available online:www.metu.edu.tr/home/wwwdmc/Files/Reports/Conferances_Meetings/Luxemburg_paper_July_02._1.PDF.

[13] International Monetary Fund, World Economic Outlook, 2011

[14] Intergovernmental Panel on Climate Change (IPCC), (2007). Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Metz, B., O.R. Davidson, P.R. Bosch, R. Dve, L.A. Myer (eds.)], Cambridge, U.K. and New York, NY, USA, Cambridge University Press.

[15] Kasapoglu, Aytul, Yildiz Ecevit and Mehmet Ecevit, 2004, "Support needs of the survivors of the August 17, 1999 earthquake in Turkey," Social Indicators Research, vol. 66.

[16] Kats, Greg, Leon Alevantis, Adam Berman, Evan Mills, Jeff Perlman. The Cost and Financial Benefits of Green Buildings, November 3rd, 2008.

[17] Kick, C., "How is 100% Renewable Energy Possible for Turkey by 2020?", July 2011.

[18] Özerdem, Alpaslan and Sultan Barakat, 2000, "After the Marmara earthquake: lessons for avoiding shortcuts to disasters," Third World Quarterly, vol.32, no. 3. Özerdem, Alpaslan, 2003, "Disaster as manifestation of unresolved development challenges,"in Mark Pelling (ed.), Natural Disasters and Development in a Globalizing World, Routledge, London.

[19] Langdon, Davis. The Cost of Green Revisited. Publication. 2007.

[20] Pivo, Gary; Fisher, Jeffrey D. Investment Returns from Responsible Property Investments: Energy Efficient, Transit-oriented and Urban Regeneration Office Properties in the US from 1998-2008. 2009.[5] Retrieved: November 5, 2010.

[21] Scawthorn, C. and G.S. Johnson, 2000, "Preliminary report: Kocaeli (Izmit) earthquake of 17 August 1999," Engineering Structures, vol. 22.

[22] Sezen, Halil, Kenneth J Elwood, Andrew S Whittaker, Khalid M Mosalam, John W Wallace, and John F Stanton, 2000, "Structural engineering reconnaissance of the August 17 1999 Earthquake: Kocaeli (Izmit), Turkey," PEER Report, Pacific Earthquake Engineering Research Center, Berkeley, University of California.

[23] Tankut, Tugrul, 2001, "Structural and educational dimensions of earthquake damage mitigation in Turkey," in Paul R Kleindorfer and Murat R. Sertel (eds.), Mitigation and Financing of Seismic Risks: Turkish and International Perspectives, Kluwer Academic Publishers, London.

[24] United Nations Environment Programme (2007). Buildings and Climate Change: Status, Challenges and Opportunities. Lead authors P. Huovila, M. Ala-Juusela, L. Melchert, and S. Pouffary. Sustainable Buildings and Climate Initiative, Paris. Available from:

[25] USGS, 2000, "Implications for Earthquake Risk Reduction in the United States from the Kocaeli, Turkey, Earthquake of August 17, 1999," US Geological Survey Circular, available online: pubs.usgs.gov/circ/2000/c1193/c1193.pdf.

Paper No: 189

The Role of Aluminium on Sustainability of Buildings and Cities for the Current and Future Applications

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ABSTRACT

Aluminium is one of the fastest growing construction material in the world. Aluminium as a building material has been evaluated in terms of current demand of the buildings and cities. Beside structural, functional and decorative prerequisites, recyclability, environmental effects, carbon emissions, energy consumptions, availability of aluminium are studied in this work. The current role of aluminium usage on for having a sustainable buildings and cities has been discussed while the future projections for aluminium as a building material have been estimated. In the scope of increasing world population, increasing in migration to the cities, decreasing product life cycle periods, increasing hunger for a better and innovative buildings and cities, aluminium has been evaluated and discussed whether it is going to ensure the tomorrow's needs or, novel alternative materials are going to be necessary for future.

Keywords: *Aluminium, aluminium and sustainability, construction materials, future sustainable construction materials*

INTRODUCTION

The fast change of world and environment lead people to reconsider about the consumption of energy and natural resources due to climate changes and environmental pollution. The world population has increased tremendously in last decade and the predictions show that only in 50 to 100 years the world population is going to reach its maximum. The scientist's reports indicate that world can keep up to 10 billion populations due to the lack of food and natural resources. Probably the world is going to experience more change and development in this period than the development achieved during whole human history.

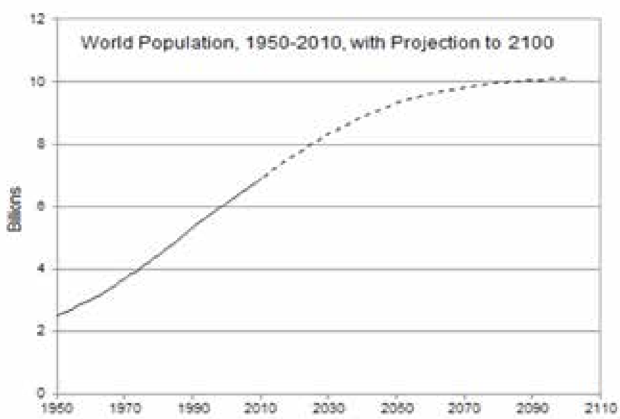

Figure 1 Global population prediction for year 2100 [1]

A typical prediction for the global human population is shown in Figure 1. More or less almost al predictions are indicating that the human populaion is reaching to maximum of about 10 billions that is the limit for the world that can carry on. Hence the rate of development and change in the world is going to reach to its maximum in next 50 to 100 years. It is also indicated that the population will increase more in urban areas rather than rural. Hence more poeple are going to live in cities.

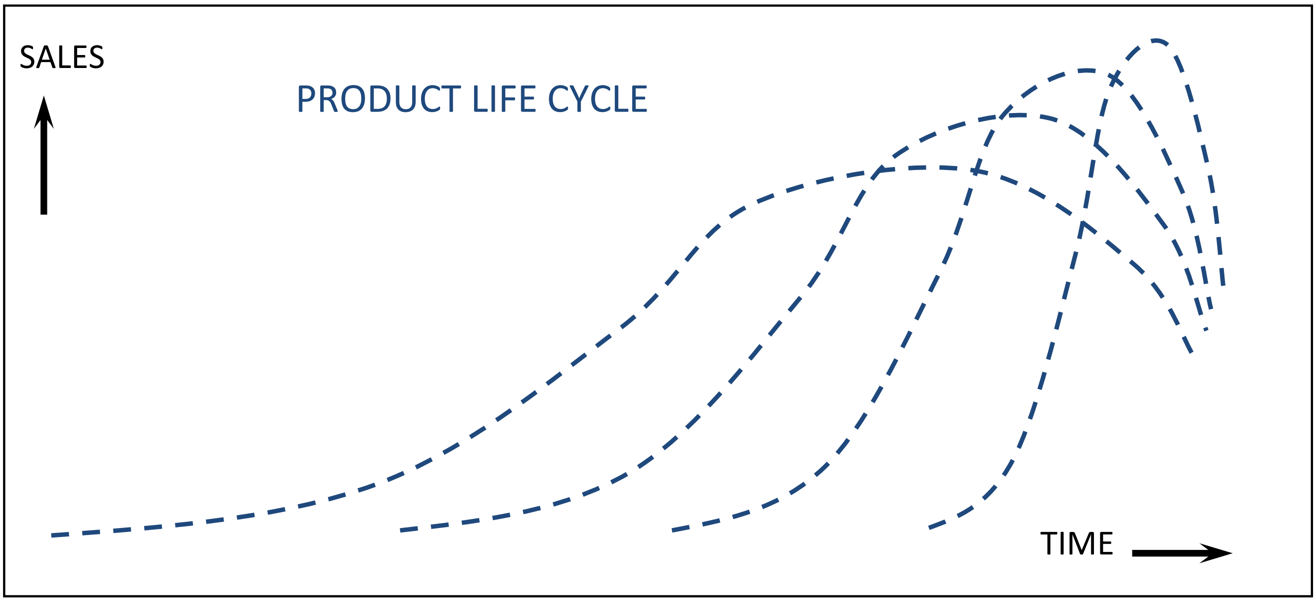

Figure 2 The change of product life cycle by time.

Another significant change is the acccumalation of the big data and creating and faster reaching the information. Hence the rate of development is very fast and this leads to faster prodcut development. The classical prodcut life cycle period is successively deacreasing by time while the volume of sales are increasing with increasing populations. Figure 2 shows the product life cycle change by time.

The rates of new product introduction and adoption are speeding up. Today, a typical automotive design cycle is approximately 30 months, which is much faster than the 60-month life cycle from five years ago. It took decades for the telephone to reach 50% of households, beginning before 1900. It took five years or less for cell phones to accomplish the same penetration in 1990.

It took 30 years for electricity and 25 years for telephones to reach 10% adoption but less than five years for tablet devices to achieve the 10% rate. Smart phones, on the other hand, accomplished a 40% penetration rate in just 10 years [2]. The reduced product life cycle periods, and increased demand for new products cause to decarese of the material resources in the world and increase of contamiantion of the enviroment since more and faster consumotion of energy and materials. Hence recycling of the materials are crucial in terms of energy use, emmisions and enviromental impact. Beside the cost and properties of materials, the ease of recycling is going to be more important in future. The future materials have to satisfy; high recycling efficiency, low recycling energy, low labor cost for dismantling, no lose of any properties after recycling, besides having properties like ease of manufacturing, flexible enough to produce any shape with a high performance.

GLOBAL CARBON EMISSIONS

Having the climate change is one of the bigest issues nowadays, the sources of corbon emmisions are started to be investigated in detail. The sources of whole carbon emmision in the world has shown in Figure 3. Aluminium responsibility in carbon emmission in the whole is at the level of just 0.6%. The share of carbon emmisions from aluminium production in industrial area is about 3% as shown in Figure 3.

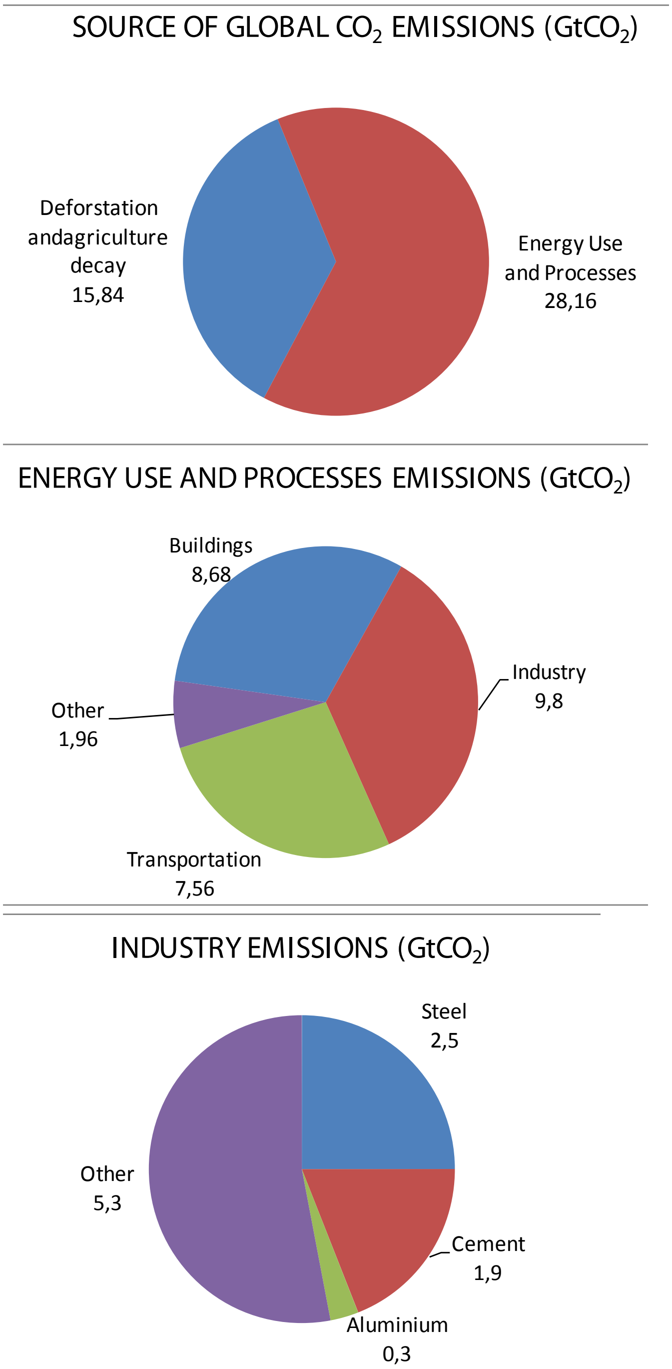

Figure 3 Share of sources of global carbon emissions by 2012 [3]

COMPARING ALUMINIUM WITH OTHER MATERIALS

The reason for aluminium having a small share in carbon emissions is that Aluminium has less consumption per capita compared to other materials as shown in Table 1. Cement is the highest consumed material in the world and annual increase rate is not small compared to the other alternative materials. The low cost and availability are main driving advantages of cement.

Table 1 The rate of change and annual consumptions of some important values per capita. [3-11]

Global Annual Consumptions per Capita	Global average by 2010	Annual Rate of Increase
Aluminium (kg/capita year)	9	4.8%
Steel (kg/capita year)	206	3.6%
Cement (kg/capita year)	480	4.6%
Glass (kg/capita year)	17	3.0%
Stock of built space (m2/capita)	27.4	2.9%
Total primary power (watts/capita)	2,449	1.2%
Silicon wafer(square inch /capita year)	1.35	5.0%

In this study most commonly used construction materials are investigated in terms of energy needs, recycling efficiency and flexibility. Table 2 shows the necessary energy to produce these materials from the nature (primary energy) and the energy necessary to recycle the same materials. The highest primary energy is necessary to produce aluminium from bauxite. The smallest primary energy is necessary to produce concrete which is obtained by mixing cement, aggregate, sand and water. Unfortunately, concrete can only be recycled by crushing to use as an aggregate or to landfill. Cement is not recyclable itself.

Although aluminium has a very huge primary energy during first production stage, the energy to recycle is just 5% of the primary energy. Thus aluminium compared to other materials has a highest reduction in necessary energy for recycling. Glass having a moderate primary energy is recyclable with high recycling rates. However, whether it is produced from the nature or recycled from old scarp there is minimal reduction in necessary energy to recycle. However, glass due to its unique property of transparency, has no alternative material for the current condition.

Table 2 Primary and secondary energies of some materials used in buildings. [4-12]

Material	Primary energy (MJ/kg)	Secondary energy (MJ/kg)	% Reduction by recycling
Steel	27	9	67%
Cement	4	-	-
Concrete	1.4	1.4	0
Glass	8	7,9	2%
Aluminium	93	5	95%

Steel and aluminium products are most commonly used metals in building industry. Usually the metals used in building industry are relatively have strength compared to concrete and other building materials they can bear higher loads with less material. The higher stiffness values of metals also satisfy to span greater distances allowing more freedom in design. Metal building products are usually seismic proof, UV resistant, weatherproof, ensuring a long service life without degradation.

Metals and glass can be recycled without any loss of quality since metallic and atomic bonds are restored upon solidification. In general metals and glass continuously recover their original performance properties even after multiple recycling loops. This allows them to be used for the same or different applications multiple times.

When a building reaches the end of life, considerable proportion of its metallic products can be directly recycled. Already, today, more than 95% of metallic products used in buildings are collected at the end of life. High economic value of metallic products is the main driver for the systematic collection and recycling. Figure 4 shows the average cost of aluminium from primary and recycled sources.

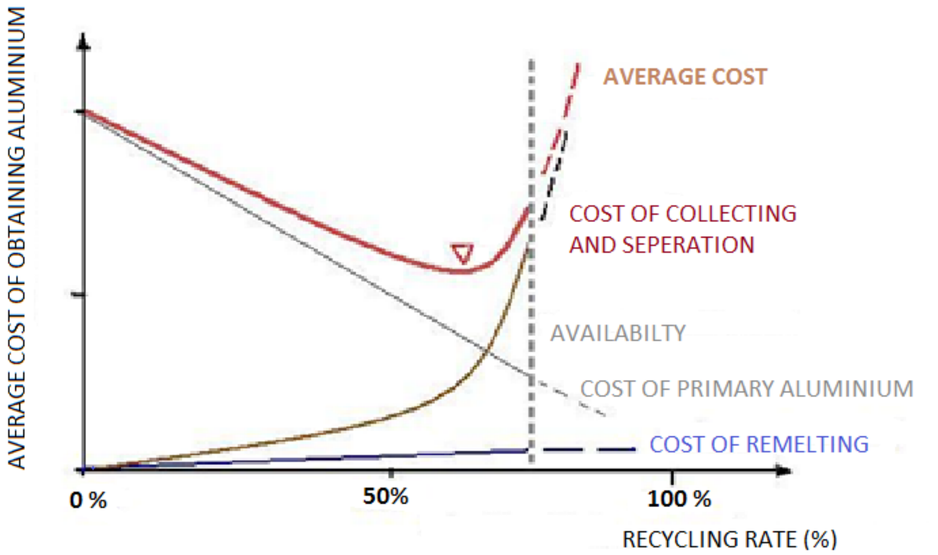

Figure 4 The average cost of obtaining aluminium from primary and recycled aluminium with respect to the recycled content percentage [13]

The upper limit of what is recycled today is governed by what was produced in the past. The rapid growth in the use of aluminium over many years and the fact that aluminium building products typically have a service life more than 50 years means that there is an actual shortage of scrap coming from buildings. As there is insufficient recycled material to satisfy the growing demand, primary aluminium has to be introduced into the supply chain. So, in spite of an efficient collection and recycling of aluminium products at the end of their life especially in the building sector, the average recycling rate in aluminium supply is still relatively low.

Hence, recycled content is not a relevant indicator to predict, today, which product will be most recyclable in the future. Instead, any environmental assessment of a product using recycled content as an indicator at its production stage must be complemented by information related to the end-of-life recycling phase. Table 3 shows end of life recycling recovery rate and, current and possible future recycling rate of common building materials.

Table 3 End of life, current and future recycling rates for some materials [4-12]

Material	End of Life Recovery Rate(%)	Current recycling rate (%)	Recycling rate by 2050 (-%)
Steel	70-90	37	69
Aluminium	95-98	30	65
Cement	0	0	0
Glass	90-99	60	70

The claims, "100% recyclable" are odds with reality. As explained in many literature, Metals are infinitely recyclable in principle, but in practice, recycling is often inefficient or essentially nonexistent because of limits imposed by social behaviour, product design, recycling technologies, and the thermodynamics of separation. Beyond the difficulty in recovering all metals for recycling, there are also problems related to separation of various metals used in alloys and coatings. Aluminium has the highest recycling efficiency between most of the commercial metals.

Figure 5 shows the global share of primary and recycled aluminium production with respect to years. Since aluminium is a very young metal compared to other metals such as steel, the recycled content is still very small. However, by the time it is believed that the recycled content will rapidly increase due to high efficiency of aluminium recyclability.

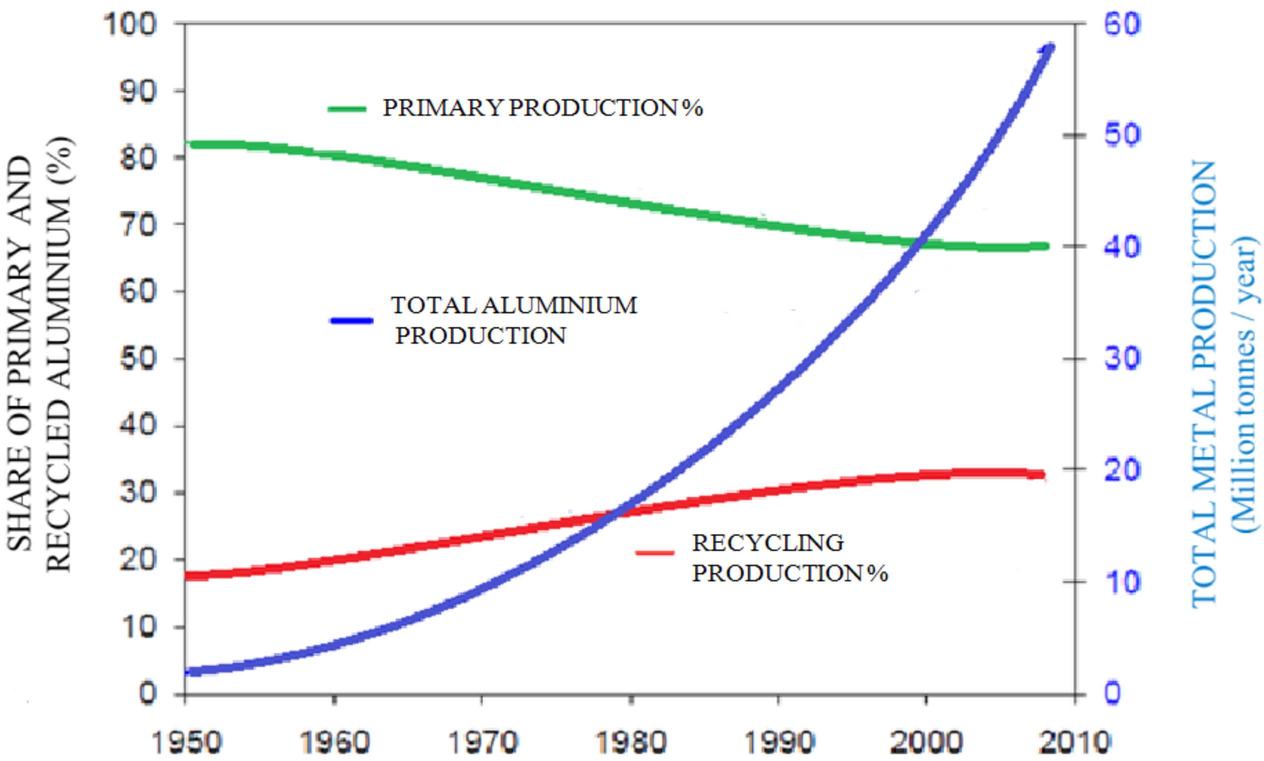

Figure 5 Global share of primary and recycled aluminium production [14]

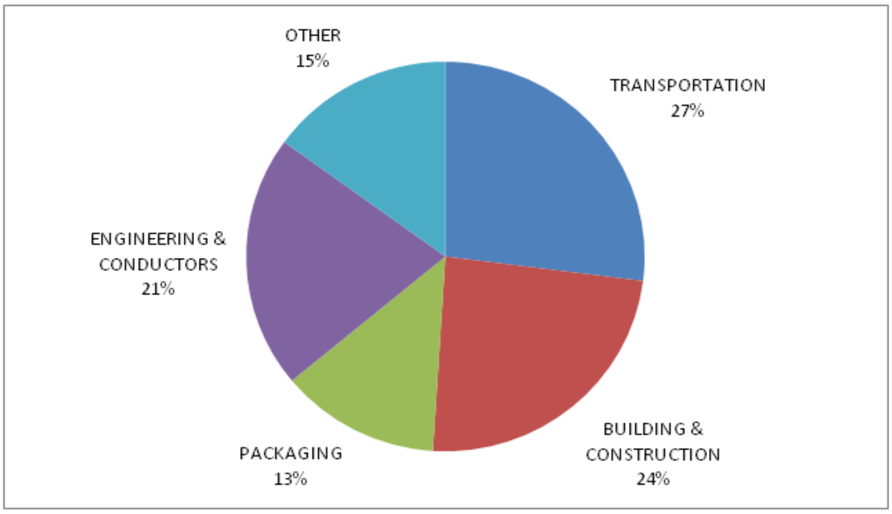

Figure 6 Global use of finished aluminium products [14]

The energy to recycle aluminium is approximately 5% of primary production while this is 20% for steel and 98% for glass. Hence the main driving force for recycling aluminium, lies behind the low energy requirement for aluminium recycling. On the other hand, aluminium recycling efficiency (end of life recovery rate) is highest between those building materials. For recycling of glass, the energy use and carbon emission are almost equal for every recycling loops. However, for steel and aluminium the number of recycling loops reduces the average energy consumed for that recycled metal. For example; the energy required for the primary aluminium production is about 93 MJ/tonne. If the same aluminium recycled and used second time, then the average energy consumed for production is almost reduced twice to the levels of 50 MJ/tonne. As the number of recycling loops increases the average energy required per tonne of aluminium is reduced significantly.

Currently about 30% of the global aluminium production is recycled from end of life scrap. The rate of increase of recycled percentage increase by time as shown in Figure 5. Compared to steel, aluminium is new material and has a commercial history of less than 100 years. Aluminium has a higher potential to increase the recycling rate in future.

The use of aluminium is not only in building industry but also in transportation, packaging and industries as shown in Figure 6. The life cycle period of aluminium products is short as 2-6 months in packaging industry while in building industry the life cycle period is along as 30-50 years. Currently, for the aluminium used in packaging industry the recycling loops can go up to 150 times until the first primary production, while the aluminium used in building industry is almost in the first or second recycling loop.

Timothy et al. studied the high potential materials in use to compare the primary energy with respect to production amount a shown in Figure 7 [15]. Plastic materials are not considered in this study since the recycling is not efficient for plastics due to fast degradation of properties even after in first recycling loops. Magnesium, titanium are not high potential materials in building industry due to availability in earth and high cost. Stainless steel seems to have limited applications and use in building industry due to economic reasons although having superior properties.

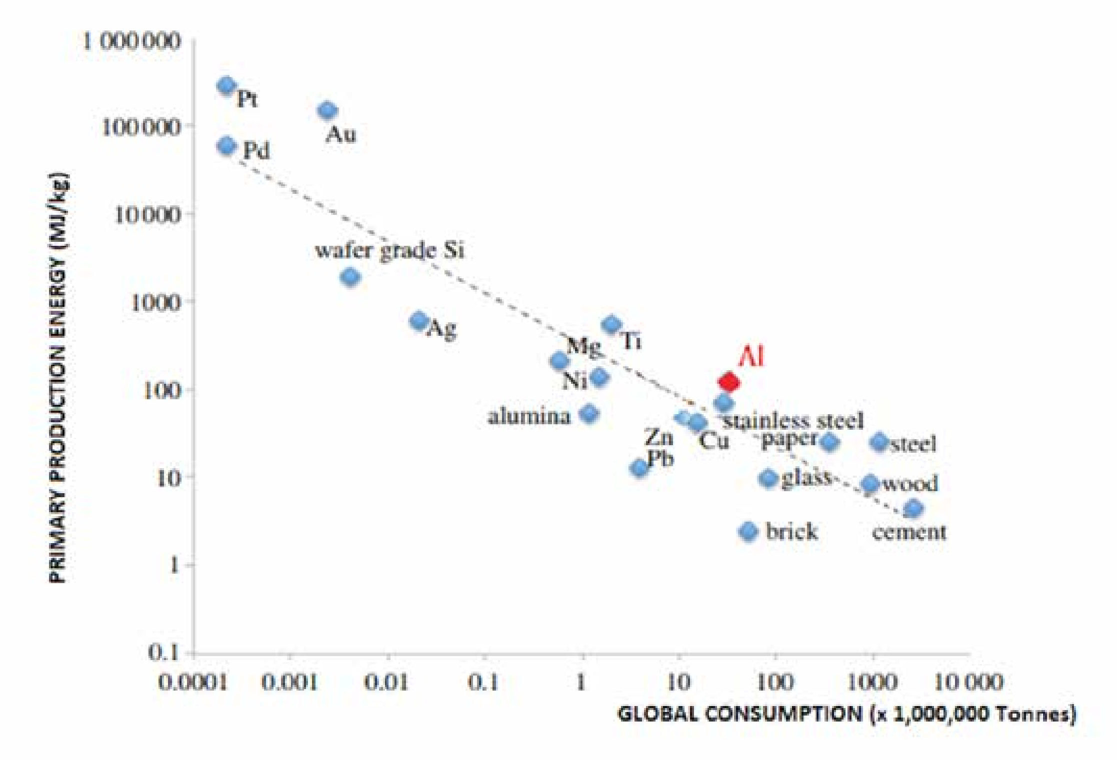

Figure 7 Primary energies of some materials with respect to global consumption amounts [15]

CANDITE MATERIALS FOR FUTURE

One of the candidates for future materials as alternative to conventional materials are the composite materials. The composites are mainly two component materials combining the superior properties of two components. They are usually constituted metals, plastics with ceramics. Most of the time the structure is formed by particulates, whiskers or fibrous reinforcement materials in a matrix material. The structure can be from macro scale to nano-scale. Composite panels can be a good example for a macro structured composite, while glass reinforced polyester is an example of micro scale composite, and nano-tube reinforced composites are good example for nano-scale composites. Although the composite materials are seeming to be the alternative to the most of conventional materials, the biggest drawbacks of composite materials is that they are almost non-recyclable. As structure of composite materials get smaller, the recycling possibility and efficiency decreases. It is going to be vital in future design for the materials and component designs for buildings to take into account the demolition, dismantling and separation stages as much as aesthetics, functionality and economics.

CONCLUSIONS

It seems that the material recycling properties beside their physical properties, is going to be crucial in deciding to use or not use in buildings. Aluminium is one of the fundamental materials in building industry. Since it is a young metal compared to other materials the recycling rate is still very low, but rapidly growing by time. In future aluminium is going to reach very high recycling rate due to its high recycling efficiency. The unique properties of aluminium having high corrosion resistance, abundance, lightweight, high strength and convenient to almost all known production technologies promote to use in many applications and increase the usage.

REFERENCES

[1] A. Kiersz, The world could have another billion people in thirteen years, Jul.29,2015, Business Insider.

[2] Rita McGrath, The Pace of Technology Adoption is Speeding up, Harvard Business Review, Nov. 25, 2013.

[3] J. Allwood, Sustainable Materials: With Both Eyes Open, CPSL's annual report of Cambride Un., 2012.

[4] T. G. Gutowski, J. M. Allwood, C. Herrmann, S. Sahni, A Global Assessment of Manufacturing, Annual Reviews MIT,2013.

[5] "Concrete CO2 Fact Sheet", National Ready Mixed Concrete Association, February 2012.

[6] Resource efficiency in the building sector", Final Report, Copenhagen Resource Inst. Rotterdam, 23 May 2014.

[7] D. J. Harris, A quantitative approach to the assessment of the environmental impact of building materials, Building and Environment 34 (1999) 75 I-758,

[8] G. P. Hammond and C. I. Jones, Embodied energy and carbon in construction materials, Proceedings of the Institution of Civil Engineers Energy 161, May 2008 Issue EN2, Pages 87–98.

[9] I. Z. Bribián, A.V. Capilla, A. A. Usón, Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential, Building and Environment, 46 , 1133, 140, 2011.

[10] R.M. Pulselli, E. Simoncini, F.M. Pulselli, S. Bastianoni, Emergy analysis of building manufacturing, maintenance and use, Energy and Buildings 39 (2007) 620–628.

[11] Recycling of end-of-life building glass,Glass for Europe, www.glassforeurope.com

[12] Sustainability of aluminium in buildings, Eurpoen Alumnium Association, www.eurpoean-aluminium.eu

[13] M.Yilmaz, 2023 Projections of Turkish Aluminium Sector, – ALUS 06, 6th Aluminium Semposium, Istanbul -2013.

[14] Global Aluminium Recycling: A Cornerstone of Sustainable Development**,** The Global Aluminium Recycling Committee Report, International Aluminium Institute, 2009.

[15] W. Timothy, G. Gutowski, Sahil Sahni, Julian M. Allwood, Michael F. Ashby and Ernst, The energy required to produce materials, ***Phil. Trans. R. Soc. A*** 2013 371, 20120003,

Paper No: 212
Air Tightness Measurements of Container Houses

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ABSTRACT

Container houses have increasingly been used for emergency purposes after major disasters or civil crises to relocate huge populations. The ease of placement at off-site locations and easy transportation capabilities make containers a preferable medium for humanitarian purposes. In spite of these advantages, container houses are criticized in terms of limited user fit and low energy efficiency.
This paper explores the air permeability of container houses. Airtightness is a key concept which has a very important impact on energy loss. Four different container samples were selected and field experiments of airtightness were carried out using the Blower Door Testing methodology. The results demonstrate the most successful and unsuccessful container types and compare them with the permanent residential examples from the literature. The problematic details of container units, in terms of detected air leakages, were also listed. The results of this paper would be crucial for the future improvement measures of prefabricated container like emergency buildings.

Keywords: airtightness, air permeability, blower door test, container houses

1. INTRODUCTION

Energy efficiency has become an important topic within the last couple of decades due to the rising cost of energy, negative impacts of global warming, and limited availability of resources. Since buildings consume more energy compared to other sectors (***i.e.,*** transportation and manufacturing) many developed countries have published standards or guidelines to regulate the construction industry. For instance, Energy Performance of Buildings Directive (EPBD), published by the European Union in 2010 [1], requires all new buildings to meet the low energy standards by December 2020.
Container houses are becoming a major typology for humanitarian efforts as a result of the increase in emergency situations. Following major natural disasters and civil crises (***i.e.***, infighting, wars), huge populations have to be relocated and new living quarters have to be established rapidly. In spite of its advantages, such as prefabrication, modularity, and the ability of fast construction; containers are criticized due to the misfit to users' life preferences and low energy efficiency. Moreover, inadequacies in the detailing of sheet panels may potentially create airtightness problems, which in turn may cause an increase in energy consumption.
This paper aims to identify the airtightness values of typical container houses in Turkey via field tests. Four main types of containers were selected and their air leakage vulnerabilities were demonstrated with thermal imaging as well.
In literature there are many examples that demonstrate the air tightness values of residential buildings. On the other hand, the air permeability in container houses have not been studied before. Therefore, the experiments on container houses will be one of its kind and will provide the foundations of the topic in this field.

2. LITERATURE REVIEW

2.1. STUDIES REGARDING AIR TIGHTNESS

Airtightness is an important parameter of building envelopes in order to attain the required energy efficiency levels. It can be defined as the inward or outward air leakage resistance through unintentional leakage points or areas within the building envelope, driven by differential pressures due to the combined stack effects, external wind, and mechanical ventilation [2]. Airtightness reduces or eliminates uncontrolled airflow through the building envelope. Air leakage can lead to problems related with health, high energy consumption, performance of the ventilation systems, thermal comfort, noise, and fire resistance [3].

There has been many studies regarding the airtightness values of residential buildings. For example Kalamess [3] did a field measurement study of the airtightness and the air leakages of 32 detached houses in Estonia during 2003-2005. Using the standardized Blower Door pressurization technique, the air leakage rate at 50Pa was found as 4,2$m^3/h.m^2$. The mean air change rate was 4.91 h^{-1}. The author also studied the typical air leakage locations in the studied houses.

In 2005, Sfakianaki ***et al.*** [4] performed the airtightness and infiltration measurements of 20 houses in the area of Attica, Greece. The authors used two measurement methods; ***the tracer gas decay method,*** and ***the Blower Door tests method***. The average number of air changes per hour (ACH) was found approximately as 0.6 ACH, when tracer gas method was used, while the average number of ACH at a 50Pa pressure was 7 ACH, when the Blower Door tests method was used.

Jokisalo ***et al.*** [5] focused on the relationship between the airtightness of a building envelope, infiltration, and energy use of typical modern Finnish detached houses. They have reported an average leakage rate of 3.7 ACH from a study of 170 detached houses in Finland. One of the important conclusions of the study is that infiltration causes about 15-30% of the energy use of space heating including ventilation in the typical Finnish detached house. The authors state that there is a clear relationship between the average infiltration rate and heating energy use.

Pan [6] explored the relationships between airtightness and its influencing factors and reported on the air permeability test results of 287 post-2006 new-built dwellings in the UK. According to the results, the airtightness of the dwellings averaged 5.97 $m^3/h.m^2$ at 50 Pa. Interestingly, the author found out that dwellings built using precast concrete panels were significantly more airtight than those built using timber frame, whilst those with masonry and reinforced concrete frame dwellings were the most leaky.

Sinnott & Dyer [7] reported on the air permeability test results of 28 Irish houses built between 1944 and 2008 and at varying stages of retrofit. According to the results, the mean air permeability of the pre-1975, 1980s, and 2008 dwellings were 7.5 $m^3/h.m^2$, 9.4 $m^3/h.m^2$ and 10.4 $m^3/h.m^2$ respectively.

d'Ambrosio Alfano ***et al.*** [8] presented the results of an air tightness experiment carried out on 20 residential buildings located in the Southern Italy using the blower door test. The average value of air change rate was found to be 7.3 h^{-1} at 50 Pa.

Chen ***et al.*** [9] measured the air tightness performance of two buildings in the cold zone of China using Blower Door method. The average air change rate was found to be 0.24 h^{-1} for the building in Hui'an and of 0.98 h^{-1} for the building in Ruiguang. The building in Hui'an, had better air tightness performance than the studied buildings in Lithuania, UK, and Russia, and even the new apartments in USA. The simulation result shows that the total energy use of district space heating was reduced by 12.6% when ACH is reduced from 0.98 h^{-1} to 0.5 h^{-1}.

A recent study carried out by Gillott ***et al.*** [10] indicated that the reduction of air permeability from 15.57 to 4.74 m^3/hm^2 at 50 Pa could bring a 9% improvement on energy consumption as a result of the combination improvements on air tightness.

These experiments show that there is a wide range of results from different countries when residential buildings are put into airtightness tests. This is normal since the building construction techniques, the level of expertise, local codes and regulations, and the quality of workmanship varies from country to country. Such a change can be seen even within countries themselves, ranging between different regions, or depending on buildings whether being upscale or low cost ones. Therefore, these numbers from different research studies should be taken as a guide, but not as an absolute value for airtightness.

2.1. CONTAINERS AS PREFABRICATED BUILDINGS

Shipping containers are based on international standards and there is a huge industry supporting the design, manufacturing, and distribution of these commodities. A shipping container has to ensure the safe-keeping of the contents via strong structural support while complying with standard dimensions and tare limitations to ensure compatibility with international trade constraints.
A new generation of temporary emergency shelter buildings were designed and constructed with an inspiration from shipping containers, borrowing their standard size, structural integrity, and stack-ability features. Shipping containers are designed to be compatible with every transport system, making them particularly suitable for easy delivery to disaster zones [11]. This makes shipping container houses a very convenient solution for disaster-struck geographies.
The Turkish Disaster and Emergency Management Authority (AFAD) readily uses these type of emergency shelter buildings (Figure 1) at disaster zones. There are many practical reasons for choosing these type of buildings, which can be listed as their rapid deployment capabilities, relatively low cost and low maintenance requirements, and better thermal qualities in comparison with tents and other temporary solutions.

Figure 1 Temporary Refuge Centers - General View (Source: AFAD, 2015)

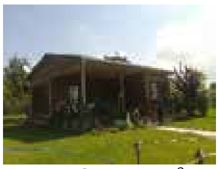
3. MATERIAL AND METHOD

3.1. MATERIAL

Container houses are a typical structure that are widely used in construction sites and disaster relief camps. This study focuses on typical single and double unit types of container houses in order to determine their airtightness. A single unit is a single story building consisting of one separate unit, while double units are examples of two or more units attached into one. The single and double unit containers are used for living and office purposes. These units are transported onto the site separately, assembled with cranes.

Type A: 37m^2 office double unit container

Type B: 21m^2 single unit container - office

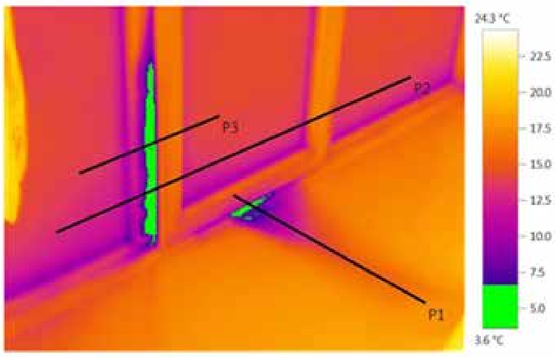


Type C: 28.5m^2 double unit container - living

Type D: 21m^2 single unit container - living

Figure 2 Selected container houses

The case study buildings are located in a semi-arid continental climate zone, with hot-dry summers and cold winters. The measuring tool for this study, Minneapolis Blower Door, is a modular testing system, which conducts tests in accordance with the following standards such as ISO 9972, EN 13829, ASTM E779-10, CGSB-149.10-M86. The common point of those standards is focusing on one goal to measure conditioned spaces.
The Infrared Thermography Camera was used to detect and document air leakages during blower door test, which increases the air flow. Actual air movement cannot be observed but the effect it has on a surface can. The air leakage, thermal bridges, and condensation can be seen in the following sample image (Figure 3).



Picture parameters:

Emissivity:	0.95
Refl. temp. [°C]:	21.0

Figure 3 Sample Infrared Thermography Image

Measurements were taken with Testo 875-1i Infrared Thermal Camera in 17.12.2014. Ambient environmental conditions have been recorded and documented through the test. +21°C indoor temperature and -1°C outdoor temperatures were measured during the tests.

3.2. METHODOLOGY

To perform the study, building surveys, on-site building measurements, and computer analyses were conducted. Firstly, the existing container houses' geometry and real conditions were evaluated. In the second step, the Blower Door measurements were carried out recording all leakages and anomalies within the building envelope. The measured on-site air change rate @50Pa values were used as input in the whole building energy simulation software to achieve the most realistic results. Airtightness data inputs were obtained as a result of the Blower Door tests. This process comprised of the fan pressurization method according to DIN EN 13829 Standard and simulation in the WUFI Plus software.

3.3. FIELD MEASUREMENTS: THE FAN PRESSURIZATION METHOD

The fan pressurization method was applied on each building. Airtightness measurements were carried out with the Minneapolis Blower Door Test supported by Infrared Thermography Camera screening to document leakages and thermal bridges in accordance with DIN EN ISO 13829 Standard and Passive House Blower Door Measurement Protocol. Weather conditions were recorded during and after the tests using digital thermometers and smartphone weather forecast application.

4. RESULTS

4.1. EVALUATION OF THE AIRTIGHTNESS OF THE CONTAINER UNITS

This study indicates that the airtightness of a building envelope could be obtained by using a thermography survey of surface temperature during Blower Door test. These thermographic images, which were taken in the sample buildings, showed thermal anomalies in the building envelope. All measurements have been conducted during good weather, avoiding high winds, rain and snow conditions or several days after precipitation.
The summary of the Blower Door measurement results of the selected container units are presented in Figure 4.

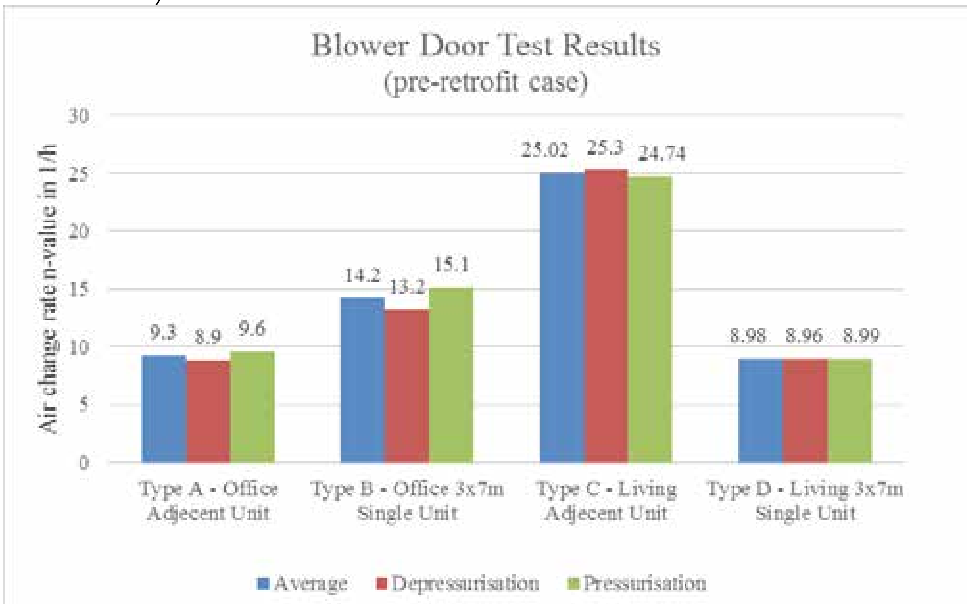
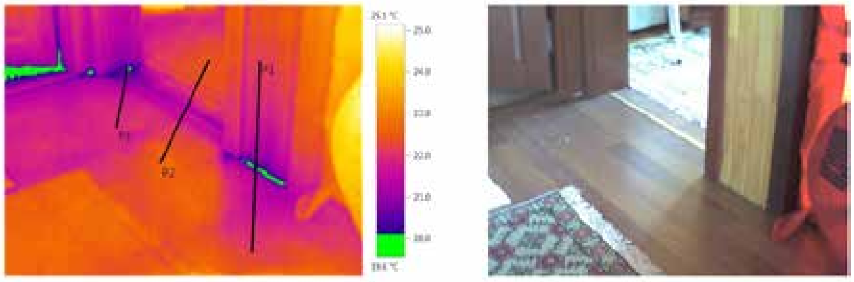


Figure 4 Blower Door Test Results of the Selected Container Units

According to the results, it has been found out that Type C, which is used for living purposes, has the most critical air tightness values. As a result of this, this case has been selected and inspected for further explorations. The problematic locations of the building envelope have been measured by thermographic cameras. These thermographic images taken in the sample buildings showed thermal anomalies in the building envelope. Most of the detected air leakages occurred in different parts of the building such as i) opening connections to the wall element, ii) penetrations of cables and pipes, iii) wall and floor conjunctions, iv) wall and ceiling junctions, v) sandwich panel junctions. Examples of these problems are presented in the following figures (see Figure 5, Figure 6, Figure 7).



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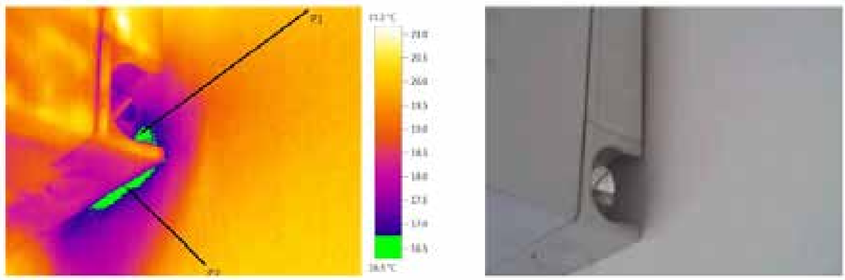
Emissivity: 0.94
Refl. temp. [°C]: 24.0

Figure 5 Thermal anomalies in the building envelope - opening elements (door)



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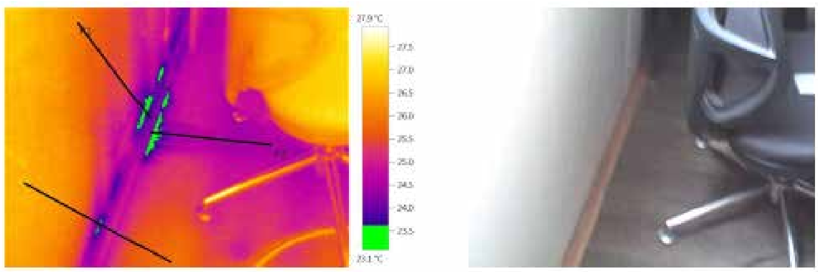
Emissivity: 0.95
Refl. temp. [°C]: 21.0

Figure 6 Thermal anomalies in the building envelope - penetrations of cables and pipes



Picture parameters:

Emissivity: 0.95
Refl. temp. [°C]: 28.0

Figure 7 Thermal anomalies in the building envelope - wall and floor conjunctions

5. CONCLUSIONS

5.1. Summary of the Research

Container houses are increasingly used as post-disaster houses. The requirement to locate many disaster victims just after disasters makes governments invest in container houses. Turkey is one of the countries that have huge number of refugees and disaster victims. Therefore, container houses have been highly used in refugee and disaster relief camps. Container houses provide many advantages such as easy transportation, fast construction, relatively low cost and low maintenance requirements. In spite of their advantages, these buildings are criticized for their energy efficiency problems and low sustainability.

Air tightness is one of the parameters of building envelope that affect the energy efficiency of buildings. Theoretically, air tight buildings consume less energy compared to their counterparts.

In literature there are many research projects that explored the air tightness levels of residential buildings in different countries. These experiments illustrate a wide range of results from different countries when residential buildings are put into airtightness tests. However, how containers houses used for emergency shelters or office purposes behave have not been investigated before. This study, therefore, examines the airtightness levels of container buildings in order to compare the findings with the ones presented in literature. Four existing container house were measured on site using the Blower Door test methodology.

5.2. Main Findings

According to the results, there is a great variation between four buildings in terms of their airtightness performance. The best performing container like building was nearly three times better than the worst performer in terms of airtightness (Figure 4). This is an expected result since these buildings are poorly constructed and have a great variation in terms of their manufacturing tolerances. During the transportation and the placement of these buildings the structures are subjected to strong stresses, which may introduce tears and holes in the skin. There is a need for improvement of these structures' design considering these issues.

When compared with the results published in the existing literature on airtightness of residential buildings, it can be seen that the best performing container houses are worse than the poor performing residential buildings (Figure 8). This result is also expected since most residential buildings are reinforced concrete or masonry structures with better airtightness properties.

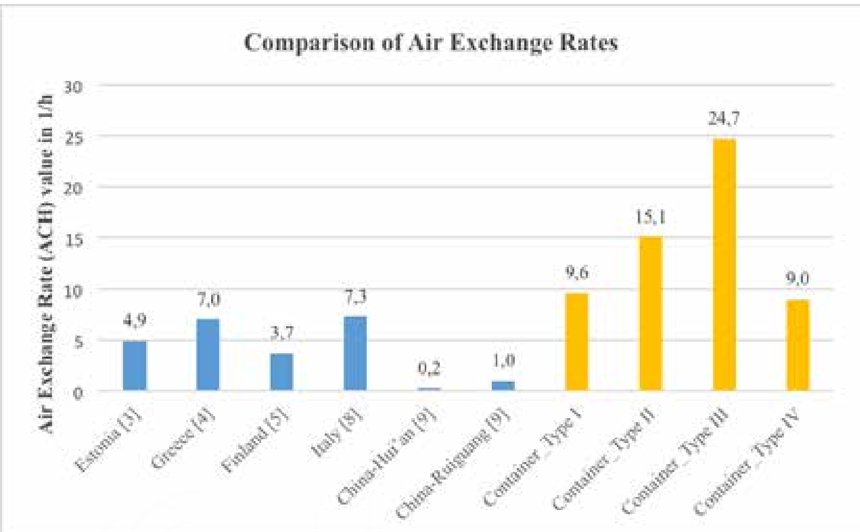


Figure 8 Comparison of Air Exchange Rates

5.3. Recommendations for Improving Air Tightness

The above results indicate that the air tightness of container houses needs to be improved. Designing better details for the critical connection points against air penetrations is very important to avoid this problem. The critical points are found to be as follows: i) opening connections to the wall elements, ii) penetrations of cables and pipes, iii) wall and floor conjunctions, iv) wall and ceiling junctions, v) sandwich panel junctions.

The current leaky windows / door systems, various connection points such as walls, ceilings and floor elements, did not allow the designers to reach the targeted values of air tightness levels. In this case, one possible solution is to replace windows with better airtight ones. Also special details must be designed for these problematic junctions.

Another recommendation would be the elimination of thermal bridges. The blower door tests for the post-retrofit case have been performed during the fall season where the temperature difference (ΔT) between inside and outside is more than 3°C. This revealed already existing thermal bridge and condensation problems. Based on field experience, the building envelope measurement was important to include IR Thermography, which significantly reduced time to detect air leakages and thermal anomalies like thermal bridges and condensation. The elimination of thermal bridges with thermal breaks and higher insulation (better U-values) would be necessary to adapt into the prefabricated building manufacturing standards.

Currently there are no obligatory 3rd party certifications that controls building airtightness in Turkey. The poor quality of workmanship is a central issue of the building sector. In order to achieve a good airtightness level, high quality workmanship, staff training related to airtightness strategies and their further implementations are crucial for the industry to prevent future application failures. In this respect, it is necessary to train manufacturers and develop airtightness methods applicable within the container houses with guidelines and brochures.

In the next step of the research, the effects of air leakages on the energy consumption of buildings will be evaluated by using simulation programs. Following this the most critical parts of the container envelopes in terms of air leakage will be sealed and the results of renewed airtightness tests will be conducted to see the impact of these changes. Finally, a set of advisory comments will be published to aid the improvement of airtightness in container like emergency shelter buildings.

6. REFERENCES

[1] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings

[2] Guyot, G., Carrié, F. R., Schild, P. ***Project ASIEPI – Stimulation of good building and ductwork airtightness through EPBD***, 2010.

[3] T. Kalamees. ***Air tightness and air leakages of new lightweight single-family detached houses in Estonia***. Building and Environment. 42, 2007, pp.2369-2377.

[4] Sfakianaki, A., Pavlou, K., Santamouris, M., Livada, I., Assimakopoulos, M.-N., Mantas, P., Christakopoulos, A. ***Air tightness measurements of residential houses in Athens, Greece***. Building and Environment. 43, 2008, pp.398-405.

[5] Jokisalo, J., Kurnitski, J., Korpi, M., Kalamees, T., Vinha, J. ***Building leakage, infiltration, and energy performance analyses for Finnish detached houses***. Building and Environment. 44, 2009, pp.377-387.

[6] Pan, W. ***Relationships between air-tightness and its influencing factors of post-2006 new-build dwellings in the UK***. Building and Environment. 45, 2010, pp.2387-2399.

[7] Sinnott, D. & Dyer, M. ***Air-tightness field data for dwellings in Ireland.*** Building and Environment. 51, 2012, pp.269-275.

[8] d'Ambrosio Alfano, F.R., Dell'Isola, M., Ficco, G., Tassini, F. ***Experimental analysis of air tightness in Mediterranean buildings using the fan pressurization method***. Building and Environment. 53, 2012, pp.16-25.

[9] Chen, S., Levine, M.D., Haiying Li, H., Yowargana, P., Xie, L. ***Measured air tightness performance of residential buildings in North China and its influence on district space heating energy use***. Energy and Buildings. 51, 2012, pp.157-164.

[10] Gillott, M.C., Loveday, D.L., White, J., Wood, C.J., Chmutina, K., Vadodaria, K. ***Improving the airtightness in an existing UK dwelling: The challenges, the measures and their effectiveness***. Building and Environment. 95, 2016, pp.227-239.

[11] Kotnik, Jure. ***Container Architecture***. Barcelona, Spain: Links Books, 2008.

Building - Lighting

Paper No: 34

Daylight performance metrics in energy efficient building design: A comparative study

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ABSTRACT

"Daylighting" can be interpreted as an important design parameter in energy efficient building design and by the use of appropriately designed daylighting systems, spaces can benefit from daylight at a great percentage. In order to assess daylight potential in buildings, diverse performance metrics are developed and are being used. These metrics are integrated into several dynamic lighting simulation algorithms so architects or lighting designers can practically determine the daylight performance of designated built environments, compare design variants and perform necessary revisions during the building design phase. The objective of this study is to introduce diverse daylight performance calculation metrics used in the building design phase and investigate their impact on potential daylight performance results on the example of a selected commercial building space in Istanbul. The methodology of this study includes use of dynamic daylight metrics; comparisons between daylight illuminance metrics and climate-based annual daylight performance metrics (Daylight Autonomy, Continuous Daylight Autonomy and Useful Daylight Illuminance) are performed on the evaluated case study. Results of this study are focused on available methods to further discuss daylight performance in energy efficient building design phase.

INTRODUCTION

Daylight is an efficient light source in the architecture that helps to increase the perception of the interior and connects inside to outside by appropriately designed apertures providing a perfect color rendering. Daylighting has also positive impacts on physiological and psychological comfort conditions as well as its impact on reducing lighting energy requirements. Nevertheless, control of daylight is also necessitated since it might cause undesired internal conditions such as glare, the sensation produced by a sufficiently greater luminance within the visual field causing annoyance, discomfort or loss in visual performance and visibility [1].

Efficient use of daylighting in buildings is only possible by means of daylight performance analysis in terms of visual comfort conditions starting from the building design stage. Thus, with the help of performed daylight performance analysis, it is possible to avoid problems that can be encountered in the future and optimization of building envelope be performed considering effective use of daylight.

Today, diverse daylighting metrics and simulaton tools have been developed and are being used to ensure desired amount of natural light in buildings. However, choice of appropriate performance metric for assessment of dynamic daylighting conditions is crucial in order to obtain the most realistic results in terms of daylight utilization and determine lighting energy efficiency in buildings [2]. The objective of this study is to introduce diverse daylight performance calculation metrics used in the building design phase and investigate their impact on potential daylight performance results on the example of a selected commercial building space in Istanbul.

DAYLIGHT ILLUMINANCE PERFORMANCE METRICS

In order to determine the performance of a building or a space in terms of daylight illuminance, several daylight performance metrics are available. These metrics are used in order to determine the daylight potential in buildings or in several spaces based on developed sky models for certain times, referring to the quantity of daylight on horizontal workplanes. With the use of dynamic daylight metrics during the building design stage, it is possible to utilize the use of daylight illuminance in spaces or building typologies where use of daylighting is of great important in terms of visual comfort conditions and lighting energy efficiency. In this part of the study, dynamic annual daylight metrics that can be used for daylight performance determination are presented.

Daylight Autonomy (DA) method is the oldest dynamic daylight metric (proposed by the Association Suisse des Electriciens in 1989 and improved by Christoph Reinhart between 2001-2004) developed to assess the daylight performance of a given space on an annual basis [3]. This metric is represented as a percentage of annual hours that a given point in a space is above the required illumination level with the use of daylighting only. This approach considers the use of geographic location specific weather information on an annual basis. This indicator is also used for daylight linked electric lighting design and estimation of lighting energy savings on an annual basis.

Contunious Daylight Autonomy (cDA) is developed by Rogers Z. in 2006 as a modification of Daylight Autonomy (Reinhart et al., 2006). This method uses the effect of dynamic conditions in spaces and attributes partial credit to time steps when daylight illuminance is less than required illuminance in the investigated space [4,1]. This indicator is also used for daylight linked electric lighting control system and correlate well to define the lighting energy saving potential of a building by the help of daylighting [1].

Useful Daylight Illuminance (UDI) metric is modified from Daylight Autonomy method by Mardaljevic and Nabil in 2005. According to this metric, the illuminance levels caused by daylight is classified into three ranges as follows:

- inadequate daylight illuminance (<100 lux),
- usefull daylight illuminance (100-2000 lux),
- daylight illuminance exceeding required levels (>2000 lux)

This metric provides full credit only to values between 100 lux and 2,000 lux suggesting that horizontal illumination values outside of this range are not useful and the upper threshold value-2000 lux is found to cause glare in this method [5].

APPLICATION OF DAYLIGHT ILLUMINANCE PERFORMANCE METRICS FOR A CASE STUDY

In this part of the study, the annual daylight performance metrics based on daylight illuminance are applied for a case study and comparison of the obtained results are performed. The evaluated space is an office module which is located in Istanbul (latitude 41° and longitude 28°.8') and the space geometry is rectangular in shape with dimensions of 5 m x 7 m and with a height of 3 m. The space is shared by four occupants and the occupation period is defined as 08:00-18:00 for weekdays, the space is not occupied during weekends.
The transparency ratio of the investigated office space is 30% and the visible transmittance value of the glazing is 80%. The orientation of the space is to the south direction. The light reflectances of room surfaces for ceiling, walls and ground are 80%, 60% and 40% respectively. This space is assumed to have no external obstructions and solar control devices. The floor plan and a 3D model of the investigated office module is given in Figure 1.

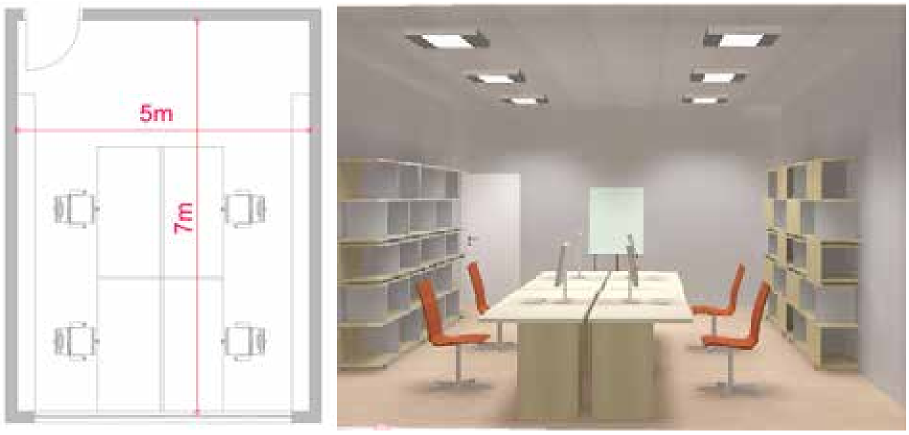


Figure 1. Plan and 3D model of the evaluated office module

In order to evaluate the daylight potential of the evaluated space on an annual basis, determination of representative calculation times is performed. In this regard, hourly daylight availability of the space is determined specifically for four representative dates (15th day of December, March, June and September) and three representative times (08:00, 12:00 and 16:00). Depending on the occupancy hours of the building (08:00-18:00) and total number of working days, representative total hours of each calculation date and time is evaluated on an annual basis. Table 1 gives information on representative calculation date and time, representative sky models and representative total hours obtained on an annual basis for the evaluated office space type. In this study, for daylight illuminance calculations times representing the winter conditions (15th December), CIE Overcast Sky Model is used while for conditions representing the summer period (15th of June) CIE Clear Sky model is selected. Daylight conditions for spring and autumn periods-represented by 15th day of March and September is calculated using Intermediate Sky Model. In Table 1, annual sky model assumptions are given.

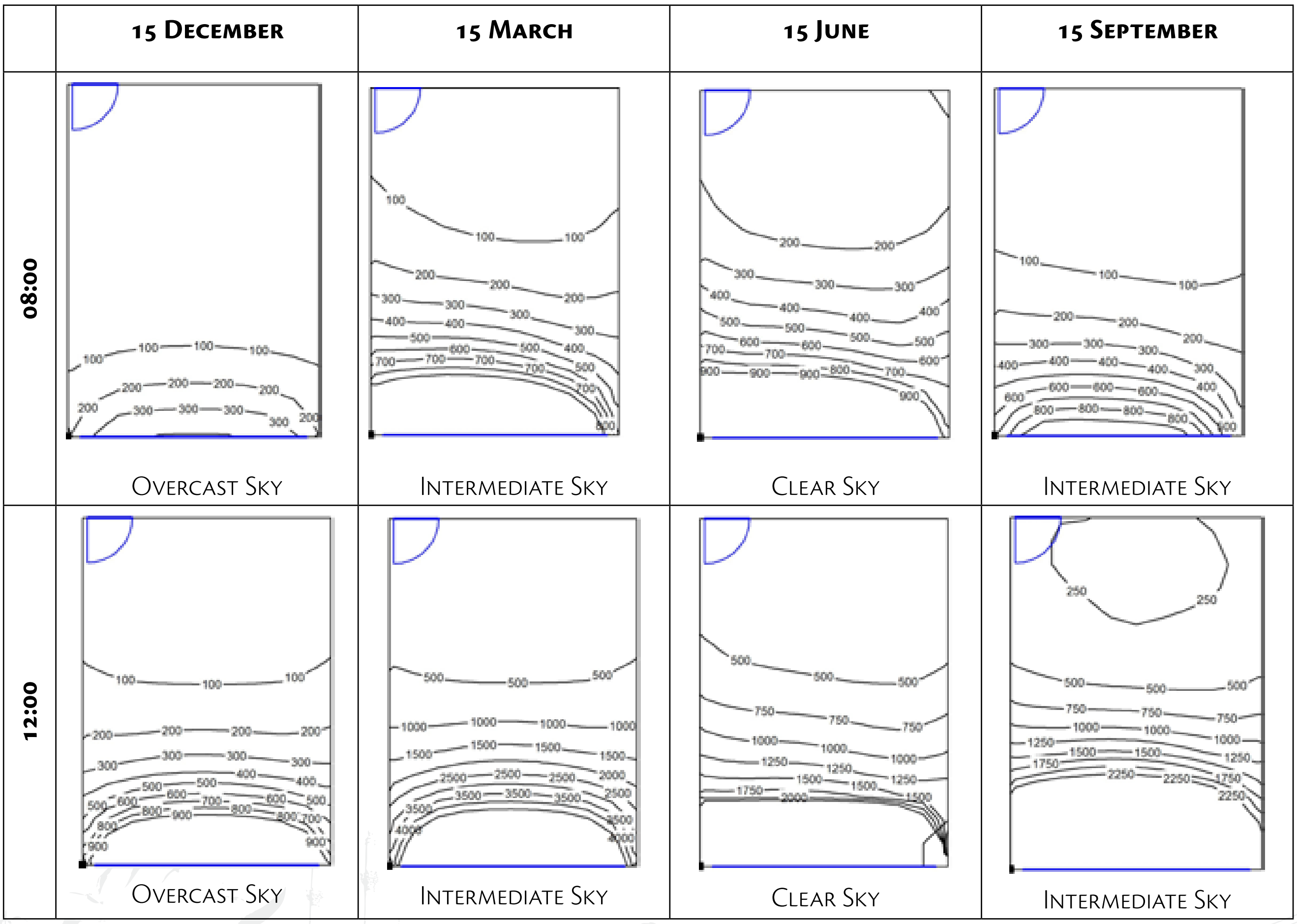
Table 1. Assumptions for daylight calculations in terms of representative calculation date and time, sky model and representative total hours obtained on an annual basis

Calculation date and time	**Representative sky model**	**Representative month**	**Number of representative working days**	**Representative total hours (h) on an annual basis**
15 December 08:00				198
15 December 12:00	Overcast Sky	November December January	66 days (22+22+22)	264
15 December 16:00				198
15 March 08:00				192
15 March 12:00	Intermediate Sky	February March April	64 days (20+22+22)	256
15 March 16:00				192
15 June 08:00				198
15 June 12:00	Clear Sky	May June July	66 days (22+22+22)	264
15 June 16:00				198
15 September 08:00				198
15 September 12:00	Intermediate Sky	August September October	66 days (22+22+22)	264
15 September 16:00				198
Total working hours				**2620**

Modeling the daylighting potential of the space on an annual basis, performance determination of the selected offices' daylighting design is assessed using diverse daylight metrics in this study. The modeling process is performed considering the natural design parameters and physical design parameters. The daylighting simulations are performed for representative dates and times by Dialux program in order to further evaluate the daylight performance calculations through diverse metrics. By means of calculating the daylight illuminance for particular dates and times, the daylight availability of the selected space is predicted. Table 2 gives the average illuminance (E_{av}) results obtained within the evaluated space for representative days and times by daylight only. When the maintained illuminance (Em) for office spaces is considered according to TS EN 12464-1 Standard (500 lx), it is clear that for some cases, supplementary electric lighting is required in order to provide required illuminance level for the space [6]. Figure 2 gives the distribution of daylight illuminance within the space obtained on the workplane with a height of 0,80 m.

Table 2. Average illuminance (Eav) results obtained within the evaluated space for representative days and times by daylighting

	15 December	15 March	15 June	15 September
08:00	81 lx (Overcast Sky)	397 lx (Intermediate Sky)	491 lx (Clear Sky)	228 lx (Intermediate Sky)
12:00	347 lx (Overcast Sky)	1826 lx (Intermediate Sky)	3262 lx (Clear Sky)	1765 lx (Intermediate Sky)
16:00	77 lx (Overcast Sky)	612 lx (Intermediate Sky)	1268 lx (Clear Sky)	1168 lx (Intermediate Sky)



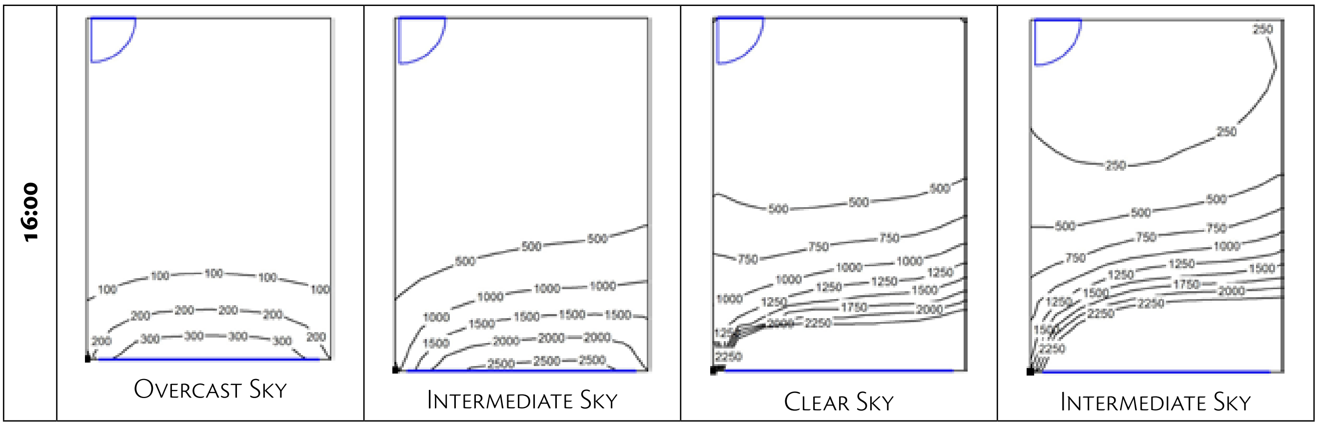


Figure 2. Daylight illuminance distribution results

Calculation of Daylight Performance: Daylight Autonomy (DA)

The daylight illuminance results evaluated on the working surface consisting of 140 (10 x 14) points with a height of 0,80 m are used in order to calculate the daylight performance of the space through Daylight Autonomy (DA) method. Since this metric represents the percentage of annual hours that a given point in a space is above the required illumination level with the use of daylighting only, the daylight illuminance values obtained for each calculation point is considered taking into account the occupancy hours of the space and the representative total hours on an annual basis. In this regard, the number of points on the calculation grid providing the maintained illuminance level-500 lx for office spaces is determined. In Figure 3 this process is illustrated for 15th of March conditions and calculation points providing the maintained illuminance level-500 lx by daylight only is highlighted with yellow where points having a lower illuminance than 500 lx are hatched in grey color.

15 March 08:00

77	65	65	63	60	60	61	62	65	79
85	70	65	62	57	57	57	59	63	78
93	74	65	64	57	57	59	62	64	81
105	86	78	75	68	67	71	72	71	91
116	91	85	77	70	68	75	75	75	96
136	112	97	96	82	78	80	81	88	111
168	140	126	123	114	107	103	105	104	132
274	249	245	238	231	214	194	185	175	203
363	345	339	355	323	315	281	252	236	237
463	458	465	467	454	422	378	349	293	293
633	656	668	693	652	637	571	499	429	364
851	908	935	950	934	914	845	765	586	451
1079	1256	1310	1329	1312	1283	1228	1148	893	558
1078	1738	1746	1753	1721	1717	1697	1646	1481	532

15 March 12:00

276	236	236	231	220	221	229	235	248	304
303	254	240	229	213	212	222	231	248	325
325	265	240	235	213	213	232	248	256	341
378	305	287	278	251	258	282	284	294	384
394	322	305	282	259	265	302	301	316	437
455	386	351	352	316	322	333	339	385	482
583	498	476	475	471	471	460	473	480	589
924	910	968	980	1025	998	964	928	890	951
1212	1289	1389	1503	1482	1507	1441	1333	1288	1246
1569	1743	2001	2057	2131	2081	2009	1911	1693	1617
2161	2705	3004	3181	3192	3213	3102	2876	2645	2130
2811	3855	4374	4507	4566	4573	4505	4306	3698	2720
3428	5487	6073	6188	6241	6217	6180	6020	5382	3427
3312	7526	7788	7831	7814	7826	7838	7749	7499	3228

15 March 16:00

109	95	98	97	92	93	97	100	108	136
118	99	95	92	87	88	94	98	109	142
122	101	95	94	87	89	98	107	114	151
137	114	111	109	102	107	122	124	130	178
140	117	116	110	105	111	132	133	143	203
161	135	127	127	121	134	147	152	186	222
189	164	159	162	171	185	192	204	225	282
275	264	288	299	340	350	375	372	407	471
326	344	391	446	471	513	538	525	575	615
400	432	556	589	670	686	729	717	739	813
504	633	785	890	965	1019	1051	1014	1075	1092
624	885	1175	1281	1376	1425	1489	1460	1439	1442
744	1342	1750	1856	1961	1980	2027	2003	1987	1859
738	2219	2497	2537	2588	2619	2651	2630	2667	1780

<500 lx   >500 lx

Figure 3. Illustration of calculation grid subdivision as daylit and non-daylit zones for 15th March conditions

The probability to perform maintained illuminance by daylighting (a) is calculated depending on the total number of points having daylight illuminance greater than 500 lx and this data is further used to evaluate the

Daylight Autonomy (DA) based on representative total hours on an annual basis (b). According to the calculation results, Daylight Autonomy (DA) of this space is evaluated as 34% on an annual basis and obtained DA results are presented in Table 3.

Table 3. Calculation of Daylight Autonomy (DA) for the evaluated space

Date and time	Number of points <500 lx	Number of points >500 lx	Probability to perform E_m (500 lx) based on DA(a)	Representative total hours on an annual basis (b)	axb	Daylight Autonomy (DA)
15 December 08:00	140	0	0,00	198	0,00	34%
15 December 12:00		107 33	0,24	264	62,23	
15 December 16:00	140	0	0,00	198	0,00	
15 March 08:00	104	36	0,26	192	49,37	
15 March 12:00	68	72	0,51	256	131,66	
15 March 16:00	87	53	0,38	192	72,69	
15 June 08:00	92	48	0,34	198	67,89	
15 June 12:00	63	77	0,55	264	145,20	
15 June 16:00	70	70	0,50	198	99,00	
15 September 08:00	117	23	0,16	198	32,53	
15 September 12:00	68	72	0,51	264	135,77	
15 September 16:00	71	69	0,49	198	97,59	

Calculation of Daylight Performance: Continuous Daylight Autonomy (cDA)

In order to evaluate the daylight performance based on Contunious Daylight Autonomy (cDA) method, partial credit is attributed when daylight illuminance is less than required illuminance in the investigated office space. The daylight illuminance results evaluated on the workplane are analyzed for each daylight calculation set and the probability to perform the maintained illuminance (E_m) by daylight only is calculated for 140 calculation points per each daylight simulation result. In this respect, the probability to perform the maintained illuminance (E_m) by daylight is calculated and credits per each calculation point is assigned as values between 0 and 1. In Figure 4, an illustration of determination of credits depending on the daylight illuminance on the calculation grid is given as an example for 15th March conditions.

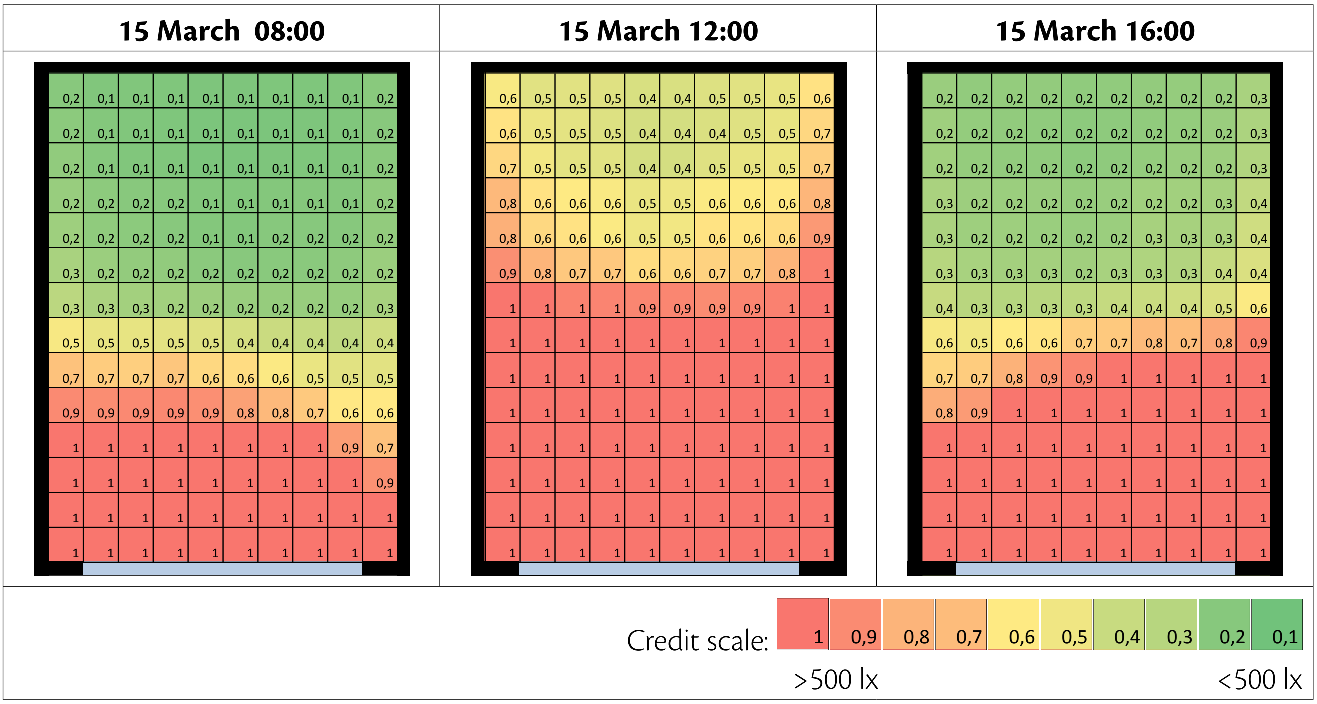


Figure 4. Determination of credits for points depending on the daylight illuminance 15th March conditions

Depending on the attributed credits, the probability to perform the maintained illuminance (E_m) by daylight is multiplied by the representative total hour of each calculation time and obtained result is divided by the total annual occupancy hour of the investigated space (2620 h). Consequently, the annual Continuous Daylight Autonomy result is obtained as a percentage for the investigated office space as 59% on an annual basis and obtained cDA results are given Table 4.

Table 4. Calculation of Continuous Daylight Autonomy (cDA) for the evaluated space

Date and time	**Probability to perform E_m (500 lx) (a) based on cDA**	**Representative total hours on an annual basis (b)**	**axb**	**Continuous Daylight Autonomy (cDA)**
15 December 08:00	0,16	198	32,01	59%
15 December 12:00	0,45	264	118,66	
15 December 16:00	0,15	198	30,63	
15 March 08:00	0,50	192	95,43	
15 March 12:00	0,82	256	209,15	
15 March 16:00	0,60	192	114,77	
15 June 08:00	0,63	198	125,15	
15 June 12:00	0,89	264	236,20	
15 June 16:00	0,81	198	160,91	
15 September 08:00	0,37	198	74,00	
15 September 12:00	0,80	264	211,66	
15 September 16:00	0,73	198	145,50	

Calculation of Daylight Performance: Useful Daylight Illumnance (UDI)

As part of this study, the Useful Daylight Illumnance (UDI) value for each daylight set is calculated by classifying the daylight illuminance levels calculated on the workplane into three ranges (<100 lux, 100-2000 lux and >2000 lux). Since this metric provides full credit only to values between 100 lux and 2,000 lux, number of points having these values are evaluated to determine the overall UDI value on an annual basis.
UDI occurrence probability is evaluated for each daylight set and this value is used to obtain the annual UDI occurrence, based on representative total hours on an annual basis (b) for each simulation date and time. Overall UDI occurrence is calculated as 42% for the evaluated office space and obtained results are given in Table 5.

Table 5. Calculation of Useful Daylight Illumnance (UDI) for the evaluated space

Date and time	<100lx	UDI Range 100-2000 lx (a)	>2000 lx	Representative total hours on an annual basis (b)	axb	UDI
15 December 08:00	0,73	**0,27**	0,00	198	53,74	42%
15 December 12:00	0,49	**0,28**	0,24	264	73,54	
15 December 16:00	0,74	**0,26**	0,00	198	50,91	
15 March 08:00	0,39	**0,35**	0,26	192	67,20	
15 March 12:00	0,00	**0,49**	0,51	256	124,34	
15 March 16:00	0,13	**0,49**	0,38	192	94,63	
15 June 08:00	0,00	**0,66**	0,34	198	130,11	
15 June 12:00	0,00	**0,45**	0,55	264	118,80	
15 June 16:00	0,00	**0,50**	0,50	198	99,00	
15 September 08:00	0,49	**0,34**	0,16	198	67,89	
15 September 12:00	0,00	**0,49**	0,51	264	128,23	
15 September 16:00	0,00	**0,51**	0,49	198	100,41	

Discussion of Results

When obtained daylight performance results are investigated, the highest daylight performance result is reached as 59% with the use of Continuous Daylight Autonomy (cDA). This simply comes out of the fact that this metric considers a partial credential system between 0 and 1, assigned for daylight illuminance on the workplane wheras Daylight Autonomy (DA) method only considers the space division into two groups as daylit (1 point) and non daylit (0 points). Thereby, the daylight performance result obtained by the use of Daylight Autonomy (DA) metric is slightly lower, constituting to a result of 34%.
Calculation of Useful Daylight Illumnance (UDI) considers the daylight illuminance between 100 lx and 2000 lx as useful, and this method excludes the illuminances greater than 2000 lx so with the use of this metric, 42% daylight performance is reached for the investigated space. In Figure 5, a comparison for three different daylight performance metrics are given in terms of daylight performance results obtained for each daylight calculation date and time.

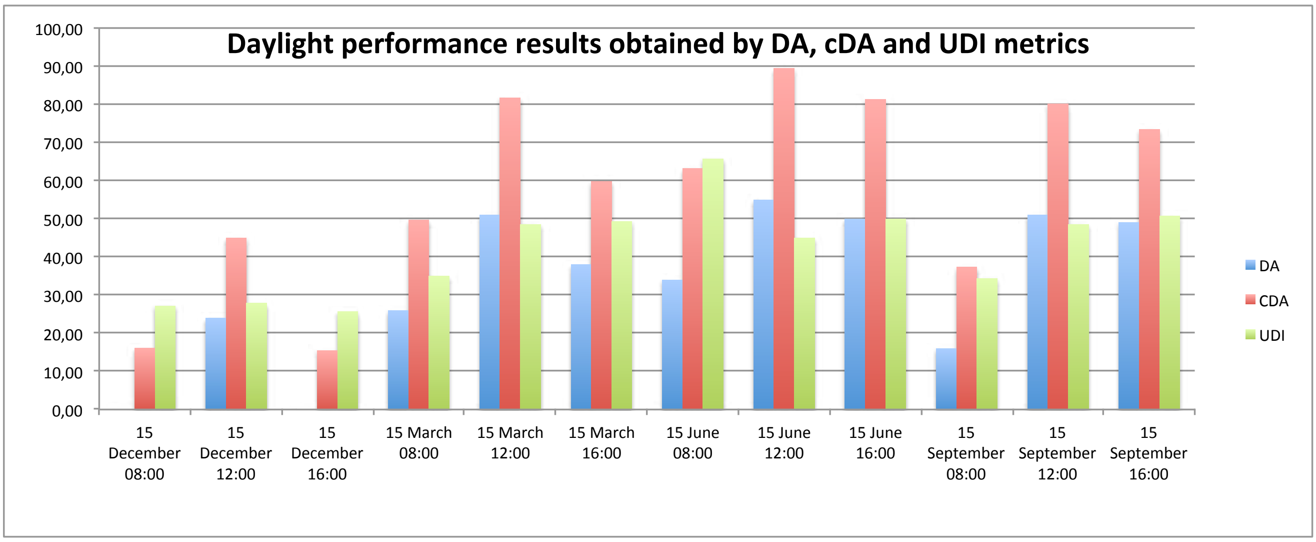


Figure 5. Daylight performance results obtained by DA, cDA and UDI metrics

CONCLUSION

This study aims to examine the effect of daylight performance metric selection in architecture on daylight performance results in buildings. It is well known that office buildings are of the building typologies where daylighting is used for obtaining required visual comfort conditions and providing lighting energy efficiency therefore this comparison is performed on the example of a selected office space.

In order to estimate the daylighting potential of the investigated space, three widely accepted dynamic daylight performance metrics had been used that are Daylight Autonomy (DA), Continuous Daylight Autonomy (cDA) and Useful Daylight Illumnance (UDI). Results of this study underline the significance of daylight metric selection during the architectural design stage since each metric can contribute to different results in terms of daylight performance.

The use of Daylight Autonomy (DA) and Continuous Daylight Autonomy (cDA) metrics are essential in cases where a daylight linked lighting control strategy is considered for the evaluated space so that the use potential of daylighting can be obtained practically and design of lighting control schemes can be performed based on obtained performance results. However, these two metrics have a main limitation of not considering the occurrence of daylight glare in their evaluation system for the daylight conditions. In building design phase, control of glare from daylight apertures is a necessity in order to perform the required visual comfort conditions. Therefore when these metrics are selected for daylight performance determination, further metrics such as Daylight Glare Index (DGI) or Daylight Glare Probability (DGP) are recommended to be used for the prediction of discomfort glare caused by daylighting, to express the discomfort through an index.

Today, there are various daylight simulation programs which can be used to evaluate and visualize the outcomes of different design alternatives in terms of daylighting and there is a growing awareness in incorporating natural light in the working environments during the architectural design stage. Daylight performance metrics are currently integrated into several dynamic daylight simulation programs so architects or lighting designers can practically determine the daylight performance of designated built environments, compare design variants and perform necessary revisions during the building design phase.

As a conclusion, buildings can be designed with a high performance of providing the visual comfort conditions while reducing the energy consumption by the use of daylighting and daylight performance metrics can be used starting from the architectural design stage of buildings. With the use of a correct daylighting strategy in buildings, it is possible to provide the maintained illuminance levels given in the international standards and perform necessary visual comfort conditions in buildings.

REFERENCES

[1]. IESNA. (2011). The IESNA Lighting Handbook: Reference & Application, 10th Edition. Illuminating Engineering Society of North America, New York.

[2]. IES. (2013). Recommended Practice for Daylighting Buildings, New York: Illuminating Engineering Society of North America, USA.

[3]. Reinhart, C. F., Mardaljevic, J., & Rogers, Z. (2006). Dynamic Daylight Performance Metrics for Sustainable Building Design, Leukos, 3(1), pp:7-31.

[4]. Cantin, F., Dubois, M.C. (2011). "Daylighting metrics based on illuminance, distribution, glare and directivity'. Lighting Research and Technology, 43, 291–307, 2011.

[5]. Nabil, A., & Mardaljevic, J. (2005). Useful Daylight Illuminance: A New Paradigm for Assessing Daylight in Buildings, Lighting Research and Technology, 37 (1), pp:41-57.

[6]. EN 12464-1. (2011). Light and Lighting: Lighting of Work Places - Indoor Work Places, Brussels: CEN.

Paper No: 107

The Influence of External Louver Design on Daylighting Performance and Lighting Energy Efficiency

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ABSTRACT

The design and control of a proper external louver system is inevitable for improving the daylighting performance in terms of window and room geometry. Daylight, which is a varying concern, during the daytime and directly affects user performance, is needed to be under control by proposing optimum louver design solutions. This simulation-based study aims to evaluate and suggest energy efficient lighting design for increasing visual comfort conditions of the workers in an office building. The purpose is to find the optimum type of shading device with appropriate slat angles, transmittance of glazing, and the luminaire type/layout. Numerous scenarios with different combinations of the stated conditions are tested for an existing office room facing southwest for winter/summer solstice and equinoxes. In retrofit studies, daylighting and artificial lighting criteria are handled together as an integrated approach.

Keywords: external louver design, energy efficiency, daylighting, artificial lighting, retrofitting, simulation.

1. INTRODUCTION

A solar shading device functions both as a protector of the building transparent envelope from solar radiation and as preventer of overheating by blocking undesired energy flow into the building. It has a crucial effect in order to reduce annual energy consumption (Bellia, Falco and Minichiello, 2013). There are two types of shading and light redirecting devices: static and movable. A lightshelf, a laser cut panel or an overhang are the examples of static device types while venetian blinds, curtains and roller blinds are the movable device types (Reinhart, Mardaljevic, & Rogers, 2013). One of the studies among the various researches conducted about shading device effects on energy consumption is carried by Tzempelikos and Athienitis (2001). They selected a building located in Montreal and evaluated exterior roller blade characteristics, shading control and glazing area on cooling and lighting loads where roller blade is considered as shading device. Bellia, Falco and Minichiello (2013) conducted another study for an office building in Italy in order to analyze the influence of shading devices on the energy requirement. They used a simulation tool for evaluating the energy demand of the lighting, heating and cooling systems and energy savings related to use of shading devices. Studies show that, shading device has an impact on daylight illuminance and uniformity inside the building and prohibits the excessive penetration of sunlight to prevent overheating. By changing their optical properties, shading devices might be act as light shelves that balance the light distribution on the horizontal plane. Thus, exterior louver design as shading devices determines the basis of this study. The aim is to propose the optimum slat angles and types of an exterior louver and to find the appropriate and energy efficient type and layout of luminaire to provide a successful uniformity and illuminance. Such an exterior louver design would result in minimum electricity consumption and LENI values.

2. PROPOSING AN EXTERNAL LOUVER SYSTEM

2.1. Geometric properties of the sample room

The sample room facing Southwest is in a building located in the campus of Izmir Institute of Technology (38°N latitude, 26°E longitude). This room has a balcony with a depth of 1.20m and fixed horizontal shading devices (Figure 1). Windows whose dimensions are 0.95x2.50m, are located on a single façade. Two significant parameters about the window design which are Window-to-Floor-Ratio (WFR) and window-to-wall ratio (WWR) are 24% and 59% respectively. The room dimension is 3.10x6.60m and the height is 3.10m. A total of 3 artificial lighting fixtures are located.


Figure 1 Views from the sample room

2.2. Illuminance measurements of the existing situation

Measurements were taken at 1 PM on December 4th, 2014 while the sky condition was partly-cloudy. A digital illuminance meter with an attached silicon photo diode receptor head having a measuring range of 0.01-299,900 lx was used for taking measurements of horizontal workplane daylight illuminance. User calibration function could be set the correction function (CCF) ranging from 0.500 to 2.000 with accuracy 2% ±1 digit of value displayed. A luminance meter having small diameter measurements (0.4mm) with SLR (single lens reflex) and measuring dark surfaces range starts at 0.001 cd/m^2. The instrument has three settings: instantaneous luminance, peak luminance and luminance ratio and categorized in the upper range of DIN quality class B (Konica Minolta, 2015). According to the method used in a previous study, both the illuminance and the luminance meter were used for measuring and calculating the optical properties of the glazing and surface materials [7]. Lambertian reflectance formulation was used for the determination of the reflectance (p) of surface materials for walls, floor and ceiling and were found 68%, 25% and 87% respectively. The transmittance of glazing was measured as 36% accordingly. They are used as surface reflectance values in DIALux simulations to resemble the real condition of the office. The constant height of reference plane with measurement points was 0.75m from the floor level and 1m away from the walls. E_{avg} (E1…E5) is calculated using these point readings (Figure 3).

2.3. Variants of louvers modelled in DIALux

DIALux is a lighting simulation tool that performs daylight illuminance calculations while taking into consideration external obstructions, artificial lighting illuminance and its energy consumption as well [5]. Variants of shading devices, luminaires and glazing of the sample room are involved in the simulation-based models. The modifications of shading device types regarding to be horizontal versus vertical and with varying slat angles determine the variants. Additionally, luminaires (fluorescent versus LED; operating number) and transmittance of glazing (GT1, GT2 and GT3 as the high (90%), medium (70%) and low (50%) transmittance) provide us the opportunity to test the energy efficient conditions for each variant. As shown in Table 1, each one is called as scenario (S1-S9). Actual measured values are carried for the base case scenario (S0).

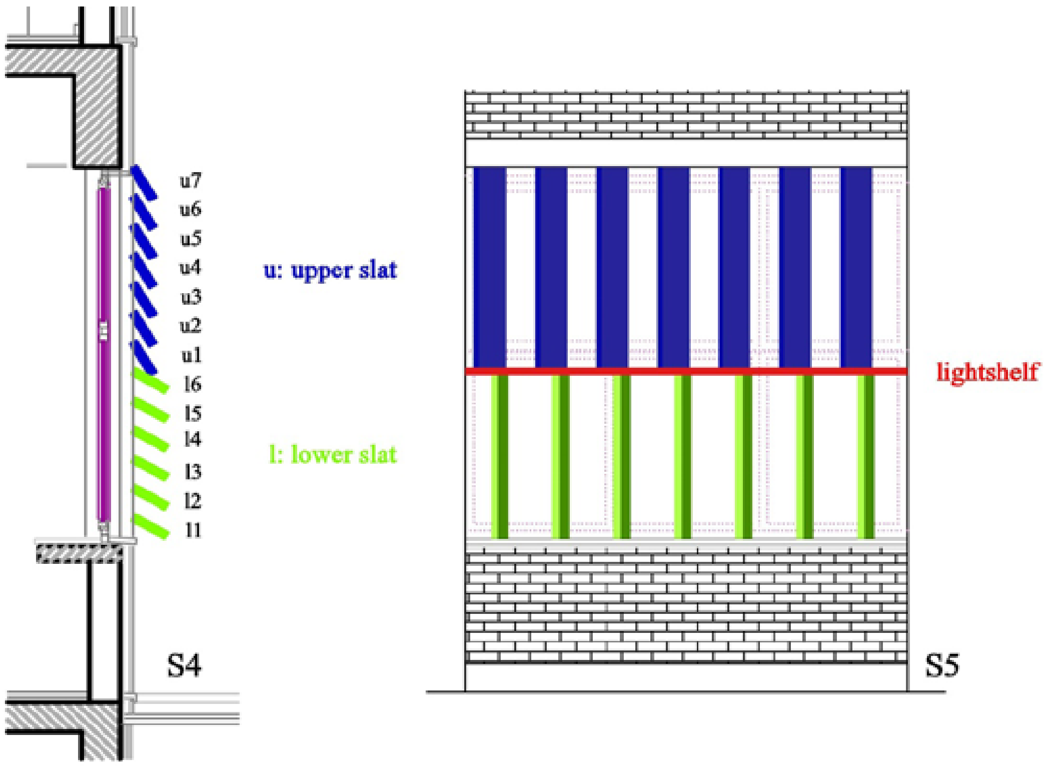

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Figure 2 Two compositions including horizontal shading device (S4; u:upper angle-60^0 and l:lower angle-30^0) and vertical shading device (S5; u:upper angle-45^0 and l:lower angle-15^0)

Each scenario is composed of above mentioned parameters including a shading system; a light shelf, horizontal shading device (HSD) or vertical shading devices (VSD) with variations of slat angles and slat distances (Figure 2). Upper and lower slats are separately movable from 0° to 90° with 15° intervals. For instance, scenario 4 (S4) involves HSD with 30cm distance between slats and all slopes (0°, 15°, 30°, 45°, 60°, 75°, 90°).

Table 1 Descriptions about scenario construction

S1	Light shelf		
S2	Light shelf + HSD: 4 upper + 2 lower slats; 30 cm slat distance.	Apply each slat angle: 0°, 15°, 30°, 45°, 60°, 75°, 90°	A total of 7 variations
S3	HSD: Choose the best performed one in S2 and exclude lightshelf, place another slat.	Similar to S2	
S4	HSD: 6 upper + 6 lower slats; 20 cm slat distance.	Similar to S3	
S5	Light shelf + VSD : 7 upper + 7 lower slats; 40 cm slat distance.	Similar to S4	
S6	VSD : Choose the best performed one in S5 and exclude lightshelf.	Similar to S5	
S7	VSD : 12 upper + 12 lower slats; 23 cm slat distance.	Similar to S6	
S8	Choose the best performed HSD + LED	Similar to S7	
S9	Choose the best performed VSD + LED	Similar to S8	

The rho value of slat's upper surface is determined as 90% to have further daylight reflection to the ceiling of the room. The rho values of other surfaces are 30% diffuse material to prevent glare. In this study, dimensions of a slat is proposed by 0.25x0.05xwindow width m (upper or lower). A recessed modular type holding 4 TL-D/18W fluorescent lamps with total power of 70W and total luminous flux of 3834 lm are used as the actual luminaire (Figure 3).

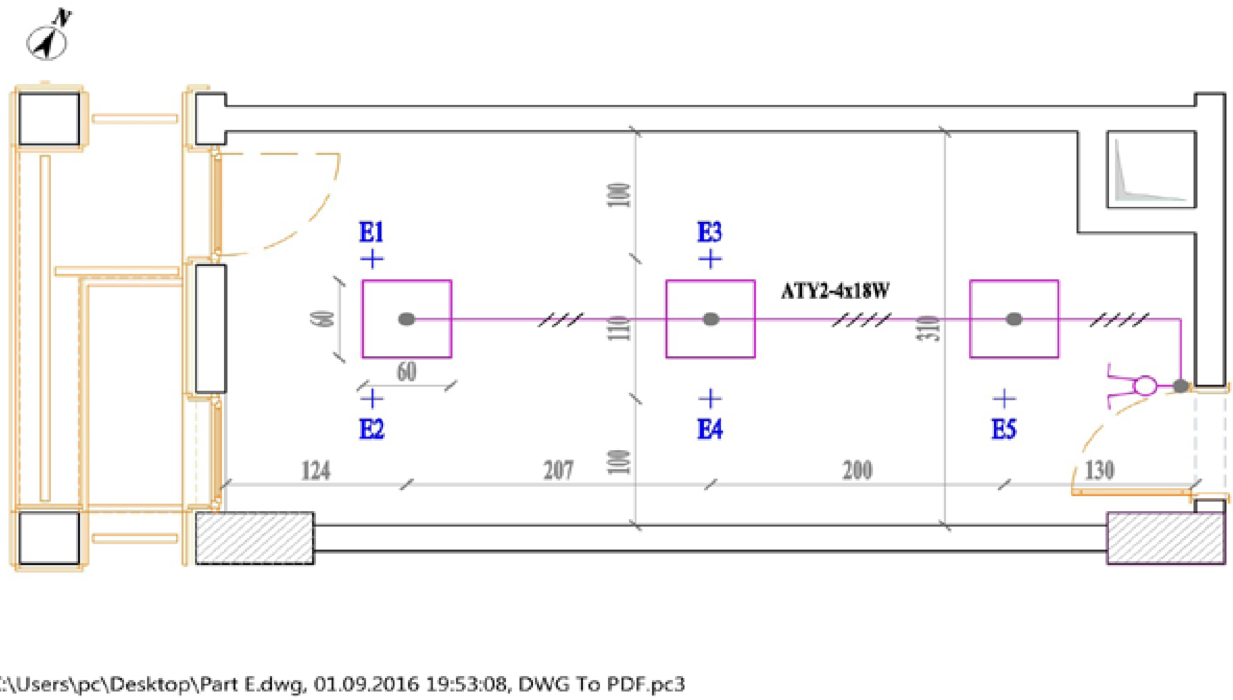


Figure 3 Existing luminaire layout for the sample room

To minimize the lighting power density [8] for the energy efficiency, LED type of luminaire with a similar luminous flux are applied with shading variants. Therefore, existing luminaire types are replaced with LEDs having total power of 41W and a similar luminous flux of 3400 lm. Luminaire layout are defined according to the number of luminaire rows which are switched on. For example, one alternative of luminaire layout included one working row near to the rear wall and others are switched off, while another alternative represents two working rows. The outputs are illuminance (lx), uniformity, LENI (Lighting Energy Numeric Indicator-kWh/yr.m^2) and the annual lighting electricity consumption (kWh/yr). The European standard EN-15193 prescribes LENI values for educational buildings of 27-34.9 kWh/yr.m^2 with basic requirements [9]. Offices need illuminance in range of 300-500 lx [8] and LENI are stated in a range of 41.8-51.9 kWh/yr.m2 with comprehensive requirements [9].

3. RESULTS

Regarding the actual situation of the office, there was a fluctuated and inadequate daylight distribution during the day due to the improper design of balconies and shading devices for this façade (Figure 4-5).

Base case average illuminance values have been found out as 56 lx, 127 lx, 142 lx and 106 lx respectively on December 21st, March 21st, June 21st and September 21st at 9:00 AM. Uniformity values (E_{min}/E_{avg}) has been found out as 0.30, 0.31, 0.33 and 0.31 respectively on December 21st, March 21st, June 21st and September 21st at 9:00 AM. Application of shading variants together with LED lighting and their operating layout improved the lighting conditions. HSD and VSD with 50% glazing transmittance for December 21st are determined to be the optimum solutions. For winter/summer solstices and equinoxes daylighting results were retrofitted. Figure 6 and 7 showed the energy consumption distribution and LENI values when optimum HSD and VSD were applied in winter/summer solstices and equinoxes. Energy consumption results were summarized in Table 2. The energy consumption for base case is 567.0 kWh/a when all the lightings are working on. Annual energy consumption results for these two optimum HSD (S4-FT3) and VSD (S7-FT3) shading device applications were found as 441.0 and 378.0 kWh/a respectively when using December 21st parameters. After retrofitting for all solstices and equinoxes, energy consumption results were calculated as 441.0 kWh/a for HSD and 425.3 kWh/a for VSD (Table 2). It meant that, selected optimum HSD and VSD scenario energy consumption results were found very close to each other. However, vertical exterior louver system performed better than the other due to lower energy consumption. Figure 8 summarizes the distribution of illuminance and uniformity throughout the year and how and what type of slat angles are adapted in each specific day and time. Slat angles vary from 0^0 to 60^0 due time. Compared to the actual office, the optimum vertical louver system saved almost 25% of energy. If the fluorescent luminaires would be replaced by LEDs in optimum case of VSD, annual energy consumption decreased to 249.1 kWh/a. That means 56% saving could be obtained according to base case (Table 2). LENI values could be enhanced from 28.8 to 12.6 kWh/a.m^2. Energy consumption results were found as minimum in December 21st for selected optimum VSD. Figure 9 presents the false color renderings of the office with optimum vertical louvers.

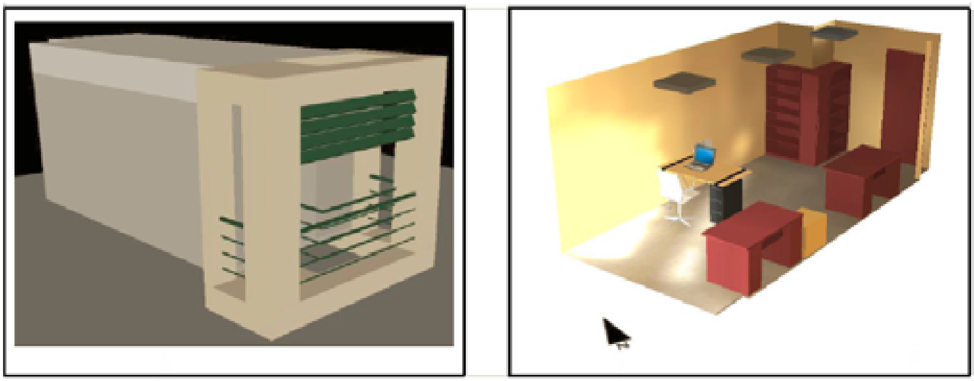


Figure 4 Outdoor and indoor perspectives of the actual office (S0) at 9:00 AM, in winter solstice

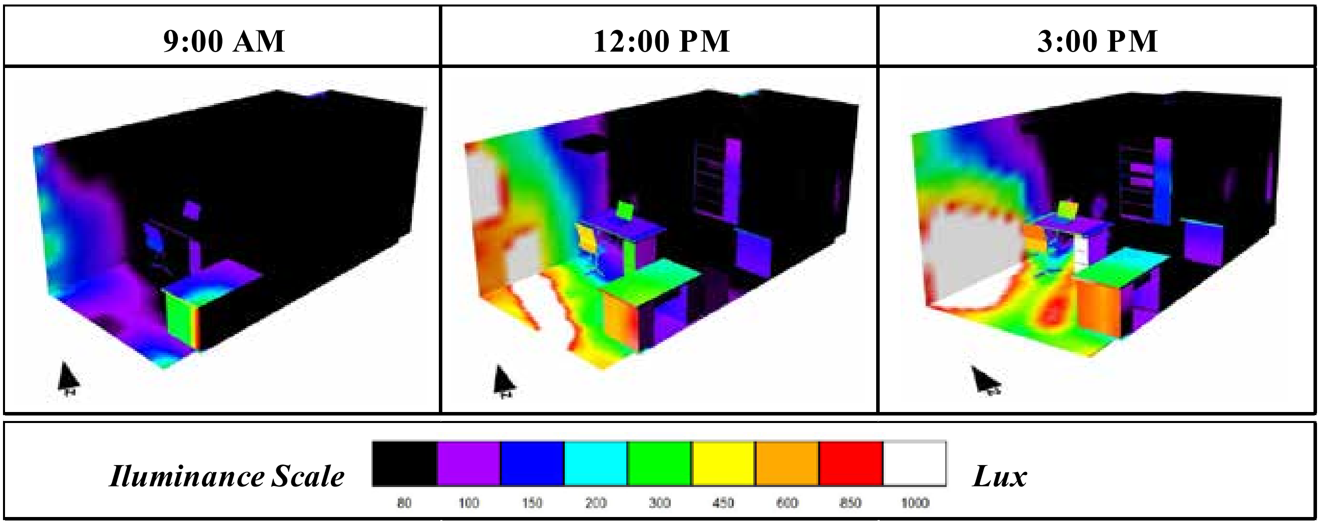


Figure 5 False color renderings in winter solstice for S0

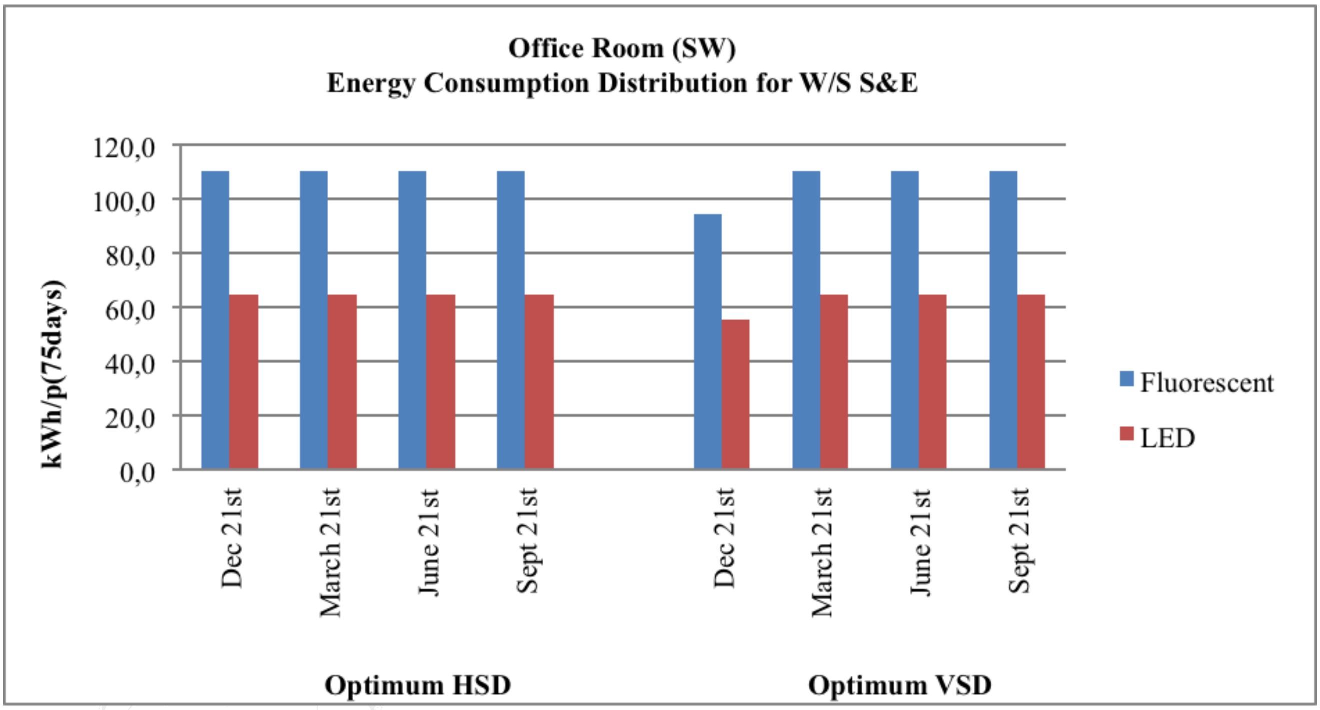


Figure 6 Energy consumption distribution for W/S S&E

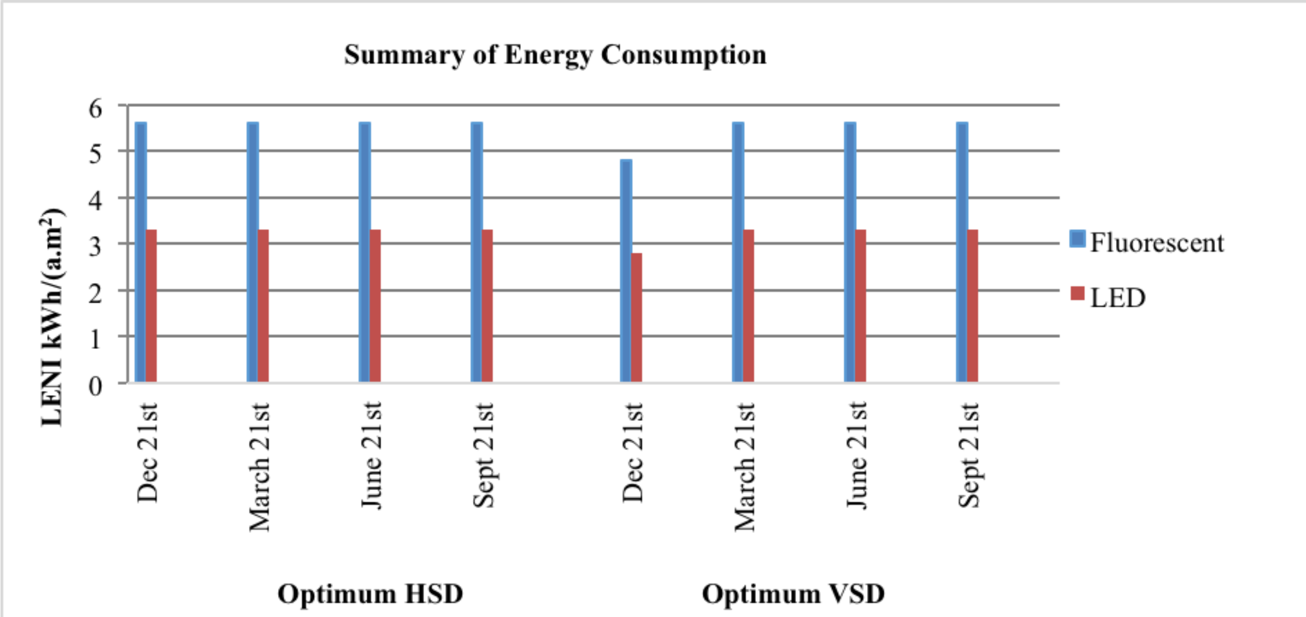
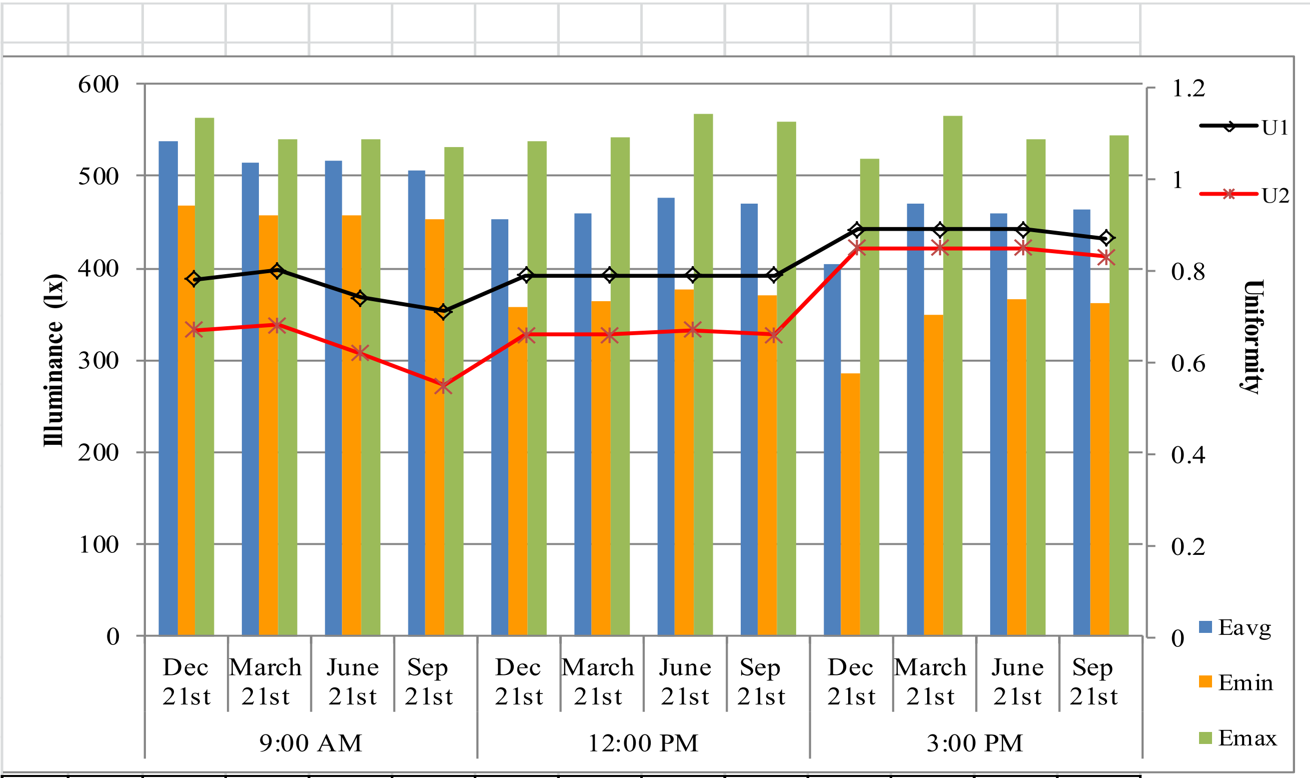


Figure 7 Summary of Energy Consumption in LENI



SD°	upper	0°	60°	60°	60°	45°	45°	45°	45°	0°	75°	60°	60°
	l	0°	60°	60°	60°	0°	30°	0°	0°	15°	60°	60°	60°
LL	no	3				2				1	2	2	2

Figure 8 Retrofitting results for the vertical shading devices at W/S S&E.

4. CONCLUSIONS

The subject room in this study is an office facing Southwest. Although there is an existing shading system composed as a balcony and horizontal dark slats (Figure 4), there are several observed deficiencies in lighting conditions (Figure 5). The coated glazing with 36% of transmittance blocks some amount of diffuse and direct daylight. This study proposes an optimum shading application for both better lighting conditions and energy efficiency.

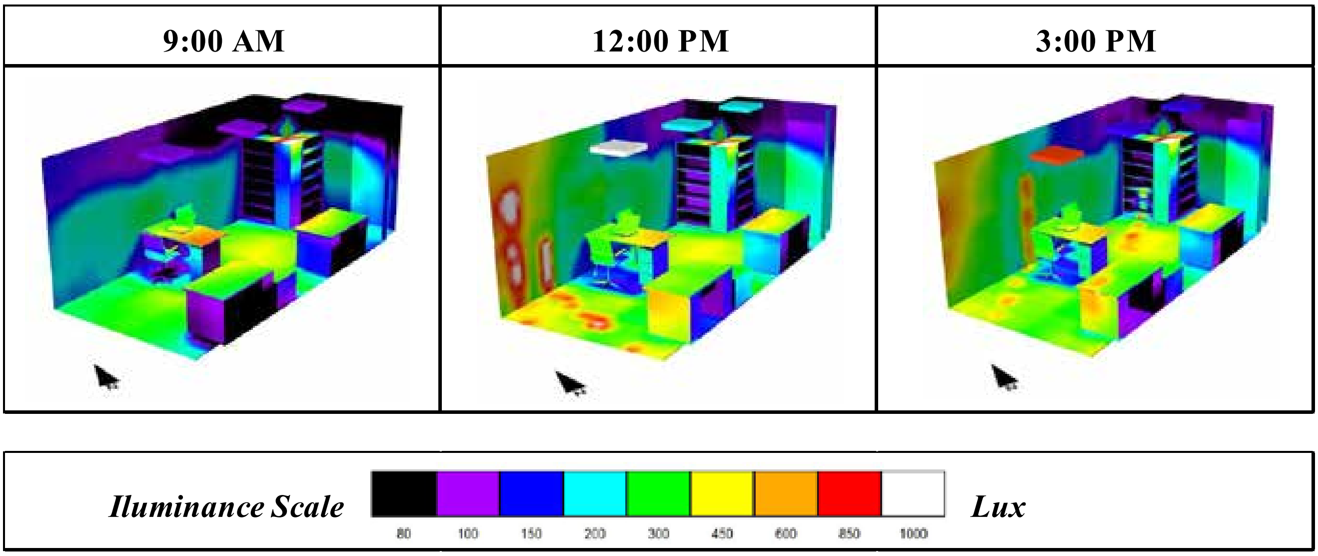


Figure 9 False color renderings in winter solstice for optimum VSD (S8)

After all exterior louver applications, in both HSD and VSD scenarios, 50% of transmittance of glazing was found optimum in terms of energy consumption results. In both cases, LENI values could be retrofitted from 28.8 to 12.6 kWh/a.m^2. Observing the identical LENI values may present the evidence of the relation between the number of lighting fixtures working and the rooms' size. In general, the sum LENI values using fluorescent lamps for this room were within the limiting benchmark values (27 - 34.9 kWh/a.m^2) of energy efficient lighting design criteria defined in EN-15193-1. In addition, the contribution of LEDs in the energy consumption reached to a reduction of 40%. The evaluation of the energy consumption for periods was based on the LENI (Lighting Energy Numerical Indicator-kWh/p.m^2). Although office room is facing southwest (i.e. the same orientation), the installation of VSD was more energy efficient (4.8 kWh/p.m^2) than the use of HSD (5.5 kWh/p.m^2) in the same room on Dec 21st. Either the use of VSD or HDS did not make any difference in LENI values (5.5 kWh/p.m^2/flourescent) in the summer solstice and equinoxes. On the other hand, HSD scenarios provide to obtain entireness in façade design. Moreover, HSD has another advantage in providing visual contact with outdoor environment.

As indicated in Table 3, annual energy consumption could be reduced by 40% by using proper shading devices and 41W LEDs instead of 70W fluorescent having similar luminous fluxes.

For base case;

70 W x 3 luminaires x 9 hours x 300 days = 597 kWh/a (by using FL)

41 W x 3 luminaires x 9 hours x 300 days = 332.1 kWh/a (by using LED)

By using Optimum HSD for Winter/Summer Solstices & Equinoxes; annual energy consumption could be obtained as: 441.0 kWh/a with FL and 258.3 kWh/a with LEDs.

Table 2 Summary of Energy Consumption

Summary of Energy Consumption

LL: Lighting Fixture Layout; n: Number of Lighting Row (on)
LT: Lighting Fixture Type; FL : Fluorescent; Luminous Flux: 3834 lm; Power=70 W
LED: Light Emitting Diode; Luminous Flux: 3400 lm; Power=41 W
LENI: Lighting Energy Numeric Indicator; kWh/(a.m^2) a: annual; p: period; d: day

DESCRIPTION		**Hour**	**LL**	**FL** kWh/a p: 75 d a: 300 d	**FL** LENI	**LED** kWh/a p: 75 d a: 300 d	**LED** LENI
Base Case (S0)		**9 AM**	3				
		12 PM	3	567.0	28.8	332.1	16.9
		3 PM	3				
Optimum HSD&VSD for December 21st	**S4-FT3**	**9 AM**	3				
		12 PM	2	441.0	22.4	258.3	13.1
		3 PM	2				
	S7-FT3	**9 AM**	3				
		12 PM	2	378.0	19.2	221.4	11.2
		3 PM	1				
Optimum HSD for Winter/Summer Solstices & Equinoxes	December 21st	**9 AM**	3				
		12 PM	2	110.3	5.6	64.6	3.3
		3 PM	2				
	March 21st	**9 AM**	3				
		12 PM	2	110.3	5.6	64.6	3.3
		3 PM	2				
	June 21st	**9 AM**	3				
		12 PM	2	110.3	5.6	64.6	3.3
		3 PM	2				
	September 21st	**9 AM**	3				
		12 PM	2	110.3	5.6	64.6	3.3
		3 PM	2				
	Annual Energy Consumption for Optimum HSD			441.0	22.4	258.3	13.1
Optimum VSD for Winter/Summer Solstices & Equinoxes	December 21st	**9 AM**	3				
		12 PM	2	94.5	4.8	55.4	2.8
		3 PM	1				
	March 21st	**9 AM**	3				
		12 PM	2	110.3	5.6	64.6	3.3
		3 PM	2				
	June 21st	**9 AM**	3				
		12 PM	2	110.3	5.6	64.6	3.3
		3 PM	2				
	September 21st	**9 AM**	3				
		12 PM	2	110.3	5.6	64.6	3.3
		3 PM	2				
	Annual Energy Consumption for Optimum VSD			425.3	21.6	249.1	12.6

Table 3. Annual energy consumption results in LENI (kWh/a.m²) and saving for office room

Orientation	Actual Office	Exterior Louver Application		Saving (%)
	FL	FL	LED	
Southwest	28.8	21.6	12.6	56

Using dimming profile for lighting control would be substantially increases energy performance as well as provides better visual comfort conditions in educational buildings (Barbhuiya and Barbhuiya, 2013). Another discussion may base on the outside view which is obstructed by shading devices. The optimum scenarios lead to a high level of visual comfort conditions and a low level of energy consumption by positioning the slats with high angles (60° or 75°). This type of location blocks the view. Such obstruction does not lead to any undesirable physical and visual conditions, although literature indicates the positive psychological effects of windows on learning and working performance. So, it is obviously crucial to achieve visual comfort conditions and less energy consumption without ignoring the visual contact. Using automation systems with intelligent sensors, slats could be controlled and adjusted according to the daylighting illuminance.

This study aimed to provide feedback information about deficiencies in the actual case and optimum solutions to satisfy energy efficient lighting criteria. Such a preceding study was considered and its methodology was built to provide foreknowledge for such a system design. This study, consequently, would made an important contribution for retrofitting of Mechanical Engineering Department in Izmir Institute of Technology in terms of visual comfort conditions and energy efficiency (Figure 9). Daylighting and energy consumption results obtained from the study would be helpful for making decisions of retrofitting. For further studies, investment cost would be calculated in order to propose the retrofitting application phase. Many different parameters such as shading device's design, structure and material, motor device, sensor, automation software, glazing and luminaire types etc. affect the total investment cost.

REFERENCES

[1] Bellia, L., Falco, F. D., & Minichiello, F. (2013). Effects of Solar Shading Devices on Energy Requirements of Standalone Office Buildings for Italian Climates. Applied Thermal Engineering(54), pp. 190-201.

[2] Reinhart, C. F., Mardaljevic, J., & Rogers, Z. (2013). Dynamic Daylight Performance Metrics for Sustainable Building Design. Leukos: The Journal of the Illuminating Engineering Society of North America, 1(3), pp. 7-31.

[3] Tzempelikos, A., & Athienitis, A. K. (2001). The Impact of Shading Design and Control on Thermal Performance
of Building by TRNSYS Simulation. Renewable Energy(23), pp. 497-507.

[4] Chartered Institution of Building Services Engineers CIBSE. Code for lighting. London: CIBSE; 2002.

[5] DIALux version 4.9. User manual. Software standard for calculating lighting layouts, Lüdenscheid; 2011.

[6] Konica Minolta. (2015). Retrieved in June 2015 from Konica Minolta: http://www.konicaminolta.com/instruments/download/catalog/light/pdf/t10a_catalog_eng.pdf.

[7] Fontoynont, M. Daylight Performance of Buildings. New York, USA: Earthscan, 2013.

[8] International Energy Agency (IEA). Guidebook on energy efficient electric lighting for buildings, (Annex45), Aalto University School of Science and Technology, 2010.

[9] PrEN 15193-1, Energy performance of buildings; Energy requirements for lighting, 2007.

[10] Barbhuiya, S., & Barbhuiya, S. (2013). Thermal Comfort and Energy Consumption in UK Educational Buildings.Building and Environment, 68, pp. 1-11.

Paper No: 152

A Survey on the Utilization Trends of LED Light Sources in Turkish Residences

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ABSTRACT

According to the International Energy Agency, lighting constitutes 20 % of the global building energy consumption. Turkey, as a European Union candidate member, strives forth to establish ambitious energy policies in terms of energy efficiency among other energy concerns. The current LED market in Turkey is receiving from a wide range of countries worldwide, this resulting in a big margin of price and quality differences, especially in terms of luminous flux, light colour, lifetime and catastrophic failures. Whether this wide margin has caused a resent effect in the users, especially in residential utilization, is a question yet to be elaborated. This study aims at investigating the Turkish point of view on LED light sources with an emphasis on energy efficiency through statistical analyses of a questionnaire based study conducted among residential users.

INTRODUCTION

According to the International Energy Agency (IEA), lighting constitutes about 20% of global building electricity consumption. Originating from the latest IEA scenarios, by the year 2030, the total electricity savings potential in building lighting could be equal to all the electricity consumed in Africa in 2013 [1]. With the 2020 energy initiative of the EU and step by step phase-out of inefficient lamps in Europe in relation to the Eco-design Directive, energy efficient lighting technologies have gained an important position in the fight against CO_2 emissions and global warming [2, 3]. The novel and highly efficient technology in the field of lighting, Light Emitting Diodes (LEDs) have rapidly moved into almost all fields of lighting, most importantly general lighting, becoming a powerful tool for energy savings.

Unfortunately, there is a significant danger to consumer embracement of Solid State Lighting (SSL) devices in the case that their quality is not enough to answer the expectances of the users. The Compact Fluorescent Lamp (CFL) uptake in the United States (US) is an important example for this. In the 70s, the first compact fluorescent lamps which couldn't meet the expectations of the end users led to a market damage in the US that lasted longer than 30 years. By the time CFLs were finally recognized by residential users in 2006, their share was only 2 % of the US lighting market. It is very important to prevent such an outcome from LED light sources in order to escalate energy efficiency. Most of the first examples of LED light sources were manufactured using high CCT, low CRI LEDs due to their higher efficacies. This may result in end users thinking that all LED light sources provide cold and unsatisfactory lighting conditions. In addition to these, most LED light sources are being designed as retrofits. In terms of thermal management and optical design, most of these products are unsatisfactory due to the drawbacks of available technology and the lack of expertise in the field. Last but not least, the deficiency of product information, especially for low quality products, reduces the trust the end-users have for these products [4, 5]. The high initial purchase costs are an important threat in the full penetration of LED light sources as well. While most market reports as well as future predictions show that the initial purchase costs are going down and will continue to decrease, for several years, LEDs will be more expensive compared to its opponents. The recent postpone of 2 years made by the EU for the phase out of D class inefficient halogen lamps as a step designated by the Eco-design Directive, which was made on the basis that the LED prices are still high compared to their rivals is an important indicator of the concerns of this study. The EU claims that the postpone to 2018 will bring lower prices and better LED performance, giving users faster pay-back times and better energy savings possibilities [2, 6].

Turkey, as a European Union candidate member, strives forth to establish ambitious energy policies in terms of energy efficiency among other energy concerns. The current LED market in Turkey is receiving from a wide range of countries worldwide, this resulting in a big margin of price and quality differences, especially in terms of luminous flux, light colour, lifetime and catastrophic failures. Whether this wide margin has caused a resent effect in the users, especially in residential utilization, is a question yet to be elaborated. This study aims at investigating the Turkish point of view on LED light sources with an emphasis on energy efficiency through statistical analyses of a questionnaire based study conducted among residential users.

METHODOLOGY

In order to proceed with the planned research study, an online questionnaire made up of 46 questions, the questions of which were prepared according to the concerns raised in the introduction part of this paper was designed. The questionnaire was initially shared with 5 experts in the field of lighting to receive their input regarding the context and the questions of the questionnaire. The questionnaire was reformulated on the basis of the input of the experts and a pre-test study was performed with 20 subjects from different educational and occupational backgrounds. The pre-test was used for a second reformulation and the questionnaire was then finalized for the study. The online questionnaire was administered through the web based questionnaire portal of Istanbul Technical University. With the help of Istanbul Technical University, Dokuz Eylül University and Erzurum Atatürk University as well as social media, the questionnaire was shared with a large number of people all around Turkey. From April 2016 to June 2016, a total number of 711 subjects from 20 different Turkish cities as well as subjects from around the world answered the questionnaire. As the questionnaire aims to analyse the situation in Turkish residences, the data of the 23 subjects who live outside of Turkey were omitted for the statistical analysis, leaving 688 subjects behind. The data obtained from the questionnaire was analysed using the Statistical Software SPSS and the results are discussed in the following sections.

DEMOGRAPHIC INFORMATION OF SUBJECTS

Table 1 gives the details of the demographic information of the 688 subjects which have completed the questionnaire. As the questionnaire was administered online through the help of Turkish Universities, the education level is very high, with 90.8 % of the subjects holding a minimum of a Bachelor's degree. The highest number of participants fell into the age group of 30-39, followed by 20-29 and 40-49, providing a good range for the age of the subjects. The highest rate of participation came from Istanbul with 59.1 %, the biggest city in Turkey population wise, followed by İzmir, the third biggest city population wise in Turkey with 20.3 %.

Table 1 Demographic Information of the Subjects

Gender	Frequency	Percentage	City	Frequency	Percentage
Female	249	36.2	Adana	1	0.1
Male	439	63.8	Afyonkarahisar	1	0.1
			Ankara	13	1.8
Age Group			Antalya	6	0.8
Below 20	9	1.3	Aydın	1	0.1
20-29	233	32.9	Bursa	6	0.8
30-39	250	35.3	Erzurum	68	9.6
40-49	113	16.0	Istanbul	420	59.1
50-59	59	8.3	Eskişehir	2	0.3
60-69	19	2.7	İzmir	144	20.3
Above 70	2	0.3	Karaman	1	0.1
			Kars	1	0.1
Education			Kayseri	3	0.4
High School	15	2.2	Kırklareli	2	0.3
2 year program	14	2.0	Turkish Republic of Northern Cyprus	2	0.3
College Student	34	5.0	Kocaeli	10	1.4
College Graduate	265	38.6	Manisa	2	0.3
Master's	189	27.6	Muğla	1	0.1
PhD	169	24.6	Niğde	1	0.1
			Sakarya	1	0.1
			Tunceli	2	0.3

LIGHTING HABITS OF SUBJECTS

Of the 688 subjects who participated in the questionnaire, 63 subjects, corresponding to 9.3 % of all participants, have never heard of the LED technology. Of these 63 subjects, 34.9 % are between the ages of 20-29, 38.1 % 30-39, 14.3 % 40-49, 11.1 % 50-59 and 1.6 % 60-69. The data shows no correlation between the recognition of LEDs to the demographic information obtained from the subjects. Subjects who declared that they did not recognize LEDs were able to skip the questions regarding LED technology, therefore some of the questions in the questionnaire are not answered by all the subjects who participated in the study. For the subjects who recognize the LED technology, the distribution of their origin of knowledge is given in Figure 1. This question enabled multiple responses to be selected simultaneously. The results show that the highest rates of information has come from the internet and from the media, while the lowest rate has been acknowledged as public authorities. This is an important finding which the authorities should take into consideration as a significant indicator of the amount of effort they need to put into raising awareness on the topic of LEDs and energy efficiency in lighting.

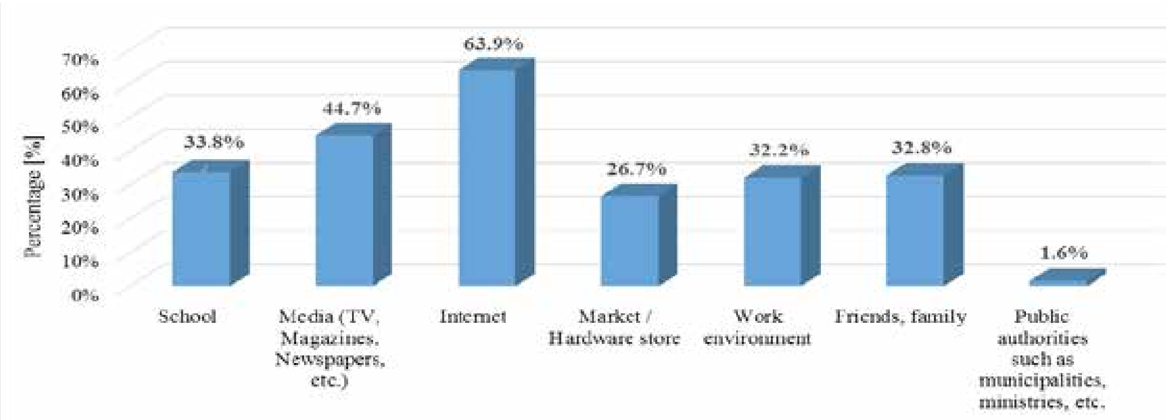

Figure 1 Distribution of the Source of LED Knowledge of Subjects

When the subjects were asked whether they are responsible for the lighting decisions at home and buy the light sources for their households, 81.1 % responded positively and 18.9 % negatively. Table 2 shows the satisfaction level of subjects from the lighting environment in their houses. The data shows that the majority of subjects are satisfied with their lighting solutions.

Table 2 The Satisfaction of Subjects from Their Lighting System at Home

Lighting satisfaction at home	Frequency	Percentage
Extremely satisfied	54	7.8
Satisfied	448	65.1
Neither satisfied nor unsatisfied	99	14.4
Unsatisfied	82	11.9
Extremely unsatisfied	5	0.7

Continuing with the subjects' lighting habits, the question of where subjects make their lamp purchases was administered, enabling multiple selections to be made. The results can be seen in Figure 2. The vast majority of subjects claimed to buy their lamps from big hardware stores (66.1 %) while the lowest percentage of purchase was from the local street markets. The authors believe that the reason behind this is that the big hardware stores train their sales assistants to provide important information to the purchasers regarding the selection of light sources. Today, where there are many alternatives with different properties and a wide selection of price ranges, this service is of upmost importance.

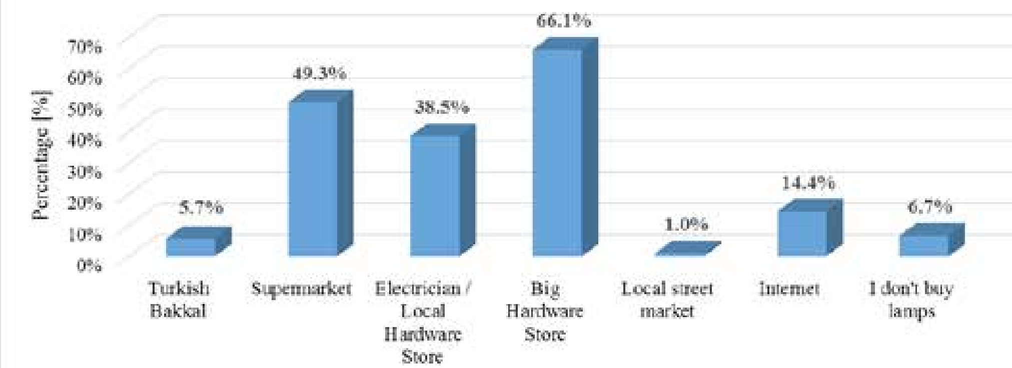

Figure 2 The Distribution of Lamp Purchase Mediums of Subjects

Figure 3 gives the distribution of answers regarding the considerations subjects have when they are making their lamp purchases, once again enabling multiple answers to be selected. The highest concern was chosen as light color, followed by lamp power, price, and quantity of light. 2.5 % of the subjects claimed that they had no idea on the properties of light sources when they were making lamp purchases.

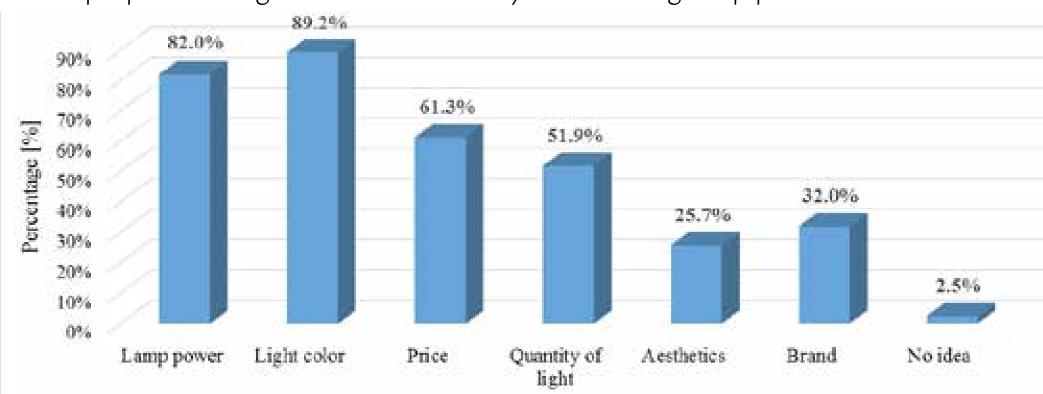

Figure 3 The Distribution of Lamp Purchase Considerations

Figure 4 represents the distribution of light sources other than LEDs that the subjects use in their households. An option of "Only LEDs" was introduced among the answers, for subjects which use only LEDs, which turned out to be 12.9 %. The highest frequency was spotted for compact fluorescent lamps (CFLs) with 61.2 %, which is a very promising result in terms of energy efficiency. However, the next highest light source is unfortunately the highest energy consumer as well; even though Turkey has decided to phase-out incandescent lamps like the EU and many other countries around the world, the results show that more than 1/3 of the subjects still use incandescent lamps in their households. This, again, is an important consideration for the public authorities.

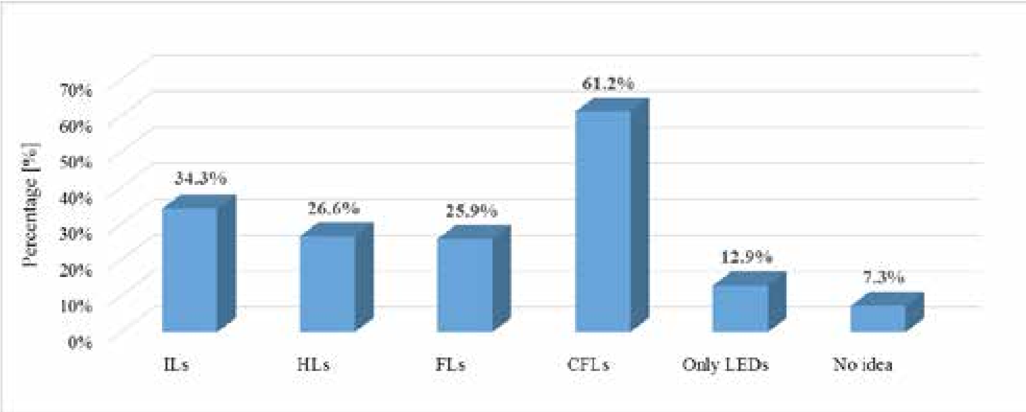

Figure 4 The Distribution of Light Sources Used in the Households (IL: Incandescent Lamp, HL: Halogen Lamp, FL: Fluorescent Lamp, CFL: Compact Fluorescent Lamp)

QUESTIONS REGARDING LED TECHNOLOGY

The subjects were asked whether if they use LED light sources in their households. The answers show that 69.6 % of the subjects do use LEDs at home, while 28.9 % do not and 1.4 % actually have no idea. Of the 46 questions in the questionnaire, 17 were designed to measure the attitude of subjects to the LED technology. In order to make this analysis, the questions given in Table 3 were prepared with the responses in a Likert Scale ranging from (1) Definitely Disagree, (2) Disagree, (3) Indecisive, (4) Agree, (5) Definitely Agree. The responses given in percentage form can be seen in Table 4.

Table 3 Questions on the Attitude of Subjects Regarding LED Technology

a	LED prices are high.
b	I don't need LEDs.
c	I don't trust LED technology.
d	I think that LEDs are low quality.
e	I don't think LEDs give out enough light.
f	I think LEDs lower visual comfort through creating glare.
g	It's difficult to find LED products.
h	I think that LEDs harm the nature.
i	I think that LEDs harm human health.
j	I think that LEDs are not aesthetic.
k	I think that LEDs do not provide energy savings.
l	I only buy LEDs by famous brands.
m	I don't care about the brand when buying LEDs.
n	When buying LEDs, price is the most important feature.
o	I find the explanations on LED packages too complicated.
p	I think that LEDs break very easily.
q	I can't find enough options when buying LEDs.

Table 4 Answers Given to Questions Regarding LED Technology [in %]

	Definitely disagree	Disagree	Indecisive	Agree	Definitely agree
a	6.8	21.1	22.6	37.0	12.6
b	34.4	39.1	16.3	7.4	2.9
c	43.4	40.2	12.1	2.7	1.5
d	33.2	39.3	17.0	8.8	1.7
e	32.3	42.9	11.7	11.1	2.0
f	18.9	40.2	23.9	13.3	3.6
g	21.5	42.5	17.9	16.0	2.1
h	27.2	35.6	33.9	2.4	0.9
i	27.2	36.4	31.7	2.9	1.7
j	32.1	46.0	12.1	7.2	2.6
k	45.3	38.8	9.1	4.6	2.2
l	6.3	16.4	22.4	40.9	14.0
m	28.2	38.8	19.8	10.6	2.6
n	10.6	41.5	28.3	16.9	2.6
o	14.4	33.9	31.6	16.7	3.4
p	15.7	33.7	34.1	11.7	4.9
q	8.7	24.2	27.4	32.3	7.4

In Table 4, the highest percentages are colour marked, and provide important findings. Looking at the column where the subjects selected the "Agree" answer, it can be seen that the subjects find the prices of the LEDs high, that they prefer to buy products from famous brands and that they cannot find enough options when buying LED light sources. Moving to "Definitely disagree" it can be seen that the users oppose the arguments of LED technology being untrustworthy and not providing energy savings. For the remainder of the questions, as the questions were formulated in negative form, it is possible to say that the subjects have a quite positive point of view of LED technology. Figure 5 summarizes the findings by giving average scores for each question in hand.

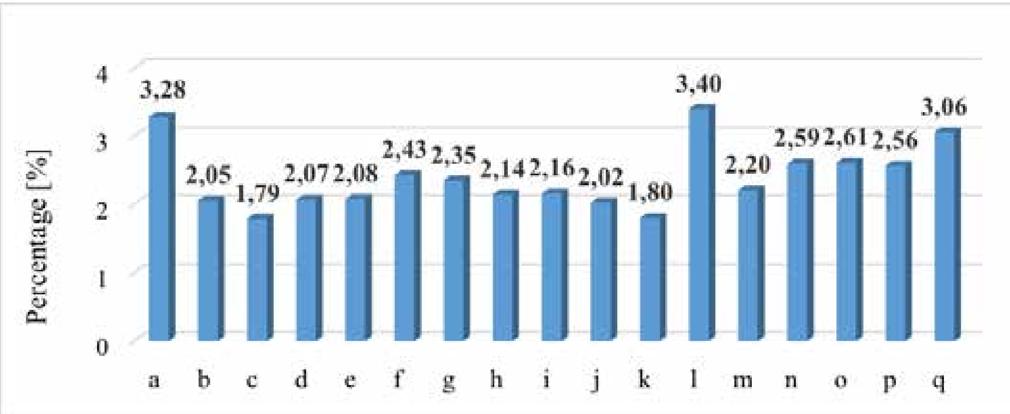

Figure 5 Mean Responses to Questions Regarding LEDs

With an open ended question, the subjects were asked to write down any harms to human health, nature or the environment they know of created by the LEDs. 188 subjects answered this question, 112 of which declaring either that LEDs were not harmful, or that they weren't aware of the harms of LEDs if they did exist. Of the remaining 73 subjects, the harmful properties of LEDs most frequently stated are the blue light hazard, damage to the eye (specifically the retina), glare, cancer and inhibition of melatonin release, causing sleep disorders, triggering epilepsy, harming the environment during the production phase, containing radioactive materials, harmonics introduced into the grid and causing electromagnetic interference.

Figure 6 shows the distribution of places inside the subjects' houses where LED lighting is used. The answers show that LEDs have penetrated into the all of the house spaces, majority usage being in the living room, which in the Turkish tradition the room which is most frequently used. This again is a promising finding in regards of energy efficiency.

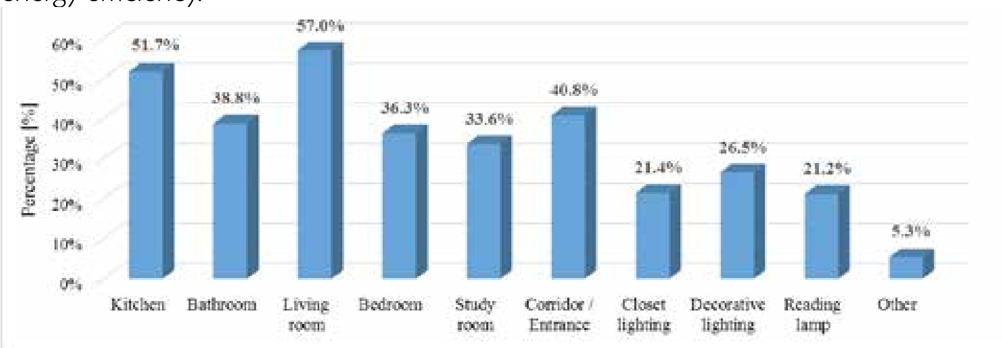

Figure 6 Distribution of the Utilization Locations of LEDs in the Household

Subjects were asked for the time periods of LED utilization in their households. Answers show that the time periods of 0-1, 1-2, 2-3 and more than 3 years have been evenly selected by the subjects, hinting at an even demand from the lighting market as well. The subjects were also asked whether if the LED products they purchased failed during utilization. 60.8 % replied no, 32.4 % replied yes and the remaining 6.9 % had no idea. When the subjects were asked about the brands they purchase from, 41 different brands came up; 40.8 % selected Philips, followed by 14.1 % Osram, and 6 % Ikea. 5 % of the users chose "no name" off the market LEDs, while 16.6 % had no idea about the brand of LEDs they purchase or use. The countries of the brands range from Turkey (18 brands), Germany (5 brands), China (4 brands), USA (3 brands), Japan (2 brands), The Netherlands (2 brands) and 1 brand each from Austria, Canada, India, Italy, Korea, Sweden and Taiwan. This data shows that the Turkish market receives LED products from numerous countries. The results, showing a higher percentage of utilization for big companies such as Philips and Osram are consistent with the findings of Table 4, as these long established companies produce higher quality LEDs that would create a positive point of view for the users as well as high price ratings as again these big companies sell the highest priced products in the market. The finding that only 32.4 % of the subjects claimed that their LEDs have failed is again most probably due to the selection of famous brands from the market. Originating from all of these findings, the results given in Figure 7 showing the satisfaction of the subjects regarding the LEDs they use at home meets the expectations. A total of 84.6 % of the subjects have declared satisfaction from the LEDs they use in their homes. The unsatisfied portion of the subjects constitute only 4.1 % of the whole sample.

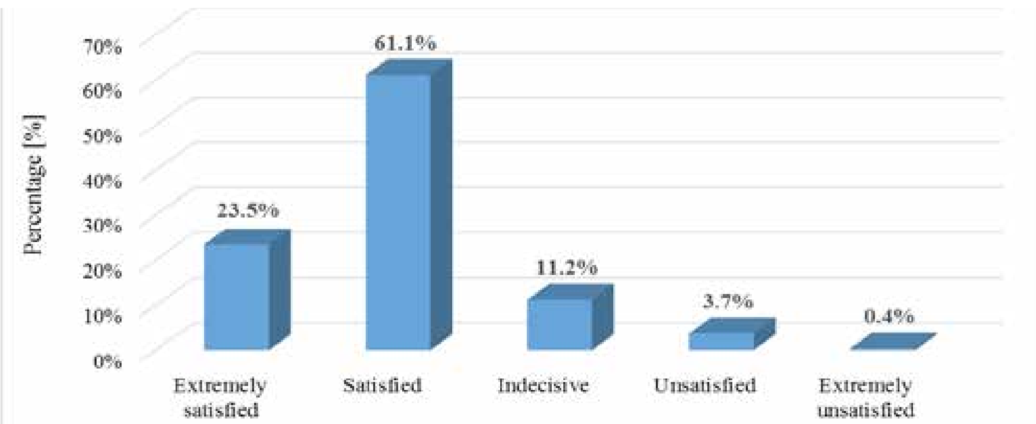

Figure 7 Satisfaction from LED Sources Used at Home

Figure 8 shows the distribution of users who would purchase LEDs again for their household. Once again, a very high percentage of 91 % of the subjects chose yes and definitely yes, while only 1.5 % chose no. Figure 9 on the other hand shows the responses given to "If you knew that you were going to make more energy savings, would you change all the light sources in your home with LEDs?". This question, when analyzed with the previous two questions, provides interesting insights. Even though, the satisfaction rate of the LEDs was 84.6 % and their re-buying ratio was 91.0 %, the percentage of subjects who would be willing to change all the light sources in their households to LEDs is 66.3 %. The graphs show that the subjects who are indecisive and who say no to the question have increased by an average of 10 % each. The reason behind this might be that the prices are still quite high compared to the rest of the light sources in the market; that the subjects are not yet ready to change their long-lived habits and give up their traditional light sources; that the government is not promoting LEDs enough for end-users and that the subjects are not able to find enough options for replacement lamps that would be suitable to the luminaires that they already use at home. At this point, it would be beneficial to emphasize that one of the most frequent critics the authors receive on replacement lamps is that Turkish buyers cannot find replacements for the E14 incandescent lamps they use with chandeliers, which are essential to the Turkish home lighting.

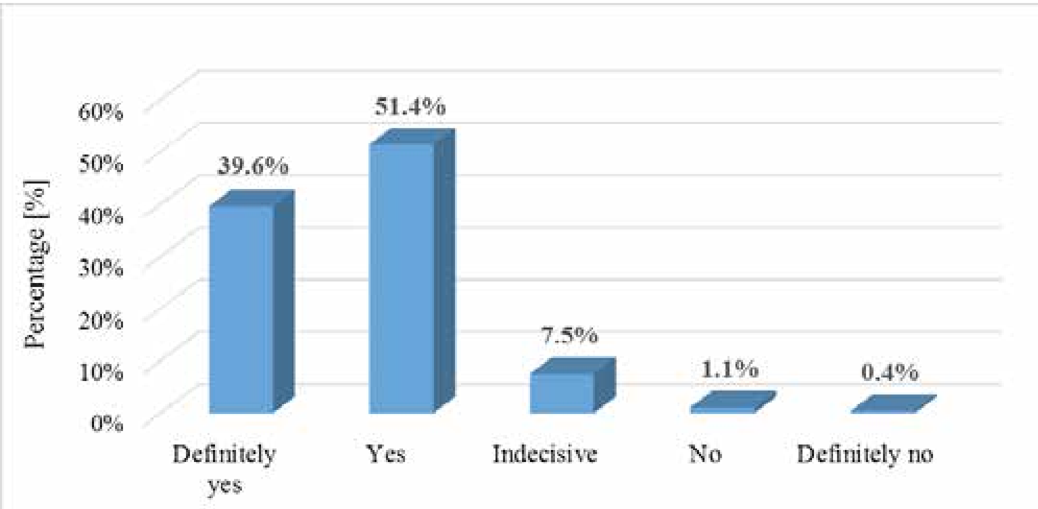

Figure 8 Distribution of Users Who Would Re-Buy LEDs

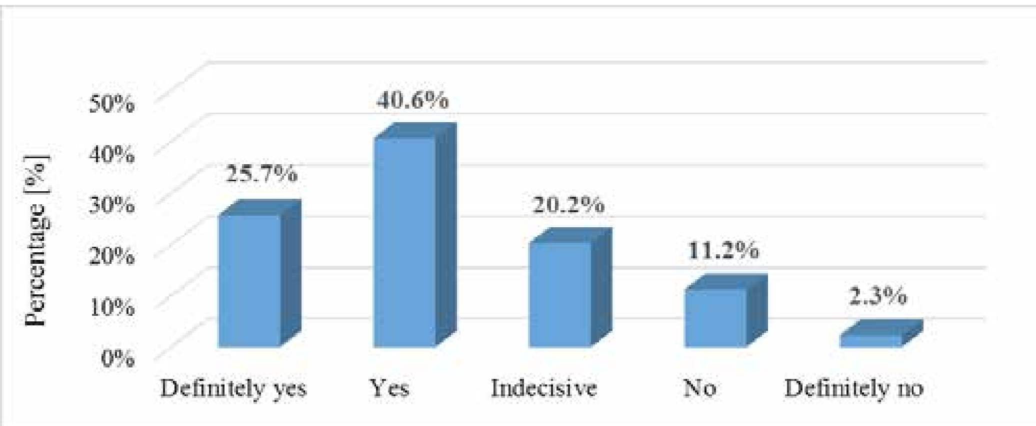

Figure 9 Distribution of Users Who Would Replace All Their Light Sources with LEDs for Energy Efficiency

One final question to be discussed in the scope of this study was whether the subjects realized any change in their electricity bills after they started using LEDs in their households. The results are quite interesting; 0.9 % claim that their bill increased, only 26.6 % have realized a fall in the bills and the remaining 72.5 % literally have no idea. Considering that 82 % of the subjects' secondary concern in lamp purchases was the power of the lamp, this finding is extremely interesting. The finding supports the fact that energy efficient lighting technologies are usually taken for granted by the most of the end users as they do not recognize the consumption caused by lighting. Therefore, most users do not comprehend the major impact of the change to LED lighting systems as they do not know neither the advantages nor the capabilities of these systems.

CONCLUSION

The current LED market in Turkey is receiving from a wide range of countries worldwide, this resulting in a big margin of price and quality differences, especially in terms of luminous flux, light colour, lifetime and failure rate. This study originated from the question mark on whether the wide margin in the LED market had caused a resent effect in the users. In order to answer this question, an online based questionnaire was administered to 711 subjects and the obtained data was analysed. The study shows that overall, the Turkish point of view for LEDs appears to be quite positive, with the LED technology having penetrated into the Turkish households very efficiently. The data from the questionnaire shows that numerous brands from all over the world are being used in the Turkish households, while the most frequent utilization belongs to the most established international companies. The subjects express their concern on the high prices as well as the lack of options when they are searching for LEDs, but also state that they are satisfied with the products they use at home and would be willing to buy LED products again. An interesting finding is that the subjects are mostly not interested in the relationship between the utilization of LEDs and the effect of this utilization on their electricity bills. It's also very interesting to see that even though the subjects express high levels of interest and satisfaction with LED light sources, an important percentage of the participants are still not ready to give up the rest of their traditional light sources, even for the benefits of energy savings. A negative finding, which should be restated for emphasis is that the data shows that the Turkish Government is falling behind on providing its citizens with data on energy efficiency of light sources and LEDs, in terms of residential utilization. Improvements made in this area would definitely provide benefits to both Turkish energy policies, economy, citizens and thus the Government.

REFERENCES

[1] http://www.iea.org/topics/energyefficiency/subtopics/lighting/

[2] European Commission. Commission Regulation (EC) No 244/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for non-directional household lamps. Official Journal L76, 24/03/2009, p. 0251-0264. Can be downloaded at: http://europe.eu.int/eur-lex/

[3] https://ec.europa.eu/energy/en/topics/energy-strategy/2020-energy-strategy

[4] European Commission. Photonics Unit, Photonics Technologies and Markets for a Low Carbon Economy – Summary Report, SMART 2010/0066. Can be downloaded at: http://cordis.europa.eu/fp7/ict/photonics/docs/studies/smart2010-0066- annex2_en.pdf.

[5] European Commission. Green Paper: Lighting the Future – Accelerating the Deployment of Innovative Lighting Technologies COM (2011) 889 Final. 15/12/2011 Brussels. Can be downloaded at: http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=1127

[6] https://ec.europa.eu/energy/en/news/phase-out-inefficient-lamps-postponed-1-september-2018

Paper No: 165

The Artificial Lighting Parameters Effecting Energy Requirements of Residential Buildings.

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ABSTRACT

In the scope of this study, taking the EN 15193 standard as a basis and while paying attention to the specific variables of residential buildings, a developing approach to lighting energy consumption parameters has been introduced and the influence of lamp selection has been discussed on the example of a residential building in Kayseri Provence of Turkey.

Two different suggestions have been examined on the residential building taken as an example for the purpose of this study, traditional lamp types and led lamps as artificial lighting parameters. Both of these two suggestions have been evaluated from the perspective of energy performance.

INTRODUCTION

All around the world, the gradual depletion of energy sources and the increase of their cost has brought forward the need for studies involving efficient use of energy in buildings. In our country 45% of electric energy is being used by buildings while 25% of total consumption is being realized in residential buildings. From the total consumption of electric energy 20% is used for lighting. In the scope of electric energy consumption, lighting has become a burdening sector, with 56% share in building consumption [1].

Residential buildings, both all around the world and within Turkey, occupy an important percentage of lighting energy consumption in buildings. It is thus necessary to give importance to studies involving lighting energy demand in residential buildings. Following the USA's 2002/91/EC regulation EN 15193 Energy Performance in Buildings –Lighting Energy Requirements standard came into force. According to this standard, Lighting Energy Numeric Indicator LENI has been taken as an evaluation criteria and was calculated as the annual lighting energy requirement per unit area. Residential buildings have been left out in the calculation method introduced by this standard [2].

In the Energy Performance Regulations for Buildings BEP-TR developed for Turkey and published in Official Gazette dated 5.12.2008. A general calculation method has been suggested for determining lighting energy requirement in residential buildings. However, it is clear that a more detailed method that takes into account specific variables of residential buildings are required [3]. Residential buildings differ from other typologies with their usage characteristics such as numeral activities in the spaces, occupation period and family profile. Since these parameters effect lighting energy requirements, they should be addressed differently and its values should be determined accordingly.

DETERMINATION OF LIGHTING ENERGY PERFORMANCE IN RESIDENTIAL BUILDINGS

In the scope of the PhD thesis titled "An Approach to Evaluating Lighting Energy Requirements of Residential Buildings in Turkey" an approach has been developed by taking EN 15193 – Lighting Energy Requirements standard as a basis. The developed approach takes into consideration visual comfort requirements and family profile of residential buildings users [4]. In this approach, ensuring visual comfort conditions is accepted as a primary condition. By using related literature, compiled minimum lighting levels have been taken as a basis. According to EN 15193 standard, annual lighting energy requirements for an area or a building are calculated using Equation 1.

$$W_{L,T} = \{(P_n \times F_c) \times [(t_D \times F_o \times F_D) + (t_N \times F_o)]\} / 1000 \text{ (kWh)} \qquad (1)$$

P_n : Power of all luminaires in the room or zone, (W)

F_c : Constant illuminance factor

t_D : Daylight time usage (h)

F_o : Occupancy dependency factor

F_D : Daylight dependency factor

t_N : Non-daylight time usage (h)

Lighting Energy Numerical Indicator related to total annual lighting energy is calculated with Equation 2.

$$LENI = W/A \text{ (kWh/m}^2 \times \text{year)} \qquad (2)$$

W: The total annual energy used for lighting (kWh)

A: The total useful floor area of building (m^2)

The developed approach includes a detailed calculation model that takes into account differences related to the above mentioned variables such as geographical area, parameters related to the daylighting and artificial systems and family profile. Pn value in Equation 1 represents power of all luminaires in the room or zone, measured in watts .Selected lamp type has an essential effect in determining this value.

Compact fluorescent and halogen lamps are usually preferred in residential buildings, even though incandescent lamps are still used in small percentage. Today, the usage of Led lamps, brought by technological advancement and produced to provide service with different purposes, is constantly spreading and, by taking the place of traditional lamps, Led lamps started holding an important position in the sector. Keeping in mind that the amount of power taken from the grid by Led lamps can be as low as 1-2W, it is clear that they need to hold important position in the scope of energy efficiency [5].

AN EXAMPLE RELATED TO THE PARAMETERS OF LAMP SELECTION IN RESIDENTIAL BUILDINGS FROM THE PERSPECTIVE OF ENERGY REQUIREMENTS

In this study, "a building in a residential area in Kayseri" was taken as an example. The example, as related to the residential building type, is a high-rise residential building, consisting of ground floor and 12 additional floors. On each floor there are 4 apartments of approximately 150 m^2. The building is positioned on the north-south axis and each apartment is composed of living room, lounge, kitchen, master bedroom and children's room. Planning scheme of residential building is presented on Figure 1.

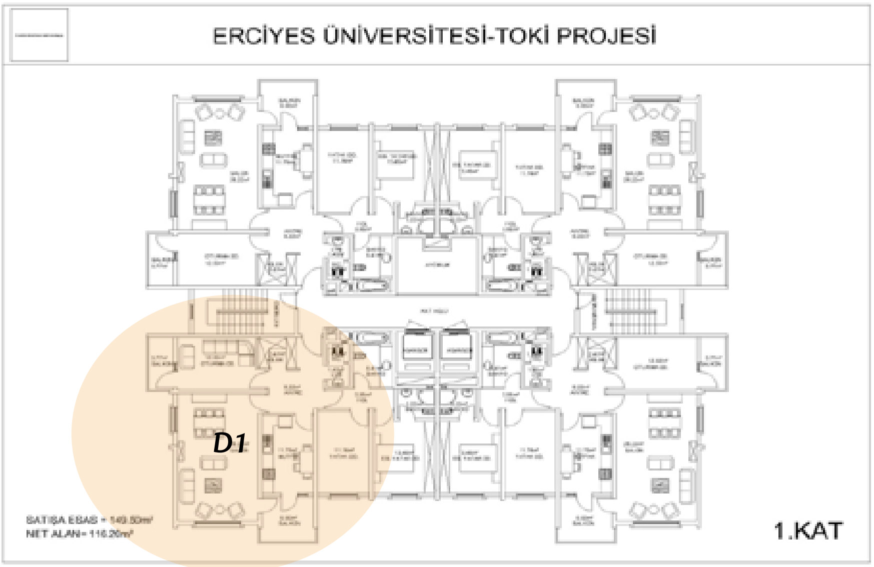

Figure 1. Planning scheme of residential building

Rooms in D-1 residential building facing South and West have been chosen for determining the effect of different lamp suggestions on lighting energy performance. Other parameters, such as the family profile, occupation period and daylight availability are accepted constant in order to enable a proper comparison. Windows are accepted without exterior obstacles.

1. Lighting Design Suggestions and Lamp Alternatives Related to Residential Building

Determination of lighting energy performance is related to power consumption of lighting system and artificial lighting design of each area in the residential building. Two different designs that ensure visual comfort conditions were developed for each area of the example residential building chosen for this study. For Suggestion 1 compact fluorescent and halogen-incandescent lamps were used, while Led lamps were used for Suggestion 2.
Calculations for determining average general illuminance were made using Dialux 4.12 for horizontal work plane on 0.80 m height. Additional calculations were made if required for planes related to specific actions preformed in a single area.
Living room: Large portion of daily life in a residential building, except sleeping hours, passes in the living room. Isolux curves related to horizontal work plane in Suggestion 1 and Suggestion 2 living room designs are determined on Figure 2 and Figure 3.

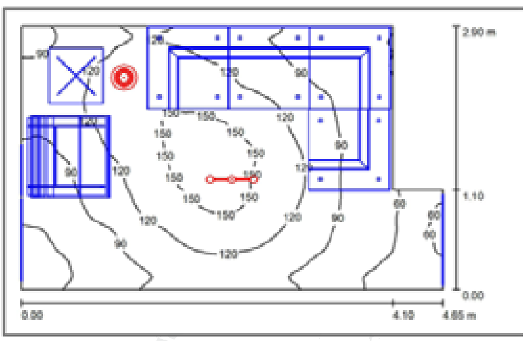

Figure 2: Isolux curves related to living room lighting design for Suggestion 1

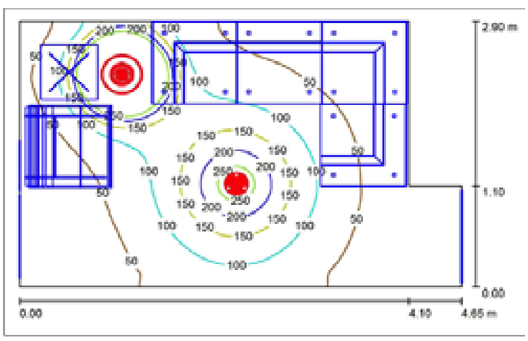

Figure 3: Isolux curves related to living room lighting design for Suggestion 2

According to the calculations made, average illuminance obtained for the living room Suggestion 1 on the work plane was 104 lux,; and for Suggestion 2 average value on the work plane was 115 lux, Thus, total power drawn from the grid was 89 Watt for the Suggestion 1 and 63 Watt for the Suggestion 2.

Children's Room: A lighting design suitable for sleep, study and play time in the same space is given for the residential building children's room example. Isolux curves related to horizontal work plane in Suggestion 1 and Suggestion 2 children's room designs are determined on Figure 4 and Figure 5.

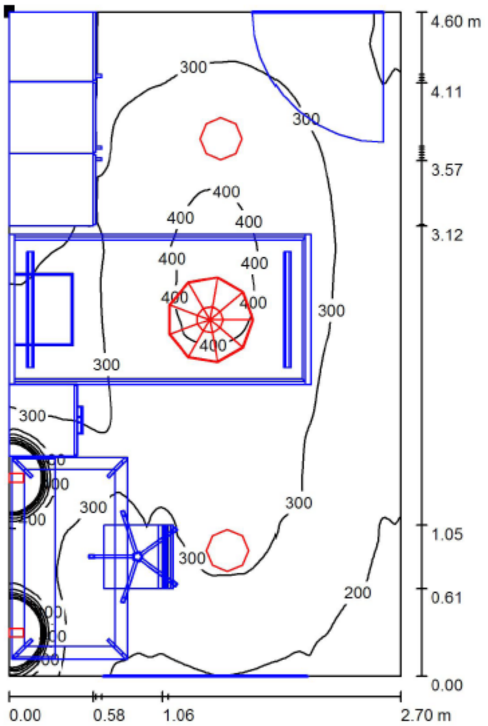

Figure 4: Isolux curves related to children's room lighting design for Suggestion 1

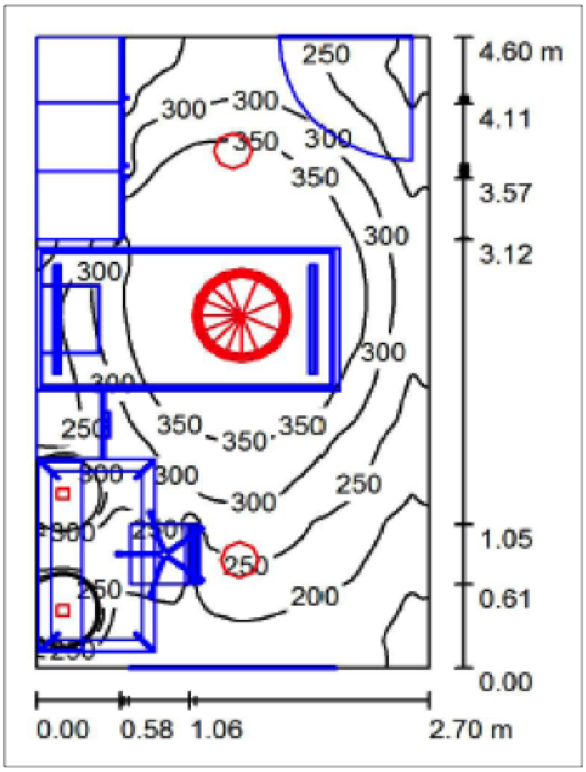

Figure 5: Isolux curves related to children's room lighting design for Suggestion 2

According to the calculations made for children's room Suggestion 1, average value of obtained was 324 lux. On the other hand, the results for the study desk surface illuminance were approximately 500 lux.

According to the calculations for Suggestion 2, average illuminance was 303 lux, while the results for the study desk surface were approximately 503 lux. Compact fluorescent downlights, ceiling-mounted and wall-mounted lamps were used for the general lighting according to Suggestion 1; while similar design solutions in Led versions were used for Suggestion 2. Thus, total power drawn from the grid in children's room was determined to be 207 Watt for Suggestion 1 and 91 Watt for Suggestion 2.

Master Bedroom:

Isolux curves related to horizontal work plane in Suggestion 1 and Suggestion 2 designs for master bedroom in the residential building chosen as an example for this study are determined on Figure 6 and Figure 7.

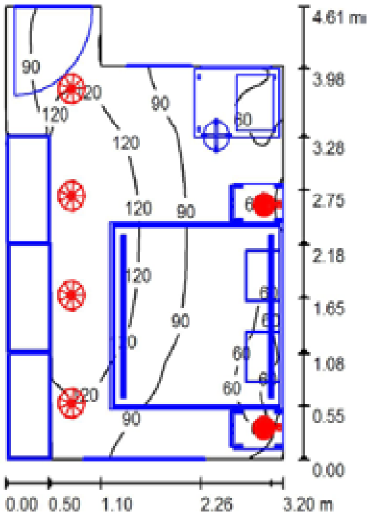

Figure 6: Isolux curves related to master bedroom lighting design for Suggestion 1

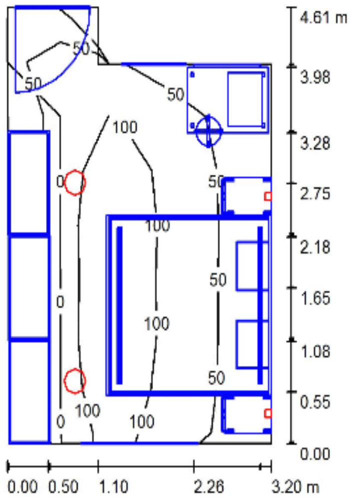

Figure 7: Isolux curves related to master bedroom lighting design for Suggestion 2

The illuminance obtained from the calculations in master bedroom for Suggestion 1 was 104 lux; while the value obtained for Suggestion 2 was 102 lux. These values are within the minimum illuminance according to the visual comfort standards. According to Suggestion 1, lighting system placed in master bedroom is composed of a ceiling luminaire with compact fluorescent lamps and wall scones. Thus, total power taken from the grid in the master bedroom was determined to be 126 Watt for Suggestion 1 and 36 Watt for Suggestion 2.

Kitchen: Isolux curves related to horizontal work plane in Suggestion 1 and Suggestion 2 designs for kitchen in the residential building chosen as an example for this study are determined on Figure 8 and Figure 9.

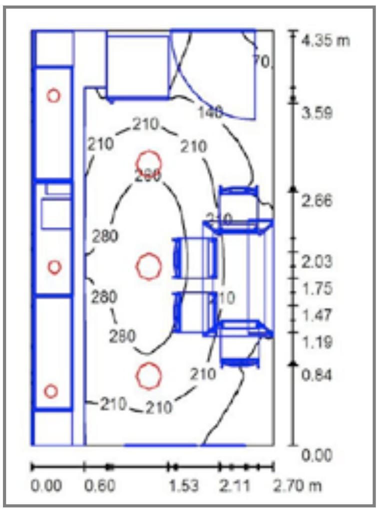

Figure 8: Isolux curves related to kitchen lighting design for Suggestion 1

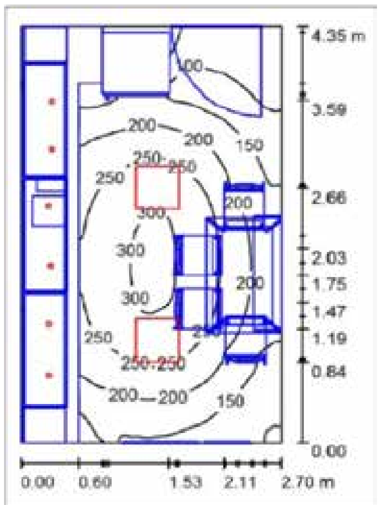

Figure 9: Isolux curves related to kitchen lighting design for Suggestion 2

In the kitchen; according to the calculations for Suggestion 1, average illuminance obtained in general space was 200 lux, and 303 lux on the counter surface. According to the calculations for Suggestion 2, average illuminance value obtained in general space was 209 lux, and 322 lux on the counter space. These values are within the minimum illuminance according to the visual comfort standards. Providing homogeneous illuminance in the kitchen was deemed necessary according to Suggestion 1, so luminaires with compact fluorescent lamps were placed on the ceiling and over the counter. The luminaire on the ceiling provided general lighting, while the armature over the counter provided illuminance approximately 100 lux higher than the general one. These values are within the minimum illuminance according to the visual comfort standards.
Total power taken from the grid in the kitchen was determined to be 114 Watt for Suggestion 1 and 58 Watt for Suggestion 2.
Lounge: In the residential building example discussed, lounge is used outside the daily life only for guests. Isolux curves related to horizontal work plane in Suggestion 1 and Suggestion 2 designs for lounge area are determined on Figure 10 and Figure 11.

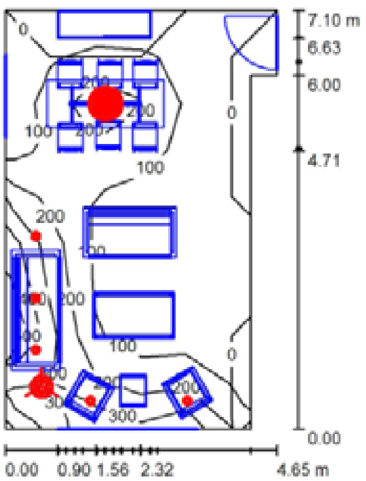

Figure 10: Isolux curves related to lighting design for Suggestion 1

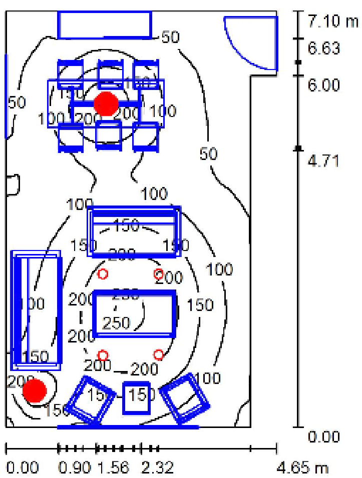

Figure 11: Isolux curves related lounge to lounge lighting design for Suggestion 2

In the lounge; according to the calculations for Suggestion 1 average illuminance obtained in the general area was 136 lux, while the value obtained for the eating area was 102 lux. According to the calculations for Suggestion 2 average illuminance obtained in the general area was 105 lux, while the value obtained for the eating area was 105 lux. These values are within the minimum illuminance according to the visual comfort standards. According to Suggestion 1, halogen and incandescent luminaire were used in the lounge area, while the lamp used in the eating area were halogen downlights._The design decision for Suggestion 2 were Led lamp versions. Thus, the total power drawn from the grid in the lounge area was determined to be 780 Watt for Suggestion 1 and 75 Watt for Suggestion 2.

Bathroom: Isolux curves related to horizontal work plane in Suggestion 1 and Suggestion 2 designs for bathroom are determined on Figure 12 and Figure 13.

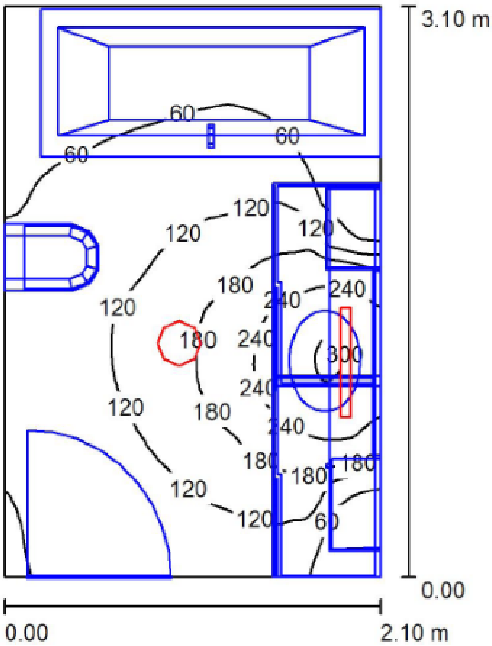

Figure 12: Isolux curves related to bathroom lighting design for Suggestion 1

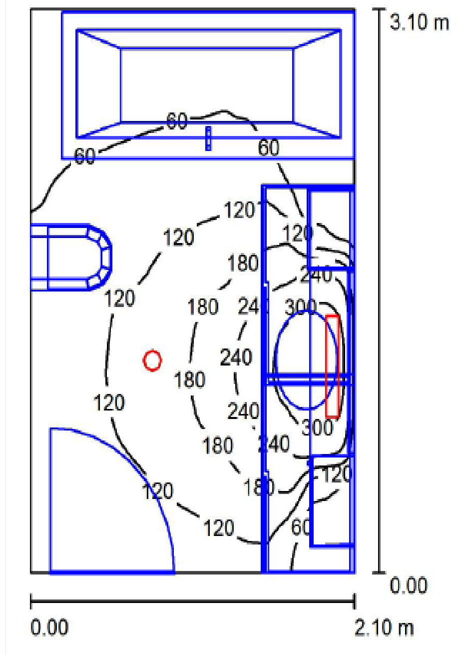

Figure 13: Isolux curves related to bathroom lighting design for Suggestion 2

In the bathroom; average illuminance obtained in the general area was 107 lux, while the average lighting level obtained on the counter in front of the mirror was 305 lux according to the calculations for Suggestion 1. According to the calculations made for Suggestion 2, however, average illuminance obtained in the general area was 114 lux, while the average illuminance obtained on the counter in front of the mirror was 302 lux. These values are within the minimum illuminance according to the visual comfort standards. According to Suggestion 1, ceiling luminaire with compact fluorescent lamp resistant to water and steam was used in the general bathroom area and linear fluorescent tube luminaire was used for the confined lighting in front of the mirror. A similar design was decided upon for Suggestion 2, but with Led lamp versions. Thus, the total power drawn from the grid in the bathroom area was determined to be 38 Watt for Suggestion 1 and 19 Watt for Suggestion 2.

Entry: In the residential building example discussed; entrance, storage area and corridor are considered as entry. Isolux curves related to horizontal work plane in Suggestion 1 and Suggestion 2 designs for entry are determined on Figure 14 and Figure 15.

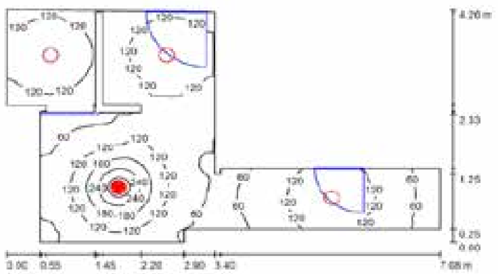

Figure 14: Isolux curves related to entry lighting design for Suggestion 1

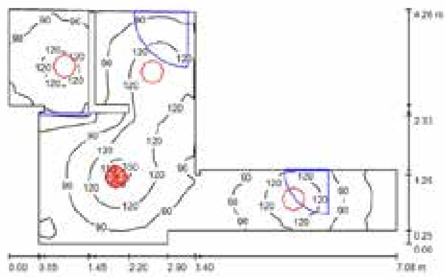

Figure 15: Isolux curves related to entry lighting design for Suggestion 2

According to the calculations made, general illuminance value obtained in the entry area was 100 lux for Suggestion 1 and 112 lux for Suggestion 2. Compact fluorescent downlights and ceiling luminaire with compact fluorescent lamps were used in Suggestion 1. Thus, total power drawn from the grid in the entry was determined to be 138 Watt for Suggestion 1 and 72 Watt for Suggestion 2.

2. Determining the Effect of Different Lamp Alternatives on the Lighting Energy Performance

Annual lighting energy requirements of the discussed residential building for Suggestion 1 and Suggestion 2 alternatives are shown on Table 1.

Table 1. Total annual lighting energy requirements according to artificial lighting system alternatives related to the residential building discussed

Artificial Lighting System	Annual Lighting Energy Requirement/kWh
Suggestion 1	2139
Suggestion2	878

The annual lighting energy requirement of the building is determined by adding the energy required for illuminating the circulation area to the sum of all apartments' requirements. Lighting power density value of circulation area is $5W/m^2$ (ASHREA, 2007) and its usage period was taken to be equal to the one of the entree areas of residential building's units [6]. Graph related to the calculated values is shown on Figure 16.

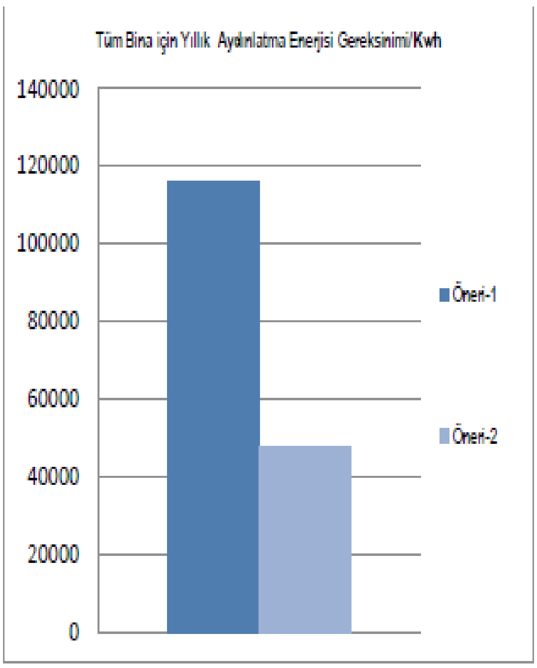

Figure 16: The calculated annual lighting energy requirements for the total building according to the Suggestion1 and Suggestion 2 alternatives.

As it can be seen on the Figure 16, the total annual lighting energy requirement of the building is calculated as *116.086 kWh* for Suggestion 1 and *47.559 kWh* for Suggestion 2.

CONCLUSION

Determination of lighting energy requirement in residential buildings is dependent on many factors such as activities in residential areas, difference in usage hours in these areas, lighting comfort requirements in lighting designs, individual preferences and users' behavioural patterns. The influence of lamp selection on lighting energy performance was determined in this study. The results of 2 different suggestions were calculated and discussed. Energy efficient Led lamps chosen for Suggestion 2 provided 1261 kWh lower annual energy requirement per house and 68.527 kWh lower annual energy requirement per building comparing to Suggestion 2 design solution with traditional lamps. By the way, evaluation of the benefits and differences in the use of LED lamps will provide a developed environment in which energy use, light quality, and longer term performance can be measured, the design approach evaluated, and occupant reaction can be collected. Information gathered from this effort, including critique and evaluation of the approach taken, will be published so that builders, architects, lighting designers, and consumers might use this information to advance positive discoveries and make improvement where needed. The aim of this study will be an advancement of lighting design quality, lamp selection by the way reduction in energy use, through demonstration of methods and technologies.

REFERENCES

[1] http://www.tedas.gov.tr/BilgiBankasi/KitaplikIstatistikiBilgiler/2009%20y%C4%B1l%C4%B1%20faaliyet%20raporu.pdf

[2] EN 15193 (2007). Energy performance of buildings- Energy requirements for Lighting European Committee, Bruge.

[3] BEP-TR Binalarda Enerji Performansı Ulusal Hesaplama Yöntemi, Ek 05-Aydınlatma, 07 Aralık 2010 Perşembe, Resmi Gazete, Sayı: 27778, 2010

[4] Sümengen Ö. (2015). Türkiye için Konut Binalarının Aydınlatma Enerjisi Gereksinimi Açısından Değerlendirilmesine İlişkin bir Yaklaşım, (Doktora Tezi), İTÜ Fen Bilimleri Enstitüsü, İstanbul

[5] Perdahçı C., Hanlı U., "Verimli Aydınlatma Yöntemleri "TMMOB Elektrik Mühendisleri odası III. Enerji Verimliliği ve Kalitesi Sempozyumu 21-22 Mayıs 2009, Kocaeli.

[6] ANSI/ASHRAE/IESNA Standard 90.1 2007. (2007). Energy standard for buildings except low-rise residential buildings, Atlanta, ABD.

Urban - Policy

Paper No: 5

Social and Environmental Sustainability Through Green Urban Transformation

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ABSTRACT

The fact that green buildings facilitate lower utility expenditures for the occupants, makes the Urban Transformation Projects the best candidate for adoption of green building principles into the specifications of these government regulated developments. This is suggested to create an approach that is socially sustainable while providing environmental sustainability. However, due to the higher investment costs for green buildings, and as the developers are not the future owners of the buildings, it is suggested that the interest in the Green Urban Transformation can only be possible through incentives put forward by the government. A suggestion to this aim is to finance the increase in the initial investment through a controlled increase in the permitted construction area to balance the increased cost based on the specifications defining the criteria for green buildings. Major sustainability criteria that are proposed for inclusion in such technical specifications are; increasing the open space, increasing the thermal performance of the envelope, utilizing the solar heating systems for a fraction of hot water supply in combination with conventional systems for higher heating requirements, and supplying electricity for the solar heating system by solar panels to provide continuity of services in cases of service shortages.

Keywords: Green Buildings, Urban Transformation, Housing Finance, Solar Heating.

INTRODUCTION

Urban Transformation Projects are carried out in Turkey within the legal framework that is put forward after the severe earthquakes in 1999, that revealed the vulnerability of the existing building stock. Due to the operational and financial difficulties involved in such a large number of repair, strengthening and replacement requirements, the projects are left to the private real estate developers, who has to agree with the building owners, where the agreement involves exchange of property rights in return for additional building area permits; which also brings the municipalities in the model as facilitators, through provision of increase in construction area by changing the zoning limitations.

The end product, mostly being gated residential complexes, usually has quite high operational costs, which can be said to be a result of the appetite of the developer to reduce the initial costs, hence disregarding the lifecycle costs of the selected infrastructure and also to increase the sellable area and disregarding the open area and service roads needs. Thus, the comfort loss and high operational costs become a burden for the occupants, as they are not involved in the decisions shaping the project, rather the decisions are serving maximization of the developer's profit. Especially for the middle-income owners, higher heating and electricity expenses may even force the existing owners out of the new facility, creating a social sustainability problem as well.

It is proposed in this study that, being facilitator of the Urban Transformation through serving additional construction area, the municipalities can impose sustainability requirements for the new constructed facilities, by putting control on the profit that is made by the developers. A model without financial justification will not find applicability in the real estate market. Therefore, a sustainable urban transformation model with financial justification is proposed.

1. FINANCING MODEL

1.1. Distribution of Shares without Sustainability

The financial model proposed for urban transformation is based on the transfer of land rights which is the applied model in almost all of the urban transformation applications in Turkey. The proposal herein tries to find the best distribution of share of rights in the new constructed facility, between the contractor and the existing building owners. Share of the contractor in the new facility can be calculated from, [1]:

$$X = \frac{Unit\ Cost\ (1 + Profit\%)}{Unit\ Price} \qquad (1)$$

where,

X: Contractor's Share in Total Construction Area of New Building
Unit Cost: Cost Estimate for 1 m^2 New Residential Construction (Declared officially every year by the Ministry of Environment and Urban Planning)
Profit%: Net profit expectation of the developer (can be fixed for the urban transformation projects)
Unit Price: Market price for 1 m^2 New Residential Construction in that particular region

Additional permit for construction area, E, that should be provided by the municipality and total construction area, A, then can be calculated from, [1]:

$$E = \frac{1}{1 - X} \qquad (2)$$

$$A = E\ x\ O \qquad (3)$$

where,

E: Ratio of new construction area over the existing construction area (New construction permit necessary for a profitable exchange of land)
O: Construction area needed for the existing owners

1.2. Introducing Cost of Sustainability into the Model

It is proposed that, additional costs of sustainability can be balanced by increase in construction area permit and thus, paying this increase in cost to the developer with the additional construction area. However, in very congested regions, it should be tested if this proposal is applicable.

Some parameters for sustainability are tested herein, for two regions of Istanbul, to understand if the model works. The sustainability parameters introduced n this study are:

1) Providing 60% open space: It is proposed to occupy 40% of the land for the buildings base area; leaving 50% bare land and an additional 10% to public amenities, such as roads, infrastructure etc.,

2) Improving the thermal conduction of the exterior walls to reduce heating load of the residential units, thus reducing heating costs of the future owners. The heat conduction coefficient used in this study is 2.1 W/m^{2}K. Cost of introducing the façade details to achieve this value is approximately calculated, based on the study in reference [2] as 50 TL/m^2.

3) Using solar hot water panels to support heating in winter and for domestic hot water needs, to reduce gas consumption, hence costs. It is suggested to use a heat pump solar heating system, backed up with natural gas private heating system for extreme weather conditions. Cost of this system is estimated approximately as 200 TL/m^2, based on the study in reference [3].

4) Using solar electricity panels of 5kW per unit, to provide electricity for heating system and as emergency backup for selected systems, when city grid fails. Cost of the solar panels is approximately calculated as 100 TL/m^2, based on the study in reference [4].

Additional sustainability practices, such as rainwater harvesting can also be simply introduced into the model; however the investment costs and benefits from the open-space and heating costs are comparably much higher and they are studied herein to test the model's applicability.

1.2.1. Testing the Model

The model is tested for two real applications in Istanbul:

A) Esenler Municipality - Havaalanı Mahallesi- Urban Transformation Project, [5]:
This project is upon completion as of 2016. It is located on 40 ha area where there are 1435 existing units. Total existing usable area (excluding some undeveloped lands) is 126,491 m^2 and after the urban transformation, area returned to owners is 133,533 m^2 including those returned for undeveloped land. After the urban transformation total number of units completed is 2428, [6] and total 320,000 m^2 area is designed, [7].

B) Fatih Municipality –Sulukule Mahallesi- Urban Transformation Project, [8]:

This finished project is located on a 91,731.46 m^2 area in Hatice Sultan and Neslişah Sultan mahallesi and the net area developed is approximately 6.2 ha. , [9]. There were 673 existing units, partly owned by the state. After urban transformation, 631 new units are constructed, [10].

C) Küçükçekmece Municipality – Tepeüstü-Ayazma Mahallesi- Urban Transformation Project

The project area is 115 ha Ayazma mahallesi and 24 ha Tepeüstü mahallesi, of which 55 ha has public owners and 60 ha has private owners. There were 1800 units in the region before the urban transformation, [11, 12].

2640 social housing has been constructed within the framework of urban transformation. The project is still in progress.

Calculation of the total permissible construction area with imposed profit percentage and sustainability criteria is shown in Table 1. Unit price for new construction is calculated as average of various real estate ad's for these units.

Table 1 Data for Some Urban Transformation Projects

Project	**Land (x1000 m²)**	**Existing Units**	**Developer's Profit**	**Unit Price(1) (TL)**	**Unit Cost(2) (TL)**	**Sustaina-bility Cost (TL)**
Esenler-Havaalanı	400	1435	%50	2315	800	350
Fatih-Sulukule	62.6	673	%50	3864	800	350
K.Çekmece-Tepeüstü-Ayazma	1150	1108	%50	3421	800	350

(1) Market price, as of year 2016 [13].
(2) Unit area cost, declared by the Ministry of Environment and Urbanization for calculation of design services – for Class IV-A type building, year 2016 [14].

Table 2 Calculations for Zoning Permit and Contractor's Share for Urban Transformation, without Sustainability Costs

Project	**X**	**E**	**A(2)**	**Base Area(3) (x1000 m²)**	**No.of.Floors**
Esenler-Havaalanı	52%	2.08	297 939	160	1.86
Havaalanı (Sustainable)	75%	3.92	563 055	160	3.52
Fatih-Sulukule	31%	1.45	97 615	24	3.90
Sulukule (Sustainable)	45%	1.81	121 574	24	4.85
K.Çekmece-Tepeüstü-Ayazma	35%	1.54	277 253	470	0.59
Tepeüstü-Ayazma (Sustainable)	50%	2.02	363 078	470	0.77

(2) Total construction area, based on average 100 m² unit size, per existing owner
(3) Total base area occupied by the buildings on this land

1.2.2. Handling the Public Share

The model above handles the ownership rights, where the buildings are 100% owned by private owners. However, there are lands where there is public and private ownerships co-existing and the ownership rights of the public has to be also protected. Currently, this issue is being handled for publicly owned lands, through public's partnership with the private developers on the basis of "revenue sharing" model. In urban transformation, the strategy can be evaluated on the basis of the density of the existing buildings. If there is sufficient land to return a basic and sustainable living standard for the existing owners, then the public's additional benefits can be minimized. Otherwise, the land sufficient to make a sustainable urban transformation can be developed on the basis of the model proposed herein, and the rest of the land can be utilized by the public institutions, either for infrastructural needs or for public housing through revenue sharing model.

CONCLUSION

- Urban transformation involves transfer of public's property rights or publicly owned lands and therefore it can and should be regulated by the government.
- Success of the urban transformation is based on its economic feasibility and the owner's assurance of a fair distribution of ownership rights, hence protection of the owner's rights. This is possible by controlling contractor's profit and calculating the share distribution accordingly as proposed herein.
- To eliminate the social problems, such as inability to stay in the neighborhood, due to either enforcement of the developer, or inability to pay for the operation costs of the new buildings, sustainable buildings may provide solutions.
- It is proposed in this study to reduce the base area of the buildings to 40%, leaving 60% open space and to incorporate solar heating and solar energy, as sustainability parameters. Even for as high as 44% increase in construction costs attributed to sustainability, it is shown that the sustainable urban transformation through regulations is applicable, even in very congested zones of İstanbul.
- The formulas proposed herein also provides a basis for the share of rights between the existing owners and developers. Rights of the public can then be adjusted, depending on the building density of the area and the zoning limitations appropriate for the region.
- Testing of the formulas on three different regions; one being a densely occupied, one at moderate density and one with very small density. It is shown in Table 1 that, even in very densely populated zones, it is possible to handle a fair share between the developer and the existing owners, despite very large increases in construction cost due to sustainability. In this very dense region, the necessary building heights do not exceed 5 floors, giving the opportunity for a more aesthetic planning for the project.
- Other considerations, such as public amenities, infrastructure, etc can also be handled, considering flexibility left after the ownership rights are distributed to the existing owners and the developer.
- Sustainable buildings can also increase resilience of the buildings in service shortages and will also reduce the overall energy consumption within the city, considering the size of the replacement needs in the cities.

REFERENCES

[1] Köylüoğlu, Ö. Urban Transformation Opportunity for Sustainable Development and Benefits Based on LCC Analysis. Report of IABSE Conference-Structural Engineering: Providing Solutions to Global Challenges, September 23-25 2015, Geneva, Switzerland, pp. 1943-49.

[2] Kocak S., Sasmaz C., and Atmaca I. Technical and Economic Investigation of a Shopping Mall Insulated in Accordance with TS 825 for Different Heating-Day Regions. Tesisat Mühendisliği Dergisi. 2012; 128: 76-88. Can be downloaded at: http://www.mmo.org.tr/resimler/dosya_ekler/d1e6ba97ecbb8d9_ek.pdf?tipi

[3] Ozyaman A.C. Space Heating Example using Solar Energy Supported Heating Pump. Sablon Magazine. 2011; June: 68-75. Can be downloaded at: http://www.mmo.org.tr/resimler/dosya_ekler/ad36576a641973b_ek.pdf?dergi=1148

[4] Example Household Power Supply by Solar Panels. Can be downloaded at: http://sunen.tr.gg/KONUT-PROJES%26%23304%3B.htm

[5] http://www.esenler.bel.tr/Files/KENTSEL_DONUSUM_SUNUM-Banner_icinn.pdf

[6] http://emlakkulisi.com/esenler-havaalani-kentsel-donusum-konutlari-bugun-teslim-edilecek/470938

[7] http://www.keym.com.tr/portfolio-view/esenler-ilcesi-havaalani-mahallesi-kentsel-donusum-projesi/

[8] http://www.fatih.bel.tr/icerik/1155/neslisah-ve-hatice-sultan-sulukule-mahalleleri-yenileme-projesi/

[9] http://www.mimdap.org/?p=9568 (sulukule data)

[10] http://www2.tbmm.gov.tr/d24/7/7-34270sgc.pdf

[11] http://www.kentseldonusumplatformu.com.tr/turkiyeden-projeler.php?qu=10&proje=K%FC%E7%FCk%E7ekmece-Ayazma+Tepe%FCst%FC+Kentsel+D%F6n%FC%FE%FCm+Projesi

[12] http://emlakkulisi.com/istanbulun-kentsel-donusum-projelerinde-son-durum-ne/1655

[13] http://www.yeniemlak.com/istanbul-emlak-haberleri/istanbulda-konut-metrekare-fiyatlari-hangi-ilcede-ne-kadar-oldu

[14] http://www.resmigazete.gov.tr/main.aspx?home=http://www.resmigazete.gov.tr/eskiler/2016/04/20160411.htm&main=http://www.resmigazete.gov.tr/eskiler/2016/04/20160409.htm

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Sustainable Urban Transformation in Turkey: A Great Undertaking

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ABSTRACT

The world today faces far-reaching challenges that affect us all and the rightful minds should be concerned by the way the world is moving forward. Problems such as unplanned urbanization, scarcity of natural resources and economic uncertainty require holistic solutions. In recent years, a rising demand for "green" and "smart" cities originated from the debate on how to challenge with climate change.

As a developing country, Turkey incorporates various opportunities for Real Estate sector. In order to comply with EU norms, numerous legislations for building energy efficiency and sustainability have been considered.

Additionally, Urban Regeneration Program, one of the biggest urban restructuring movements in the world, gaining pace year by year, expected result in reconstruction of more than 7.000.000 dwelling units until 2023. If administered properly, this could be a very important opportunity for Green Development and sustainable cities. There are and will be incentives for green and smart cities with high efficiency, which protects environment, enhances economy and enliven social life, hence providing a more quality way of life.

INTRODUCTION

According to United Nations Department of Economic and Social Affairs (World Urbanization Prospect Report - 2014 Version) [1] more people live in urban areas than in rural areas, with 54 per cent of the world's population residing in urban areas in 2014. In 1950, 30 per cent of the world's population was urban, and by 2050, 66 per cent of the world's population is projected to be urban. The urban population of the world has grown rapidly since 1950, from 746 million to 3.9 billion in 2014. According to the report, as the world continues to urbanize, sustainable development challenges will be increasingly concentrated in cities, particularly in the lower-middle-income countries where the pace of urbanization is fastest. Integrated policies to improve the lives of both urban and rural dwellers are needed.

Starting from 1960's, one of the main problems in Turkey has been informal settlements caused by the unplanned, rapid population growth. This ongoing problem resulted in a huge inventory of buildings that are vulnerable to natural hazards, mainly earthquakes and floods.

A progressive urban renewal and transformation has started in Turkey after May 2012 when the Law of Transformation of Areas under the Disaster Risks (No. 6306) (so called Urban Regeneration Law) and related legislation was adopted. The law aims to reconstruct approximately 7 million Dwellings which are under risk by 2023. [2]

Regulations issued under Urban Regeneration Law define procedures and provide further information regarding fundamental steps of the process. This includes information about the relevant authorities and their scope, property rights, exchange processes for the type and place of the property and assessment of the risk-prone buildings and areas. Several Public Institutions are given vast authorities which should be exerted carefully in order to protect rights of all parties.

Such a huge undertaking came up with its own problems, including excess funding needs and problems associated with high density development. The magnitude of required funding exceeds 500 billion USD. Additionally, imminent earthquake risk mandates rapid action, which results in expedited If not over fast planning processes. Defectively, these problems are trying to be solved by increase in development density and urban sprawl.

In addition, due to the delay of the process, current urban transformation is limited only at the building level, whereas real benefits are usually achieved in broader scale transformation. Modern urban planning strategies such as smart growth and planned development incorporate features mainly related to macro level planning.

Eventually, limiting urban transformation only in lot level may avert the earthquake risk in the new emerging residential areas. But it shall also bring problems triggered by population growth such as chronic traffic congestion, loss of green spaces, and lack of open spaces and inefficient use of resources.

Land-use problems will gradually increase along with an intense urban sprawl caused by rapid increase in the population. The character of the urban areas that are composed of roads, offices, shops, residential areas and open public areas will affect the life quality of inhabitants as well as the environment.

Considering the fact that the newly developed urban areas would be used for decades, not only the construction of earthquake resistant buildings, but also designing and developing the neighbourhood and urban areas which have the minimum impact on the environment, protect the existing ecology and the habitat, keep the energy efficiency at the forefront and provide healthy and comfortable living space for its users, bears great importance for cities in Turkey.. As an example, it could be argued that, if all buildings in the urban transformation achieved the international energy efficiency standards, the energy savings from these buildings would be about $3 billion annually. This amount is approximately 10% of Turkey's annual current deficit and can be an additional financial resource for the urban transformation program. In addition, the importance of green transformation would be better understood when the increase in human productivity and efficiency is realized.

This Paper provides insights regarding the common urban problems of cities in Turkey and discusses the potential benefits of adopting green urban systems through urban Regeneration program.

GREEN CITIES: Why Do We Need Them?

Edward Glaeser's Book Triumph of The City (2011) [3] provides a detailed vision regarding the features of a successful city, as well as those that can enlead a city's downfall. Glaeser states that although all of humanity could fit in Texas, each with a personal townhouse, people chose to live in cities mainly because of the convenience and benefits of proximity. Glaeser states that, value of being face to face that comes with a reasonable level of urban density shall be one of the reasons for innovations that is the main driver for successful cities. He stresses that "There is no such thing as a successful city without human capital". The main reason for the success of cities is to bring skilled people and ideas together by providing a high level of life quality. According to Glaser, This can only be done by providing a good infrastructure, keeping housing costs low, reducing congestion, and promoting education. Most of the best practices and case studies from different cities involve common urban problems. Also strategies and measures that have been used to address these are usually parallel with sustainable development methodologies. Criteria presented by green building and green community rating systems are being developed to respond many of the problems inherent in today's urban spaces. Although these problems may differ due to geological and socio economic reasons, they could still be consolidated and grouped according to their sources:

TRANSPORTATION RELATED PROBLEMS

Transportation related problems, especially congestion are usually ranked first among today's urban development problems. Traffic congestion is basically defined as [4] ***"a condition on transport networks that occurs as use*** *increases, and is characterized by slower speeds, longer trip times, and increased vehicular queueing. The most common example is the physical use of roads by vehicles"*

Congestion in major cities of Turkey, primarily in Istanbul has come up to very severe level in last years. Traffic congestion in Istanbul has impact in different dimensions. It results in waste of valuable resources such as time, energy and money, has negative effects on environment by increasing carbon emissions and has adverse effects on quality of life in otherwise such a beautiful city. It is evident that these problems are usually caused by unplanned urban development and /or insufficient urban planning. Contemporary sustainable urban planning promote strategies such as, compact development, walkable streets, proximity to amenities, public transport access and alternative transportation systems [5].All of these practices are major aspects of Green Neighbourhood Design and Construction. It is foreseen that implementation of these strategies both in urban and building scale will reduce the individual use of fossil fuels by reducing dependency on car, as well as providing a solution to congestion problems, contributing to the reduction of carbon emissions.

Urban Regeneration projects; when applied at regional level instead of building or lot level, shall have the flexibility to adopt strategies for sustainable transportation. These may include provision of additional public transport, adoption of compact design strategies to increase walkability, alternative and low emitting transportation infrastructure such as bicycle network and Electric vehicle charging stations.

Public Planning of Urban Regeneration in different risk prone regions of Istanbul should be made not only to avert disaster risks but also to reduce the need for passenger cars, improve public transportation and alternative transportation infrastructure. In current controversial status, involvement of public authorities in planning and provision of additional regulations to current legislation at a macro level is a must. This subject is too important for the success or failure of Turkish Urban Life to be left to the private sector. Public authorities must lead the way and this guidance should follow green development principles, and must include all aspects of green community design and construction.

Some of the best practices for sustainable transportation in urban areas include [6]:

<u>Compact Development:</u> New Projects should be designed and built to meet the specific densities for the region. Public authorities and Urban Planners must determine densities to encourage balanced communities with a proximate housing and employment opportunities. Sustainable urban planning in Renewal Areas must diminish the need for passenger car use by reducing the adverse effects of urban sprawl.

Urban Regeneration projects that have high levels of internal connectivity and are well connected to the community must be encouraged (financially and/or by additional zoning rights) to form mixed use neighbourhoods.

<u>Walkable Streets:</u> In order to reduce the negative impacts of passenger car use, and reduce vehicle distance travelled, Municipalities must provide secure, appealing, and comfortable streets that encourage pedestrian use. Projects that border a part of the circulation network must meet a previously determined height-to-street with ratio. Also Continuous sidewalks or equivalent all-weather routes for walking are provided along block length within new projects.

<u>Bicycle Use Network and Infrastructure</u>: Each building must be required to designate areas to install adequate amount of bicycle racks depending on the size of the building or projected amount of building users.

Municipalities must be encouraged to plan and develop Bicycle networks that are easily accessible and well-maintained. These networks could be developed with coordination and funding support from the Real Estate

Developers in Urban Transformation areas.

Electric Vehicle Infrastructure: Public programs must be developed to encourage developers and public institutions to install EV charging stations in Urban Regeneration zones. Preferred parking spots and parking incentives for EV owners could also be applicable.

Transportation Demand Management: Multimodal travel in urban renewal areas must be encouraged in order to reduce car related negative impacts such as energy consumption, pollution, carbon emissions. Several strategies may be applicable depending on the regulations.

Sustainable Travel Plan: Commercial Buildings such as Office Towers, Shopping Malls, Public Institutions, HealthCare Facilities and other buildings with high level of daily transients and commuters must develop and present a sustainable travel plan, where building users are informed about alternative transportation methods to reach the facility. This plan must include key performance criteria in order to reduce the need for travel, reduce the length of trips, reduce distances from buildings to public transport access, and encourage sustainable transport preferences.

Developer Sponsored Transit Services: A program for Urban Regeneration areas should be established to provide year-round, developer-sponsored transit service (vans, shuttles, buses) from at least one central point in the project to other major transit facilities or to other destinations, such as a retail or employment centre, with specific frequency of trips. Secured parking stops and bicycle parking racks must be also provided in each major transit point.

Vehicle Sharing: Developers in Urban Regeneration areas must be encouraged to introduce specific vehicle sharing programs. Parking capacities must be designated in order to encourage vehicle sharing.

Provision of Local Parking: Parking regulations for the newly transformed places must be customized. Appropriate level of parking that encourages sustainable alternative transport choices must be determined with feedback from the local authority, developer and other relevant parties. The number of parking spaces for each development must be determined by considering several factors including:

- Size and type of development
- Distances between parking and residential areas
- Expected levels of car ownership in building users and visitors
- Other vehicle uses
- Proximity to facilities and Public transport

LOSS OF GREEN SPACES

Built Environment emerged by uncontrolled population growth and unplanned development, urban sprawl may lead to an increase in building footprint and loss of green areas. Accessible green space should be located close to residential areas, walkable, physically accessible, safe to use, and provides well maintained facilities. [Definition by Public Health England]

The World Health Organization (WHO) has suggested that every city should have a minimum of 9 square metres of green space per person.[7] According to the Turkish construction zoning law (1999 Addenda) green space per person must be at least 10 m2 in major cities.[8]

According to 2014 data, Istanbul, one of the biggest metropolitan areas in the world, with a population of over 14 million people, provides only 5.61 square metres of green space per capita. [9]

This is one of the urgent problems facing new urban transformation program in Turkey, especially in Istanbul. Problems such as loss of human interaction with nature, negative impact on biodiversity, flooding issues related with rainwater drainage and heat island effects shall arouse. In particular, reduction in the percentage of green areas constitutes a serious network problems as heavy rain and flooding cause life and property losses in dense urban areas. One of the important aspects of Turkish Urban Regeneration is to transform areas under any natural hazard risks. So far only earthquake risks are fully accounted for. Although seismic risks are very high in most parts of Turkey, other natural hazards such as flooding must also be taken into account, especially in some areas located in dense urban centres such as Istanbul. Green Building and community systems offer several strategies to protect or restore habitat, to increase public open space and parks, and to promote sustainable landscaping. Some of these strategies shall be adapted to Urban Transformation Legislation:

Open Space Requirements: Current construction regulatories should include minimum vegetated open space ratios. Development densities must be arranged accordingly. This should be controlled during construction permit stage. Each residential development located in Urban Regeneration Areas must be within walking distance of at least one public open space such as a park or a sport field.

Protection and/or Restore Habitat: Construction sites larger than a determined size must present a before/after analysis regarding impact on ecology and biodiversity. Any flora/fauna located on the previous site must be determined before the commencement of construction activities and strategies to protect or restore any significant ecological features must be reported by a qualified professional.

Flood Risk Analysis: Flood Risk Maps of Istanbul are still under development stage. Any Construction site larger than a previously determined size and that does not have a flood map, must present a flood risk analysis report. A flood Risk analysis is different than storm water sizing calculations that are already required. It should provide a flood level, probability of flood risk, by considering all the sources of it in the region and any precautions to avoid them. If possible, redevelopment must be avoided in previous urban sites with high probability of Flooding.

EFFICIENT USE OF WATER RESOURCES:

Reduction of fresh water sources and the growth in population suggest that access to water sources will be a serious problem in the near future. Turkey with annual amount of 1519 m3 of water is among the poorest countries in terms of water resources. [10] A growing population requires efficient and effective use of these resources. For new developments, water usage must be reduced compared to a baseline. Green buildings respond to these needs through the implementation of several strategies:

Water Efficient Fixtures: For new developments in Urban Regeneration areas, building regulations must specify max. water consumption levels for all newly installed toilets, urinals, private lavatory faucets, and showerheads. National or International labelling systems must be required to show compliance.

Alternative Water Sources: In order to reduce burden on sewer system and to reduce use of potable water, strategies like Grey Water and Rain water reuse should be adopted in Urban Renewal Projects.

Grey Water is defined as "relatively clean waste water from baths, sinks, washing machines, and other kitchen appliances."[11] Special treatment systems have been developed to treat Greywater back to appropriate standards and facilitate its use for irrigation and/or for flush fixtures, which will reduce the burden on the sewage system by limiting the amount of wastewater required to be conveyed and treated, as well as reduce the unnecessary demand for fresh clean water.

Rainwater Harvesting is actually "the accumulation and deposition of rainwater for reuse on-site, rather than allowing it to run off." [12] This is one of the most effective sustainable solution for urban regeneration projects. One of the important environmental problems associated with increasing level of construction in Turkey is loss of permeable green areas and increase in impermeable hardscape. This results higher discharge rate in common rainfall events and problems with drainage infrastructure. Several flooding event has occurred in even newly developed parts of Istanbul where development density is high. There is a cheaper solution to this problem than reinstalling infrastructure with a higher capacity. All new buildings must be required to install rainwater harvesting systems to prevent conveying rainwater directly to the public storm water system in a major rainfall event. Capacity of the system must be determined during design development stage by considering several factors, including the size of the collection area, point of use, project size and occupancy.

Irrigation Efficiency
Project located in Urban Regeneration zones must be required to install only native or adapted species that require less water and maintenance. Water Efficient Irrigation systems must be installed. Additionally, Drought tolerant and non-invasive plants that enhance biodiversity must be specified. Landscape design must include the utilisation of Alternative water sources.

ENERGY:

According to International Energy Agency; Energy Supply Security and costs of energy demand are ranked high amongst the major problems of the World Today. [13]The use of fossil fuels for energy has several adverse effects in both environmental and economic dimensions Excess use of these fuels with limited sources shall result in fluctuation of energy prices, bringing further geopolitical and economic problems, sometimes resulting in wars. Additionally, fossil fuels are one of the main reasons for air pollution and carbon emissions causing global warming.
Current Research by UNEP (United Nations Environment Program) [14] demonstrates that buildings are responsible for 30% of energy consumption and approximately 40% of GHG emissions. In Turkey according to Ministry of Environment and Urbanization approximately 35 % of the total secondary energy is consumed in Buildings and Services. Also energy import contributes app. 60 % of Turkey's current account deficit. Hence, any improvement in Energy efficiency of Buildings shall have direct positive impact on environment and economy.
Efficient design, installation and operation of energy consuming service systems in buildings including HVAC, lighting, insulation, automation systems etc. is one of the most important topics under green building systems. Additionally, where available, adequate use of alternative and low carbon energy technologies such as solar, wind power, CHP (Combined Heat and Power) systems are encouraged. Turkish Energy Efficiency Law and Building Energy Performance Directive mandate compliance with international standards for energy efficient design and requires feasibility studies on renewables and low carbon energy systems. All of the existing and new buildings are also required to get Energy Performance Certificates (EPC) to display the level of energy consumption of the building. Although sufficient legislation for energy efficiency is in place with respect to EU compliance agenda, quality control mechanisms are still not working properly. This must be improved during Urban Renewal Progress, making energy efficiency a primary target for newly built structures. As stated above Urban Regeneration program has a energy cost savings potential of 3 Billion USD if all buildings under urban transformation achieved the International Energy Efficiency standard Ashrae 90.1. This amount is approximately 10% of Turkey's annual current deficit and can be an additional financial resource for the urban transformation program.

Several energy efficiency strategies could apply for projects in Urban Regeneration Areas;

Energy Efficient Facade Design: Current Turkish Thermal Insulation standard TS 825 must be improved by starting with selected projects in pilot urban regeneration areas, and adopting further nationwide. Glazing and drywall systems must be specified according to thermal properties.

Alternative Energy Sources: Geographically, Turkey is at a very advantageous location for the utilisation of solar and wind power. Additionally, with the increasing source of supply, costs to install domestic solar and wind systems are getting lower each year. There are some bureaucratic problems with the successful integration of these systems to the grid. These issues must be resolved primarily for Urban Regeneration Projects, where installing a solar system is more attractive to the developer.
Where possible and feasible, district heating systems and Combined Heat and Power (Cogen) systems must be considered for further energy efficiency.

Energy Efficient HVAC Equipment:
HVAC systems include heating, ventilating and air conditioning equipment and usually controlled via BMS systems. HVAC systems use up to 35% of total building energy. [15] The selection process for these systems must include energy efficiency as a major criteria.
Turkish Building Energy Performance Directive sets the standards for relevant systems. Additionally, ASHRAE 90.1 Energy Efficiency Standard could be used as a guideline for speciation of complex HVAC systems.

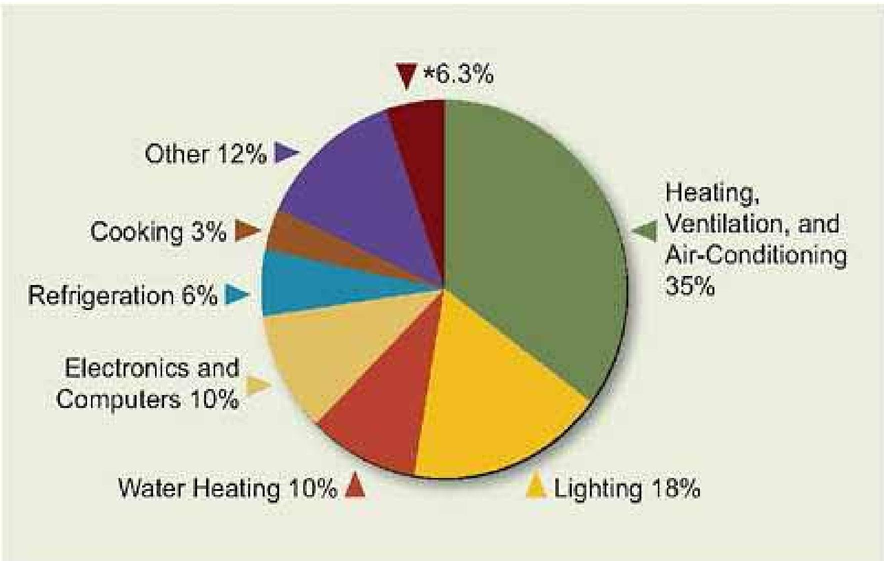

Figure 1: Building Energy End Uses [16]

Energy Efficient Lighting Systems:
High performance lighting systems, including indoor and outdoor lighting must be speficied in projects located in Urban Regeneration zones. Indoor and outdoor Lighting Power Densities (LPD) must be predetermined for project types and compliant lighting fixtures with designated lumen/watt ratios as well as required lighting levels must be installed.

QUALITY OF LIFE:

People spend 90% of their lives in buildings. [17] Therefore, design of buildings must secure the comfort and health of its users. In return, the productivity will increase and the life quality shall improve. In the design of green buildings and cities, many issues related to human health and comfort are considered.

Daylighting: Sufficient access to daylight improves indoor environmental quality as well as reduces the need for artificial lighting and energy consumption. Adequate access to daylight for all building users must be taken into consideration during the design process of new projects located in Urban Regeneration areas. Daylight modelling must be performed for new projects as a part of design development and results must be approved by the authorities.

Open spaces with vegetation: As stated above, according to World Health Organization (WHO), life quality in a city is directly correlated with the amount of green space per capita. WHO recommends at least 9 m2 of green space/ per person. Urban Regeneration program is a great opportunity for Turkey to increase its green space, especially in major cities, primarily in Istanbul.. This could only be achieved through master planning and urban regeneration at block or regional level. Current urban regeneration process going on Istanbul is usually on plot level, where only one building is demolished and a bigger one is constructed, sometimes with a larger footprint. This approach limits the opportunity to increase open spaces.

Indoor Air Quality: Provision of adequate levels of outdoor air is crucial for all types of buildings with occupants. In Turkey, common approach for ventilation in residential buildings is natural ventilation where air comes into the building through operable windows and doors on the façade. Although this could be an efficient approach in regions where climate is mild and transitional periods are long, it might bring additional thermal and moisture problems in other places with severe climates. Additionally, utilisation of natural ventilation in high rise residential buildings is very hard and usually causes problems with thermal comfort. Serious consideration must be given to ventilation design of urban regeneration projects located in regions with severe weather conditions and /or projects with high rise buildings.

International standards including EN and Ashrae norms must be specified in urban regeneration construction documents.

Low Emitting Materials: Low-emitting materials are products that do not release significant pollutants into the indoor environment such as Volatile organic compounds (VOCs). [7]

According to EU, A VOC is any organic compound having an initial boiling point less than or equal to 250 °C (482 °F) measured at a standard atmospheric pressure of 101.3 kPa

Some VOCs are dangerous to human health or cause harm to the environment. Harmful VOCs typically are not acutely toxic, but have compounding long-term health effects.

Hence Construction chemicals that are going to be used in New Construction project must be regulated further to comply with international VOC Limits.

Noise Pollution Prevention and Acoustic Design:

With the increasing number of urban population, local authorities need to continue their efforts implement better measures to mitigate noise pollution in more and more densely populated cities. One of the major contributors of noise pollution is transportation systems. Sustainable Transportation planning must also consider effects of noise pollution. In Urban Regeneration areas, design and specification of building materials must be in compliance with Turkish Environmental Noise Directive [18] and other international standards accredited by authorities.

MATERIALS AND RESOURCES

Demolition and rebuild of hundreds of thousand building in the upcoming years shall result in generation of large amounts of waste and vast use of construction materials.

This process must be well managed under Green principles such as:

<u>Regional Materials:</u> Selection of regional materials in large construction projects shall increase demand for building materials and products that are extracted and manufactured within the region, thereby supporting the use of indigenous resources and reducing the environmental impacts resulting from transportation. Regulations must encourage Urban Regeneration projects to Use a certain amount of building materials or products that have been extracted and manufactured, within certain proximity of the project site.

-
<u>Construction Waste Management</u>: Demolition of old buildings in large numbers must be controlled under well-developed waste management program. Necessary actions must be taken to divert construction and demolition debris from disposal in landfills and incineration facilities. When available, reusable and recyclable materials must be diverted to recycling facilities and/or reuse in construction sites. A waste management that includes issues such as strategies to reduce waste generated on site, procedures to sort and reuse/recycle different types of wastes on and off site must be developed as templates by the Public Authority. These plans must then be customized for each project located in the region Turkish laws require each building to designate areas for the separation of recyclable waste. [19] Compliance with these regulations must be strictly enforced. Public Institutions must facilitate the required infrastructure and provision of facilities for waste management.

CONCLUSION

Residential Areas developed under sustainable urbanization principles shall contribute to improvements primarily in quality of life in major cities which will go under a macro-scale transformation during Urban Regeneration. As a result, inhabitants could benefit from economic and ecological improvements, while the investors will benefit from new sustainable tools. While the main reason for the UR is to rebuild structurally risk prone building stock, a better urban life could also be developed concurrently. Turkey with a level of Urbanization above 70 %, (See Fig. 4), Environmental decisions made over the upcoming years will be crucial to meeting the global sustainability challenge.

If environmental concepts are adopted into urban programs today, there will be a chance for future generations to avert negative impacts of urbanization. The benefits for green cities include increased resilience to the impacts of climate change, but also a better quality of life for residents. Green buildings are important features that pave the way to green cities. According to USGBC (United States Green Building Council), Green buildings contribute to environment and economy by reducing Energy use, CO2 emissions, Water Use and Solid waste.

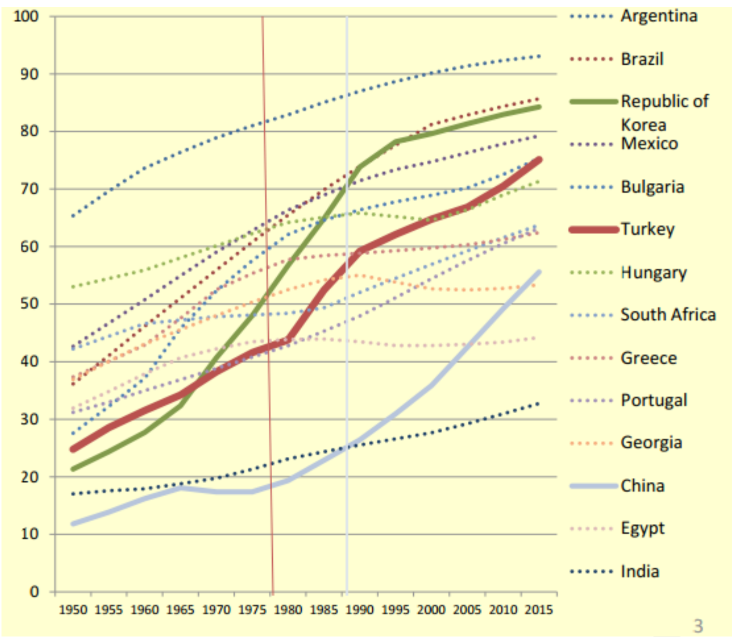

Figure 4: Unprecented Pace of Urban Growth [20]

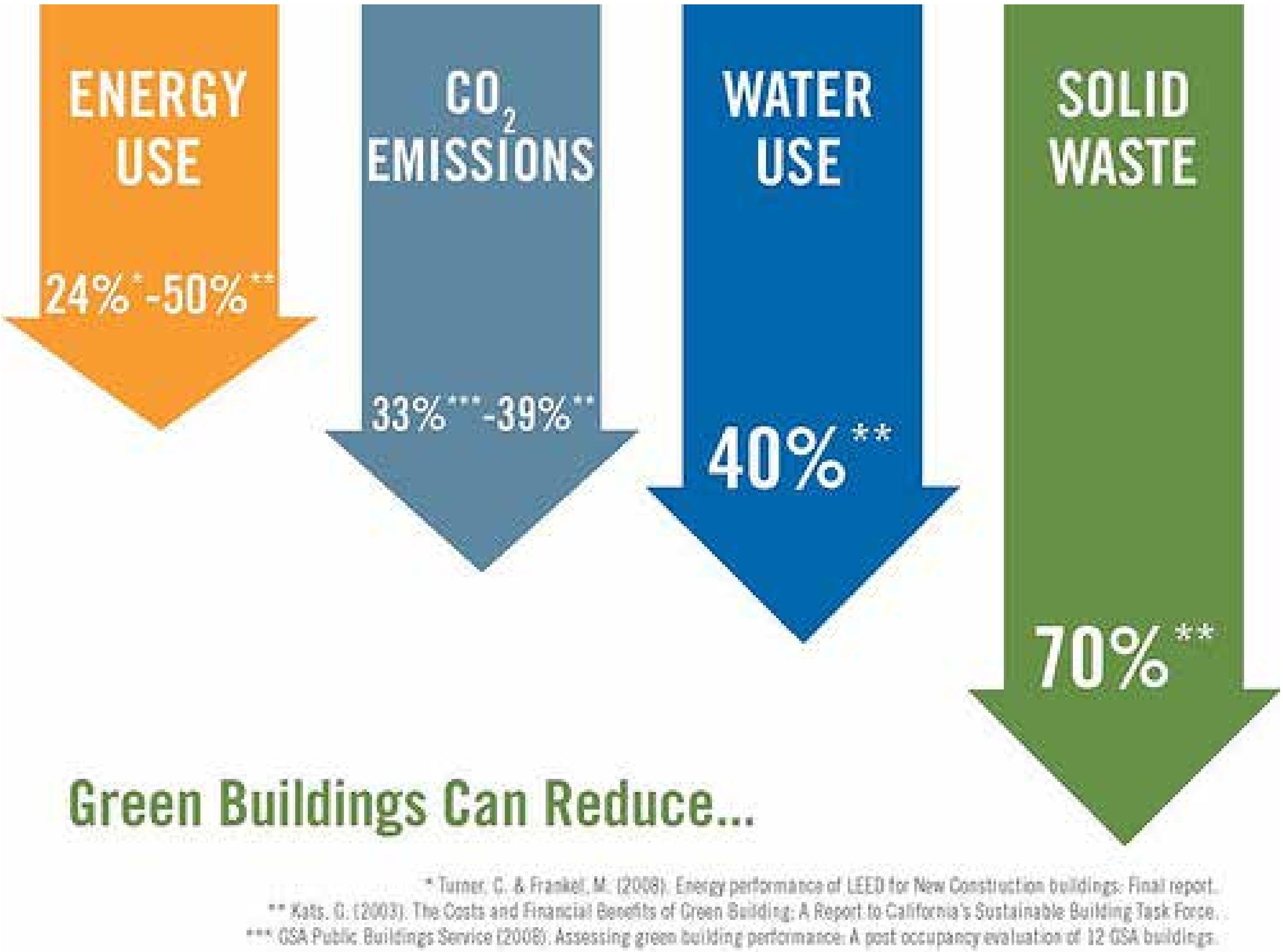

Figure 5: Green Building Statistics [21]

Most important drivers of progress in the Sustainable Urban Regeneration in Turkey are Government regulations and Incentives. Public Authorities should further involve in the process, to define limits and mandatory actions. This is very crucial for the successful operation of such a complicated program. Municipalities and The Ministry of Environment and Urbanization must set goals, prepare zoning plans and provide funding solutions in a more transparent and strict way. Also more effective Financial and regulatory incentives for Private developers must be identified. Currently Urban Regeneration Law and relevant legislation includes financial tools such as loans with low interest rates and rent support. However only approximately 4% progress rate [22] in Urban Regeneration since 2013 indicates that there is a need to increase these incentives in variety and amount to catalyse the urban regeneration projects.

Additionally, bureaucratic steps must be taken down to a minimum for the processes to be accelerated. Property Rights are very important, defended by the Constitution. However they should not be abused in order to stop a process that is mandatory for the safety of others. Unsafe buildings and areas with insufficient infrastructure must be dealt with sooner or later, and appropriate ways to satisfy all stakeholders must be found to do so. However since the earthquake risk is very real and there is no certain way to determine its timing, win-win situations may not always occur. Nevertheless, in a world where urbanization levels increase every day, developing green cities is a very valuable investment to each country's own natural resources and most importantly to its own people.

REFERENCES

[1] United Nations Department of Social and Economic Affairs. World Urbanization Prospects 2014 Version – p.7

[2] Turkish Ministry of Environment and Urbanization. Law No 6306. http://www.csb.gov.tr/gm/altyapi/index.php?Sayfa=sayfa&Tur=banner&Id=114

[3] Glaeser, Edward (February 15, 2011). Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier. Penguin Books.

[4] https://en.wikipedia.org/wiki/Traffic_congestion

[5] Sharifi, Ayyoob; Murayama, Akito (2013). "A critical review of seven selected neighborhood sustainability assessment tools". Environmental Impact Assessment Review 38.

[6] USGBC LEED Neighborhood Development RatingSystem.
http://www.usgbc.org/DisplayPage.aspx?CMSPageID=148

[7] Hidden cities: unmasking and overcoming health inequities in urban settings. Kobe, World Health Organization/WHO Centre for Health Development & United Nations Human Settlements Programme, 2010.

[8] İMAR PLANI YAPILMASI AİT ESASLARA DAİR YÖNETMELİKTE DEĞİŞİKLİK YAPILMASI HAKKINDA YÖNETMELİK 02.09.1999 – Ek1 http://www.resmigazete.gov.tr/arsiv/23804.pdf

[9] http://www.ibb.gov.tr/tr-TR/BilgiHizmetleri/Yayinlar/FaaliyetRaporlari/Documents/2014/pdf/07_cevre_yonetimi/yesil_alan_yonetimi.pdf

[10] WWF Türkiye'nin su riskleri Raporu 2014 http://awsassets.wwftr.panda.org/downloads/turkiyenin_su_riskleri__raporu_web.pdf

[11] http://www.greymatters.org.nz/greywater/_layouts/15/start.aspx#/SitePages/Home.aspx

[12] https://en.wikipedia.org/wiki/Rainwater_harvesting

[13] International Energy Agency Energy Supply Security – Emergency Response of IEA Countries
https://www.iea.org/publications/freepublications/publication/ENERGYSUPPLYSECURITY2014.pdf

[14] UNEP SBCI "Buildings and Climate Change Summary for Decision Makers"

[15] Center for Climate and Energy Solutions Http://www.c2es.org/technology/overview/buildings

[16] Http://www.c2es.org/technology/overview/buildings

[17] https://www.theguardian.com/sustainable-business/healthy-buildings-sustainable-offices-employees
http://www.resmigazete.gov.tr/eskiler/2010/06/20100604-5.htm

[18] http://www.resmigazete.gov.tr/eskiler/2011/08/20110824-6.htm

[19] http://www.csb.gov.tr/gm/altyapi/index.php?Sayfa=sayfahtml&Id=2091

[20] Stephen Karam, Sustainable Development Program Leader, World Bank April, 2015
"Turkey Urbanization Review"

[21] Turner.C & Frankel, M. (2008) "Energy Performance of LEEd for NC Buildings"
Kats, G. (2003) "The Costs and Financial Benefits of Green Buildings"
GSA Public Buildings Service (2008) "Asssessing Green Building Performance"

[22] https://www.emlakwebtv.com/kentsel-donusum-de-hedef-6-5-milyon-yapi/27729

Paper No: 99

A SWOT Analysis for the Urban Development Policies in Turkey: Impacts on the Construction Sector

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ABSTRACT

Urban transformation policies in Turkey are based on economic concerns rather than scientific evaluation. The current model, creates reasonable amount of trade volume, high profits and employment opportunities for all actors of the system. The model makes it easier for local authorities to provide infrastructure (in terms of sewage, drinking water, electricity, and communication services) easier and cheaper. The total urban transformation yields wealth in short term and renewed housing with the cost of adverse environmental, cultural and social impacts in long term. In this paper we will focus on the lost opportunity to benefit from solar technologies (included but not limited to energy production). Department of Energy (DOE) in United States recently published a multiyear program for energy efficiency. A discussion of this report is made in conjunction with the increasing residential building stock in Turkey. A SWOT analysis of construction activities in Turkey (building and infrastructure) shall be made based on data obtained from the Turkish Statistical Institute to compare the scope and roadmap of the DOE report with the ongoing urban transformation output in Turkey. A brief list of articles shall be suggested for the update of relevant key regulations in force.
Keywords: Urban development, Urban transformation, Regulations, Sustainability, Construction Sector

INTRODUCTION

Urban development in Turkey is mostly based on a narrow set of rules defined in the zoning law (Law Nr. 3194). The rule set is considered narrow because urban planning principles are based on "land ownership" and a holistic approach to urban planning is technically not easy. The regulation based on the law defines strict architectural constrains and a calculation method for the land plot to constrain total construction area and height. In 2012, a major urban transformation process started in Turkey with the law number 6306 (Law for The Transformation of Settlements which Impose Disaster Risks). This law represents a high risk for the sustainable urban development within the scope of the current zoning law and regulation whilst promising major opportunities to realize high standard, healthy and sustainable development as well and this paper elaborates on this paradox with a SWOT analysis for construction sector. Talas, a district in Kayseri is selected as the case subject.

BACKGROUND AND SCOPE OF WORK

The aim of the law 6306 is defined as "to provide safe, healthy, high standard buildings resistant to natural disasters which are built according to applicable science and technology, relevant standards, regulations and codes in practice." The law permits, sustainable retrofitting (in the form of structural strengthening and renovation) as well as demolishing and reconstructing the old and risky building stock in areas where there is elevated risk for natural disasters or for those buildings which are examined by an authorized body and denoted as "not safe". Unfortunately the law focuses on "safety" only but neglect conditions required for "healthy" renovation of the

existent building stock.
Law number 6306 defines a "business model" and a "policy" which enables rapid transformation of the existing building stock. In this research we use both terms to refer to law based on the context. The government and legal authorities are two major actors of this model and acting as facilitators for the overall process. The law defines a new actor on behalf of building users whom nonexistent in any other part of the Turkish Laws, namely "building tenant". There is a definition for "Floor owner" in the Condominium Law and the legists argue if the "building tenant" means "any" or "all" of the "floor owners". Nevertheless, the current practice assumes the building tenant is "one or many" of floor owners. The relationship between two is illustrated in Figure 1 as an Express G diagram.

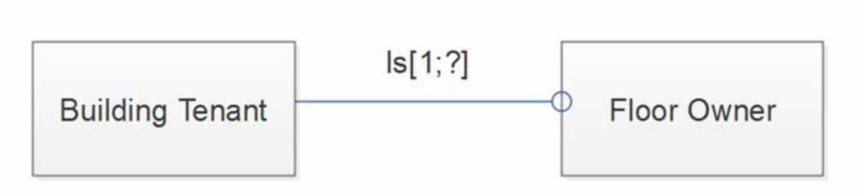

Figure 1 Express G diagram for Building Tenant - Floor Owner Relationship

Legal framework

Besides the law 6306 (Urban Transformation Law), the 3194 (Zoning Law) and relevant regulations, the following laws in force define the legal framework for the arguments and hypotheses in this research;

- The Turkish Constitution
- Forest Law (nr.6831, 1956)
- Condominium (Property Ownership) Law (nr.634, 1965)
- Environment Law (nr.2872, 1983)
- Mass Housing Law (nr.2985, 1984)
- Settlement Law (nr. 5543, 2006)
- Energy Efficiency Law (nr.5627, 2007) and Building Energy Efficiency Regulation,
- The Turkish Civil Code (nr. 4721, 2001)
- 5393 Municipality Law (2005) & 5296 Metropolis Municipality Law (2004).

A complete list for the legal framework is available on the Turkish Contractors Union website (TMB, 2015). This legal framework is designated according to the 23rd, 35th, 57th and 63rd articles of the Turkish Constitution. Overall, these articles define the citizen rights to own a property; freedom of travelling; sustainable, healthy, social and economic growth as a function of those rights and government's role to establish healthy and ordered urban development whilst protecting natural, cultural and historical heritage. Discussion of the law framework and its interdependencies is out of the scope of this research but current interpretation of the law and its effects over the construction sector and the sustainable urban development is what we focus on.

Sustainability framework

Sustainability can only be achieved when only three components are optimally integrated which are "Economic Sustainability", "Social Sustainability" and "Ecological Sustainability". The most common approach for analyzing sustainability begins with environmental impact of the underlying technologies. McDonough and Andrew's principals define the characteristics of sustainable technology as (Braungart et. al. 2007):

- Renewable, as opposed to extractive and finite
- Emulates nature: no waste
- Cyclical: cradle to cradle versus cradle to grave
- Focused on resource productivity rather than labor productivity
- Benign and even restorative in its effects on the biosphere
- Reduced CO_2 emissions (2030 challenge)
- Depend on monitoring and measurement
- Higher rates of internal return (IRR) in terms of economics
- Do not harm human health, salubrious

PROBLEM CONTEXT

The current model, creates reasonable amount of trade volume, high profits and employment opportunities for all actors of the system. The model makes it easier for local authorities to provide infrastructure (in terms of sewage, drinking water, electricity, and communication services) easier and cheaper. The total urban transformation yields wealth in short term and renewed housing (so seems a good policy) but with the cost of adverse environmental, cultural and social impacts in long term. There is a lot of debate on the inconveniences of the zoning law for the last three to four decades and law 6036 enables "no delay" transformation of land with further marginal expansion of the zoning law, and results with a short to mid-term, "unsustainable" growth in construction sector. The law itself and the supporting legal framework is capable of establishing environmental, social and economic sustainability but, within the current practice we face just the opposite. Irrecoverable damage is given to urban social life (in the form of demographic change and increased population density) with extreme damage to environment including the loss of green land, and neither the area would support such population increase in the form of employment nor there is a backup plan or policy for the newly established (unskilled, non-institutionalized) construction companies to sustain their business once the construction rally is over.

METHODOLOGY

In this research we will draft an ontology between three different information and knowledge domains: The legal framework and historical development of zoning law within the scope of the problem context, sustainability (taking health and safety issues to the core) and the state of housing construction industry in Turkey.

Graphical Express notation modelling language (Express G) shall be used to define the ontology of concepts. EXPRESS-G is a standard graphical notation for information models widely used in interoperability research, and we will benefit from the cardinality function of it. These cardinalities may be defined between actors, processes and products namely "entities" of the ontology model. Express G notation uses four different kinds of cardinalities namely, "none or one [0:1]", "none, one or many [0:?]", "one and only one [1:1]" and "one or many [1:?]". The cardinality may be denoted by a letter "S or L" (i.e. S[0:?]) where S defines that the cardinality is composed of a

"Set of values" and L defines that the cardinality is composed of a "List of values". The main difference between S and L is that, L requires an order that is; S enables random access to the information whereas L permits only sequential access.

Talas, a district in Kayseri is a significant case to support the output of this research. Talas, was a former green town famous with country cottages and a 1st degree archaeological site (the old town); a Neolithic settlement is now a place that became a high density housing district with fifteen storey apartments, a process started long before law 6306 came in force.

RELATED WORK

The legal framework had been composed from the notes taken from a Symposium on Urban Transformation Law on June 2016. Özdal (2010) elaborates on the changing role of urban design as a result of globalization. Tekeli (2016) discusses the lessons learned from urban transformation and development examples with specific emphasis on works of Ebül'ula Mardin and Gerhard Kessler. He also criticizes the unique rapid development progress of Turkish cities (Tekeli, 2014). Ercoskun and Yalçıner Ercoskun (2005) criticizes increasing density without establishing required infrastructure. Çubuk (1984) discusses nationwide problems for urban planning and development. Although an old research, this helped us to compare the past data with the present situation. Çahantimur and Yildiz (2008) analyzed the Bursa case as an example of social approach to sustainable urban development,

The urban transformation process is a major driver for the development of construction sector. Sancak and Karaman (2015) elaborate on the topic and take a snapshot of the current state of the sector. Dincel (2015) makes an evaluation of the construction sector in terms of growth and makes a comparison of the current conditions between Turkey and the world. Şat Sezgin and Aşarkaya (2015) also performs a similar analysis and evaluates the sector according to the bank credits in use.

AEC (Architecture / Engineering & Construction) cluster is the primary industry with all its stakeholders' procurement channels and workforce that is directly affected from the decisions taken for urban development policies. Unfortunately, domestic strategies provide very limited input to investigate the relationship between urban development and its effects on the construction sector. Nevertheless, we also have to compare the trends in the world to those in other countries. International strategies and priorities provide invaluable input to this research in that sense. We analyzed the UK Government's defined set of aspirations for UK construction (HM Government, 2013) and compared UK Infrastructure and Projects Authority's strategic plans against the Turkish Governments 10th Development Plan (TC Kalkınma Bakanlığı, 2013). We selected US Department of Energy's (DOE, 2015) Multi-Year Program Plan (MYPP) for Fiscal Years 2016-2020 to align the economic expectations with sustainability requirements.

SWOT ANALYSIS FOR CONSTRUCTION SECTOR WITHIN THE SCOPE OF CURRENT URBAN TRANSFORMATION TRENDS

To determine the ontology behind different factors shaping the competency ground of construction sector, the SWOT analysis is intentionally prepared to show interdependencies between Strengths, Weaknesses, Opportunities and Threats. Bigger construction firms have the power and strength to close strategic gaps in terms of human resources, knowledge and efficiency thus, we elaborate on Small to Medium Enterprises (SMEs) in the construction sector. There are examples all over Turkey, in some districts thousands of construction projects are in progress now and hundreds of new construction firms are founded.

Table 1 SWOT Analysis Matris for AEC Industry

Drivers	Strengths	Weaknesses	Opportunities	Threats
Workforce	Young workforce; open to new trends and knowledge; Flexible open to change; Familiar to available Information & Communication Technology (ICT) tools	Lack of experience and skills required for high value projects; Higher education may neglect some contemporary skills and knowledge; Not aware of the full potential which ICT may provide	Easy to improve; better outcomes possible from vocational training; Labor expenses are low compared to Europe, Asia and America markets, which defines an opportunity to transform workforce into "brain-workers" and export "brain-labor".	Lack of experience may lead to wrong decisions. Being unaware of some contemporary technological trends may decrease competent strength within a decade; Industry 4.0 trends may replace some portion human labor with machines
Sub-Contractors	Skilled Sub-Contractors (one company provides services to many construction projects); Required expertise is available for procurement process. Legal and contractual issues are resolved.	Young construction companies have inadequate control over sub-contracted work (in terms of quality and value equilibrium) and may not be aware of the procurement conditions that should be existent in contracts	Construction volume is expected to be high for the following decade; It is possible to export sub-contracting services. Easier to transform and institutionalize the business as an outcome of routine tasks	Although the amount of building stock that should be "renewed" is still high, the progress is very fast and business volume may significantly drop within a few decades
Coordination and Leadership	Turkey comes 2nd in terms of the contractor number after China and 8th in terms of annual turnover of construction sector. Turkish Contractors Union works effectively for monitoring and measurement of the sector performance and to develop sustainable growth policies in collaboration with the Economic Ministry and Development Ministry of Turkish Republic.	Many of the construction firms are young & not institutionalized. It is very easy to become a contractor. Having adequate initial capital is enough. This means government has little or no control over contractor inflation.	If Civil, Non-Governmental Organizations (NGOs) are contributed to the process by law, urban transformation may function to develop beautiful cities with high quality of life whilst renewing old building stock. There is a need to merge current legal framework. This would lead to decreased bureaucracy and better coordination	Many of the construction companies are founded within the last three to five years. No trusted data is available on their reliability. No expectations for contribution of civil initiatives. Required support from professionals in sector, NGOs and academy is not taken. There is no observed intention to contribute academy, labor and NGOs to the process.
Client Capability, and Quality of Life	Easy to start building renewing process. Request from one "building tenant" is enough, municipalities act fast, and construction usually starts ASAP. Government provides incentives for the construction period to the floor owners.	Since only one applicant is enough, a common agreement among floor owners may not exist. Residents of buildings may get adversely effected from the process. Clients are not aware about their legal rights. Long term costs because of health issues and adverse effects on the society and environment are unknown. Construction companies have no liability against post construction effects.	Within a year or two, floor owners' capital increases as the realized rent surplus which is tax-free as well. Legal framework to protect client rights is well established.	Indoor air quality is not studied. There is a significant increase in chronic respiratory diseases especially in Northern Europe (WHO, 2016) most likely cause is improper building details and materials. Adverse effects of demographic change and inadequate infrastructure are not studied. Health and safety risks exits on construction sites which are spread throughout the streets of the city.

Information Utilization & Knowledge Management	NA, only financial tracking, accounting and legal duties	Neither government nor construction companies benefit from ICT supported knowledge management	Technology provides every tool and service required in the form of either on the cloud (internet based, pay per use models) or tightly integrated solutions (desktop software)	Lack of monitoring and measurement yields huge waste and inefficient use of resources. Turkey is dependent on import goods, services and energy. It is a must to use money and resources efficiently.
Building Information Modelling (BIM)	NA, only a few frontier labor and companies are aware Ultimate interoperability and integration promises huge amount of savings in terms of resources and money.	A big portion of construction sector is unaware of BIM and its outcomes Interoperability between different Information Models (IM) is not functional yet. A lot of glue processes are required.	BIM is mandatory in UK and US by law. It should be made mandatory in Turkey by law as well. We have required domestic workforce and technology to develop national solutions	If Turkish companies will not act soon, they may face the risk of losing their export chances and their chance to enter foreign markets. The more we wait, harder and more expensive to adopt new tools and techniques to business processes.
Collaborative Procurement	There are various financing opportunities. Interest rates are low. Initial capital requirement is at reasonable levels.	No tracking mechanism is available for the actual debt stock of companies. Companies prefer to stay out of the banking system and run their business with cash. Trust between actors of the system is low.	Innovative models are existent. Sometimes it is possible that sub-contractor's progress payments are made by barter. At The sub-contracting level there are already established Virtual Organizations (VOs) for collaborative procurement.	There is no or little effort to develop New Models of Construction Procurement.
Business Sustainability	New construction companies somehow manage to sustain their business with simple accounting. A very robust legal framework is defined for health and safety at work. A very robust legal framework is defined for client rights and construction quality	Although required by law, not enough importance is given to health and safety at work. No funds are allocated for R&D nor ICT investments. End of construction rally is only a few decades ahead.	A lot of opportunity exits to reduce waste, energy efficiency, business efficiency and savings (but very unlikely that young construction companies are capable to benefit from those opportunities)	Sanctions against health and safety may end the business (though, required priority and importance is not given). Conflicts around country borders increases prices and makes it harder to enter foreign markets.

SOLUTIONS FOR SUSTAINABLE URBAN TRANSFORMATION

The ontology of the preliminary solutions and their potential impact on construction sector are denoted by the following Express G diagram (Figure 2) and proceeding tables. The main concept denotes the requirement of a central information model for interoperability between distinct domains. Around the central model are main information streaming resources.

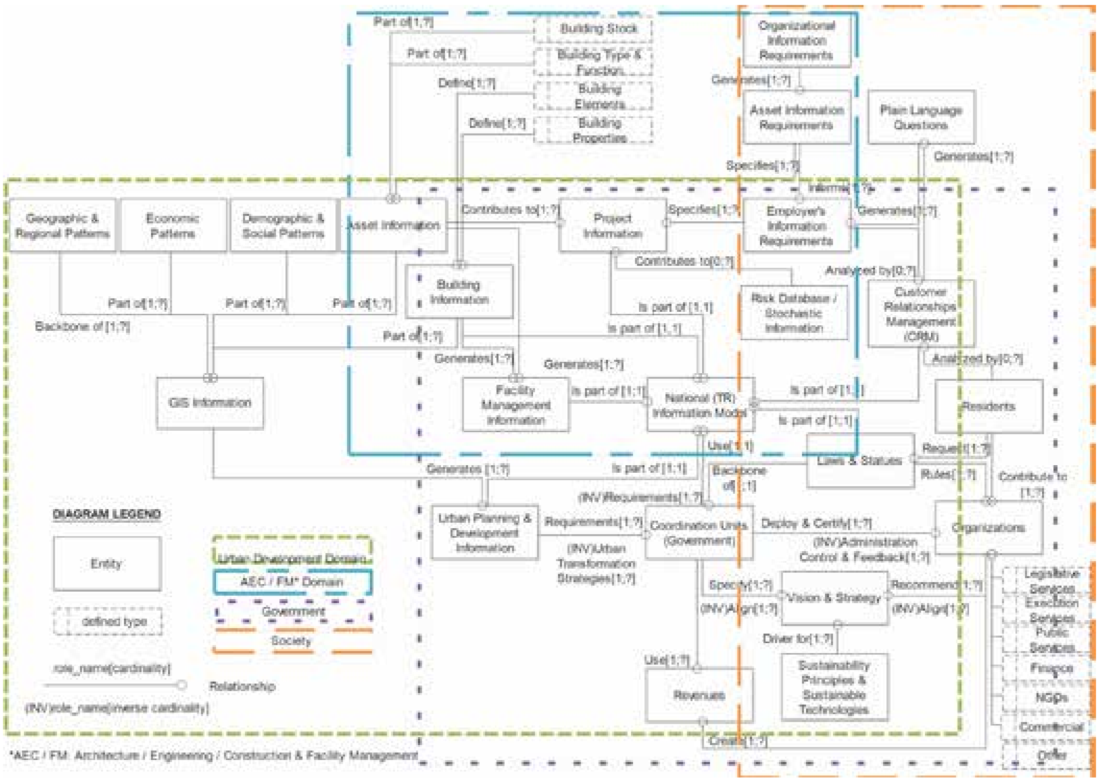

Figure 2 Express G diagram showing Integration Scenario for Sustainable Urban Transformation

The above diagram is far from being perfect though it shows some essential facts. The common part of all domains (in a nation) are the entrepreneurs (hidden as a subset of "Employer's Information Requirements); a (proposed) central, "National Information Model"; laws and statues; the government; a central risk database which all parties can benefit; and last but not least, a collaborative, dynamic and robust vision and strategy specification with the contribution of all actors in the society. NGO's play a key role for the development of such vision.

Besides the "integration scheme" shown in above diagram. The following recommendations are identified to support healthy and sustainable urban transformation process:

Recommendation 1: Give authority and responsibility to a union of Non-Governmental Organizations (NGOs) to control and report to the government as a supervisor over building inspection authorities.

Table 2 Recommendation 1 Impact Expectation

Why	How	Impact on Construction Sector
Building inspection authority companies are focusing on technical compliance only. Although they are responsible with the technical quality of construction, it is not secret that despite the risk of losing license and legal sanctions the system is not working as intended. Besides, keeping track of sustainable solutions is out of the scope of such companies.	Attach the responsibility of sustainable development and compliance checking against the environmental impact report of the project to building inspection authority companies. This will require for those companies to employ skilled personnel for such purpose. Give right and responsibility to a NGO union (not a single one but a union, composed of all suitable non-profit organizations) to give vocational training, provide consultancy, inspect the operations and report to the government as well as to the Architecture/Construction/Engineering (AEC) sector as a supervisor over "building and construction inspection authorities". Make "monitoring and measurement" a job of NGOs.	Construction companies will gain direct access to NGOs to obtain vocational training about: • Safety and health at work • Sustainability • Waste reduction • State of the art (hard and soft) technologies The anonymous reports from NGOs may be used to help construction firms to strategically align themselves with the rest of the industry.

Recommendation 2: Leave plot based evaluation of urban transformation. Require 500 (five hundred) housing units as a baseline for urban transformation and require environmental impact report according to law 2872.

Table 3 Recommendation 2 Impact Expectation

Why	How	Impact on Construction Sector
Five hundred units is the borderline for environmental effect evaluation of a mass housing project.	Work on city blocks instead of individual plots. Develop a holistic approach to urban design taking into account vehicle, pedestrian and public transport access. Designate urban facilities for all age groups.	The increase of construction volume will eliminate insufficient SME construction firms or force them to merge forces. This will require supporting legal and training services and some vocational training. This dynamic may be used as a driver force to transform these SMEs into institutionalized companies.

Recommendation 3: Improve the legal framework

Table 4 Recommendation 3 Impact Expectation

Why	How	Impact on Construction Sector
There is need to define the legal aspects of new relationships. The zoning law and regulation should give priority to the designation of empty areas (public spaces), substructure, infrastructure within the scope of sustainable urban development and transformation	People and society has the right to vote on their own destiny. Keep the central zoning law, but let local regulations. Increase the initiative of local management. Give NGOs a supervisory role over local municipal authority. Define a framework convention based on Habitat III issue papers.	Better coordination will establish better procurement and support services for construction companies.

CONCLUSION

Talas, like many other parts of Turkey was “unique” in terms of natural, historical, cultural heritage and employs a very high touristic activity potential. However the district itself with all the former life quality was (like rest of Kayseri) damaged as a result of a wild urban transformation process. During the time this paper was written; an essential fuse to prevent environmental damage had been removed by a recent decrees which makes the environmental impact assessment obsolete in order to prevent losses from bureaucratic processes for investments. Strong collaboration between government, commerce, industry and NGOs is essential to improve the future of our country. Within this information age, a central information model is essential for improved interoperability between stakeholders of a country. A strong law backbone is essential to protect common wealth and heritage. All future strategies and vision thereof must be based on common sense. Although not emphasized in this paper, a robust and contemporary education system is a good start. Despite many insider and outsider interventions Turkey is one of the strongest countries in the world on a precious piece of land own by a unique nation. A well-known fact is that, construction sector is the locomotive sector for a major part of the economy. Turkish construction companies are extremely versatile, dynamic and like to take risk. There is a need for a transparent solution which will utilize the hidden potential and opportunities to improve economy and social life. A national knowledge exchange model supported by a strong backbone in the form of laws and statues which reduce bureaucracy whilst improving trust may be very beneficial to explicate this potential.

REFERENCES

Baransu, B., 1987, *Türkiye'de Şehirsel yenileme planlamasında uygulanabilecek bir yöntem araştırması*, Istanbul Tehnical University (İTÜ) Mimarlık Fakültesi Baskı Atölyesi, Doktora Tezi, İstanbul

Çahantimur A., Turgut Yıldız H., 2008, *A socio-cultural approach for sustainable urban development: A case study for Bursa*, itüdergisi/a (mimarlık, planlama, tasarım), Volume: 7, Issue: 2, September 2008, Istanbul, pp.3-13

Çubuk M., 1984, *Ülke ölçeğinde planlama ve düzenleme sorunları*, Volume 3: Dünya Şehircilik Günü kolokyumları, Mimar Sinan Üniversitesi Mimarlık Fakültesi, Şehir ve Bölge Planlama Bölümü, İstanbul

Dincel G., 2015, *Büyüme bağlamında inşaat sektörü*, TSKB Ekonomik Araştırmalar, Ankara, January 2015

DOE, 2015, *US The Department of Energy's Building Technologies Office's (BTO's) Multi-Year Program Plan (MYPP) for Fiscal Years 2016-2020*, (Last Access Date: June 15th 2016) http://energy.gov/eere/buildings/downloads/multi-year-program-plan

Eraydın A., 1994, *Değişen Planlama Kuramları Çerçevesinde Ekolojik Yaklaşım*, Mehmet Çubuk (Ed.), 17. Dünya Şehircilik Günü Kolokyumu: Kent ve Çevre: Planlamaya Ekolojik Yaklaşım, 4-5-6 Kasım 1993, Bursa, Mimar Sinan Üniversitesi Mimarlık Fakültesi, Şehir ve Bölge Planlama Bölümü, İstanbul, pp. 240-252

Ercoskun C., Yalçıner Ercoşkun Ö., 2005**,** *İstanbul Kent Merkezinin Dönüşümü ve Finans Merkezlerindeki Ofis Alanlarının Gelişimi: Maslak-Büyükdere Aksı*, 8 Kasım Dünya Şehircilik Günü 28. Kolokyumu, Değişen Dönüşen Kent ve Bölge, BRC Basım ve Matbaacılık, Ankara, pp. 651–661.

Genç F. N., 2008, *Türkiye'de Kentsel Dönüşüm: Mevzuat ve Uygulamaların Genel Görünümü*, Yönetim ve Ekonomi Journal, Volume: 15, Issue: 1, Celal Bayar Üniversitesi, İ.İ.B.F. MANİSA, pp. 115-130

Habitat III, *Issue Papers and Policy Units*, http://unhabitat.org/issue-papers-and-policy-units/ (Last Access Date: June 15th 2016)

Özdal S., 2010, *Küreselleşme sürecinde kentsel tasarımın değişen rolü ve yeni kentleşme akımı ilişkisi üzerine bir irdeleme*, Yüksek Lisans Tezi, Tez Danışmanı: Prof. Dr. Güzin KONUK, T.C. Mimar Sinan Güzel Sanatlar Üniversitesi, Fen Bilimleri Enstitüsü, Şehir ve Bölge Planlama Anabilim Dalı, Kentsel Tasarım Programı, İstanbul, Haziran 2010

Sancak E., Karaman S. C., 2015, *İnşaat Ekonomisi*, Turgut Özal Üniversitesi Yayınları No: 021, ISBN: 978-605-4894-10-9, Ankara, April 2015

Şat Sezgin A. G., Aşarkaya A., 2015, *İnşaat Sektörü, İş Bankası İktisadi Araştırmalar Bölümü Raporu*, Ankara, April 2015

TC. Kalkınma Bakanlığı, 2013, *10. Kalkınma Planı*, (Last Access Date: June 15th 2016) http://www.kalkinma.gov.tr/Lists/Kalknma%20Planlar/Attachments/12/Onuncu%20Kalk%C4%B1nma%20Plan%C4%B1.pdf

Tam D., 2004, *Çevre Duyarlı Planlamanın ve Deprem Duyarlı Planlamanın Bütünleştirilmesinin Sağlayacağı Faydalar*, Planlama, Journal of the Chamber of City Planners, Volume: 2004/3, Issue: 29, pp. ISSN 1300-7319

Tekeli İ., 2014, *Türkiye'nin Kentleşme Deneyiminden Öğrenebileceklerimiz*, TEPAV, Merih Celasun'a Saygı Günü Paneli, http://www.tepav.org.tr/upload/files/1456398873-1.Turkiye_nin_Kentlesme_Deneyiminden_Ogrenebileceklerimiz.pdf (Last Access Date: June 15th 2016)

TMB, 2016**,** *Mevzuat*, http://www.tmb.org.tr/tr/mevzuat/kanunlar/33 (Last Access Date: June 15th 2016)

UK HM Government, 2013, *Construction 2025, Industrial Strategy: government and industry in partnership*, Report, www.gov.uk/bis. (Last Access Date: June 15th 2016)

UK Cabinet Office, 2011, *Government Construction Strategy Report*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61152/Government-Construction-Strategy_0.pdf (Last Access Date: June 15th 2016)

UK Infrastructure &Projects Authority, *Government Construction Strategy 2016-20 Report*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/510354/Government_Construction_Strategy_2016-20.pdf (Last Access Date: June 15th 2016)

Braungart M., McDonough W., Bollinger A., 2007, *Cradle-to-cradle design: creating healthy emissions e a strategy for eco-effective product and system design*, Journal of Cleaner Production, 15, pp.1337 – 1348, available online at www.sciencedirect.com (Last Access Date: June 15th 2016)

WHO, 2016, World Health Organization, Regional Office for Europe Data, http://www.euro.who.int/en/health-topics/noncommunicable-diseases/chronic-respiratory-diseases/data-and-statistics (Last Access Date: June 15th 2016)

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Neighbourhood Sustainability Assessment Tools - Suggestions for Turkish Case

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ABSTRACT

In every country, the building sector is a major contributor to socio-economic development and also a major user of energy and natural resources. This sector is one of the main actors, which is responsible for world's environmental degradation at the areas of energy and water consumption, raw material employment and usage of land.

Till the end of 20^{th} century world economy did not take into consideration the importance of building sector on energy demand and also after World War II, by the help of cheap fossil fuels, the technical progress of building design did not take into consideration energy efficiency or other ecological aspects.

Nowadays we know that buildings are responsible of %35 of the total energy used and approximately 25% (including transport) of the global CO2-emissions. By the help of this knowledge we can easily declare that building sector has a very important role against global warming.

After realizing the importance of building sector for sustainable issues sustainable building assessment tools have evolved since 1990. The pioneers of these tools were LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Methodology). Today there are plenty of tools dealing with sustainable assessment of buildings but the sector has understood the importance of communities, neighbourhood level. But in fact using a certification scheme for assessing the sustainability of entire neighbourhood is relatively new.

In recent years, BREEAM (U.K.), LEED (U.S.) and DGNB (Germany), CASBEE (Japan); HQE^2R have developed their own version of Neighbourhood Sustainability Assessment (NSA): BREEAM Communities, LEED-ND (Leadership in Energy and Environmental Design for Neighbourhood Development) and DGNB NSQ/NUD (German Sustainable Building Council assessment tool for new urban districts) ; CASBEE-UD (Urban Development)

The aim of this paper is investigating well known NSA tools and emphasizing the important issues and themes for new developing countires. To do so the writer of this paper will investigate the sustainable community assessment tools' categories and sub categories. With the help of this knowledge writers will discuss the necessary categories for urban transformation projects in developing communities.

1. INTRODUCTION

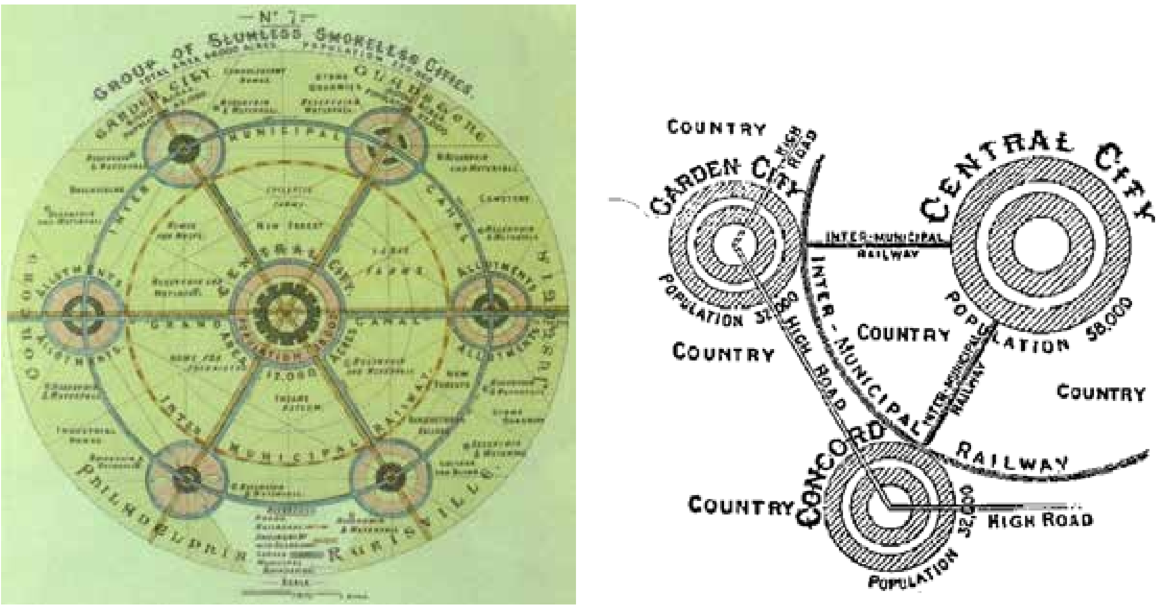

Figure 1-2: Ebenezer Howard's garden City plan [1]

The term "sustainable communities" has different definitions, but briefly we can say that the communities which are suitable for sustainable living are sustainable communities. Different experts from different countries have made various attempts to create sustainable communities.

At early 20th century Ebenezer Howard came with Garden City idea which was seeking a solution for city planning problems. He wanted to design smaller "Garden Cities" (32000 people each) in order to have sustainable green cities. According to him this approach had power to give a chance for people to live best of city and country living.

In the 1920's, Clarence Perry introduced a concept that he referred to as "The Neighborhood Unit" and in 1930's Le Corbusier came with a plan named "Towers in the Park". He proposed high rise buildings each surrounded by green space.

In 1998 European Commission published a report called 'Sustainable Urban Development in the European Union: A Framework for Action'. This report was a guidance for national and local governments for the principles and strategies towards a sustainable urban development Policy.

Academia, industry and government have developed several evaluation methods and frameworks to support decision making during the sustainable urban development process.

Due to the complexity of planning's process and objective, there is not a unique evaluation approach: the evaluation methods and frameworks that exist are appropriate for specific stages of the urban development process, for specific spatial or temporal scales of development, and often for specific sustainability issues [2]

In December 2005, on behalf of the UK Presidency of the European Union, Ministers and representatives from Member States and European institutions gathered in Bristol. They discussed a common European approach to sustainable communities.

BRISTOL ACCORD

The Bristol Accord identifies Europe-wide principles and characteristics of a sustainable community. It provides a comprehensive and coherent framework to deliver sustainable development, economic prosperity and social justice in an era of rapid global economic change. And it encourages a better environment, stronger democracy and effective local leadership [3].

Ministers endorsed the "**Bristol Accord"**, which set out **eight characteristics of a sustainable community**; [3].

- **Active, Inclusive and Safe -** Fair, tolerant and cohesive with a strong local culture and other shared community activities
- **Well Run -** with effective and inclusive participation, representation and leadership
- **Well Connected -** with good transport services and communication linking people to Jobs, schools, health and other services
- **Well Served -** with public, private, community and voluntary services that are Appropriate to people's needs and accessible to all
- **Environmentally Sensitive** - providing places for people to live that are Considerate of the environment
- **Thriving -** with a flourishing, diverse and innovative local economy
- **Well Designed and Built -** featuring quality built and natural environment
- **Fair for Everyone -** including those in other communities, now and in the future

SUSTAINABILITY ON DISTRICT LEVEL

Different countries established tools for sustainable communities. The prominence of the local properties constituted one of the main reasons for these differences

Some of the well known tools are LEED-ND,USA; BREEAM Communities, England ; DGNB for Urban Districts, Germany; CASBEE-UD, Japan ; Green Star Communities, Australia; QSAS Neighbourhoods, Qatar; Pearl Communities, Abu Dabi; and Green Mark for Districts, Singapur; HQE^{2}R, CSTB; Sustainable Community Rating (SCR), Victorian State Government; EcoDistrict performance and Assessment Toolkit, Portland Sustainability Institute; Cascadia Scorecard, Sightline Institute; One Planet Living, BioRegional Development Group nd WWF International; Sustainable Project Appraisal Routine, ARUP. [4].

Today there is a large number of assessment tools exclusively designed for evaluating sustainability at the neighborhood scale.

In this paper writers will give details about well known LEED-ND; BREEAM communities, DGNB NSQ, CASBEE-UD; HQE^{2}R tools and within this knowledge suggestions for developing countries will be offered

a. LEED-ND

Starting from 1994, LEED grew from one standard for new construction to a comprehensive system of interrelated standards covering aspects from the design and construction to the maintenance and operation of buildings.

In 2007, United States Green Building Council (USGBC), Congress for New Urbanism (CNU), and the National Resources Defense Council (NRDC), came together to found LEED-ND as a voluntary tool for guiding sustainable

neighborhood development. [5].
Different projects around the world have adopted LEED-ND as a guiding framework for neighborhood development plans.
Assessment criterion of LEED-ND v4 are categorized into five themes: [6]

- Smart Location & Linkage
- Neighborhood Pattern & Design
- Green Infrastructure & Buildings
- Innovation & Design Process
- Regional Priority Credits

Each theme is further divided into individual criteria.

b. BREEAM Communities

First launched in 1990, BREEAM was the world's first environmental assessment method for new building designs. [7]
In BREEAM Communities the environmental assessment method is expanded to more holistically approach sustainability with consideration of the social and economic impacts of development.
BREEAM Communities is a simple and flexible route to improving, measuring and certifying the sustainability of large-scale development plans. It provides a framework to support planners, local authorities, developers and investors through the masterplanning process, before embarking on procurement, detailed building level design and construction. [8]

- Governance
- Social and economic wellbeing (SE)
- Resources and energy (RE)
- Land use and ecology (LE)
- Transport and movement (TM)
- Innovation (Inn)

Each of these themes is further broken down into individual criterion.

c. DGNB Neighbourhood development Neubau Stadtquartiere (NSQ)

Based in Stuttgart, the German Sustainable Building Council (DGNB) was founded by leading experts from various disciplines within the construction and real estate industry in summer 2007. [9]

The DGNB System was developed in close collaboration with the German Federal Ministry of Transport, Building, and Urban Affairs (BMVBS) with a view to actively promoting sustainable building. [9]
DGNB Certificates and Pre-Certificates are awarded in the following grades: [9]

- Gold (at least 80% of overall score and at least 65% in each criteria category)
- Silver (at least 65% of overall score and at least 50% in each criteria category)
- Bronze (at least 50% of overall score and at least 35% in each criteria category)
- Certified (awarded to existing buildings only, at least 35% of overall score)

DGNB- NSQ is the German version and DGNB-NUD the international version
The NSQ/NUD scheme is designed for new urban districts covering an area of at least 2 hectares[9]
This scheme takes the following fields into account:

- Environmental Quality,
- Economic Quality,
- Sociocultural and Functional Quality,
- Technical Quality,
- Process Quality.

Site Quality is integrated here as a criterion for assessment. [10]
The assessment focuses on the areas between buildings in a district, such as sidewalks, bike lanes, roads, and green spaces. [10]
DGNB pays more attention to the cohesion of sustainable development aspects (environmental, economic, and social)

d. CASBEE-UD

CASBEE was developed in 2004 by the Japan Sustainable Building Consortium (JSBC), involving committees in academic, industrial, and government sectors [17]
80 criteria. All credits are equal. Uses five-step scale based on the ratio of achieved and maximum points.
CASBEE-UD calculates environmental efficiency by dividing the environmental quality (QUD) within the site boundary to environmental load (LUD) on the spaces beyond the site boundary. The criteria for environmental quality are divided into three themes of "natural environment", "service functions for the designated area", and "contribution to the local community". [5]
Each major category, from $Q_{UD}1$ to $LR_{UD}3$, comprises from 4 to 6 medium-level categories. The medium-level categories are divided into minor categories as required. The minor categories are graded on 5 levels; 1–5, level 3 being the reference level. In addition, the weighting coefficients are applied to calculate the results. The coefficient cannot be changed. [18]

- QUD1 — Natural environment (microclimates and ecosystems)
- QUD2 — Service functions for the designated area
- QUD3 — Contribution to the local community (history, culture, scenery and revitalization)
- LRUD1 — Environmental impact on microclimates, façades and landscape
- LRUD2 — Social infrastructure
- LRUD3 — Management of the local environment [18]

CASBEE-UD excludes the interior of buildings from assessment (although there are exceptions in some assessment items). Therefore, this configuration makes it possible to use CASBEE-UD to assess a development area as a whole. [19]
CASBEE-UD applies weights to nested categories of criteria. The weighted scores of sub-criteria are added up to give the total score of the higher level criteria. This procedure is reiterated until the scores for environmental quality (Q) and environmental load (L) are obtained. [19]

e. HQE²R

HQE²R was a 30-month European research and development project on sustainable renovation of the built environment and the regeneration of urban neighborhoods [14]. The project started in 2001 and continued until 2004. It was coordinated by Centre Scientifique et Technique du bâtiment (CSTB) in France.
In order to assess the different scenarios and to support decisions for action, HQE²R proposes three tools: – A model to assess the long term impacts on the neighborhood and sustainability of scenarios for buildings and planning projects, using the indisputable indicators system (INDI model). – An environmental impact model at both the neighborhood and the buildings scales (ENVI model) – An economic and environmental assessment model for renovation or construction of a building (ASCOT MODEL)
The HQE2R theoretical basis and framework are[20]:

- 6 sustainable development principles at the city scale (amongst the 28 principles of the Rio Declaration)
- the ISDIS system, i.e. a system of 5 main sustainable development objectives and 21 targets backed up by a system of 51 key issues with their 61 indicators for the neighbourhood and its buildings
- the participation of residents and inhabitants scale

Assessment criterion of HQE²R are categorized into five themes

- Resources and heritage;
- Local environment;
- Diversity;
- Integration;
- Social life

The 5 objectives and 21 targets for sustainable neighbourhoods and buildings [20].

<u>To preserve and enhance heritage and conserve resources</u>
1 - To reduce energy consumption and improve energy management
2 - To improve water resource management and quality
3 - To avoid land consumption and improve land management
4 - To reduce the consumption of materials and improve their management
5 - To preserve and enhance the built and natural heritage

<u>To Improve the Quality of the Local Environment</u>
6 - To preserve and enhance the landscape and visual comfort
7 - To improve housing quality
8 - To improve cleanliness, hygiene and health
9 - To improve safety and risk management
10 -To improve air quality
11 -To reduce noise pollution
12 -To minimise waste

<u>To Ensure Diversity</u>
13 -To ensure the diversity of the population
14 -To ensure the diversity of functions
15 -To ensure the diversity of housing supply

<u>To Improve Integration</u>

16 -To increase the levels of education and job qualification

17 -To improve access for all residents to all the services and facilities of the city by means of easy and non expensive transportation mode

18 -To improve the integration of the neighbourhood in the city by creating living and meeting places for all the inhabitants of the city

19 -To avoid unwanted mobility and to improve the environmentally sound mobility infrastructure

<u>To Reinforce Social Life</u>

20 -To reinforce local governance

21 -To improve social networks and social capital

ASSESSMENT OF SELECTED NSA TOOLS

Table 1 Major characteristics of the selected NSA tools [4-11]

Tools Name	Developer	Country
LEED-ND	USGBC, CNU, and NRDC	US
BREEAM Communities	Building Research Establishment (BRE)	UK
CASBEE-UD	CASBEE-UD Japan Sustainable Building Consortium (JSBC), and Japan Green Building Council	Japan
DGNB-NSQ	German Sustainable Building Council (DGNB)	Germany
HQE^2R	CSTB	EU

Table 2 Properties of selected NSA Tools [4-11]

NSA Tool	LEED-ND	DGNB-NSQ	BREEAM Communities	CASBEE-UD	HQE^2R
Development date	2009 (pilot 2007)	2011	2009	2006 (revised 2007edition)	2001–2004
Country/ region	USA, Canada, and China	Germany	UK	Japan	7 European countries (Denmark, France, Germany, Italy, Netherlands, Spain, UK)

Table 3 Inclusion of mandatory credits in percentage[4-11]

	LEED-ND	DGNB-NSQ	BREEAM Communities	CASBEE-UD	HQE^2R
Mandatory	21%	0%	24%	0%	0%
Optional	79%	100%	76%	100%	100%

Table 4 Parties involved in NSA development [11]

Rating System	Gov.	Non- Gov.	Industry	Academia	Citizens
LEED -ND	-	X	-	-	-
BREEAMC Communities	-	X	-	-	-
DGNB-NSQ	-	X	X	-	-
CASBEE-UD	X	-	X	X	-
HQE²R	-	X	X	X	-

Table 5 Breaking down categories based on indicators [11]

Category	**Criteria**	**LEED -ND**	**BREEAM Communities**	**DGNB-NSQ**	**CASBEE-UD**	**HQE²R**
Location and site selection		18%	4%	3%	0%	2%
Transportation	Connectivity to public transportation, Connectivity to bike lane, Pedestrian-friendliness, Private car, Parking, etc.	6%	11%	9%	7%	7%
Infrastructure and design	Design principles, mixed use, compact development, green infrastructures, heat island innovation	34% 5%	14% 0%	31% 0%	30% 0%	15%
Sociocultural quality	Safety, well-being, quality of life, sound emission, affordable housing, inclusive communities, social networks and infrastructure, heritage	17%	16%	12%	19%	45%
Economic quality	Local economy, employment and local jobs, business, investments	5%	15%	15%	1%	5%
Institutional		0%	9%	6%	1%	0%
Environment, ecology and resource efficiency	Water, Energy, Materials, resource conservation, Waste management, Biodiversity, natuıre and micro Climate	“3% 5% 2% 5%	4% 4% 8% 15	2% 6% 5% 15%	4% 11% 6% 1%	7% 7% 12% 0%

f. Mixed use development

All the tools except CASBEE-UD have included some criteria for mixed use development. Since the sustainability issues are inter-related [21] and mixed use development affects the other issues such as energy and transportation, it is essential [5]

Especially for DGNB-NSQ there is a balance between different sustainability dimensions**.** For the rest of the tools this balance is also necessary

g. Social Criterion

Social Criterion are important for these tools.There are many criteria defined for this theme by HQE^{2}R and DGNB-NSQ.

There are fewer social criteria in other tools, and just 6% of CASBEE-UD's criteria address social and community well-being criteria. [5]

h. Finance and Economy

Finances and economy has also significance important but unfortunately have not received enough attention among the selected tools.

DGNB-NSQ evaluates the districts according to economical performance under the theme Economic Quality by the help of Life Cycle Cost and Value Development indicators

CASBEE-ND stands out again for not including this theme. [5]

i. Location and Site

All tools except CASBEE haveincluded certain criteria to the Location and Site Selection.

Location has high priority in LEED-ND (18%) while other tools dedicated muchfewer points for it (4% or less).

j. Water

Water-related credits are fairly similar among all tools (2% to 4%)

k. Innovation

Innovation ability is seen as a core element of all sustainability strategies [13] Acknowledging innovation's significance, LEED-ND, BREEAM Communities award points for innovative ideas.

l. Institutional sustainability

What is obvious from the results is that NSA tools have failed to address institutional sustainability. Institutions have an essential role in guiding human interactions [14]

As the NSA tools evolve, institutional sustainability criteria are expected to be included in the sustainability

checklists to address the issue of governance and need for more efficient administrative procedures. [12]
Thelatest versions of BREEAM-Community and DGNB-NSQ have both included criteria which primarily fall into institutional sustainability. However, LEED-ND and HQE[2]Rhas not assigned any points for assessingprojects based on institutional sustainability**.**

m. Mandatory Criteria

Tools have to give importance to mandatory criterion. If we want to shape the communities to a sustainable future we have to emphasise the important criterion by the help of mandatory ones. It is important to ensure a project meets certain minimum performance to get certified.

CASBEE-UD; HQE[2]R and DGNB does not have anymandatory criteria.

n. Stakeholders

Moreover, NSA tools do not include a wide array of stakeholders in developing the tools. A more balanced approach toward different aspects of sustainability in some NSA tools can be attributed to their comprehensive array of stakeholders. [11]

The results of this study indicated current NSA tools have failed to include all stakeholders, which might have different priorities and concerns both in criteria selection and their weightages. Specially, inclusion of citizens' opinion inassessment process is another field for improvement in current NSA tools. [11]

o. Infrastructure

In BREEAM Communities, the categories Infrastructure and Transportation are emphasised most.
In LEED ND, Infrastructure is the most significant category.

However, CASBEE-UD has a few criteria in the category.

URBAN TRANSFORMATION IN TURKEY AND ROLE OF NSA TOOLS

Especially developing countires has enjoyed unique growth. On the other hand because of wrong political decisions inhabitantants of villages moved to cities in most of the developing countries. These actions enlarged cities in an unplanned way. Nowadays cities suffer from this unplanned growth and urban transformation can be a solution for this problem.
Urban transformation is such a complicated process which has to solve the economic, social and environmental changes in the cities at the same time. Also urban transformation is a helpful way for transforming urban areas to a cleaner, safer, more attractive and inviting spaces. In fact, the transformation of cities includes economic change, demographic change, urban physical and environmental change as well as the social change.
The concept of "transition" indicates a process of change toward a predetermined and conceived target [15]
According to Yuheng Li [16], the term "transformation" avoids the inevitability of transition and emphasizes the process of changes.
This change can be in good or bad ways and the role of NSA tools is to shape the future of cities in a better way during urban transformation projects.

- **Turkish Case - Super City**

In The framework of "The Law of Transformation of Areas under the Disaster Risks" a Protocol had been signed between the Ministry and Istanbul Technical University. This Protocol is aimed to determine the standard of "Ecological Settlement Unit". [22]

The Project aims; to carry out transformation of areas at disaster risk in the framework of the law according to the principles of sustainability and to provide international and domestic credit extensions for urban transformation. [22]

The system consists of six main criteria and performances called

Land Use and Urban Design;

- Energy;
- Water;
- Transportation;
- Materials and Resources;
- Social and Economical Sustainability

that are named as Sustainable Performanced Urban Transformation (SUPERCITY)

CONCLUSION

According to the results of this study it is obvious that

- Infrastructure, design & innovation and Environment, ecology and resource efficiency themes are the most important ones according to the given weights of these topics.
- Water-related credits are fairly similar among all tools (2% to 4%)
- Infrastructure is the most significant category.
- NSA tools do not include a wide array of stakeholders in developing the tools, NSA tools have failed to include all stakeholders
- Tools have to give importance to mandatory criterion
- NSA tools have failed to address institutional sustainability
- Finances and economy has also significance important but unfortunately have not received enough attention among the selected tools
- Social Criterion are important for these tools
- Balance between different sustainability dimensions in NSA tools is also very important.

Urban Transformation projects in Turkey have to be careful about the issues above

- **Local *priorities***

  Because of life style differences, country specific features and traditions there will be differences according to countries. For tha reason countries have to take into consideration their priorities and they have to have a chance to adapt different tools according to their needs or they can establish their own tool by keeping in mind their necessities.
  We have to keep in mind that we shape cities and cities shape the civilization.

- **Weightings**

  Weigtings have to be different in different locations. For example potable water is a very important problem in Middle East region. Beacuse of the scarcity of potable water resources in this region water related credits has to be more efficient.

- **Correct*ed Mistakes***

  Turkey has to be careful about the former mistakes so NSA tools for developing countries have to:

  0 include a wide array of stakeholders

  0 to give importance to mandatory criterion

  0 to address institutional sustainability

  0 give importance to finances and economy

  0 give importance to social criterion

  0 be careful to have a balance between different sustainability dimensions

REFERENCES

1. The Urbanist [web page] (www.spur.org/publications/urbanist-article) 2016. [Accessed June 2016].
2. Lopes Gil, J. A., & Pinto Duarte, J. (2013). Tools for evaluating the sustainability of urban design: a review. Proceedings of the ICE-Urban Design and Planning, 166 (6), 2013.
3. Presidency, U. K. (2005, December). Bristol Accord. In Conclusions of Ministerial Informal Meeting on Sustainable Communities in Europe. Bristol (pp. 6-7).
4. Sharifi, A., & Murayama, A. (2013). A critical review of seven selected neighborhood sustainability assessment tools. Environmental Impact Assessment Review, 38, 73-87.
5. Sharifi, A., & Murayama, A. (2014). Neighborhood sustainability assessment in action: Cross-evaluation of three assessment systems and their cases from the US, the UK, and Japan. Building and Environment, 72, 243-258.
6. U.S Green Building Council [web page] (http://www.usgbc.org/resources/leed-v4-neighborhood-development-current-version) 2016 [Accessed March 2016].
7. BREEAM Communities Manual 2012, Technical Manual SD 202 0.1.2012
8. BREEAM [web page] (http://www.breeam.com/communities) 2016 [Accessed May 2016].
9. Sustainable Building Alliance [web page] (http://www.sballiance.org/our-work/libraries/new-urban-district-nsqnud/) 2016 [Accessed April 2016].
10. DGNB [web page] (http://www.dgnb-system.de/en/schemes/scheme-overview/neubau_stadtquartiere.php) 2016 [Accessed April 2016].
11. Komeily, A., & Srinivasan, R. S. (2015). A need for balanced approach to neighborhood sustainability assessments: A critical review and analysis.Sustainable Cities and Society, 18, 32-43
12. Sharifi, A., & Murayama, A. (2014). Neighborhood sustainability assessment in action: Cross-evaluation of three assessment systems and their cases from the US, the UK, and Japan. Building and Environment, 72, 243-258
13. Gleich AV. Comment: innovation ability and innovation direction. In: Lehmann- Waffenschmidt M, editor. Innovations towards sustainability conditions and consequences.
    New York: Physica-Verlag; 2007. p. 140–53
14. Valentin A, Spangenberg JH. A guide to community sustainability indicators. Environ Impact Asses Rev 2000;20:381–92.
15. Ma, L. J. (2002). Urban transformation in China, 1949–2000: a review and research agenda. Environment and planning A, 34(9), 1545-1569.
16. Li, Y. (2011). The complexity of urban transformation in China: New trends in current transitionalera. Journal of ITU Faculty of Architecture, 8(1), 155-168.
17. Sev A. A comparative analysis of building environmental assessment tools and suggestions
    for regional adaptations. Civ Eng Environ Sys 2011;28(2):231–45.
18. CASBEE Manual , 2007
19. http://www.ibec.or.jp/CASBEE/english/toolsE_urban.htm [Accessed May 2016].
20. Charlot-Valdieu C, Outrequin P. The European Commission community research; 2003 [WEB PAGES] http://www.box.net/shared/bc3sptnucj & http://www.suden.org/en/ european-projects/the-hqe2r-project/.
21. Gaffron Ph, Huismans G, Skala F, editors. Ecocity book II: howtomake it happen. Vienna:FacultasVerlags-und Buchhandels AG; 2008.
22. http://www.csb.gov.tr/gm/altyapien/ [Accessed May 2016].

"Materials - Eco Applications"

Paper No: 37

The Role of Cement and Concrete in Sustainable Construction

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ABSTRACT

Cement and concrete are the most widely used construction materials in the world [1]. Especially the production of cement has bad effects on environment due to release of high amount of carbon dioxide (CO_2) and greenhouse gases; consuming natural resources is another issue. In most countries like Turkey usage of Portland cement is very high. However, there are more eco-friendly and sustainable solutions such as blended cement or mineral additives used in concrete production process. It is very important to keep in mind that most of these additives are waste or by product. For this reason, usage of these types of material in concrete production is environmentally friendly.

Another important issue is lifetime of our buildings for sustainability. Moreover, maintenance costs have considerably high economic impact. Buildings, bridges, roads, railways, dams, ports and other construction facilities suffer aging over lifetime. The environmental exposure affect the structural performance. Usage of mineral additives or blended cements leads to improve durability of concrete structures and extend their lifetime. There are a lot of detailed scientific studies about mineral additives and their effects on mechanical and durability properties of concrete in literature but the aim of this paper is to emphasize the impacts of mineral additive usage in cement and concrete production on sustainable construction.

INTRODUCTION

Environmental pollution is not a new phenomenon. However, due to the rapidly growing volume of the pollutants, the environmental challenge we face now is not regional but global. According to scientists, the greatest environmental challenge today is that of man-made climate change due to global warming, which is caused by the steadily rising concentration of greenhouse gases in the earth's atmosphere during the past 100 years [2]. Worldwide, over ten billion tons of concrete are being produced each year. In addition, it has been estimated that the production of one ton of Portland cement causes the release of one ton of CO_2 into the atmosphere [3]. CO_2 is known to be a greenhouse gas that contributes to global warming. The production of Portland cement is also very energy-intensive. The environmental issues associated with greenhouse gas GHGs, in addition to natural resources issues, will play a leading role in the sustainable development of the cement and concrete industry during this century. Therefore, it is necessary to look for sustainable solutions for future concrete construction. Sustainable constructions must have small impact on the environment. They use green materials, which have low energy costs, high durability, low maintenance requirements, and contain a large proportion of recycled or recyclable materials. Durability of reinforced concrete structures is mainly dependent on the quality of the concrete, minimum shrinkage cracking, minimum to zero corrosion of reinforcing steel, cover for the reinforcement, curing of concrete, and quality management of concrete construction.

MAIN TEXT

Concrete is formed when cement creates a paste with water that binds with aggregates to harden. The main component of cement is clinker that is produced from raw materials, such as limestone and clay, which are crushed, homogenised and fed into a rotary kiln. The clinker burning takes place at a material temperature of 1450°C. The next phase is handled in a cement grinding mill. Gypsum and other additional materials (such as blast furnace slag, coal fly ash, natural pozzolanic materials, limestone, etc.) are added to the clinker. All constituents are ground leading to a fine and homogenous powder: cement. The production of cement releases GHG emissions both directly and indirectly. As shown in the following chemical reaction, the direct emissions of cement occurs when limestone, which is made of calcium carbonate ($CaCO_3$), is heated, breaking down into calcium oxide (CaO) and CO_2.

$CaCO_3 \rightarrow CaO + CO_2$

This process accounts for around 50% of all emissions from cement production. Indirect emissions are produced by burning fossil fuels to heat the kiln. Kilns are usually heated by coal, natural gas, or oil. This process accounts for around 40% of cement emissions. The electricity used to power additional plant machinery, and the final transportation of cement, represents another source of indirect emissions and account for 5-10% of the industry's emissions.

The cement industry is one of two largest producers of CO_2, creating up to 5% of worldwide man-made emissions of this gas. The energy consumed in the production of Portland cement, shown in Table 1, was estimated to be 4.88 MJ/kg.

Table 1 Energy used in the production of Portland cement [4]

Production Step	Energy (MJ/kg cement)
Extraction of raw materials	0.044
Transportation of raw materials	0.089
Crushing and grinding of raw materials	0.386
Pyroprocessing	4.041
Grinding cement	0.188
Transportation of cement	0.133
Total	4.882

The energy in the production of concrete, shown in Table 2, was estimated to be 0.89 MJ/kg or 2.07 GJ/m^3.

Table 2 Energy used in the production of concrete [4]

Constituent	Energy (MJ/kg concrete)
Coarse aggregate	0.028
Fine aggregate	0.028
Portland cement	0.735
Water	0.000
Manufacturing	0.102
Total	0.893

The methods by which CO_2 emissions can be reduced in the production of cement are [5]:

i) Improvement of the energy efficiency of the process

ii) Replacing high carbon fuels by low carbon fuels

iii) Replacing fossil fuels with alternative fuels (e.g. waste-derived fuels)

iv) Applying lower clinker/cement ratio

Efficiency measures can reduce the demand for fuel by addressing the production process itself (such as switching from inefficient wet kilns to dry ones) or through technical and mechanical improvements (such as preventative maintenance to repair kiln leaks). While some estimate that energy efficiency improvements could achieve emission reductions of up to 40%. Burning fossil fuels to heat the kiln can be reduced by switching to alternative fuels, including natural gas, biomass and waste-derived fuels such as tires, sewage sludge and municipal solid wastes. These less carbon-intensive fuels could reduce overall cement emissions by 18-24% [6].

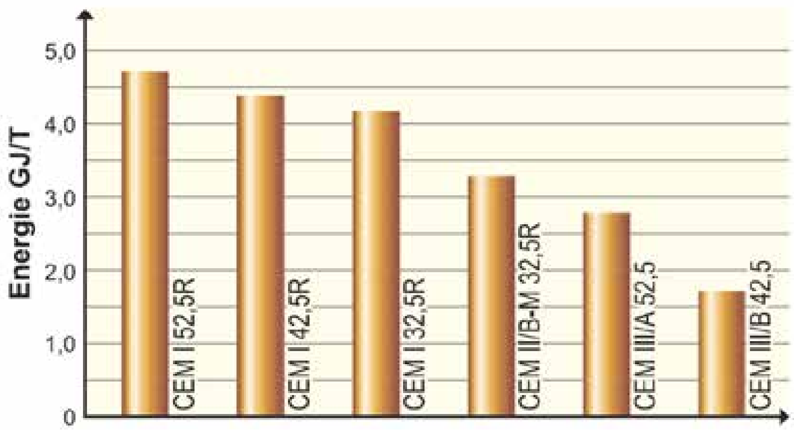

Figure 1 Energy consumption for cement production [7]

Ordinary Portland Cement (OPC) is the most common cement type which is composed of 95% clinker and 5% gypsum. The gypsum is ground together with the cement clinker to control the setting time to allow mortar or concrete produced with the cement to be worked into moulds and placed around reinforcement. Reducing emissions from the calcination process means looking to a material other than limestone. Blended cement replaces some of the limestone-based clinker with other materials. CO_2 emissions from cement production depend on the ratio of clinker/cement which varies from mostly 50% to 90%. Cement in Europe must be manufactured according to the harmonized standard EN 197 which clearly indicates the 27 common cements according to their main constituent. Depending on availability, part of the clinker can be replaced with alternative pozzolanic constituents. [8]. Pozzolanic materials do not require heat treatment, as a substitution to clinker in production. These materials containing minerals can provide the same properties in cement as clinker does. Figure 1 shows amount of energy required for the production of different cement types. The required energy amount degreases with the increasing quantity of mineral additives used as substitution (From CEM I 52,5R to CEM III/B 42,5).
Three major examples are granulated blast furnace slag, silica fume, and fly ash. The fly ash is a product of the pulverized coal firing system, through conventional boilers, mostly used in the thermal power plants. While carbon burns in oxidizing surroundings, the inorganic mineral matter gets sintered and liquefied at high temperature. The melt flows down the walls of the furnace and some part (approximately 25%) gets collected as bottom ash. It is crushed before disposal. The rest, fly ash, gets entrained in the up-flowing hot gas in the form of fine particles, which get trapped in the economizer, air-preheater, mechanical separator, and, finally, battery of

electrostatic precipitators [9]. At one time, most fly ash was landfilled, but today a significant portion is used in concrete and cement industry.
Silica fume is a waste by-product of processing quartz into silicon or ferro-silicon metals in an electric arc furnace. Silica fume consists of superfine, spherical particles. When added to concrete, silica fume acts in two ways. As filler, it improves the physical structure, occupying the space between hydrated cement particles, and as a pozzolan, it reacts chemically with the calcium hydroxide released during the hydration of cement, imparting greater strength and durability to concrete. The special properties of silica fume improve the rheology of fresh concrete benefiting concrete pumping and the stability of concrete mix. The important characteristics that make silica fume an effective pozzolanic material are its fineness (15000–25000 m^2/kg, N_2 adsorption method), with an average particle diameter 100 times smaller than that of Portland cement, its spherical shaped particles that improve the rheology of concrete, and its glassy structure and high amorphous silica that enhances reactivity with cement [9]. It is used for some high-rise buildings to produce concrete which exceeds 140MPa compressive strength and in bridge and parking garage construction to help keep chlorides from deicing salts from corroding steel reinforcement.
Blast furnace slag is the waste by product of iron manufacture. After quenching and grinding, the blast furnace slag takes on much higher value as a supplementary cementitious material for concrete. Blast furnace slag is used as a partial replacement for cement to impart added strength and durability to concrete. Besides use as a cementitious material, iron slags are used as raw feed in cement manufacture and aggregates in concrete mixtures.
For sustainable concrete, sustainable infrastructures, resource conservation, and reduction in carbon footprint of concrete-based infrastructures are the principle driving parameters. The idea of sustainable concrete includes recycling of appropriate industrial by-products for the reduction of consumption of virgin natural resources and energy without compromising quality and service life by ensuring an improved quality construction. Sustainable concrete is a smart solution that limits the adverse effects of its manufacturing by consuming less energy and less natural resources (for example, recycling of suitable by-products from industry) for its manufacturing. Additionally, it ought to be highly durable, and have little adverse impact on the environment. To produce sustainable concrete, it is crucial to use reasonably the natural resources and decrease the environmental impact in comparison with conventional concrete. This is generally achieved through reduced mining of natural resources required for the manufacture of concrete. This can be achieved by recycling of suitable industrial by-products such as coal-combustion by-products and other types of biomass ash, pulp, and paper mill residual solids, silica fume, ground granulated blast furnace slag, rice husk ash, limestone mining and processing by-products, cement kiln dust, waste-washed water, and other similar materials. The use of these materials not only reduces manufacturing cost and the adverse environmental effects of concrete but also improves the service life of the structures [10].
The enhancement of service life is designing concrete structures based on performance criteria. The addition of mineral additives to concrete affects reduction in cement consumption, energy consumption, and cost. The gain is maximized in case of high performance concrete (HPC) with the durability criteria predominating over strength. The HPC, with a well-designed mix proportion, produces structures with adequate durability for the desired service life and reduces cost and energy demand for the construction-repair-demolition-recycling-reconstruction cycle, making the construction process self-sustainable, contributing toward the conservation of natural resources [11].
Durability is the ability of a structure to resist weathering action, chemical attack, and abrasion, while maintaining minimum strength and other desired engineering properties. Nowadays, designing for strength and durability is similar to design for sustainability. The performance-based approach is linked to structural design based on

durability-based service life. The structure's reliability is the probability of a structure to fulfil the given functions during its service life, that is, to keep the performance characteristics: safety, durability, and serviceability, within the given limits [12]. When mineral admixtures are used, the strength of concrete can be considered as a result of three principal factors: reduction in the quantity of cement, heterogeneous nucleation (physical) and pozzolanic reaction (chemical). The net result is higher long-term strength, in most cases.

Exposed to the environment, the commonly observed processes causing deterioration of concrete are carbonation, alkali-aggregate reactions, corrosion of reinforcement, sulphate action, decalcification or leaching, and frost action [12].

The below mentioned factors could improve the concrete performance [13]:

a) The pores in hardened cement paste are filled up by the C-S-H formed by the secondary hydration of mineral additives, making the structure finer and denser. The reduced permeability suppresses the movement of pore solution within and the diffusion of deteriorating agents from outside.

b) The attack of sulphates (Na_2SO_4 and $MgSO_4$) on the hardened cement paste at later stage is promoted by the surplus C_3A, which remains after reaction with gypsum during hydration. The C_3A content can be reduced by the replacement of cement with mineral admixtures.

c) In case of sulphate attack, alkali sulphates react with CH to produce additional $C\hat{S}$ leading to expansive ettringite formation. CH produced during Portland cement hydration is consumed by the pozzolanic/cementitious reactions occurring during the hydration of mineral admixtures. The reduction in CH during hydration of mineral admixtures leads to reduction in $C\hat{S}$ generation and helps decrease sulphate attack risk.

d) Some mineral additives have greater chloride-binding capacity in comparison to OPC. This property limits the ingress of chloride ions, responsible for corrosion, into the hardened concrete.

e) The packing effect created by the unreacted particles of mineral admixture permit the densification and consequent reduction in the permeability of concrete structure.

Supplementary cementitious materials (SCMs) such as blast furnace slag, fly ash and silica fume are industrial by-products which are used for concrete production offering environmental and performance benefits. The addition of these materials to cement and concrete improves performance in terms of long term strength and the durability.

By the use of SCMs, the environmental footprint can be reduced and improved fresh and hardened properties of concrete can be obtained. Typical SCM proportions range from 15 to 40% of a mix design (by mass) and their use is also influenced by the local availability of these materials [14].

CONCLUSION

As the one of the largest consumer of natural resources and energy, the cement and concrete industry is one of the primary contributors to unsustainability. But the situation is not as bad as it might seem, because properly produced concrete is inherently an environmentally friendly material. Cost-effective and ecological technologies are now available that will allow the substitution of substantial amounts of industrial by-products into conventional concrete and cement mixtures. Major improvements in the resource efficiency of the concrete industry are possible if, in the long run, we reduce the rate of concrete consumption by lengthening the service life of newly built structures.

The mineral additives that are in fact industrial wastes substitute clinker or cement in cement and concrete production respectively. The alternative usage of these "wastes" permits us to get rid of them in an eco-friendly way and to produce concrete and cement with low energy, contributing toward the conservation of natural resources. Additionally, structures that are built with these construction materials modified by by-products have improved design and service life. These improvements enable to decrease maintenance and repair costs of structures which get more durable with better performance against various severe exposure conditions. To ensure not only the sustainability of cement or concrete but of the structure itself, usage of mineral additives, by-products have to be promoted all over the world.

REFERENCES

[1] Baghchesaraei A., Baghchesaraei O.R., Portland Cement, International Conference on Transport, Civil, Architecture and Environment engineering (ICTCAEE'2012) Dubai (UAE),December 26-27, 2012, pp. 51-54

[2] Mehta P.K., Greening of the Concrete Industry for Sustainable Development, Concrete International, July 2002.

[3] Malhotra V.M., Role of Supplementary Cementing Materials in Reducing Greenhouse Gas Emissions, Concrete Technology for a Sustainable Development in the 21st Century, London, 2000.

[4] Struble L., Godfrey J., How sustainable is concrete? International workshop on sustainable development and concrete technology Beijing, May 20-21 2004, pp. 201-211

[5] The Executive Committee of the International Energy Agency CO_2 Capture in the Cement Industry Technical Study Report Number: 2008/3

[6] State of the Planet Earth Institute Emissions from the Cement Industry, Columbia University, http://blogs.ei.columbia.edu/2012/05/09/emissions-from-the-cement-industry

[7] De Herde A., Evrard A., Le Béton et la Construction Durable, Publication de FEBELCEM

[8] The European Cement Association (CEMBUREAU) Sustainable cement production, 2009

[10] Tarun R. N., Kumar, R., Green Building with Concrete Sustainable Design and Construction, Chapter 12. Sustainable Concrete with Industrial and Postconsumer By-Product Materials, Second Edition CRC Press 2015 Pages 337–372 Print ISBN: 978-1-4987-0410-6, DOI: 10.1201/b18613-13.

[11] Isaia G. C., High-performance concrete for sustainable constructions. In Waste Materials in Construction, Eds. G. R. Woolley, J. J. J. M. Goumans, P. J. Wainwright, Elsevier Science Ltd., Amsterdam, the Netherlands, 2000.

[12] Bapat, J. D., Mineral Admixtures in Cement and Concrete, CRC Press 2012 Print ISBN: 978-1-4398-1792-6

[13] Bapat J. D., Performance of cement concrete with mineral admixtures, Adv. Cem. Res., 13(4), 2001, 139–155.

[14] Using concrete as a sustainable solution for buildings, Print Course, presented by PCA America's Cement Manufacturers

Paper No: 108

Energy Labelling of Electrical Lamps and Luminaires in the Scope of Eco-design

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ABSTRACT

Promoting energy efficiency is one of the main objectives laid down by the European Parliament and the Council in the Directive 1600/2002/EC in order to reduce greenhouse emissions in the energy sector under the scope of the European Climate Change Programme. As stated in the Directive 2009/236/EC of the European Parliament and of the Council: "Energy-related products account for a large proportion of the consumption of natural resources and energy in the Community" and these products have a remarkable potential for being improved and consuming less energy. The European Council states that labelling certain types of household appliances allows users to choose more energy-efficient alternatives. Light sources are considered as one of the many appliances that should be labelled by the Council Directive 92/75/EEC. The first directive thatfocused on the labelling of household lamps was published in 1998 and replaced in 2012 by the Regulation 874/2012 "Energy Labelling of Electrical Lamps and Luminaires". In this study, the evolution of the energy labelling system and the calculation methodology for light sources and luminaires are investigated and the necessary energyefficiency measures are explained.

INTRODUCTION

Improving energy efficiency and reducing the energy demand can be considered as the fastest and cheapest ways to deal with increased carbon emissions and climate change for a sustainable world. In this context, the European Union (EU) laid down the "Sixth Community Environment Action Programme – 1600/2002/EC" in 22 July 2002 which addresses the key environmental objectives and priorities [1]. By 2020, the EU aims to reduce its greenhouse gas emissions by at least 20%, increase the share of renewable energy to at least 20% of consumption, and achieve energy savings of 20% or more [2]. Through achieving these targets, the EU can help in the fight against climate change and air pollution, reduce its reliance on foreign fossil fuels, and maintain energy affordable for consumers and businesses. There are five priorities in the 2020 Energy Strategy, the first of which is of importance to this study, which is to make Europe more energy efficient by accelerating investment into efficient buildings, products, and transport. This includes measures such as energy labelling schemes, renovation of public buildings, and Eco-design requirements for energy intensive products.Among other environmental issues, this Programme aims at reducing greenhouse gas emissions by promoting energy efficiency. In order to assure that purchasers are better informed about the products in terms of their environmental impacts, the Programme suggest the applications of eco-labels and other forms of labelling that allow comparison between similar products. eco-design assumes that the effect a product has on the environmentshould be considered and reduced in all stages along the product life-cycle [3]. The European Council states that labelling certain types of household appliances allows users to choose more energy-efficient appliances, which is essential in the concept of eco-design.The first directive which specialized for the labelling of household lamps was published in 1998(98/11/EC, "energy labelling of household lamps") and replaced in 2012 by the Regulation 874/2012 "Energy Labelling of Electrical Lamps and Luminaires" [4-5]. The historical development of the labelling system and the necessity and rules for the eco-labelling are explained in the next sections.

THE ENERGY LABELLING PATH OFTHE EUROPEAN UNION

The EU Council Directive 92/75/EEC of 22 September 1992 on the"indication by labelling and standard product information of the consumption of energy and other resources by household appliances" requires rational utilization of natural resources and energy [6]. The directive states that it is necessary to introduce a uniform label for all appliances of the same type to provide supplementary standardized information on those appliances' costs in terms of energy and the consumption of other resources. The Directive's main aim is to allow consumers to choose more energy-efficient appliances. The Directive is valid for following types of appliances:

- Refrigerators, freezers and their combinations,
- Washing machines, driers and their combinations,
- Dishwashers,
- Ovens
- Water heaters and hot-water storage applications,
- Lighting sources,
- Air-conditioning appliances.

The Directive states that a technical document should be prepared including a general description of the product, the results of relevant design calculations and test reports. Information related to the consumption of energy should be given by means of a fiche and a label. All suppliers should supply a label indicating the energy use and should be responsible for the accuracy of the data on the labels.

The Commission Directive 98/11/EC of 27 January 1998 "Implementing Council Directive 92/75/EEC with regard to energy labelling of household lamps" applies to household electric lamps supplied directly from mains (filament, integral compact fluorescent lamp-CFL) and to household fluorescent lamps (linear and non-integral CFLs) [4]. The lamps with a luminous flux of more than 6500 lumens, lamps with an input power of less than 4 Watts, reflector lamps, lamps for using with other energy sources, lamps that produce light outside of the 400-800nm region and lamps whose primary purpose is not illuminative are excluded. The label should be placed or printed on or attached to the outside of the individual package. The label design is given in the ANNEX of the directive and is explained in the next section.

The Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 "Establishing a framework for the setting of eco-design requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council" provides for the setting of requirements which the energy-using products covered by implementing measures must fulfil in order for them to be placed on the market [7]. The Directive addresses Directive 2000/55/EC of 18 September 2000 "On energy efficiency requirements for ballasts for fluorescent lighting" which aims at reducing energy consumption for ballasts for fluorescent lighting by moving towards the more efficient ballasts which may offer extensive energy saving features [8]. The Directive 2005/32/EC states that the existing measures for the lighting products should be integrated into the present framework.

The Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009, "Establishing a framework for the setting of eco-design requirements for energy-related products" has substantially amended The Directive 2005/32/EC which established a framework for setting of community eco-design requirements [7]. The products that have been identified by the European Climate Change Programme (ECCP) [9] offering

a high potential for cost-effective reduction of greenhouse gas emissions such as heating and water heating equipment, electric motor systems, lighting in both the domestic and tertiary sectors, domestic appliances, office equipment, consumer electronics and heating ventilating air conditioning (HVAC) systems and also for reducing stand-by losses. The Directive is also a complimentary to Council Directive 92/75/EEC (22 September 1992) on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances [6].
The Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on "The indication by labelling and standard product information of the consumption of energy and other resources by energy-related products" establishes a framework for the harmonization of national measures on end-user information, particularly by means of labelling and standard product information on the consumption of energy and where relevant of other essential resources during use and supplementary information concerning energy-related products thereby allowing end-users to choose more efficient products and applies to energy-related products which have a significant direct or indirect impact on the consumption of energy and on other essential resources during use [10].
The Commission delegated regulation of EU No 874/2012 of 12 July 2012 "Supplementing Directive 2010/30/EU of the European Parliament and of the Council withregard toenergy labelling of electrical lamps and luminaires" establishes requirements for labelling of and providing supplementary product information on electrical lamps such as filament lamps, fluorescent lamps, high-intensity discharge lamps, LED lamps and LED modules [5]. The following products are excluded from the scope of the regulation:

- Lamps and LED modules with a luminous flux of less than 30 lumens,
- Lamps and LED modules marketed for operation with batteries,
- Lamps and LED modules for applications where their primary purpose is not lighting,
- Lamps and LED modules marketed as a part of a luminaire and not intended to be removed by the end-user,
- Lamps and LED modules that becoming applicable in 2013 and 2014
- Luminaires that are designed to operate exclusively with the lamps and LED modules with a luminous flux of less than 30 lumens or for applications where their primary purpose is not lighting.

The label definitions for the lighting products are explained in the ANNEX of the regulation and detailed information and calculations are given in the next section.
The Commission delegated regulation of EU No 1194/2012 of 12 December 2012 "Implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to eco-design requirements for directional lamps, light emitting diode lamps and related equipment" establishes eco-design requirements for directional lamps, LED lamps, lamp control gear and control devices [11]. The calculation methodology is explained in the next section. It is stated that the combined effect of the eco-design requirements set out in this regulation and the Commission Delegated Regulation 874/2012 is expected to result in annual electricity savings of 25 TWh by 2020 among directional lamps, compared with the situation if no measures were taken.
In the next section the labelling process and eco-design calculations are explained in detail.

ENERGY LABELLING AND ECO-DESIGN CALCULATIONS

In this section Commission Directive 98/11/EC and regulations 874/2012-1194/2012 are elaborated in detail and the labelling process is explained.

1. **1998 - Commission Directive 98/11/EC "Energy Labelling of Household Lamps"**

The Commission Directive 98/11/EC entitled "Implementing Council Directive 92/75/EEC with regard to energy labelling of household lamps" was published in 27 January 1998. The Label design is given in the ANNEX section of the directive and can be seen in Figure 1.

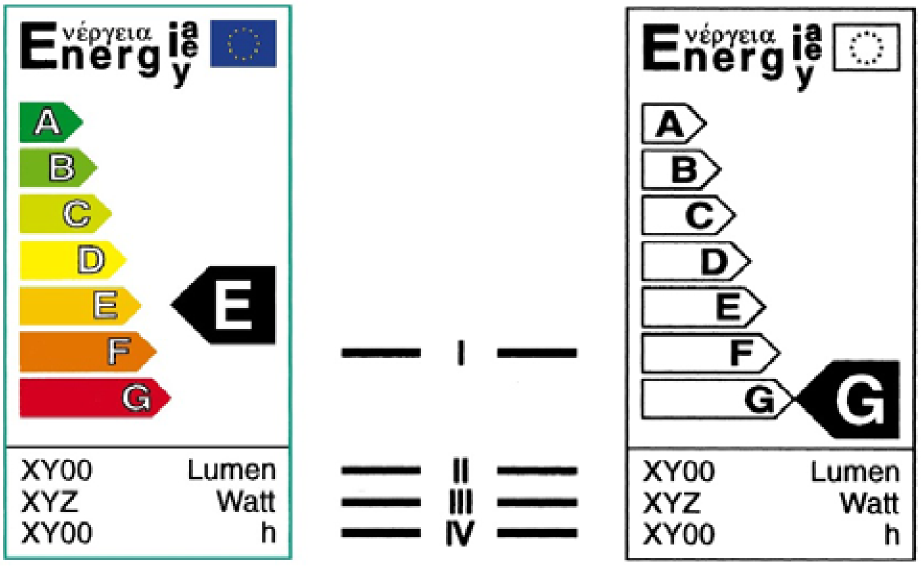

Figure 1. Label design according to the Directive 98/11/EC

The energy efficiency class –I-of the lamp is determined using the instructions given in ANNEX IV. The fluorescent lamps without an integral ballast is classified in class A if:

$$W \leq 0.15\sqrt{\Phi} + 0.0097 \qquad \text{(I)}$$

Where W is the power of the lamp and ɛis the luminous flux of the lamp.
Other kinds of lamps are classified in the A class if:

$$W \leq 0.24\sqrt{\Phi} + 0.0103\,\Phi \qquad \text{(II)}$$

If a lamp is not classified in class A, a reference wattage for all kinds of lamps,$W_R W_R$ should be calculated as follows:

$$\begin{aligned} W_R &= 0.88\sqrt{\Phi} + 0.0049\,\Phi, \text{when } \Phi > 34\ lumens \\ W_R &= 0.2\,\Phi, \qquad \text{when } \Phi \leq 34 \text{ lumens} \end{aligned} \qquad \text{(III)}$$

As the next step, an energy efficiency index (E_I) should be set as:

$$E_I = \frac{W}{W_R} \qquad \text{(IV)}$$

where W is the power of the lamp.
The energy efficiency classes are given in Table 1.
Table 1. Energy Efficiency Classes according to the Energy Efficiency Index

Energy Efficiency Class	Energy Efficiency Index (E_I)
B	$E_I < 60\%$
C	$60\% \leq E_I < 80\%$
D	$80\% \leq E_I < 95\%$
E	$95\% \leq E_I < 110\%$
F	$110\% \leq E_I < 130\%$
G	$E_I \geq 130\%$

The luminous flux -II-, wattage -III- andrated life -IV- of thelamp, as denoted on the energy label, is measured according to the test procedures of the harmonized standards.

2. **2012 (a) - Commission Delegated Regulation 874/2012 "Supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of electrical lamps and luminaires"**

Directive 2010/30/EU requires the labelling of energy-related products having significant potential for energy savings. The energy labelling directive 98/11/EC is extended to include luminaires and LED based sources as well with the Regulation 874/2012. The label design shall be as in Figure 2 where I is the supplier's name or trademark, II is the model identifier, III is the energy efficiency class and IV is the weighted energy consumption per 1000 hours.

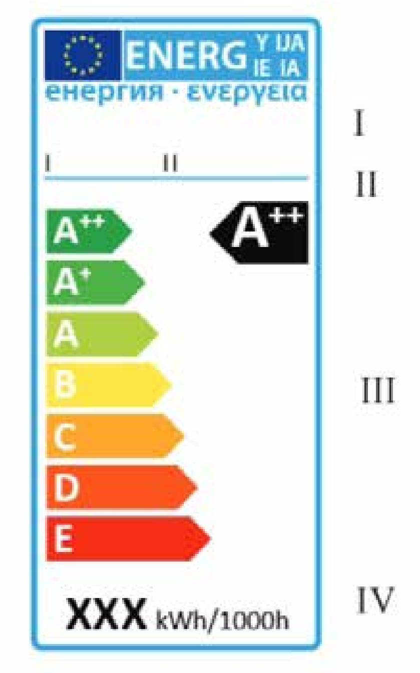

Figure 2. Label design for lamps according to Regulation 874/2012

There are 7 energy efficiency classes defined in 874/2012 as in 98/11/EC. The classes are determined on the basis of their Energy Efficiency Index (EEI). The EEIs for different classes are given in Table 2. In contrast to 98/11/EC the EEIs are different for directional and non-directional lamps, directional lamps having at least 80% of light output within a solid angle of π sr – which corresponds to a cone with an angle of 120°.

Table 2. Energy Efficiency Classes for directional and non-directional lamps

Energy Efficiency Class	Energy Efficiency Index (EEI) for non-directional lamps	Energy Efficiency Index (EEI) for directional lamps
A++ (most efficient)	EEI≤0.11	EEI≤0.13
A+	0.11<EEI≤ 0.17	0.13<EEI≤ 0.18
A	0.17<EEI≤ 0.24	0.18<EEI≤ 0.40
B	0.24<EEI≤ 0.60	0.40<EEI≤ 0.95
C	0.60<EEI≤ 0.80	0.95<EEI≤ 1.20
D	0.80<EEI≤ 0.95	1.20<EEI≤1.75
E (least efficient)	EEI>0.95	EEI>1.75

The EEI is calculated using Formula V, roundedto two decimal places:

$$EEI = P_{cor}/P_{ref} \quad \text{(V)}$$

Where P_{cor} is the rated power for models without external control gear. P_{cor} for the models with external control gear is calculated using Table 3.

Table 3. Power correction for the models with external control gear

Scope of the correction	Power corrected for control gear losses (P_{cor})
Lamps operating on external halogen lamp control gear	$P_{rated}\ x\ 1.06$
Lamps operating on external LED lamp control gear	$P_{rated}\ x\ 1.10$
Fluorescent lamps of 16 mm diameter (T5 lamps) and 4-pin single capped fluorescent lamps operating on external fluorescent lamp control gear	$P_{rated}\ x\ 1.10$
Other lamps operating on external fluorescent lamp control gear	$P_{rated}\, x \dfrac{0.24\sqrt{\Phi_{use}} + 0.0103\Phi_{use}}{0.15\sqrt{\Phi_{use}} + 0.0097\Phi_{use}}$
Lamps operating on external high-intensity discharge lamp control gear	$P_{rated}\ x\ 1.10$
Lamps operating on external low pressure sodium lamp control gear	$P_{rated}\ x\ 1.15$

P_{ref} is the reference power obtained from the useful luminous flux of the model by the following formulae:

For models with $\Phi_{use} < 1300\ lumen$: $P_{ref} = 0.88\sqrt{\Phi_{use}} + 0.049\Phi_{use}$ (VI)

$\Phi_{use} < 1300\ lumen$: $P_{ref} = 0.88\sqrt{\Phi_{use}} + 0.049\Phi_{use}$

For models with $\Phi_{use} \geq 1300\ lumen$: $P_{ref} = 0.07341\Phi_{use}$ (VII)

$\Phi_{use} \geq 1300\ lumen$: $P_{ref} = 0.07341\Phi_{use}$

The useful luminous flux ($\Phi_{use}\Phi_{use}$) is defined in Table 4.

Table 4. Definition of the useful luminous flux

Model	**Useful Luminous Flux** ($\Phi_{use}\Phi_{use}$)
Non-directional lamps	Total rated luminous flux ($\Phi\Phi$)
Directional lamps with a beam angle ≥ 90° other than filament lamps and carrying a textual or graphical warning on their packaging that they are not suitable for accent lighting	Rated luminous flux in a 120° cone ($\Phi_{120°}\Phi_{120°}$)
Other directional lamps	Rated luminous flux in a 90° cone ($\Phi_{90°}\Phi_{90°}$)

The weighted energy consumption (E_c) per 1000 hours is calculated as follows and is rounded to two decimal places:

$$E_c = \frac{P_{cor} x 1000h}{1000} [kWh/1000h] \tag{VIII}$$

The labels for luminaires can be seen in Figure 2.

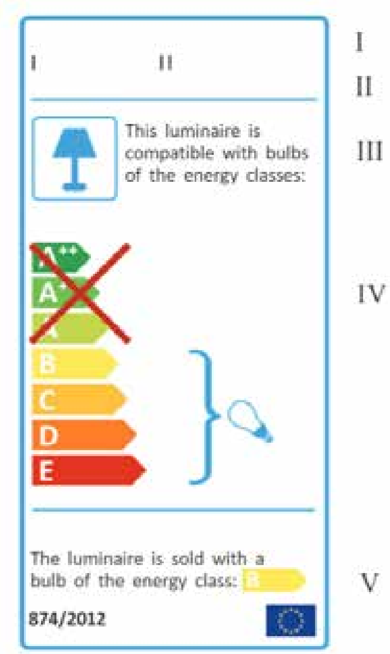

Figure 2. Label design for luminaires according to Regulation 874/2012

The first section I-II should include the supplier's name and model description. III-IV describes the compatible lamp energy classes and V describes the energy class of the current lamp.

3. **2012 (b) Commission Regulation 1194/2012 "Implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to eco-design requirements for directional lamps, light emitting diode lamps and related equipment"**

The regulation establishes eco-design requirements for placing on the market for directional lamps, light-emitting diode (LED) lamps and equipment designed for installation between the mains and the lamps including lamps control gear/devices and luminaires. For each eco-design requirement, the following stages are defined:

- Stage 1: 1 September 2013
- Stage 2: 1 September 2014
- Stage 3: 1 September 2016

The Energy Efficiency Index (EEI) is defined as in Regulation 874/2012 (Formula V and Table 2). The calculation methodology for EEI is the same as 874/2012 as described above. The maximum EEI values defined for different lamp types according to three stages are given in Table 5.

Table 5. Maximum energy efficiency index

Application Date	**Maximum energy efficiency index (EEI)**			
	Mains-voltage filament lamps	**Other filament lamps**	**High-intensity discharge lamps**	**Other lamps**
Stage 1	If $\Phi_{use}\Phi_{use}$>450lm: 1.75	If $\Phi_{use}\Phi_{use}$≤450lm: 1.20 If $\Phi_{use}\Phi_{use}$>450lm: 0.95	0.50	0.50
Stage 2	1.75	0.95	0.50	0.50
Stage 3	0.95	0.95	0.36	0.20

In addition to maximum EEI, as of Stage 2 the maximum stand-by power should not exceed 1.0W. As of Stage 3, this limit should be 0.5W.

Furthermore, the Regulation defines functionality requirements for directional fluorescent lamps, LED lamps and other lamps. These are as follows:

- Lamp survival factor,
- Lumen maintenance,
- Number of switching cycles before failure,
- Starting and warm-up times,
- Premature failure rate,
- Lamp power factor,
- Color Rendering Index (CRI/Ra).

In order to verify these, authorities should test a sample batch of minimum 20 lamps of the same model from the same manufacturer using appropriate measurement methods. As these functionality requirements are beyond the scope of this study, they have not been elaborated in detail.

CONCLUSION

According to the European Commission Guidelines accompanying "Regulation (EU) 874/2012 with regard to energy labelling of lighting products and Regulations (EC/EU) 244/2009, 245/2009 and 1194/2012 with regard to eco-design requirements for lightingproducts" published in July 2015, lighting accounts for 19% of the worldwide electricity consumption and 14% of all electricity consumption in the EU [12]. Residential lighting, which includes halogen, fluorescent (tubular/compact), LEDs and also control systems and luminaires represent 30% of the total European lighting market. The European Union has set very ambitious energy targets with its Energy 2020 strategy and energy labelling schemes along with eco-design requirements are a strong pillar of this policy. Energy labelling regulations establish a framework for the harmonization of national measures on end-user information concerning energy-related products and allowing end-users to choose more efficient products, thus significantly contributing to the energy efficiency target of the EU. In addition to Energy Labelling targeting the end-users, Eco-design Regulations target the manufacturers and obligate them to decrease the energy consumption of their products by establishing minimum energy efficiency standards at European level, once again contributing to the energy efficiency targets of the Union. In this study, the evolution of the energy labelling system and the calculation methodology for light sources and luminaires as well as the implementing Directive of eco-design requirements have been investigated through analysing the step by step evolution of the energy label and the different calculation methods. The speed of change of the lighting technologies, especially due to the fast evolving LED light sources, are a direct driving force for new regulations and as the study clearly shows, novel technologies will bring new calculation methods and new labelling needs in the near future.

REFERENCES

[1] European Council. Council Decision No 1600/2002/EC of 22 July 2002 laying down the Sixth Community Environment Action Programme. Official Journal L242, 10/09/2002 p. 0001-0015

[2] European Commission. "A strategy for competitive, sustainable and secure energy". Can be downloaded at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52010DC0639&from=EN

[3] http://www.ecodesign.at/einfuehrung/allgemein/ecodesign/index.en.html

[4] European Commission. Commission Directive 98/11/EC of 27 January 1998 implementing Council Directive 92/75/EEC with regard to energy labelling of household lamps. Official Journal L7, 10.03.1998, p. 01-08. Can be downloaded at: http://europe.eu.int/eur-lex/

[5] European Commission. Commission Delegated Regulation No 874/2012 of 12 July 2012 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of electrical lamps and luminaires. Official Journal L258, 26/09/2012, p. 01-20. Can be downloaded at: http://europe.eu.int/eur-lex/

[6] European Council. Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances. Official Journal L297, 13/10/1992 p. 0016-0019

[7] European Council. 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of eco-design requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council. Official Journal L191, 22/07/2005 p. 0029-0058

[8] European Council. Directive 2000/55/EC of the European Parliament and of the Council of 18 September 2000 on energy efficiency requirements for ballasts for fluorescent lighting. Official Journal L279, 01/11/2000 p. 0033-0039

[9] European Commission. European Climate Change Program. http://ec.europa.eu/clima/policies/eccp/index_en.htm

[10] European Council. Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products. Official Journal L153, 18/06/2010 p. 0001-0012

[11] European Commission. Commission Regulation (EU) No 1194/2012 of 12 December 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to eco-designrequirements for directional lamps, light emitting diode lamps and related equipment. Official Journal L342, 14/12/2012, p. 0206-0227. Can be downloaded at: http://europe.eu.int/eur-lex/

[12] European Commission. Guidelines accompanying Regulation No: 874/2012 with regard to energy labelling of lighting products and Regulations No: 244/2009, 245/2009 and 1194/2012 with regard eco-design requirements for lighting products. https://ec.europa.eu/energy/sites/ener/files/documents/Implementation%20Guide%20Lighting.pdf

Paper No: 149

Sustainability of Steel Structures and Contribution to Circular Economy

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ABSTRACT

Sustainability of human presence on the planet Earth is the number one challenge facing humanity and the construction sector. Steel is one of the most promising structural material of our age in this respect. Steel is already being widely used as a structural element in reinforced concrete in round forms. However when to be used as beams or in other forms alone or in composite structures, steel meets a lot of prejudice from conservative designers or contractors who are not well informed about the characteristics and advantages of steel as a structural material. This article will clarify the role of steel and its contribution to sustainability and circular economy while correcting the frequently made conceptual mistakes about steel structures.

INTRODUCTION

We live in a rapidly changing world with finite resources. Global population growth, exert pressure on our already stressed ecosystems. Forecasts predict that the world human population will grow to 9 billion and 70% of this population will be living in the cities up from 6 billion and 50% today. In addition to the population increase, improvements in standards of living, policies towards eradication of poverty and consumerist life styles are exacerbating the pressure on the resources and self-regeneration capacity of the planet earth. The result -as was predicted many years ago by proper scientists- is human induced global warming and climate change on Earth. We started seeing the adverse effects of the climate change in our daily lives much faster than a distant future as most people wished it to happen. It is no more only an issue for next generations and polar bears but ours as well. Therefore we humans have to listen to the scientific reports of UN ICCP and take immediate action to curb emissions causing the greenhouse warming in order to moderate the already confirmed climate change results and build resilience to our societies and lifestyles.

The solution passes not through radical point and shoot temporary remedies but by a fundamental change of paradigms in human society and economy realizing the fact that both can only exist in a sustainably habitable environment. First, we have to put the widespread motto of the three-Ps in the right order as Planet-People-Profit (Figure:1). Second, we have to finalize all decisions on total life-cycle evaluation of environmental effects but not on partial scopes. Third we have to replace the consumerist take-make-use-dispose linear economy practices with "circular economy" models where long life use phase is followed by re-use as many times as possible in order to conserve the finite resources of our home planet and recovering, recycling without burying in graves or garbage mounds.

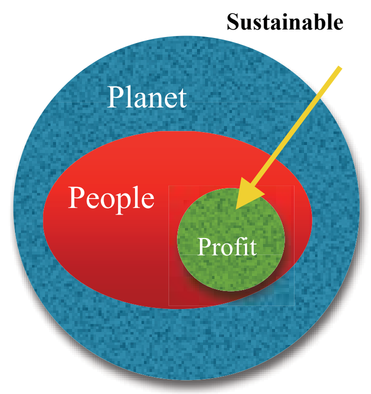


Figure 1 Correct Paradigm

Buildings alone represent 40% of the greenhouse gas emissions in their full life cycle, 25% in construction and 75% during use phases, in average round figures. Thus any attempt to curb the greenhouse gas emissions necessities considering the building sector as a priority topic keeping in mind the predicted future demand due to population growth and urbanization pressures.

We cannot continue with the common short-term, fragmented decision-making approach existing in the building sector today and look at the construction phase metrics alone. It is evident that the full life cycle of a building bears more burden but also more potential to save and profit than the construction phase only. Therefore we should evaluate the long-term lifecycle costing and performance according to the existing norms and standards while making decision on selection of construction materials [4 and 24].

Steel is everywhere in our lives as well as our buildings in many forms. The rebar in the widespread use of reinforced concrete is also steel. Steel is one of the most sustainable building materials we have on earth. Steel is infinitely reusable, recoverable and recyclable. Thus it is time to consider using more structural steel for full life cycle evaluation of buildings for sustainable and economical results and resilient buildings to the benefit of our planet-people and profits.

CIRCULAR ECONOMY

The consumerist societies are used to take raw materials from the planet, make products, consume and dispose after use and often times sadly even after the first use, ending in heaps of garbage that are familiar scenes around the world. This is called the “linear economy” that works from cradle to immediate grave for most products. (Figure: 2)

Figure 2 Linear Business Model

“Circular economy” on the other hand (Figure:3) promotes zero waste, reduces the amount of materials used for optimal resource efficiency, and encourages the reuse and recycling of materials [9].

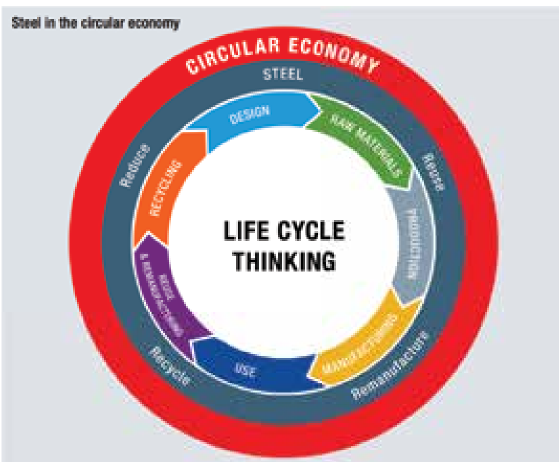


Figure 1 Correct Paradigm

However circular economy is not only about materials but the same principles apply to all other natural, social, human, financial, manufacturing resources. This approach enhances the flow of goods and services [2] allocating resources efficiently to products and services to the economic wellbeing of everyone. Fundamental to the triple-bottom-line concept of sustainability, which focuses on the interactions and limitations from environmental, social to lastly economic factors.

"Eco-design" approach -as complimentary enabling tool to circular economy- ensures that value is maintained within a product even when it reaches the end of its useful life while reducing or eliminating waste at the same time. Products intelligently eco-designed to be durable, easy to repair and, ultimately, to be recycled, eliminate the practice of replacing a product with a new one from being a norm. The six Re-words define the advantages of circular economy and eco-design: Reduce-Repair-Recover-Reuse-Re-Manufacture-Recycle. Of course the cost of reusing, repairing or re-manufacturing products has to be socially and economically competitive to encourage these practices.

Eco-design of products and services is only possible through a full "life cycle approach" covering the entire life cycle analysis (LCA) of a product in making decisions. Without such "life cycle thinking" (LCT), it is impossible to have a genuine circular economy.

In a well-structured circular economy, the steel industry has significant competitive advantages over competing materials to be compatible with the requirements of six Res and its full life cycle assessment techniques.

LIFE CYCLE ASSESSMENT - LCA

Life Cycle Thinking (LCT) is a term that is used to describe the holistic thinking that is needed to solve society's problems sustainably. Every product has a life cycle. Every product is manufactured, used, and then can be reused, recycled or disposed of at the end of its useful life.

Life cycle assessment (LCA) is the tool that enables us to measure the holistic environmental impact or performance of a product at each stage in its life cycle. Thus LCA provides an objective, quantifiable measure, which can be used to compare the environmental sustainability of similar products, and services, which have the same function. LCA considers the potential impacts from all stages of the material's life cycle including manufacture, product use and end-of-life stages by calculating the resources and energy used, and the waste and emissions produced from raw material extraction through to end-of-life recycling or disposal and beyond [16 and Annex A].

When a material is fully recycled back into the same material at the end of its useful service life, with no loss in quality, as is the case for steel, this is referred to as the cradle-to-cradle approach. A well-designed, steel-containing product will already anticipate the reuse or recycling of its components at the end-of-life which is already cradle-to-cradle approach unlike most other construction materials that have to be down-graded, discarded or buried, referred to as cradle-to-grave approach.

A full scope life cycle approach is vital in delivering true sustainable results. For buildings this means analyzing the entire life cycle of a product within the building service life and beyond before making decisions. Decisions to be based on the construction phase and/or on primary cost considerations only -which is the usual case of a contractor employing alternative lower cost materials- may adversely affect the "use phase" of the building typically resulting in higher environmental burden and also more expensive solutions [4] when the whole life cycle is considered. Life cycle thinking must become a key requirement for all building performance decisions as stipulated by the standards [17-24]

LCA calculations enable us to identify where the long-term environmental sustainability can be improved. For example, the small increase in energy consumption or the addition of alloying elements required to produce high-strength steels is compensated many times over when considered over the entire life cycle of the product.

STEEL LCA

Key raw materials needed in steelmaking include iron ore, coal, limestone and steel scrap [2] (recycled steel). The ingredients for steelmaking are still relatively abundant except steel scrap that is in short supply globally, largely due to the long service life of steel. However, the steel industry recycles as much steel scrap as possible that becomes available. Steel is produced through one of two main production routes, the blast furnace (BF) also called integrated route (70%) or the electric arc furnace (EAF) route (30%).

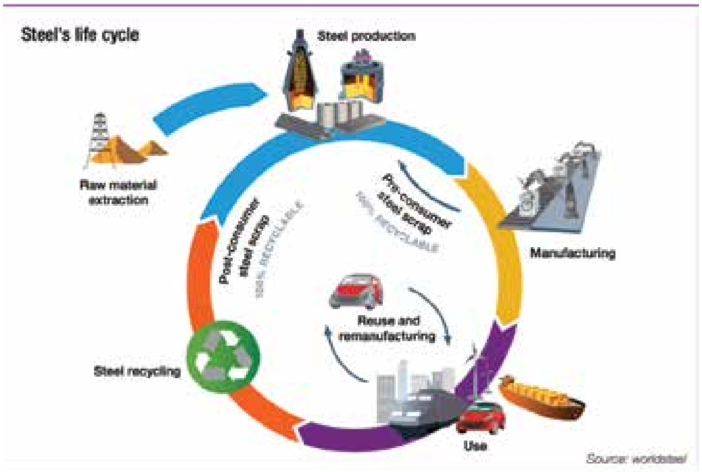


Figure 4 Steel LCA

The steel industry has dramatically reduced its energy consumption over the past half century [1, 2, 3] Members of WSA are collectively and individually exploring the development of new breakthrough technologies which may make it possible to reduce the energy consumption and CO_2 emissions of the steelmaking process further.

In addition to reducing their demand for raw materials, steelmakers have become more effective at reducing waste and finding markets for the by-products produced in the steelmaking process. This helps to significantly reduce waste from steel's life cycle. Today, approximately 96% of the raw materials used to make crude steel are converted into steel products or by- products [4]. The aim is to increase this to 100%.

The global construction industry has established a number of standards, which are driving the adoption of life cycle thinking in new buildings and renovations. Credits are awarded for the use of construction products that have lower environmental impact and are responsibly or locally sourced. One of steel's major benefits in these schemes is that it contributes to use phase, energy efficiency and it can be completely recycled or reused at the end of the building's life. LEED v4 [10] for building design and construction, released in November 2013, incorporates new credits for whole building LCAs, EPDs and product transparency documents.

The adoption of these standards has led many steelmakers to create EPDs (ISO 14025: 2006 Type III environmental labels and declarations [22]) for their own construction products. Typically an EPD presents LCA results covering each step of the product's life from raw material sourcing to its eventual disposal. However, cradle-to-gate EPDs are also being developed.

SUSTAINABLE CONSTRUCTION and THE STEEL INDUSTRY

Globally, the construction sector faces an unprecedented challenge to significantly reduce the greenhouse gas emissions generated by the building stock and new construction activities in order to improve the environmental, social and economic performance for a sustainable future. Steel industry is an integral part of the global circular economy and key supply partner to the construction industry. Currently 50% of all steel produced globally goes to the construction sector [1].

In 2012, WSA members signed the WorldSteel Sustainable Development Charter [5]which commits them to improving the social, economic and environmental performance of their companies. By signing the Charter, WorldSteel's members agreed to operate their businesses in a financially sustainable way, supply steel products and solutions that satisfy customer needs and provide value, optimize the eco- efficiency of steels throughout their life cycle, and foster the well-being of employees and communities. The Charter represents a definitive commitment by the global steel industry to embrace life cycle thinking and all three pillars of sustainability (environmental, social and economic). The steel industry is one of the few industries to monitor and report its sustainability performance at the global level, since the publishing of the first sustainability report in 2004. This has enabled the steel industry to benchmark its performance and to enhance transparency. Most companies also report on their sustainability performance individually.

In terms of ***environmental sustainability***, changes at every phase in the steel production process over the past 50 years have resulted in significant improvements in the resource and energy efficiency in the production of steel, including a 60% drop in energy consumption per tonne of steel produced. [9] The environmental benefits related to steel's durability, allowing for long product lifetimes and reuse, recyclability, high strength to weight ratio and wide variety of product choice for design optimization are also crucial contributions to the construction sector.

Social sustainability is achieved if the manufacture, use and end-of-life processes for a given product are respectful of the needs of the society and human beings and ensure that future generations can enjoy the same lifestyle as we do today. This involves protecting the health and safety of the people who make or use a product, managing resources for future generations, and ensuring that social issues such as inequality and poverty are addressed.

Steel industry directly employs more than two million people with a further two million contractors on site. Indirectly, many millions more have jobs with upstream suppliers and in the downstream industries that rely on steel. In turn, these people and businesses contribute to their own communities through taxes and by providing further employment [6].

Economic sustainability requires businesses to make ethical profits, which are used to ensure the long-term viability of their enterprises investing and maintaining in environmentally safe plants, for creating sustainable employment, which has a positive impact on the wellbeing of environment, people and communities.

STEEL AS A SUSTAINABLE CONSTRUCTION MATERIAL

Let's look at the six "re- principles" of circular economy and eco-design through the perspective of steel as a sustainable construction material.

REDUCE

Reducing the weight of products, and therefore the amount of material used, is key to the circular economy. Through investments in research, technology and good planning, steelmakers have over the past 50 years drastically reduced the amount of raw materials and energy required to make steel.

There are many different ***steel qualities*** ranging from mild conventional structural to high-strength and advanced high-strength structural steels to specialty steels such as weathering or stainless. Each grade of steel has properties designed for its specific application purposes. Steel industry is actively promoting and developing the use of advanced high-strength steel grades, as less steel is needed to provide the same strength and functionality. Other materials that weigh less due to a lower density than steel may appear to be interesting alternatives at first glance. However, when the total life cycle of a material is taken into account, steel remains competitive, owing to its strength, durability, recyclability, versatility and cost [11].

Steel's durability is one of the key properties that contribute to reduction of use of resources. Durability of steel is key to its long life as a structural building product and long service life for the building. Although all new steel can be made out of recycled scrap, this is not possible due to the long service-life of steel products. Eiffel Tower, Brooklyn Bridge, first skyscrapers of Chicago and New York are just a few examples of numerous other buildings still standing and are being used over 100 years or more and none are scheduled to be replaced soon. Likewise 75% of all the steel products that are ever produced are still in use today subject to proper maintenance.

REPAIR

Steel building elements in structures are physically ***visible, accessible*** and can be replaced, removed and repaired and if necessary, can also be reinforced due to the changes in building service conditions and/or maintenance requirements.

Also the steel supporting structures are fully ***compatible with*** mechanical, electrical, sanitary ***services and installations*** in the buildings, enabling their accessibility and serviceability to the maximum, at the lowest cost. This may be practically impossible or rather costly with other structural materials.

REUSE

By ***eco-designing*** steel products for reuse or remanufacturing, even more resources can be conserved. Reuse through repurposing involves a specially designed collection and reprocessing system to make the product fit for a new application. The amount of energy and resources required for reuse applications can be significantly lower than producing a new application from raw materials.

Steel's ***durability*** ensures many products to be partially or fully reused at the end of their life. This can extend the life cycle of the steel product significantly. However, initial eco-design based on life cycle thinking is critical if reuse is to succeed. The construction industry has been one of the first to embrace the reuse of steel components such as structural beams, roofing and wall elements. Increasingly these elements are being eco-designed for reuse however co-operation from the whole production chain is necessary to ensure that reused or re-manufactured steel products may become common place.

Steel is ***flexible*** in use where steel-framed buildings can be easily adapted if the configuration of the structure needs to be changed. Strong, durable exterior steel structures can accommodate multiple internal reconfigurations to suit changing needs of the building thus extending the service life and flexibility of use of the building. There are many examples of warehouses or industrial buildings made with steel that were easily ***converted*** into modern living or working spaces and/or horizontal and vertical ***additions*** to the existing buildings extending the useful life of the building (and the life of the steel it contains) to save resources and reduce costs [13].

RECOVER

As stated above steel building elements are easily accessible and when changing or reusing they are also very easy to recover. In the worst case where these are mixed in the general demolition litter, steel is still easily recoverable due its magnetic properties.

REMANUFACTURE

Steel also facilitates its own ***longevity***. Steel not only ensures a long product life but also enables re-manufacturing of many construction products. Many steel products, such as beams and columns from older buildings can be disassembled and remanufactured for reuse to take advantage of the durability of steel components. A steel building can be taken apart totally and rebuilt with minimal disruption to local communities and the environment.

Remanufacturing restores durable used products to like-new condition with the possible inclusion of new parts [10, 12]. It involves the disassembly of a product, during which each component is thoroughly cleaned, examined for damage, and either reconditioned or replaced with a new part. The product is then reassembled and tested to ensure proper operation.

There are numerous examples of larger buildings being ***transferred*** to new locations in full or by splitting in two or more buildings. These applications extend the useful life of the buildings and the life of the steel it contains, to further save resources and reduce costs [13].

Also re-use or remanufacture of steel is not limited to its original application; repurposing dates back to ancient times. Old rails may be transformed into other building products like railway sleepers, old beams can be remanufactured to be used as hand tools or agricultural equipment.

RECYCLE

Steel is 100% recyclable without loss of its inherent material properties, over and over again to create new steel products in a closed material loop. Steel is the most recycled material in the world. All scrap from steel production and downstream processing (often referred to as pre-consumer scrap) is collected and recycled directly in the steel production process. The recycled content of any steel product can range from 5 to 100%. Recycling has been carried out in the steel industry since steel was first made. Approximately 650 million tons [14, 15] of pre- and post-consumer scrap are recycled annually, leading to significant savings in energy and raw material use. The magnetic property of steel ensures a high rate of easy and affordable recovery (98% [25]) for recycling from almost any waste stream while the high value of steel scrap guarantees the economic viability of recycling. Recycling also ensures that the value of the raw materials invested in steelmaking lasts far beyond the end of a steel product's life, and that the steel remains a permanent resource for society. Thus recycling is important in the circular economy as it conserves valuable resources.

All types of steel can be recycled back into new steel of various grades, keeping its inherent material properties. Thus, steel scrap from lower value steel products can also be converted into high strength, high quality steels "up-cycled" by using appropriate processing and metallurgy. To the grace of some production techniques, up cycling for high strength steels requires less alloying materials and energy input which is not typically possible with other materials. Indeed the quality of recycled material is often downgraded or "down-cycled" in the case of concrete, wood and aluminum [26, 27].

SUSTAINABILITY OF STEEL STRUCTURES

Structures built by using steel structural elements have further sustainable traits that has to be mentioned:

Architectural Design of steel buildings is foremost differentiating factor due to light, small size sections providing wide unobstructed, uncluttered spaces, allowing greater useful floor area and ceiling height, letting in more day-light and enabling proper heat and noise insulation while creating comfortable, efficient, healthy living and working environments. Steel is the material of choice providing creative freedom to the architect while supporting eco-design principles to the limits. Steel structures provide optimum solutions for all types of buildings tall, large, wide span, lightweight, prefabricated, modular etc. Steel construction details fully adaptable to cladding, insulating, renewable energy systems and all other energy saving design details to the highest advantage of collecting credits for the sustainability programs.

Designed thoroughly, analyzed reliably and optimized for economic use of construction materials according to the state-of-the-art codes, standards and highly analytical design tools backed by ample research and testing, producing already ***BIM*** and ***integrated-design*** compliant fabrication and erection CAD / CAM design models and data. Buildings are ***resilient***, ***seismic and fire safe*** by nature of design practices and codes, to analytically verified performance measures. Lower weight (mass) of the steel structures is of utmost importance in seismic safety and resistance as well as lower environmental footprints (resources, transport, disturbance, wear and tears, etc.).

Safety of steel structures is further ensured by high quality, high strength structurals tested and certified by the producing mills, prefabricated off-site, in quality assured steelwork shops.

Erection of steel is fast, dry in safe, small job sites with less traffic, dust, noise and minimal disturbance to the neighborhood. Also minimum wear and tear to the roads and infrastructure due to less transportation and savings in emissions. Thus lower carbon and water footprints compared to all other modes of construction methods.

Steel structures are totally ***flexible*** in operation and use ***durable***, ***adaptable*** to changing user needs with highest occupancy rates, freely available for internal inspections, tests, modifications, alterations as well as horizontal and vertical additions and expansions of the structure itself if need be. Ease of maintenance, repairs and renewals for all the services and installations having much shorter service lives than the supporting structure lowers the use stage costs. High and sustained portfolio value of the building to the profit of owners and investors is a premium bonus for the owners and investors.

CONCLUSIONS

Steel sustainable by nature of the product and responsibly produced by the industry has many beneficial aspects in construction that can be very shortly formulated as follows:

- High strength to weight ratio results in lower weights, less resource use, higher safety, less wear/tear to the infrastructure, lower emissions and smaller environmental footprint
- Architectural elegance, differentiation; comfortable, healthy, flexible buildings, durable, longer service lives, high occupancy, sustained portfolio values

- Energy efficient, higher sustainability credits from leading green building codes, economic to run and maintain
- Prefabricated, quality assured, fast erection with dry construction methods, economy [7][8] in construction time and money
- Small, tidy, safe job sites tithe minimum disturbance to the neighborhood
- Re-use, re-manufacture or recycling for cradle-to-cradle life cycle for environmental, social and economic sustainability.

ACKNOWLEDGEMENTS

The author has benefited from reference [1and 2] and [7] with ample references and quotations. As the scope and volume of this paper is limited it is advisable to consult these references for further information.

REFERENCES

[1] World Steel Association www.worldsteel.org

[2] World Steel Association- WSA Steel in the Circular Economy - A life cycle Perspective

[3] WSA - Steel's contribution to a low carbon future, 2014

[4] WSA - Sustainable Steel: Policy and Indicators, 2014

[5] WSA - Sustainable Development Charter, www.worldsteel.org sustainability pages

[6] WSA - worldsteel fact sheet: Working in the steel industry, October 2014.

[7] Turkish Constructional Steelwork Association - TUCSA www.tucsa.org

[8] Özdil, S., Articles and Presentations on Steel Sustainability and Economy 2009, 2010, 2015, TUCSA, www.tucsa.org

[9] Ellen MacArthur Foundation, www.ellenmacarthurfoundation.org, 2014

[10] USGBC - www.usgbc.org/articles/about-leed

[11] Lund, R. Remanufacturing: The experience of the United States and implications for developing countries. World Bank technical paper, ISSN 0253- 7494, no. 31. Integrated resource recovery series 2. Washington, DC: World Bank and United Nations Development Program, The International Bank for Reconstruction and Development.

[12] Lund, R. 1993. Remanufacturing. In The American edge: Leveraging manufacturing's hidden assets, edited by J. Klein and J. Miller. New York: McGraw-Hill.

[13] Allwood J.M., Cullen J.M., et al., Sustainable Materials: with both eyes open, UIT Cambridge, England, 2012.

[14] Bureau of International Recycling (BIR), World Steel Recycling in Figures 2009-2013, 2014.

[15] Estimate according to BIR Global facts and Figures: Ferrous Metals: World Steel Recycling in Figures 2009 - 2013.

[16] EN 15978 Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method

[17] EN 16309 Sustainability of Construction Works - Assessment of Social Performance of Buildings – Methods

[18] ISO 14040: 2006 - Environmental management - Life cycle assessment - Principles and framework

[19] ISO 14044: 2006 - Environmental management - Life cycle assessment - Requirements and guidelines

[20] ISO TS 14067: 2013 - Carbon footprints

[21] ISO 14046: 2014 - Water footprint

[22] ISO 14025: 2006 - Environmental labels and declarations

[23] ISO 21930: 2007 - Sustainability in building construction

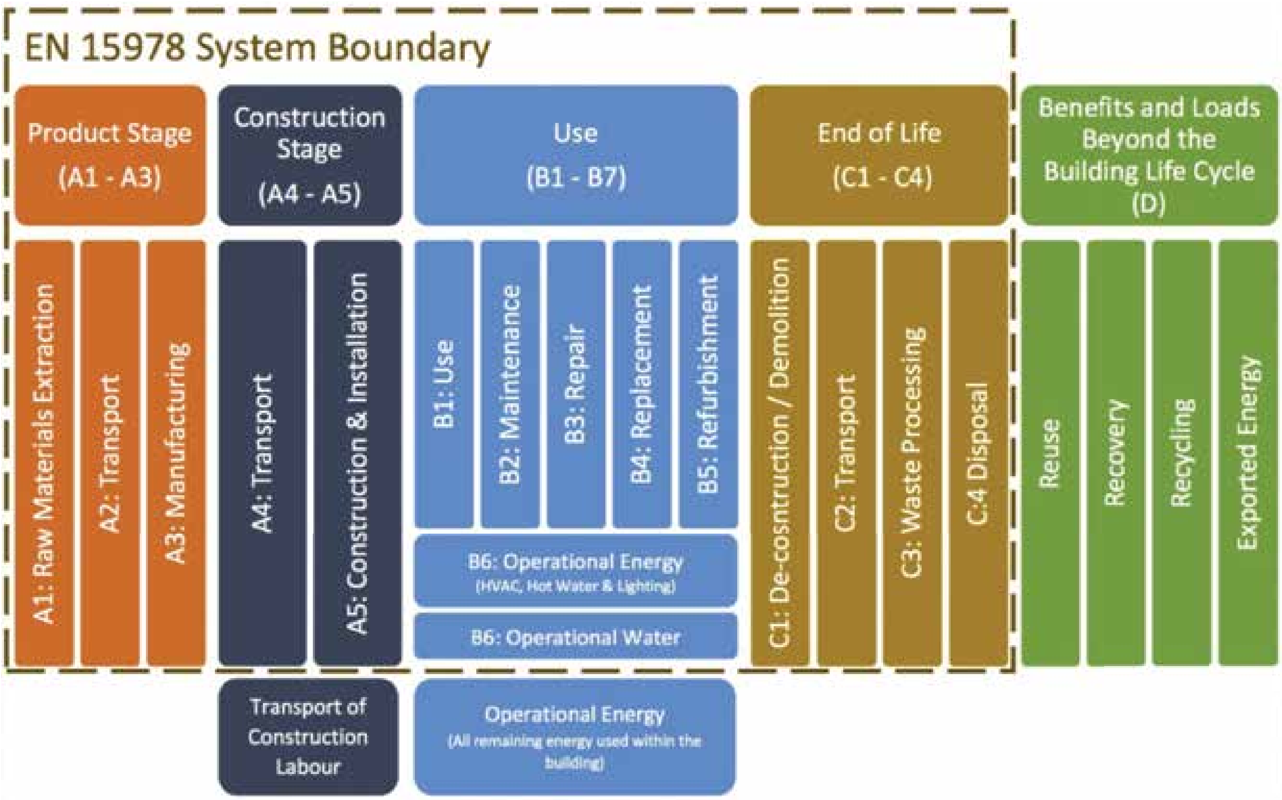
[24] ISO 15686-5 Building Construction Service-life Planning - Life-cycle Costing

[25] Steel Recycling Institute, Structural Steel recycling rates, 2014

[26] Volker Thome from the Fraunhofer Institute for Building Physics IBP from the Concrete Technology Group in Holzkirchen, Lightning, strike! Research News Oct 01, 2012

[27] William McDonough and Michael Braungart, Cradle to Cradle: remaking the way we make things (New York: North Point Press, 2002), 56.

ANNEX A FULL LIFE CYCLE of STEEL in BUILDINGS ACCORDING TO EN 15978



Paper No: 78

An Investigation of Turkey's Real Estate Sector within the Scope of Sustainable Development and the Human Development Index (HDI)

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ABSTRACT

As the humankind has perceived the nature as an unlimited source of resources for centuries, it has excessively used natural resources, which led to the emergence of environmental problems. Upon understanding that natural resources are limited and exhaustible, utilizing natural and cultural resources taking into account the economic and social needs of both the existing population as well as the needs of future generations has revealed the concept of sustainable development. Sustainable development is also dealt with its environmental, economic and social aspects. Indicators such as the atmosphere, oceans, seas and coasts, water, biodiversity are environmental; such as national income, trade, consumption and production patterns are economic; and such as equality, health, education, shelter, security, population are social sustainability indicators. Meanwhile, the fact that economic development remains inadequate in solving many social problems and calculation of the human development index (HDI) created to measure socio-economic development level in 160 to 190 countries, and inclusion of relatively simple components of the data collected for this index, and the limited number of indices calculated in this field render the HDI important. In addition to income, the HDI considers education and healthrelated indicators, as well. Despite the progress in the economic field in Turkey in recent years, it has been unable to take the leap expected in terms of the HDI. This study analyses the real estate sector, the construction sector in particular, in Turkey in the context of sustainable development and HDI indicators.

Keywords: Sustainable Development, Human Development Index, Real Estate Sector.

1. INTRODUCTION

Development is the increase in national income, which is the monetary value of goods and services produced annually in addition to the changes in economic, social, and political structures that further human life in material and moral areas, which gradually lead to an increase in social welfare [1]. The origin of the idea of development is founded on the basis of progress from traditional society to the modern mass consumption society [2]. With the development efforts, the human being has perceived the nature as an unlimited source of resources, excessively used and populated it and led to emergence of environmental problems [3]. Rapid population growth and depletion of nonrenewable natural resources are forcing the science of economy to use limited resources effectively. Efficient use of natural resources requires increasing their productivity and realization of investments for human capital. The efficiency of human capital depends on increase of people's economic and social welfare [4]. Countries make assessments based on the human development index as an indicator of the level of development in order to determine the required income level for a long and healthy life, education, and a decent life [5].

Real estate refers to properties that cannot be moved from one place to another. In other words, real estate are properties that are immovable such as land, land fields, houses, land lots, and multistory buildings [6]. When the economy is classified in terms of the agriculture, industry, and services industries, real estate is observed to directly or indirectly contribute to all the sectors. However, the wide extent of the real estate sector as well as the issues related to measuring its indirect effects makes it inevitable to take into account the construction industry, which provides measurable contributions to development and human development. Another problem is that whether the contribution of the construction industry to development and the human development index is considered from a sustainability point of view.This study aims to evaluate the progress Turkey shows in development and human development with regard to sustainability criteria within the scope of the construction sector and with the next steps to be taken, the aim is to develop policies in accordance with these criteria and thereby, achieving positive results in environmental, social, and economic indicators in the transmission of scarce and exhaustible resources to future generations.

2. CONCEPTUAL FRAMEWORK

2.1 Sustainable Development

Sustainable development is a concept that requires the perspective of different disciplines. Environmental science, economics, social sciences are among the most noteworthy ones of these disciplines. Environmental scientists focus on renewability of resources, consumption of nonrenewable resources, environmental damage, biodiversity, and protection of ecosystems. Economists work on sustainability in the production of goods and services, manageability of internal and external debt, and factors that damage agricultural and industrial production. Social scientists engage in discussions around ensuring equality in the provision of healthcare and education as well as gender equality and the provision of social services adequately.

2.1.1 Sustainability and Sustainable Development Indicators

Sustainability is a newly developing and widely discussed concept. Although there is no single definition, of the word means "the ability to endure". However, there are different definitions according to varying perspectives. According to Gilman (1992), sustainability is the continuation of the functioning of a community, ecosystem, or any system without consuming significant resources until a certain future [7]. Galdwin et al. (1995) define sustainability as a participatory process where the community ensures all the social, cultural, scientific, natural and human resources of the society are utilized under certain measures that is based on respect for this with a social point of view [8]. Sustainability requires a change in the way of thinking without letting a backwards movement in the current quality of life. These changes encompass not only being a society that focuses on consumption, but also one that is in universal solidarity for the common values of humanity with targeted responsibilities in environmental management, economic solutions, and social responsibilities [9].

The major developments throughout the world following the industrial revolution, particularly technological innovations have led to a giant increase in production and rapid consumption of nonrenewable natural resources.

The environmental and ecology movements started with the realization of the great extent of damage given to the environment in the 1960'ies, which internationalized in the 1970'ies, and finally the World Commission on Environment and Development (WCED) was established under the United Nations in 1983. The concept of sustainable development was defined by Ms. Gro Harlem Brundtland, Chair of the said commission, in a 1987 report titled "Our Common Future" [10]. Also commonly called the Bruntland Report, this study defines sustainable development as provision of today needs without compromising future generations to meet their own needs. Sustainable development is a broad and dialectical concept that balances environmental protection and the need for economic growth with social justice [11]. The United Nations Commission on SustainableDevelopment(UNCSD) has created sustainability indicators that encompass environmental, economic, social, and institutional aspects of sustainable development. These sustainability indicators are depicted as theme and sub-theme indicators in Table 1.

Table 1. Sustainability Indicators Developed by the UNCSD [12]

	THEME	**SUB-THEME**	**INDICATOR**
ENVIRONMENTAL INDICATORS	ATMOSPHERE	Climate change	Greenhouse gas emissions
		Deterioration of the ozone layer	Consumption of ozone depleting substances
		Air quality	Concentration of air pollution in urban areas
	LAND	Agriculture	Arable areas
			Fertilizer use
			Use of agrochemicals
		Forests	Percentage of forested lands
			Tree cutting intensity
		Desertification	Areas affected by desertification
		Urbanization	Width of urban residential areas
	OCEANS, SEAS AND COASTS	Coastal areas	Coastal algae concentration ratios
			Proportion of the population living in coastal areas
		Fishery	Annual rate of hunting of key species
	WATER	Water quantity	Annual rate of use of groundwater
		Water quality	Level of organic materials in water
	BIODIVERSITY	Ecosystem	Areas of important ecosystems
			The rate of conservation areas
		Species	Abundance of selected key species
ECONOMIC INDICATORS	ECONOMIC STRUCTURE	Economic performance	GDP per capita
			Investment share in GDP
		Trade	Balance of payments for goods and services
		Financial situation	Debt to GNI ratio
			Foreign aids as percentage of GDP
	CONSUMPTION AND PRODUCTION PATTERNS	Material consumption	Material consumption intensity
		Energy Consumption	Annual energy consumption per capita
			Share of renewable energy sources in total energy use
			Intensity of energy use
		Waste generation and management	Industrial and municipal solid waste generation
			Generation of hazardous waste
			Management of radioactive waste
			Recycling and reuse of waste

SOCIAL INDICATORS	EQUALITY	Poverty	Percent of population living below national poverty line
			Gini index of income inequality
			Unemployment rate
		Gender Equality	The ratio of average female wages to male wages
	HEALTH	Nutritional Status	Nutritional status of children
		Mortality Rate	Mortality rate under 5 years old
			Life expectancy at birth
		Hygiene Conditions	Proportion of population with access to adequate waste water disposal service
		Drinking Water	Proportion of population with access to clean drinking water
		Health Services	Percent of population with access to primary health care facilities
			Immunization against infectious childhood diseases
			Contraceptive prevalence rate
	EDUCATION	Education Level	Number of primary education graduate children
			Number of high-school graduate adults
		Literacy	Adult literacy rate
	SHELTER	Living Conditions	Living area per capita
	SAFETY	Crime	Crime rate per 100,000 people
	POPULATION	Population change	Population growth rate
INSTITUTIONAL INDICATORS	INSTITUTIONAL ENVIRONMENT	Strategic sustainable development practices	National sustainable development strategy
		International cooperation	Implementation of the signed global agreements
	INSTITUTIONAL CAPACITY	Access to information	Number of internet users (per 1000 population)
		Communication infrastructure	Fixed telephone lines (per 1000 population)
		Science and technology	Gross domestic expenditure on R&D as a percent of GDP
		Preparedness for natural disasters	Human and economic loss due to natural disasters

The indicators determined by the UNCSD and shown in Table 1 are of great importance in the road to sustainable development decisions to be taken in terms of environmental, economic, and social aspects and in measuring the progress achieved towards sustainability.

2.1.2 Sustainable Development Goals and Approaches in Turkey and the World

In the United Nations Sustainable Development Summit held in New York between 25 - 27 September 2015, seventeen sustainable development goals in relation to termination of poverty by 2030, fight with inequality and injustice, and resolving climate change have been proposed. The proposed global goals were "end to poverty, end to hunger, healthy individuals, quality education, gender equality, clean water, hygiene and public health, cheap and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduction of inequalities, sustainable city and life, responsible production and consumption, climate action, aquatic life, terrestrial life, peace and justice, and partnerships for targets". These sustainable development goals indicate that the eight goals for which the United Nations member countries pledged to commit to combat poverty by 2015 (the Millennium Development Goals) have still not been achieved as of today. The intention of new goals is to address the causes of poverty and achieve development for all [13].

It can be argued that the first step to sustainability practices in Turkey was taken by the establishment of the

Undersecretariat of Environment under the Prime Ministry in 1978. Article 56 of the 1982 Constitution stipulates that everyone has the right to live in a healthy and balanced environment, and that the state and the citizens have a duty to improve the environment, to protect environmental health, and to prevent environmental pollution. Article 166 of the Constitution has given the state the tasks to ensure economic, social, and cultural development and particularly to improve industry and agriculture in a balanced and harmonious way throughout the homeland, to make an inventory and evaluation of the country's resources and to plan effective use of these resources, and to establish the necessary organization for this purpose.

The Law on Environment entered into force in 1983. A set of regulations for the implementation of the Law has been issued. Some examples of the regulations in force today include Air Quality Assessment and Management [14], Water Pollution Control [15], Assessment and Management of Environmental Noise [16], Environmental Impact Assessment [17], Medical Waste Control [18], Regulation on Restriction and Regulation of Hazardous Substances and Mixtures [19]. Beyond these regulations, Turkey has signed a number of regional and international regulations. These agreements include, for example, the Convention Concerning the Protection of the World Cultural and Natural Heritage, the Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, and Convention for the Protection of the Mediterranean Sea against Pollution [20].

In Turkey, sustainability indicators such as environment and human health are found in the development programs prepared by the State Planning Organization and in the works of the Ministry of Environment and Urban Planning. In addition, works carried out jointly by the Ministry of Environment and Urban Planning, the United Nations Development Programme (UNDP), and civil society organizations are observed to act directly in line with the sustainable development goals, however, these indicators are not addressed as a whole in these activities.

2.2 The Human Development Index (HDI)

The HDI is a measurement method. It is used to evaluate the long-term development in three basic dimensions of human development. These three basic dimensions are a long and healthy life, access to knowledge, and a decent standard of living.

2.2.1 Characteristics and Calculation of the Human Development Index

To enable benchmarking between countries, the HDI is calculated based on data provided by the United Nations Population Division, the United Nations Organization for Education, Science and Culture (UNESCO), Institute for Statistics (UIS), and the World Bank (WB). Countries are classified into four groups showing very high, high, medium, and low human development [21].

The HDI is regularly prepared by the UNDP since 1990. While education, health, and income dimensions are considered in the HDI calculations, the criteria used in some of these dimensions are observed to differentiate. A long and healthy life, education and a decent standard of living, life expectancy at birth, adult literacy rate and gross school enrollment rate and income level adjusted for purchasing power parity (PPP) indicators of human development were used between the years 1995-2009 whereas the income and education measures were differentiated in 2010. Education was started to be measured by indicators of lifelong average of adult education years of people of 25 years and older and in case age-dependent school enrolment rates remain the same as their current level, expected years of schooling of children of school starting age, which shows the total number of years of a child's educational life. Instead of gross domestic product (GDP) adapted to PPP, income was started to be calculated using gross national income (GNI) adapted to PPP [22].

Through the minimum and maximum values for the indicators of education, health, and income categories, each year a main indicator is transformed into a value between 0 and 1 and are placed on the HDI formula. The minimum and maximum values in 2014 were 20-85 years in health (life expectancy at birth); 0-18 years for expected schooling and 0-15 years for average years of schooling in education; and 100-75000 US dollars in income.

The calculation formula used for the indicators is as follows: $\frac{Main\ Value - Minimum\ Value}{Maximum\ Value - Minimum\ Value} = V\ (0-1)$ $\frac{Main\ Value - Minimum\ Value}{Maximum\ Value - Minimum\ Value} = V\ (0-1)$ The values obtained here are placed into the HDI calculation formula.

The HDI calculation formula is as follows: $\sqrt[3]{V\ Health * V\ Education * V\ Income}$ $\sqrt[3]{V\ Health * V\ Education * V\ Income}$

The value of countries calculated according to the HDI formula is affected from their own performance, performances of other countries, and the changes in the calculation techniques and data sets [23].

2.2.2 Progression of Turkey's Human Development Index

Turkey has been included in the related reports and indices since the publication of the human development reports began in 1990. A better understanding of the country's performance will based on the values obtained throughout the years. Table 2 shows the progression of the HDI in and classification of Turkey.

Table 2. HDI Progression in Turkey between 1990 and 2014 [24]

Years	**1990**	**2000**	**2010**	**2011**	**2012**	**2013**	**2014**
HDI	0.576	0.653	0.738	0.751	0.756	0.759	0.761
HDI Groups	High	High	High	High	High	High	High

As indicated in Table 2, there have been different HDI values in Turkey throughout years. However, it remained within the group of countries with high human development and ranked at different levels within the group. In 2010, Turkey ranked 84th based on health indicators, 112th based on education indicators, 96th based on expected years of schooling, 57th based on gross national income per capita, and ranks 83rd in terms of HDI among 169 countries. Based on this order, Turkey obtains the highest ranking with the income indicator and ranks lower in terms of the other indicators of the HDI.

2.3 The Real Estate Sector

The real estate (immovable) sector is growing and changing in parallel with the economic developments throughout the world and a revival is observed in all types of real estate in recent years due to both increasing investments and significant legal and institutional arrangements. This lively structure in the market has positive effects reflecting on the increase of the number of local and foreign investors. Beyond merely being a sector that meets accommodation requirements, the real estate sector is evolving into one that has economic, political and strategic importance while being a sign of prestige and social status. This transformation will not only bring along more development but also serve to increase the contributions of the sector to the national economy and raise the quality of life in cities [25]. The scope of the real estate sector can be addressed with its place in the national economy and sustainability aspects. Real estate and real estate-related investments have an important weight in the emerging economies. In addition to the features mentioned, securitization of real estate assets is also of significance in the developed countries. In this way, much greater economic growth is made possible while this may also lead to global shocks that impact economies.

2.3.1 The Scope of the Real Estate Sector

The real estate sector can be expressed in a narrow or broad sense. In the narrow sense, only the construction industry is addressed whereas all kinds of real estate required by the agriculture, industry, and services sectors distinction is implied. The crop production (such as plantations, vineyards, and gardens), animal production (such as pastures, grasslands, and winter quarters), and forests and fisheries sub-sectors of the agricultural sector are in need of real estate. The industrial sector is divided into the manufacturing, intermediate goods and investment goods sub-sectors. The lands on which the factories are established and the areas of underground and surface resources where raw materials are obtained from are places needed by industry. The services sector is divided into the tourism, transport, contracting, telecommunications, communication, and other services sub-sectors. In particular, utilization of natural and historical sites in a good way is gaining importance. When the real estate sector is considered in a broad sense, the problem of measuring how much of the economic value gained by each sector is provided by the real estate used by that sector as infrastructure or superstructure arises. Therefore, in this study, the real estate sector will be analyzed in the narrow sense and only the construction sector will be subjected to evaluation.

2.3.2 The Place of the Real Estate Sector within the Economy

Particularly upon the enactment of Law No. 6306 Related to Transformation of Areas Under Disaster Risk, in the real estate industry with a significant share in the country's economy, urban transformation, urban renewal, and urban conservation activities as well as development and implementation of housing and other real estate projects have been accelerated in many of the cities' different districts and neighborhoods. With the integration of these activities with other arrangements such as Law No. 5582 on Hosing Financing, Law No. 5216 on Metropolitan Municipalities, and Law No. 5393 on Municipalities, financing and roles-authorization aspects of the mentioned activities are also regulated. On the other hand, development plans or projects of cities are also being prepared intensively by the related institutions in order to contribute to Turkey's economic development. Development plans, regional plans, master plans for different sectors as well as environmental layout and land use plans have been completed in many cities across the country and development at the local levels has been targeted to be directed according to the said plan provisions. Along with research and reporting activities for examination of and policy development for the real estate markets, with regard particularly to urban development and housing, congresses, symposiums and panel discussions also serve the target of awareness-raising at the regional, national, and global scales [25].

The construction sector functions as a leverage in many economies with its aspects of creating added value and contributing to employment. In addition to new constructions, maintenance, repair, and operating activities are also considered to be within the scope of the construction industry. Today, construction translates into an environment-friendly, responsible, transparent and sustainable means of production with a direct impact on the social structure [26]. The many sub-sector components of the construction industry lead to high flexibility in terms of production and employment. The national and international potential of the sector is of a major nature and the sector is said to stimulate more than 250 other sectors [27]. There is a high correlation between economic growth and the construction sector. The share of the construction sector within the GDP is given on a percentage basis at current and constant prices for the period between the years 2013-2015 in Table 3.

Table 3. Share of the Construction Industry in the GDP [28]

GDP	2013				2014				2015	
	I	II	III	IV	I	II	III	IV	I	II
At Current Prices %	4.5	4.7	4.2	4.4	4.7	5.0	4.3	4.3	4.4	4.8
At Constant Prices %	5.9	6.0	5.6	6.0	6.0	6.1	5.7	5.7	5.7	5.9

According to Table 3, the share of the construction sector within the GDP between the years 2013-2015 at current prices is approximately 4.5 percent. This share is about 6% at constant prices. Table 4 shows the GDP growth rate at constant prices. A comparison of the share of the construction sector within the GDP at constant prices with GDP growth rates will enable a better consideration of the position of the construction sector within the economy.

Table 4. GDP Growth Rate at Constant Prices (%) [29]

2010	2011	2012	2013	2014				2015	
				I	II	III	IV	I	II
9.2	8.8	2.1	4.2	5.1	2.4	1.8	2.7	2.5	3.8

The GDP growth rate between the years 2013-2015 compared to the share of the construction sector within the GDP apparently shows that the sector has outperformed the GDP growth rate.

2.3.3 Sustainable Construction Sector

Countries have to assume the responsibility for providing an environmentally sustainable future while trying to upgrade the quality of life. Due to globalization, economic and cultural values of a society are felt outside the boundaries of a country soon. Rapid increase of the population is particularly damaging to the environment by increasing consumption of natural resources. There is an obligation for efficient use of resources and taking precautions against damage given to the environment. Therefore, a perspective that takes into account the rights and interests of present and future generations is required in all sectors. From this perspective in mind, aiming sustainability in the construction sector is very important.The construction sector is directly related to economic activities and it constitutes 8% of GDP (3.5 trillion US dollars) all over the world [30]. 17% of freshwater resources, %25 of forest products, and 40% of energy resources in the world are consumed by the construction sector [31].The ratio of waste generated by the construction sector exceeds 30% of all waste. 28% of the resources consumed in Turkey are met with own resources and 72% is imported and this rate is increasing day by day [32]. In parallel with these ratios, sustainability has gained importance in the construction sector, too.

The manufacturing, construction, operation, maintenance, repair, and demolition of structures activities in the construction industry affect the natural environment and buildings can harm the environment throughout their entire life cycle [33]. Conservation of materials, water, and energy and design of livable environments should be targeted for a sustainable construction sector. Reducing the use of materials, eco-friendly material selection, reduction of water consumption, reuse of water, using water without contaminating it, use of renewable sources of energy instead of fossil fuels, taking account of the physical environment conditions, energy efficient building form design, energy efficient building skin selection, energy efficient landscaping design, recycling or reuse of waste, habitat conservation, ecological urban design, design for human health, and creation of environmental awareness in the society are the sustainability strategies should be applied in the construction industry [33, 34]

3. THE IMPACT OF THE REAL ESTATE SECTOR ON THE HDI AND SUSTAINABLE DEVELOPMENT OF TURKEY

Together with the existence of mankind, environmental and ecological assets were started to be changed, which has affected human life and the environment. The industrial revolution brought about much more significant changes in the economic and social indicators. The technological advances and population growth following the industrial revolution have led to increased production and overuse of natural resources.

3.1 The Relevance of the Sustainability Indicators and Turkey

Turkey is among the countries wishing to development and the real estate sector, as in many developing countries, is at the forefront in the development process. The HDI developed by the United Nations is among the most important development indicators. When the HDI indicators are taken as GNI, health (life expectancy), and education (expected years of schooling and mean years of schooling), a contribution to the real estate sector in all of these elements can be seen. The contribution of the real estate sector to the HDI indicators in developed, developing, or underdeveloped countries does not seem to be possible to consist entirely of sustainable development indicators. Sustainability in the construction sector is dealt with in terms of protection of resources and ecosystems from the environmental perspective; in terms of efficiency of resources, low maintenance and running costs from the economic perspective; and provision of human health and comfort as well as compliance with social and cultural values from the social and cultural perspectives. In other words, sustainable construction should not only encompass a building construction process consisting of technical, architectural, social or cost constraints but also an understanding that focuses on environmental compromise, respects natural resources, and tolerates cultural and historical differences [35]. It can be argued that in Turkey, sustainability indicators are quite newly being addressed both in government policies and construction industry. Taken from this perspective, it cannot be asserted that Turkey's HDI indicators are results achieved by considering the indicators of sustainable construction and development. Over time, it will be possible to put an increasing amount of sustainability indicators into practice.

3.2 An Evaluation of the Impact of the Construction Sector on HDI Indicators in Turkey

Because the economic contributions of sustainable buildings to the construction sector are not fully measured, it is thought that they are not included or contain only a little share in the national accounts. As also expressed in Tables 3 and 4, the growth rate of the construction sector in Turkey taken at constant prices is higher than the growth rate of GDP. The construction industry provides one of the highest contributions to gross income, which is an HDI indicator. This contribution can be further improved, however, the main problem is to increase the share of the two other education and health indicators. Both of these two indicators can be considered as elements of the construction sector infrastructure elements. The construction infrastructure of health and education indicators and positive externalities that they might reveal are considered to enable significant progress in the HDI. Turkey is facing a situation called “middle income trap” in terms of increasing national income. The national income fails to exceed a certain level, therefore, reaching the level of developed countries somehow does not become possible. Nevertheless, it is in a much higher level within the HDI indicators with regard to national income. In terms of health and education indicators, however, it is in a low position. That the element of income alone cannot enable progress in the HDI is very clear.

It can be argued that the concrete contribution of indicators of sustainable construction industry to HDI may be certification of buildings with green building certification systems. The concept of sustainable buildings in the construction sector in Turkey has developed rapidly in recent years. Due to the increased awareness of the Turkish construction industry about environmental pollution and support from large companies to pollution-reducing practices, green building certification systems used all over the world are gaining widespread use. Because of the fact that a local certification system developed particularly for Turkey does not exist, certification systems developed by different countries are used [36].

The LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), and DGNB (Deutsche Gesellschaft fur Nachhaltiges Bauen) are the three systems that are commonly used in Turkey. Turkey took its first green building certification in 2008 [37]. As of May 2016, there are 187 building awarded with certification including 153 LEED [38], 33 BREEAM [39] and 1 DGNB [40]. Of the LEED-certified buildings, 104 have gold level certification, 26 have silver level certification, 14 have platinum level certification, and 9 are certified [36]. In 2014, the Society of Real Estate and Real Estate Investment Trusts (GYODER) conducted a research on a total of 216 buildings including 60 LEED certified (4 platinum, 34 gold, 15 silver, and 6 certification level buildings) and 156 certification candidate buildings [41]. This research, which was conducted by the references 42-52 [42-52], evaluated how much savings different levels of LEED certification may provide for different types of buildings including housing, educational buildings, shopping malls, offices, hospitals. The resulting ratios are presented in Table 5.

Table 5. Savings Ratios for Different Types of LEED Certified Buildings [41]

Building Types	**LEED Certification Level**	**Energy Savings (%)**	**Water Savings (%)**	**Maintenance, Repair, Staffing, Services Savings (%)**
Housing	Platinum	35	40	20
	Gold	32	35	20
	Silver	27	32	15
	Certified	25	30	15
Education	Platinum	55	75	20
	Gold	42	67	20
	Silver	35	62	15
	Certified	30	55	15
Shopping Malls	Platinum	48	55	20
	Gold	44	50	20
	Silver	38	42	15
	Certified	35	37	15

Office	Platinum	50	55	20
	Gold	40	48	20
	Silver	27	37	15
	Certified	20	30	15
Hospital	Platinum	40	50	20
	Gold	35	42	20
	Silver	30	35	15
	Certified	25	30	15

In the study conducted by the GYODER, for each project identified in the main items of energy saving, water saving, maintenance and repair, staffing, and services savings, operating expenses were calculated as for how much savings could have been achieved in these items and in the total operating expenses if these projects had been LEED-certified. Each item in the percentage distribution was multiplied by the related savings rate to reach the total savings rates through percentage distribution. Minimum and maximum total operating costs savings rates obtained for different building types through these calculations are shown in Table 6.

Table 6. Total Operating Expenses Reduction Rates for Different Types of Buildings [41]

LEED Certification Level	Housing		Education		Shopping Malls		Office		Hospital	
	Min. %	Max. %	Min. %	Max. %	Min. %	Max. %	Min. %	Max. %	Min. %	Max. %
Platinum	16.55	23.44	20.87	20.87	27.49	27.49	21.49	21.49	12.55	13.99
Gold	16.42	22.65	20.35	20.35	26.42	26.42	20.94	20.94	12.43	13.86
Silver	12.45	17.85	15.45	15.45	21.20	21.20	15.14	15.14	9.41	10.49
Certified	12.36	17.45	15.23	15.23	20.21	20.21	15.15	15.15	9.29	10.37

As indicated in Table 6, in addition to energy and water savings, a project with LEED certification can provide in operating costs at a rate of 12.36% to 23.44% in residential buildings; 15.23% to 20.87 in educational buildings; 20.21% to 27.49% in SMs; 15.14% to 21.49% in offices; and 9.29% to 13.99% in hospitals [34] Based on this information, it can be argued that significant gains can be obtained using sustainable building design criteria through green building certification systems. Taking sustainable building design measures into consideration will make it possible to increase the share of the construction sector particularly in the HDI indicators.

The development desire of many countries throughout the world and their positive progress in this regard makes it difficult to get a good HDI ranking (See Table 2). In this case, it could be stated that Turkey needs to make further efforts from competitors in every sector. Ensuring the sustainability of the construction industry in Turkey is expected to provide a major contribution to the HDI in terms of the GNI, health and education indicators, subject to compliance with the indicators referred to in Table 1.

4. CONCLUSIONS AND RECOMMENDATIONS

A sustainable construction sector should pursue objectives such as efficient use of materials, water, and energy; reducing waste; avoidance of harmful and hazardous substances that are difficult to recycle and dispose; minimizing the health and safety risks; ensuring a healthy indoor air quality; and protection of biodiversity. When considered in terms of sustainability criteria, the contribution of the construction sector to the HDI indicators has not yet reached the desired level in any country yet. Reasons such as this concept being a new one, the long time it takes to conduct studies on this topic, the difficulty in imposing sanctions on countries who violate the sustainability indicators are effective in the formation of this situation.

Turkey is among the countries with high human development, which is the second best group of the four in the HDI ranking. When the HDI of Turkey is considered in terms of the sustainable construction principles, the indicators lead to the conclusion that the factors that should be evaluated within the construction sector were obtained without observance of these principles. Turkey is expected to contribute in the advancement of the HDI and the common future of the World by implementing the principles of sustainable development and construction. While it can be speculated that the principles of sustainable construction sector may increase investment costs in the beginning, it should not be overlooked that it may provide some cost advantages in the long term. Particularly, if there is a desire to be in the group of countries showing high human development, there is a requirement to put efforts ahead of other countries in terms of sustainable development and sustainable construction sector indicators; and national income, health and education indicators.

REFERENCES

[1] İlkin, A. 1983. EkonomiAnsiklopedisi. PaymaşPublishing, Vol: II,pp.722, İstanbul, Turkey.
[2] Haris, J. M. 2000. Basic Principles of Sustainable Development. Global Development and Environment Institute Working Paper 00-04, pp.1-26, Tufts University, Medford MA, USA.
[3] Tıraş, H.H. 2012. SürdürülebilirKalkınmaveÇevre: TeorikBirİnceleme. KahramanmaraşSütçü İmam ÜniversitesiİktisadiveİdariBilimlerFakültesi,Vol:2, No: 2, pp.57.
[4] Gürlük, S. 2001. DünyadaveTürkiye'deKırsalKalkınmaPolitikalarıveSürdürülebilirlik. UludağÜniversitesiİktisatFakültesiDergisi, Vol:19, No: 4, pp.1-2.
[5] United Nations Development Programme, UNDP Human Development Report 2007/2008, ISBN 978-0-230-54704-9, New York, USA.
[6] Kardeş, S. 2008. MilliEmlakSözlüğü.Devlet Malları Uzmanları Derneği Yayınları, First Edition, pp.55, Ankara, Turkey.
[7] Gilman, R. 1992. Sustainability. (http://www.context.org/about/definitions/) (Access date: 22.03.2016).
[8] Gladwin, T.N., Kennelly, J.J., Krause, T-S. 1995. Shifting Paradigms for Sustainable Development: Implications for Management Theory and Research, Academy of Management Review, Vol:20, No: 4, pp. 67-77.
[9] Özmehmet, E. 2008. Dünyadave Türkiye SürdürülebilirKalkınmaYaklaşımları, Journal of Yaşar University, Vol: 3, No:12, pp. 1853-1876, İzmir, Turkey.(http://journal.yasar.edu.tr/wp-content/uploads/2012/11/vol_3_no_12_ Ecehan_OZ _Makale.pdf), (Access date: 02.03.2016).
[10] UN Documents. 1987. Gathering a Body of Global Agreements, Development and International Co-operation: Environment Report of the World Commission on Environment and Development, Note by the Secretary-General, Our Common Future, Distr: General 4 August 1987, A/42/427.
[11] Wilson, M. 2003. Corporate Sustainability; What Is It and Where Does It Come From?, Ivey Business

Journal, March, pp.1-5.
[12] UNCSD, 1996. Indicators of Sustainable Development: Guidelines and Methodologies. New York, USA.
[13] UNDP, 2015. Sustainable Development Goals. (http://www.undp.org/content /undp/en/home/sdgoverview/post-2015-development-agenda.html) (Access date: 20.03.2016).
[14] Ministry of Environment and Urban Planning, (2008). HavaKalitesininKorunmasıYönetmeliği. Date of Official Gazette: 06.06.2008, Number of Official Gazette: 26898, Turkey.
[15] Ministry of Environment and Urban Planning (2004). Su KirliliğiKontrolYönetmeliği. Date of Official Gazette: 31.12.2004, Number of Official Gazette: 25687, Turkey.
[16] Ministry of Environment and Urban Planning (2010). ÇevreselGürültününDeğerlendirilmesiveYönetimiYönetmeliği. Date of Official Gazette: 04.06.2010, Number of Official Gazette: 27601, Turkey.
[17] Ministry of Environment and Urban Planning (2014). ÇevreselEtkiDeğerlendirmesiYönetmeliği. Date of Official Gazette: 25.11.2014, Number of Official Gazette: 29186, Turkey.
[18] Ministry of Environment and Urban Planning (2005). TıbbiAtıklarınKontrolüYönetmeliği. Date of Official Gazette: 27.05.2005, Number of Official Gazette: 25883, Turkey.
[19] Ministry of Environment and Urban Planning (2008). ZararlıMaddeveKarışımlarınKısıtlanmasıveYasaklanmasıHakkındaYönetmelik. Date of Official Gazette: 26.12.2008, Number of Official Gazette: 27092, Turkey.
[20] Okumuş, K. 2002. Turkey's Environment: A Review and Evaluation of Turkey's Environment and its Stakeholders. The Regional Environmental Center for Central and Eastern Europe,pp.10, Szentendre, Hungary.
[21] Anonymous, 2014. (http://hdr.undp.org/en) (Access Date: 05.05.2016)
[22] Şeker, S. D. 2011. Türkiye'ninİnsaniGelişmeEndeksiveEndeksSıralamasınınAnalizi. T.C. KalkınmaBakanlığı, pp.7, Ankara, Turkey.
[23] Akçiçek, A. 2015. 2014 İnsaniGelişmeEndeksiveTürkiye'ninİnsaniGelişmePerformansı, StratejikDüşünceEnstitüsü, s.7.
[24] UNDP, Human Development Report, 1990-2014.
[25] Tanrıvermiş, H.,Çekici, N., Kayseri İli GayrimenkulSektörüDeğerlendirmeveÖngörüler, pp. 8, İstanbul, Turkey.

[26] Ergül, N. 2007. İnşaatSektöründeGloballeşmeninEtkileri, VergiSorunlarıDergisi, Sayı:227.

[27] Dalkılıç, B., Aşkın, M. 2014. GayrimenkulveKonutSektörüneBakış, GayrimenkulveKonut Raporu-3, pp.78.
[28] TÜİK, www.tuik.gov.tr/PreHbGetirHTLM. (Access Date: 02.03.2016).

[29] TÜİK, www.tuik.gov.tr/PreHaberBultenleri. (Access Date: 02.03.2016).

[30] Özorhon, B. 2012. Türkiye'deİnşaatSektörüveDünyadakiYeri. İTO Yayınları. No: 2012-31, pp.20, İstanbul.

[31] Gültekin, A.B.,Yavaşbatmaz, S. 2013. Sustainable Design of Tall Buildings, Gradevinar, 65/5, pp.449-461.

[32] Gültekin A.B., Farahbakhsh, E.B. 2015. Evaluation of the Energy Performance of Glass Construction Materials, 2ndInternational Sustainable Buildings Symposium, Gazi University, pp. 824-834, Ankara, Turkey.
[33] Gültekin, A.B.,Ersöz, B.A. 2013. Ecological Building Design and Evaluation in Ankara, Gradevinar 65/11, pp.1003-1013.

[34] Talu, B. 2015. İnşaatSektöründeSürdürülebilirlik, TMB Gündem, Türkiye MüteahhitlerBirliğiDergisi, AydoğduOfsetMatbaacılık, pp.44-45, Ankara, Turkey.

[35] Özmehmet, E. Avrupa'daveTürkiye'dekiSürdürülebilirMimarlıkAnlayışınaEleştirelBirBakış. (http://journal.yasar.edu.tr/wpcontent/uploads/2012/05/No_7_vol2_12_ozmehmet.pdf.)(Access Date: 02.03.2016)

[36] Bulut, B. 2014. Green Building Certification Systems: Suggestion of a System for Turkey, Gazi University Graduate School of Natural Applied Sciences, Master's Thesis, Ankara, Ankara.

[37] Anonim. 2016. http://www.dunya.com/guncel/turkiye, Access Date: 03.05.2016.

[38] Anonim. 2016. http://www.gbig.org/search/advanced?page,Access Date: 03.05.2016.

[39] Anonim. 2016. http://www.greenbooklive.com/search/buildingsearch,Access Date: 03.05.2016.

[40] Anonim. 2016. http://www.dgnbsystem.de/en/projects/index., Access Date: 03.05.2016.

[41] Society of Real Estate and Real Estate Investment Trusts (GYODER).2014. BirDeğerlemeYaklaşımı: Yeşil Bina SistemlerininGayrimenkulDeğerineEtkisi. BizimMatbaa. pp.16, İstanbul, Turkey.

[42] Uluslararası Değerleme Standartları, UDES.

[43] Kayabaşı, S. 2007. T.C Maliye Bakanlığı Milli Emlak Genel Müdürlüğü Genel Olarak Taşınmaz Değerleme İşlemleri ve Hazine Taşınmazları Kıymet Takdirlerinde Uygulanan Değerleme İşlemleri ile Karşılaştırılması, Milli Emlak Uzmanlığı Tezi, Denizli Defterdarlığı Buldan Malmüdürlüğü, Denizli, Turkey.

[44] http://www.usgbc.org/

[45] http://www.altensis.com/

[46] Turner,C.,Frankel, M. 2008. EnergyPerformance of LEED® for New Construction Buildings Final Report, U.S. GreenBuildingCouncil.

[47] Timothy, P. R.,T. Stacey. 2010.IntegratingSustainabilityandGreenBuildingintotheAppraisalProcess, Josre, Vol.2 No.2.

[48] Yudelson, J. 2008. The GreenBuildingRevolution, Island Press, USA.

[49] Yudelson, J. 2008. Marketing GreenBuilding Services: StrategiesforSuccess, Elsevier.

[50] http://greenbuildconsult.com/pdfs/PPA-Yudelson.pdf

[51] Popescu, D.Mladin, E. C.,Bienert, R.B.S. 2009.Methodologyfor Real EstateAppraisal of Green Value, EnvironmentalEngineeringand Management Journal, Vol.8, No.3, pp. 601-606.

[52] Stuart, E. 2013. CleanEnergy Program PolicyBrief. The Value of EnergyPerformanceandGreenAttributes in Buildings: Review of ExistingLiteratureandRecommendationsforFutureResearch, Lawrence Berkeley NationalLaboratory.

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What is the meaning of being smart for a city?

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ABSTRACT

Despite the ongoing discussion of the recent years due to considering energy, environmental, economic, social and technical aspects together, there is no commonly accepted definition of a "smart city". For this reason, this paper aims to identify these kind of aspects shaping the smart city in terms of both the conception and the reality.

With regard to main drivers; economy, social perception, need for the resources, environmental protection and the last but not the least technological innovations can be stated. In order to balance them the paper aims to show the current technology push and demand pull for smart city solutions with feasibility and social concerns. In other words, technological innovation rate increases rapidly and creates a booming market for being a smart city. However, there is a demand which desires cost effectiveness, efficiency while using resources and hence sustainability. Under these circumstances, the purpose of this paper is to outline how to design and implement strategies for building both conceptual and real smart city by means of a discussion on whether "smart" is a label or a concept.

INTRODUCTION

The world's population will increase from 7.3 billion to 9.7 billion between 2015 and 2050 [1]. Globally, more people live in urban areas than in rural areas, with 54% of the world's population residing in urban areas in 2014 and by 2050, 66% of the world's population is projected to be urban. Close to half of the world's urban dwellers reside in relatively small settlements of less than 500,000 inhabitants, while only around one in eight live in the 28 mega-cities with more than 10 million inhabitants. For example, Tokyo is the world's largest city with an agglomeration of 38 million inhabitants, followed by Delhi with 25 million, Shanghai with 23 million, and Mexico City, Mumbai and São Paulo, each with around 21 million inhabitants. By 2030, the world is projected to have 41 mega-cities with more than 10 million inhabitants [2]. As the world continues to urbanize, sustainable development challenges will be increasingly concentrated in cities, particularly in the lower-middle-income countries where the pace of urbanization is fastest. Integrated policies to improve the lives of both urban and rural dwellers are strictly needed. The basic elements for the required policies can be stated as density, diversity, design and discovery.
Density means that the concentration of people in a particular place. City is the place that provides key elements of identity and structure and connection. In case of diversity, there are abundant evidences that a more diverse population—by age, race, national origin, political outlook and other qualities—helps provide a fertile ground for combining and recombining ideas in novel ways. While designing, how to populate and arrange the physical character of cities matter greatly. For the diversity element, it can be stated that the city is an evolving organism and constantly being reinvented by, its citizen inhabitants. A part of the attraction of cities is their ability to inspire, incubate, and adapt to change. On the other hand, it should be kept in mind that all of these attributes of cities are susceptible to analysis as "information flows" or "systems of systems." They may be improved by better or more widespread information technology [3] (Figure 1).

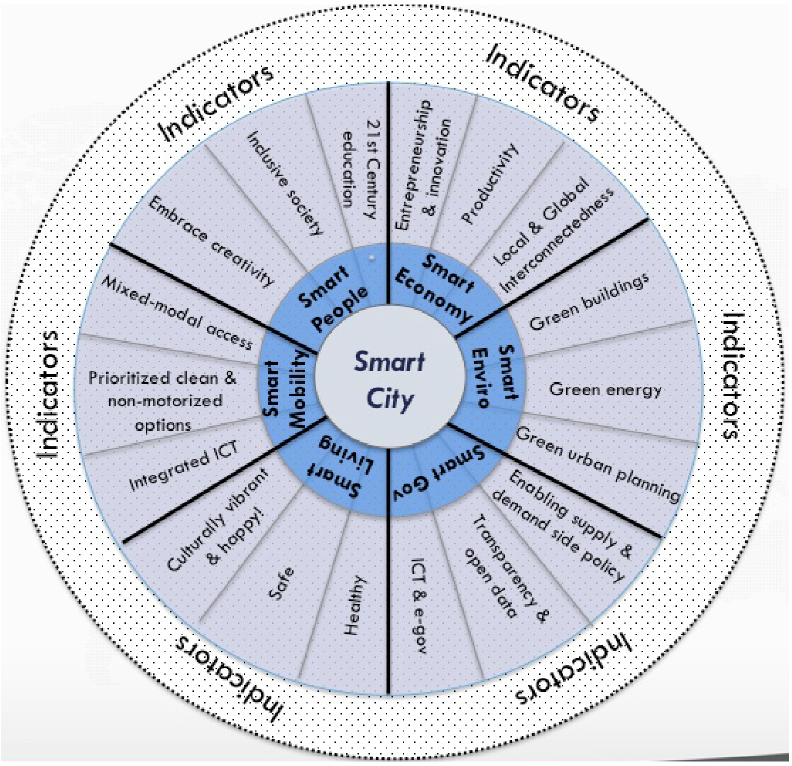

Figure 1 Smart city wheel [4]

A SHORT OVERVIEW: THE LITERATURE ON THE SMART CITY

The first reference to the term ***smart cities*** appears in the book *The Technopolis Phenomenon*-Smart Cities, Fast Systems and Global Networks [5] published in 1992. In this book, smart cities are defined as a "metaphor of intelligent cities". Smart cities are "***global network cities of dispersed highly interactive economic nodes linked by massive networks of airports, highways, and communications; inhabited by 'knowledge processors' engaged in rapid information exchanges***", hence, the metaphor with intelligent cities. The author illustrates the concept with the examples of Hong Kong, Singapore and London. It can be observed from the quotations above, ***smart cities*** and ***intelligent cities*** were presented as parallel concepts, but with the latter having stronger relationships with information, knowledge and science. Afterwards, anticipated something that we have not yet achieved, that telecommunications would offer not only the advantages of better communications and improved urban management but also "smart growth", consisting of "attractive combinations of economic and cultural vibrancy, social equity and long-term environmental responsibility" [6].

Examining the etymology of both the terms ***intelligent*** and ***smart***, in order to show the nuances of these adjectives when applied to cities is crucial. ***Smart*** comes from both the old English form of ***smeart*** and the Proto-Germanic suffix ***-smartz***. Both forms filled the current term ***smart***, used as an adjective, with a variety of meanings, the most common of which are: 1. Causing sharp pain, stinging; 2. Sharp, keen, poignant; 3. Exhibiting social ability or cleverness; 4. Exhibiting intellectual knowledge. Nevertheless, ***intelligence*** comes from the Latin form ***intellegēns***, meaning ***discerning***. Its present active participle form is ***intellegō***, which means ***understand***, ***comprehend***. ***Intellegō*** is a compound term formed by the prefix ***intus-*** (transforming into ***inte-***, after compounding), which means ***in between*** and the suffix -***legere*** (turning into -***legō***, when compound), which means ***read inside***, ***pick out***, ***choose***. Although the term ***intelligent*** has a more profound, complex, interactive, educational, collaborative and lasting meaning, all these being qualities and characteristics of cities, the adjective ***smart*** has somehow been selected to characterize features of cities.

In particular, economic development and structural urban variables such as population profiles and knowledge density are likely to influence a city's to call as smart [7]. Furthermore, for cities to achieve smartness, the conditions for continuous learning and innovation must be created. More importantly, these conditions will be created if cities connect together and learn from each other [8].

In Europe, the concept has become extremely popular, especially after the expression smart city became part of the complex mechanisms of EU research funding [9]. The Seventh Framework Programme for Research and Technological Development and the current Horizon 2020 introduces the term 'smart city' in the energy policy issues. Financial support is provided to initiatives aiming at reducing greenhouse gas emissions through improvement in the energy efficiency of buildings, energy distribution networks and transport systems. However, despite the fact that several billion Euros have been allocated in the pursuit of energy and technology-efficient cities, it is relatively easy to perceive that the idea of smart city is still unclear and undefined. For example, it is connected to a rather simplified visual vocabulary, characterised by stereotyped images with lights representing digital flows, tall buildings and a lack of people in the streets [9].

Currently, it is possible to classify the literature on smart cities in urban studies and social sciences in three strands. Firstly, there is a large body of literature situated at the crossroads between social, technological and managerial studies. These contributions analyse and evaluate the potential benefits and problems relating to the implementation of smart technologies, for example through the pages of international journals such as ***Journal of Urban Technology*** or ***International Journal of e-Planning Research***. Technical and policy-oriented documents from the European Commission, the OECD and other international bodies have also contributed to this body of literature. Secondly, there is an increasing amount of critical debates developed within social sciences. Contributions focus on the relations between smart city projects and neoliberalism, the corporate-oriented and profit-oriented logics behind smart city projects, the new forms of power and control triggered by these initiatives the socio-technical regimes enacted, and specific analytical perspectives on issues of bottom-up governance, surveillance, anonymity and the management of big data. Thirdly, a new strand of literature, still rather limited in size, explores 'diverse' smart city initiatives, proposing critical analysis that looks beyond both 'celebrative' and 'always critical' approaches, via the consideration of different and various cases of smart city projects, and at the various ways in which new urban technologies are used, negotiated and even subverted by citizens [9]. Table 1 summarizes some important definitions of the smart city.

Although these definitions include technology, people, and institutions, the literature usually focuses on technology's dominant role. Indeed, smart technologies transform cities' public and private services by integrating real-time communications, citizens' needs, and information and by enhancing liveability. In a period of sluggish growth, key technology adoption offers extraordinary opportunities for cities and can spark a new wave of wealth creation [15].

Table 1. Definitions of smart cities in the literature

Definitions of smart cities	Source
"A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens." "A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better organize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens."	[10]
"The use of Smart Computing technologies to make the critical infrastructure components and services of a city-which include city administration, education, healthcare, public safety, real estate, transportation, and utilities- more intelligent, interconnected, and efficient."	[11]
"It is the implementation and deployment of information and communication technology infrastructures to support social and urban growth through improving the economy, citizens' involvement and governmental efficiency."	[12]
"Safe, secure, environmental and efficient urban centre of the future with advanced infrastructures such as sensors, electronic devices and networks to stimulate sustainable economic growth and a high quality of life."	[13]
Smart Cities can be defined as "territories with high capacity for learning and innovation, which is built-in the creativity of the population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management."	[14]

STRATEGIES FOR SMART CITY DEVELOPMENT

A major differentiating characteristic among smart city strategies is whether they concern an entire country or nation, or they are focused on a more local level, municipality, city, metropolitan area or even a region.
Most applied strategies are built on the local level. The advantages of local-level smart city strategies, as they have been recently cited in the smart city literature, include that:

- Innovation has a geographical locus and knowledge has a geographical stickiness. Cities are capable of engaging various constituents in the innovation process on a much broader range of activities, fostering citizen-centric governance; the result is well established smart city ecosystems.

- Becoming smart includes fostering a competitive economy and local characteristics are the ones that differentiate cities among each other.

- Cities are more flexible in exploring and adjusting a variety of business and governance models to their own profit. Their experience, agility and proximity provide them the necessary knowledge and ability to set up a favourable climate for the purposes of becoming smart.

- Urban problems are of manageable size and known nature, and respond to locally selected goals, which make them less effort-intensive.

On the other hand, the disadvantages of local-level smart city strategies include the following:

- Small and medium sized cities compete for resources against larger and better-equipped cities; therefore, they are less likely to be able to receive or afford the necessary funds for smart city projects.

- Cities will have to find a way to align their smart city strategy with the complex policy agendas already operating at the government level.
- Innovative pilot projects and small-scale developments do not necessarily guarantee an effective uptake on city-wide level.

Considerably far fewer researchers advocate the implementation of smart city strategies on a national level (i.e. to become a 'smart country'). National-level strategies enjoy state backing; they allow for a broader view and firmer control over related policies and coordinated resource pooling, and by doing so they provide a very strong point of reference for smart city strategies. The advantages of national-level smart city strategies, as they have been recently cited in the smart city literature, include the following:

- Top-level coordination and resource allocation encourages the assignment of clear roles and responsibilities to the institutional authorities involved, enhancing the effectiveness of the strategy.
- The operational continuity of basic choices at all levels is guaranteed and a common platform can be implemented.
- Complementarity in weak and strong points and joint addressing of challenges can be foreseen.

The disadvantages of national-level smart city strategies include:

- Possibility to fail in capitalizing on the sum of local resources effectively, and ignoring local needs and priorities in all of a country's cities [16].

Another significant qualitative characteristic of a smart city strategy is the urban development stage of the city they involve, i.e. existing or new cities. On the one hand, urban planners endorse the belief that there is no need for new cities. Our long-lived cities are already big and complex enough to accommodate the current population and its activities. Emphasis should be placed on regenerating degraded urban areas, rather than developing new cities. Mostly in developing countries, on the other hand, several initiatives have been taken to develop entirely new smart cities, such as PlanIT Valley (Portugal), Skolkovo Innovation Center (Russia), Cyberport Hong Kong (China), Songdo International Business District (South Korea), Cyberjaya (Malaysia), Masdar City (Abu Dhabi-UAE). These new cities are designed and built from scratch, showcasing leading edge 'smart' technology and certifications of green physical planning. It is impressive that in China alone, as many as 154 proposals have been introduced to build a smart city, and population growth and migration will give rise to 81 new cities by 2025 [17, 18]. However, the existence of several recently-built but empty ghost cities in China—such as Kangbash, Zheng Zhou New District, Zhengdong New District, Erenhot, Dantu, Bayannoao'er and Tunnan University Campus—raises concerns about their exact purpose, affordability and building quality, and ultimately their ability to attract inhabitants and become sustainable in social terms.
The most important advantages of applying a smart city strategy for a new city include:

- Opportunity to address the smart city vision from inception, and clarity of purpose
- Integrated physical design and development of infrastructure and buildings, incorporating all aspects of edge technology, modern amenities and best practices of city planning
- Capability to explore innovative business models and funding options

- Selection of a strategically placed location
- Replication of standard approaches, resulting to faster deployment, economies of scale and higher chance for success

However, major disadvantages of developing new smart cities are as follows:

- There is an imminent risk of slow progression due to a variety of problems ranging from budgetary issues to insufficient planning and failure to attract residents and/or capital.
- They require generous investments and a conducive governance model.
- Singular focus on efficiency could cause a restricted view of societal values, such as social cohesion and quality of life, questioning the 'sustainability' dimension of new cities.
- The replication of technological solutions entails risks. The same solution may not be suitable for all cities.

On the other hand, comments on the new versus existing smart city discourse stress the importance of collaboration among public and private actors, and most importantly the engagement of the city's people, in order to design socially sustainable and livable smart cities. In this sense, the most important advantages of applying a smart city strategy on an existing city are:

- Opportunity of employing open innovation techniques and a bottom-up approach to accelerate the innovation process
- An ecosystem of stakeholders is already present, allowing for innovatory ways to collaborate and secure funding
- Smart city revenue sources now tend to extend from products to services (namely platforms and applications), eliminating the need for large investments on smart city infrastructure

The most important disadvantages of applying a smart city strategy to an existing city are:

- Complex ecosystems of people, institutions and stakeholders require extreme effort to organize and discipline.
- An existing city's infrastructure could be old and outmoded, hindering the realization of the smart city vision.
- Besides becoming 'smart', existing cities have many problems that must be addressed and which compete for a share of the city's recourses. Therefore, it is not possible to address all aspects of a smart city; the strategy has to be highly selective and based on a laborious prioritization process [16].

A final significant differentiating characteristic among smart city strategies is their reference area: economic sector-based versus geographically based strategies. This issue, although fundamental and clearly articulated, has not been studied extensively in the context of the smart cities topic, and thus the available literature is very restricted. However, it still remains as a differentiating factor among smart cities.

Economic sector-based strategies refer to smart city strategies aiming at the transformation of specific economic sectors of the city [19, 20]. This seems to be the mainstream approach within the broader smart cities landscape, as most cities appear to be concerned with deploying new technologies for a range of sectoral and/or actor-specific objectives. In this framework, cities aiming to become smart focus on enhancing the intelligence of specific socio-economic aspects of everyday living, such as business, housing, commerce, governance, heath, education, and community, without placing specific emphasis on the geography of each sector, but on its effectiveness and performance instead. For example, IBM, through their 'smarter cities' program, offers solutions for 'government and agency administration', 'smarter buildings and urban planning', 'environment', 'energy and water', 'transportation', 'education', 'healthcare', 'social programs', and 'public safety' [21]. In a similar manner, Cisco's 'Smart + Connected Communities' platform offers solutions in fields such as transportation, learning, safety and security, sports and entertainment, utilities, real estate, health and government [22].

On the other hand, other smart city strategies focus on geographically-determined districts and clusters [20] such as business districts, research and development clusters, university and education areas, logistical clusters, tourism and leisure clusters, or even smaller areas, such as neighbourhoods. This is a spatially-determined perspective and it addresses specific user groups, who are meant to enjoy the benefits of the district/neighbourhood they live in/work in/visit.

The existing literature on smart cities does not point out advantages and disadvantages of sector-based and geographically based strategies. The only related reference mentions the fact that geographically-based strategies enable economies of scope, as each district's functions are upgraded due to spatial proximity and resources savings [23].

DIFFERENT APPROACHES TO THE SMART CITY

The Smart City has been functionalized in many diverse ways, which can differ dramatically based on the perspective of the stakeholder describing the concept. This section briefly outlines two of those extreme approaches and a final one that aims to meet them in the middle.

The top-down Smart City

"***A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens***" [24]. The first approach is top-down dynamics, often closely related to the technologically deterministic idea of a "control room" for the city. It aims to provide an ICT-based architecture to overview urban activities as well as the tools to interact with infrastructures and adjust parameters to predefined optimums [25]. Songdo and Masdar can be accepted as examples, but both have been criticized for being sterile, overly planned, prohibitively expensive, uniform and conformist [26] and these cities do not attract enough economic activity.

In this approach smart City is a city "***connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city***" [27]. Many major IT companies and municipalities around the world are looking for their slice of the Smart City pie (e.g. Cisco, IBM, Siemens). On the other hand, cities are about citizens, about the people who live and use them; in terms of for whom they are built, but also in regards of the potential for innovation and finding appropriate solutions to the challenges that are actually pertinent to these citizens. Therefore, this top-down vision is contrasted by the opposite: a purely bottom-up view on the Smart City, which is outlined in what follows.

The bottom-up Smart City

In bottom-up approach, change and improvement comes only from the people "using" the city. It dismisses any form of top-down urbanization, in particular with the involvement of powerful private companies. The bottom-up Smart City is about the ***Smart Citizen;*** those who live, work, and engage in all kind of activities in the city [28, 29].

Examples of bottom-up approaches can be found in citizen initiatives and even (semi)-illegal interventions in the public space, such as so-called guerrilla bike lanes where citizens, unhappy with local biking infrastructure, gather via social media and paint bike lanes on the street without authorization. These types of initiatives are also referred to as tactical urbanism [30]. Tactical urbanism tends to consist of "small scale interventions, characterized by their community-focus and realistic goals" and are often short-term or temporary, cheap and aimed at increasing quality of life in a certain way or addressing a specific neighbourhood concern.

Bottom-up initiative can also come from large and small businesses or start-ups that aim to instigate innovation in a certain urban sector. One such well-publicised example is the mobile app Uber that offers an alternative private driver service that is completely organised within and via the app. In each city Uber has launched so far, protest has risen, in particular from the taxi services operating in these areas that saw it as a threat to their business. In Brussels, Uber was met with a lot of resistance as well and labelled as illegal by Brussels minister [31], responsible for the taxi policy in the city (a statement which was in turn strongly rejected by Digital Agenda Commissioner [32]). Nevertheless, Uber continues to operate and serves as an illustration of how a commercial entity can also be seen as a bottom-up approach to a Smarter

Smart citizen that uses a variety of tools to interact with and move around the city, and for whom the emphasis lies on his/her citizenship, rather than technology can be argued as a primary factor. However, relying purely on bottom-up initiatives remains problematic thinking about the city of the future in which all responsibility for its success is regarding with its citizens [33].

Functionalization of a Smart City

Smart Cities should capture creative and collaborative innovation through interactions between public bodies, businesses and citizens in:

- dealing with the next data flood, digital footprint and data trails (coming from use of linked open data, big data, IoT, sensor data etc.);
- identifying new relational complexities between actors;
- facing grand societal challenges in a local context (e.g. mobility, security, local and participatory governance etc.);
- offering new and engaging experiences to citizens.

The element collaboration refers not only to cooperation of citizens, companies or local governments amongst each other (i.e. horizontal) but also more important is vertical collaboration, working with all stakeholders on all levels; public, private and citizens. It is working together in dealing with the vast amounts of information and data that modern cities increasingly produce that will allow them to tackle some of the major urban challenges of the future and today and then "smart" city is being collaborative, collective and contextual (Figure 2).

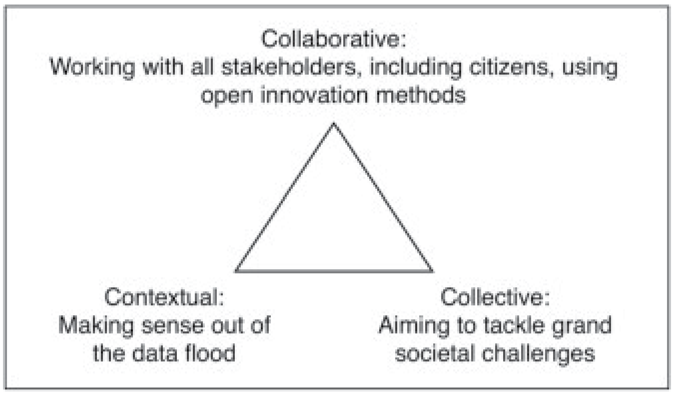

Figure 2 The constituting characteristics of the Smart City [33].

CONCLUSION

As can be concluded from the above mentioned strategies and approaches to the smart city, it is both a concept and a label depending on the how it is handled by politicians, scientists, philosophers, citizens, etc. in todays' world. In the future, "intelligent" may replace the "smart", at least conceptually, due to the fact that intelligence is the measurement of cities' ability to become smarter through learning.

REFERENCES

[1] UN, http://www.un.org/en/development/desa/population/, 2015

[2] UN, http://www.un.org/en/development/desa/population/, 2014

[3] http://cityobservatory.org

[4] http://www.fastcoexist.com

[5] Gibson D.V., Kozmetsky G., Smilor R. W. The technopolis phenomenon: Smart cities, Fast Systems, Global networks. Rowman & Littlefield, Boston (1992)

[6] Mitchell, W. Electronic cottages, wired neighborhoods and smart cities. Lincoln Institute of Land Policy, Cambridge (2002), pp. 69–83

[7] Campbell, T. Beyond smart cities — How cities network, learn and innovate. International Journal of Sustainability in Higher Education, 14 (1) (2013), p. 105

[8] A. Greenfield Against the smart city. A pamphlet by Adam Greenfield. Part I of the city is here for you to use, e-book, do projects, New York (2013)

[9] Vanolo A. Is there anybody out there? The place and role of citizens in tomorrow's smart cities.

[10] http://www.smart-citu.ies.eu/download/smart_cities_final_report.pdf)

[11] Washburn D, Sindhu U., Balaouras S., Dines R.A., Hayes N.M., Nelson L.E.. Helping CIOs understand "smart city" initiatives: Defining the smart city, its drivers, and the role of the CIO. Forrester Research, Inc., Cambridge, MA (2010)

[12] Hollands R. Will the real smart city please stand up? City, 12 (3) (2008), pp. 303–320

[13] https://ideas.repec.org/p/vua/wpaper/2009–48.html

[14] Vanolo A. Smartmentality: The smart city as disciplinary strategy. Urban Studies, 51 (5) (2013), pp. 883–898

[15] Soumaya Ben Letaifa How to strategize smart cities: Revealing the SMART model. Journal of Business Research 68 (2015) pp.1414–1419

[16] Angelidou M. Smart city policies: A spatial approach. Cities Volume 41, Supplement 1, July 2014, pp. S3–S11

[17] http://www.chinadaily.com.cn/bizchina/2012-11/15/content_15931273.htm

[18] http://www.scientificamerican.com/article.cfm?id=the-social-nexus

[19] http://whatmatters.mckinseydigital.com/cities/talking-back-to-your-intelligent-city

[20] N. Komninos Intelligent cities: Towards interactive and global innovation environments International Journal of Innovation and Regional Development, Special Issue: Intelligent Clusters, Communities and Cities: Enhancing Innovation with Virtual Environments and Embedded Systems, 1 (2009), pp. 337–355

[21] http://www.ibm.com/smarterplanet/us/en/smarter_cities/overview/

[22] http://www.cisco.com/web/strategy/smart_connected_communities.html

[23] Komninos, N., Sefertzi, E. Intelligent cities: R&D offshoring, web 2.0 product development and globalization of innovation systems. In 2nd Knowledge Cities Summit, 5–7 November 2009, Shenzhen, China.

[24] Hall, R. E. The vision of a smart city. In: Proceedings of the 2nd International Life Extension Technology Workshop, Paris, France, September 28, 2000

[25] IBM. How Smart Is Your City? IBM Institute for Business Value, Executive report, 2009

[26] Sennet, R. No One Likes a City That Is Too Smart. The Guardian, 4 December 2013

[27] Harrison C., Eckman B., Hamilton R, Hartswick P., Kalagnanam J., Paraszczak J., Williams P. Foundations for smarter cities. IBM J. Res. Dev., 54 (4) (2010)

[28] De la Peña, B. The autocatalytic city. In: Books, T.E.D. (Ed.), City 2.0: The Habitat of the Future and How to Get There (Ebook). TED Conferences.

[29] Lindsay G. Not-So-Smart Cities. New York Times, 24 September 2011.

[30] Hamdi N. Small Change: About the Art of Practice and the Limits of Planning in Cities Routledge, London (2004) pp. 184

[31] http://newsmonkey.be/article/9310

[32] http://ec.europa.eu/commission_2010-2014/kroes/en/content/crazy-court-decision-ban-uber-brussels-show-your-anger

[33] Walravens N. Mobile city applications for Brussels citizens: Smart City trends, challenges and a reality check. Telematics and Informatics Volume 32, Issue 2, May 2015. pp. 282–299

Paper No: 167

Developing Resilience through Spatial Organization and Accessibility of Health Facilities in Urban Environments

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ABSTRACT

Urbanization in Turkey as well as across the world has accelerated fast as it has never been before and this tendency is predicted to last in the near future. Urban areas besides their attractiveness are usually prone to vulnerabilities due to disasters and destructive environmental conditions. Natural disasters cause major problems which affect a population's health and hinder a nation's socioeconomic development by draining its scarce financial resources in an effort to repair damages. Therefore, public health infrastructure in a city must be organized and ready to act in disaster situations as well as under normal conditions and must be prepared for the type of measures to be taken in event of a disaster.

This study aims at analyzing the infrastructure of public health in İzmit that is under risk of a potential earthquake by examining the spatial organization and accessibility of the health facilities. Health utilities including three types of services: Hospitals, clinics, and pharmacies with respect to road network were analyzed with Geographic Information Systems (GIS) and Network analysis to find the service area of health utilities. Health utility services were digitized from up-to-date maps and satellite data. Road network is obtained from municipality and a network is produced to generate service areas of grades of accessibility. Service area is investigated twofold; access by walking and access by vehicle. Areas that have poor accessibility conditions are considered as more vulnerable especially in the event of a disaster such as an earthquake. These urban environments need to be examined for building up resilience by increasing their accessibility to health services.

Keywords: Health Utility Services, Vulnerability, Earthquake, GIS, service area, resilience

INTRODUCTION

Amount of people who live in cities increases each year. In the year 2050, urban population residing in urban sprawls of developing countries is expected to double in number [1]. To accommodate urban population growth, urban sprawl enlarges and densifies leading to rapid changes in land use patterns with adverse consequences affecting environmental and social life in cities. Healthcare on the other side becomes an increasingly important issue as population grows, especially for vulnerable population including infants, elders and poverty.

The growth and development of an urban area largely depend on proper urban planning. Efficiency and spatial organization of urban utility services determine the level of urban wellbeing; especially health services constitute a major role on quality of life of residents of the city as well as city's resilience to hazards.

A resilient city is described as sustainable backbone of physical and social systems [2]. The backbone has to survive after the stress caused by the hazard [3]. A resilient city develops capacity to adopt for maintaining its critical functions with measures of 'hazard mitigation' and city recovers faster [4]. Systems composing a resilient city are described as an amalgamation of four components: Accessibility system, Open and Safe areas, Main Lifelines, and Strategic Building Systems [5] where health utility systems constitute the major part of strategic building systems.

Access to healthcare is a major issue to consider after a hazard takes place, especially a destructive and pervasive one like an earthquake. The ability to access healthcare can impact the public health of a population under normal conditions, but it becomes of vital significance after an earthquake event. Therefore, it is essential to provide efficient health service utilities and moreover, a sound transportation infrastructure for residents to have the capacity to access healthcare.

Accessibility is defined as "the extent to which land use and transport systems enable individuals to comfortably reach activities or destinations in a reasonable time by means of transport models [6, 7]."

An accessibility analysis is spatial in nature and is well suited for a Geographic Information System (GIS) environment. GIS provides an environment by which geographically dependent data can be stored, analyzed and displayed in an easily understandable visual format to simplify the process s of decision making. An accessibility analysis is not a fully integrated and standard GIS function. Instead, underlying network analysis functions that are part of the Network Analyst extension are manipulated to create a measurement of accessibility [8]. A service area calculation is a procedure that is accomplished with network analysis. Service area can be defined as a geographical zone characterized around an entity or institution that distinguishes the population which utilizes its services [9].

This study investigates the efficiency and accessibility of the health utility services including three major units; hospitals, clinics and pharmacies in İzmit city through service area tool of Network analysis within a GIS environment. Both walking distance circles based on time and travel distance circles by vehicles were calculated and mapped. Service area circles depict the grades of accessibility of the urban environments to the health care services. Areas that have low accessibility are assumed as more vulnerable and these regions of the urban environments should be developed.

STUDY AREA

İzmit city is located at the İzmit Bay of the Marmara Sea, in the Northwest of Turkey (Figure 1). The city is the industrial heart of Turkey with ports connected to major highways and railway. İzmit is situated on the main transportation corridors connecting İstanbul and the Capital city Ankara. The city covers approximately 18,71 km2 of land surface and has about 350.000 inhabitants [10]. The topography gets rough in the northern parts of the city which limits the settlement activities and leads to densification in the city center. City sprawls mainly on east-west direction. Road network is not well-organized due to barriers such as; sea, topography and major transportation corridors.

Figure 1 Study Area: İzmit, Kocaeli

MATERIALS AND METOD

In this study, spatial organization and accessibility of Health utility services is investigated through network analysis and service area calculation in GIS environment. All of the analyses and cartographic illustrations were conducted using tools of ArcGIS v. 9.3. Method relies on the assumption that 'Accessibility to health service utilities builds up resilience in urban environments, especially on hazard situations'. Therefore, service area circles on pre-defined intervals are utilized to determine the grades of accessibility to health utilities.

First phase of the analysis is the collection of data. Roads and paths were obtained from Municipality dataset. Three types of health utility services were considered for the analysis. These are 17 hospitals that are fully-equipped, 40 clinics with limited care services and 121 pharmacies that provide drugs and first-aid materials (Figure 2). Geographic locations of these utilities were digitized using up-to-date maps and satellite images and transferred into GIS environment.

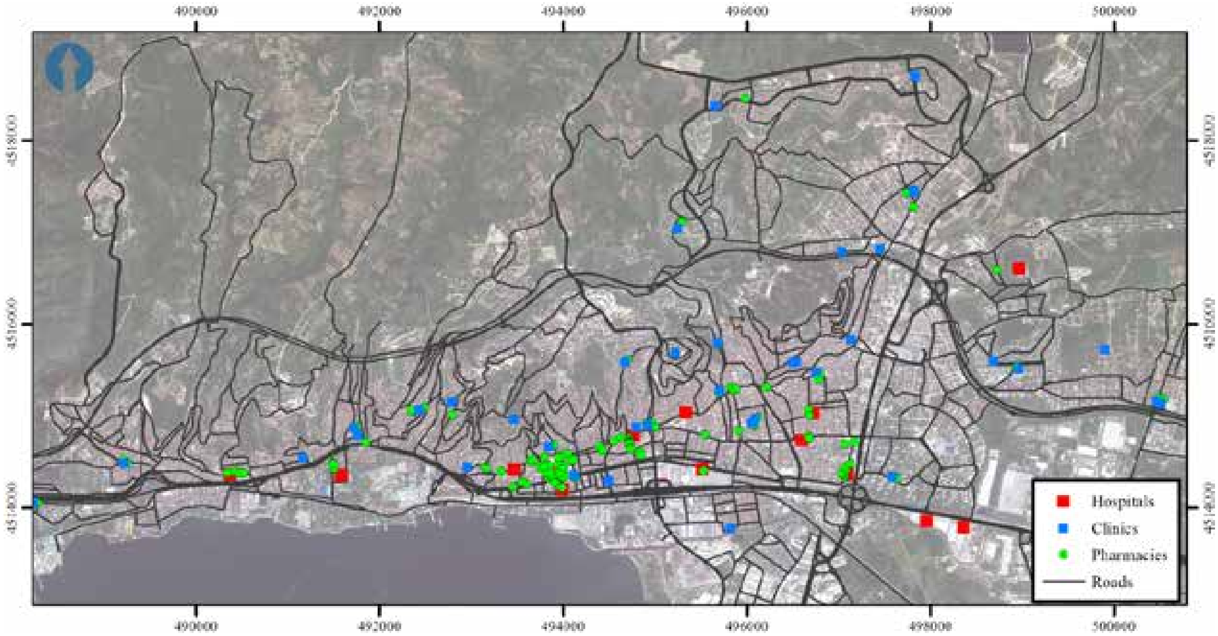

Figure 2 Health Utility Services and Roads

The software ArcGIS10.1 has been used as a GIS platform in this study. The geodatabase was created with four feature datasets and many feature classes that represent the study data. These are road data, hospitals, clinics and pharmacies. Road data was processed to build up a network to conduct network analysis. Regular road vector data was converted in to a set of segments and junctions / intersection nodes (Figure 3).

Figure 3 Roads transferred into Network structure

Network analysis utilizes road network data characterized as a sequence of segments which are connected by nodes (intersections), where each segment is accredited a travel cost. Health utility services points are assigned a location and the nearest segment or node is assigned as the centroid of the service area.

In order to calculate service area intervals based on time or distance should be pre-defined to determine the grades of accessibility across the urban environment. In this study we adopted time constraint. Accordingly, regular walking speed of an individual is 1.33 m/sec walks 400 m in 5 minutes and 800 m in 10 minutes [7]. A close-reach interval was added as 1-2 minute walk that is 100 m and is accepted critical for hazard events.

Table 1 Accessibility intervals for walking

	Service area circles	**Walking distance**	**Walking time**
High accessibility	0-100 m	100 m	1-2 min.
Medium accessibility	100-400 m	400 m	5 min.
Low accessibility	400-800 m	800 m	10 min.

Accessibility is analyzed twofold; for walking and for vehicle transport. For vehicle transport accessibility intervals in time were accepted as the same as walking time. Average speed for inner city roads was taken as 50 km/h.

Table 2 Accessibility intervals for vehicle transport

	Service area circles	**Walking distance**	**Walking time**
High accessibility	2000 m	2000 m	1-2 min.
Medium accessibility	2000-4000 m	4000 m	5 min.
Low accessibility	4000-8000 m	8000 m	10 min.

Service area analysis were conducted both for walking accessibility and vehicle transport accessibility that include three health utility service; hospitals, clinics, and pharmacies points. Resultant accessibility maps for walking are depicted in Figure 4-6 and accessibility maps for vehicle transport are depicted in Figure 7-9. Dark to light shade of the color represents the decrease of accessibility from high to low. The lightest urban areas are with the least accessibility to health utilities.

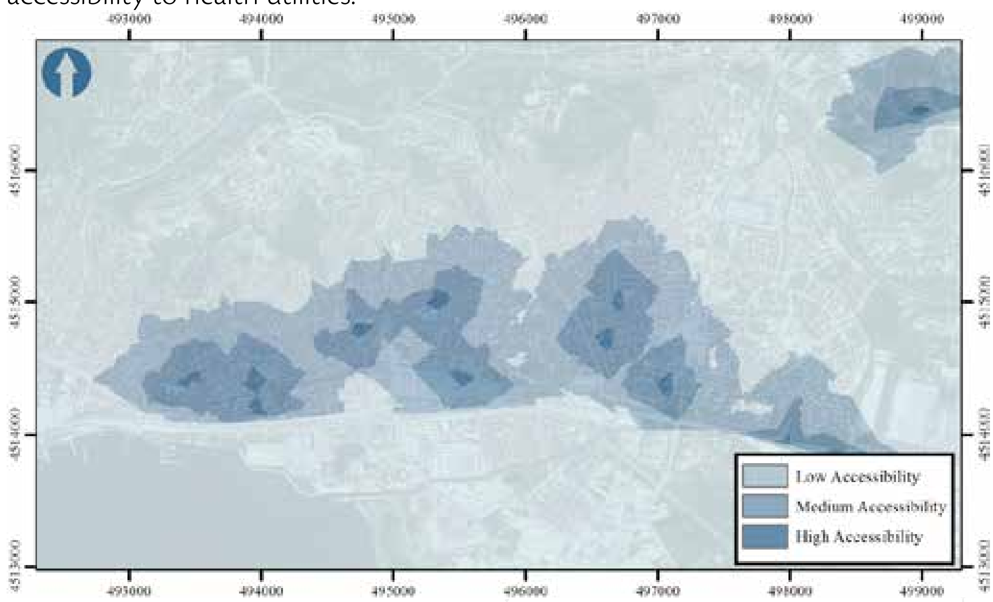

Figure 4 Accessibility to Hospitals by walking

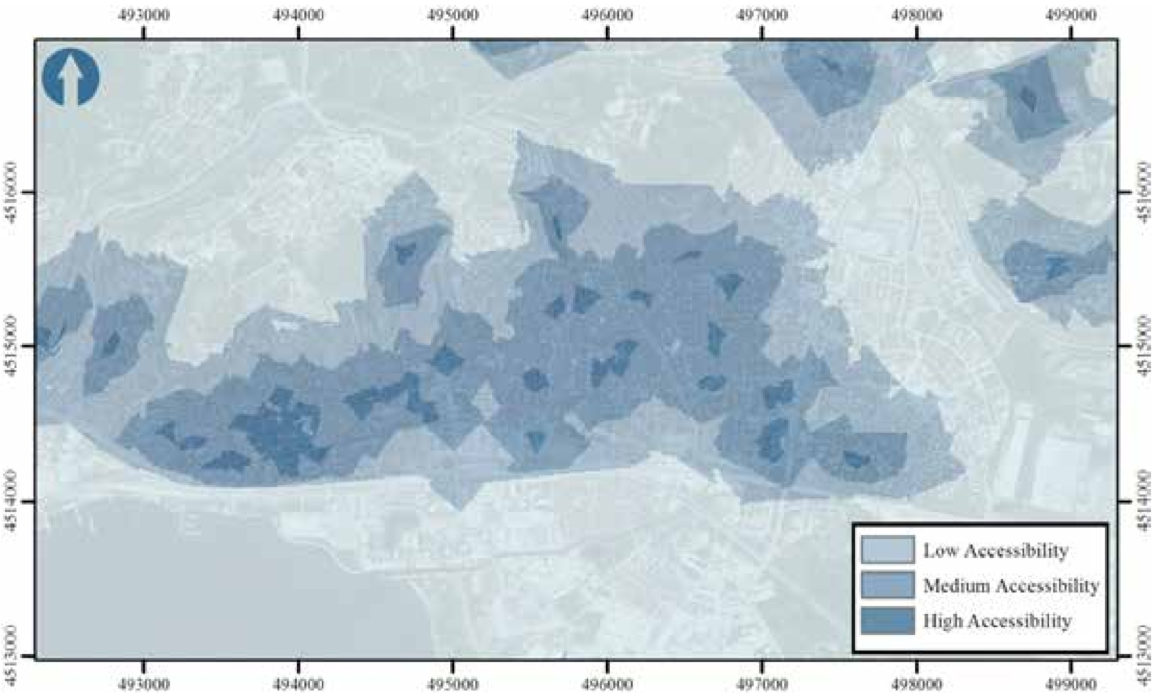

Figure 5 Accessibility to Clinics by walking

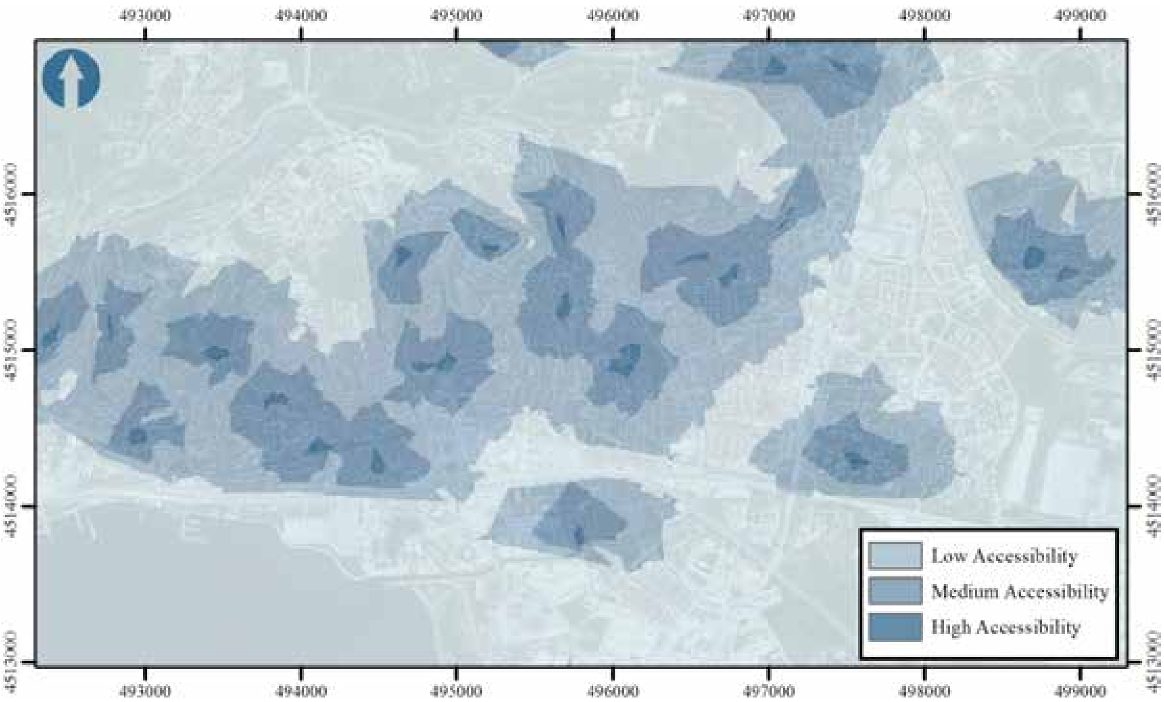

Figure 6 Accessibility to Pharmacies by walking

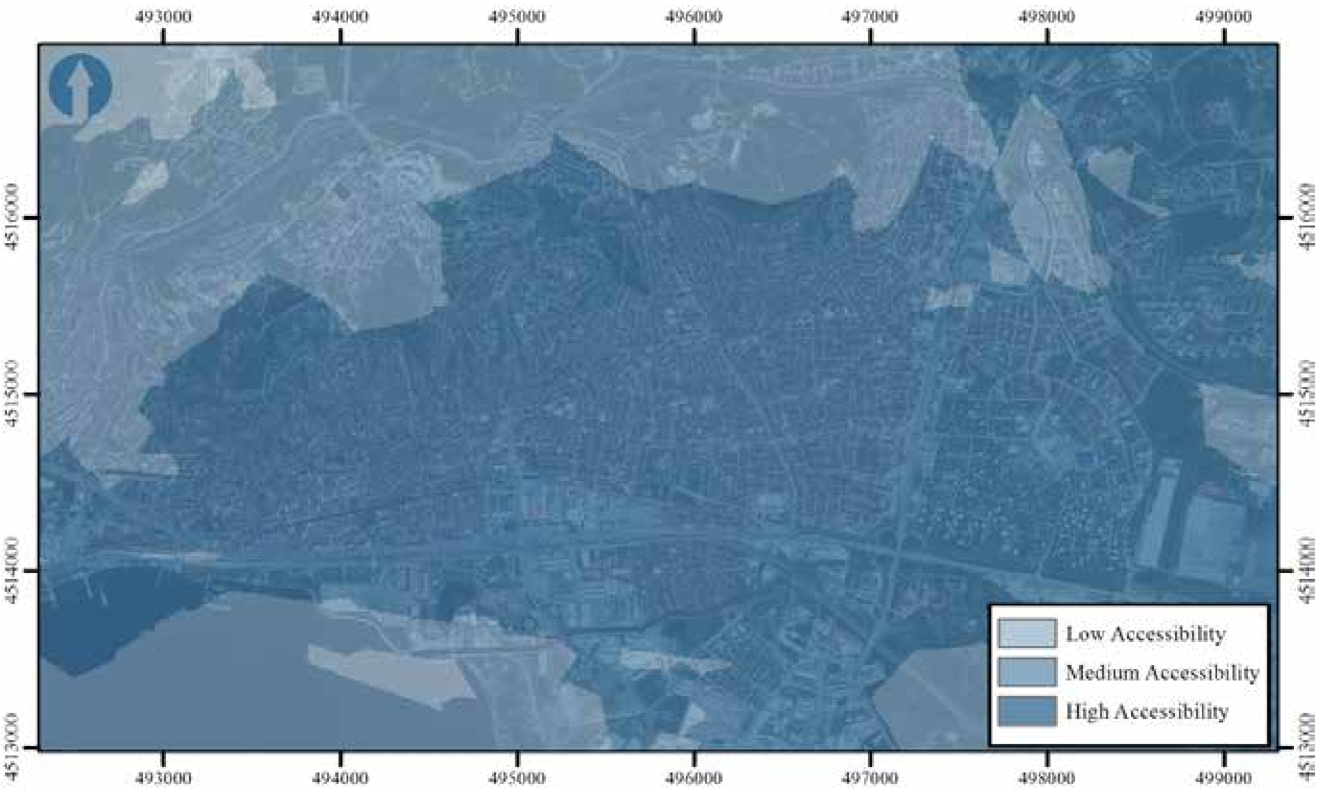

Figure 7 Accessibility to Hospitals by vehicle transport

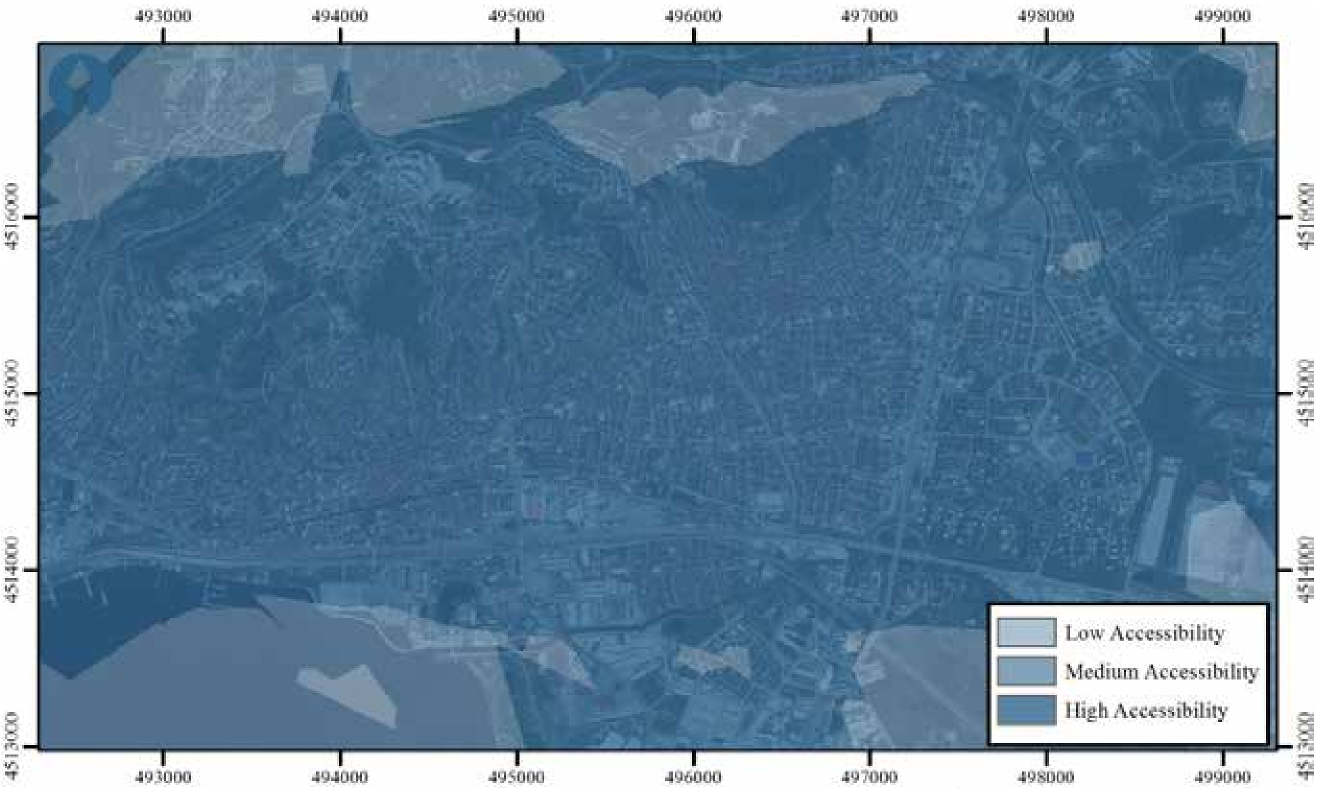

Figure 8 Accessibility to Clinics by vehicle transport

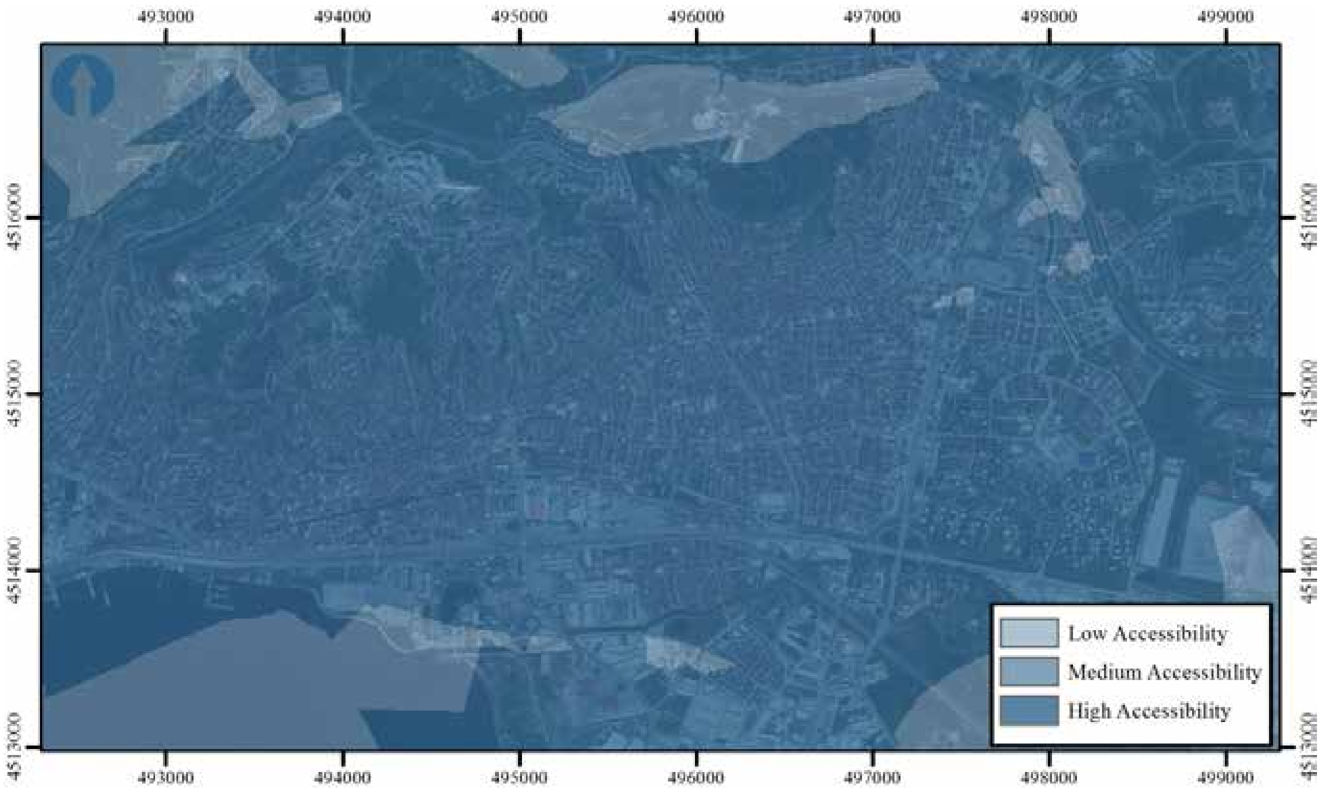

Figure 9 Accessibility to Pharmacies by vehicle transport

All of the three types of health utilities were taken into account in equal weights and a total accessibility map is produced. Figure 10 depicts the total accessibility to Health Utility Services by walking.
All of the three types of health utilities were taken into account in equal weights and a total accessibility map is produced. Figure 11 depicts the total accessibility to Health Utility Services by vehicle transport.

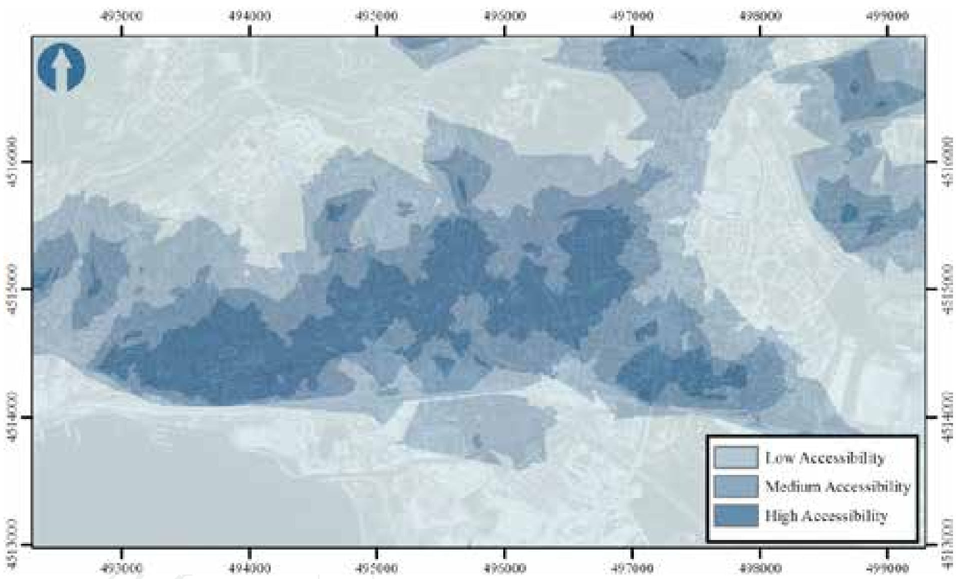

Figure 10 Total Accessibility to Health Utility Services by walking

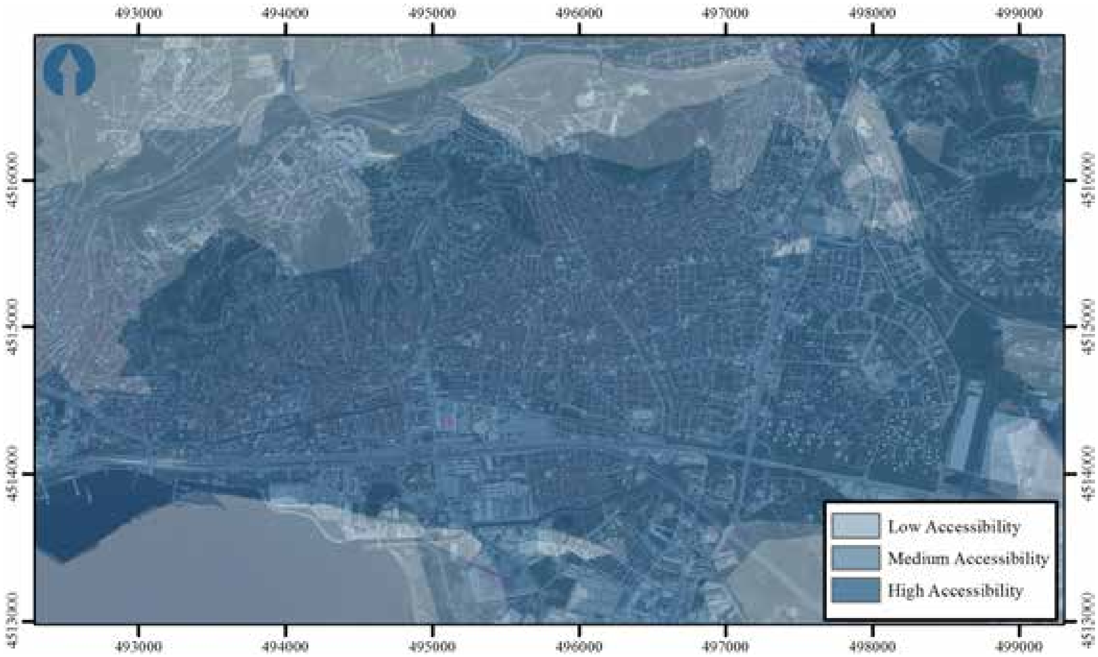

Figure 11 Total Accessibility to Health Utility Services by vehicle transport

CONCLUSIONS

This study investigates the spatial organization and accessibility of Health Utility Services through network analysis within a GIS environment in order to determine the resilience of the city within the scope of health care that is of vital significance in the case of disasters; i.e. earthquake. Walking distance is a critical issue especially in the case of disasters were people may have to reach the health services whether or not they may have a vehicle or the roads were corrupted or closed.

According to the results shown in Figure 10, a region that covers the city center has high accessibility to health utilities on foot. However, new settlement areas first; being in northern part that are on sloping topography, second; eastern areas and, third southern areas that are divided from the city center by transportation corridor have low accessibility to all of the types of health services. These areas although with their fairly dense population and planned growth, do not get sound access to health utilities. Results shown in Figure 11 portray that northern periphery of the city has low accessibility to health utilities by vehicle transport. The highway that physically limits the region doesn't give link to the region and there are no efficient service road to provide access of these areas to health services.

Outcomes of the study addresses the urban area that has to be developed to build up resilience in the scope of health care. Two measures are proposed; first being establishing 'clinic' level health utilities for the residents of the regions and second being increasing accessibility of these regions by alternating routes.

ACKNOWLEDGEMENT

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REFERENCES

[1] United Nations, 2014. United Nations: world urbanization prospects: the 2014 revision: highlights Department of Economic and Social Affairs, Population Division, United Nations.ISBN 978-92-1-151517-6.

[2] [hartek 12] Paton, D., Millar, M., Johnston, D., 2001, Community Resilience to Volcanic Hazard Consequences, Natural Hazards, 24(2), p.p. 157–169

[3] [hartek 8] Godschalk, D. R., 2003, Urban Hazard Mitigation: Creating Resilient Cities, Natural Hazards Review, 4(3), p.p. 136-143

[4] [hartek 13] Guo Y., 2012. Urban Resilience in Post-Disaster Reconstruction towards a Resilient Development in Sichuan, China, International Journal of Disaster Risk Science, 3(1), 45-55.

[5] Tilio, L., Murgante, B., Trani, F., Vona, M., Masi, A., 2011, Resilient City and Seismic Risk: A Spatial Multicriteria Approach, Computational Science and Its Applications - ICCSA 2011, p.p. 410-422

[6] Geurs, K.T. & Van Wee, B. (2004). Accessibility Evaluation of Land Use and Transport Strategies: Review and Research Directions, Journal of Transport Geography, (12), 127 -140.

[7] Transport for London, 2010. Measuring Public Transport Accessibility Levels, PTALs

[8] Curtin, K., 2007, Network analysis in geographic information science: review, assessment, and projections, Cartography and Geographic Information Science, 34 (2), p.p. 103–111

[9] Birkin, M., Clarke, G. P., & Clarke, M. (2005). GIS for business and service planning. In Geographical Information Systems: Principles Techniques Management and Applications, 2 abridged edition. Edited by Longley PA, Goodchild MF, Maguire DJ, Rhind DW. New York: John Wiley & Sons

[10] URL-2: https://tr.wikipedia.org/wiki/%C4%B0zmit (accessed: June, 2016)

Building - Indoor Environmental Quality

Paper No: 41

Decentralized Ventilation for Energy Efficient Indoor Air Quality

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ABSTRACT

Building regulations are getting tightened to reduce energy consumption. Buildings use 40% of total energy. The energy consumption of heating, ventilation, air conditioning and sanitary systems are about 60% in the buildings. Thickness of thermal insulation and walls are getting thicker. Windows and doors are leak proof to reach required energy efficiency figures. People, living in houses, hotels, offices, schools and hospitals need fresh air to keep their health. Uncontrolled ventilation by opening windows causes energy loss and intake of dust and insects to the indoors.

We can only be sure about the quality of indoor air with permanent mechanical ventilation systems. Centralized ventilation is an optimum system for the big areas such as shopping malls, concert halls, atriums besides that centralized systems consume high energy because of air ducts and air distributing elements.

Decentralized ventilation systems are being installed directly into the walls and they supply fresh air from outside to inside in the shortest way therefore energy consumption of those systems is very low in amount.

Decentralized ventilation equipment includes fan, heat recovery unit and filter in a compact casing. Each device can be operated individually. Decentralized ventilation systems keep comfort of indoors without using that much energy.

In this study, the comparisons of different types of ventilation will be held.

INTRODUCTION

There are two main ways of ventilation in the buildings; natural and mechanical. Mechanical ventilation has also different methods such as centralized and decentralized.

It is too difficult to supply fresh air and to extract polluted air from indoor areas by natural ventilation without losing energy. Comfort conditions are disturbed by natural ventilation during the high seasons, summer and winter.

On the other hand, the correct mechanical ventilation system shall be chosen carefully according to features of the building.

VENTILATION SYSTEMS

Average indoor exposure, which is 90-95% of a life-time, is spent at home and at work.

35% of energy is consumed for creating indoor climate in Europe. Energy Performance of Buildings Directive, EPBD 2002/91/EC, is a measure to improve the energy performance of buildings.

Directive requires that the improvement of energy performance of buildings would be met with respect to indoor climate requirements, so the energy reduction cannot have any negative effect on indoor environment conditions.

Building design and operation affect indoor environmental quality (IEQ) and human responses, thus affect health, comfort, and individual performance and productivity.
Ventilation is required for the indoor areas to remove the followings:

- Vaporized chemicals from the goods, carpets, curtains, furniture, etc.
- Dust particles
- Humidity
- CO2

Educated ventilation rates are determined according to usage purpose of the space, floor area and the number of people. There are different ventilation rates in several standards. Some of the ventilation values can be seen in table 01

Table 01, Ventilation Rates in different Standards

STANDARD	DESCRIPTION	VENTILATION RATES
TS 3419 Article 2.2.2.2 Turkish Standard	Ventilation for non-smoking areas. Low performance activity (houses, offices)	20 m^3/h per person
DIN 1946-6 German Standard	Intensive ventilation for houses	0,71 ach (air change per hour)
ASHRAE American Standard	Ventilation for Bedroom, Livingroom, Office	9 m^3/h-person + 1 m^3/h-m^2

We will not study in this paper how ventilation rates should be calculated. The ventilation systems for the buildings will be discussed.
There are mainly 3 types of Ventilation Systems:

1. Natural Ventilation (not scope of this study)
2. Centralized Mechanical Ventilation
3. Decentralized Mechanical Ventilation

Buildings can be considered as commercial buildings and residential buildings. Industrial buildings are out of our scope in this paper.
Commercial buildings, offices, shopping centres, hotels, schools, hospitals are more complex buildings than residential and regular small office buildings therefore design and construction stages of those buildings are done by professionals. Mechanical ventilation systems for the commercial buildings are mainly designed as centralized ducted system. Ducted ventilation systems are more suitable for the bigger space areas such as open offices, meeting rooms, ball rooms, atriums. Those areas need high air volumes. Distribution of supply and exhaust air should be arranged by well-designed duct system (figure 01). Duct system should be distributed over the areas to have balanced ventilation. Those ducts create high pressure drops and consume energy.

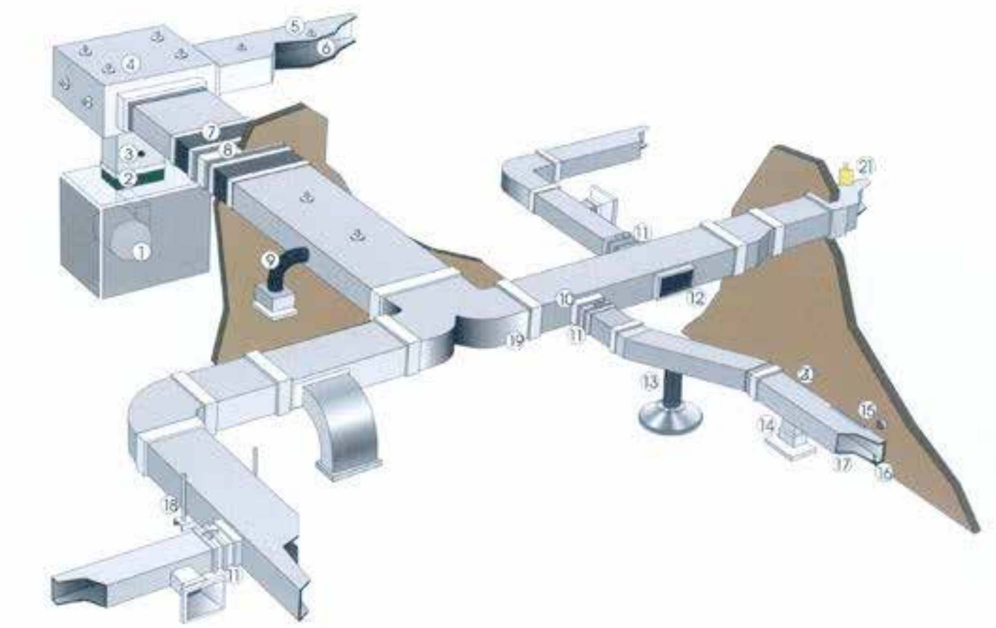

Figure 01 Centralized Ventilation, ducted system

On the other hand, the maintenance and cleaning of air ducts are difficult and cost money and take time. Fire and smoke dampers shall be used at the crossing section of the zones in ductwork.

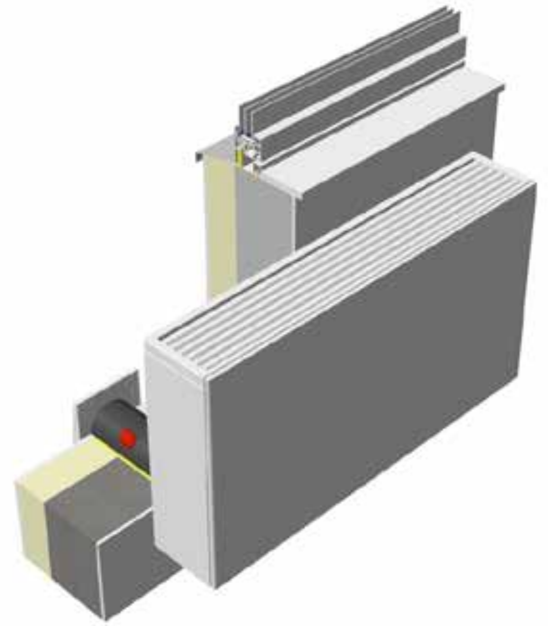

Figure 02, Wall type decentralized ventilation device

Because of above mentioned reasons ducted ventilation system should be chosen carefully.

There is another ventilation system called as decentralized ventilation for smaller areas such as small offices and shops, living and bedrooms in houses, hotel rooms. There are two application types of decentralized ventilation system. One of them is applied with bigger capacity devices which have two fans and one heat recovery unit. Those devices have a range of air volume capacities approximately between 200 – 4000 m^3/h. Devices can be installed directly to the walls and connected to outside for supplying and exhausting air (figure 02). Decentralized ventilation devices can be also installed on the ceiling and connected to outside with short ducts (figure 03). The thermal efficiencies of the devices are between 50-90% according to the type of heat recovery units; cross flow, counter flow, rotary, etc.

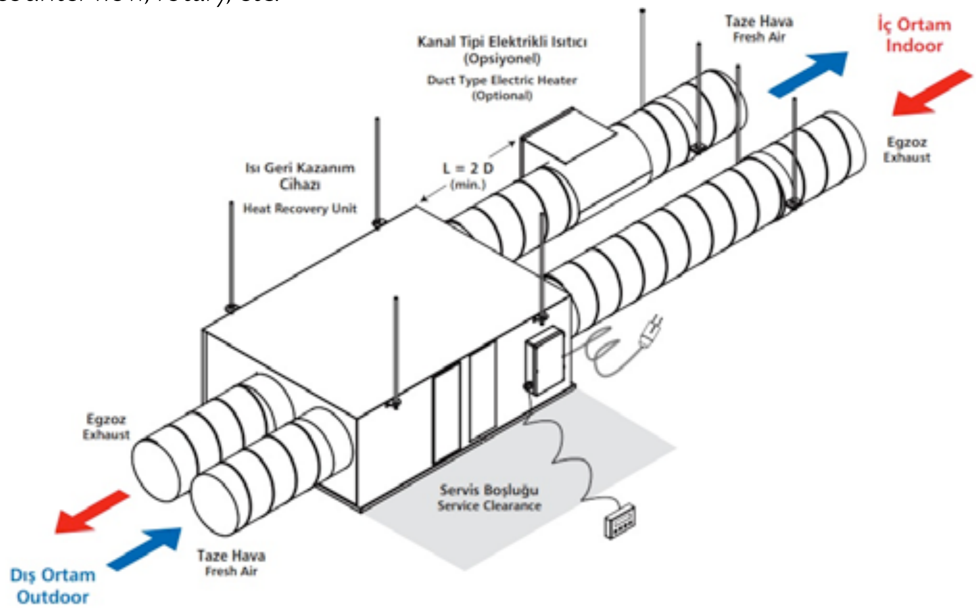

Figure 03, Ceiling type of decentralized ventilation device

This type of decentralized ventilation system is used for open offices, shops, residential buildings. The air volume capacities can be educated for 40 to 400 m^2 areas. The other way of decentralized ventilation system is realized by small devices directly installed inside the walls (figure 04). Those types of devices have only one fan, ceramic heat recovery unit and filter. Just a small cover can be seen from the room side.

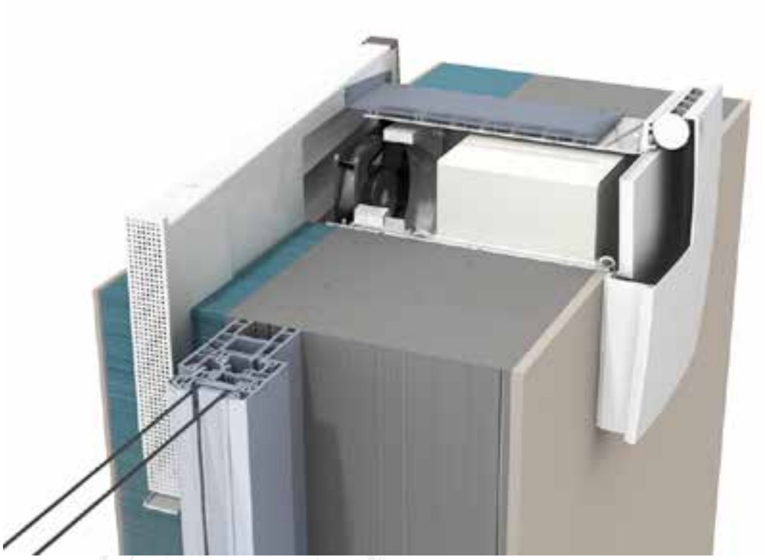

Figure 04, Decentralized ventilation unit inside the wall

Why is decentralized ventilation system with small compact devices important?
Up to now, we mentioned about central ventilation and decentralized ventilation with high capacity. The using of those types of systems is decided in investment stage by the professionals for the related buildings. The owners and users of the building have ventilation system from the beginning on and do not have any problem for the ventilation.
The new generation building construction system has tightened windows and doors and thicker insulation on the façade in order to keep Energy Performance of Buildings Directives.
There is almost not air leakage from windows, doors and façade for natural ventilation. Mechanical ventilation has to be taken into account for regular office and residential buildings.
In our country, ventilation systems for small offices, shops and houses are not frequently considered at the design and construction stage. Generally, just air conditioning and heating systems are installed. Most of the users of those small areas suppose that the air conditioning system, mostly split type, is also ventilation system. When they notice that there is not any ventilation in their premises, there is only way for ventilation which is opening the window.
There are several negative consequences of opening windows;

1. The most important one is loss of energy. Amount of lost energy can be seen in figure 5 according the position of window.

   For example; Ventilation is possible with half open window for two hours in a day in order to keep annual energy consumption 50 kW/h per m^2.

   100 m^2 house will consume 5000 kW/year. Energy lose will be half of this amount, **2500 kW/year** since spring and autumn time there will not be that much energy lose in Turkey.

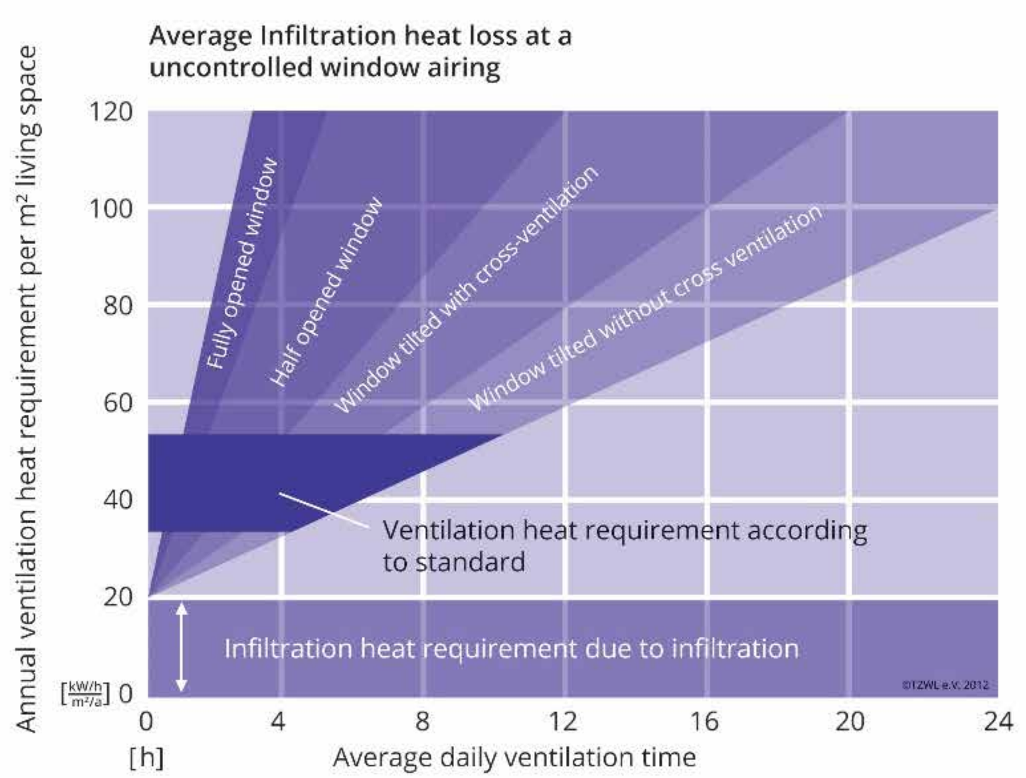

Figure 05, Energy lost because of open window

2. Windows cannot be kept open continuously. People feel uncomfortable themselves because of big temperature difference between inside and outside during the summer and winter time.
3. Sound pollution from the outside can disturb the occupants.
4. Dust and insects can enter the room.
5. Open windows are unsafe because of theft.

As we mentioned at the beginning, we are spending of our life-time mostly in offices and house.

Uneducated fresh air in indoor areas can cause health problems, lack of productivity. Performance problem can be occurred especially for the students.

There is a very simple way to sort out ventilation problem for small rooms without doing big investment and construction work. Small decentralized ventilation unit can be installed directly inside the wall by making just a hall on the wall. There are many advantages using decentralized ventilation units for the rooms;

- Devices have good sound insulation up to 59 dB Dnew
- Energy consumption of a single device is about max. 3,4 W/h

  100 m2 house needs 4 pieces of ventilation units;

  4 x 3 W/h (in average) = 12 W/h x 7000 h (annual operation time) = **84 kW/year**
- They can be operated in both way as supply and exhaust thanks to axial fan with EC motor thus air changing can be achieved with a single compact unit
- Honeycombed ceramic heat recovery unit has thermal efficiency up to 90%. 0°C outside air can be heated up 21°C for 24°C extracted indoor air thus the balance of room temperature is not affected.
- Cover, filter, heat recovery unit and fans can be removed for cleaning and maintenance and reinstalled easily (figure 06).
- Inlet air is filtered with G3 class electrostatic or P6 class pollen filters
- The air volume and operation programme can be arranged from control panel located on the unit itself

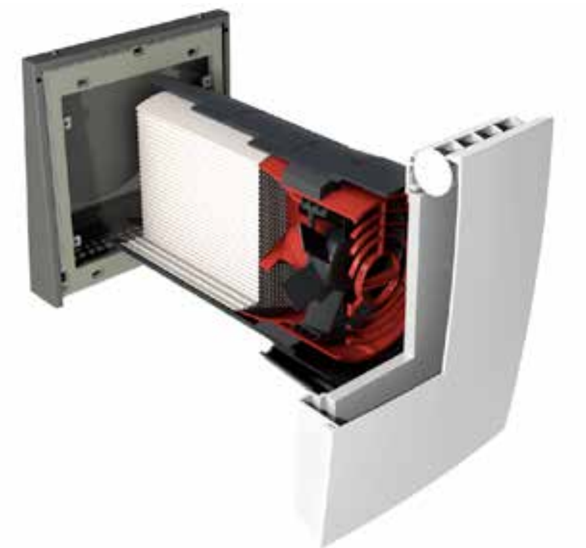

Figure 06, Decentralized ventilation unit section

CONCLUSION

As a result of subject; Ventilation is important as much as air conditioning. We cannot keep our health without adequate fresh air. Building and the goods also need ventilation to protect them against mould because of humidity.

Commercial buildings are planned for ventilation systems from the beginning stage of investment but we are spending most of our times in our houses and regular small offices where permanent mechanical ventilation are not taken into account.

We need always ventilation in houses and offices since the new buildings are constructed as leak-proof. Opening the window for ventilation is causing big amount of energy loss and make us uncomfortable. Small decentralized ventilation units are the best solution for small areas such as bedroom, Livingroom, shops, small offices.

REFERENCES

[1] Pawel Wargocki Effect of ventilation and thermal climate on health and productivity. Seminar Notes 2010. International Centre for Indoor Environment and Energy Department of Civil Engineering. Technical University of Denmark.

[2] Hellmuth Weiss. Technical Basics of Decentralized Ventilation. Seminar Notes 2016. Ventomaxx-International GmbH, Germany.

[3] ANSI/ASHRAE Standard 62-2001

Paper No: 47

The Effect of Air Circulation and Window Properties on User Thermal Comfort in a Classroom: A CFD Analysis

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ABSTRACT

In this paper, the thermal comfort level of a classroom at an academic building (SCOLA) in the Özyeğin University campus has been studied. Our primary focus is on the optical properties of window glasses and their impact on thermal comfort. The classroom is equipped with ceiling diffusers for mechanical ventilation (MV), and additional natural ventilation is assumed to be supplied by opening windows depending on user preferences. For the evaluation of thermal comfort, computational fluid dynamics (CFD) simulation has carried out and the solar heat gain from windows were compared. Effects of solar transmissivity (T_{solar}) of window glasses and mean radiant temperature (MRT) on thermal comfort are analyzed in detail. Different scenarios have been performed with the wavelength dependent absorption coefficient of window glasses, mechanical and natural ventilation alternatives and their combinations.

Thermal comfort criteria have been qualified by using analytical approximation specified in ISO 7730 Standard with CFD simulations results. All simulations and measurement performed have been on stationary scenarios. However, unsteady effects resulting from instantaneous changes of occupants' behaviors and outdoor conditions resulting from weather changes need to take into account in further studies.

INTRODUCTION

The NEED4B Project, based on an EU-FP7 grant to Center for Energy Environment and Economy (CEEE) at Özyeğin University aimed to satisfy the conditions for the energy efficiency and comfort in an academic building throughout the construction design period and after. In this paper, we considered an occupied classroom to carry out detailed measurements and perform simulations under different conditions, building materials and ideas, particularly for thermal comfort. With this knowledge gained, we can scale up our efforts to the entire building [1]. Thermal comfort simulation depends on solving conservation of energy equation between the environment and human body, for which there is a well-accepted approach [2]. The heat gains and losses from body skin occurs by radiation, convection, conduction, respiration and evaporation. Energy balance equation can be expressed in simple term as:

$$M-W= E+R+C+K+S \tag{1}$$

where, M is metabolic rate, W is the external work and E, R, C and K are the temperature exchange of evaporation, radiation and convection and S is the stored temperature energy [3]. This simple equation requires many inputs about the human thermo regulation system and it can be extendable for solving different methods as analytical, empirical or numerical solutions. In literature, studies using analytical approach are found to be adequate for models as only manikins or simple room geometries [4],[5]. For instance, Fig. 1 illustrates the temperature exchange between outside and windows of a room. By using the heat transfer equations (2), (3), and (4) for steady-state condition helps in solving this simple modeling problem.

$$q_{conduction} = -k\frac{dT}{dx} \quad (2)$$

$$q_{convection} = hA(T_s - T_f) \quad (3)$$

$$q_{radiation} = \varepsilon\sigma A_r(T_r^4 - T_s^4) \quad (4)$$

Fourier's law for conduction heat transfer is equation (2) and **k** is the coefficient of heat conductivity. For convective heat flux equation (3); **h** is heat transfer coefficient, *A* is the area of object, T_s is the surface temperature of objects and T_f is the air temperature. Equation (4) is the form of radiative heat flux and ε is emissivity of surfaces, σ is Stefan's constant, A_r is radiating area, T_r is temperature of radiator surface and T_s is surrounding surfaces.

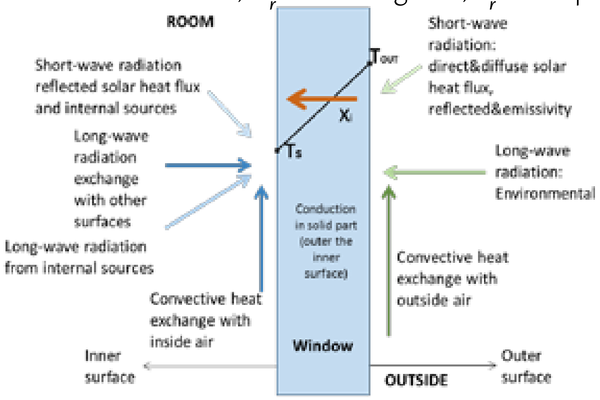


Figure 1 Energy balance on window

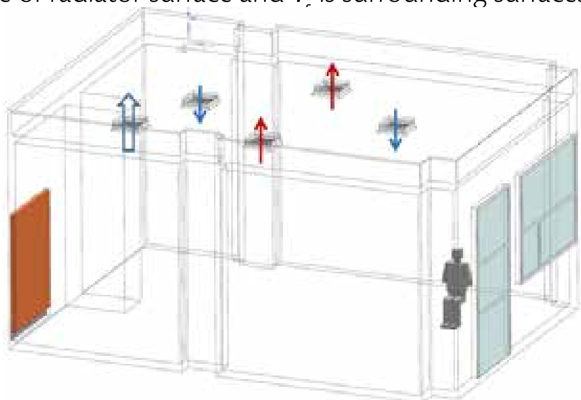


Figure 2 Geometry for the CFD model of an occupied classroom

As can be seen in Fig. 2, with complex geometries walls, windows, occupants and HVAC tools require using numerical model to show flow distribution and solving conjugating heat transfer.

An empirical approach is considered here on it is the most reliable procedure. However it is not suitable for construction design phase and also models are very expensive. By utilizing analytical or simple empirical approach along with numerical solutions validation of the complex models can be performed. CFD tool provides an opportunity to achieve design criteria with low cost and speed. By using CFD, determination of the thermal effects in a complex model and validation of the results with measurement data is possible. CFD is a useful design tool for construction environmental projects analysis from outdoor climate problems to detailed indoor human-scale climate studies have been used extensively for last 15 years [6]. Moreover, it procures including HVAC system the working principle as air flow distribution with defined temperature, temperature generation model of human body, solar heat flux on surfaces and inclusive of radiation in materials. In CFD analyze, solid opaque or transparent materials physical properties (conductivity, capacity of temperature and density etc.) can be implemented. In order to reduce the cost of calculation for complex models, we omitted the human thermoregulation modeling and applied only inside environmental thermal and flow characteristic in this study. Considering all of these, CFD supports solving the heat transfer in solid materials and air flow distribution as coupled in more details [7],[8].

Glazing systems, that is window glasses, are important due to thermal, visual and acoustic comfort for façade design [9],[10]. Visual and acoustic comfort are not considered in this study. Utilizing the advantage of glass materials for thermal comfort, physical properties of windows are analyzed under different conditions. To examine the thermal comfort in details, effect of window glasses modeled as solar radiation, long-wave radiation and convective drafts, where physical surface properties (absorption, transmissivity and reflectivity) of a window glasses for solar heat flux (SHF) have an impact on thermal comfort. In summer time, temperature of highly radiation heat flux absorber window glasses causes discomfort due to long-wave radiation and increase convection in front of window glasses as drafts. If highly transmitted window glasses are used, solar radiation hits on the occupant surface directly, results in a diverse thermal comfort as asymmetrical radiation. In winter time, mean radiant temperature decrease inside of the classroom and heat transfer occurs from the body surface of occupant to outside [11]. Occupant impress by windows surface viewing area. Higher view factors due to larger windows or a person sitting closer to it, affects thermal comfort significantly [12].

In order to evaluate the thermal comfort, we can use different standards which utilize the analytical calculation of Fanger comfort parameters. Fanger comfort parameters were described by P.O. Fanger in 1970 [13]. Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfaction (PPD) are two parameters. Calculation of these parameters analytically can be found in ISO 7730 Standards. CFD tool constitutes required parameters for Fanger method as air velocity, air temperature, mean radiant temperature and humidity (Called; four variables-FV). After calculation of PMV and PPD, however, we need to submit the result in a comfort zone which is defined in the norm of EN 13779. All assumptions have been made in this study for an occupied classroom during the day of April and May. In order to understand the effects of different window glasses on thermal comfort, verification of a measured data with the CFD results has been done and compared with a case study for only using two different window glasses. One window glass is assumed to has high absorption coefficient (HAC), low solar radiation transmissivity ($T_{sol}=13$) and other has low absorption coefficient (LAC) and highly solar radiation transmissivity ($T_{sol}=80$).

2. SUMMARY of MEASUREMENTS

2.1 Details of Classroom Geometry

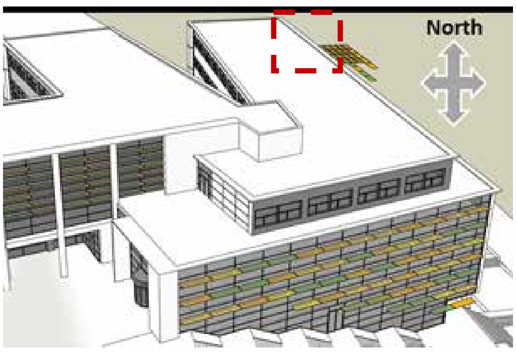


Figure 3 General view of SCOLA Building at Özyeğin University is shown for the location of simulations

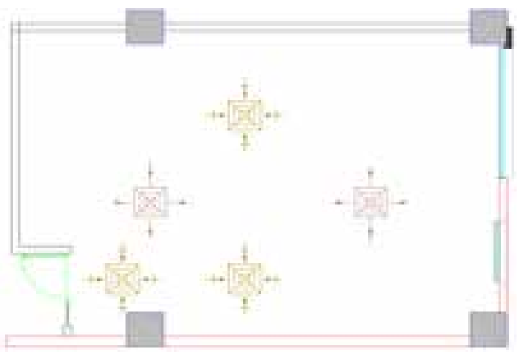


Figure 4 Top view of occupied classroom with diffusers, door and window

Fig. 3 illustrates the general view of 6-storey SCOLA Building. The measurements conducted in the marked floor (as shown in Fig. 3), 2D plan of hindmost classroom are illustrated in Fig. 4. Generally, the classroom is occupied by 20 students. As it is demonstrated in the fig. 2, the windows are closed during the cooling period in a day. In the classroom, there are 4 diffusers, two of them blow the cooled air and others pass through the hot air to the ceiling floor in summer time. Moreover, there is another diffuser which works continuously. This diffuser holds the classroom under negative pressure to take fresh air inside to classroom from cracks of under door. Regularly, halls of this building are maintained with independent air conditioner system for fresh air channel.

2.2 Measurements

In order to evaluate the accuracy of numerical simulations, a test scenario was built in the unoccupied classroom for the conditions corresponded to that for the 27th of April. Ambient temperature was obtained from the university weather station. Furthermore, inside air temperature was measured for 25 minutes. The mechanical ventilation worked during the day until 20 minutes before the measurement. Therefore, SHF from the windows and measurer metabolic rate were energy sources during this time.

There were few surfaces cause in air leakages into the classroom and one occurs under the door of classroom. Moreover, classroom's environment divided into two parts equally with the same area and our measurement classroom is one of them. Thus, there are other leakages from adjacent classroom, were in same conditions and had same air temperature at measurement time. So, only the effects of solar radiation can cause temperature change inside the classroom. Moreover, air temperature in hall 1°C colder than classroom temperature because the sun temperature flux is less and there is always active mechanical ventilation for stationary temperature along the hall. Outside air temperature was accepted constant at 18°C (fig. 5) and the relative humidity was 37%. In measurement day, sky was clear. Therefore, environmental temperature was calculated by ambient temperature and dew-point temperature. By this way the environmental temperature applied as -1°C for radiation calculation between the outside of classroom and sky. There was only one person seated at rest in classroom and its metabolic rate was defined constant 58.2 W/m² for latent and sensible temperature. Other details of boundary conditions are illustrated in table 1 for wall surfaces.

Boundary Conditions	**Temperature**	**Heat transfer Coeff.**
Outside walls with windows	18°C	8 W/m²K
Outside wall without windows	24.5°C	3 W/m²K
Inside wall near of hall another classrooms	24.5°C	-

Table 1 initial boundary conditions on walls of classroom

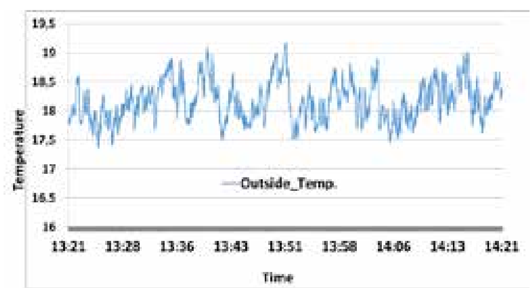


Figure 5 Ambient air temperature fluctuation during one hour was taken from the weather station at the University

Testo-635 device was used to collect the data of temperature, velocity, humidity and radiant globe temperature with one-minute intervals. This device has two different probes and one thermocouple. One of the probes is for mean radiant temperature; globe thermometer and other is for hot-wire anemometry probe. Thermocouple has been used to measure wall and glass temperatures. Fig. 6 illustrates the thermocouples on the window glass. Collecting globe thermometer radiation data showed in Fig. 7.

Figure 6 Thermocouples on the window glasses

Figure 7 Mean radiant temperature measurement on the surface of person

3. NUMERICAL MODELING

CFD analysis based on the data obtained has been performed and verified with the measurement results. Simulation model does not include fancoil details. To reduce the computational requirements we did not model the heat exchangers, fan geometry away others. The fancoil mechanism modeled as the hot air passes from the two diffusers inside classroom to celling environment (as shown by red arrows in figure 2) and sucked/drawn by the wall surface of ceiling floor. Moreover, cold air is blown from the other two diffusers (as shown by blue arrows in figure 2). In Fig. 8 blue areas illustrate the surface of the return air exhaust boundary conditions. In validation, mechanical ventilation has been neglected in simulations. It only activated in comparison scenario. Fig. 9 shows the 3D model of the diffuser, where diffusers are of general industrial use. The geometrical design based on the targeted air diffusion performances of four different directions.

Figure 8 Side view of classroom– Blue parts inside of ceiling floor are surfaces of virtual fan for air changes.

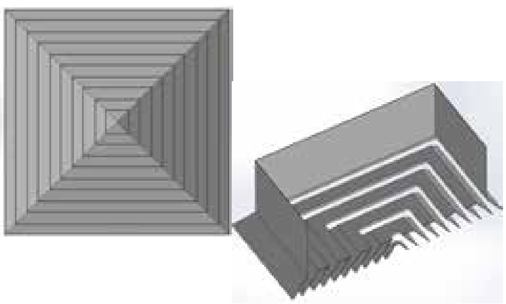


Figure 9 Geometrical shape of diffusers

In Table 2, physical properties of material used in construction of the classroom are given. The walls are composed of paint, plaster board, gypsum and bricks layers, due to that united resistance data for the wall have been obtained from the constructor during the construction period of SCOLA Building and utilized. Furthermore, absorption coefficient of window glasses mentioned in Fig. 18.

Physical Properties of Materials	**Density** kg/m^3	**Specific Temperature** J/(kg.K)	**Thermal Cond.** W/m.K
Concrete (Side walls)	850	1000	0,55
Glass (Windows)	2600	670	1,3
Aluminum (Profile)	2700	953	155
Wood (Door)	650	1200	0,14

Table 2 Physical properties of solid materials

3.1 CFD Solver and Mesh Generation

Transient analyses have been performed by utilizing the FloEFD software. Favre averaged Navier-Stokes equations has been solved using the finite volume method with k-epsilon turbulence model [14]. Generally, using fine grid size gives higher numerical accuracy than coarse mesh especially in geometrical model's narrow channels for flow distributions and on the wall surfaces for thermal boundary layer heat transfer. Both immersed boundary mesh and Cartesian mesh types are applied, as in solving the Navier-Stokes equations with k-epsilon turbulence model requires very fine mesh. To overcome this computational problem, software's novel Two-Scale Wall Function (2SWF) with special integral technique is used to solve sub-scale boundary layer on walls. [12]. In Fig. 10, mesh details are illustrated on the diffusers.

Figure 10 Detailed diffuser mesh view

Initially, for 5 seconds solution data one time mesh refinement was applied and time steps was 0.05 seconds. After 5s, time step was increased to 0,5s. Total duration of the analysis was 20 minutes. Most critical point in simulations is to solve the heat transfer as coupled solid materials and air. Thus, temperature absorption of solid materials, especially temperature source of solar energy, is simulated by using coupled approach. In steady-state conditions, solving the heat transfer equation ignores the temperature capacity of solid materials. Including the temperature capacity of solid materials indicates the heating and cooling time in transient solutions. Therefore, the effects of these parameters on thermal comfort can be simulated.

3.2 Radiation Model:

In general, CFD software packages prefer to use surface to surface (S2S) radiation model to solve the radiation heat transfer with ray tracing algorithm in building simulations, as it computationally cheaper and more adequate. Although, FloEFD software obliges to use discrete ordinates (DO) model, when to solve heat transfer for transparent materials especially glasses while applying absorption coefficient for transparent materials. Accepting glass materials as participating medium and using absorption coefficient changing with wavelength can be applicable. In this way, absorption coefficient is applied instead of solar transmissivity of surface properties of glasses in simulations. Discrete Ordinates (DO) model solves the radioactive transfer equation (RTE) for a finite number of discrete solid angles, each associated with a vector direction. In addition, number of discrete directions determines the accuracy of the solution. In the DO method the RTE is solved for a set of discrete directions $\vec{s}$ representing the directional domain of 4π at any position within the computational domain defined by the position vector $\vec{r}$. The directional domain resolve into specified number of equal solid angles or directions. The total number of directions is defined as the following:

$$N_{ord} = 8 \cdot \frac{RL \cdot (RL+1)}{2} \quad (5)$$

Discretization level (7 applied in simulations) can define by RL parameter in software. In each direction, the radiation intensity is considered as constant. Software does not include scattering coefficient in RTE, can be written as:

$$\frac{dI(\vec{s},\vec{r})}{ds} = \alpha \cdot [n^2 \cdot I_b(\vec{r}) - I(\vec{s},\vec{r})] \quad (6)$$

In here, radiation intensity I per solid angle and to calculate I_b which blackbody radiation intensity is:

$$I_b = \frac{\sigma T^4}{\pi} \quad (7)$$

Transient analysis was performed for the duration of 25 minutes. Due to which, SHF decreases from 760 to 615 W/m^{2}K in 25 minutes. For the last time step which has been at 18:05pm, distribution of air temperature is illustrated in Fig. 11. SHF heats up the walls and window glasses. So, temperature surface of inward walls increased and thermal gradient occurs. In the same way, in Fig. 12 MRT distribution was shown on human skin. MRT can be calculated by using the formula:

$$T_r^4 = \frac{1}{4\sigma}\int I_{diffuse}(\Omega)d\Omega + \frac{1}{4\sigma}\sum I_{sun} \quad (8)$$

Where, $I_{diffuse}$ is the intensity of the diffuse (thermal) radiation (W/m^2/rad), I_{sun} is the intensity of the solar radiation (W/m^2), σ is the Stefan-Boltzmann constant.

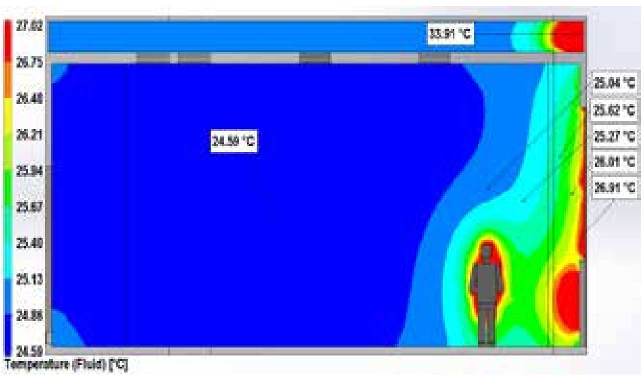


Figure 11 Cross section plot left to right – from windows to door inside air temperature at 18:05pm

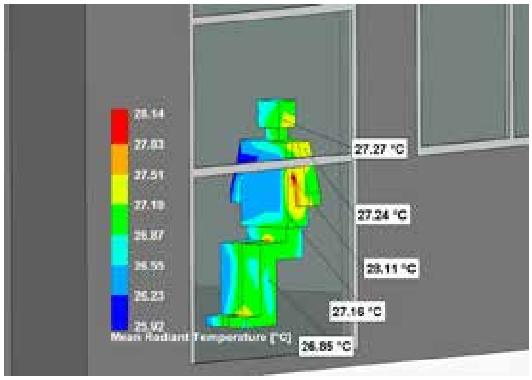


Figure 12 Mean radiant temperatures on the skin at 18.05pm in simulation

Simulation results provide appropriate data in making the comparison with the measurements obtained. Temperature change occur on the wall surface is comparatively slower than on the window glasses during the sunset time. A reasonable agreement was found between the measured data and the simulation results as shown in Fig. 13 and 14. Measuring and exporting data from simulation, the surface near to subject's face provide comparable result for MRT. Using this verified solution, one can derive new different materials and conditions for thermal comfort comparison.

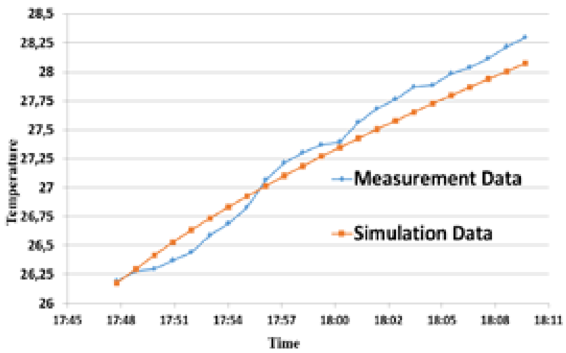


Figure 13 Mean Radiant Temperature near of the skin surface of subject

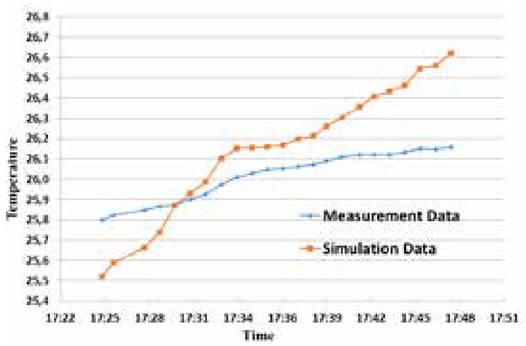
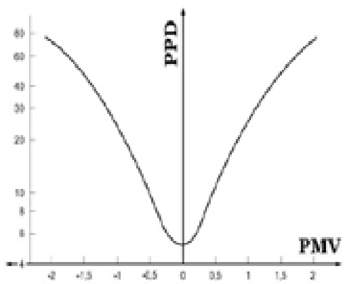


Figure 14 Inside surface temperatures of windows measurement and simulation results from the same surface of windows

4. THERMAL COMFORT EVALUATION CRITERIA

Fanger comfort parameters have been utilized to calculate thermal comfort analytically in simulations. While calculating PMV, software generates **FV** using boundary conditions on surfaces from computational fluid domain numerically. Later, computational solution completed, metabolic rate of human body and clothing resistance values were defined in simulations. So, software solved it analytically using the equations which was included in ISO 7730 Standard. Cold to hot range, 7 thermal sensation points gives feedback regarding people's thermal comfort level mentioned in Fig. 15. Additionally, PPD parameter is used for a quantitative prediction of the percentage of thermally dissatisfied people [16].



+3	Hot
+2	Warm
+1	Slightly warm
0	Neutral
-1	Slightly cool
-2	Cool
-3	Cold

Figure 15 shows the PPD (%) as a function of PMV values [14]

Distance from the inner surface	**Default Values (m)**
Floors (lowers boundary)	0.05
Floors (upper boundary)	1.8
External windows and doors	1
HVAC appliances	1
External Walls	0.5
Internal Walls	0.5

Table 3 Comfort zone general distance from the boundaries [17]

Under different circumstances, CFD model allows us to calculate the FVs. In this way, we can compare different components or physical assumptions rapidly in designing phase by putting the other two variables; clothing resistance and metabolic rate. While evaluating the comfort parameters, we need to examine them in a comfort zone. The recommended distance between people to surfaces (walls, windows, floor etc.) mentioned in Table 3, and these distances supplied from EN-13739 [17]. All CFD simulation results are showed on surfaces in a comfort zone to make them meaningful. Otherwise, examining the thermal comfort so close the windows, diffusers or walls can be uncomfortable than excepted.

5. COMPARISON OF TWO DIFFERENT GLASSES BY CFD

Later, three distinct window glasses have been analyzed. One of them, for the validation scenario that is accepted for mid-transparent, others have higher absorption coefficients (case 1) and lower absorption coefficient (case 2) window glasses. In Fig. 16 comparison of their physical properties for absorption coefficient along with the wavelength distribution between 300-2500 nm was shown.

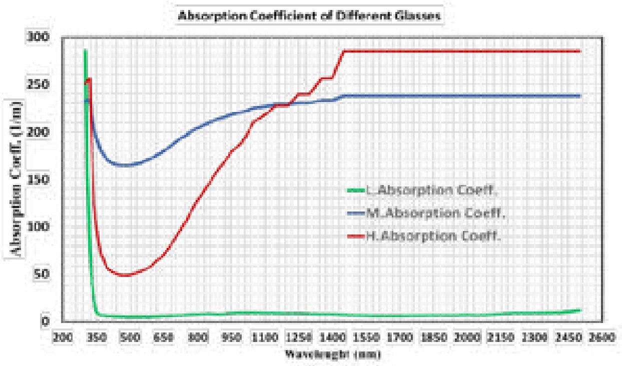


Figure 16 Comparison of three different window glasses absorption coefficient.

Figure 17 Measurement points in comfort zone for figure 20 and 21.

Computationally, solving transient analyses require so much time by coupling solid-fluid interaction and solar changing hourly. Thus, in order to decrease the simulation time, only two students in the classroom are considered and completed the simulation along the 12:00pm to 18:00pm (analysis period). Airflow distribution remains unchanged for various time steps, due to the reason that only SHF data changed during iterations. Therefore, flow-freezing option was used periodically during the six hours simulation time. As the flow-freezing option activated, only heat transfer equations are solved for solid materials. After a short time, again they will be solved couples (air and solid body's heat transfer). Thus, this approach saves time.

In these two comparison cases only properties of window glasses are different. All other boundary conditions remain same and constant due to the nature of turbulence models, however, there are definitely certain differences apart from choosing different window glasses. Fig. 18 and 19 illustrates the air temperature and MRT changing average of seven points in classroom. These seven points was marked in Fig. 17. In case 1, near of windows in comfort zone boundary, SHF causes increasing more air temperature and MRT. In Case 2, thermal comfort does not affect the comfort zone immensely as it has high absorption for SHF.

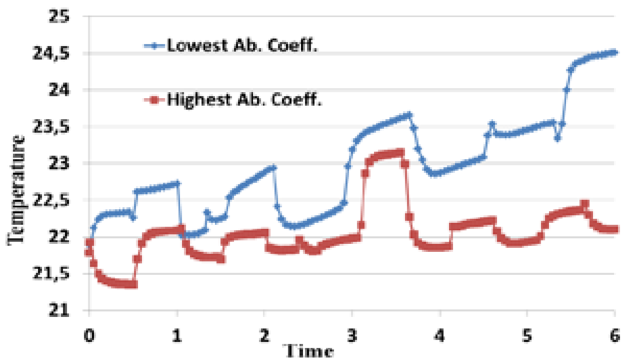


Figure 18 Average air temperature differences with two types of window glasses (LAC-HAB) at seven points.

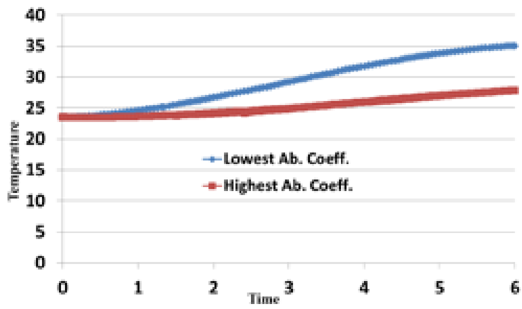


Figure 19 Average MRT differences with two types of window glasses (LAC-HAB) at seven points.

Fancoil mechanism works in these simulations. The cold air was blown (19°C) into the classroom during the six hours at a constant temperature from two diffusers, in summer time. Simulations for two cases include mechanical ventilation inside the classroom. Air distribution from the diffusers remains similar in each cases. Thus, only for one step velocity distribution is illustrated in Fig. 20. Increased air velocity has been observed near of windows caused by convection effects. During the analysis (sunset time), only changing of solar heat flux affects the classroom thermal comfort. In order to comment about the thermal comfort, air and mean radiant temperatures illustrated in Fig. 21 respectively. As the figure shows increase in air temperature in case 1 and has slightly higher temperature, approximately 2°C (Fig.21-1). In addition, MRT comparison illustrates after 14:00pm for case 1, radiant temperature difference increases especially near of windows. Right side of the classroom from the top view, MRT effects are observed much higher than air temperature rise for thermal comfort. Whereas, HVAC mechanism controls only the air temperature and humidity. So, instead of decreasing air temperature, MRT should be blocked before taking inside the classroom for thermal comfort.

While evaluating the comfort parameter of PMV, it is important to wear suitable summer trousers and short-sleeved shirts, whose thermal resistance with naked body is 0,4 Km^2/W of total clothes. PMV distribution on the surface is calculated for the illustrated field in Fig. 22-1 by this assumption. As shown in Fig. 22-1, PMV values does not exceed the 2 (WARM) and occurs barely as only the window glasses with low absorption coefficient are selected. Enough SHF was taken inside the classroom and temperatures rises on the surface of walls for case 1. If students sit near of the windows in the comfort zone, until sun radiation left the classroom student felt warmer. Fig. 22-2 illustrates the PPD distribution in comfort zone. Case 1 executes more discomfort area than case 2. Upper of 35% people near of windows in case 1 feel themselves discomfort. Between 17:00 pm and 18:00 pm PPD values are still higher due to inside high temperature of walls. Emissivity value has been applied 0.9 all of the inside wall surfaces. Thus, walls despite the SHF decreasing still causes the discomfort due to their heat capacity and radiation emissivity. On the other hand, Case 2 is more thermally comfort than case 1. Where light transmissivity in case 2 is 24% for the selected window glasses. Generally, designers prefer at least 60% light transmissivity in classrooms for visual comfort. Our light transmissivity of used window glass for measurement case was 74%. Lowest absorption window glass had 83% light transmissivity. Thus, window glass of case 2 had the lowest transmissivity for the visual comfort.

6. CONCLUSIONS

In this study, the effects of air circulation and window properties on user thermal comfort in a classroom were studied in transient fashion. Air and wall surface temperature changes in the classroom depending on only the SHF change have been validated with the measured values. Given the consistency obtained after validation study, a number of analyses have been completed for comparisons by defining the window absorption coefficients according to spectral properties. In two case studies which were carried out was PMV and PPD values, we observed discomfort when the transmissivity of window glass is too high for solar heat flux. Thermal comfort can be analyzed by changing physical properties of materials or making certain physical changes in the classroom by utilizing of CFD simulations (For example, opening the windows, using curtains, changing the type or angle of diffuser).

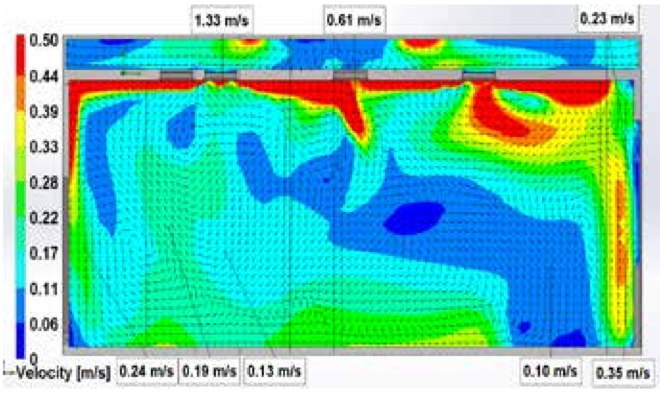


Figure 20 Average velocity distributions on cut-plot surface have been generated in front of sitting person.

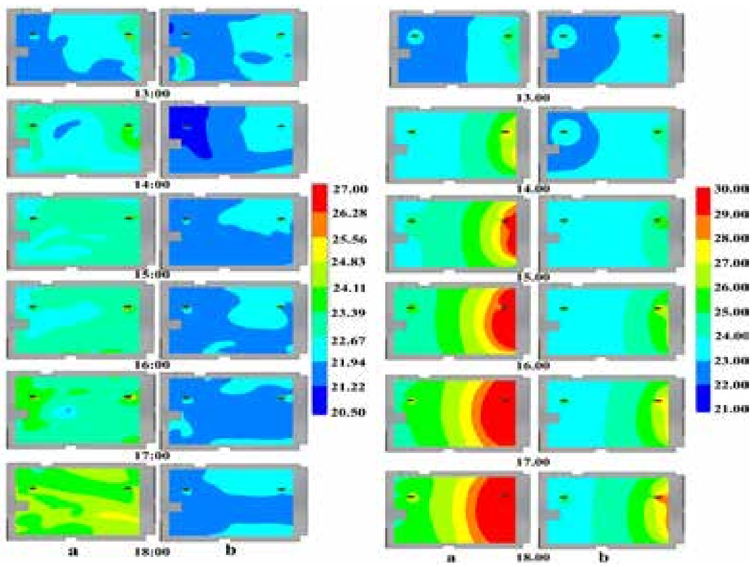


Figure 21 Top view at the height of between the head and chest of a person. "a" illustrates the window glass of low absorption coefficient case and "b" illustrates the highest absorption window glass case. Fig. 21-1 from 12:00pm to 18:00pm cut-plots illustrate comparison of the air temperature distributions. Fig. 21-2 illustrates comparison of MRT distributions.

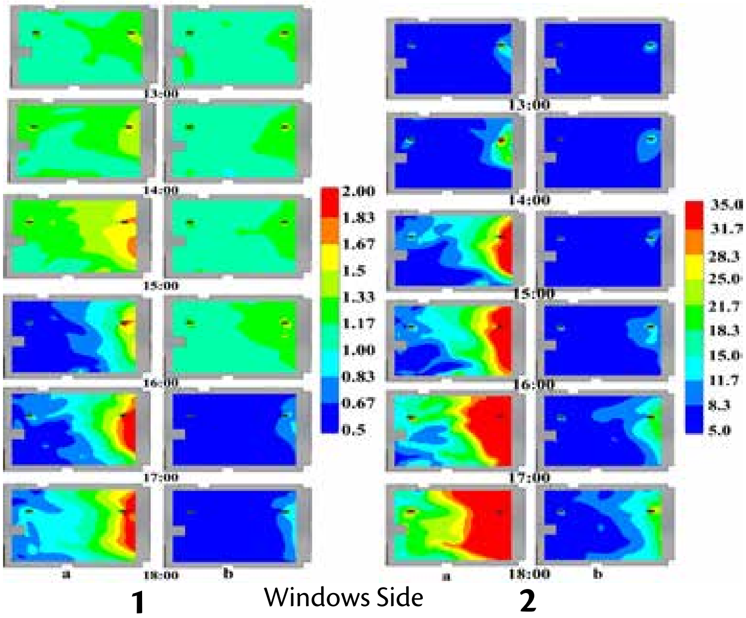


Figure 22 Top view at the height of between the head and chest of a person. "a" illustrates the window glass of low absorption coefficient case and "b" illustrates the highest absorption window glass case. Fig. 22-1 from 12:00pm to 18:00pm cut-plots illustrate comparison of the PMV distributions. Fig. 22-2 illustrates comparison of PPD distributions.

REFERENCES

[1] M. P. Mengüç, Y. Somuncu, Ş. Çağlayan, S. Özcan, B. Sefer, and U. Simitli, "Integrated Engineering and Architecture for the Energy Efficient Academic Buildings Center for Energy , Environment and Economy (CEEE)," ***Build. Simul. Conf.***, pp. 543–550, 2015.

[2] H. O. Nilsson and I. Holmér, ***Comfort climate evaluation with thermal manikin methods and computer simulation models.***, vol. 13, no. 1. 2003.

[3] S. Bolineni, S. Stratbücker, and C. van Treeck, "Development of reduced order flow responsive models of convective heat transfer for human body segments," ***Build. Simul.***, vol. 8, no. 4, pp. 393–404, 2015.

[4] R. Cheng, Y. Zhang, and X. Wang, "Analytical Analysis of the Thermal Performance of Building Walls Based on the Thermal-electric Analogy Method."

[5] E. D. Yildirim,"A Mathematical Model of the Human Thermal System," ***Thesis Master***. January, 2005

[6] S. Murakami, "Indoor/outdoor climate design by CFD based on the Software Platform," ***Int. J. Heat Fluid Flow***, vol. 25, no. 5, pp. 849–863, 2004.

[7] T. Kim, S. Kato, and S. Murakami, "Indoor cooling / heating load analysis based on coupled simulation of convection , radiation and HVAC control," ***Build. Environ.***, vol. 36, pp. 901–908, 2001.

[8] M. Taheri, M. Schuss, A. Fail, and A. Mahdavi, "A performance assessment of an office space with displacement, personal, and natural ventilation systems," ***Build. Simul.***, vol. 9, no. 1, pp. 89–100, 2016.

[9] N. Khamporn and S. Chaiyapinunt, "Effect of installing a venetian blind to a glass window on human thermal comfort," ***Build. Environ.***, vol. 82, pp. 713–725, 2014.

[10] J. A. Clarke, M. Janak, and P. Ruyssevelt, "Assessing the overall performance of advanced glazing systems," ***Sol. Energy***, vol. 63, no. 4, pp. 231–241, 1998.

[11] ANSI/ASHRAE, "Thermal environmental conditions for human occupancy," ***Stand. 55-2013***, vol. 2013.

[12] C. Huizenga, Z. Hui, and E. Arens, "A model of human physiology and comfort for assessing complex thermal environments," Build. Environ., vol. 36, no. 6, pp. 691–699, 2001.

[13] P. O. Fanger, Thermal Comfort Analysis and Applications in Environmental Engineering. 1970.

[14] M. G. Corporation, "Technical Reference Software Version 14," 2014.

[15] MentorGraphics, "Advanced Immersed Boundary Cartesian Meshing Technology in Flotherm XT," p. 29, 2015.

[16] CEN (2005). European Committee for Standardization. EN ISO 7730:2005, "Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) indices and local thermal comfort," 2006.

[17] DIN EN, "Ventilation for Residential Building- performance Requirements for Ventilation and Room-Conditioning Systems," ***Management***, p. 72, 2007.

Paper No: 127

Evaluation of Indoor Environmental Control and Psychology in Healthcare: A Case Study on Inpatient Rooms in Hospitals

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ABSTRACT

Understanding the indoor environmental control and psychology (IECP) which affect inpatient health and wellbeing are crucial parameters for having positive experience on healthcare interiors. Recent research on IECP in healthcare building facilities underlines these issues with regard to users' needs, expectations and satisfactions. Thus, flourishing consciousness on IECP for interior design has a positive effect on the healthcare experience. In particular, inpatient rooms exclusively act on this experience since inpatients spend most of their recovery time there.

Within the scope of this study, healthcare experience in inpatient rooms were examined in terms of IECP. A case study was chosen to measure and verify the concrete outcomes of the effect of hospital facilities on inpatients. Two methods were followed for this purpose; observation of inpatient rooms in terms of IECP and an inpatient questionnaire which was conducted among the volunteer inpatients. In the lights of these methods, following parameters were analyzed; stress, social interaction, privacy and territory, interior layout, lighting, daylighting, colors, textures, finishing, acoustical environment, aural comfort and noise control. As a result, problems related with the selected parameters in healthcare experience of inpatient rooms were revealed. This study aims to enlighten the current literature on the IECP for inpatient rooms.

Keywords: *indoor environmental control, indoor environmental psychology, hospitals, inpatient rooms*

INTRODUCTION

In the context of this study, the positive effect of IECP parameters on spatial satisfactions of inpatients which are evaluated as prior user group in healthcare interiors was investigated; through obtained data spatial and social suggestions were presented.

Undoubtedly, inpatients rooms are the spaces that inpatients are spending most of their times in healthcare interiors. These spaces, inpatients are forced to reside for a period of time, if not communicate properly with inpatients, create negative effects with the other stress factors sourced from the disease. Similarly, Ulrich states that two main stress factors are effective on patients [1]. First of them is the pain and ache due to medical procedures, sense of uncertainty and physical illiteracy; second is the noise coming from physical and social environment, inadequacy of visual and aural privacy and scantiness of social support. For the purpose of decreasing negative impact of physical environment and increasing inpatient satisfaction; to support inpatients' social interaction, to regard his/her privacy need, to define physical and psychological borders in true way, to design furniture and surfaces in space regarding user expectations and to use positive distractions for increasing belonging of inpatient to space are considered valuable. Besides of spatial solutions, to provide

satisfaction of inpatient in social aspect, the role of healthcare staff is vital. To use methods for reducing pain and ache, to have professional competence, have a friendly attitude to inpatient and his/her immediate family are influencing experiences of inpatients during healing process, positively.
Lighting is another important aspect of interior healthcare experience. It includes daylight and electric light, can have a significant impact on people's healthcare experience in terms of navigation, wayfinding, aesthetic, user friendly, safety, coding, promoting a sense of well-being and even on recovery rates[2]. A number of research have pointed on the improved faster recovery rates such as 10% can be achieved with the improvements on lighting design[3], [4]. In addition to those, there are also experimental studies which suggest that for different functions and spaces in healthcare units, certain types of lighting design patterns contribute to staff and patient morale with enhancing the space[5]. On the contrary, poor lighting may cause problems in staff performance, medication errors and injuries (such as falls). However, lighting design in healthcare building projects rarely involve professionals from this field who acknowledges the importance of proper lighting design[2]. Visual comfort requirements show a wide variety for healthcare premises, both qualitatively and quantitatively. User satisfaction should be obtained in terms of visual comfort, visual performance and safety[6] yet for enriching healthcare experience, view to the outside, color temperature and bright rooms with ample windows providing natural light are also needed[7]. Obtaining the various visual requirements, using daylight and viewing towards nature improves the healthcare experience for users' while reduce length of stay (LOS)[3].
Similar to lighting, empirical evidence shows that noise in healthcare settings generates stress [8]. Hospitals are noisy places in terms of WHO (World Healthcare Organization) guideline values which are with levels far exceeding: WHO specifies 35 dB(A) or less for background noise, but research finds 45 dB(A) to 68 dB(A). WHO specifies 40 dB(A) or less for nighttime peak, but research finds 80 dB(A) to 90dB(A) [9].In healthcare settings telephones, alarms, trolleys, ice machines, paging systems, nurse shift change, staff caring for other patients, door closing, staff conversations, and patient crying out or coughing are common noise sources [10]. When we look the previous studies, Topf (1992) measured nighttime sound levels and found out a minimum of 50, a maximum of 86.8, and average of 56.3 dB(A) at the location [11]. Good acoustic design can improve patient comfort, for that reason there are number of guidelines for acoustic design criteria and design considerations[12]–[15].

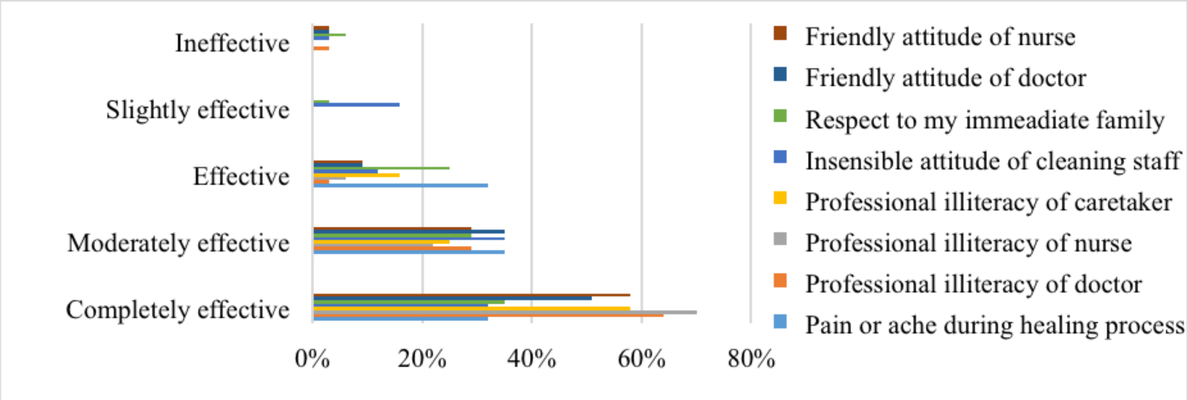
METHODOLOGY AND DATA ANALYSIS

Within this research a face to face questionnaire was conducted among randomly selected 31 inpatients on two hospitals located in İzmir. The questionnaire started by demographic information which was followed by three sections; namely perception, lighting and acoustics. Questions were constructed with rating scales, open ended, multiple choice, and yes-no questions. The responses were analyzed by using crosstab query, chi-square tests and frequency methods. On the following part, each section analyzes will be discussed individually.

PERCEPTION RESULTS

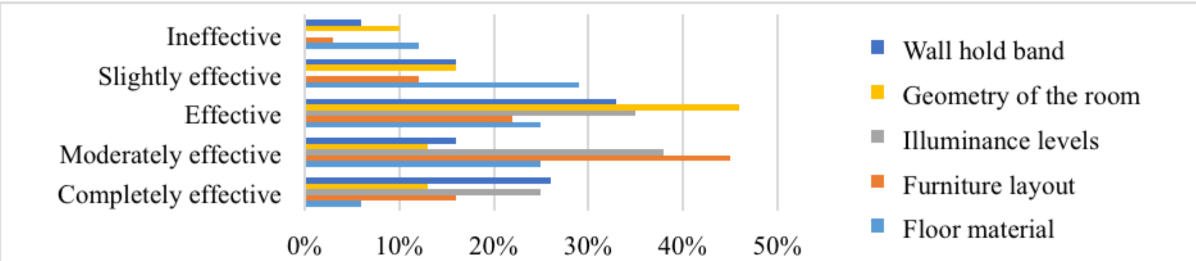
Three main factors; stress, privacy and belonging were analyzed to evaluate the satisfaction of inpatients on their rooms in terms of perceptual aspects. The professional competence (70%) and friendly attitude of nurse (58%) are more affected on inpatient stress than the professional competence (64%) and friendly attitude of doctor (%51) (Table 1). In addition, the attitude of nurse towards to patient is effective on patient's stress by the equivalent rate (35%) with ache and pain in healing process.

Table 1 Contribution of attitude of staff on inpatients' stress



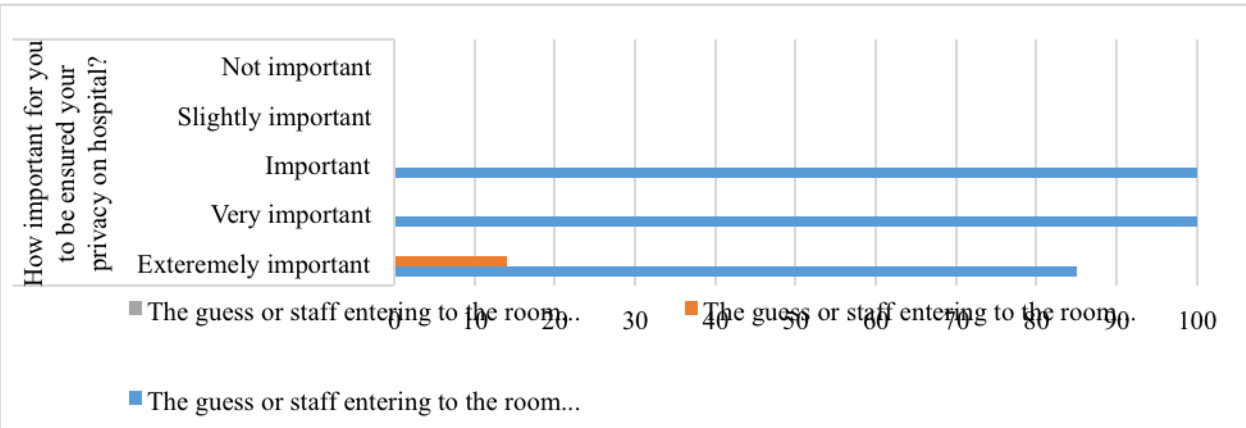
Physical capability also affects patient's stress. The most effective space parameter affecting physical capability of patient and causing an increase in the stress, is furniture layout with 45%, while the level of light is observed secondary with 38% (Table 2).

Table 2 Contribution of physical capability on inpatients' stress



In the group of questions which were questioned to understand privacy need of patient room were analyzed in crosstab query. According to data obtained from the survey results; 85% of respondents who considered the privacy on inpatient room is extremely important, prefer to that the visitors coming to the room should pass through a corridor (Table 3).

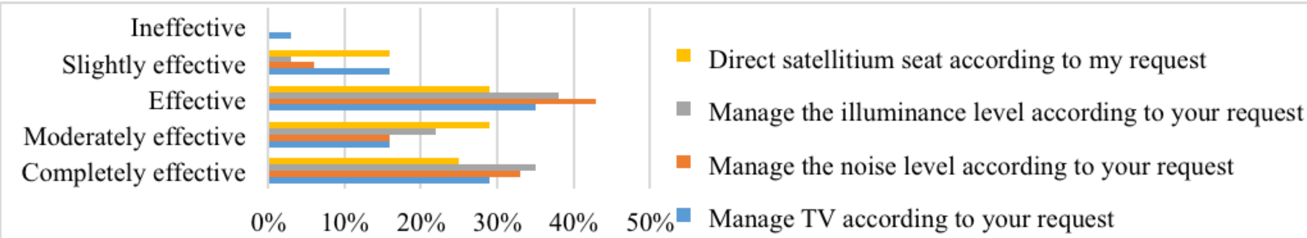
Table 3 The relation between privacy and entrance preference



To understand the factors affecting privacy needs on inpatient room, the question "would you prefer any blind/ screen to block visual or/and aural communication with other patient in multi- bed patient room" were asked to respondents. According to the results; 89% of respondents who are considered that "the privacy on inpatient room is extremely important" are prefer to have a blind/screen to block visual and aural communication in multi-bed inpatient room.

Controlling the parameters in spaces are affecting belonging sense of user in space. Relevantly, in the context of survey, patients' preferences in controlling some situations were asked. As it can be understood from the results, directing satellitium seat according to their request is the most effective factor on their belonging sense to space among the other given situations.

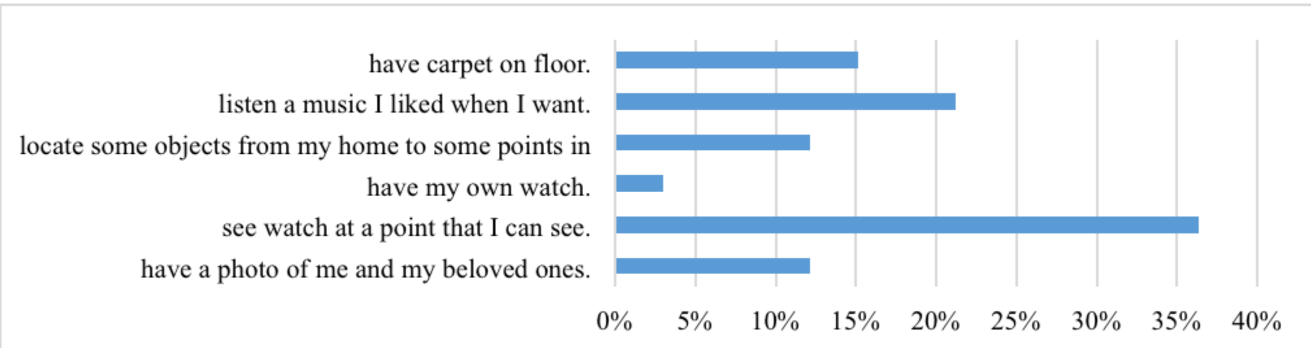
Table 4 Contribution of controlling to the belonging sense of inpatients on inpatient room



When it was asked to rank the effect of given objects on their sense of belonging 37% of respondents prefer to see watch at a point that they can see; 22% of them prefer to listen a music they liked when they want (Table 5).

The view of inpatient room is also effected on the sense of belonging in healing process. Thus, in survey, several options to view from the window of inpatient room were presented to respondents. According to received responses; 52% prefer to view sea from inpatient room, while 41% prefer to see forest view.

Table 5 Contribution of familiarity on the sense of belonging on inpatient rooms



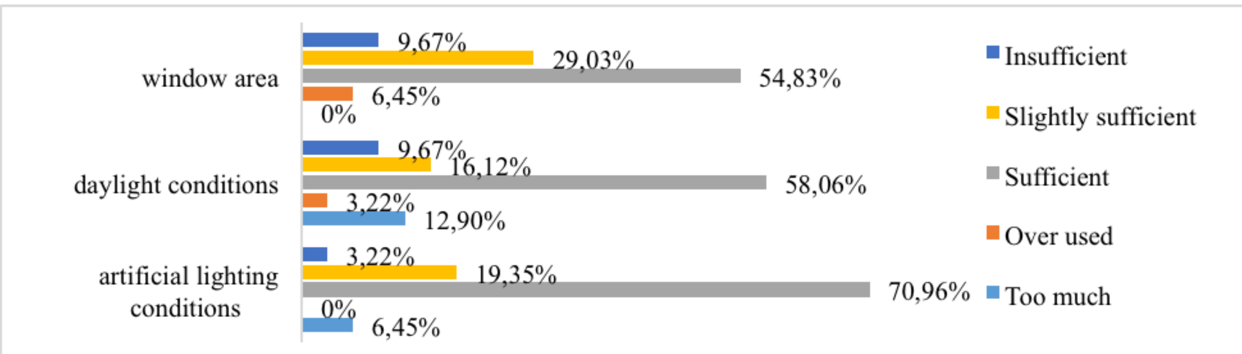
In the context of questionnaire, three images and 11 adjectives were given and it was expected respondents to choose an adjective (s) representing better their sense due to the dominant color of images. According to received responses; red colored inpatient room were evaluated as cosy and energetic, blue colored one was evaluated as cold and depressive and white colored one was evaluated as relaxed and cold (Figure 1).

Figure 1 The relation between colors and feelings of inpatients

LIGHTING RESULTS

Responses of the questionnaire were analyzed to understand the lighting's contribution and visual comfort during healthcare experience. The relations between variables, namely, lighting experience, daylight conditions, artificial light conditions, area of the window, lighting control and area of the window were Chi-square (x*) tested for independence. The six factors which were analyzed by cross-tabulation and Chi-square tests are listed below:
i) the relation between daylight conditions and healthcare lighting experience
ii) the relation between daylight and visual conditions on the inpatient room
iii) the relation between the window area and daylight satisfaction on the inpatient room
iv) the relation between improvement demand and visual comfort
v) the relation between daylight condition and the hospital
vi) the relation between artificial light condition and the hospital
The lighting analyses show that lighting is an important contributor on healthcare experience (91%). When respondents were asked to assess their room in terms of artificial lighting, daylight and window area conditions, it was observed that they were satisfied with the existing conditions by 71%, 58% and 55% respectively (Table 6).

Table 6 Evaluation of lighting conditions on inpatient room



The Chi-square tests, which aimed to show the relation between various factors, show that daylight and artificial lighting condition satisfactions are dependent with each other (a=0,0016). Another significant dependency was observed among the window area and daylight satisfaction with a=0,019. Besides satisfactions, due to the visual discomforts (such as glare, flickering, veiling reflections), inpatients demand improvements on the lighting conditions (a=0,039)(Table 7).

Table 7 Dependency evaluation on Chi-square test

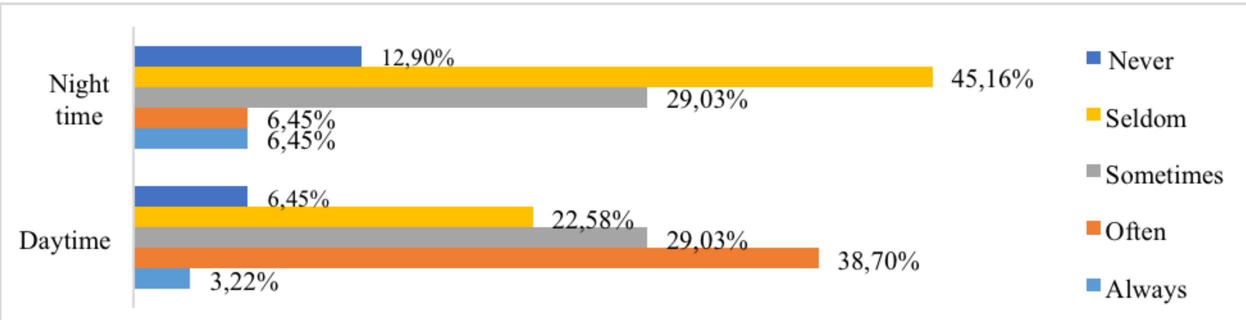
		Pearson chi-square	p-value	Dependency
i	Daylight condition-Healthcare experience	12,08	0,74	Independent
ii	Daylight-Artificial lighting satisfaction	37,88	0,002	Dependent
iii	Window area-Daylight satisfaction	29,72	0,019	Dependent
iv	Discomforts-Visual improvement need	10,11	0,39	Dependent
v	Daylight satisfaction- Hospital	9,67	0,046	Dependent
vi	Artificial light satisfaction- Hospital	4,95	0,026	Dependent

Response analyzes show that daylight conditions and healthcare experience are two independent factors. The two sample hospitals have different visual environments, therefore though the respondents' visual comfort expectations are similar, their level of satisfaction with lighting condition show difference.
Though derived from a study of limited scope on two hospital facility, a number of the lighting results were considered noteworthy on their own merit. One was the independence of daylight condition and healthcare experience. Though previous research shows the benefit of daylight usage on hospitals specially to healing process, in regard to healthcare experience it was observed that it's not necessarily related. This was also considered to indicate that there was no significant difference between artificial and daylight condition with hospital.

ACOUSTICS RESULTS

Findings of the questions about acoustics performance were presented in this line; considering noise as a problem, complaining about outdoor noise, disturbance level from daytime and night time noise, noise sources which disturb the patients mostly, problems with speech intelligibility and hearing staff, acoustic performance of the room and annoyance level of inpatients from the noise. When results were analyzed, 64,53% of the inpatients strongly think the noise as a big problem, 22.58% of them agree with this, only 3.23% of the inpatients do not disturbed by the noise. According to 51.61% of the inpatients, outdoor noise generates the noise, but 48.39% of them do not find it as a problem. This results may arise from the insulation qualities of the hospitals because there is a significant difference between chi-square analyses in two hospitals. According to chi-square test p-value (0,048) is smaller than 0.05 so in terms of hospitals disturbance of the inpatients from outdoor noise is different ($X^2(1)=3{,}89$). The disturbance question on daytime noise shows that 93% of the respondents were disturbed accurately or slightly by the noise, but this ratio decreased 87% in the night time.

Table 8 Disturbance level of noise according to time of the day



Results indicated that majority of the respondents were disturbed by conversation on inpatient rooms, conversation out of the rooms and activities on corridor. The other given factors seem to have slightly less impact on the inpatients' disturbance (Table 9).

Table 9 Disturbance level of noise on inpatient room

Disturbance Level of Noise	**Traffic Noise**	**HVAC**	**Medical equipment on inpatient rooms**	**Medical equipment outside of the inpatient rooms**	**Conversation on inpatient rooms**	**Conversation outside of inpatient rooms**	**Activities on corridor (foot steps)**	**Alarm**	**Tv**	**Telephone**
10	4	2	1	4	8	5	2	3	1	1
9	1	0	3	3	7	6	6	0	4	2
8	6	0	2	0	2	5	7	2	2	4
7	2	1	2	2	6	2	6	0	9	2
6	2	7	5	5	1	3	2	4	1	3
5	2	5	4	3	3	5	1	1	3	5
4	5	4	3	3	1	1	4	3	2	4
3	5	5	1	1	3	1	1	1	6	3
2	1	4	6	6	0	2	1	2	3	7
1	3	3	4	4	0	1	1	15	0	0

CONCLUSION

Within the context of this descriptive study on healthcare experience on inpatient rooms, IECP parameters were analyzed with the conducted questionnaire in two different hospitals. The gathered outputs were grouped into three subgroups (perception, lighting and acoustics) to make suggestions to improve inpatients' IECP.

Perception

Stress: Physical capability is affected on stress of inpatients during their healing process. Among the parameters related with physical capability on inpatient room such as floor material, illuminance level, the geometry of room, hold band; furniture layout is the most effective factor influencing physical capability of inpatients. According to the survey results; inpatients are affected from the professional competence and friendly attitude of nurse more than the attitude of doctor.

Privacy: In the context of this research inpatients are questioned by their needs of privacy. By the lights of the results, it seems that the privacy on inpatient room is provided by both visual and aural privacy of patients. Patients preferred to have visual and aural border with the other patient(s) staying in same room or visitor(s) coming to the room.

Sense of belonging: The will to control has a close relation with the sense of belonging in space. Especially on inpatient rooms, this illiteracy has a crucial import for patients due to their lack of physical abilities. In similarly, according to results, controlling of furniture or lighting are giving positive senses for belonging to the patients on inpatient room. In addition; as it is seen from the results, the objects or situations are raising the sense of belonging with providing familiarity of inpatients to the inpatient rooms.

Lighting

Majority of respondents (91%) think lighting is an important contributor on inpatients' healthcare experience. Especially among the given factors; daylight, artificial lighting and window area were directly related with the meeting the visual requirements on inpatient room. Limited daylight penetration and visual discomforts (such as glare, veiling reflection, flickering etc.) ruin the satisfaction with lighting conditions. In order to fulfill occupants' expectations in terms of IECP, window area should be optimized to get sufficient daylight penetration while artificial lighting should be controlled individually by the user. Preventing discomfort factors and enriching lighting conditions within the room may shorten the length of stay as it was proposed in the literature.

Acoustics

Noise is a crucial problem for in our daily lives, especially inpatients mostly consider noise as a problem. Outdoor noise of the hospital disturbs the inpatients but level of disturbance changes according to hospitals insulation. Results indicate that daytime noise sources are more disturbing than night time which effects aural comfort of respondents. Noise sources are conversation between patients and staff or relatives, activities in corridors and the hospital equipment such as TVs, telephones, alarms but medical equipment are not problem as much as them. Most of the inpatients does not have a problem in communication with the staff but nearly half of them are not decisive about the acoustic performance of the room. The corridor noise can be reduced by some precautions, for instance in the day time footsteps should be decreased and the floor covering should be designed according to it. It shows that hospitals are notoriously lacking in the materials that one normally associates with acoustical absorption. Moreover, inpatients are not pleasant with the outdoor and corridor noise, so some insulation materials had better be enriched.

Optimizing quality of healthcare with questioning inpatients 'experience is a crucial element on improving satisfaction. In order to enrich the healthcare experience in terms of IECP, indoor environmental control and psychological parameters should not be underestimated. This study aims to give an insight knowledge on IECP conditions on inpatient rooms.

REFERENCES

[1] R. Ulrich, "Effects of interior design on wellness: theory and recent scientific research.," ***J. Heal. Care Inter. Des.***, vol. 3, no. February 2016, pp. 97–109, 1991.

[2] H. Dalke, J. Little, E. Niemann, N. Camgoz, G. Steadman, S. Hill, and L. Stott, "Colour and lighting in hospital design," ***Opt. Laser Technol.***, vol. 38, pp. 343–365, 2006.

[3] R. S. Ulrich, "View Through a Window May Influence Recovery from Surgery," ***Science (80-.).***, vol. 224, no. 4647, pp. 420–421, 1984.

[4] R. Ghazali and M. Y. Abbas, "Newly Built Public Paediatric Wards Increase Length of Stay (LOS)?," ***Procedia - Soc. Behav. Sci.***, vol. 50, no. July, pp. 623–632, 2012.

[5] P. R. Boyce and P. R. Boyce, ***Human factors in lighting - 3rd Edition***. 2014.

[6] EN 12464-1, "Light and lighting - Lighting of work places - Part 1 : Indoor work," ***European Standard***. European Committee for Standardization, Brussels, pp. 1–43, 2002.

[7] M. Ferri, D. a Zygun, A. Harrison, and H. T. Stelfox, "Evidence-based design in an intensive care unit: End-user perceptions," ***BMC Anesthesiol.***, vol. 15, no. 1, pp. 1–9, 2015.

[8] R. Ulrich, R., Zimring, C., Quan, X., Joseph, A., & Choudhary, "The Role of the physical environment in the hospital of the 21st century: A once-in-a-lifetime opportunity," ***Cent. Heal. Des.***, 2004.

[9] M. Rashid and C. Zimring, "A Review of the Empirical Literature on the Relationships Between Indoor Environment and Stress in Health Care and Office Settings: Problems and Prospects of Sharing Evidence," ***Environ. Behav.***, vol. 40, no. 2, pp. 151–190, 2008.

[10] M. Ulrich, R.S., Lawson, B., & Martinez, "Exploring the patient environment: An NHS estates workshop.," 2003.

[11] M. Topf, "Effects of personal control over hospital noise on sleep," ***Res Nurs Heal.***, vol. 15, no. 1, pp. 19–28, 1992.

[12] "Australasian Health Facility Guidelines Revision v4.0 (AusHFG)." [Online]. Available: https://healthfacilityguidelines.com.au/. [Accessed: 15-Jun-2016].

[13] Department of Health, "Specialist services Health Technical Memorandum 08-01: Acoustics," 2013.

[14] D. H. Schwela, "World Health Organization Guidelines for Community Noise," in ***TRB Session 391 "Setting an Agenda for Transportation Noise Management Policies in the United States,"*** 2001.

[15] CISCA, "Acoustics in Healthcare Environments," 2010.

Paper No: 202

A study on different dynamic solar shading control strategies using multi-criteria design optimization

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ABSTRACT

The correct design of shading devices that control the amount of daylighting entering a building is an integral part of performative building design. Solar control devices have the potential to reduce building cooling load, improve the daylighting performance and reduce the negative effect of glare in building spaces. Solar shading design strategies, therefore, need to consider multiple criteria together and find an optimal tradeoff between them. This paper presents our experiments on different solar shading control strategies that respond to various external conditions such as cooling rate, solar radiation incident and glare. We use a design tool that optimizes building energy use and daylighting. The tool implements a multi-criteria genetic algorithm coupled with an energy simulation tool in the design of the sizes of building openings. We investigate various shadings and their control types that are activated with various solar orthermal conditions in the environment. We implement Pareto-based comparative analyses and report their effect on building energy and daylighting performance. The results suggest that correct shading devices drastically contribute to building performance, but the control strategies should be carefully selected to be able to satisfy all design criteria.

Keywords: building shading control, energy and daylighting performance, multi-criteria decision-making, design optimization

INTRODUCTION

As European Union's targets to reduce CO2 emissions and improve energy efficiency are becoming stricter, there is increased importance placed upon the design and control strategies that aim to improve building performance and resource efficiency. Building envelope is a major contributor to improve building performance towards the use and implementation of efficient envelope materials, air tightness, and natural ventilation. Building openings also play a crucial role in high-performance buildings. U-value, solar heat gain coefficient (SHGC) and visible transmittance are defining characteristics of high performance glazing. However, especially highly-glazed buildings require additional measures to control solar gain in the form of shading devices. The effective use of such solar shading devices on the building envelope is integral to high-performing buildings. There is significant potential in achieving high energy efficiency in buildings by reducing cooling loads resulting from sunlight entering a building through envelope openings, whereby reducing energy use. Sun shading is also an effective way to avoid excessive solar heat gain in a conditioned space during the cooling season.Ensuring indoor environmental quality and the satisfaction of the needs of the comfort of building occupants is another important factor in shading design. Daylighting, when used as the primary lighting source in building interiors, can contribute to high-quality indoor conditions, increase occupant satisfaction and health, and reduce the lighting energy consumption. Furthermore, the type and control of shading devices have an effect on indoor visual comfort by reducing glare and areas of high contrast. The integral consideration of thermal, visual and conform related issues is crucial in the use and control of solar shadings in buildings. This means that these criteria need to be quantified and a trade-off should be made between these design criteria.

Therefore, there is need to support the design of effective sun shading devices and control strategies to achieve the above-mentioned benefits. Computational design tools have proven to be effective in aiding the designer in decision-making based on quantitative and objective criteria. Simulation-based optimization methods that are based on numerical simulation and mathematical optimization can support building design towards well-informed decision making[2]. Especially in performative design, where a multitude of design criteria that may be in conflict with each other (such as initial cost versus performance or energy use versus occupant comfort), it is important to reach trade-off optimal solutions that satisfy these criteria in different degrees. This approach is known as Pareto optimization that simultaneously optimizes all design criteria and presents a number of non-dominated design alternatives for the user to decide upon. In this respect, genetic algorithms (GA) has been successfully implemented in the design to select a number of design variables towards optimizing a number of criteria regarding building performance. GA operates with the principles of evolution, where a population of individuals (design alternatives) are evolved to global optimality through genetic operators such as crossover and mutation. By balancing exploration and exploitation, it can globally search the design space and find the high-performing building alternatives.

The aim of the present study is to test the feasibility of different sun shading types and control strategies with the use of energy / daylighting simulation tools and multi-objective genetic algorithms. For each type and strategy, we first determine the activation set pointsthat yield the lowest energy by running simulations in EnergyPlus. Following, we compute the Pareto frontier of each strategy by varying the window-wall-ratio of its thermal zones and considering energy use and daylighting autonomy as objective functions. For this, we use a design optimization tool that we have previously developed that implements a multi-criteria genetic algorithm as coupled with EnergyPlus. We install on each building instance exterior shading devices that activate on different conditions, and run simulations to test the feasibility of these activation conditions. We explore solutions on the Pareto-front for each control type, and make a comparative analysis between them by means of their fitness satisfaction. Finally we discuss the results of our findings and suggest future work.

A DESIGN TOOL FOR ENERGY AND DAYLIGHTING OPTIMIZATION

We study the effect of different sun shading types and control strategies by using the simulation tool EnergyPlus and a design tool that we have previously developed that supports the decision of window sizes using a multi-objective genetic algorithm. We first select a number of different shading types, both static and dynamic. We make an initial exploration for a number of shading control strategies by applying them on a building, and calculating their energy use. We then select the best strategies and separately apply on them the multi-objective genetic algorithm to determine the window-wall-ratio in a Pareto set.

As a case study, we use a building with a 7200 m^2 surface area and eight thermal zones with different internal gains, illuminance and glare setpoints and heating/cooling setpoints (Figure 1, Table 1). The window-wall-ratio is initially taken as 0.5. The envelope material properties can be seen in Table 2. The simulations are run for only four representative days of the year for Ankara, Turkey. We use an ideal HVAC system in EnergyPlus that calculates loads without the need to model a full HVAC. The ideal system mixes zone air with the specified amount of outdoor air, adding or removing heat and moisture at %100 efficiency.

Table 1 Zone internal loads, glare indices and setpoints

	People gains (person/m²)	**Lights gains (W/m²)**	**Electric equipment gains (W/m²)**	**Illum. setpoint ($E_{Zi}E_{Zi}$) (lux)**	**Max. daylight glare index (DGI DGI)**	**Heating setpoint (C°)**	**Cooling setpoint (C°)**
Z_1	0.056511	10	10.76	500	22	22	25
Z_2	0.11	10	10.76	500	22	22	26
Z_3	0.005	10	0.58	150	22	20	26
Z_4	0.056511	10	10.76	400	22	22	25
Z_5	0.29	10	6.4	250	22	23	26
Z_6	0.056511	10	10.76	500	22	22	25
Z_7	0.056511	10	10.76	150	22	22	25
Z_8	0.29	10	6.4	250	22	23	26

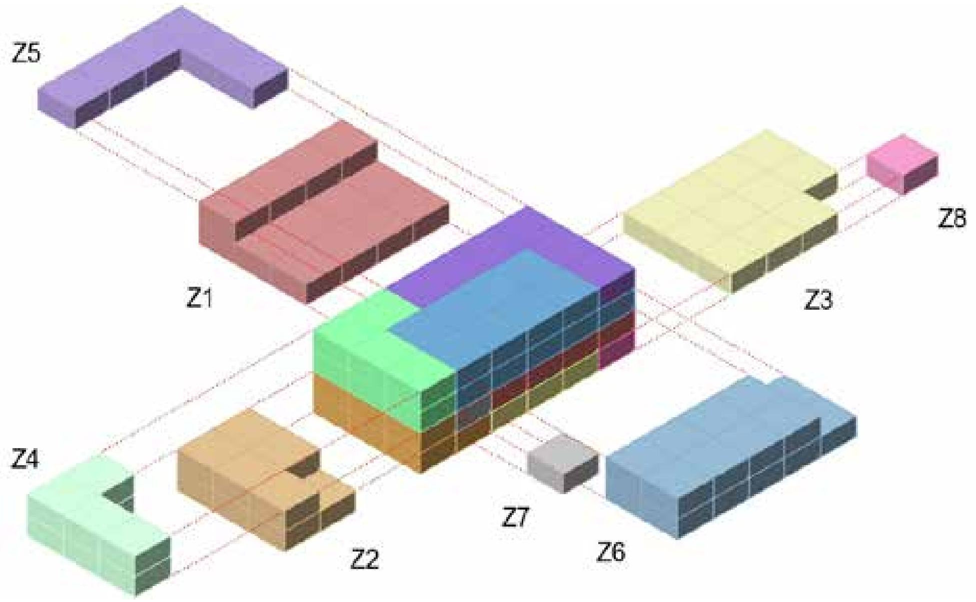

Figure 1The test building (center) and its thermal zones exploded to the sides

Table 2 Material properties

Material thermal properties (W/m²K)	
U_{wall}	0.500
U_{roof}	3.300
U_{floor}	0.450
U_{window}	2.400

On this building, we test seven different solar shading strategies that use two different shading devices; controllable blinds for strategies 1 to 5 and static shading devices that are either vertically or horizontally placed for east / west and south facades respectively. The control setpoints for the controllable blinds are determined by a trial and error study, wherein we ran several simulations on a range of possible values are finally select the best performing one. We present in Table 3 only the setpoints

Table 3. Shading strategies

SHADING STRATEGY	CONTROL	SHADING DEVICE
1. ALWAYS_ON	The shading is always on.	Horizontal blind. Slit width: 0.1 cm Slat separation: 0.1 cm Slat thickness: 0.01 cm Slat beam solar reflectance: 0.5
2. HIGH_COOLING	Active if zone cooling rate exceeds 60 W/m^2	
3. HIGH_INSOLATION	Active if solar radiation incident (beam + diffuse) on the window exceeds 600 kw/m^2	
4. HIGH_GLARE	Active if zone glare exceeds 22 ($DGI\ DGI$)	
5. HIGH_TEMP	Active ifthe outside temperature exceeds 25 C°	
6. STATIC_SHADING	Static shading devices; no control	Horizontal overhang on south windows: 2 m depth Vertical fins on west and east windows: 1 m depth
7. NONE:	No shading.	

For each control type, we run energy simulation with EnergyPlus and calculate the energy use by aggregating the heating, cooling and lighting use (Table 3). The results show that shading devices have the highest effect on lighting and cooling energy use, and very little effect on heating energy use. Strategies 1 and 5 keep the shades active most of the time, so they achieve the highest reduction in cooling energy use while dramatically increasing the lighting energy use. Therefore, they have the highest overall energy use in general. Strategies 2, 3 and 4are the most energy efficient alternatives, achieving up to 2.3% energy savings compared to no shadings.

Table 4The energy use values of the different control strategies

		Energy use (kWh)				
		Heating	**Cooling**	**Lighting**	**Total**	**%change from NONE**
1	ALWAYS_ON	1057.36	926.13	1661.32	3644.81	1.032
2	HIGH_COOLING	1069.56	1034.15	1323.04	3426.75	0.970
3	HIGH_INSOLATION	1069.75	1026.34	1323.04	3419.13	0.968
4	HIGH_GLARE	1080.27	1011.77	1323.07	3415.11	0.967
5	HIGH_TEMP	1113.34	926.13	1600.08	3639.55	1.030
6	STATIC_SHADING	1089.7	997.76	1348.91	3436.37	0.973
7	NONE	1069.48	1139.65	1323.04	3532.17	1.000

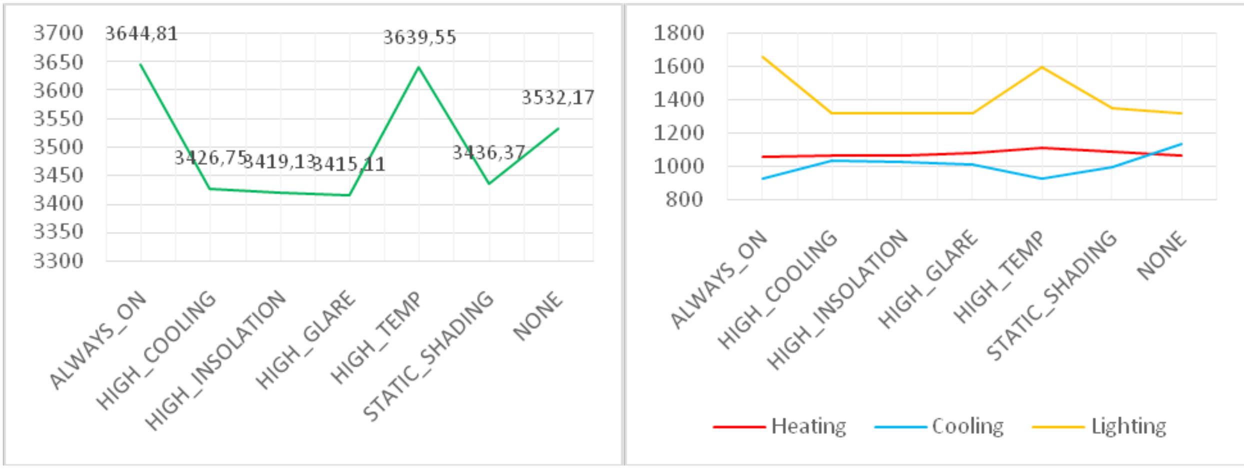

Figure 2A comparison of the detailed energy use values of the different control strategies

In conclusion, the results reveal the tradeoff between lighting and cooling energy use. In the next step, we apply the genetic multi-criteria optimization tool that we have previously developed on strategies1, 2, 3 and 6. We select these buildings to demonstrate the trade-off performances of both the better-performing strategies (2,3 and 6), as well as poorer-performing ones. The tool varies the window-wall-ratio of the buildings (previously simplified as 0.5) and simulates the building in EnergyPlus to calculate the buildings' daylighting autonomy (DA) and energy use (EU). The tool then computes a non-dominated Pareto set that minimizes EU and maximizes DA. It then visualizes the tradeoff between these two objectives and allows the designs select an optimal solution.

The design optimization tool implements the NSGA-II (Non-dominated Sorting Genetic Algorithm-II) multi-criteria optimization method, a Pareto-based elitist approach that applies non-dominated sorting in its selection process[1]. In NSGA-II, two ranking operations are implemented as a selection mechanism to balance exploitation and exploration in its search of the Pareto optimality. For exploitation, NSGA-II demonstrates a higher bias towards the selection of Pareto-dominant solutions. For exploration, clustering needs to be eliminated to achieve a more even distribution and to preserve solution diversity. The window-wall-ratios of a building's thermal zones areused as the design variables, which indicate the total area a window occupies on an exterior wall. The chromosome, accordingly, maintains the ***wwr*** values of the thermal zones in all four directions ($wwr_{Zi}^{N} wwr_{Zi}^{N}$, $wwr_{Zi}^{S} wwr_{Zi}^{S}$, $wwr_{Zi}^{E} wwr_{Zi}^{E}$, $wwr_{Zi}^{W} wwr_{Zi}^{W}$) and can vary in the range of (0-1). The algorithm was run for 40 generations for a population size of 30 individuals. We use binary tournament selection for crossover selection. The crossover rate is %70 and the mutation rate is %10.

The tool is seamlessly integrated to EnergyPlus through the OpenStudio SDK[3] for the calculation of two objective functions, energy use (EU), and daylight autonomy (DA). EU aggregates cooling, heating and lighting energy use, and is minimized. For the calculation of DA, a daylighting reference point is selected in the center of gravity point of each a zone's lowest level, where the least amount of daylighting is expected. DA considers the total number of hours that zones' illuminance setpoints are met only with daylighting. For this, it calculates *Daylight Illuminance Setpoint Met Time* ($DISMT$) $DISMT$) for each zone zz for calculation step ***h*** in hours. $DISMT DISMT$ is expressed an asymmetric triangular fuzzy membership function that indicates how close a zone's calculated daylight illuminance ($E_z^{calc} E_z^{calc}$) level is to that zone's daylight illuminance setpoint (E_z^{min} E_z^{min}) (Figure 3).

$$\max DA = \sum_{z=1}^{t} \sum_{h=0}^{k} DISMT_z^h \, NA_v^i$$

$$DISMT_z^h = \begin{cases} 0, & E_z^{calc} \in [0, E_z^{lowB}) \\ \dfrac{E_z^{calc} - E_z^{min}}{E_z^{min} - E_z^{lowB}} + 1, & E_z^{calc} \in [E_z^{lowB}, E_z^{min}) \\ \dfrac{E_z^{calc} - E_z^{min}}{E_z^{min} - E_z^{highB}} + 1, & E_z^{calc} \in [E_z^{min}, E_z^{highB}] \\ 0, & E_z^{calc} \in [E_z^{highB}, \infty) \end{cases}$$

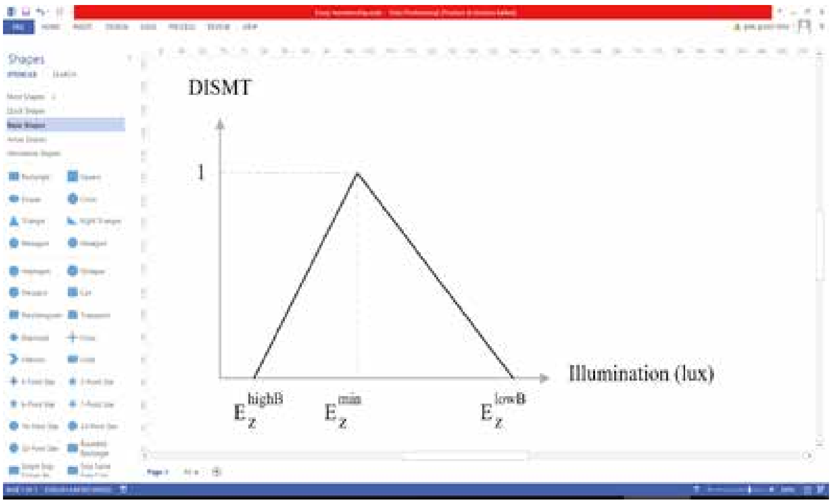

Figure 3The fuzzy membership function for daylight autonomy

We plot the Pareto set of the four shading strategiesin Figure 4. The results show that all shading strategies except of ALWAYS_ON perform similarly in terms of the range they span in EU. This means that ALWAYS_ON fails to achieve a comparative energy use and performs poorly in DA as compared to the other strategies. HIGH_COOLING and HIGH_INSOLATION plot very similar curves, meaning they also have similar operational parents throughout the day. This also points out to a correlation between cooling loads and high incoming solar radiation. STATIC_SHADING, on the other side, spans a wider Pareto front but fails to maximize daylight autonomy as much as the other two strategy. We conclude that static devices cannot respond to the energy and daylighting conditions throughout the day or during different weather conditions.

As a result, we can conclude that dynamically controlled shading devices achieve the optimal trade-off solutions in energy use and daylighting. However, there might be other design criteria that can guide the final selection. For instance, when initial or operational cost of shading devices is considered, static devices can be preferred due to their robustness and relatively low and complexity. Moreover, it has been known that dynamic building devices demand higher need for maintenance and repair, as they have a lower operational burden. This calls for the consideration of other design criteria that we haven't taken into account yet, such that they are integrated into the problem and the relevant information guides the search accordingly. As future work, the proposed tool can be extended further towards the formulation, modeling, calculation and optimization of other performance criteria that can facilitate a wider objective space. Other potential research directions include the integration of the control of shading devices with building components such as controllable lighting, night ventilation for passive cooling.

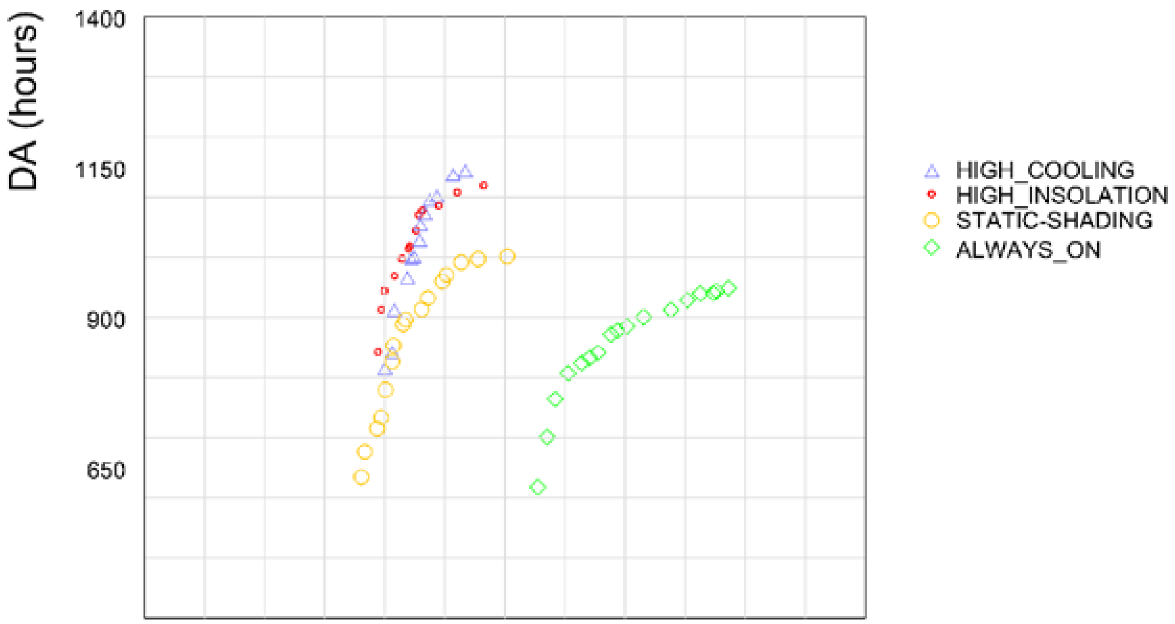

Figure 4 The Pareto sets of strategies ALWAYS_ON, STATIC_SHADING, HIGH_COOLING and HIGH_INSOLATION

CONCLUSION

This paper has presented the use of an existing energy simulation tool and a multiple-objective optimization tool that we have previously developed in the determination of devices and control strategies of solar shading devices. The tool calculates daylighting and energy performance as the objective functions while varying in the window-wall-ratio of a building. We test different shading strategies that prioritize the cooling loads and visual comfort (in the form of achieving the correct daylighting levels). The results point out to the benefits of dynamic shadings in achieving the optimal performance for the two objectives. The studies presented in this paper are the first steps towards the multi-objective evaluation of a wider range of shading types, shading sizes / materials or shading control strategies. Future work includes the integration of various such design parameters into the problem formulation, provide a thorough analysis considering a richer design space and evaluate a higher number of design variations regarding building shading.

ACKNOWLEDGEMENTS

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REFERENCES

[1] K. Deb, Multi-objective optimization using evolutionary algorithms, John Wiley & Sons, 2001.

[2] A.-T. Nguyen, S. Reiter, P. Rigo, A review on simulation-based optimization methods applied to building performance analysis, Applied Energy 113 (2014) 1043-1058.

[3] E. Weaver, N. Long, K. Fleming, M. Schott, K. Benne, E. Hale, Rapid Application Development with OpenStudio, 2012 ACEEE Summer Study (2012).

Building - Energy / Emission

Paper No: 53

Integrated Approach to Energy Efficiency: Energy Management Systems

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ABSTRACT

Companies, wishing for reducing energy consumption and greenhouse gas emissions, controlling and decreasing energy expenses, following performances by monitoring energy consumptions, increasing productivity and complying with legal regulations, perform some works on "Energy Efficiency".

The most important issue on Energy Efficiency is to applying these practices as systematically. At this point, ISO 50001-Energy Management Systems (EnMS)" becomes the most significant solution.

Institutions wishing to apply energy management are supposed to consider all the aspects with "energy" glasses from merchandising to maintenance agreement and also supposed to provide continuous improvement on performance.

In EnMS, steps to be followed may be sorted as due diligence, indicating policies, objectives and targets of company regarding energy, taking necessary actions to achieve these objectives and targets, recording benefits of performed works and execution of this cycle all over again by reviewing system and eliminating shortcomings.

Indispensable points to implement these steps made in order to establish a reliable EnMS can be sorted as discovering current situation and identifying potentials by implementing detailed energy audit, reducing energy consumption by applying projects of study and implementing appropriate automation systems to make efficient operation continuous, setting appropriate energy monitoring systems for verification of benefits and sustainable performance.

Keywords: energy, management, efficiency, energy management, ISO 50001, energy efficiency

INTRODUCTION

Today one of the most basic needs, energy, has also become a critical issue perhaps as never before. On the one hand, the needs of energy by developed and developing countries, on the other hand presence of around 1.2 billion people who do not even have access to electricity yet, who are about 17% of the world population [1], on the another hand targeting of keeping global temperature increase limited to + 2 ° C as the goal, held at the 2015 Paris Climate Conference (COP21), all reveals the necessity of serious works need to be done regarding "energy" and this concept should be managed in a systematic way. At this point, "Energy Management Systems" and "ISO 50001 - Energy Management System Standard", which aimed to settling these systems on a basis, come into play. The aims of this article are, to mention about these management systems and the relevant standards and to identify the benefits that can be achieved thanks to these works to be done in this regard.

ENERGY MANAGEMENT
WHY ENERGY MANAGEMENT?

Energy has now become an issue of vital importance for private sector firms, public institutions, municipalities, cities and countries. In order to reduce energy costs and increase profitability and to reduce energy-related carbon emissions, it began to take cautions on energy in many areas which starting from the house to the country policies. While one of the main reasons is to reduce costs, increasing energy demands and expected energy shortage scenarios due to the limited resources are the most important drivers for countries to take cautions in this regard. According to the World Energy Outlook 2015 report, published by The International Energy Agency (IEA), the world's energy usage is expected to increase by one third towards the year 2040, especially owing to increasing energy demand of India, China, Africa, the Middle East and Southeast Asia [1].

On the other hand, the need for energy is increasing rapidly for our country also, since it is one of the developing countries. According to World Bank data, from 1990 to 2014, energy consumption per capita has increased by approximately 61%. From 2010 to 2014, the energy consumption per capita has experienced an increase of approximately 8%. From 1990 until 2011, an increase of 62% in CO_2 emissions per capita is in question [2].

The increase of energy demand in the world and in our country pushes us as individuals, private sector firms as well as country leaders to take measures in this aspect. The most important studies on this subject are of course take place in the energy efficiency field. Now it is possible to reduce the energy demand from globally on macro basis to our homes on micro basis thanks to "energy efficiency" projects, which has been seen as a new energy source. Today, in Turkey, the potential for energy efficiency is estimated about a 1.3 billion USD per year.

Critical issue here is that, all the energy efficiency studies should be done in a systematic way. At this point, "Energy Management Systems" comes into play. An "Energy Management System" means, looking each of the steps with the view of "energy", from the product design to maintenance agreements and maintaining continual improvement on energy performances.

Taking commitment of the top management, forming an energy team, ensuring at all levels of internal and external communication continuously, determining a detailed Energy Policy, setting an energy planning and providing continual improvement are can be counted as the indispensables of an effective Energy Management System.

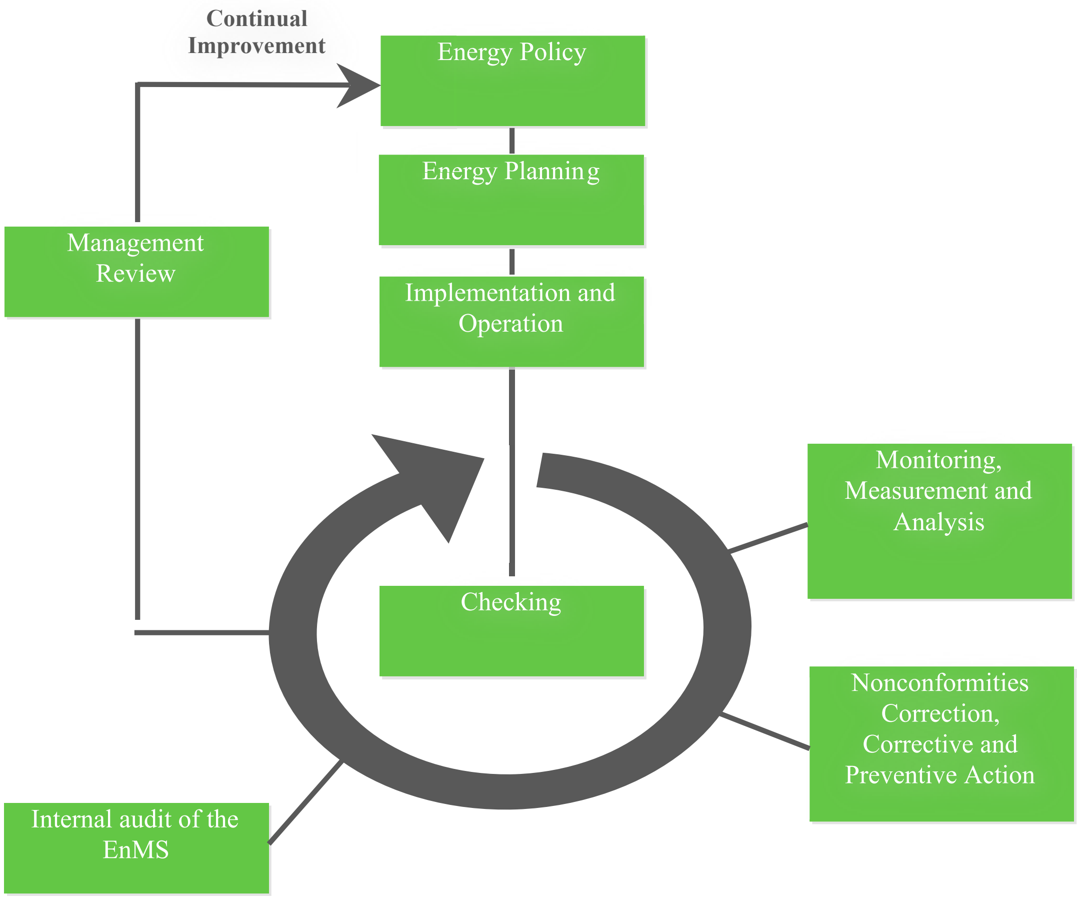

Figure 1 Plan-Do-Check-Act (PDCA) cycle

ENERGY MANAGEMENT OR ENERGY EFFICIENCY?

Before the difference between traditional approaches to energy efficiency and energy management system approach, it would be useful to make one point clear. An "Energy Management System" means a systematic approach to how to manage the energy of a facility. This is an approach completely based on the culture, history and perspective of energy of the facility, and it may vary from facility to facility. As for the ISO 50001, it is a "Standard for Energy Management Systems" which includes the indispensables of a management system on basic level and aims to place an equivalent base all over the world. This standard is formed by compiling all the energy efficiency and energy management studies which are being conducted for a long time by the energy experts coming together from more than sixty countries and the International Organization for Standardization (ISO) was published in June 2011.

Companies, wishing to perform energy management, can carry out this work, of course, with their own perspectives and methods. However, carrying out these works under cover of the ISO 50001 Standard will maximize the benefits to be gained while giving opportunity to save time for companies, as it is a result of the long term experiences which includes the ideal methods to do this work. When the differences between the traditional energy efficiency approach and systematic approach are assessed, it has been seen that the execution of this work by systematically, increases the benefits derived much more.

In the traditional approach, usually the company's / plant's technical manager or maintenance manager is responsible for the work. Even in the best case scenario, this work is managed with a team of these managers, so a single person or a team consisting of a few people carries out all these activities. In addition, usually there is not a commitment of top management on the efficiency works carried out in this way. Besides, both other departments of the company and the suppliers of the company do not have any information about the works done in this traditional way.

An energy efficiency work which depends on the responsibility of a single person or a small technical team is very inconvenient. Because, all the details, knowhow, data history and knowledge of the works done remains limited with this person / team. Therefore, in case of this manager's or some of these team members' quitting their jobs or becoming retired, these people leave with all this knowledge and data.

Newcomer person / team is forced to start from scratch in these studies, which inherently subject to energy efficiency efforts hampered. However, in an energy management system, due to all activities related to energy are going to be conducted by a team which is dedicated for this work and all kinds of transactions are going to be documented, it will not be experienced such a loss of information and the system can be continued from where it was before with newcomer person or persons.

The second biggest drawback of executing these works by the company's technical / maintenance manager or technical team by themselves is that, these works which are being performed usually on voluntariness basis brings an additional and heavy workload to these personnel/team, whose the primary responsibility is to maintain the production / operations continuity . Therefore, this person / team is not going to be motivated for energy efficiency aspects, even if they are, they will not have enough time to perform it. Because they are expected to eliminate malfunctions as soon as possible as the main task. Technical manager and his team often fill their shifts, sometimes even nights as well, by fixing these failures especially in large facilities. Therefore, they cannot find much time to devote to energy efficiency efforts; they are unable to follow the agenda of energy efficiency and innovations on this topic.

On the other hand, in an Energy Management System this workload will be distributed among lots of people, thanks to every person/team in the company will be involved and all responsibility will not be on a limited personnel/team. All the duties will be fulfilled on time without of any shortages and any "timelessness" problem, due to the roles and responsibilities for each person is going to be identified and they are going to be followed.

Table 1 Example Table for Roles and Responsibilities [3]

Task	What is required?	Frequency	Communication	ENERGY MANAGEMENT TEAM									
				Mgt. Drctr.	En. Mgt. Rep.	En. Mngr.	Maint. Eng.	Prod. Sprvsr.	Purch. Off.	Env. Off.	Accnt.	HR Off.	Ext. Cons.
Preparation & Commitment													
Develop the energy policy	Develop and periodically review the energy policy document	Review annually prior to management review	As appropriate	Inf.	Ld.	Prtcp.							
Set objectives and targets	Based on available opportunities but aligned with relevant commitments	Annually	Top mngm. and energy team	Inf.	Ld.	Prtcp.							
Planning													
Legal and other requirements	Identify and document all legal and other requirements	Quarterly	Energy Team		Prtcp.	Prtcp.				Prtcp.			Ld.
Complete the energy review steps	Complete all the steps in the energy review process	Annually	Energy Team			Ld.	Prtcp.	Prtcp.					
Operating													
Implement training	Ensure that all personnel including contractors who may significantly impact the energy use are competent to carry out their roles through a mixture of education, training, experience and skills	As planned	As appropriate						Prtcp.	Prtcp.	Prtcp.	Ld.	
Document Control	Ensure that critical documents and records pertaining to energy performance and the EnMS are maintained and available to those requiring them	Continual	As appropriate			Ld.							
Operational Control/ Opr. of SEUs	Ensure that all significant energy using equipment and systems are operated efficiently	Continual	Operational staff			Ld.	Prtcp.	Prtcp.					Prtcp.
Procurement	Ensure that energy performance is taken into account in the procurement of energy using equipment	Continual	Procurement and energy personnel			Prtcp.	Prtcp.	Prtcp.	Ld.				
Checking													
Monitor energy metrics	Monitor and take action related to energy bills, EnPIs and other energy metrics	Continual				Ld.							
Internal Audits	Schedule and organize internal audits of the EnMS	Quarterly	As appropriate	Inf.	Inf.	Ld.							Prtcp.
Manage non-conformities	Manage corrective and preventive actions related to the EnMS.	Continual	As appropriate	Inf.	Ld.	Prtcp.							Prtcp.

* Inf.: Inform, Ld.: Lead, Prtcp.: Participate

Field experiences have shown as one of the biggest problems faced by the technical team is that, they do not get enough support from top management to energy efficiency projects as they want to do. Even though in terms of employees has forced to reduce energy costs by performing energy efficiency studies by top management, technical team cannot find enough source and support in terms of both financial and reliance means, especially when projects require investments. But in the Energy Management System, the first thing that must be done in this regard is taking a written commitment from the top management while the system is on its setup phase. This commitment begins with the signing of the Energy Policy by top management and is the first step of a management system. The studies won't begin without of this policy, in other words this commitment, is being signed; so the top management promises to give support to these works and required investments by signing this commitment in the first place.

There are 5 essential commitments in an effective Energy Policy that should be given by top management. These are; commitment of continual improvement (energy performance), commitment of deployment of information (documentation, training, etc.) and resources (financial resources, human resources, etc.), commitment of upholding legal and other requirements regarding energy, commitment of considering energy performance in procurement and design and modification in facilities, equipment, systems and processes [3].

One of the biggest benefits that can be obtained by choosing "Energy Management" instead of "Energy Efficiency" is, knowhow and information about the works performed regarding energy efficiency does not stay within a limited group. Because the an Energy Management System requests that, to make the establishment of a team with participation of almost all parts of the company in order to carry out these works, as well as a highly effective internal and external communications. The biggest contribution of these requirements is that, all company employees are being informed of these studies in the first place. Each individual within the company from the cleaners to the general manager, is aware of the work itself and will act accordingly and take precautions. Even, it has been seen in many studies that, when these works has been announced throughout the company, a lot of ideas had been started to come about energy efficiency opportunities from many employees, who were not putting into words, as they had been thinking that the company did not care about energy or they couldn't find a collocutor to tell [3].

In addition, by the way of the company's external communication activities, suppliers and/or contractors of the company who were being well informed about the studies on this regard, they can be forced and it can be achieved that taking energy efficiency at the forefront during the activities of these actors. Furthermore, one of the biggest benefits to be doing external communication is, it has a very impressive effects on the direction of strengthening the corporate image of the company.

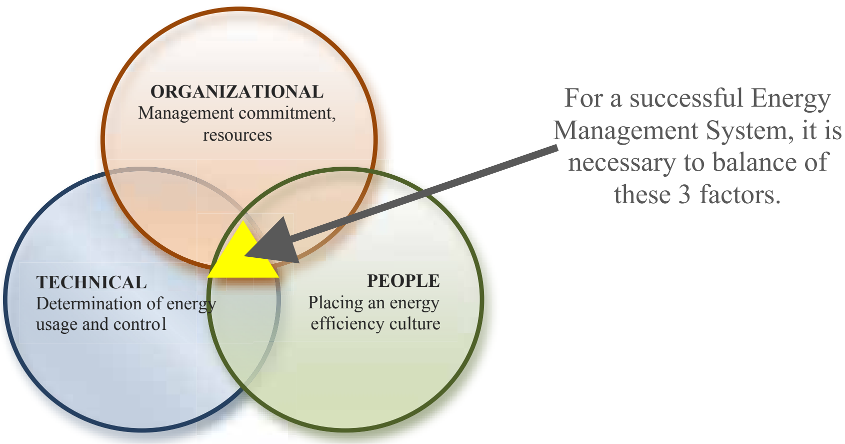

Figure 2 3 Main Factors of the Energy Management System [3]

STEPS OF THE ENERGY MANAGEMENT SYSTEM

In the energy management system, necessary steps to be followed can be listed as follows;

1. *First Steps of Building Energy Management System*

Taking results from the efficiency operations while building an Energy Management System, not only depends on technical operations, but also depends on managerial and strategic settlement. Energy Management System becomes effective with the awareness of taking responsibility which will take place enterprise-wide. For integration of an Energy Management System, the following items are performed and strategic configuration is created as the first steps.

- Current State Assessment
- Top Management Approval and Participation
- Determining the Scope and Boundaries
- Assigning the Management Representative
- Establishing an Energy Team
- Energy Policy

2. *Energy Planning*

Following the administrative structuring and submission of commitments necessary for Energy Management System, technical steps are performed. The values to be taken as the basis for improving the energy performance and efficiency opportunities can be revealed by analyzing the energy usage of the facility via a Detailed Energy Audit during the planning phase. Much more accurate and detailed historical and expected data analysis, curves, usage trends can be created thanks to obtained data by installation of an Energy Monitoring System.

- Energy Data
- Significant Energy Users
- Baseloads
- Energy Performance Indicators (EnPIs)
- Improvement Opportunities
- Targets and Objectives
- Action Plans

3. *Implementation of Energy Management System*

Implementation of the Energy Management System is the steps taken to achieve the targets and objectives which are committed to improve the energy performance. It is very significant for Energy Management System continuity, that these steps are settled into the institutions systematically and periodically. Thanks to Energy Monitoring Systems and Automation Systems, the results to be obtained from action plans are guaranteed and taken under registration easily.

- Determining of Operational Controls
- Competency, Training and Awareness Study

- Implementation of the Action Plans
- Communication
- Documentations and Records
- Design
- Procurement and Purchasing Procedures

4. *Checking of Energy Management Systems*

The Checking Phase of the Energy Management System is that the activities which are to ensure continuity of the system and performance improvements. These steps are performed in order to provide smooth operation conditions in terms of facility, equipment and management system, to prevent irregularities and to prevent any potential non-conformities.

- Monitoring, Measurement and Analysis
- Device Calibrations
- Conformity of Legal and Other Requirements
- Internal Audits
- Corrective and Preventive Actions

5. *Management Review of Energy Management System*

Management Review of Energy Management System is a process that takes place after the establishment and implementation of the system to check its functionality. The aim is to provide continuity of Energy Management System by controlling the components by the top management.

CONCLUSIONS AND DISCUSSIONS

Energy efficiency, far beyond the work of a single individual or a single team, is a concept that should be "managed". It is a cultural conversion that has to be spread throughout the company and all personnel of the company from worker to General Manager, suppliers and contractors, in brief all the stakeholders have to be a part of this conversion. Because this subject is not a simple phenomenon that can be performed with just organizing meetings and with just the decisions taken in this meetings. The actors whom working in the field (employees, contractors, etc.) is one of the key points of this system. It is essential that, energy efficiency studies should be done in a systematic way and in accordance with standards which are including best practices. The benefits obtained by energy efficiency studies can be increased about 10% (in other words, up to 3 times), thanks to a correctly configured energy management system, compared to conventional approaches [3].

United Nations Industrial Development Organization (UNIDO), thanks to the projects carried out in Egypt, established the Energy Management System in two iron and steel facility. With this system one of the factories were able to provide approximately 14.5 million USD (2.19 $mtCO_2$), and the other one were able to provide 934,000 USD (> 100,000 tCO2e) energy saving annually. Moreover, the payback period for all projects to be carried out is 4 months for each of the factories [3].

United States Department of Energy is carrying out a program called "Superior Energy Performance". According to this program, the Department gives silver, gold or platinum certificates to the companies which have implemented the ISO 50001 standard, in terms of improving ratio of their performances. In companies implementing this program; from 36,000 USD to 938,000 USD annual energy saving potential has been determined with no or low cost investments, a reduction of 12% in average has been realized on their energy bills within 15 months and between 5,6% - 30% improvement was achieved on their energy performances within 3 years [4].

With an Energy Management System functioning right, the benefits which companies able to realize can be summarized as follows:

- **Continual Improvement** is guaranteed as the first and foremost, concerns about energy and energy efficiency do not be at the top of the agenda time to time and they are not shelved for long periods after then.
- **Reduction in Costs** can be achieved as a result of determining, measuring and managing the energy consumptions,
- **Conformity for Legal and Other Requirements** is guaranteed due to they will be monitored continuously,
- **Reliance in Energy Supply** can be set, since the risks and vulnerable points are determined,
- **Participation of Top Management** can be ensured as the first step of this work is a "written commitment" of the top management,
- **Performance of Employees Develops,** as all employees of the company would be in this work,
- **Close Follow-Up of Innovations** regarding energy is provided.

REFERENCES

[1] International Energy Agency. World Energy Outlook 2015 Executive Summary. Can be downloaded at: http://www.iea.org/publications/freepublications/publication/WEB_WorldEnergyOutlook2015ExecutiveSummaryEnglishFinal.pdf

[2] http://databank.worldbank.org/data/reports.aspx?source=2&country=TUR&series=&period=# (IEA Statistics © OECD/IEA 2014 (http://www.iea.org/stats/index.asp, subject to https://www.iea.org/t&c/termsandconditions/)

[3] United Nations Industrial Development Organization. Industrial Energy Efficiency Programme-EnMS Capacity Building programme.

[4] http://energy.gov/eere/amo/superior-energy-performance

Paper No: 60

Comparison of Exergetic and Sustainability Evaluation of Various Building Heating Systems

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ABSTRACT
In every country, the building sector is a major contributor to socio-economic development and also a major user of energy and natural resources. Buildings are responsible of %35 of the total energy used and approximately 25% (including transport) of the global CO_2-emissions by considering heating, cooling and lighting appliances. Therefore, main components of the building heating systems play an essential role in terms of energy consumption [1-3].
The importance of energy for economic and social development of any nation is very clear. Energy related emissions are the main reason of the most serious global environmental impacts including climate change, acid deposition, smog and particulates. The key issue is how to make buildings both energetically and exergetically sustainable. Exergy as a thermodynamic analysis tool may help achieve this objective. The low exergy (LowEx) approach is one of these approaches, which has been and still being successfully used in sustainable buildings design [4]. Through the LowEx approach, the energy/exergy flows from the primary energy production to the building envelope are determined to indicate the potential for further improvements in the energy and exergy utilization at each stage of the building heating/cooling system [5].
The main objective of the present study is to assess the performance of various building heating systems in Ankara and Athens, in terms of energetic, exergetic and sustainability aspects by using LowEx approach. For the heating applications, six options are studied with (1) a condensing boiler, (2) an electric boiler, (3) district heat, (4) a solar collector, (5) an air heat pump, (6) a ground heat pump water/water, which are driven by renewable and non-renewable energy sources. Since three-four floor apartment buildings are very common in Turkey, a three-floor apartment building, which has 90 m^2 floor area, will be assessed in this study. In the analysis and assessment, various metrics (indices or indicators) such as exergetic efficiency, exergy flexibility ratio, sustainability index, exergy destruction ratio and environmental destruction coefficient are utilized.

Keywords: Exergy, performance, building heating system, sustainability

INTRODUCTION

Energy consumption in the Greek residential buildings is among the greatestenergy consuming sectors. The national energy balance data, available from theHellenic Ministry of Development report the percentage of energy consumption duringthe past 40 years. Residential dwellings represent 25% of the total energy consumption ofthe Hellenic building stock and consume 32.7% of the total electricity produced inGreece. They consume 21.5% of the total energy [6]
Building can be defined as an open thermodynamic system, which exchanges with the environment energy and material fluxes. The energy analysisconsiders all energy fluxes (such as water, air, fuel etc.), provide to the energy requirement of the building during its useful lifetime. Exergy is a thermodynamic potential measure of energy

and work potential of a system in a reference environment. Exergy analysis is method whichallows a complete thermodynamic assessment of a building energy use by accounting the potential of the energy carriers that cross the system boundary and their destruction. Therefore, exergy can be a powerful tool for the optimisation of a system may be introduced in every natural or built environments.Even though buildings needusually low quality energy carriers for thermal purposes at low temperatures and but the energy demand of the buildings is mainly satisfied by high quality energy sources [7,8].

The low exergy (LowEx) approach is one of the approaches, which has been and still being successfully used in sustainable buildings design. In recent years, the number of various studies on LowEx heating/cooling systems, of which flow temperatures are very close to the room to be heated/cooled, has dramatically increased. Through the LowEx approach, the energy/exergy flows from the primary energy production to the building envelope are determined to indicate the potential for further improvements in the energy and exergy utilization at each stage of the building heating/cooling system.

Considering some LowEx studies [9-13], Balta et al. 2010,studied a ground source heat pump and a low exergy heating system. Theenergy and exergy flows are presented for the selected building boundary conditions. Hasan et al. 2009,investigated the performance of a building by using a dynamic simulation. Low temperature water heating system was compared with floor heating systems and radiator. Their results showed that, the low temperature water heating system had more appropriate temperature levels [9]. Yucer and Hepbasli evaluated an educational building heating system from the point of view of exergy. They accounted the system performance for each stage, namely generation, distribution, emission, and building envelope [10]. Yildirim and Hepbasli, assessed performance of a building heating system in terms of energetic, exergetic and sustainability aspects. They considered two heating options as a condensing boiler and an air heat pump. The overall exergy efficiencies of the heating systems were computed to be 3.3% [14].

The main objective of this contribution is to apply the Lowex approach to a three story building from the generation stage to the building envelope to reveal the inefficiencies of the components and their interrelations. In order to examine the energy efficiency of multi-generational single-family homes in Turkey and Greece, a three story building with basement and a flat roof was chosen as a representative single-family house type building.

1. METEOROLOGICAL DATA

In this study, the main objective is to assess the performance of six different building heating systems in Ankara and Athens, in terms of energetic, exergetic and sustainability aspects by using LowEx approach. Therefore, one of the main parameters of the study is meteorological data for the city of Ankara and Athens. The monthly average outside air temperature are shown in Figure 1.

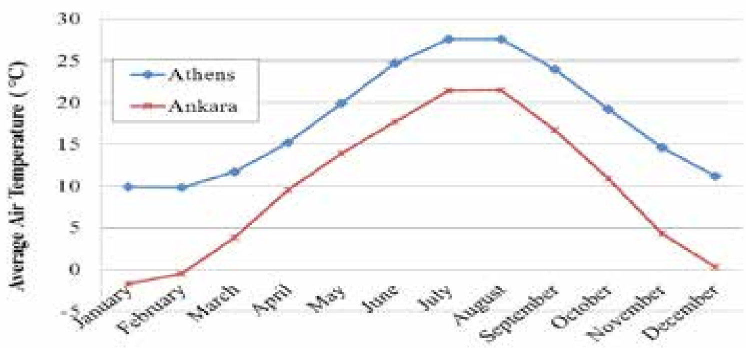

Figure 1. Monthly average air temperature of the city of Ankara and Athens.

The winter design outside temperatures can be taken as -9.4 °C for Ankara and 1.5 °C for Athens with 99.6% frequency [15, 16]. That means the heating system will provide thermal comfort 99.6 percent of the time but may fail to do so during 0.4 percent of the time. The indoor air temperature is taken as 20 °C.

The other vital parameter of the cities is solar radiation per square meter area to calculate the solar heat gain. The daily average solar radiation values of the cities are given in Figure 2 and Table 1.

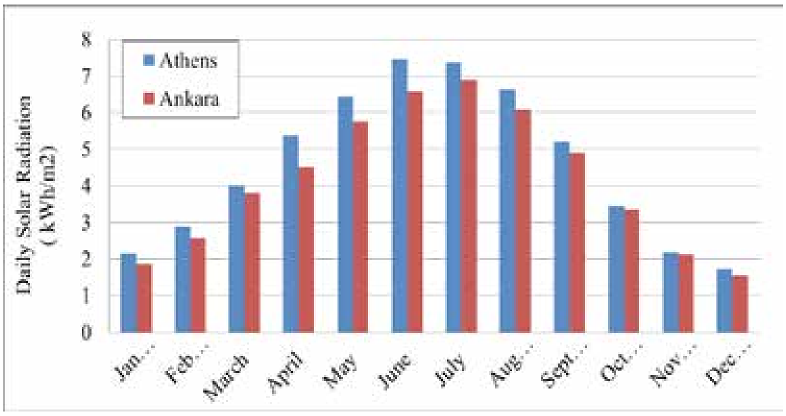

Figure 2. The daily average solar radiation values for the city of Ankara and Athens.

Table 1. The main meteorological data of Ankara and Athens.

Month	ATHENS Air Temperature (°C)	Heating Degree Days (°C-d)	Daily Solar Radiation (kWh/m²/d)	ANKARA Air Temperature (°C)	Heating Degree Days (°C-d)	Daily Solar Radiation (kWh/m²/d)
January	9.9	251	2.14	-1.7	611	1.86
February	9.8	230	2.88	-0.5	518	2.57
March	11.7	195	4.00	3.8	440	3.80
April	15.2	84	5.37	9.5	255	4.51
May	19.9	0	6.43	13.9	127	5.75
June	24.7	0	7.46	17.7	9	6.59
July	27.6	0	7.36	21.4	0	6.89
August	27.6	0	6.62	21.5	0	6.08
September	24.0	0	5.21	16.7	39	4.91
October	19.2	0	3.44	10.9	220	3.35
November	14.6	102	2.18	4.3	411	2.13
December	11.2	211	1.73	0.3	549	1.53
Annual	18.0	1,073	4.58	9.9	3,179	4.17
Annual solar radiation (MWh/m²)		1.67		1.52		

2. SYSTEM DESCRIPTION

In this study, a three-floor apartment building with a volume of 731.8 m^3 and a net floor area of 90 m^2 is considered as a case study. The plan and panoramic view of the apartment building is shown in Fig. 3.

Figure 3. Plan and front view of the considered apartment building.

As it can be seen from Fig.3, each floor has two flats and in the building totally there are six flats.The architectural features, such as direction and size of walls and windows of the building are listed in Table 2.

The construction materials are locally manufactured. The exterior construction consists of load-bearing cavity walls 0.3 m thick. The double wall consists of paint, plaster 0.02 m in the interior, 0.03 m in the exterior plus two layers of bricks of 0.085 m and 0.135 m thickness. Between the bricks 0.3 m thick extruded polystyrene foam insulation exists. The calculated U-value for the exterior wall is 0.533 (W/m^2-K) (Table 3).

Table 2. The architectural features of the apartment building.

Building part/ Direction	Area (m^2)				U-(Thermal transmittance) (W/m^2K)
	E	N	W	S	
Exterior wall	**34.40**	**92.40**	**37.13**	**92.40**	**0.533**
Window	**29.40**	**-**	**29.40**	**-**	**2.4**
Door	**2.73**				**2.4**
Roof	**91.08**				**0.410**
Upper story floor	**11.88**				**0.551**
Floors to ground	**79.20**				**0.611**

Table 3. The thickness and calculated U (thermal transmittance) values of the building construction materials

Wall Component	Layers	Thickness (m)	Thermal Conductivity (W/mK)	U-(Thermal transmittance) (W/m^2K)
Exterior Wall	Inner Plaster	0.02	1.0	0.533
	Brick-1	0.085	0.33	
	Extruded polystyrene foam	0.03	0.03	
	Brick-2	0.135	0.33	
	Exterior Plaster	0.03	1.6	
Ceiling	Inner Plaster	0.01	1.0	0.410
	Reinforced cement	0.13	2.5	
	PVC cover	0.003	0.19	
	Extruded polystyrene foam	0.07	0.035	
	Cement mortar screeds	0.05	1.4	
	Bituminous cardboard	0.003	0.19	
	Cement mortar screeds	0.03	1.4	
	Artificial stones	0.01	1.3	
Ground Contact Floor	Artificial stones	0.01	1.3	0.611
	Cement mortar screeds	0.03	1.4	
	Extruded polystyrene foam	0.06	0.03	
	Plain concrete	0.1	1.65	
	PVC cover	0.003	0.19	
	Cement mortar screeds	0.03	1.4	
	Sand-Gravel	0.1	0.7	
Floor	Artificial stones	0.01	1.3	0.551
	Cement mortar screeds	0.03	1.4	
	Extruded polystyrene foam	0.02	0.03	
	Reinforced cement	0.13	2.5	
	Extruded polystyrene foam	0.02	0.03	
	Exterior Plaster	0.02	1.6	

Fig. 4 shows the energy flows in forms of primary and electricity for a building from primary energy transformation through the heat generation system and a distribution system to a heating system, and from there, via the indoor air, across the building envelope to the surrounding air. All heat flows, heat losses via the envelope, and internal gains, occurring inside the building.

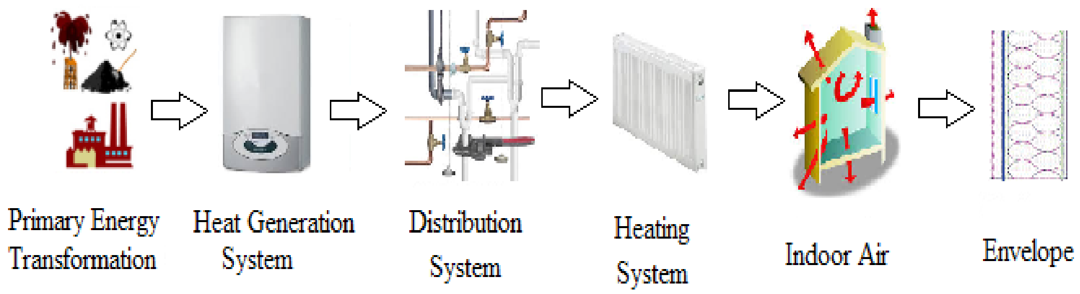

Figure 4. Energy flow from primary energy transformation to the environment [14].

For the heating applications, six options are studied. The considered cases are;

Case 1: A condensing boiler, Case 2: An electric boiler,
Case 3: District heat, Case 4: A solar collector,
Case 5: An air heat pump, Case 6: A ground heat pump water/water.

The distribution systems are considered to have a good insulation.For all cases heat storage is not considered. The DHW energy demand is ignored in this study.

3. ANALYSIS

Energy and exergy analyses of the considered systems are evaluated by an Excel tool, which has been developed within the framework of International Energy Agency (IEA) formed within the Energy Conservation in Buildings and Community Systems Programme (ECBCSP) Annex 37 [17]. The tool and the calculation approach follow the method developed by Schmidt [18]. The main equations of energy analyses are listed in Table 4.

Table 4. Main equations of energy analysis

Heat Losses		
Transmission heat losses [W]	$Q_T = \sum (U_i.A_i.F_{xi})(T_i - T_o)$	(1)
Ventilation heat losses [W]	$Q_V = (c_p.\rho.V.n_d.(1-\eta_V))(T_i - T_o)$	(2)
Heat Gains		
Solar heat gains [W]	$\dot{Q}_S = \sum (I_{s,j}.(1-F_f).A_{w,j}.g_j.F_{sh}.F_{no})$	(3)
Internal gains of occupants [W]	$Q_o = Q_o''.no_o$	(4)
Internal gains of equipment [W]	$Q_e = Q_e''.A_N$	(5)
Other Uses		
Lighting power [W]	$P_l = p_l.A_N = Q_l$	(6)
Ventilation power [W]	$P_V = p_V.V.n_d$	(7)
Heat Demand		
Heat demand [W]	$Q_h = (Q_T + Q_V) - (Q_S + Q_o + Q_e + Q_l)$	(8)
Specific heat demand [W/m²]	$\dot{q}_h = \dot{Q}_h / A_N$	(9)

The total energy input rate per area, $E''_{tot,pa}$ (W/m²), is calculated by

$$E''_{tot,pa} = \frac{E_{tot}}{A_N} \tag{10}$$

The total energy input rate per volume, $E''_{tot,pv}$ (W/m³), is calculated by

$$E''_{tot,pv} = \frac{E_{tot}}{V_N} \tag{11}$$

The total exergy input rate per area, $Ex''_{tot,pa}$ (W/m²), is calculated by

$$Ex''_{tot,pa} = \frac{Ex_{tot}}{A_N} \tag{12}$$

The total exergy input rate per volume, $Ex''_{tot,pv}$ (W/m³), is calculated by

$$Ex''_{tot,pv} = \frac{Ex_{tot}}{V_N} \tag{13}$$

The total energy efficiency of the system, η_{sys} (%), is expressed as follows:

$$\eta_{sys} = \frac{E_{building}}{E_{tot}} \tag{14}$$

The total exergy efficiency of the system, ψ_{sys} (%), is expressed as follows:

$$\psi_{sys} = \frac{Ex_{building}}{Ex_{tot}} \tag{15}$$

The exergy destruction rate of the system, Ex_{dest} (W), can be calculated from:

$$Ex_{dest} = (1 - \psi_{sys})Ex_{tot} \tag{16}$$

In the study, it was explained in the system description section, six different generation systems are considered. Main assumptions and constant parameters of the analysis for all cases are given in Table 5. As a heating system radiators are considered and the supply and return temperatures of the radiators are taken as 70 and 60°C with a heat loss/efficiency of 0.95, respectively. The constant parameters and assumptions of the cases are summarized in Table 6.

Table 5. Main assumptions of the energy and exergy analysis

	Parameter	Unit	Symbol	Value
Heat Losses	Air exchange rate	[ach/h]	n_d	0.4
	Heat exchanger efficiency	[-]	h_V	0.8
	Specific heat of indoor air	[kJ/kgK]	Cp	1.005
	Density of indoor air	[kg/m³]	ρ	1.2

Heat Gains	Window frame fraction	[-]	F_f	0.3
	Total transmittance	[-]	g_j	0.58
	Solar radiation: SE to SW, NW to NE Other directions	[W/m^2]	$I_{s,j}$	130 54 121
	Emitted heat per occupant	[W/person]	[illegible]	80
	Specific internal gains of equipment	[W/m^2]	[illegible]	2.05
Other Uses	Specific lighting power	[W/m^2]	p_l	2
	Specific ventilation power	[W/m^2]	p_V	0.26
Distribution System	Temperature drop	[K]		<5
	Heat loss/efficiency	[-]	h_{dis}	0.86
	Auxiliary energy	[W/kW$_{heat}$]	$p_{aux,dis}$	9.02
Storage	Solar fraction	[-]	F_S	0
Heating System	Radiator inlet temperature	[°C]	T_{in}	70
	Radiator return temperature	[°C]	T_{ret}	60
	Auxiliary energy	[W/kW$_{heat}$]	$p_{aux,H}$	0.2
	Max. heat emission	[W/m^2]	$p_{heat,max}$	100
	Heat loss/efficiency	[-]	h_{H}	0.95

Table 6. Main assumptions and constant parameters of the cases for heat generation.

Parameter	Unit	Symbol	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Efficiency	[-]	h_{B}	0.95	0.98	0.70	0.70	2.5	1.53
Primary energy factor source	[-]	F_P	1.30	3.00	2.00		3	3.00
Quality factor of source	[-]	$F_{q,S}$	0.95	1.00	0.21	0.23	1	1.00
Max. supply temperature	[°C]	$T_{CB,max}$	75	75	75	75	75	75
Auxiliary energy	[W/kW$_{heat}$]	$p_{aux,Gen}$	1.80	0.02	0.01	0.01	10	10
Auxiliary energy constant	[W]	$P_{aux,gen,const}$	20			0.70		
Primary energy electricity factor	[-]	F_{Pel}	3				3	

4. RESULTS

The energetic and exergetic performance of a three-floor apartment building with a volume of 731.8 m^3 and total net floor area of 275.4 m^2, located in the city of Ankara-Turkey and Athens-Greeceare evaluated. The exterior air temperatures are taken as -9.4 °C for Ankara and 1.5°C for Athens.

According to the data, the heat demand rate and the specific heat demand rate of the building calculated are 7425.22 W and 26.96 W/m^2 for Ankara, 3332.02 W and 12.10 W/m^2 for Athens, respectively.

For selected cases energy flow in the subsystems is calculated (Table 7- Fig.5). Energy rate range of Athens is between 7612.3- 14399.7 W, for Ankara the range is between 14579.5-29778.5 W. Table 7 also represents that energy demand of the indoor air, heating system and the distribution system are as equal to for all cases.

Table 7. Energy flow of the selected cases

ENERGY FLOW	Case 1		Case 2		Case 3		Case 4		Case 5		Case 6	
(W)	Ankara	Athens	Ankara	Athens	Ankara	Athens	Ankara	Athens	Ankara	Athens	Ankara	Athens
Input	14579.5	7612.3	29778.5	14399.7	27932.8	13571.4	15014.9	7774.6	18644.6	9403.4	22988.1	11352.5
After primary transformation	10253.6	4957.9	9926.2	4799.9	13616.9	6456.1	13616.9	6456.1	9831.9	4757.6	9759.5	4725.1
After generation	9114.5	4090.1	9114.5	4090.1	9114.5	4090.1	9114.5	4090.1	9114.5	4090.1	9114.5	4090.1
After distributon	7817.5	3508.1	7817.5	3508.1	7817.5	3508.1	7817.5	3508.1	7817.5	3508.1	7817.5	3508.1
After heating system	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0
After indoor air	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0
After envelope	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0	7425.2	3332.0

Additional to energy analysis a detailed exergy analysis is conducted for selected cases. As shown in Table 8 exergy rate range of Athens is between 1977.8 – 14399.7 W, for Ankara the range is between 7522.5 - 29778.5 W.

Table 8. Exergy flow of the selected cases

EXERGY FLOW	Case 1		Case 2		Case 3		Case 4		Case 5		Case 6	
(W)	Ankara	Athens	Ankara	Athens	Ankara	Athens	Ankara	Athens	Ankara	Athens	Ankara	Athens
Input	13960.8	7334.7	29778.5	14399.7	7522.5	4412.4	15014.9	1977.8	18644.6	9403.4	22988.1	11352.5
After primary transformation	9669.5	4684.7	9854.0	4767.5	3339.7	1844.2	3598.0	1960.2	4243.9	2250.0	6524.2	3273.3
After generation	3314.2	1242.0	3314.2	1242.0	3314.2	1242.0	3314.2	1242.0	3314.2	1242.0	3314.2	1242.0
After distributon	2939.8	1091.0	2939.8	1091.0	2939.8	1091.0	2939.8	1091.0	2939.8	1091.0	2939.8	1091.0
After heating system	1219.0	431.9	1219.0	431.9	1219.0	431.9	1219.0	431.9	1219.0	431.9	1219.0	431.9
After indoor air	744.7	210.3	744.7	210.3	744.7	210.3	744.7	210.3	744.7	210.3	744.7	210.3
After envelope	0	0	0	0	0	0	0	0	0	0	0	0

The energy and exergy flow diagram of the system is shown in Fig. 5. It is obvious from Fig. 5 that the amount of exergy is consumed in each component for all cases. There is still a remarkable amount of energy left while the flow of energy leaves the building envelope (Fig. 5), but for exergy the situation is not same. The total exergy is zero while the flow of energy leaves the building envelope Therefore, exergy flow on the last row at the Table 8 has to be zero.

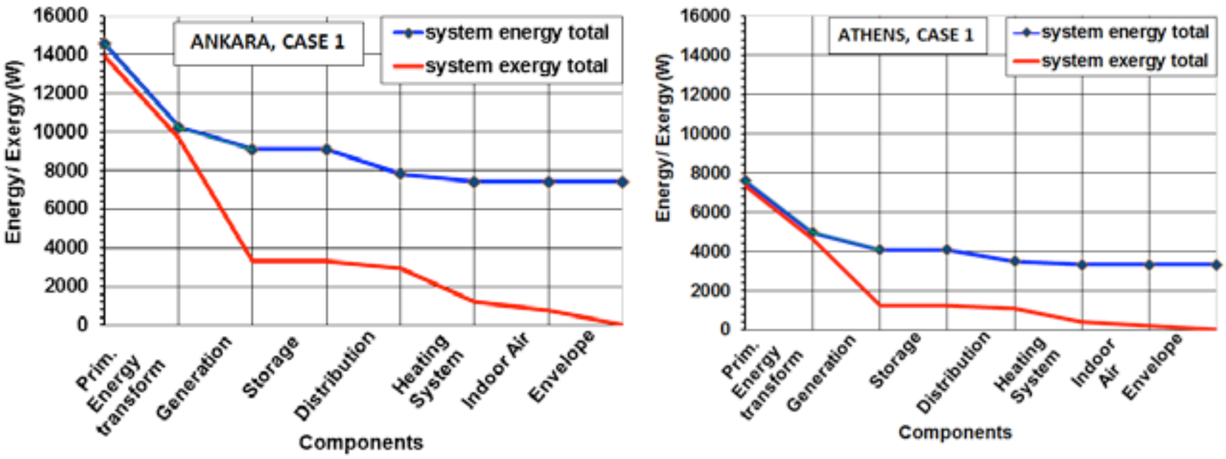

Figure 5. Energy and exergy flow of the considered buildings for case 1

The variations of energy and exergy loss rates through components are illustrated in Fig.6 and given in Table 9. Case 2 has the highest exergy loss rate in heat generation components with 19924.51 W and 9632.2 W for Ankara and Athens, respectively.

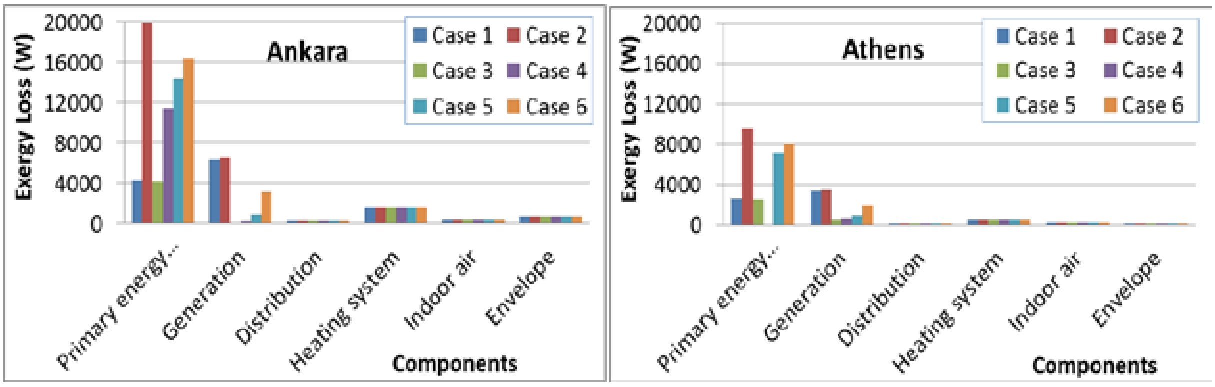

Figure 6. Exergy loss of the selected cases.

Table 9. Exergy loss of the selected cases

Components	EXERGY LOSS (W)											
	ANKARA						ATHENS					
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Primary energy transform	4291,4	19924,5	4182,8	11416,9	14400,6	16463,9	2650,0	9632,2	2568,2	17,6	7153,4	8079,3
Generation	6355,2	6539,8	25,4	283,8	929,7	3210,0	3442,7	3525,5	602,3	718,2	1008,1	2031,3
Distribution	374,5	374,5	374,5	374,5	374,5	374,5	150,9	150,9	150,9	150,9	150,9	150,9
Heating system	1720,7	1720,7	1720,7	1720,7	1720,7	1720,7	659,1	659,1	659,1	659,1	659,1	659,1
Indoor air	474,4	474,4	474,4	474,4	474,4	474,4	221,7	221,7	221,7	221,7	221,7	221,7
Envelope	744,7	744,7	744,7	744,7	744,7	744,7	210,3	210,3	210,3	210,3	210,3	210,3

Case 1 has the highest and Case 2 has the minimum overall energy efficiencies for both cities. The overall energy efficiency range of the selected cases is 24.9-50.9 % for Ankara and 23.1-43.8% for Athens. On the other hand Case 4 has the highest the overall exergy efficiencies among the selected cases with 19.6 % and 21.8% for Ankara and Athens, respectively (Fig. 7). Case 4 is used a solar collector. Since Athens has higher daily solar radiation and air temperature than Ankara, its overall exergy efficiency is also higher than Ankara's.

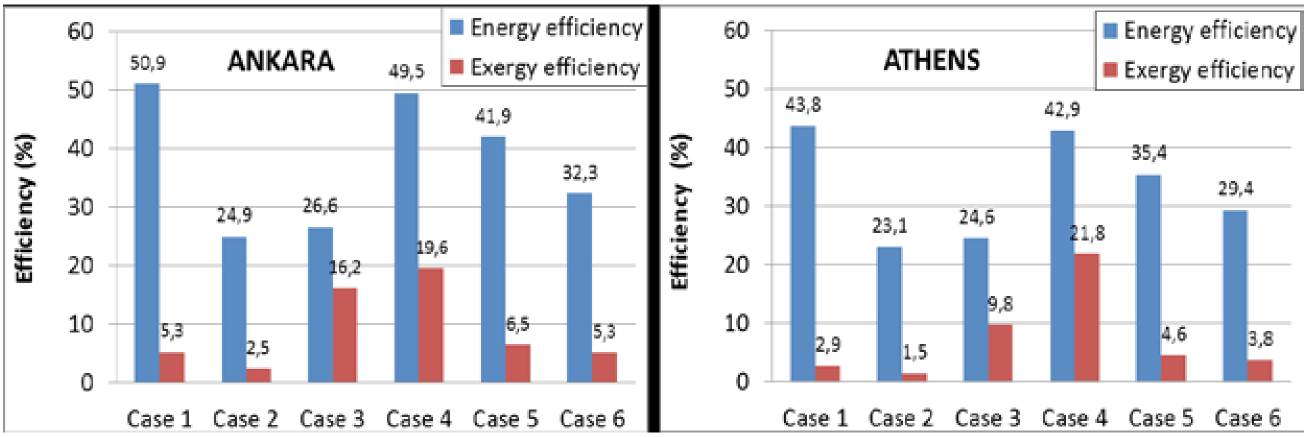

Figure 7. Energy and exergy efficiencies of the selected cases.

Finally, results of the energy and the exergy analyses and total energy and exergy input per area / volume are summarized in Table 10. The minimum exergy input per area and volume is 7.2 W/m2 and 2.7 W/m3 for Case 4 of Athens, and the maximum is 108.1 W/m2 and 40.7 W/m3 for Case 2 of Ankara, respectively.

Table 10. Results of the Energy and the exergy analyses and total energy and exergy input per area / volume

Studied cases	$\dot{E}''_{tot,pa}$ (W/m²)		$\dot{E}''_{tot,pv}$ (W/m³)		$\dot{Ex}''_{tot,pa}$ (W/m²)		$\dot{Ex}''_{tot,pv}$ (W/m³)	
	Ankara	**Athens**	**Ankara**	**Athens**	**Ankara**	**Athens**	**Ankara**	**Athens**
Case 1	52,9	27,6	19,9	10,4	50,7	26,6	19,1	10,0
Case 2	108,1	52,3	40,7	19,7	108,1	52,3	40,7	19,7
Case 3	101,4	49,3	38,2	18,5	27,3	16,0	10,3	6,0
Case 4	54,5	28,2	20,5	10,6	54,5	7,2	20,5	2,7
Case 5	67,7	34,1	25,5	12,8	67,7	34,1	25,5	12,8
Case 6	83,5	41,2	31,4	15,5	83,5	41,2	31,4	15,5

CONCLUSIONS

In this study, a comprehensive energy and exergy analysis for sustainable buildings are considered and applied to six different heating options with (1) a condensing boiler, (2) an electric boiler, (3) district heat, (4) a solar collector, (5) an air heat pump, (6) a ground heat pump water/waterfor a three-floor apartment building with a volume of 731.8 m³ and a net floor area of 90 m² is considered as a case study fort he cities of Athens and Ankara. Their energetic end exergetic performance is evaluated by applying Lowex approach. For that reason energy dispersals, energy and exergy flow, energy and exergy losses are determined and illustrated to compare the selected cases of both cities.

The main conclusions drawn from the results of the present study may be listed as follows:

- The energy demand rate of the building is 7425.22 W for Ankara and 3332.02 W for Athens.
- The minimum and maximum primary energy rates are 14579.5 W and 29778.5 W for Ankara, 7612.3 W and 14399.7 W for Athens, respectively. Case 2, an electric boiler, requires the highest primary energy rates.
- While Case 4, a solar collector, has the minimum exergy demand rates of the heating systems with 1977.8 W for Athens, Case 3, district heat, has the minimum exergy demand rate for Ankara with 7522.5 W.
- The highest exergy loss rateoccurs in primary energy transformation for Case 2 for both cities.
- Ankara has the highest overall energy efficiency for Case 1, a condensing boiler, with 50.9%, Athens has the highest overall exergy efficiency for Case 4, a solar collector, with 21.8%.
- According to overall exergy efficiency of the Case 4, a solar collector, is the best option for both cities.

Nomenclature

A	area (m^2)	*flex*	flexibility
c_p	specific heat at constant pressure (kJ/kg.K)	*HS*	heating system
$\dot{E}$	energy rate (W)	*i*	indoor, counting variable
$\dot{Ex}$	exergy rate (W)	*in*	input, inlet
F	factor (-)	*ins*	insulation
g	total transmittance (-)	*j*	counting variable
I	radiation intensity (W/m^2)	*l*	lighting
l	length (m)	*loss*	thermal losses
n_d	air exchange rate (1/h)	*max*	maximum
n_o	number (-)	*N*	net
P	power (W)	*no*	effect of non-orthogonal radiation
p	specific power, pressure (W/m^2, N/m^2)	*o*	outdoor, occupants
$\dot{Q}$	heat transfer rate (kW)	*p*	primary energy
R	pressure drop of the pipe (Pa/m)	*pa*	per area
T	temperature (K)	*plant*	plant
U	thermal transmittance (W/m^2K)	*pv*	per volume
$\dot{V}$	volumetric flow rate (m^3/s)	*q*	quality
V	volume (m^3)	*R*	renewable energy
Greek letters		*ref*	reference
η	energy efficiency (-)	*ret*	return
ψ	exergy efficiency (-)	*S*	solar,
ρ	density (kg/m^3)	*s*	source
Δ	difference	*sh*	shading effects
Subscripts		*sys*	system
air	indoor air	*T*	transmission
aux	auxiliary energy requirement	*td*	temperature drop
circ	circulation	*tot*	total
dest	destruction	*usf*	useful

dis	distribution system	*V*	ventilation
dt	design temperature	*w*	window,water
En	energetic	*x*	part x
Ex	exergetic	***Superscripts***	
e	equipment	over dot	rate
el	electricity	***Abbreviations***	
env	environment	COP	coefficient of performance
ex	external	DHW	domestic hot water
f	window frame, parameter		

REFERENCES

[1] Baumert, K. A., Herzog, T. and Pershing, J., (2005), "Navigating the Numbers: Greenhouse Gas Data and International Climate Policy", Washington, DC: World Resources Institute.

[2] "Directive of the European Parliament and the Council on the Energy Performance of Buildings 2008" date: 19 November 2008 , http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098

[3] European Parliament (EP), 2010. "Directive of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings" Directive 2010/31/EU.

[4] Balta, M.T.. "Performance and sustainability assessment of energy options for building HVAC applications", Energy & Buildings, 201008.

[5] Yucer, Cem Tahsin, and Arif Hepbasli. "Exergoeconomic analyses of an energy supply chain for space heating in a building", Energy and Buildings, 2013.

[6] Maria Davaki, Analysis of Energy Use in Typıcal Greek Residential Buildings and Proposed Retrofit Strategies, M.Sc. Thesis of High Performance Buildings in the School of Architecture, Georgia Institute of Technology, August 2011

[7] Baldi, Marta Giulia, and Lorenzo Leoncini. "Thermal Exergy analysis of a building." Energy Procedia 62 (2014): 723-732.

[8] Dovjak, Mateja, Masanori Shukuya, and Aleš Krainer. "Connective thinking on building envelope–Human body exergy analysis." International Journal of Heat and Mass Transfer 90 (2015): 1015-1025.

[9] A. Hasan, J. Kurnitski, K. Jokiranta. A combined low temperature water heating system consisting of radiators and floor heating. Energy and Buildings, 41 (2009), pp. 470–479.

[10] C.T. Yucer, A. Hepbasli. Thermodynamic analysis of a building using exergy analysis method. Energy and Buildings, 43 (2011), pp. 536–542.

[11] M.T. Balta, I. Dincer, A. Hepbasli. Performance and sustainability assessment of energy options for building HVAC applications. Energy and Buildings, 42 (2010), 1320-1328.

[12] M.T. Balta, I. Dincer, A. Hepbasli. Development of sustainable energy options for buildings in a sustainable society. Sustainable Cities and Society, 1 (2011), 72-80.

[13] M. T. Balta, Exergetic cost analysis and sustainability assessment of various low exergy heating systems. Energy and Buildings, 55 (2012) 721-727.

[14] Yildirim N ., Hepbasli, A., "Exergetic and Sustainability Evaluation of a Building Heating System in Izmir, Turkey", Proceedings of International Conference on Environment and Renewable Energy (ICERE2014), 18-19 September, 2014, Rome, Italy.

[15] T. Yilmaz, H. Bulut, New Design Outside Temperature Values of Turkey, Proceedings of V. National Sanitary Systems Engineering Congress and Exhibition, Izmir, Turkey, (2001) (in Turkish).

[16] Retscreen software, Meteorological properties of Athens, http://www.nrcan.gc.ca/energy/software-tools/7465, 2016

[17] IEA, Low exergy heating and cooling of buildings–Annex 37.http://www.vtt.fi/rte/projects/annex37/Index.htm, 2008 (retrieved 19.05.08).

[18] D. Schmidt, Design of low exergy buildings-method and a pre-designtool, International Journal of Low Energy and Sustainable Buildings (2003)1–47.

Paper No: 103

Analysis of Fourth-Generation District Energy Systems with Renewable Energy Cogeneration by Using Rational Exergy Management Model

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ABSTRACT

Recent 4th-generation district energy systems envision optimum bundling of different energy resources and conversion systems with main emphasis on sustainability and renewable energy use. Because renewable energy sources generally have low exergy and some of them are interrupted, they must be stored, time and exergy matched with low-exergy demands. The complex nature of the source and demand hybridization requires new exergy focused controls based on ***Rational Exergy Management Model***. This need actually defines the main concept of smart metropolis. In this paper a new algorithm for optimizing the exergy bundling of renewable energy and conversion systems in cogeneration format with low-exergy metropolis demands is described with the objective of minimizing the CO_2 emissions. A second algorithm for the control of the hybrid system, which is tested in a smaller scale in a LEED Platinum building Ankara has been adopted and projected to typical metropolis. New definitions like Net-Zero Exergy Metropolis, Net-Zero Carbon Metropolis are also described. The paper concludes that the Second Law of thermodynamics leading to the exergy concept is the primary player in developing smart metropolis and minimizing their carbon foot print.

INTRODUCTION

Districts have several tasks to accomplish with highest reliability and best sustainability while facing time-dependent loads of different forms and exergy. Fig. 1 shows typical hourly variation of thermal and power loads of a District. According to this figure, peaks of different loads are not coincident and every different load has a different profile. Consequently, not only the magnitudes but also the load proportions change with time. Large variations of different load proportions are particularly important for cogeneration systems, because they deliver heat and power almost at a constant ratio over their regular operational range. All these factors make it necessary to employ more than one energy conversion system and to bundle various energy sources, preferably by utilizing different sustainable systems. This makes it essential to extensively use TES (Thermal Energy Storage) systems and –if feasible to employ- electrical storage systems, besides grid exchange. One also needs to know the availability of renewable energy systems on an hour-by-hour basis for a sustainable and near-zero design and operation. In addition, controls, systems, and equipment primarily respond to comfort cooling and heating loads, which impose time-dependent temperatures: not only the magnitudes and proportions of loads change but at the same time demand temperatures for thermal equipment and systems change continuously. For example, in a HVAC system supply temperatures are proportionately controlled with respect to outdoor air temperature, which affect the system and equipment performance. Finally, the factors that affect part-load efficiency of the equipment must be also considered in order to yield accurate hourly equipment energy demand data [1].

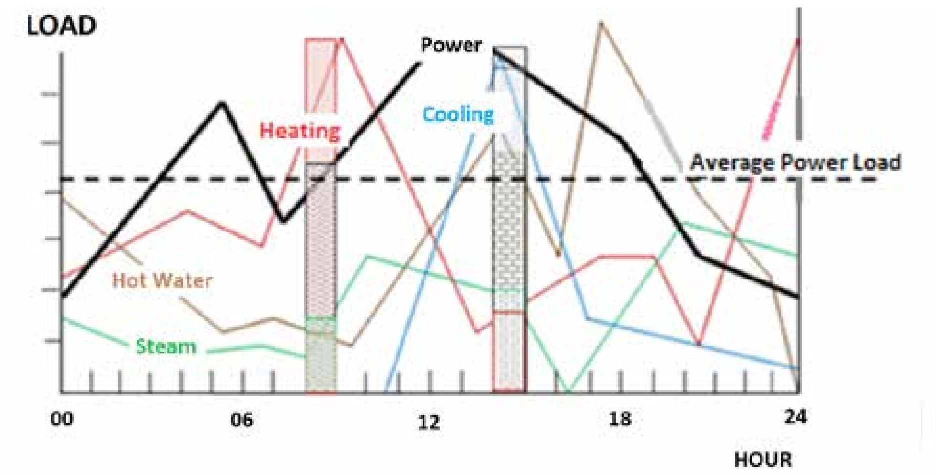

Figure 1 Typical Daily Load Profiles in a District [1]

On the other hand, Districts are becoming a vital partner of the built environment and get multi-dimensionally connected to the cities forming a nexus of economy, energy (exergy), and environment. For example, Districts send their trash to biogas plants in the nearby cities and receive power and energy in return. For a sustainable future, the most recent trend is to connect Districts to 4DE (Fourth Generation) district energy systems in the built environment, where low-temperature heat (for DHW, LowEx heating), high-temperature heat (for conventional space heating, process heat), moderate-temperature cold (space cooling), low-temperature cold (process cold) and power generated with conventional and renewable energy systems and resources are exchanged at various exergy levels. Solar energy is used to generate power in the built environment widely [2]. However, when it comes to harvest solar and wind energy, Districts face serious limitations due to air traffic safety. Generally new District construction and their operation may impose serious environmental risks [3]. In spite of all these complexities, U. S. Department of Energy (DOE) has recently defined Zero-Energy Building (ZEB) in an over simplistic format by using only the First-Law of Thermodynamics [4]. In their definition, energy supplied-received balance is simply based on an annual single cumulative basis of all kinds of energy with different exergy values without taking into account the exergy variations and associated CO_2 emissions, which are hidden in the Second-Law. This issue was first addressed by [5] by developing new definitions for net or near building in terms of exergy (NZEXB, nZEXB). In fact, according to Marszal and Heiselberg, the definition of net or near zero building is quite complicated [6].

THEORY

Several European countries are in the process of developing and implementing their road maps for near-zero energy buildings (nZEB) according to the relevant EU Directive for High Performing Buildings. There are several definitions for nZEB concept and all models, definitions, and implementations are based on the First-Law, which only deal with the quantity of the energy exchange between the building, grid, and the district [5]. Current practice is primarily focused on electric power exchange. Today, Denmark is the only EU country that factors-in the thermal energy exchange. Thermal energy at different states and temperatures mean a wide variation of the thermal energy quality (exergy). Other shortcomings of the current NZEB or nZEB definitions, which may be inferred from Kılkış, Ş. [5, 7, 8, 9] are:

- Thermal energy exchange definitions must distinguish different forms of heat like steam, hot water, service water, cold water etc.
- Quality of energy exchange needs to be embedded in the nZEB definition.
- The quality of energy exchanged in calculating the harmful emissions must be taken into account by a new definition.

More importantly, the temperatures of the heat received from and supplied to a district system must be taken into account in determining the supply and demand exergy balance as shown in Fig. 2. For example, an exergy exchange deficit occurs in the grid-connected building if the building delivers 30°C water to the district but receives 40°C water from the district in the same amount over a given period of time. A similar deficit occurs for cooling, because exchange temperatures of the chilled water are different.

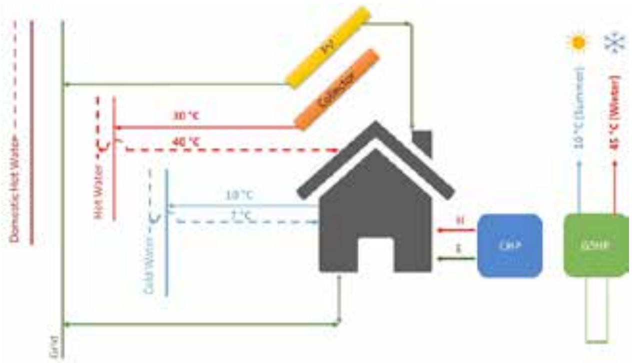

Figure 2 Supply and Return temperatures between a Sustainable Building and DE System [9]

Therefore, the unit exergy of each 1 kW-h of the supply heat, ε_{sup} according to the ideal Carnot Cycle must be considered. Eq. 1-a may also be used for destroyed exergy and demand exergy. Equations 1-a,1-b, 2, and 3 establish the energy, environment, and economy nexus, respectively.

<u>Energy</u>

$$\varepsilon_{\mathrm{sup}} = \left(1 - \frac{T_{ref}}{T_{sup}}\right) \times (1\,\mathrm{kW\text{-}h}) \qquad \text{\{Unit Exergy\}} \qquad (1\text{-a})$$

$$E_x = \varepsilon_{\mathrm{sup}} \times Q_{\mathrm{sup}} \qquad \text{\{Energy and Exergy\}} \qquad (1\text{-b})$$

$$\psi_R = 1 - \frac{\sum \varepsilon_{des}}{\varepsilon_{\mathrm{sup}}} \qquad \text{\{Rationality of Energy Use\}} \qquad (1\text{-c})$$

Eq. 1-a through 1-c establish the energy and exergy metric of the nexus. For a green district and subscribing building the annual average of ψ_R must be greater than 0,70.

Environment

$$\sum CO_2 = \left[\frac{c_l}{\eta_l} + \frac{c_m}{\eta_m \eta_T}(1-\psi_R)\right] Q_H + \frac{c_m}{\eta_m \eta_T} E \qquad \{\text{Environment}\} \qquad (2\text{-a})$$

Eq.2-a, which is derived from the Rational Exergy Management Model (REMM) establishes the environment metric of the nexus. At below, *EDR* is the Ratio of Emissions Difference. The CO_{2base} term is the standardized emission rate calculated with practical defaults for 0,5 kW-h thermal and 0,5 kW-h electrical load per hour (*C* =1). See Eq. 2-c, where CO_{2base} is 0,63 kg CO_2/kW-h, which is derived from Eq. 2-a. *EDR* must be close to one.

$$EDR = 1 - [CO_{2on\text{-}site}/CO_{2\,base}] \qquad \{\text{Emissions are based on REMM}\} \qquad (2\text{-b})$$

$$\sum CO_2 = \left[\frac{0{,}2}{0{,}85} + \frac{0{,}2}{0{,}35}(1-0{,}2)\right] 0{,}5 + \frac{0{,}2}{0{,}35} 0{,}5 \qquad (2\text{-c})$$

Economy

$$PES = \left[1 - \frac{1}{\left(\frac{\text{CHPH}\eta}{\text{RefH}\eta} + \frac{\text{CHPE}\eta}{\text{RefE}\eta}\right) \times \frac{(2-\text{Ref}\psi_R)}{(2-\psi_R)}}\right] \times 100 \qquad \{\text{Economy}\} \qquad (3)$$

Eq. 3 provides the economy metric, where *PES* must be greater than 35% in order to qualify for a green status. In order to satisfy the above metrics, a complex design example for achieving NZEXAP status is shown in Fig. 3 (Kilkis, B., 2012). In this design the combined heat and power system (CHP) is supported by renewable energy systems including solar collectors, PV systems, and their derivatives, and remote green electricity power from wind. Buildings and large complexes need to use radiant heating and cooling systems and thus may easily qualify for Low-Exergy Building status, while they employ moderate working temperatures. Thus solar energy may be directly utilized in their HVAC systems. Hot water, chilled water, and ice tanks shave the peak loads, shift the loads to converge to the supply profiles, and match the thermal exergy levels of various supplies and demands in the complex.

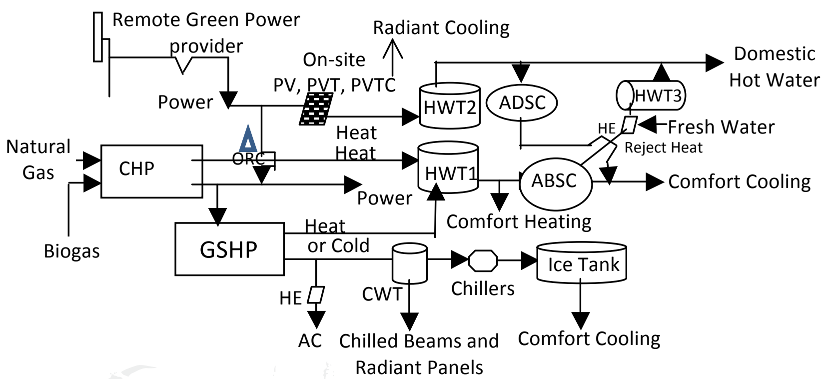

Figure 3 NZEXAP Tri-generation Plant Design

NEW DEFINITIONS

NZCB: Net-zero carbon building is a building, which on an annual basis has an EDR value of one (See Eq. 2-b).
nZCB: Near-zero carbon building is a building, which on an annual basis has an EDR value equal or greater than 0,80.
NZEXD: Net-zero Exergy District is a district, which has its own (local) centralized and/or distributed energy system in the same district, which on an annual basis, supplies the same total exergy of heat and power to the local district energy system subscribers as the total exergy of heat and power received from them. Exergy of power and different thermal energies like heat or cold or at different temperatures are calculated separately on the ideal Carnot Cycle and then summed.
nZEXAP: A district energy complex, which satisfies NZEXAP conditions by at least 80% on the annual exergy balance sheet.
nZEXB: Near- zero Exergy Building. It is an individual building or compound connected to the district, which on an annual basis provides at least 80 % of the total exergy of heat and power to the district as the total exergy of heat and power received from the district. Exergy of power and different thermal energies like heat or cold or at different temperatures are calculated separately and then summed.
LoWEXB: Low-Exergy Building is a building, which can satisfy its heating loads with low exergy sources at about 40°C and sensible cooling loads at about 15°C to 18°C.

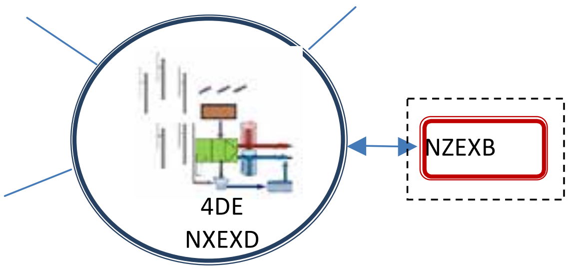

Figure 4 NZEXD and NZEXB

MtoEX: Another major universal flaw in the literature and energy platforms is the use of Mtoe (Megaton of oil equivalent), which is obviously a First-Law definition for a given quantity of energy. Crude oil has a standardized adiabatic flame temperature, AFT (About 2373 K) and its unit exergy, ε_{sup} is 0,881 W/W in terms of the ideal Carnot cycle. Its exergy, E_X is 10,246 MW-h for an energy amount, Q of 11,63 MW-h for one tonne of crude oil. Now consider 11,63 MW-h of hot water supplied by solar energy at 50°C (ε_{sup} = 0,124 W/W). According to the widely-used Mtoe definition, this amount is exactly 1 Mtoe. In contrary to this misleading equivalency, 11,63 MW-h of water at 50°C has only 1,44 MW-h exergy (0,124 W/W x 11,63 MW-h), which is equivalent to only 0,14 tonne of oil (1,44/10,246). Obviously, exergy of solar heat and crude oil do not match at all.

OPTIMIZATION OF 4DE SYSTEMS

Fig. 5 shows a typical daily power load profile at different (c) values with respect to P_P (Peak power load). (c) is the ratio of the selected capacity of a cogeneration plant to the peak power load. For example, if a tri-generation system in Fig. 5 is selected with a capacity equal to P_P, then it will only operate for about only two hours at a capacity near to its full capacity. At the same time because most CHP engines are not allowed to operate below 40% capacity, it will remain idle for about 9 hours in a typical day. Unless cascaded, the CHP unit at part load will have reduced efficiency. It is obvious that NZEXAP or nZEXAP conditions may only be satisfied and energy, environment, and economy nexus be established by a careful selection of the tri-generation plant. Therefore, the capacity(ies) of CHP systems must be carefully optimized and cascaded, if necessary.

Figure 5 Typical Hourly Change of Power Demand

Objective Function and its Simplification

The primary objective is to maximize the performance of a CHP system under the energy, environment, and economy nexus. Main parameters are First-Law efficiency (η), (c) value, Operating Factor (IF), Rational Exergy Management Efficiency (ψ_R), CO_2 emissions, and economic return. Terms (j) and (l) are correlation parameters.

$$OF = f(\eta, c_i, IF, \Psi_R, CO_2) \qquad \{\text{Maximize}\} \qquad (4\text{-a})$$

(c_i) for natural gas it is 0,2 kg CO_2/kWh-h. IF depends on (c) that is shown in Fig. 6, where $IF = f(c)$ [8].

$$OF = \left[\frac{0{,}6 + j(IF - 0{,}6)^l}{0{,}9}\right] + \left[\frac{IF)}{0{,}9}\right] + \left[\frac{0{,}088}{\left(\frac{c_i}{\eta}\right)(1 - \psi_R)}\right] \qquad (4\text{-b})$$

Where,

$$\eta_l = \left[\frac{0{,}6 + j(IF - 0{,}6)^l}{0{,}9}\right] \qquad (5)$$

After taking the upper limit of $\Psi_R \leq \eta_{EX}$ conditional inequality, assuming $C = 1$, and using the upper limit of the $\eta_{EX} \leq 0{,}9 \cdot \eta_I$ conditional inequality, Eq. 4-b reduces to a single-variable expression.

$OF = f^*(c)$. {Maximize} (6-a)

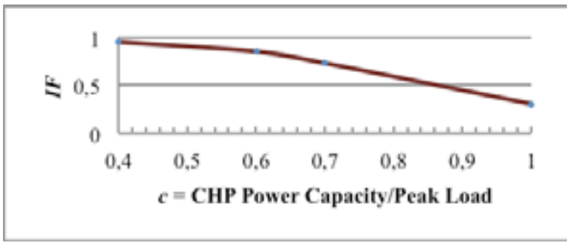

Figure 6 Approximate Change of IF with (c)

Provided that for gas engines (c) must be greater or equal to 0,4, Eq. 6-b gives the initial solution:

$$\frac{dOF}{dc} = 0 \qquad (6\text{-b})$$

<u>Constraints of the nexus:</u>
$\eta_I \geq 0{,}80$,
$0{,}4 \leq c \leq 0{,}75$, $0{,}7 \leq IF \leq 1$,
$\Psi_R \geq 0{,}6$, $CO_2 \leq CO_{2base}$.

Once the optimal (c) value is determined, the CHP system may be cascaded, in optimal numbers and individual capacities depending upon the daily-averaged hourly load profiles. In general, the first cascade is allocated to the minimum continuous load (24 hours a day), the second one is sized such that it operates about 16 hours a day between its full capacity and 60% capacity, and the remaining one(s) are sized for peaking purposes such that they operate about 8 hours a day between full capacity and 75% capacity. Extreme caution must be exercised for these practical set of capacities and cascading schemes. Instead, they must be selected after an hourly load-based economic analysis, with an objective of achieving a simple return period of at most four years.

AUTOMATION

Without a dedicated general automation system, a 4DE system will not operate successfully. A novel automation system was developed for the ESER LEED Platinum Building in Ankara Turkey, keeping in mind that the same algorithm is expandable to the district level. A green and hybrid electromechanical system consists of several energy sources, energy conversion systems, and varying time based performance values, as a requirement of the system. Eser Green Building is also designed and constructed as a high performance green building and has various green and hybrid systems incorporated within its electromechanical structure. The building has platinum certification from LEED. Winter and summer operation diagrams of ESER Green Building are given in Figure 1 and Figure 2. It is almost impossible for these different systems to work together in harmony and supply various energy and power demands of the building and achieve the desired energy savings with the use of the existing Building Management Systems. An automation algorithm for high performance buildings, based on exergy balance between supply and demand was developed. This software is called as "Rational Exergy Automation (AEO) Program". The main objective of the algorithm is to deliver exergy from on-site sustainable systems and other equipment to various demand points with maximum supply and demand exergy balance. Increasing the balance reduces exergy destructions and thus compound CO_2 emissions [10]. The method is based on Rational Exergy Management Model (REMM).

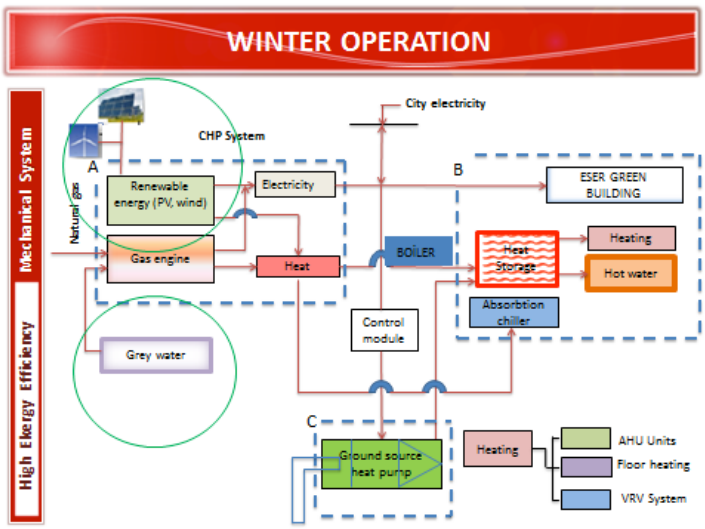

Figure 7 Winter Operation Scheme for the District

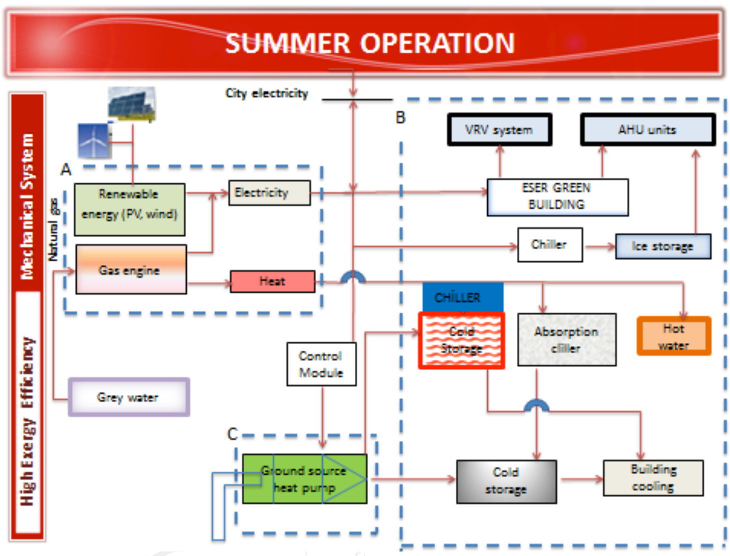

Figure 8 Summer Operation Scheme for The District

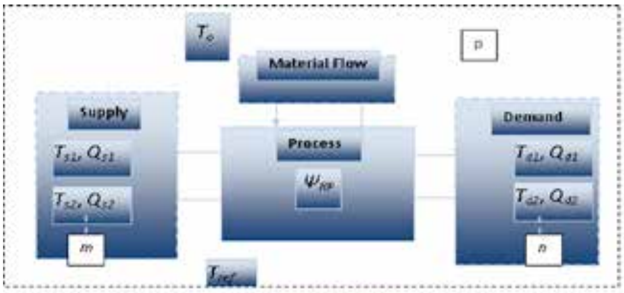

Figure 9 Basic REMM Block

$$\bar{\Psi}_R = \frac{\sum \Psi_{ij} \times \frac{Q_{ij}}{\eta_{ij}}}{\sum \frac{Q_{ij}}{\eta_{ij}}} \qquad (7)$$

Equation 7 gives the overall REMM efficiency of the district with *m* supply points and *n* demand points. If there are a colocation of sub-districts, then *p* is the number of sub-districts.

CONCLUSIONS

In this paper the importance of exergy rationality in net-zero or near-zero buildings connected to 4DE systems was discussed and new definitions were made. It has been shown that net-zero or near-zero exergy building definitions are more realistic and definitive compared to the DOE definition. In the same token, CO_2 emissions need to be calculated according to both First and Second Laws of thermodynamics. In this respect a new zero carbon definition was also made, which supersedes previous definitions, being developed only in terms of the First-Law.

SYMBOLS

c	Ratio of the selected CHP power generation capacity to the peak power demand
c_i	Unit CO_2 emissions of any fuel combustion (*i*), kg CO_2/kW_h-h
C	Power to heat ratio of CHP, dimensionless
CHPEη	Partial electrical power generation efficiency of CHP, dimensionless
CHPHη	Partial thermal power generation efficiency (including steam) of CHP, dimensionless
CO_2	Carbon dioxide emission, kg CO_2
EDR	Ratio of carbon CO_2 emissions difference to the base emission, dimensionless
E_x	Exergy, kW or kW-h
IF	Operating factor, dimensionless
OF	Objective function, dimensionless
PES	Primary energy savings percentage (According to Rational Exergy Management Model, REMM)
Q	Thermal load, kW-h
RefEη	Reference value for partial power generation efficiency of CHP, dimensionless

RefHη Reference value for partial thermal generation efficiency of CHP, dimensionless

T Temperature, K

Greek Symbols

$Ref\psi_R$ Reference value of ψ_R, 0,2

η First-law efficiency, dimensionless

η_{EX} Second-law efficiency, dimensionless

η_T Power transmission and distribution efficiency (Eq. 2-a)

ψ_R Rational exergy management efficiency, dimensionless

ε_{dem} Unit demand exergy, kW/kW, or kW-h/kW-h

ε_{des} Unit destroyed exergy, kW/kW, or kW-h/kW-h

ε_{sup} Unit supplied exergy, kW/kW, or kW-h/kW-h

Subscripts

$_E$ Electric

$_H$ Thermal

$_{l,\ m}$ Local power plant, distant power plant, respectively

$_P$ Peak

$_{ref}$ Reference

$_{sup}$ Supply

Superscripts

j, l Correlation parameters in Eq. 4-b

Abbreviations

ABS Absorption chiller

AFT Adiabatic flame temperature, K

AC Air conditioning

ADS Adsorption chiller

CHP Combined heat and power

CWT Cold water tank

DHW Domestic hot water

DOE US Department of Energy

HVAC Heating, ventilating, air-conditioning

HE Heat Exchanger

HWT Hot water tank

IT Ice tank

LowEX Low-exergy

Mtoe	Megaton of oil equivalent (According to First Law)
MtoEX	Megaton of oil equivalent exergy (According to Second Law)
nZCB	Near-zero carbon building
NZCB	Net-zero carbon building
NZEXD	Net-zero exergy District
NZEXB	Net-zero exergy building
nZEXB	Near-zero exergy building
OF	Objective function
ORC	Organic Rankine cycle
PV	Photo-voltaic
PVT	Photo-voltaic-thermal
PVTC	Photo-voltaic-thermal-cooling
PHVT	Photo-thermal-voltaic-heat
REMM	Rational Exergy Management Model
TES	Thermal energy storage

REFERENCES

[1] Kılkış, B. and Ş. Kılkış, Cogeneration with Renewable Energy Resources (in Turkish), 373 pages, TTMD Pub. No. 32, Doğa Yayıncılık, İstanbul, Turkey, 2016.

[2] Goran, G., Kılkış, Ş., Krajacic, G., and Duic, N., Campus and Community Micro Grids Integration of Building Integrated Photovoltaic Renewable Energy Sources - Case Study of Split 3 Area, Croatia - Part A, *Thermal Science*, January 2016.

[3] Kilkis, S., Energy System Analysis of a Pilot Net-Zero Exergy District, *Energy Conversion and Management*, 87. p.p. 1077-1092, 2012.

[4] U.S. DOE., 2015 Energy Efficiency and Renewable Energy, a Common Definition for Zero Energy Buildings, September 2015.
http://energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf>
Last visited on 28.02.2016.

[5] Kılkış, Ş., A net-zero building application and its role in exergy-aware local energy strategies for sustainability**,** *Energy Conversion and Management*, Volume 63, November 2012, pp. 208–217, 10th International Conference on Sustainable Energy Technologies (SET 2011), 2012.

[6] Marszal, A. J. and P. Heiselberg, Zero Energy Building Definition- a literature review. Joint Project- Task 40/Annex 52 Net Zero Buildings, SHC, 2011.

[7] Kilkis, S., Sustainable Development of Energy, Water and Environment Systems Index for Southeast European Cities, *Journal of Cleaner Production*,

[8] Kılkış Şan, Kılkış Şiir, 2015, Benchmarking Districts Based on a Sustainability Ranking Index, *Journal of Cleaner Production*, p.p. 1-12, 2015.

[9] Kilkis, B., 2016, An Economic Analysis Tool for Tri-generation Systems in Net-Zero Exergy Buildings (NZEXB), Proceedings on usb, XII th Int. HVAC+R Symposium, TTMD, 31 March- 2 April 2016.

[10] B. Kilkis, Şefik B. , and A. Gülbeden, An Exergy-Based Automation System in ESER LEED Platinum Building, Proceedings on usb, XII th Int. HVAC+R Symposium, TTMD, 31 March- 2 April 2016.

Paper No: 144

New U-Values for Turkey: Applying the Comparative Methodology Framework for Cost-Optimality in the Harmonization Process of the Energy Performance for Buildings Directive

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ABSTRACT

The Energy Performance of Buildings Directive adopted by EU Member States in 2010 creates a cost-optimum methodology which asks Member States to calculate energy performance levels which leads to the lowest cost during the estimated economic lifecycle of the building. The methodology is applied to existing and new buildings. The outcome of this calculation has not only created a shift in the policies of each Member State towards maximizing energy efficiency from buildings, but also contributed positively to the post-Kyoto emissions reduction targets of the EU and the future INDCs commitments in the aftermath of COP21.
Turkey is in the path of harmonizing EU directives into its legislations. At the same time, Turkey spends 55 billion USD (in 2014, 25% of total imports) on energy imports. Creating an energy efficient economy is high on the agenda of the Government as defined in the 10th Development Plan. Buildings consume 40% of the total energy. The research and conclusions provided in this presentation will highlight the potential energy savings, its positive impact on the national budget and the contribution to CO2 emissions reduction once the Energy Performance of Buildings Directive is implemented and current national standards are revised accordingly [1].

Key words: Energy Performance of Buildings, EPBD, cost-optimum, cost optimality, energy efficiency, u value, INDC

INTRODUCTION

Turkey is the country with the fastest growing building stock on the European continent. With new construction rates of more than 4% it is considerably faster growing than the EU average of less than 1%. This leads to the fact that the construction sector is one of the most important drivers of the Turkish economy with a contribution of 6.6% of real GDP growth [2]. The building sector in Turkey (residential and services sectors) is responsible for about 35% of the national final energy consumption [3]. Due to the significant new construction activities this share is expected to further increase in the future. The building stock is expected to grow by more than 50% from approximately 2,400 million m² today to almost 4,000 million m² in 2050. While this creates a big potential for energy savings, it also makes clear that the Turkish building sector is one of the most important pillars for achieving Turkey's climate protection targets as defined in Turkey's "Intended Nationally Determined Contribution" (INDC) which has been submitted to the UNFCCC in 2015 [4].

For limiting the national increase in energy consumption of Turkey's building sector and thus reduce Turkey's significant dependency from energy imports, in 2008 the Turkish government has implemented the latest version of its building code TS825 [5] which defines the calculation procedures for heating energy demand in buildings and which provides accompanying reference and permeable values. In this context, TS825 also defines minimum requirements on U-values for roof, façade, windows and ground plate of new buildings and buildings to be renovated. However, the regulation just contains rules for the heating energy demand, other energy related calculations including cooling are not included in this mandatory standard for buildings in Turkey.

In the European Union (EU), the main legal instrument providing requirements and calculation procedures for limiting the energy demand of buildings is the Energy Performance of Buildings Directive (EPBD) [6]. There are two major concepts as regards the ambition level of energy performance requirements that were introduced with the recast EPBD and which have to be fulfilled by each EU Member State:

Cost-optimality

This is a life-cycle cost approach, including initial investment and operational cost (energy & maintenance) which needs to be applied by each EU Member State adjusted to national or regional circumstances for determining the minimum energy performance of building elements (e.g. U-values) and whole buildings (e.g. primary energy demand). The nationally required minimum energy performance needs to be set (based on assessment of reference buildings) at the level that results in the lowest life cycle costs.

Nearly zero-energy building (nZEB)

According to Article 2 EPBD, an nZEB is a building "that has a very high energy performance, the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources". From 2021 onwards, all new buildings in the EU are to be nearly zero-energy buildings. At the same time, the principle of cost-optimality is still valid. That means that ideally by 2021 nearly-zero energy buildings are cost-optimal. Therefore, in order to systematically derive a reasonable ambition level and definition for nearly zero-energy buildings it makes sense to conduct cost-optimality calculations using (cost) assumptions that seem to be plausible for 2021 (or another year in which Turkey intends to introduce nearly zero-energy buildings).

To give a contribution to the energy efficiency efforts in Turkey with the idea to create a clear and well-founded position on future standards, İzoder decided to issue a report and contacted Ecofys GmbH, the body that supports EC to evaluate [7] the mandatory reports of member states according to EPBD. The report is to apply the comparative methodology framework for cost-optimality in the context of the EPBD to the Turkish residential building sector with the aim to investigate cost-optimal U-values and assess their potential role in achieving Turkey's climate protection targets [1]. A second aim of the project was to be able to generate GIS (Geo Information System. Maps have been created with ArcGIS) -based U-value maps for Turkey, methodologically adjusted to the cost-optimality principle of the EPBD recast. The analysis has been conducted for the 12 Turkish cities Antalya, İzmir, Gaziantep, Muğla, İstanbul, Bursa, Ankara, Niğde, Sivas, Ağrı, Kars and Erzurum by using city specific calculation parameters and hourly climate data. Based on this limited number of cities it should be noted that results that have been extrapolated to regional scale (e.g. climate regions) are not necessarily 100% representative for the whole region but provide a sound first indication.

U-VALUES ACCORDING TO COST-OPTIMALITY

In this study, the EPBD underlying EU regulation No 244/2012 on "establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements" [8] and its accompanying guidelines [9] is applied to Turkish market conditions with the aim to identify a possible gap between current requirements as defined by TS825 and the Turkish cost-optimal thermal building standards according to the EPBD's cost-optimality approach. Moreover, we have analysed whether these cost-optimal levels can already fulfil the greenhouse gas (GHG) emission reduction targets and if not, demonstrate a scenario which would lead to the envisaged amount of GHG emissions that needs to be mitigated. Such further strengthened energy requirements therefore could be a good starting point for the definition of a Turkish nearly zero-energy building standard.

For this purpose, Ecofys has developed a cost-optimality tool according to the requirements as defined in the Commission Delegated Regulation (244/2012) regarding the energy performance of buildings. The model calculates cost-optimal building configurations (considering both demand and supply side) for different reference buildings under varying climatic conditions. The model can be adapted to local conditions. With regard to physical issues, local construction practices as well as climatic circumstances are taken into consideration for instance, in order to calculate hourly heating and cooling demands as specified by EU norm EN ISO 13790. Local hourly climate data sets are exported from METEONORM. Along with micro- and macroeconomic parameters such as dynamic costs for building components and variable energy prices, the calculated heating and cooling demands are fed into the calculation of global costs. The model calculates thousands of combinations of U-values, heating and cooling systems and identifies the technical configuration which yields the lowest global costs over the calculation period (30 years for residential buildings according to the EPBD's cost-optimality approach). A private or societal perspective can be adopted for defining cost-optimality. The calculation model can be applied to both new and renovated buildings as well and is able to include typical local reference buildings and geometries. Based on the 2011 and 2001 census results for Turkey, it has been decided to use a 5 story multi-family house as the reference building for the calculations, as it is the most frequently encountered type especially in the Turkish urban building stock and therefore most relevant for this analysis. For calculating the energy saving potential and identifying the U-values that are needed in order to reach climate protection targets as defined in Turkey's INDC, the results on the reference building level have been extrapolated to the entire building stock and its modelled future development until 2050.

Due to the quite heterogeneous climate conditions in Turkey as seen from the degree days maps for heating and cooling in Figures 1 and 2 and in order to allow a more appropriate extrapolation of derived results for a limited number of cities to the whole Turkish building stock, the four climate regions as defined in TS825 have been restructured into 6 new climate regions according to Table 1.

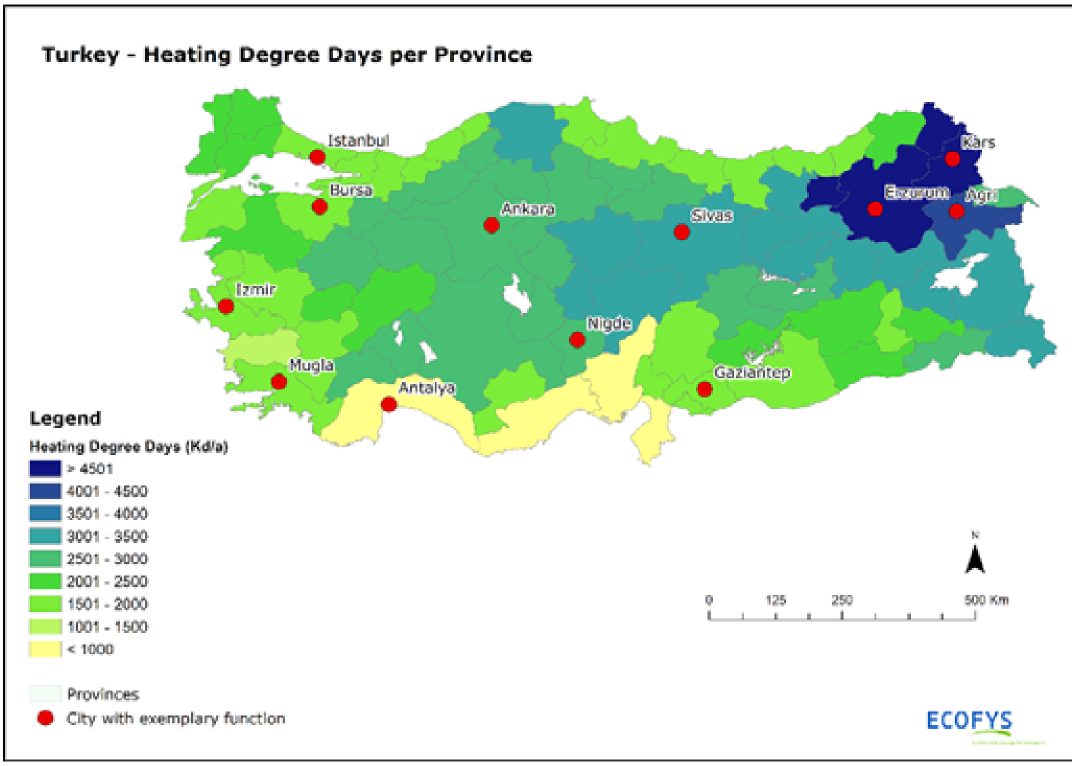

Figure 1. Turkish heating degree days map (ASHRAE method)

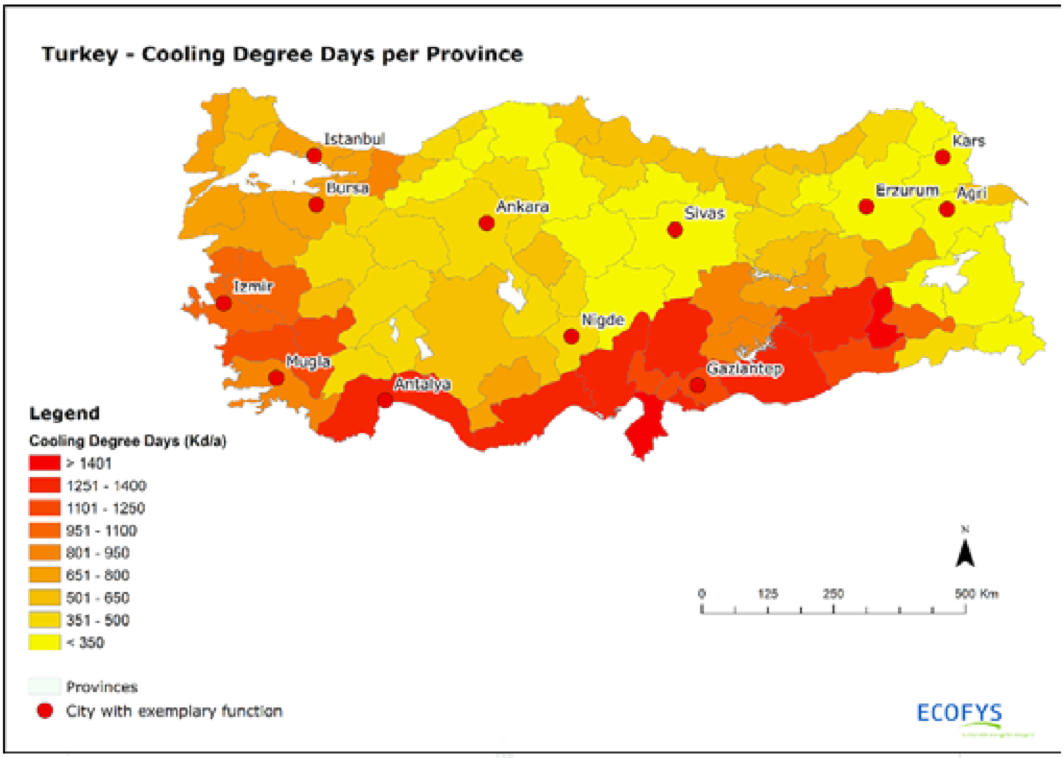

Figure 2. Turkish cooling degree days map (ASHRAE method)

Table 1. Proposed climate regions for Turkey

Region	Climate classification	HDDs (acc. to ASHRAE)	CDDs (acc. to ASHRAE)	Number of Turkish provinces in class	Climate region according to TS825
1	Hot	<1000	>1000	4	1
2	Cooling-based	1000-2000	>=1000	10	1-2
3	Moderate	<2000	<1000	17	2
4	Rather cold	>=2000	<1000	32	3
5	Medium cold	>=3000	<1000	13	4
6	Cold	>=4000	<1000	5	4

These six regions allow a more detailed analysis of recommendable U-values based on different climate conditions and therefore have been used for all tasks of this study.

Tables 2 and 3 present the results of the cost-optimality calculations adjusted to the six climate regions as used in this study. The results represent the average of the covered reference cities in the respective regions.

Table 2. Results of the cost-optimality calculations for new buildings adjusted to the six climate regions as used in this study

Component	Unit	Hot	Cooling-based	Moderate	Rather cold	Medium cold	Cold
Roof	$W/(m^2*K)$	0.27	0.21	0.19	0.16	0.16	0.14
Façade	$W/(m^2*K)$	0.35	0.28	0.27	0.21	0.22	0.18
Windows	$W/(m^2*K)$	1.80	1.80	1.57	1.10	1.10	1.10
Ground	$W/(m^2*K)$	0.57	0.43	0.42	0.32	0.36	0.29
Primary energy demand (cost-optimality)	$kWh/(m^2*a)$	34.9	54.2	50.1	64.7	75.1	100.2
Primary energy demand (U-values TS825)	$kWh/(m^2*a)$	43.4	70.6	66.5	90.2	97.9	135.6

Table 3. Results of the cost-optimality calculations for existing buildings to be renovated adjusted to the six climate regions as used in this study

Component	Unit	Hot	Cooling-based	Moderate	Rather cold	Medium cold	Cold
Roof	$W/(m^2*K)$	0.25	0.20	0.20	0.15	0.17	0.13
Façade	$W/(m^2*K)$	0.35	0.28	0.27	0.22	0.22	0.19
Windows	$W/(m^2*K)$	1.80	1.45	1.17	1.10	1.10	1.10
Ground	$W/(m^2*K)$	0.51	0.42	0.41	0.34	0.33	0.28
Primary energy demand (cost-optimality)	$kWh/(m^2*a)$	42.5	61.5	55.7	73.7	84.8	112.2
Primary energy demand (U-values TS825)	$kWh/(m^2*a)$	49.7	79.2	73.9	99.8	108.2	149.4

Figures 3, 4, 5 and 6 show the calculation results of cost-optimal U-values according to EPBD's cost-optimality procedure and U-values for reaching climate protection targets according to the national INDC for both new and existing buildings undergoing a major renovation. Turkey's INDC defines a climate protection target of reducing Turkey's greenhouse gas emissions by up to 21% from the Business as Usual (BAU) level by 2030. The figures also provide a comparison with current requirements according to TS825.

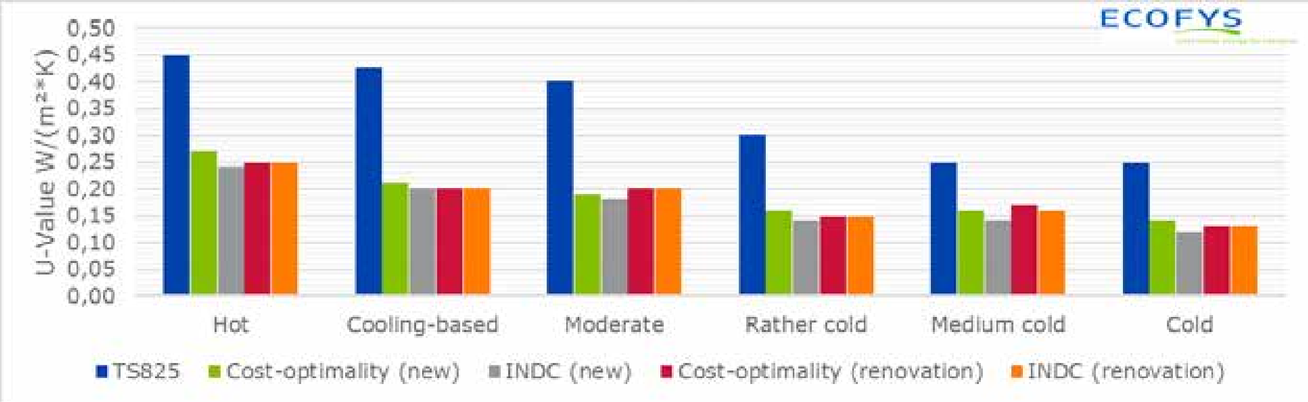

Figure 3. U-value results for roofs in new and existing buildings undergoing a major renovation according to cost-optimality and achievement of climate targets as defined in Turkey's INDC for all six climate regions as used in this study

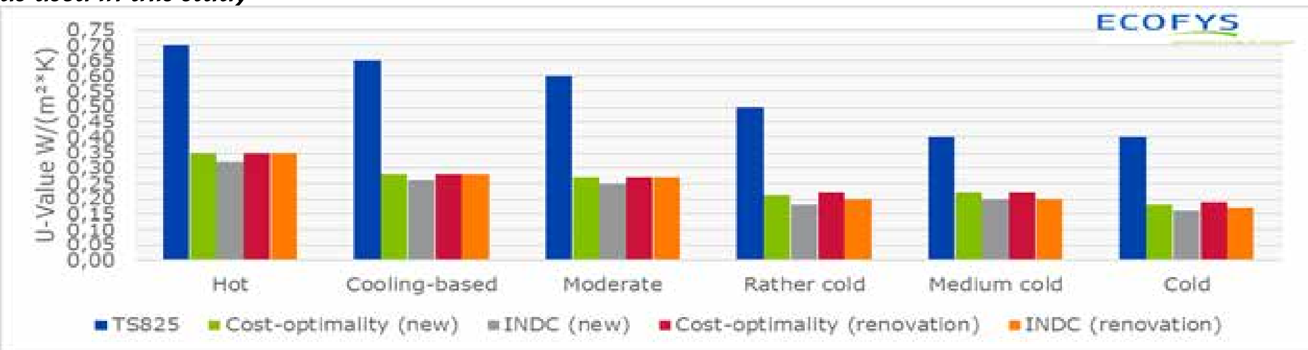

Figure 4. U-value results for façades in new and existing buildings undergoing a major renovation according to cost-optimality and achievement of climate targets as defined in Turkey INDC for all six climate regions as used in this study

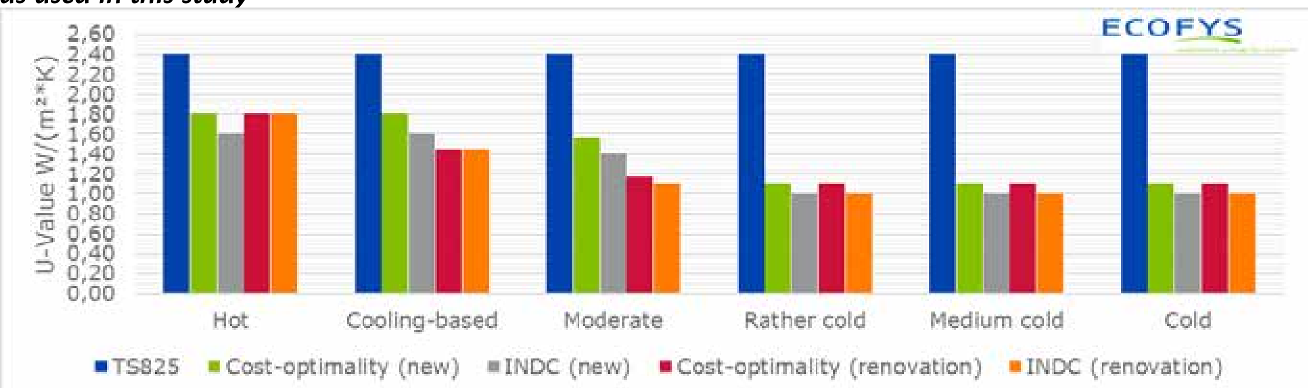

Figure 5. U-value results for windows in new and existing buildings undergoing a major renovation according to cost-optimality and achievement of climate targets as defined in Turkey INDC for all six climate regions as used in this study

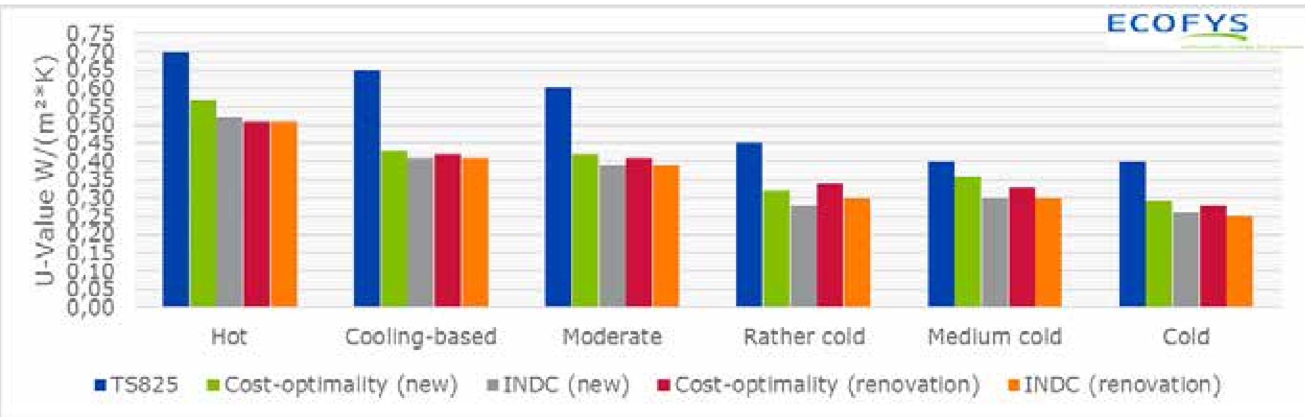

Figure 6. U-value results for ground plates in new and existing buildings undergoing a major renovation according to cost-optimality and achievement of climate targets as defined in Turkey INDC for all six climate regions as used in this study

Based on the identified U-values, primary energy demands for space heating and space cooling have been determined. The results are presented in Figure 7.

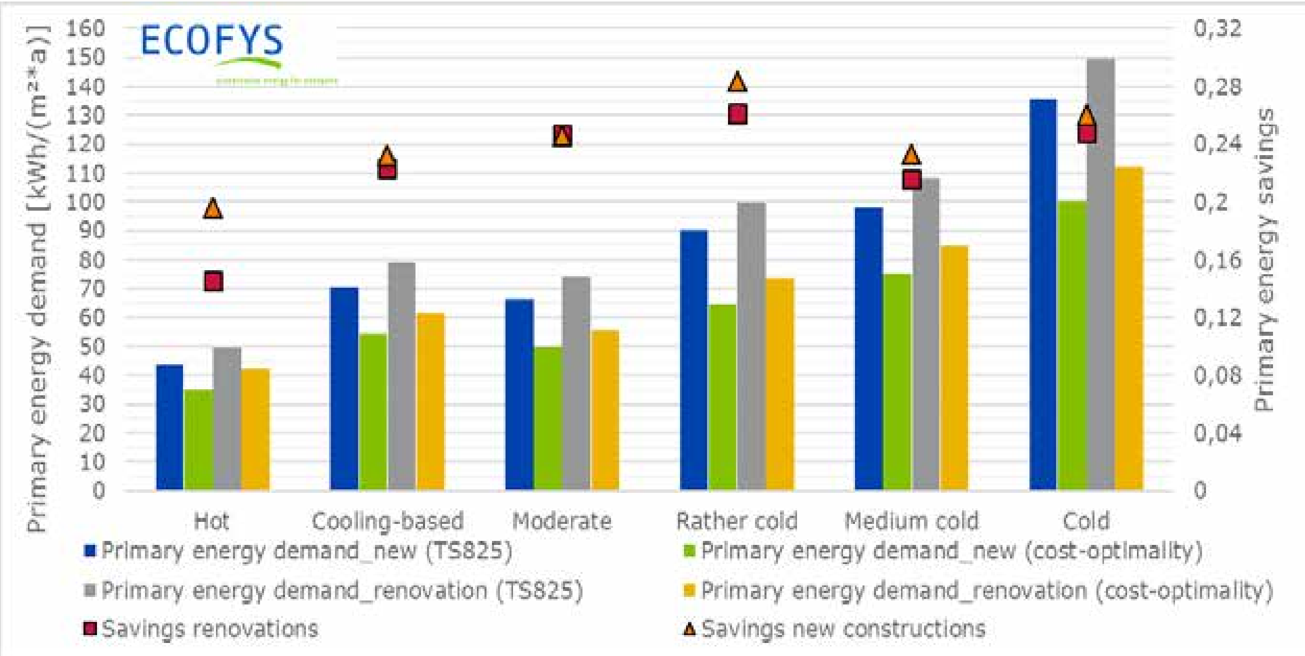

Figure 7. Primary energy demands of new and existing buildings undergoing a major renovation according to the current building code TS825 and cost-optimality calculations for all six climate regions as used in this study

By applying the new standards, Figure 8 presents the potentials for final energy savings until 2023, 2030, 2040 and 2050.

As can be seen, by increasing the U-value requirements to cost-optimal levels, about 7% final energy can be saved until 2023, 14% by 2030 and 28% until 2050. As the implementation of the cost-optimality standards leads to final energy savings of approximately 14% in 2030 and by using IPCC standard emission factors for fossil fuels and an emission factor of 0.55 kg CO_2 e/kWh for electricity and assuming that the emission factors keep stable until 2030, this energy saving potential correlates with an emission reduction potential of ~12% until 2030.

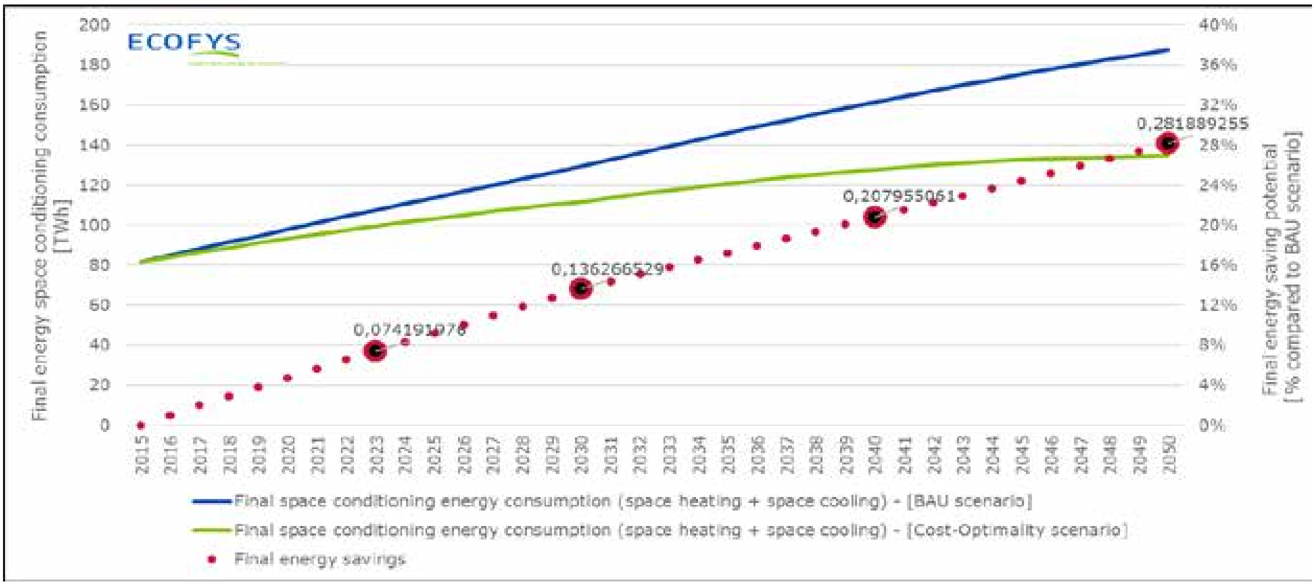

Figure 8. Projected final energy consumption for space conditioning (space heating and space cooling) in Turkey's residential building sector 2015-2050 in the BAU and the cost-opt scenarios and the resulting final energy savings in the cost-opt scenario compared to the BAU scenario

In order to close the remaining gap of ~9% to reach the targeted 21% emission reduction as defined in the INDC, with a focus on energy efficiency measures on the demand side, a combination of increased renovation rate and further improved U-values is necessary. As a possible solution, today's renovation rate of 0.45% [10] should be increased to 1% and furthermore increased linearly to 2% in 2030. This correlates with an average renovation rate of 1.5% in the period 2015-2030. Additionally, the calculated cost-optimality U-values need to be further strengthened, on average by 11% for new buildings and by 10% for existing buildings to be refurbished (see Figures 3-6). In addition, the heat/cold bridge factors need be reduced from the current value of approximately 0.1 W/(m^2*K) in new buildings and 0.15 W/(m^2*K) in existing buildings to 0.05 W/(m^2*K) and 0.1 W/(m^2*K) respectively. In warm regions, this improvement of the heat bridge factor can already be sufficient for achieving the needed emission reduction.

Tables 4, 5 and 6 present the final results of the cost-optimality calculations and also the current requirements according to TS825 in order to highlight the higher ambition. For the calculation of the primary energy demand for space heating and space cooling, primary energy factors of 1.0 for gas [11] and 2.36 for electricity [12] have been used. It should be considered that the same calculation parameters have been used for both the energy demand calculations according to TS825 and cost-optimality [1]. Considering that these parameters and the whole methodology based on EN 13790 can differ from TS825, the calculated energy demand benchmarks can differ to those provided in TS825. U-values are presented in W/(m^2*K), specific primary energy demand in kWh/(m^2*a), heating and cooling load in kW.

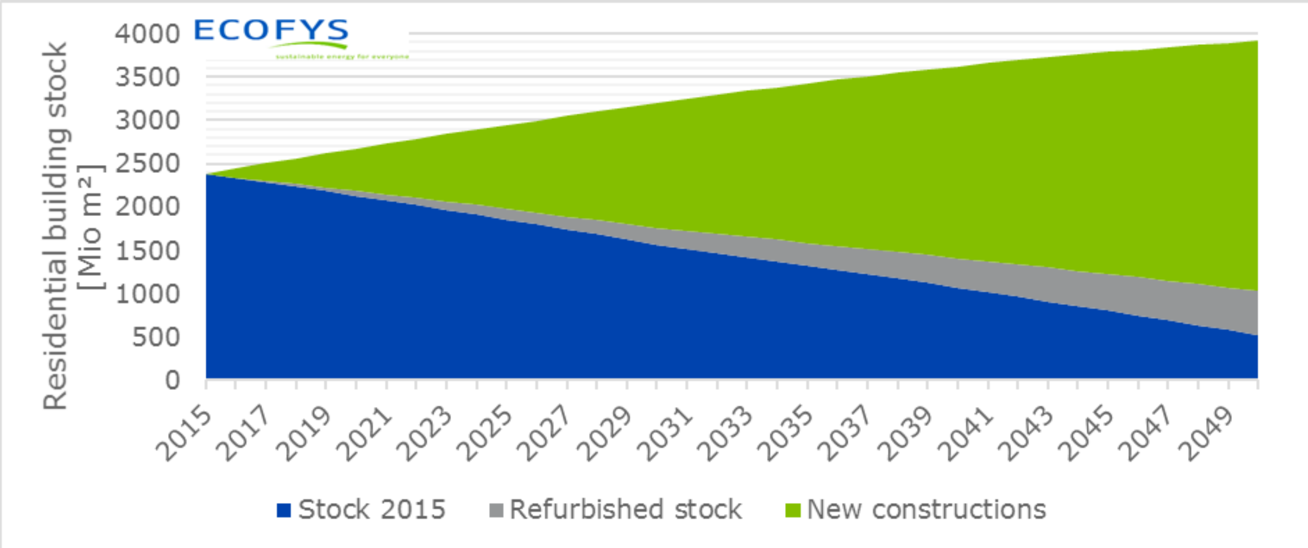

Figure 9. Illustration of the building stock and emission development from space heating and space cooling assuming an increase of the renovation rate from 1% in 2015 to 2% in 2030 and 11% more ambitious U-values for new constructions and 10% for renovations compared to CO-levels

Table 4. Results of the cost-optimality calculations for new constructions

Cost-optimal U-values and resulting primary energy demand for new constructions												
City	**Antalya**	**İzmir**	**Gaziantep**	**Muğla**	**İstanbul**	**Bursa**	**Ankara**	**Niğde**	**Sivas**	**Ağrı**	**Kars**	**Erzurum**
U-value roof	0.27	0.22	0.21	0.19	0.19	0.20	0.16	0.16	0.16	0.15	0.13	0.13
U-value façade	0.35	0.29	0.27	0.27	0.28	0.27	0.21	0.21	0.22	0.20	0.18	0.17
U-value windows	1.80	1.80	1.80	1.80	1.80	1.10	1.10	1.10	1.10	1.10	1.10	1.10
U-value ground	0.57	0.45	0.41	0.43	0.43	0.41	0.30	0.35	0.36	0.32	0.29	0.26
Primary energy (heating & cooling)	34.9	48.4	59.9	56.0	45.6	48.8	65.6	63.7	75.1	91.0	103.2	106.4
Primary energy (space heating)	15.6	32.4	41.0	42.9	37.1	39.5	58.8	56.9	70.9	88.3	102.4	105.0
Primary energy (space cooling)	19.3	16.1	18.9	13.0	8.6	9.3	6.8	6.8	4.1	2.7	0.8	1.4
Heating load	22.2	31.2	34.4	32.4	30.6	32.0	42.0	42.4	48.0	56.1	60.2	62.5
Cooling load	29.2	26.9	30.2	26.2	17.6	20.9	19.0	17.5	17.3	12.1	8.0	11.2

Table 5. Results of the cost-optimality calculations for renovations

Cost-optimal U-values and resulting primary energy demand for renovations												
City	**Antalya**	**İzmir**	**Gaziantep**	**Muğla**	**İstanbul**	**Bursa**	**Ankara**	**Niğde**	**Sivas**	**Ağrı**	**Kars**	**Erzurum**
U-value roof	0.25	0.20	0.20	0.19	0.20	0.22	0.15	0.15	0.17	0.15	0.13	0.12
U-value façade	0.35	0.29	0.28	0.27	0.28	0.27	0.22	0.22	0.22	0.21	0.18	0.17
U-value windows	1.80	1.80	1.10	1.10	1.30	1.10	1.10	1.10	1.10	1.10	1.10	1.10
U-value ground	0.51	0.41	0.43	0.41	0.41	0.41	0.33	0.34	0.33	0.31	0.27	0.25
Primary energy	42.5	56.6	66.4	60.7	50.0	56.3	74.9	72.5	84.8	102.5	115.2	119.0
Primary energy (space heating)	17.4	35.8	42.2	44.0	39.0	44.4	66.3	64.0	79.6	99.3	114.2	117.3
Primary energy (space cooling)	25.0	20.7	24.2	16.7	11.0	11.9	8.6	8.6	5.2	3.3	0.9	1.7
Heating load	23.1	32.4	33.8	31.5	30.5	33.8	44.3	44.5	50.8	59.2	63.1	65.6
Cooling load	29.9	27.5	29.9	25.8	17.6	21.4	19.5	17.9	17.7	12.3	8.0	11.3

Table 6. Current U-value requirements according to TS825 and calculated primary energy demands according to EN 13790

Current U-value requirements according to TS825 and calculated primary energy demands according to EN 13790												
City	**Antalya**	**İzmir**	**Gaziantep**	**Muğla**	**İstanbul**	**Bursa**	**Ankara**	**Niğde**	**Sivas**	**Ağrı**	**Kars**	**Erzurum**
U-value roof	0.45	0.45	0.40	0.40	0.40	0.40	0.30	0.30	0.25	0.25	0.25	0.25
U-value façade	0.70	0.70	0.60	0.60	0.60	0.60	0.50	0.50	0.40	0.40	0.40	0.40
U-value windows	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
U-value ground	0.70	0.70	0.60	0.60	0.60	0.60	0.45	0.45	0.40	0.40	0.40	0.40
Primary energy new	43.4	64.3	76.8	72.0	59.2	68.2	91.0	89.5	97.9	120.5	140.6	145.6
Primary energy new (space heating)	23.0	47.5	56.9	58.5	50.8	59.0	84.7	83.5	94.3	118.5	140.2	144.6
Primary energy new (space cooling)	20.4	16.8	20.0	13.4	8.4	9.2	6.3	6.0	3.6	2.0	0.4	1.0
Heating load new	29.4	43.3	44.7	43.1	39.8	45.7	56.9	57.8	62.5	72.4	78.8	83.4
Cooling load new	34.5	32.5	35.6	30.6	19.8	25.3	22.4	20.2	19.5	13.1	8.1	12.2
Primary energy renov.	49.7	72.0	86.3	80.2	65.7	75.7	100.5	99.1	108.2	132.8	154.9	160.3
Primary energy renov (space heating)	25.5	52.2	62.6	64.3	55.9	64.8	93.2	92.2	104.0	130.5	154.4	159.2
Primary energy renov (space cooling)	24.2	19.8	23.7	15.9	9.9	10.8	7.3	6.9	4.2	2.3	0.5	1.1

As can be seen in the tables 4-5, cost-optimal U-values for renovations in some cases are slightly better than for new constructions. The main reasons for this result are the assumed efficiencies of the space heating and space cooling supply systems which are significantly worse in the renovation case. These low efficiencies lead to more energy cost savings when improving the building envelope. As investment costs for renovations are assumed to be just a bit higher for façade renovations, this leads to more ambitious cost-optimal values over the calculation period of 30 years.

CONCLUSION

The U-values as derived from the cost optimality methodology are suitable to support reaching 2030 climate protection targets. This means that climate protection and cost-optimality are not contradictory but can be well combined.

- Reaching climate targets requires further strengthening of the U-values by ~10% towards 2030 compared to today's cost-optimality levels (needed 2030 values are likely to be cost-optimal as well, if energy prices are further raised)
- For the improvement of U-values from TS825 standard to cost-optimal U-values would require additional investment costs of 3-10€ per m² building floor area, in average ~6.5 €.
- Recommended maximum U-values resulting from the analyses based on cost-optimality and fitting climate protection targets are significantly more ambitious than current requirements according to TS825, offering room for strengthening of requirements.
- For reaching climate targets, U-value requirements should be strengthened rather sooner than later to avoid lock-in effects or capital intense upgrades of building envelopes before the end of their technical life-time.
- In residential buildings in warmer parts of Turkey, thermal insulation also reduces the energy demand for cooling. A well balanced package of roof, wall and floor insulation and selection of the right window with suitable U-values as well as g-values results in a significant and cost-effective reduction of energy demand for space heating and cooling.

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REFERENCES

[1] Report by Ecofys by order of IZODER: U-Value maps Turkey, Applying the comparative methodology framework for cost-optimality in the context of the EPBD, 17 June 2016 http://www.ecofys.com/files/files/ecofys-2016-u-value-maps-turkey.pdf http://www.izoder.org.tr/haber/28/turkiye-u-degerleri-haritasi-raporu-2016-ingilizce

[2] Kaymaz, Necmettin (2015). ***Economic Outlook and Construction Sector in Turkey***. Available: http://www.docfoc.com/download/documents-pdf/icgHf8nXRdefRvLrbYBh41gvBUGOY5V772Ed0S1HV5NCroUsclA6cHsErZjgU4dSWIWMq

[3] EUROSTAT (2016). ***Complete energy balances - annual data (nrg_110a)***. Last update 02-05-2016. Available: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_110a&lang=en

[4] Republic of Turkey (2015). ***Republic of Turkey's Intended Nationally Determined Contribution (INDC)***, submission to the UNFCCC. Available: http://www4.unfccc.int/submissions/INDC/Published%20Documents/Turkey/1/The_INDC_of_TURKEY_v.15.19.30.pdf

[5] Turkish Standards Institution, 2008, "Thermal Insulation Requirements for Buildings, Turkish Standard 825", Official Gazette Number 27019, (In Turkish)

[6] EU (2010). ***Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)***. European Parliament and the Council of the European Union, 2010. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0031&from=en

[7] Assessment of the cost-optimal reports by Member States. http://www.ecofys.com/en/projects/assessment-of-the-cost-optimal-reports-by-member-states

[8] EC (2012a). Commission Delegated Regulation ***(EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements***. European Commission, 2012. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0244&from=EN

[9] EC (2012b). ***Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements***. European Commission, 2012. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012XC0419(02)&from=EN

[10] Rainer Elsland, Can Divrak, Tobias Fleiter, Martin Wietschel (2014). Turkey's Strategic Energy Efficiency Plan – An ex ante impact assessment of the residential sector. Energy Policy 70 (2014) 14–29

[11] Neşe Ganiç Sağlam, A. Zerrin Yılmaz (2014). ***Adaptation of the cost optimal level calculation method of Directive 2010 31EU considering the influence of Turkish national factors***. Applied Energy 123 (2014) 94–107

[12] Suzi Dilara Mangan, Gül Koçlar Oral (2016a). ***Assessment of residential building performances for the different climate zones of Turkey in terms of life cycle energy and cost efficiency***. Energy and Buildings 110 (2016) 362–376

Paper No: 200

A Methodology to Develop a User-Behaviour Tool to Optimize Building Users' Comfort and Energy Use

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ABSTRACT

The total amount of energy spent in buildings is quite significant, reaching up to 40% of the world's total energy usage. Accordingly, the EU has set goals requiring zero CO2 emission in buildings by 2020 to respond to the increasing energy demand and started continuously supporting innovative research approaches for improving energy efficiency in buildings. However, innovative approaches cover the challenges in specific parts (specific facilities, building functionalities, etc.) of both new buildings and renovation of existing buildings. Therefore, main challenge in current building facilities is scaling up of the building innovative approaches in combination with the building usage. So, it is crucial to influence the complex interaction between users and buildings. To reinforce the building configuration and adaption according to the occupants' behaviour, this paper presents a methodology to construct a building-user interaction. This methodology aims at developing data mining algorithms and semantic models with stream reasoning capabilities that allows occupants and facility managers to monitor and control the energy consumption, to detect the energy inefficiencies and to generate recommendations to reduce energy consumption whilst increasing occupant comfort. The proposed methodology is modular which could be integrated in the existing building management systems and that is promising to reduce energy use in existing buildings.

Keywords: User behaviour, data mining, semantic modelling, energy efficiency.

INTRODUCTION AND PROBLEM STATEMENT

The rapid increase in energy consumption and carbon dioxide emissions require the governments and the society to be aware of the need to conserve natural resources. In this sense, the most common strategy is to move towards more sustainable and energy efficient paradigms. As an example, one of the EU priorities is to be more sustainable towards 2020 and beyond through promoting strengthen directives and policy frameworks as for example Communication on Energy Union (COM (2015)080) [1], the SET-Plan Integrated roadmap, 'Towards an Integrated Strategic Energy Technology (SET) Plan' (COM (2015) 6317) [2], 'New deal for consumers' (COM (2015)339) [3] and the accompanying 'Guidelines for self-consumption'.

Towards achieving more sustainable and energy efficient paradigms, buildings play a central role. Building energy consumption accounts for about 40% of total final energy consumption and around 55% of electricity consumption in the EU-28. Considering the rest of EU sectors, building energy consumption is followed by transport (32%), industry (26%) and agriculture (2%) [4]. A similar pattern is seen worldwide where buildings account for over 41% of national energy consumption in US (22% for residential buildings and 19% for commercial buildings) [4]. In China, building energy consumption reaches 34% of the total energy consumption [5]. Therefore, it is important that buildings in the developed countries continue to provide energy savings.

Energy savings in buildings can be produced along the entire building life cycle (planning, construction, utilization and end of life). However, the literature showed that life cycle energy use mostly depend the operation energy of the buildings [6]. Therefore, important energy gains can be produced through reducing its operating energy significantly using latest advances in technology and management systems. Thus, building operations (especially public buildings) are managed by Building Management Systems (BMS). These systems are capable of automatically control the operation of energy systems and to monitor the energy consumption. These mentioned automation in the energy monitoring and control is carried out by data mining and machine learning techniques such as decision trees [7], time series analysis [7], neural networks [8] and optimization algorithms among others [9, 10]. Moreover, Multi-Agent System architectures and complex event processing technology have been also applied to be more efficient the actuation over the building and fault diagnosis [11]. However, these systems might not fully operate efficiently mainly due to increasing demand on maintaining occupant comfort. Furthermore, BMS lack interoperability between facilities due to the lack of communication standards in building information modelling and data modelling. Spite of the last years communication data models like Industry Foundation Classes (IFC) have been developed, there exist a gap into its adoption in commercial tools. To avoid this interoperability lack, several authors [12, 13] have tried to semantic modelling the building facilities in order to deal with the building operational complexity and also support the construction of a more integrated decision support system. However, these systems have caused data exhaustion and reasoning inefficiencies due to the plausible weakness in semantics in matter of temporal and geospatial combined reasoning [14, 15]. Therefore, the fact is that these systems operate as isolated islands according to fixed schedules and maximum design occupancy assumptions. Also, these systems make use of code defined occupant comfort ranges increasing energy consumption even more [16].

Latest trends in BMS rely on including the user behaviour and interaction with the building as a new variable. There exist is a need to understand interactions between users and building systems, which can significantly reduce the total building energy use [17]. Among various factors influencing building energy consumption, occupant behaviour plays an essential role and is difficult to investigate analytically due to its complicated characteristics [18]. It should be noted that occupant behaviour refers to actions and reactions of building users that have a direct or indirect impact upon building energy consumption. Studies have shown occupant behaviour could affect the energy consumption in buildings by a factor of 3 [19] and in some cases up to a factor of 10 [20]. However, existing BMS cannot include user behaviour in their operating systems due to the complexity of understanding the driving factors that could impact occupant behaviour in interacting with different building systems and modelling these behaviours.

Under this framework, the HIT2GAP-EU funded project (http://www.hit2gap.eu/) is aimed at reducing the gap between the real energy consumption of the building and the simulated one through elaborating an intelligent BMS. This BMS will be composed by intelligent modules to analyse the building facilities and consider also the user interaction as a main driver to contribute to achieve energy gains. In this overall architecture, the "***User Behaviour Tool (UBT)***" will be in charge of analysing the behaviour of the building facilities and building occupants to recommend suitable building operational strategies. The novelty of the proposed system is to convey building facilities with user behaviour under an intelligent system capable of dealing with huge torrents of information and dynamically adapt behaviour according to the building performance and user-interaction. In this sense, the proposed intelligent system will use streaming semantic reasoning to filter relevant events from the huge torrents of data available in the building according to the user state. These relevant user or state will serve as input point to adapt building facilities considering also the building occupancy. For this adaptation, data mining algorithms will be used to elaborate dynamic semantic rules that filter the incoming information and support detection of energy abnormalities. The decision support regarding to perform the building adaptation will be done using semantic reasoning based on the relevant events, the dynamic rules and also user comfort definitions extracted from standard comfort models and implemented as semantic axioms and facts. As a result, building adjustments (e.g. set-points) will be proposed by facility according to the building occupancy and state. To achieve this, the document firstly provides the main functionalities of the User-Behaviour Tool and identifies data requirements ("***User-Behaviour Tool: Functionalities and Data Requirements***" section). Based on the elicitation of the requirements, "***The Architecture of the User-Behaviour Tool***" section will depict the proposed system to recommend building managers suitable control strategies moving the overall building behaviour towards zero-energy and low carbon paradigms. At last but not least, "***Conclusions and Future Work***" section will rely on describing main conclusion and future work to be performed under the HIT2GAP-EU funded project framework.

USER-BEHAVIOUR TOOL: FUNCTIONALITIES AND DATA REQUIREMENTS

Due to increasing energy demand, especially for commercial and public buildings, the installation of building automation systems with more actuation possibilities could confer a large energy-saving potential. The focus is generally on the integrated control of HVAC, lighting and shade/blind positioning of an individual building/floor/zone so that different separations can be actuated independently from each other. Accordingly, independent actuation enables making adjustments on set-points as well as actuation, which increase the possibility of reducing the corresponding energy use. However, these systems lack information about user comfort levels and have default settings mainly based on thermal comfort standards, which might not represent the preference of users within a particular environment. Accordingly, specific conditions of a building might lead users to take actions for increased comfort levels such as opening windows for increased thermal comfort or turning on lights for increased visual comfort.

The UBT aims at detecting wasteful user behaviour practices in a building in order to generate cross-dimensional recommendations for optimized user comfort and energy efficiency. The functionalities of the user-behaviour tool were determined via a survey among HIT2GAP consortium consisting of 22 partners representing different stakeholders including facilities managers, construction companies, end-users and BMS providers. Different use-cases were analysed and the main functionalities of the user-behaviour are identified as follows:

- Maintaining ambient comfort of thermal and visual levels for the working environment,
- Supervising HVAC system, its energy consumption and generating recommendations towards reducing energy consumption
- Programming and optimizing the HVAC equipment operation
- Operating lighting systems based on occupancy
- Treating aggregated user complaints, preferences and associated troubleshooting

The tool takes into consideration aggregated/anonymized users' indoor environmental condition preferences and their state (i.e. stressed, excited) as well as air quality requirements. The preferences and perceived comfort of users will be obtained via online questionnaires and will be associated with the current status of building systems (i.e. thermal comfort conditions and illuminance). In addition, wearable devices will be utilized to extract information on the user state. Therefore and in order to model user behaviour, current statuses of the building including energy consumption, indoor and environmental conditions have to be collected. In addition, sensor and actuator information as well as their current status have to be integrated in the model to further generate and/or implement recommendations aiming at reducing energy consumption. As can be seen in Figure 1, physical and contextual parameters both at the mid-term and immediate level have direct impact on the user behaviour. These parameters and corresponding data can be categorized under 4 main groups: (i) Data for defining building / facility (i.e. building type, elements, infrastructure), (ii) Data for defining building systems (i.e. HVAC type, lighting systems), (iii) Measured and/or predicted data (i.e. environmental conditions, energy consumption), (iv) User behaviour and state data (i.e. user profile , preference of users). Overall, these data have to be collected in order to provide a comprehensive approach to modelling user behaviour and building performance.

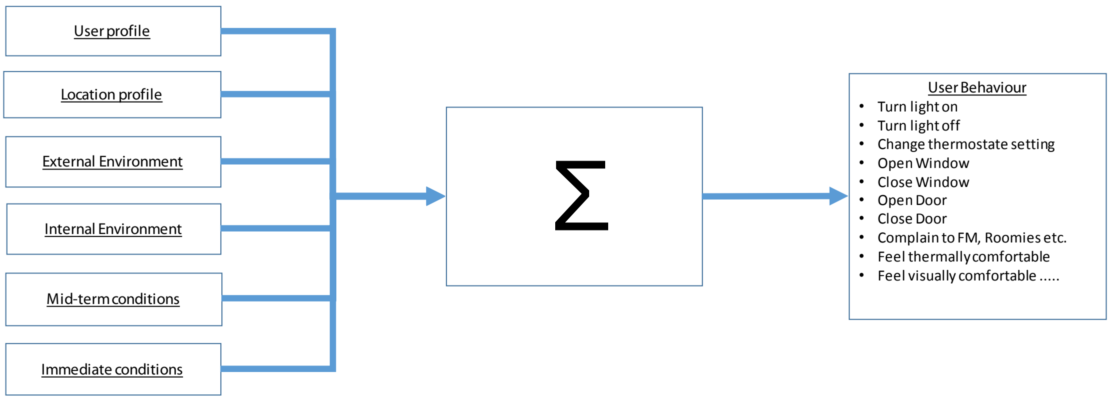

Figure 1 Predominant parameters on the user behaviour

THE ARCHITECTURE OF THE USER-BEHAVIOUR TOOL

The main focus of the UBT is to provide different stakeholders (Facility/Maintenance Managers and Building Managers) a framework to tackle efficient decision according to the building status and the occupant's behaviour and state. Indeed, the benefits for the Facility/Maintenance Managers will be an integrated framework for supervising the building interventions and early reaction to building operation abnormalities that could occur. From the Buildings Managers perspective, the UBT will facilitate the accomplishment of policies at regional, national and pan-European. For the end-users or building occupants, the benefits of the module will mainly be focused on adapting building behaviour according to their preferences. Therefore, the UBT will provide suitable recommendations and building control strategies for the benefit of building occupants' comfort through adapting and making efficient the building operations.

Hence, the proposed UBT (Figure 2) will collect the Facility Manager (FM) and Energy Manager (EM) requests. These requests activate the "***User Behaviour Models***" that indeed uses the information from BMS, user sensors, and occupant preferences through the semantic model ("***Building and User Knowledge Base***"). It should be noted that user sensors will collect data in the form of events to be real-time analysed and semantically filtered. Mentioned sensor data will correspond with presence/movement information and user state. This event information will be combined with building specific data such as occupant presence/movement, indoor environmental conditions (temperature, CO_2, relative humidity etc.), lighting, window opening/closing behaviour, thermostat adjusting behaviour. In addition, online questionnaires will be used to gather occupant preferences, which then will be used to identify comfort ranges of occupants per profile.

The semantic model ("*Building and User Knowledge Base*") stores current building occupants' contextualized information with the aim at deriving new knowledge from the stored information by applying semantic reasoning combined with rules reasoning. Thus, this new knowledge can be corresponded with the application of the FM/ EM decision-making procedures, identifying comfort levels, detecting complex abnormalities, etc. The available and generated information (knowledge) from the knowledge base is shared with the "*User Behaviour Models*". These models derive new thresholds and semantic information (e.g. new set points, operational strategies, etc.) through knowledge discovery algorithms to support the generation of the mentioned complex abnormalities and indeed generate recommendations. These thresholds will be included into the reasoning in the form of semantic rules that dynamically will provide specific building behaviour. Hereafter, these kinds of rules will support the decision-making and the generation of recommendations. During the generation of these recommendations, the FM/ EM or even the models can use external simulation tools to refine the recommendations with the user experience. The final model recommendations are stored in the semantic model that indeed returns it to the mentioned stakeholders. As a result, the knowledge base can interact to the user behaviour models to enhance the recommendations and generate effective knowledge based on the actual state of the building and users. This module can be capable of real-time actuation over the building by the identification and remediation of complex behavioural events (e.g. semantic rules/restrictions over the events) to avoid energy inefficiencies meanwhile the user comfort is maintained or enhanced.

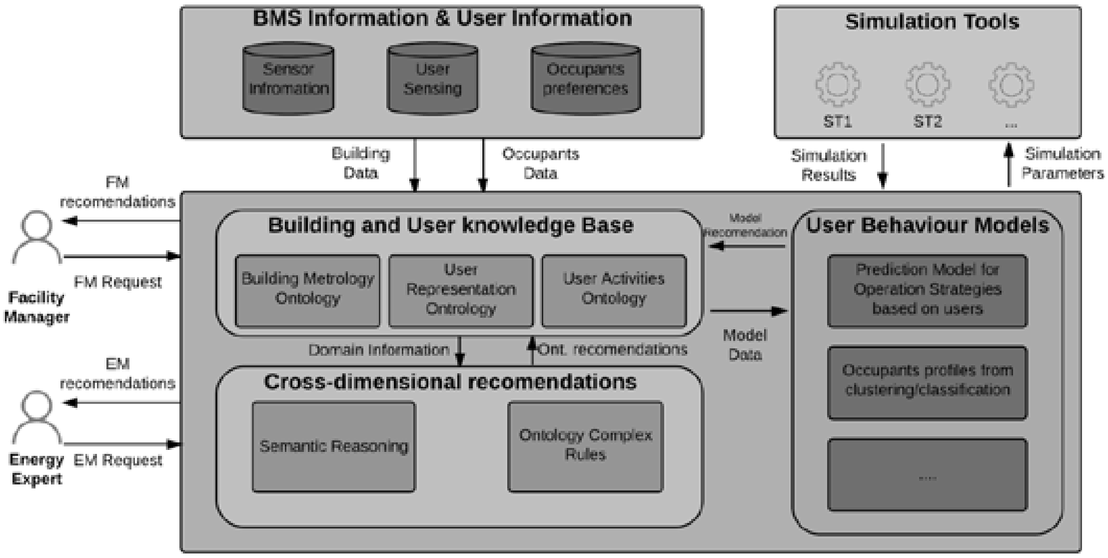

Figure 2 Concept and Approach of the proposed User Behaviour Module

Consequently, the recommendations are derived from information directly acquired from the occupants via health monitors and questionnaires. Both inputs are analysed by the user behaviour models and combined with building information to generate a dynamic, adaptable and holistic recommender and decision support system. As mentioned, the main components of the UBT are the (i) "*Building User Knowledge Base*" as a model to contextualise the building and user-related information; (ii) "*Cross-dimensional recommendations*" as a recommender and decision making system to derive suitable building operation according to user comfort and state; and (iii) "*User Behaviour Models*" as a set of data mining and machine learning algorithms for inferring dynamic rules for the "*Building User Knowledge Base*".

Building-User Knowledge Base

The building-user knowledge base of the UBT is aimed at representing (i) the building infrastructure and systems; (ii) the user behaviour and state; and (iii) the decision paths and flows that take place in the building. For that purpose, the building knowledge base will consider current standard semantic models related to buildings such as IFC-OWL [21] and SAREF [22]. In terms of building sensors, abstraction will be conducted through W3C-SSN [23] and Geo-SPARQL [24] for representing building geometry. Finally, user behaviour will take advantage of the conversion the developed models ("*Functionalities and Data Requirements for the User Behaviour Tool*" section) into semantic resources over the Schema.org [26]. The main novelty of this combination between existent and non-semantic resources will permit the knowledge base to be standard and linked with open building data. Moreover, the construction of this semantic model will advance in providing comprehensive abstractions and data fusion (integration) for the building and energy domain. Therefore, this paradigm will advance towards adopting semantic sensor web paradigms [25].

Cross-Dimensional Recommendations

Cross-Dimensional recommendation is aimed at taking advantage of the building-user knowledge base to derive the proper recommendations based on the incoming building information. This cross-dimensional recommendation will be generated through semantic reasoning with temporal and spatial reasoning capabilities. The semantic reasoning to be applied will comprise the use of streaming reasoning to select critical events at different time stamps [27]. These crucial streams of data will be stored in a semantic data store or semantic repository (Sesame [28], Virtuoso [29], StarDog [30], etc). The spatial reasoning will be conducted through the geo-reasoners applied over the information stored in the semantic repository.

More complex reasoning and cross-recommendation will be performed through the dynamic rules reasoning. In the one hand, dynamic rules coming from the "User behaviour models" and encapsulated in SWRL [31] or SPIN [32], will be incorporated into the elaborated knowledge base. Moreover, rule-based reasoning over the building will be performed using JENA-SWRL [33] for SWRL rules or SPIN engine for SPIN rules.

The novelty of the cross-dimensional recommendations generation will be focused on the combination between temporal and spatial reasoning at low level. Moreover, other highlighted benefits will come from the generation of cross-dimensional recommendations using OWL reasoning and rule-based reasoning.

User Behaviour Models

User-Behaviour Models will be focused on applying data mining and machine learning algorithms in order to detect energy abnormalities and user behaviour and comfort abnormalities. With this aim, this specific part of the module will apply a Knowledge Discovery in Databases (KDD) methodology [34] to encode adaptive knowledge in the form of SWRL or SPIN rules.

This methodology will use (i) forecasting techniques; and (ii) classification techniques to infer mentioned kind of rules. Forecasting techniques (e.g. Linear Regression, Multi-Variate Forecasting, etc.) will be applied in order to predict user behaviour and then, detect possible abnormalities of uncomforted building states. Finally, classification techniques will permit to generate a decision tree with the efficient and inefficient building activities based on user information combined with the building information.

The novelty of this part of the UBT is the generation of dynamic and adaptive knowledge to be applied over the current building state (facts). Moreover, this approach will permit also to move to more holistic decision systems not only including intra-building information but also with the possibility to include other building decision making procedures.

CONCLUSIONS AND FUTURE WORK

This study presented a framework to integrate user-behaviour in the operation strategies of building systems. The proposed framework also has the capability to be integrated with building simulation tools for improving the accuracy of energy performance of the buildings in the design phase. The framework includes three main components: the preferences and state of the users which must be met in order for the user to be comfortable and satisfied with their environment; the behaviours which users can perform in order to increase their satisfaction levels in the environment; the building systems with which users can interact to affect the building energy consumption. The proposed UBT provides novelties and benefits at social, technological and energy perspective. From social perspective, UBT module will provide the building occupants and building managers to convey on behalf the energy efficiency and sustainability of the building operation. From the technologic perspective, the UBT presents answers to most common challenges and needs proposed to the adoption of semantics in building management and semantic sensor web research lines. In this sense, the application of semantic stream reasoning to detect initial relevant events and more cross-dimensional recommendations and higher level (like a divide and conquer approach) will permit to create a reinforced decisions combining all building processes and information. From the energy perspective, this presented conceptual model will permit to interrelate different stakeholders' energy decision-making procedures to enable holistic decision-making. As a conclusion, the adoption of the framework will enable buildings to be more energy efficient, moving towards the accomplishment of the EU energy challenges in matters of zero-energy buildings, low carbon and circular economy paradigms.

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REFERENCES

[1] COM (2015)080, ***A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy***, 2015

[2] COM (2015) 6317, ***Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation***, 2015

[3] COM (2015)339, ***New Deal for Energy Consumers***, 2015

[4] Klein, L., Kwak, J., Kawulya, G., Jazizadeh, F., Becerik-Gerber, B., Varakantham, P. and Tambe, M., 2012, ***Coordinating occupant behavior for building energy and comfort management using multi-agent systems***, Automation in Construction, March 2012, pp. 525-536.

[5] Zhao, L., Zhang, J. and Liang, L., 2013, ***Development of an energy monitoring system for large public buildings***, Energy and Buildings, November 2013, pp. 41-48.

[6] Ramesh, T., Prakash, R. and Shukla, K.K., 2010, ***Life cycle energy analysis of buildings: An overview***, Energy and Buildings, Vol 42, Issue 10, pp. 1592-1600.

[7] Papantoniou, S., Kolokotsa, D. and Kalaitzakis, K. ***Building optimization and control algorithms implemented in existing BEMS using a web based energy management and control system***, Energy and Buildings, Volume 98, 1 July 2015, pp. 45-55. ISSN 0378-7788, http://dx.doi.org/10.1016/j.enbuild.2014.10.083.

[8] Ferlito, S., Atrigna,M., Graditi, G., De Vito, S., Salvato, M., Buonanno, A. and Di Francia, G., ***Predictive models for building's energy***

consumption: An Artificial Neural Network (ANN) approach, AISEM Annual Conference, 2015 XVIII, Trento, 2015, pp. 1-4.doi: 10.1109/AISEM.2015.7066836

[9] Xiao, F. and Fan, C., ***Data mining in building automation system for improving building operational performance***, Energy and Buildings, Volume 75, June 2014, Pages 109-118, ISSN 0378-7788, http://dx.doi.org/10.1016/j.enbuild.2014.02.005.

[10] Saleem, F. and Al-Malaise, A. S. ***Implementation of data mining approach for building automated decision support systems***, International Conference on Information Society (i-Society-2012), London, pp. 127-130.

[11] Fangwen, C., Yahui, W., Li, S., Chao L. and Mingjia, D. ***The design of the building electrical fault diagnosis system based on multi-agent***,"The 27th Chinese Control and Decision Conference (2015 CCDC), Qingdao, 2015, pp. 3345-3349.

[12] Venugopal, M., Eastman, C.M., Sacks, R. and Teizer, J., 2012, ***Semantics of model views for information exchanges using the industry foundation class schema***, Advanced Engineering Informatics, Volume 26, Issue 2, April 2012, pp. 411-428, ISSN 1474-0346, http://dx.doi.org/10.1016/j.aei.2012.01.005.

[13] Venugopal, M., Eastman, C. M. and Teizer, J., 2015, ***An ontology-based analysis of the industry foundation class schema for building information model exchanges***, Advanced Engineering Informatics, Volume 29, Issue ***4, October 2015, pp. 940-957, ISSN 1474-0346,*** http://dx.doi.org/10.1016/j.aei.2015.09.006.

[14] Corry, E., Pauwels, P., Hu, S., Keane, M. and O'Donnell, J., 2015, ***A performance assessment ontology for the environmental and energy management of buildings***, Automation in Construction, Volume 57, September 2015, Pages 249-259, ISSN 0926-5805, http://dx.doi.org/10.1016/j.autcon.2015.05.002.

[15] Costa, G. and Madrazo, L., 2015, ***Connecting building component catalogues with BIM models using semantic technologies: an application for precast concrete components***, Automation in Construction, Volume 57, September 2015, Pages 239-248, ISSN 0926-5805, http://dx.doi.org/10.1016/j.autcon.2015.05.007.

[16] Hong, T., D'Oca, S., Turner, W.J.N. and Taylor-Lange, S.C., 2015, ***An ontology to represent energy-related occupant behavior in buildings. Part I: Introduction to the DNAs framework***, Building and Environment, Volume 92, October 2015, pp.764-777.

[17] Hong, T., D'Oca, S., Turner, W.J.N., Taylor-Lange, S.C., Chen, Y. and Corgnati, S.P., 2015, ***An ontology to represent energy-related occupant behavior in buildings. Part II: Implementation of the DNAS framework using an XML schema, Building and Environment***, Volume 94, December 2015, pp. 196-205.

[18] Yu, Z, Fung, B.C.M., Haghighat, F., Yoshino, H. and Morofsky, E., 2011, ***A systematic procedure to study the influence of occupant behavior on building energy consumption***, Energy and Buildings, Volume 43, Issue 6, pp.1409-1417.

[19] Fabi, V., Andersen, R. V., Corgnati, S. P., and Olesen, B. W., 2013, ***A methodology for modelling energy-related human behaviour: Application to window opening behaviour in residential buildings***, Building Simulation, Volume 6, No 4, pp. 415-427.

[20] Sieminski, A., 2013, ***International energy outlook 2013***, US Energy Information Administration (EIA) Report Number: DOE/EIA-0484.

[21] Terkaj, W. and Šojić, A., 2015, ***Ontology-based representation of IFC EXPRESS rules: An enhancement of the ifcOWL ontology***, Automation in Construction, Volume 57, September 2015, Pages 188-201, ISSN 0926-5805, http://dx.doi.org/10.1016/j.autcon.2015.04.010.

[22] Daniele, L., den Hartog, F. and Roes, J., 2015, ***Created in Close Interaction with the Industry: The Smart Appliances REFerence (SAREF) Ontology***, Lecture Notes in Business Information Processing, Volume 225, pp. 100–112.

[23] Compton, M., Barnaghi, P., Bermudez, L., García-Castro, R., Corcho, O., Cox, S. Graybeal, J., Hauswirth, M., Henson, C., Herzog, A., Huang, V., Janowicz, K., Kelsey, W.D., Le Phuoc, D., Lefort, L., Leggieri, M., Neuhaus, H., Nikolov, A., Page, K., Passant, A., Sheth, A and Taylor,

K., 2012, ***The SSN ontology of the W3C semantic sensor network incubator group, Web Semantics: Science, Services and Agents on the World Wide Web***, Volume 17, December 2012, pp. 25-32, ISSN 1570-8268, http://dx.doi.org/10.1016/j.websem.2012.05.003.

[24] Battle, R. and Kolas, D., 2012, ***GeoSPARQL: Enabling a Geospatial Semantic Web***, ***Semantic Web Journal***, Volume 0, No. 0, pp. 1–17.

[25] Sheth, A., Henson, C.and Sahoo, S. S., 2008, ***Semantic Sensor Web***, ***IEEE Internet Computing***, Volume 12, No 4, July-Aug. 2008, pp. 78-83, doi: 10.1109/MIC.2008.87

[26] Schema.org website: http://schema.org/

[27] Whitehouse, K., Zhao, F. and Liu, J., 2006, ***Semantic Streams: A framework for composable semantic interpretation of sensor data***, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), Volume 3868 LNCS, pp. 5–20.

[28] Sesame Web page: www.openrdf.org/

[29] Virtuoso Web page: http://virtuoso.openlinksw.com/

[30] StarDog Web page: http://stardog.com/

[31] Horrocks, I., Patel-schneider, P. F., Boley, H., Tabet, S., Grosof, B. and M. Dean, 2004, ***SWRL : A Semantic Web Rule Language Combining OWL and RuleML***, ***W3C Memb. Submiss. 21***, May 2004, pp. 1–20.

[32] Knublauch, H., Hendler, J. A. and Idehen, K., 2011, ***SPIN - Overview and Motivation***, ***http://www.w3.org/Submission/spin-overview/.***

[33] McBride, B., 2002, ***Jena: A semantic web toolkit***, IEEE Internet Computer, Volume 6, No. 6, pp. 55–58.

[34] Fayyad, U., Piatetsky-Shapiro, G. and Smyth, P., 1996, ***The KDD process for extracting useful knowledge from volumes of data***, Communication. ACM, Volume 39, No. 11, pp. 27–34.

Paper No: 204

Exergoeconomic Evaluation of the IKVA Shopping Centre in the City of Sopron, Hungary

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ABSTRACT

The paper deals with exergoeconomic analysis of a heat pump (HP) heating system in a building. The total heating and cooling demand rates of the first floor are 39.5 kW and 66.9 kW, respectively. The retrofitting surface area is 984.7 m2. The HP system is integrated with a capillary tube radiant cooling/heating system with inlet water and outlet water temperature values of 32°C and 28°C, and 16 °C and 18 °C in the heating and cooling modes, respectively.

Exergy, cost, energy and mass (the so-called EXCEM) method is used in the analysis. In this regard, we, as one of the Partners of the ECOSHOPPING project under the name of YASAR, briefly explain the heating and cooling system considered first. We then assess the performance of the retrofitting section of the building using the EXCEM and low exergy (LOWEX) methods. Finally, we present the results obtained and discuss about them. The overall exergy efficiencies of the heating system from the primary energy production to the building envelope were determined to be between 9.2% and 11.5% while the ratios of the exergy loss rates to capital cost values were in the range of 0.0387-0.063 W/Euro.

INTRODUCTION

Energy conservation in a building is an important issue from the point of view of global warming and depletion of fossil fuels. Nowadays, there is a strong need to design buildings, in which renewable sources of energy are utilized, in order to use minimum fossil fuel based conventional power [1]. At present, the building sector represents about 40% of the total primary energy consumed in the European Union while the heating, ventilation and air conditioning (HVAC) systems account for two-thirds of this demand. The European Directive on the energy performance of buildings (EPBD) encourages the European Union member states to approve energy policies that promote the implementation of very low and even close to zero energy buildings [2,3].

Exergy of a thermodynamic system is the maximum theoretical useful work (shaft work or electrical work) obtainable as the system is brought into complete thermodynamic equilibrium with the thermodynamic environment while the system interacts with this environment only. Besides this, exergoeconomics is the branch of engineering that appropriately combines, at the level of system components, thermodynamic evaluations based on an exergy analysis with economic principles, in order to provide the designer or operator of a system with information that is useful to the design and operation of a cost-effective system, but not obtainable by regular energy or exergy analysis and economic analysis [4].

An exergy analysis (or second law analysis) has proven to be a powerful tool in the simulation thermodynamic analyses of energy systems. Exergy analysis method is employed to detect and to evaluate quantitatively the causes of the thermodynamic imperfection of the process under consideration. It can, therefore, indicate the possibilities of thermodynamic improvement of the process under consideration, but only an economic analysis can decide the expediency of a possible improvement [5, 6].

In the literature, there are various exergoeconomic analysis methods. Exergy-based analyses have been widely used by many investigators in the performance assessment of various energy-related systems. Among these, exergoeconomic evaluation methodology is a combination of exergy analysis and economic aspect analysis. Various methods such as engineering functional analysis (EFA), exergetic cost theory (ECT), specific exergy costing (SPECO), exergy cost energy mass analysis (EXCEM) and modified productive structure analysis (MOPSA).

The methodology of the EXCEM method was developed earlier by Rosen [6] and used more recently by Rosen and Dincer [7, 8] for power plants. This method was also applied to a gas engine driven heat pump system [9]. Based on some recent studies on the HP systems, Akbulut et al. [10,11] assessed both experimentally and theoretically the performance of a vertical ground source heat pump wall heating system in the heating [10] and cooling [11] modes using exergoeconomic analysis method. The exergoeconomic factors varied between 74.97% and 75.77% in the heating mode while the exergoeconomic factor values of all the system were determined to be 77.68% in the cooling mode. The value of the exergo-economic factor changed depending on some particular components, with the values of 69.43%, 62.59%, 62.53% and 29.15% for the accumulator tank, the undersoil heat exchanger, the evaporator and the condenser, respectively.

In this regard, the main objective of the present contribution is to assess the performance of a Shopping Center located in Sopron, Hungary through exergoeconomic analysis method.

SYSTEM DESCRIPTION

The demo building IKVA considered in this study was built in 1979 in the city of Sopron, Hungary. It has two main sections, namely (i): the main building part (commercial area), which consists of two floors plus an open parking lot on the ground level, and (ii) a service area with three floors and a basement. The total heat demand of the building, taking into account different functions, is 618.6 kW/year, of which 136.7 kW are used by the air heating unit. The heating energy is produced by three Viessmann condensing gas boilers. The total thermal capacity of the boilers is 3 x 66 kW = 198 kW. The gas boilers supply only the radiators.

Within the scope of the European Commission project, the so-called ECOSHOPPING (Energy Efficient & Cost Competitive Retrofitting Solutions for Shopping Buildings), some modifications have been planned and are still implemented to reduce the primary energy consumption down to less than 80 kWh/m2 per year and to increase the share of Renewable Energy Sources (RES) more than 50% compared to the state of the art through building a holistic retrofitting solution for commercial buildings, as explained in more detail elsewhere [12].

The assessment of the pre-retrofit status is necessary to select, which building structures and building energy service systems should be retrofitted. In this regard, three different retrofitting possibilities are studied while the proposed retrofit solution is then determined for the IKVA Shopping center. As part of the improvements to be made, it is aimed at designing a RE powered heat pump (HP) system and assessing its performance using energetic and exergetic analysis tools. The HP system will be integrated with a capillary tube radiant cooling/ heating system with inlet water and outlet water temperature values of 32°C and 28°C, and 16 °C and 18 °C in the heating and cooling modes, respectively. Based on the simulation results, the total heating and cooling loads of the retrofitting area are determined to be 39.5 kW and 66.9 kW, respectively. The retrofitting surface area is 984.7 m2 with about a volume of 3250 m3 while the outdoor design temperatures for the heating and cooling seasons are -15 oC and 32 oC, respectively. Figure 1 illustrates a schematic of the HP system where there are 5 HPs, of which four are alternating current (AC) types while the remainder is a direct current (DC) type. A buffer tank with a volume of 1000 liter is also used to improve the overall system operating efficiency by reducing unnecessary equipment short cycling. The indoor and outdoor air temperatures are taken to be 22 oC and -15 oC, respectively. The domestic hot water (DHW) energy demand was ignored in this study.

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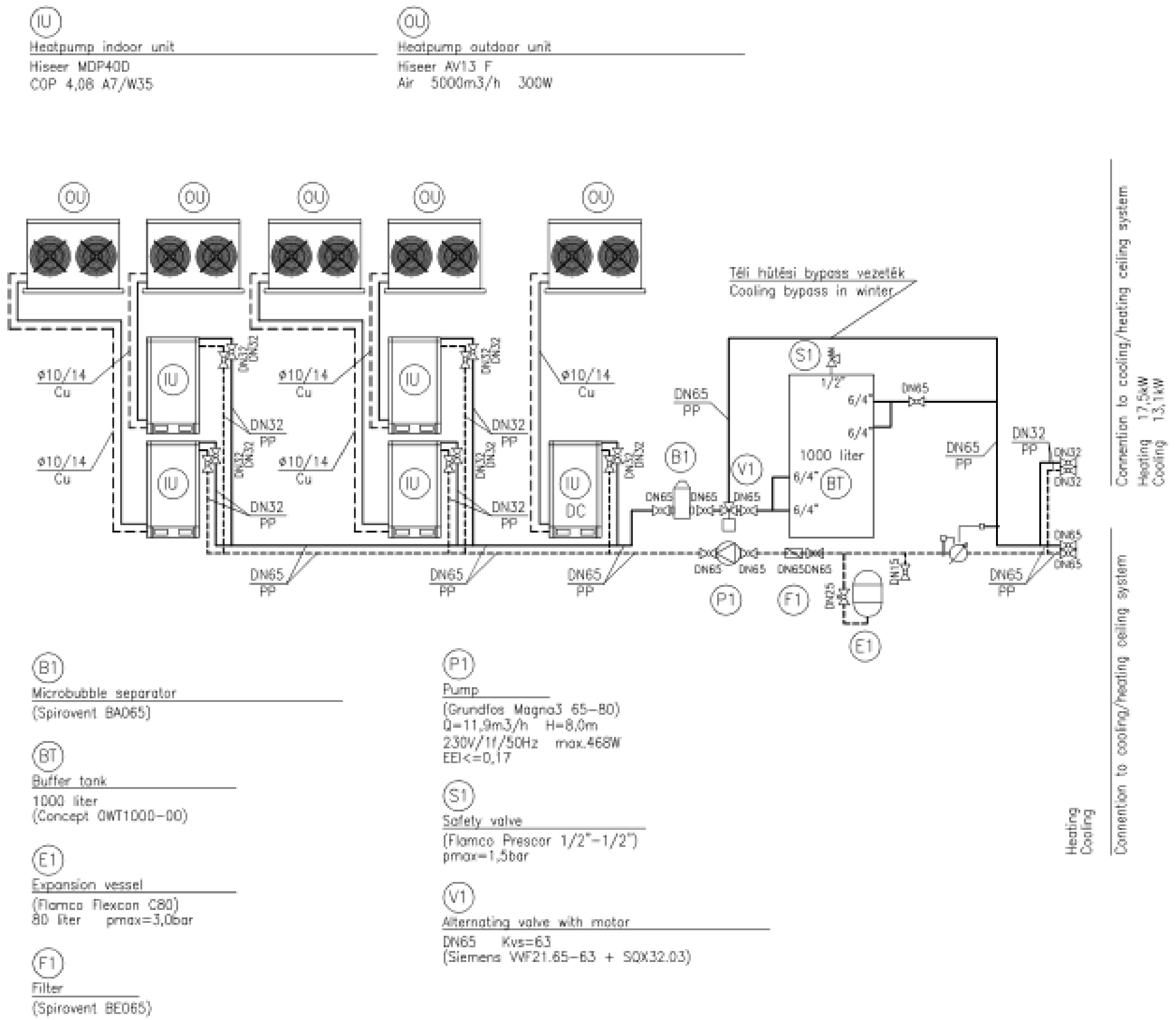

Figure 1 A Schematic of the Heat Pump System

ANALYSIS

The EXCEM method proposed by Rosen and Scott [8] could be useful to investigators in engineering and other disciplines. This method provides a comprehensive assessment by accounting for the quantities exergy, cost, energy and mass [13]:

The energy loss rate for a system is denoted as L_{en} (loss rate based on energy), as given below:

L_{en} = *Waste energy output rate* (1)

The loss rate based on exergy, L_{ex} is defined as;

L_{ex}= *Exergy consumption rate + Waste exergy output rate* (2)

The capital cost (*K*) is simply that part of the cost generation attributable to the cost of equipment.

The principal reason that capital costs are used here is that the use of the cost generation term increases significantly the complexity of the analysis, since numerous other economic details (interest rates, component lifetimes, salvage values, etc.) must be fully known. There are two main justifications for this simplification:

- Capital costs are often the most significant component of the total cost generation. Hence, the consideration of only capital costs closely approximates the results when cost generation is considered.
- Cost generation components other than capital costs often are proportional to capital costs. Hence, the trends identified in the present work will likely be in qualitative agreement with those identified when the entire cost generation term is considered.

For a thermal system operating normally in a continuous steady-state steady-flow process mode, the energy and exergy loss rates can be obtained through the following equations

$$L_{en} = \sum_{inputs} E - \sum_{products} E \qquad (3)$$

and

$$L_{ex} = \sum_{inputs} Ex - \sum_{products} Ex \qquad (4)$$

where the summations are over all input streams and all product output streams.

Another parameter, R is defined as the ratio of thermodynamic loss rate L to capital cost K as follows:

$$R = L / K \qquad (5)$$

The value of R generally depends on whether it is based on energy loss rate (in which case it is denoted R_{en},), or exergy loss rate (R_{ex}), as follows:

$$R_{en} = L_{en} / K \qquad (6)$$

and

$$R_{ex} = L_{ex} / K \qquad (7)$$

Values of the parameter R based on energy loss rate, and on total, internal and external exergy loss rates are considered. In investigating sets of R-values, maximum (R_{max}), minimum (R_{min}), mean (R_m), standard deviation (SD(R)) and coefficient of variation (CV(R)), which is the ratio of standard deviation to mean, are considered.

The exergetic assessment of the building from the primary energy production to the building envelope has been done using low exergy (LOWEX) approach, whose details have been given in Ref. [14].

The methodology and relations used for LOWEX are based a pre-design analysis tool, which has been produced during the ongoing work for the International Energy Agency (IEA), the Energy Conservation in Buildings and Community Systems (ECBCS) Programme Annex 37 [15].

RESULTS AND DISCUSSION

The outdoor air temperature was taken to be -10 °C because the coefficient of performance (COP) values for the heat pump unit were given between -10 °C and 20 °C (Figure 2) and the total heat demand rate was 39.5 kW.

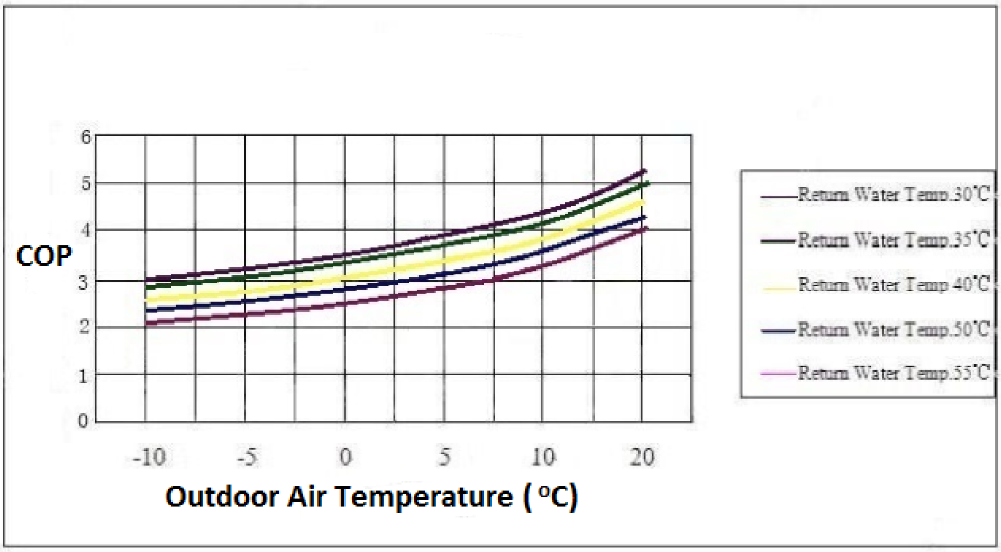

Figure 2 COP Values for the Heat Pump Unit

Using the LOWEX approach stated in Ref. [14], energy and exergy flows through the components were determined, as indicated Figure 3 where the exergy loss values were also included. At an outdoor air temperature of -10 °C and a COP value of 3, the total exergy system efficiency (exergy demand room / total exergy input), Y , was calculated to be 4.81% while the exergy flexibility factor (exergy demand emission / total exergy input), *ExFF*, was obtained to be 11.5%.

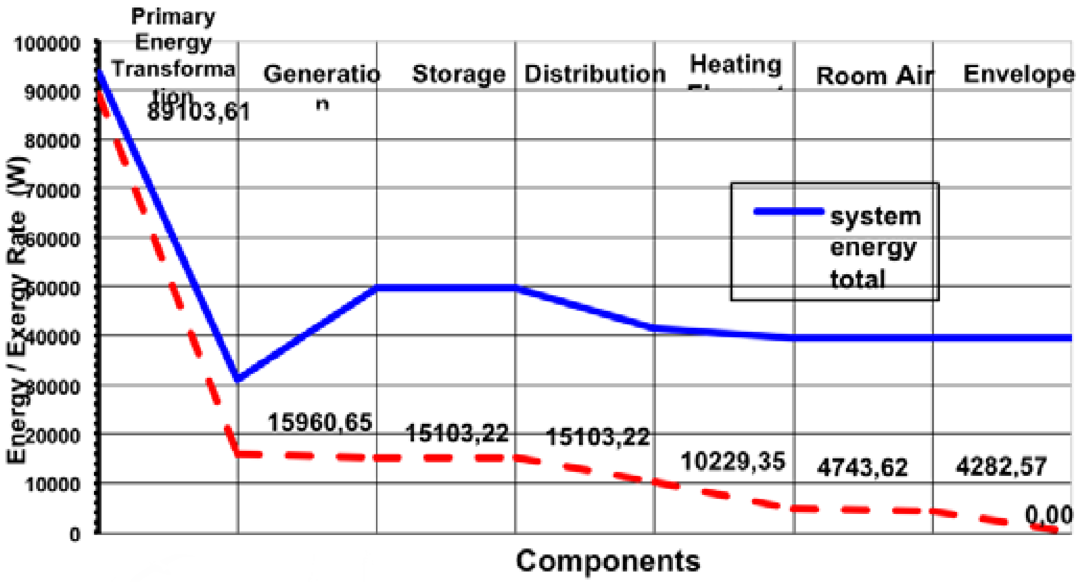

Figure 3 Energy and Exergy Flows through the Components

The authors have also undertook a parametric study to investigate how varying reference state temperatures ranging from -10 to 0 °C will affect the exergy efficiencies of the system along with its components. Exergy is evaluated with respect to the reference (dead) state, as known. The exergy losses in each component of the whole system are determined from Figure 3 and are listed in Table 1 at various outdoor air temperatures. It is clear from the figure that the exergetic efficiency values decrease with increasing the reference state temperatures.

Table 1 Exergy Losses in Each Component of the Whole System in W

States	**Primary Energy Transfor-mation**	**Gene-ration (Heat Pump)**	**Stor-age**	**Distri-bution**	**Heating Element**	**Room Air**	**Enve-lope**
State 1 COP = 3 Outdoor air temp. = -10 °C Y = 4.81% *ExFF* = 11.5%	73142.96	857.43	0	4873.87	5485.73	461.05	4282.57
State 2 COP = 3.2 Outdoor air temp. = -5 °C Y = 4.20% *ExFF* = 10.3%	71147.87	1268.34	0	4811.60	4799.99	469.81	3613.42
State 3 COP = 3.5 Outdoor air temp. = 0 °C Y = 3.58% *ExFF* = 9.2%	68582.77	1394.24	0	4749.34	4114.15	478.57	2944.27

In the calculations, the prices of the distribution and the heating element (radiant ceiling system) were assumed to be 10% and 50% of the price of the heat pump unit, respectively. Table 2 illustrates $\dot{R}$ values for some main components in the whole building system at various reference state temperatures from -10 °C to 0 °C.

Table 2 Values for the Ratio of Thermodynamic Loss Rate-to-Capital Cost, $\dot{R}$(W/Euro) at Various Dead State Temperatures

Component	**K (Euro)**	**L_{ex-i} (W)**			**R_{ex-i} (W/Euro)**		
		-10 °C	**-5 °C**	**0 °C**	**-10 °C**	**-5 °C**	**0 °C**
Heat Pump Units (5 pieces)	4430x5= 22150	857.43	1268.34	1394.24	0.0387	0.057	0.063
Distribution System	2215	4873.87	4811.60	4749.34	2.20	2.17	2.14
Heating Element	11075	5485.73	4749.34	4114.15	0.495	0.429	0.371

The value of $\dot{R}_{\alpha}$ may vary for different situations (e.g., technology, time, location, resource costs, knowledge). For example, the values of $\dot{R}_{\alpha}$ may be different for different technologies. Also, during periods when energy-resource costs increase (as was the case in many locations in the 1970s), the value of $\dot{R}_{\alpha}$ likely decreases (i.e., greater capital is invested to reduce losses). For any technology, it appears that the design of a device may be made more successful if it is modified so that its value of $\dot{R}_{\alpha}$ approaches appropriate $\dot{R}_{\alpha}$. A balance is obtained between exergy loss and capital cost in real systems. If successful technologies conform to an appropriate $\dot{R}_{\alpha}$, then it follows that technologies which fail in the marketplace may do so because they deviate too far from the appropriate $\dot{R}_{\alpha}$ [7].

CONCLUDING REMARKS

In this study, we have considered a heat pump system for the ECOSHOPPING project, co-funded by the European Commission, with each other in the heating mode using both the EXCEM and LOWEX methods. We have also assessed the performance of the system through overall exergy efficiency values under the design conditions and at various dead state temperatures. The application place of this project is the IKVA Shopping Centre in the city of Sopron, Hungary. The retrofitting surface area is 984.7 m^2, which will be heated using a HP system. The design stage of the system has been completed and the installation works are still in progress.

We have drawn the following main concluding remarks from the results of the present study as follows:

a) The total exergy efficiencies of the heating system from the primary energy production to the building envelope are determined to be between 9.2% and 11.5%.
b) As reference state temperatures increased, the values of exergy efficiency decreased.
c) Simple termo economic optimization methods on HP systems could contribute to determining the correct design of new equipment, especially by ensuring that value of $\dot{R}_{\alpha}$ for the equipment approaches an appropriate value of $\dot{R}_{\alpha}$.
d) The ratios of the exergy loss rates to capital cost values were obtained to vary from 0.0387 to 0.063 W/Euro.
e) The results appear to be useful to those involved in the development of analysis and design methodologies that integrate thermodynamics and economics, and in the HP systems.
f) It may be concluded that exergy analysis is a useful tool for determining the locations, types and true magnitudes of energy losses, and therefore help in the design of more efficient energy systems. An exergoeconomic analysis, which is a combination of exergy and economics, is also a good tool to be used for providing useful insights into the relations between thermodynamics and economics.

ACKNOWLEDGEMENTS

The presented work was developed within the framework of project "ECOSHOPPING-Energy Efficient & Cost Competitive Retrofitting Solutions for Shopping Buildings", co-funded by the European Commission (FP7-2013-NMP-ENV-EeB, Grant agreement no: 609180).

NOMENCLATURE

$\dot{E}$	energy rate (kW)
$\dot{Ex}$	exergy rate (kW)
ExFF	exergetic flexibility factor (%)
K	capital cost (Euro)
$\dot{L}$	thermodynamic loss rate (kW)
$\dot{R}$	ratio of thermodynamic loss rate to capital cost (kW/Euro or W/Euro)

Greek letters

Y	total system exergy efficiency (%)

Indices

en	energetic
ex	exergy

Abbreviations

EXCEM	exergy, cost, energy and mass
HP	heat pump
LOWEX	low exergy

REFERENCES

[1] Tiwari G.N., Saini H., Tiwari A., Deo A., Gupta N. and Saini P.S. ***Periodic theory of building integrated photovoltaic thermal (BIPVT) system***. Solar Energy, Vol. 125, 2016, pp. 373-380.

[2] European Union. ***Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings***, 2010. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF.

[3] Saadona S., Gaillarda L., Girouxa S. and Ménézoa C. ***Simulation study of a naturally ventilated building integrated photovoltaic (BIPV) envelope***. Energy Procedia, Vol. 78, 2015, pp. 2004-2009.

[4] Tsatsaronis G. ***Definitions and nomenclature in exergy analysis and exergoeconomics***. Energy, Vol. 32(4), 2007, pp. 249253.

[5] Szargut J, Morris D.R, Stewart F.R. ***Exergy Analysis of Thermal, Chemical, and Metallurgical Processes***, Hemisphere Publishing Corporation, 1988. ISBN3540188649.

[6] Rosen M.A. and Dincer I. ***Exergy methods for assessing and comparing thermal storage systems***. International Journal of Energy Research, Vol. 27(4), 2003, pp. 415-430.

[7] Rosen M.A. and Dincer I. ***Exergoeconomic analysis of power plants operating on various fuels***. Applied Thermal Engineering, Vol. 23, 2003, pp. 643-658.

[8] Rosen M.A. and Dincer I. ***Thermoeconomic analysis of power plants: an application to a coal-fired electrical generating station***. Energy Conversion and Management, Vol. 44, 2003, pp. 1633-1651.

[9] Gungor A., Erbay Z. and Hepbasli A. ***Exergoeconomic analyses of a gas engine driven heat pump drier and food drying process.*** Applied Energy, Vol. 88(8), 2011, pp. 2677-2684.

[10] Akbulut U., Utlu Z. and Kincay O. ***Exergy, exergoenvironmental and exergoeconomic evaluation of a heat pump-integrated wall heating system***. Energy, Vol. 107, 2016, pp. 502-522.

[11] Akbulut U., Utlu Z. and Kincay O. ***Exergoenvironmental and exergoeconomic analyses of a vertical type ground source heat pump integrated wall cooling system system***. Applied Thermal Engineering, Vol. 102, 2016, pp. 904-921.

[12] ECOSHOPPING. http://www.ecoshopping-project.eu/. [Accessed 20.02.16].

[13] Rosen M.A. and Scott D.S. ***The Enhancement of a Process Simulator for Complete Energy-Exergy Analysis, in Analysis and Design of Advanced Energy Systems: Fundamentals***, MRA Gaggioli (Ed), American Society of Mechanical Engineers, New York, Vol. 3, 1985, pp. 71-80.

[14] Hepbasli A. L***ow exergy (lowex) heating and cooling systems for sustainable buildings and societies.*** Renewable & Sustainable Energy Reviews, Vol. 16(1), 2012, pp. 5297-5328.

[15] IEA. ***Low Exergy Heating and Cooling of Buildings–Annex 37***, retrieved May 19, 2008. http://www.vtt.fi/rte/projects/annex37/Index.htm.

"Urban - Urban Area Assesment"

Paper No: 109

Energy Efficiency Consultancy and Contracting for Industry - Results from Projects Implemented in Bursa

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ABSTRACT

ENERVIS is one of the group companies of EWE Turkey Holding A.S, which is a representative of the German energy giant EWE AG in Turkey. Enervis is an ESCO which leads Energy efficiency audits and implementations using the performance contracting model. For example, The "Energy Efficiency Cluster Project" which is the most comprehensive energy efficiency project in Turkey so far, was completed in Bursa Organized Industrial Zone (BOIZ). In total, 131 possible projects were studied in 17 companies, an average energy saving ratio of 22%, a saving potential of 5.7 million TL/year and a CO_2 reduction potential of 14,500 tons/year have been identified. Additionally, Enervis has realised an energy efficiency implementation project in which the EPC model was used. As a leading market player, Enervis developed a unique EPC model which is called Enervay (Energy Efficiency Improvement Investments). According to the model, Enervis leads the turnkey implementation with its own financial solutions. Also, energy performance guarantee is given to the implemented system. The customer makes the repayment according to the monthly energy saving amount. A "Waste Water Heat Recovery" system has been implemented for a textile company in Bursa using the Enervay model. The project was realized as turnkey by Enervis project team. The monthly saving amount is 8.2 million kWh. The payback of the project is only 7 months. Thanks to this energy efficiency project, the company contributed to a CO_2 emission reduction with 1,528 tons/year.

INTRODUCTION

As a developing country, Turkey is making fast progress in energy consumption. Thanks to its young and dynamic population and consistently developing economy in recent years. According to the Energy Consumption Report of the Turkish Statistical Institute (TÜİK), while the total primary energy consumption was 87 MTOE in 2004, it increased to 125 MTOE by the end of 2014 [1]. It is expected to reach 218 MTOE primary energy consumption by 2023. Turkey is advancing in energy consumption and in the liberalization of energy markets. The total electricity consumption in Turkey was 264 TWh in 2015 which is expected to reach 414 TWh by 2023.

Fossil fuels account for 90% of total energy consumption in Turkey. Natural gas took the lead for oil as the most used primary energy resource for the first time in 2008 and still dominates the energy mix of Turkey. By 2015, the total oil consumption reached 28 million tons and natural gas consumption reached 51 bcm. The gas consumption of Turkey is steadily increasing in line with its increasing population and prosperity. The increase in consumption is expected to continue at a considerable speed and total consumption is expected to exceed 60 bcm by 2020.

Turkey needs new energy investments due to its growing economy. If it is considered that the system and equipment will be imported for the energy production facilities, this will be a reason to increase the current deficit. Nevertheless, 1 unit of energy efficiency investment would prevent 2.5 units of the investment for energy production. Thus, it is obvious that energy efficiency is one of the most effective medicine for the current deficit problem in Turkey.

According to the International Energy Agency (IAE), about 300 billion USD of energy efficiency investments were realized worldwide in 2011. Also, from 2005 to 2010, 11 IAE member countries had an energy savings of 570 Mio. TOE. This energy saving amount is pretty appealing considering that Turkey's total energy consumption was 125 Mio. TOE in 2014 [3].

In Turkey, The Energy Efficiency Law, which was adopted in 2007, sets the rules for energy management in industries and large buildings, project support, energy efficiency consultancy companies, voluntary agreements, etc. The law covers industries, power plants, transmission and distribution systems, buildings, services and transport.

Enforced in 2011, the regulation on Increased Energy Efficiency in the Use of Energy Resources and Energy put in place authorizations and certifications for universities, engineering organizations and energy consultancy companies to support energy efficiency projects in industries through voluntary agreements.
The Energy Efficiency Strategy Paper (2012-2023) sets a 20 percent reduction target for primary energy intensity until 2023 compared with the 2011 level. This target set by Turkey is also in line with the 2020 Energy Efficiency target of the EU.

According to the report of World Bank in 2010, there is a total energy saving potential in buildings and industries of 27 percent with a total amount equal to 15 Mio. TOE annually. The energy-saving potential of buildings is approximately 30 percent which amounts to 7 Mio. TOE and 12 billion TL. The share of industries is 25 percent which equals 8 Mio. TOE and 10 billion TL annual energy saving potential in Turkey [2]. The current unit energy prices in industries and buildings are taken account to calculate the annual energy saving potentials. There would be a chance to save energy which is equal to the electricity production of natural gas fired power plants with the capacity of 23,000 MWe if the total energy saving potential in industries and buildings are realized. In other words, this saving potential equals the electricity production of 14 gas fired power plants with the capacity of Ovaakça Gas Power Plant which is located in Bursa. This remarkable data shows that energy efficiency can make a significant contribution in order to meet the energy demand of our country.

Energy efficiency has a significant importance for the Turkish industry which consumes 34 percent of the total energy demand in Turkey. 25 percent of total natural gas consumption occurred in industries in 2013. The share of industrial consumption in electricity is even more impressive in comparison with its share in gas consumption. The share of industrial consumption in overall electricity consumption of Turkey is around 47 percent implying an electricity consumption of 116 TWh. in iron-steel, cement, chemical and textile industries which constitute about 75 percent of total energy saving potential in Turkish industry.

Organized Industrial Zones (OIZ) play important roles in Turkish industries. According to the OIZ statistical portal, OIZs have 11% share in natural gas consumption and 21% share in electricity consumption in energy consumption in Turkey at the end 2014. Thus, energy efficiency in OIZs is a critical issue in order to decrease the energy consumption in Turkey. The energy efficiency projects 33 facilities in Bursa Organized Industry Zone (BOIZ) and Demirtaş Organized Industry Zone (DOIZ) are vital in order to show the energy efficiency potential and identify the improvement projects. The environmental effects of the projects are also another important benefits of energy efficiency.

1. BURSA ORGANIZED INDUSTRIAL ZONE (BOIZ) PROJECT

1.1 Overview of the Project

As stated previously, Turkey is targeting to reach a 20% energy efficiency increase by 2023. In line with the mentioned national target, Bursa Organized Industrial Zone (BOIZ) initiated the energy efficiency assessment study on textile and automotive clusters within the scope of the "Communiqué on Supporting Development of International Competitiveness with No 2010/08" issued by the Republic of Turkey Ministry of Economy. The Ministry of Economy supported this remarkable project by covering 75% of the project costs as a grant. Bursa is a very important industrial city which has 8% share in total turnover of Turkish industry and 4% share in overall GDP in Turkey. Textile, automotive and food sectors lead the industry and there are 13 Organized Industrial Zones in Bursa. BOIZ is the oldest and one of the biggest Organized Industrial Zones in Turkey. Currently, BOIZ has around 240 active industrial plants in which the production is dominated by 80 textile and 50 automotive companies. For these reasons, an energy efficiency cluster project in textile and automotive sectors can make a significant contribution to decrease the energy consumption of the facilities. On the other hand, increasing the awareness of the employers and employees, development of technologies and the reduction of CO^2 emission are among the main targets of this project. BOIZ management aims both to increase the awareness of its members about the importance of energy efficiency for production and to promote the project with its results to the companies in BOIZ and other Organized Industrial Zones.

1.2 The Project Outcomes

The results of the project caused an extremely positive impact on the companies and BOIZ management. According to the findings after the energy efficiency assessments of these companies, Enervis project team found a total of 131 Golden Opportunities with an average energy saving rate of 22 percent. It means that the companies in cluster can save about 51,000 MWh of their annual energy consumption which is 215,000 MWh. The companies can save around 5.7 million TL/year annually. Due to these results, the average amortization period will be 1.5 years. In addition, about 14,500 tons of CO_2 emissions can be reduced every year if all these investment opportunities are realized. According to the carbon stock markets in Germany, about 200,000 Euro extra revenue could be generated with the trade of the reduced carbon emissions. This result explicitly shows that this project has not only achieved an economical but also an environmental impact. In the textile cluster, the companies can save around 25 percent of their total energy consumption. About 2.6 million TL in energy saving annually and 1.5 years of payback period explicitly illustrate the success of the project. On the other hand, similar results also apply to the automotive cluster. The automotive companies in the cluster can make an energy saving of 20 percent and reduce their annual energy bills by 3.1 million TL. The payback of the total investment is 1.5 years. These impressive results show that the targeted energy efficiency improvement rate seems quite achievable for the industry of Turkey. The study conducted by Enervis constitutes a significant sample study for overall industry of Turkey in this context. The companies are extremely satisfied with the energy saving opportunities and results which were concluded in this cluster project. Some of them have already started to implement these opportunities. Enervis has started to provide services to implement turnkey energy improvement projects with its unique business model which is consisted of different financial solutions and a performance guarantee. Enervis has also taken responsibility to provide supervision services for some of these investments. It is strongly believed that the findings and energy saving potentials will make an impact on industries in Bursa and the project will encourage other Industrial Zone Managements in order to initiate new energy efficiency cluster projects.

1- DOSAB ORGANIZED INDUSTRIAL ZONE PROJECT

Demirtas Organized Industrial Zone (DOIZ) is the biggest industry zone in Bursa with 428 active industrial facilities. 68% of the facilities are from the textile industry and 20% are active in the automotive industry. Enervis completed an energy efficiency cluster Project also in DOIZ. 16 facilities attended the project from textile and metal sectors. The project started in May 2015 and was completed in February 2016. 56 Golden Opportunities with 5.7 million TL annual saving potential were identified. The average payback period is 2 years. In addition, about 14,150 tons of CO_2 emissions can be reduced every year if all these investment opportunities are realized. The project results are important to show the energy efficiency potential in industries again.

2- ENERGY EFFICIENCY IMPLEMENTATIONS WITH ENERVAY MODEL

The energy efficiency audit projects in BOIZ and DOIZ are very important to show the energy efficiency in Bursa's industries. However, these projects are not enough to realize the potential. The implementations should speed up. Otherwise, the audit project reports would not be meaningful in reality. The energy efficiency implementations are not still very popular in Turkey. The industrialists are reluctant about allocating a budget for energy efficiency. The awareness should be increased. Also, necessary financial, technical and legal solutions should be provided to the sector.

Enervis developed an energy performance contracting business model which is called "Enervay". The model consists of turnkey implementation, energy performance guarantee and financial solution. After the identification of the energy efficiency project opportunity with measurement and analysis, the feasibility study is prepared and presented the company board. If they approve the project, the contract will be signed with the customer. After that, detailed projecting, system and equipment procurements, implementations and commissioning phases are lead by the Enervis team. In addition, the finance of all these steps are funded by Enervis' own sources. The customer pays the project fee back after the system starts to run. The project is paid back monthly due to the guaranteed energy saving. Thus, the customer does not have to allocate a budget for the project.

The Enervay model ensures what Turkish industrialists need in order to realize the energy efficiency improvement implementations. Enervis completed two projects with the Enervay model. The details of these projects are given below.

3.1 Waste Water Heat Recovery Project

The client is one of the oldest textile companies in Bursa Organized Industry Zone. They have a dying process in order to dye the fabric. This process needs 250 tons / day clean water with 90-130 °C. The clean water at 20-25 °C is heated with natural gas. After the process, the water has to be drained. The project idea is recovering the heat of the drained hot water with a heat exchanger and re-using it to heat the clean water at 20-25 °C to 50-60 °C. Thus, the heat demand and natural gas consumption would be decreased.

The Enervis project team made the necessary measurements, analysis and detailed projecting. The system mainly consists of a heat exchanger, clean water and water tanks, pumps, filters and energy monitoring. After the design and projecting, the procurement was completed. After the implementation and commissioning were completed, the energy saving amount was measured via calorimeter and approved by the technical manager of the client. The finances of the whole project was provided by Enervis. The client has started to pay monthly after the system has started to save money. Thus, the company did not pay extra money to have the system. The monthly saving is around 50.000 TL with 75.000 m^3 natural gas and the payback period is only 7 months which is shorter than the guaranteed saving amount.

Picture 1. Waste Water Heat Recovery Project

The client is extremely satisfied with outcomes of the project and implementation model. It is aimed to enhance the usage of Enervay model and contribute to increase the energy efficiency in Turkey.

3.2 Pressured Air System Optimization Project

The client is an active textile company in Demirtas Organized Industrial Zone. The pressured air system of the facility consumes high amount of energy. Although the pressure need differed up to the process, same pressure with 7.2 bars provided to all processes. It is planned to seperate the pressured air lines and install new pipeline according to the demand of the processes and decrease the pressure if it is required. In addition, the optimisation of the 11 compressors has been made. So, they will run according to the efficiency rates. The more efficient compressor will run in priority. Also, pressured air leaks have been renovated.

Picture 2. Pressured Air Optimisation Projec

Regarding the Enervay model, all phases of the project have been completed by the Enervis team. The annual energy saving is 1,3 million kWh and about 360.000 TL. The payback period of the project is 1.5 years.
Also, an energy monitoring system was installed to the project in order to monitor the energy consumption and energy savings of the each compressor. Thus, the technical managament of the facility can observe the actual situation of the running system.

3- **RESULTS**

Recently, energy efficiency is becoming increasingly popular all over the World. Due to the high potential, energy efficiency should be more prioritised in Turkey. There are already some new regulations and attempts but there needs to be more energy efficiency awareness between industrialists, NGOs and relevant government institutions. The incentives, funds and advantages should be increa sed and enhanced for the audits and implementations. Especially, smart and attractive business models, such as energy performance contracting, should be developed in order to encourage the implementations.
In that regard, Enervis is dominating the energy efficiency market with its own business models in Turkey. The energy efficiency cluster projects in Bursa and Demirtas Organized Industrial Zones made great impact in Bursa and also in Turkey. The results of the projects are remarkable and they give foresight about the energy efficiency potential in the Turkish industry.
Additionally, energy efficiency implementation is much more important in order to realize the potential. Otherwise, all appealing reports would not be meaningful. That's why, Enervis developed it own energy efficiency implementattion model, called Enervay and completed two projects in Bursa. The results of the projects have been successful which saves a remarkable amount of energy for the facilities.
It is believed that with strong regulations, incentives and business models, the energy efficiency sector could contribute to the decrease of energy bill and CO_2 emmissions of Turkey as well.

REFERENCES

[1] Turkish Statistical Institute (TÜİK) Bulletin, 24 February 2016, No:21587
[2] World Bank, ***Tapping the Potential for Energy Savings in Turkey***, January 2011
[3] International Energy Agency, ***Medium-Term Energy Efficiency Market Report 2015***, p 24-30

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Eco-city Model for Sustainable Urban Development

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ABSTRACT

With rapid changes in economic, social and cultural structures of cities, unsustainable urban forms and patterns create harmful effects on people and the environment. Central and local decision makers and residents of the city have not foreseen the results of these evolutions. Thus settlements remain behind planning. Especially superfluous energy consumption, unconscious use of resources and environmentally hazardous practices lead to unhealthy conditions for urban-dwellers.

Within this context, transferring existing cities into more ecologically-based and liveable settlements is a critical issue for future generations. Eco-city is proposed as the future model for new/existing settlements. This is a city concept consisting of living organisms and natural eco-systems, in which the city and the natural environment continuously interact. The eco-city is a city of social and functional integration, cultural diversity, accessible education, resource conservation and regional dialogue.

This paper evaluates such dimensions by considering guiding principles of sustainable urbanism by giving examples from several cities throughout the world. Issues will be studied under the headings of these eco-city guiding principles. Consequently, it will be possible to conceive how better human and environmental circumstances might be accomplished in public spaces.

Keywords: eco-city, sustainable urbanism, eco-systems, green city, human use, environmental factors

INTRODUCTION

In the twenty-first century, especially developing countries have great difficulties in controlling over-crowded cities. With rapid urbanization, countries face significant challenges in sustainable urban development. They actively explore novel ways to expand urban areas while conserving natural resources. For compensating climate change, environmental pollution, water shortage and energy demand, planners and policy makers increasingly involve in processes of implementing the idea of eco-city. Radical changes in city planning are being made to switch to sustainable development, with new cities being designed to be ecologically friendly and guided by principles like carbon neutrality and self-sufficiency.

Among the principles of eco-city planning and management, a cyclical urban metabolism, minimizing the use of land, energy and materials and impairment of the natural environment are the most important ones. Due to high costs and long-term investments, improving existing cities according to eco-city idea is preferred instead of planning completely new eco-cities. In such a way, the realization of well-known ideas, such as “carbon neutral”, “zero waste” and “car-free” city may be implemented. Current developments show that the needs and tendency toward eco-cities will accelerate rapidly and eco-city movement will be adopted by both existing and new cities. Today, some of the principles and technologies of these cities have already been used such as solar, wind and recycling technologies, green buildings and businesses, urban environmental restoration projects, urban gardening, organic farming, as well as individual preferences like using foot, bicycles and public transportation.

DEFINITION OF ECO-CITY

The eco-city concept has been regarded as an urban development paradigm in the global wave of ecological civilization which was influenced by other movements such as urban ecology that was developing over the same period. In an eco-city, it is believed that environment will be properly protected and maintained while the society and economy develop smoothly. These in turn promote human development. Seriously considering the relationship between human-being and nature led to the final conclusion that human-being must develop in harmony with nature in order to realize their own sustainable development. A survey of several paradigms may help to understand the dimension of eco-city concept, a program launched by UNESCO, put forward five key points of eco-city planning: an ecological protection strategy, ecological infrastructure, resident's living standard, protection of history and culture, and merging nature into the city. Moreover, the appropriate technology (AT) movement with the main goal of enhances the self-reliance of people at local level. Characteristics of self-reliant communities include: low resource usage coupled with extensive recycling, preferences for renewable over non-renewable resources, emphasis on small scale industries, and a high degree of social cohesion and sense of community [1]-[2].

In changing the nature of urban development to a more ecological and therefore sustainable model, some critical issues must be considered. In the core of these, urban transport systems and their relationship to urban form are placed. So, reducing automobile dependence in cities, building more sustainable urban form and creating more livable places are most critical problems for fast-growing prosperous cities in low- and middle-income nations.

Characteristics of Eco-City

In this article, referring to the definition and understanding of an eco-city, characteristics of eco-city are summarized combining different dimensions which were mentioned by different researchers.
Kenworthy (2006) defines ten critical issues related with eco-city characteristics, focusing on transport and planning dimensions, for sustainable city development. These are:

1. A compact, mixed-use urban form that uses land efficiently and protects the natural environment, bio-diversity and food-producing areas.
2. The city not only has a natural environment, but also provides a major proportion of its food needs.
3. Car and motorcycle use are minimized while transit, walking and cycling infrastructure are maximized, with a special emphasis on rail.
4. Environmental technologies for water, energy and waste management are emphasized and the city's life support systems becomes a closed loop system.
5. The city centre and sub-centres of the city are human centres. A high proportion of employment and residential growth is located in these areas. Access and circulation are provided by modes of transport other than the automobile.

6. A high-quality public realm is realized with public culture, community, and equity and good governance.
7. Public environments are highly legible, permeable, robust, varied, rich, visually appropriate and personalized for human needs.
8. With innovation, creativity and the uniqueness of the local environment, culture and history, environmental and social quality of the city's public environments are improved.
9. A visionary "debate and decide" process for planning for the future of the city is better instead of a "predict and provide", computer-driven process.
10. In all decision-making processes, sustainability-based, integrating social, economic, environmental and cultural considerations as well as compact, transit-oriented urban form principles are considered. In such a way, democratic, inclusive, empowering and engendering of hope approach is achieved.

Roseland (1997) also defines 10 principles of ecological cities by referring to the statement of Urban Ecology Organization. Within these principles the following 5 items are different from the preceding ones.

11. Damaged urban environments are restored (especially creeks, shore lines, ridge lines and wetlands).
12. Decent, affordable, safe, convenient and racially and economically mixed housing is created.
13. Social justice is nurtured and improved opportunities for women, people of color and the disabled are created.
14. Voluntary simplicity is promoted and excessive consumption of material goods is discouraged.
15. Awareness of the local environment and bio-region have been increased through activists and educational projects that increase public awareness of ecological sustainability issues.

Fifteen Dimensions of Eco-Cities

1. A compact, mixed-use urban form that uses land efficiently and protects the natural environment, biodiversity and food-producing areas. Transport patterns and impacts of a city are affected by land needed to house its people and accommodate its economic activities. Urban form factors affect food, materials and water requirements of a city, thus determine city's ecological footprint. The level of car dependence and effectiveness of public transport have a very strong relationship with urban form. The level of automobile and environmental impact of cities is related with low-density urban development. In many studies strong relationship between more compact, mixed-use urban form and reduced car use is put forward to reduce urban sprawl and create more transit-oriented communities. And also to create more compact, human-scale and walkable development patterns relationship with much higher quality urban public realm must be maintained. These involve a real sense of place and meaning for people. Public transport gain a greater role in higher densities and higher centralization. In more centralized cities, less central city parking, stronger rail systems and more use of public transport are common. Greater mixing of land uses, shorter travel distances and higher use of non-motorized transport are among the other characteristics of high-dense cities [3]. These sustainability goals have been experimented by European cities in new ways. For instance, the concept of "***eco-budgeting***" is developed by the city of Heildelberg at which elected officials understand and compensate for environmental damage. In Denmark, a number of cities including Copenhagen, ***"green accounts"*** system has been developed to track annual consumption of energy, greenhouse gas emissions and so forth [4].

2. The city not only has a natural environment, but also provides a major proportion of its food needs. The key issues are access to green space and food security. For the "green living" in the city, the two opposing views are seen. One of them is "***low-density rural"*** or ***"semi-rural"*** context in which citizens grow their food, practicing permaculture, recycling liquid and solid wastes and using decentralized energy and water supplies. The second view suggests ***higher-density development*** which allows more land for open space, gardens, urban agriculture, forestry and horticulture. With this way, locally managed systems for waste, energy and water can be achieved. More use of green transport nodes, traffic calming to promote greener and safer streets, less energy use and less environmental impact all of which support "urban commons" approach. Zurich, Stockholm, Helsinki and Freiburg are the most important cities which have adopted the "urban commons" approach and have become greener cities [4]. They also supplied urban agriculture, forests and community gardens through compact planning which also enable excellent public transport systems and high levels of walking and cycling. These two views have different resolutions. By planning a city more compact and urban, more space for nature and less dependence to automobiles can be achieved. Moreover, population density can grow and diversity in rural areas achieved through a "rural commons" approach to development.

3. Car and motorcycle use are minimized while transit, walking and cycling infrastructure are maximized, with a special emphasis on rail. In sustainable cities car and motorcycle use are minimized. Automobile use is linked closely to the provision of roads and parking. Higher freeway provision has been linked with higher car and energy use in cities that has been explained in terms of longer travel distances rather than savings in time. Walking and cycling as non-motorized systems are the most sustainable modes of transport. Public transport services by rail, which was arguably more competitive with automobiles due to high reliability and speed, highlight the important role of urban rail systems in achieving high public transport ridership. Only rail systems compete with cars in terms of speed, which is, in turn, linked to the provision of reserved alignments. The only way for any city to become more sustainable in terms of transportation is to have better quality public transport system, especially rail, and better conditions for pedestrians and cyclists [3].

4. Environmental technologies for water, energy and waste management are emphasized and the city's life support systems become closed loop systems. Most of the researchers share the same opinion that cities are "parasitic organisms" and they are consumers of water, energy and other resources, and producers of large quantities of wastes. Accordingly, ecological footprint of prosperous cities already extends many times beyond the area of land that they actually occupy [3]. For a sustainable city, use of all resources must be reduced and waste outputs must be decreased. At the same time, livability in terms of health, employment, income, education, housing, leisure activities, accessibility, urban design quality and sense of community and neighbourhood must be increased. The systematization of this argument is realized by offering "extended metabolism" model of human settlements [5]. Environmental technologies aim to maximize the possibility that cities can meet their needs from the natural capital of their own bio-regions in a renewable way. On the other hand, they try to use ***closed loop infrastructure systems*** that recycle and re-use their own wastes [3]. A competition, related to these issues mentioned above, searches for cities to develop realizable 100-year staged vision for transforming their city into an ecologically responsive system. Vologda, san Diego/Tijuana, Changshu, Vancouver, Numazu, Mishima, Chuo City, Goa, Berlin and Buenos Aires are among these cities. They are searching for innovative systems for water, energy and waste, as well as a vision where nature and natural processes are much more visible and accessible. Additionally, they have been asked how they incorporated public transport, pedestrian and bicyclist infrastructure to eliminate dependence on cars [6].

5. The city centre and sub-centres of the city are human centres. A high proportion of employment and residential growth is located in these areas. Access and circulation are provided by modes of transport other than the automobile. The greatest concentration of jobs remains in the central city. That is why central business district and sub-centres accounted as the most important parts of any city. In other words, increasing the number of jobs and the amount of floor space means that the city centre significantly shapes the transport pattern, especially rail system, focused on central city. Central city is always the focal point for new rail systems, and is the first to adopt sustainable transport and planning policies to reduce traffic, and residential revitalization. These policies included, pedestrianization, urban design and streetscape improvements, traffic calming schemes, control over parking provision, road-pricing schemes to reduce traffic, and residential revitalization. The other fact in the central city is the size of the resident population that affects the amount of car parking. Examples include Portland (Oregon), Singapore, Toronto, Freiburg, Copenhagen and many other European cities. Toronto, for example, experienced huge increases in central city housing, and reduced commuting due to more workers walking, cycling and taking public transport. The other aim of controlling automobiles in the central city is to improve economic performance. Besides, it is also clear that attractive, human-scale centres with good public transport systems and diverse cultural and entertainment attraction are preferred sites for globally mobile jobs linked to the new information economy [5].

6. **A high-quality public realm is realized with public culture, community, and equity and good governance.** Public realm is a factor which distinguishes well from bad cities. Mike Davis mentions of urban communities by discussing, their sense of responsibility concerning "the commons", the most obvious components of which are shared urban spaces, streets, parks and transit systems. He explains that Los Angles is a highly privatized, fear-driven environment that he characterizes as the "Ecology of fear" or "Fortress LA". According to Robert Putnam, planning policies in American cities over the last 50 years was based on automobile. He addresses the breakdown (and rediscovery) of communalism in American society, at the core of fragmentation and alienation that has occurred there [3]. Apart from physical and biological system, in order to maximize the possibilities of social capital, cities must make their public realms humane and equitable places.

7. Public environments are highly legible, permeable, robust, varied, rich, visually appropriate and personalized for human needs. Physical layouts and designs of cities make them more enduring and loved. For example, permeable street patterns based on regular or deformed grids, and legible streetscapes punctuated by well-placed landmarks and significant buildings are appreciated. Others have developed a host of measurable design qualities that need to be incorporated into the urban development. These are as follows:

• Permeability: Choice of how to get to places, a number of alternative routes through an area, places that are permeable provide access and have a clear definition between public and private places.

• Variety: Places that have variety offer experiential choice, but only if they can be accessed, and they attract a variety of people at various times for varied reasons.

• Legibility: How easily people can understand a place, and how quickly they can interpret what goes on there. Legible places enable an understanding of how to negotiate with an area. Legibility can be achieved through street function, landmarks and different land uses.

• Robustness: Robustness is the flexibility to use a place for a variety of purposes, especially over a long period of time. Robustness is the means by which cities survive and are "recycled" according to the needs of each era.

• Visual appropriateness: Richness and personalization is concerned with how comfortable and familiar a place is and how well it engenders a sense of belonging. Places that display visual appropriateness and richness can be interpreted easily by many people and create satisfying sensory experiences. Visually appropriate places have uses that match their physical appearance.

In creating a city that truly meets human needs for interaction, support and community, or one that functions well in an economic sense, the principles outlined above need to be applied. Automobile cities, however, have largely ignored them, but are now rediscovering these principles through movements such as The New Urbanism [7]
.

8. With innovation, creativity and the uniqueness of the local environment, culture and history, environmental and social quality of the city's public environments are improved. This dimension discusses the relation between cities and the economy. Jane Jacobs states that cities are key sites and drivers of national economies and cities themselves cannot survive without a viable economic base. Globalization has strengthened the role of cities in driving the global economy. As a result, there is now a global network of world cities which are tightly interconnected and dependent on each other for their sustainability. This network has increased the competition between urban regions for global capital and jobs. The new "creative class" of employees dictates, where companies locate, according to the quality of life being offered by the city [3]. There is an argument that cities that do not have the automobile under control run their environments down. In the worldwide quality of life survey by Mercer, Zurich was ranked first and Geneva, Vancouver and Vienna, all cities with excellent public transport systems and very attractive public realms (Fig.1, 2) [8]. Punter (2003) explains that Vancouver has no freeways and is an exemplar in the creation of convivial, vibrant and livable urban environments [9]. Although the quality of life ranking of the cities in this survey depends not only on transport. Cities which are less automobile dependent and having developed public transport system are ranked well.

Figure 1 The MFO Park occupies a previously vacant site in northern suburbs of Zurich, Switzerland. Completed in 2002 and designed by local design practice Raderschall, the 'park house' serves as a memory of the former building by replicating its original footprint, scale and mass to complete the streetscape with a living, seasonal façade [10];

Figure 2 Public Spaces of CEVA railway halt in Chéne-Bourg, Geneva, [11]

9. A visionary "debate and decide" process for planning for the future of the city is better instead of a "predict and provide", computer-driven process.

"Predict and provide" planning: Future transport systems in relation to land use has vital importance for any city aiming to have sustainable features. After WWII, the number of automobiles in cities has rapidly increased. Transportation/land use planning models were later developed and named as Urban Transportation Planning (UTP) process. In this model according to the projected traffic density, planning was made by transport planners and traffic engineers. They called this the "predict and provide" approach. With this planning method, urban fabric of cities were damaged. Harmful effects of freeways were seen in neighbourhoods. They demolished existing urban fabric and destroyed natural environments and food-producing areas. To be able to accommodate heavy traffic, new roads were constructed and existing ones were widened. Especially newly industrializing cities similar to those of China and India were affected from this approach [3].

"Debate and decide" planning: Urban Transportation Planning process has ignored some basic problems related to sustainable urban environment. This awareness about deficiencies of this system lead to questioning future of the cities in terms of sustainability. Future of cities, predicted levels of future traffic, land use options for the city, breaking out of trend-based planning, optimizing existing road network, making strategic investments in public transport, walking and cycling and reducing road space are the main issues of this new planning attitude. In this "debate and decide" process, "engagement with communities" and "planning a more ecological and sustainable future for the city" are the main aspirations [3].

10.In all decision-making processes, sustainability-based, integrating social, economic, environmental and cultural considerations as well as compact, transit-oriented urban form principles are considered. In such a way, democratic, inclusive, empowering and engendering of hope approach is achieved. Implementing sustainable development has rather different steps than that of normal planning and decision-making processes in cities. For this reason, various visions of sustainable development for cities has been developed around the world. Among these efforts, the common features are their cooperation with diverse "communities" and "stakeholders". These two component constitute any city nowadays and give a new sense of hope for our urban future [3]. To be able to comprehend the holistic approach in urban form principles, some of the eco-city examples throughout the world are presented in this section. These are as follows:

Portland, Oregon: Portland is perhaps the most successful and well-known example in the USA of a city that has reshaped itself under a strong vision extending as far back as the 1970s. Portland now has a visioning process called Region 2040, a broad-based community representation process, fundamental to the 2040 Growth process are:

- A hierarchy of mixed-use, pedestrian friendly centres that are well connected by high capacity transit and corridors
- A multi-modal transportation system that ensures continued mobility of more people and goods throughout the region, consistent with transportation policies
- Coordination of land uses and the transportation system, to embrace the region's existing locational advantage as a relatively uncongested hub for trade
- A jobs-housing balance in centres and a jobs-housing balance by regional sub areas to account for the housing and employment outside of the Centres
- An urban to rural transition to reduce sprawl, keeping a clear distinction between urban and rural lands and balancing re-development
- Separation of urbanizable land from rural land by the UGB for the region's 20-year projected need for urban land [12].

Figure 3 Portland Region's 2040 Growth Concept-transportation [13];

Figure-4. Portland Region's 2040 Growth Concept-transportation [14]

Perth, Western Australia: As Perth has faced huge increase in urban sprawl and car ownership, the state government has developed a future vision for the city for 2030. This effort was called "Dialogue with the City". During this process a community survey was held and it covers over 1700 households. Also a one-day forum was held involving 1000 participants. All the results were recorded and a final report was issued. Sustainability strategy of the city covers innovative and efficient use of resources, less waste output, enhanced equity and liveability and a greater sense of place in local communities.

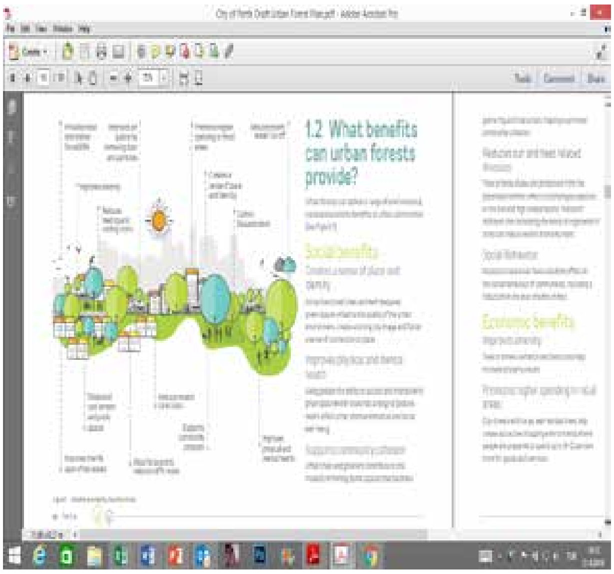

Figure 5 Urban Forest Benefits, Perth, Australia, [15];

Figure 7 Perth, Australia [17].

Figure 6 Perth, Australia [16]

Vancouver, British Columbia: Using collaborative planning and engagement over a very short period of time, a 100-year sustainability vision was developed for Vancouver region. Urban planning focuses on liveability, creating a city of neighbourhoods where people can work, play and shop. The city is planned for a liveable and sustainable future. These planning characteristics are as follows:

- Create communities that prioritize sustainable modes of transportation, minimize dependence on cars;
- Facilitate high-quality urban design that contributes to an attractive, functional, memorable, and safe city;
- Incorporate parks and open spaces, sidewalks and walkways, bodies of water, trees, landscaping and lighting into our urban fabric; and
- Protect the beauty of the city and its surroundings, while allowing for density and growth [18].

Figure 8 Vancouver-bicycle paths [19]**,**

Figure 9 Stanley Park Vancouver [20]

Figure 10, 11. Dongtan City [21].

11. Damaged urban environments are restored (especially creeks, shore lines, ridge lines and wetlands). This dimension will be explained by an example from a Chinese city, Shanghai which has over 20 million people. Chongming is the rural part of the city, which has little manufacturing industry. In this area, the idea of transforming it into an ecological island to serve as a national model for sustainability, energy efficiency, and environmental awareness was applied. 86 square kilometres of land includes unique wetland landscape, rich biological resources, and an ideal environment for harvesting solar and wind power which have been transformed into a model integrated ecological area. The "integrated urbanism" approach that considers the environment, social, and economic aspects to create sustainable communities has been conducted as well as becoming a showcase for technologies and urban design. At Dongtan, various disciplines including urban planning, transportation, housing, energy, economic development, and natural habitats come together to create the eco-city. Besides agricultural development, a wetland park and a wind farm are also being developed at Dongtan. With the second phase of construction completed in the end of 2007, a total area of 1.3 square kilometres has been developed in the wetland park. Former man-made ditches and pounds were converted into lakes, and various native benthophyte and floating plants now flourish throughout the park (Fig.10, 11). Over 100 wild bird species, including many endangered ones, have been attracted to the park [22].

12. Decent, affordable, safe, convenient and racially and economically mixed housing are created.

Mixed housing types can take many forms: rooftop housing conversions, flats above shops, accessory housing units and live-work designs, among others. Many examples of new Dutch housing projects embody a mixing of housing types, styles and income levels. GWL-terrain in Amsterdam is one of the best examples of this type that illustrates well the belief in mixing people, activities and housing types (Fig.12, 13). The project has intended to mix rental and purchased housing. Ground- level units have been designed for handicapped or invalid residents. On the ground floor of several buildings and in the corner units, retail spaces are provided. The master plan for the project preserves and re-uses several of the original buildings which belong to historic water pumping station. An old storage area has been converted into residential units while the old pumping house has been adaptive reused as offices and a restaurant. Moreover, the blocks of housing are organized by considering the existing street network [23].

Figure 12, 13 GWL-terrain in Amsterdam [24].

13. Social justice is nurtured and improved opportunities for women, people of color and the disabled are created. Social ecology is the study of both human and natural ecosystems and in particular of the social relations that affect the relation of society as a whole with nature. Social ecology advocates a holistic worldview, appropriate technology, reconstruction of damaged ecosystems and creative human enterprise. Eco-community, a human-scale, sustainable settlement based on ecological balance, community self-reliance and participatory democracy are all components of the primary social unit of a proposed ecological society. Social ecology is the struggle for the liberation of women, workers, blacks, native people and nature (the ecology movement). These are ultimately all part of the struggle against domination and hierarchy [2].
Urban sustainability discourse promotes the increased use of green infrastructure (GI) because of its contribution of important ecosystem services to city dwellers. Under this vision, all urban green spaces, including those at the household scale, are valued for their potential contributions to a city's social-ecological functioning and associated benefits for human well-being [25].

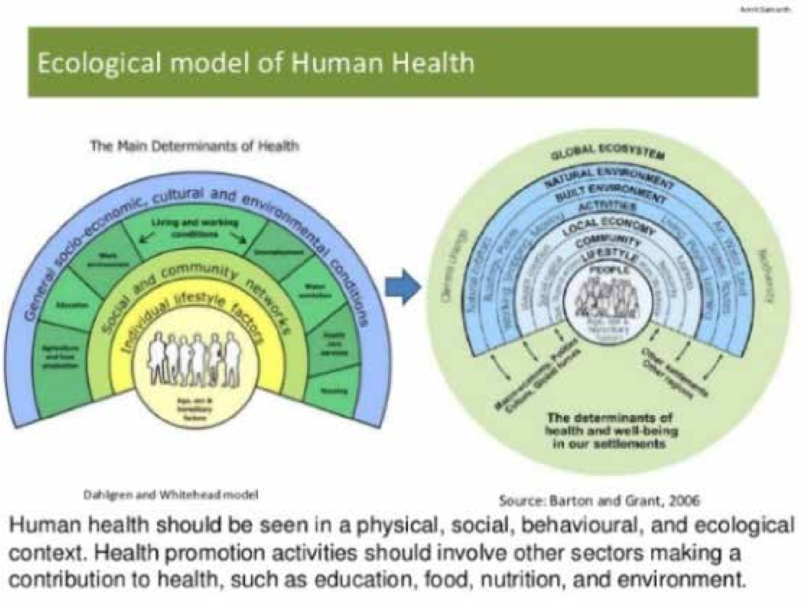

Figure 14 Ecological model of Human Health [26].

14. Voluntary simplicity is promoted and excessive consumption of material goods is discouraged. Disapproving consumerism and viewing overconsumption as an illness in society, this strategy aims to assist people to find alternative ways to satisfy their needs and promote simple ways of living [27]. "Voluntary simplicity"- a phrase which is borrowed from Richard Gregg who, in 1936, was describing a way of life marked by a new balance between inner and outer growth. The essence of voluntary simplicity is living in a way what is outwardly simple and inwardly rich. In this way frugality of consumption, a strong sense of environmental urgency, a desire to return to living and working environments which are of a more human scale and an intention to realize our higher human potential –both psychological and spiritual- in community with others can be realized. Voluntary simplicity may prove an increasingly powerful economic, social and political force over the coming decade and beyond if large numbers of people of diverse backgrounds come to see it as a workable and purposeful response to many of the critical problems. With the emergence of voluntary simplicity, traditional American values are transformed as well as multifold shifts are seen in consumption patterns, institutional operations, social movements, national policies and so on. Values central to voluntary simplicity are the following: material simplicity, human scale, self-determination, ecological awareness and personal growth [28].

15. Awareness of the local environment and bio-region have been increased through activists and educational projects that increase public awareness of ecological sustainability issues. Sustainability must be understood in such a way that it should be both in production and consumption, in context of using natural resources and growing public awareness in recycling, reduction and reuse of materials. Conscious consumers expect that production technologies will be cleaner and less polluting the natural environment. The sustainable methods of production would use much fewer resources and generate close to zero waste. But future strategies of sustainable consumption, promoting a new lifestyle while ensuring high quality of life, are also important. Education is sought to educate consumers the ways in which to meet their needs without consuming much non-renewable resources. The promise is however that reducing resource use should not mean lowering quality of life. Application of this strategy needs to be adopted at both household and corporate levels, in order to achieve a meaningful reduction as a consequence. Government and institutions, together with households need to adopt purchasing programs using the notion of sustainability. This sustainable shopping behaviour should build up more sustainable markets by consuming less. It is evident that more attention should be directed towards more environmentally sound products [27].

CONCLUSION

In this paper, key dimensions of eco-city concept are summarized in fifteen principles. By giving examples throughout the world, how these principles are applied for sustainable urban development process is clarified. Although government authorities' decisions on eco-city planning concentrates on different points according to the characteristics of the cities, it has seen that the main issue of the planning is constructing an effective transportation infrastructure. From these dimensions the most critical ones are determined as "sustainable urban form and transport", "compact, mixed-use urban form", "protecting and enhancing green spaces –both natural and food-producing areas- of the city" and "well-defined high-dense centres linked to public transport system". Apart from these issues walking and cycling paths, public realm throughout the city, urban forests, economic growth supporting creativity and innovation, environmental technologies, environmental, social and cultural amenities need to be applied as well as sustainable urban design principles.
The aim of designing for sustainability must be create more environmentally enriched, healthier and more comfortable places for people to live. Additionally, creating flexible, socially rewarding and equitable urban forms are necessary. Design of public commons as an essential component of this process are also important to a healthier, more equitable, environmentally enriched and delight-filled urban future. To be able to accomplish the idea of eco-city in a holistic way, cooperation is needed between local communities, authorities, academic institutions and organizations. In improving the quality of life of a community city planning plays a critical role. The new understanding of planning should be integrated with social policies in order to embrace critical issues such as social exclusion. It is crucial to state that each city has different dynamics and this implicates that there is not fixed-size for an applicable eco-city model. Different countries must develop their own eco-city development strategies by considering their own financial, technological, social and cultural circumstance

REFERENCES

[1] Yang, Zhifeng, Eco-Cities A Planing Guide (London: Taylor & Francis, 2012) .

[2] Roseland, Mark, "Dimensions of the Eco-City". ***Cities.*** Vol.14, No.4 (August, 1997), 197-202.

[3] Kenworthy, Jeffrey R. The Eco-City: Ten Key Transport and Planning Dimensions for Sustainable City Development. ***Environment and Urbanization***, Vol 18(1) (2006), 67-85.

[4] Beatley, Timothy (Ed.), ***Green Cities of Europe*** (Washington DC: Island Press, 2012).

[5] Newman, Peter.W.G., Kenworthy, J. R. and Laube, F. "The Global City and Sustainability- Perspectives from Australian Cities and a Survey of 37 Global Cities". In Brotchie, J., Newton, P., Hall, P. and Dickey, J. (Eds.) ***East-West Perspectives of 21st Century Urban Development: Sustainable Eastern and Western Cities in the New Millennium*** (Ashgate, Aldershot, England, 1999), 327-354.

[6] Itoh, Shigeru (Ed.), ***Proposals for the International Competition of Sustainable Urban Systems Design: Report of the International Gas Union Special Project,*** 22nd World Gas Conference Tokyo 2003, Can be downloaded at: http://www.rmaarchitects.com/files/goa-2100-lowres.pdf

[7] Katz, Peter, ***The New Urbanism: Toward an Architecture of Community*** (New York: McGraw Hill, 1994).

[8] Western European Cities Top Quality of Living Ranking – Mercer. (United Kingdom, London**,** 23 February 2016). Can be downloaded at: http://www.mercer.com/newsroom/western-european-cities-top-quality-of-living-ranking-mercer.html [Accessed: 15-Jun-2016]

[9] Punter, John, The Vancouver Achievement: Urban Planning and Design (Vancouver: UBC Press, 2003).

[10] https://sjbcitiesprogram.wordpress.com/2012/06/27/memory-of-a-building-zurich/

[11] http://www.ilex-paysages.com/en/2540/achievements/espaces-publics-de-la-halte-ceva-de-chene-bourg-geneve-2/#

[12] Summary of 2040 Growth Concept. (January 13, 2011,). Can be downloaded at: http://www.oregonmetro.gov/sites/default/files/01132011_regional_framework_plan_2011_update_summary_of_2040_growth_concept.pdf
[13] http://www.oregonmetro.gov/2040-growth-concept

[14] http://www.slideshare.net

[15] http://www.perth.wa.gov.au/sites/default/files/City%20of%20Perth%20Draft%20Urban%20Forest%20Plan.pdf

[16] http://www.smh.com.au

[17] http://theconversation.com

[18] City of Vancouver. http://vancouver.ca/home-property-development/urban-planning [Accessed: 17-Jun-2016]

[19] http://www.planetizen.com

[20] http://www.travelandleisure.com/slideshows/worlds-most-beautiful-city-parks/3

[21] http://www.panoramio.com/photo/38454746; https://ecocity.wordpress.com/tag/dongtan/

[22] Cheng, Hefa & Hu, Yuanan, "Planning for sustainability in China's urban development: Status and challenges for Dongtan eco-city project". ***Journal of Environmental Monitoring***, 2010, 12: 119-126.

[23] Beatley, Timothy, ***Green Urbanism Learning from European Cities*** (Washington: Island Press, 2000).

[24] http://www.kcap.eu/en/projects/v/gwl_terrein/

[25] Meléndez-Ackerman, Elvia. J., Nytch, Christopher J., et.al. "Synthesis of Household Yard Area Dynamics in the City of San Juan Using Muti-Scalar Social-Ecological Perspectives". ***Sustainability***, 8 (5), 481 (2016), 1-22.Can be downloaded at: http://www.mdpi.com/2071-1050/8/5/481/html [Accessed: 15-Jun-2016]

[26] http://www.slideshare.net/AmitSamarth/healthy-cities-india-v

[27] Lobejko, Stanislaw; Stankowska, Anna & Zabielski, Mariusz, Planning and Management in Eco-Cities (1st Edition) (Warszawa, 2015), doi:ISBN 978-83-7556-218-1, Can be downloaded at: http://administracja.sgh.waw.pl/en/dop/projects/eic/Documents/E-book_3_Planning_and_management_ostat.pdf[Accessed: 10-Jun-2016].

[28] Elgin, Duane & Mitchell, Arnold, "Voluntary Simplicity"***. The Co-Evolution Quarterly*** (1977, Summer). Can be downloaded at: https://energiesuffizienz.files.wor dpress.com/2014/12/voluntary_simplicity.pdf [Accessed: 12-Jun-2016].

Paper No: 192

Towards More Sustainable Construction Value Chain for Sustainable Cities

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ABSTRACT

Emissions from the construction and maintenance of the buildings has a significant impact on the carbon footprint of the cities. With the ever-growing demand, the World cement production has increased by 12 fold in the second half of the last century. Annual per capita consumption of this essential construction material has reached to 1.5 – 3 tons, which makes concrete the single most widely used material in the world. In order to reduce the urban footprint, it is necessary to create and implement new circular economy models for the construction value chain. To address this issue, FISSAC Project aims develop and demonstrate a new paradigm built on an innovative industrial symbiosis model towards a zero waste approach in the resource intensive industries of the construction value chain. The closed-loop FISSAC model under development will take advantage of valorisation of construction and demolition waste streams in addition to industrial wastes from steel, non-ferrous metals, natural stone, ceramics, glass, and chemical industries for manufacturing of eco-cement, green concrete, innovative ceramic tiles, and wood-plastic composite panels. In this study the innovative FISSAC model will be introduced and implications of this model on sustainable cities will be discussed.

Keyword: circular economy, industrial symbiosis, cross-sectorial synergies, construction, urban sustainability

INTRODUCTION

Within the European Union (EU), approximately 75% of the population reside in urban areas and this number is expected to increase to 80% by 2030 [1]. Cities, in particular built environment within the urban system boundaries, are globally among top consumers of energy and resources. Urban sources are believed to generate 75% of all greenhouse gas (GHG) emissions, which makes cities fundamental to achieving resource efficiency, low-carbon performance and urban resilience necessary to deliver sustainable living spaces [2]. According to some estimates, the building stock alone generates more than 40% of the total amount of GHG emissions [3][4][5]. Furthermore, the building sector, in Europe and globally, accounts for around 40% of the total energy use, 30% of raw materials use, 25% of water use, 12% of land use, and 25% of solid waste generation [6][7][8]. These figures indicate that Europe cannot meet its environmental targets without dramatically reducing the environmental impact of buildings and infrastructure especially in terms of global climate change [9]. In this sense, it is essential to tackle global climate change and resource efficiency issues in a holistic manner to reduce environmental footprints of construction and building sectors in order to establish sustainable practices.
The Intergovernmental Panel on Climate Change (IPCC) synthesis report lists buildings as "having the greatest

estimated economic mitigation potential of all the sector-linked solutions". The IPCC suggests that measures to reduce GHG emissions from buildings include: ***reducing embodied energy in buildings, reducing energy consumption of buildings, and switching to low-carbon fuels*** [10][11].

Over their life cycle, buildings create environmental impacts during their construction, operation and maintenance as well as demolition. Previously, operation and maintenance of the buildings were assumed to be the dominant phase to contribute to the embodied energy [12] and consequently the operational GHG emissions to make up the major portion of the life-cycle GHG emissions of a building. However, introduction of various energy efficiency measures are expected to lower operational emissions progressively. Energy-efficient buildings use less energy in their operation phase and have lower GHG emissions over their life time.

As the operational GHG emissions are reduced, the relative importance of the embodied GHG emissions associated with building materials increases. ***Therefore, the embodied emissions from construction materials will result in an even greater proportion of building life-cycle emissions in the future*** [7][12]. Based on a review conducted by Sartori and Hestnes (2007), the embodied energy of a conventional building could account for 2–38% of the total life cycle energy, whereas, for a low energy building this range could be 9–46% [13]. Thormark (2006) concluded that with energy efficient solutions, material related embodied energy of a low energy house could be equal to 40–60% of total life cycle energy [14]. Table 1 lists examples of conventional and energy-efficient buildings based on contribution of their life cycle phases to total emissions. It is observed that embodied impacts of traditional buildings can be lower than 10%. However, through refurbishment and utilization of energy performance optimization, the share of embodied energy and CO_2 emissions can be as high as 40 – 45%.

Table 1 Share of life cycle phases of buildings in energy consumption and GHG emissions according to different studies (Adapted from [7])

Building types	Location	Life time	Embodied	Operational	Other phases	Unit	Ref
Generic office building	Canada	50 yrs	10 – 13%	80%	7 – 10+	Energy	[15]
Office buildings	Japan	40 yrs	15%	82%	3%	Energy	[16]
Office buildings	Japan	40 yrs	18%	78%	4%	CO_2	[16]
Office buildings	Greece	80 yrs	8%	91 – 94%	--	Env impacts	[17]
Typical office building	US	60 yrs	10%	90%	--	CO_2	[18]
Refurbished office	US	60 yrs	45%	55%	--	CO_2	[18]
Dwellings	Sweden	50 yrs	15%	85%	--	Energy	[19]
Low energy house	Norway	50 yrs	30%	70%	--	Energy	[20]
Traditional houses	Norway	50 yrs	6%	94%	--	Energy	[20]
Residential blocks	Hong Kong	50 yrs	19 – 25%	74 – 81%	<1%	Energy	[21]
General buildings	Greece	50 yrs	12 – 18%	--	--	Energy	[22]
Typical office building	UK	25 yrs	30%	70%	~0%	CO_2	[23]
25% energy reduction office	UK	25 yrs	40%	60%	~0%	CO_2	[23]

Thormark (2006) also estimates that substitution of materials used in buildings could decrease embedded energy use by approximately 17%. Other numerous studies also report a significant effect of material choice during the construction phase on the environment. Building materials are thus an increasingly important part of the overall environmental footprint of buildings [10].

Aim of this paper is to introduce Fostering Industrial Symbiosis for a Sustainable Resource Intensive Industry Across the Extended Construction Value Chain – FISSAC Project, which aspires to develop low-carbon and sustainable construction materials (eco-cement, green concrete, innovative ceramic products and wood-plastic composites) through establishment of an industrial symbiosis (IS) scheme. Furthermore, the FISSAC IS model developed throughout the Project for replicability is introduced. Finally, the extended impacts of new construction materials and FISSAC model on urban systems is discussed.

LIFE CYCLE PHASES AND EMBODIED ENERGY OF BUILDINGS

A ***building's life cycle*** consists of initial stage, operational stage, renovation stage and end-of-life stage. The initial or cradle stage consists of the processes by which the materials and products required to satisfy a building design i.e. upstream processes (mineral extraction, energy production etc.), transport, manufacturing processes including production of ancillary materials or pre-products and packaging, and waste processing [24].

Embodied energy is the amount of energy consumed to extract, refine, process, transport and fabricate a material or product (including buildings). It is often measured from cradle to (factory) gate, cradle to site (of use), or cradle to grave (end of life) [25]. For buildings, the embodied energy is the cumulative energy consumed by all processes associated with the entire life cycle of a building, from the acquisition of natural resources including mining and manufacturing, through transport and other functions, and finally, the operational energy, involving the energy utilised by the building's operations and use (air conditioning, heating and lighting, office and kitchen equipment) [26].

As presented in Table 2, the embodied energy of some construction materials including aluminium, copper, rubber, plastics and acrylic paint have high embodied energy per kg of product. This is due to the fact that they are produced as a result of energy-intensive manufacturing processes. Although per kg embodied energy of cement is not as high as steel, aluminium or PVC, due to high amount used during construction, it can contribute to up to 60% of the total embodied energy (Figure 1) [12].With the ever-growing demand, the World cement production has increased by 12 fold in the second half of the last century. Annual per capita consumption of this essential construction material has reached to 1.5 – 3 tons, which makes concrete the single most widely used material in the world. Combined impact of construction materials result in overall embodied energy of the buildings to be high. In addition to embodied energy and carbon, construction materials lead to water consumption and waste generation (Figure 2).

Table 2 Embodied energy of construction materials [12]

Material	Embodied energy (MJ/kg)	Material	Embodied energy (MJ/kg)
Kiln dried sawn softwood	3.4	Plastics – general	90.0
Kiln dried sawn hardwood	2.0	PVC	80.0
Air dried sawn hardwood	0.5	Synthetic rubber	111.0
Hardboard	24.2	Acrylic paint	61.5
Particle board	8.0	Stabilized earth	0.7
MDF	11.3	Imported granite	13.9
Plywood	10.4	Local granite	5.9
Glue-laminated timber	11.0	Gypsum plaster	2.9
Laminated veneer lumber	11.0	Plaster board	4.4
Fibre cement	4.8	Clay bricks	2.5
Cement	5.6	Glass	12.7
In-situ cement	1.9	Aluminium	170
Precast steam-cured cement	2.0	Copper	100
Precast tilt-up cement	1.9	Galvanized steel	38
Concrete blocks	1.5	AAC	3.6

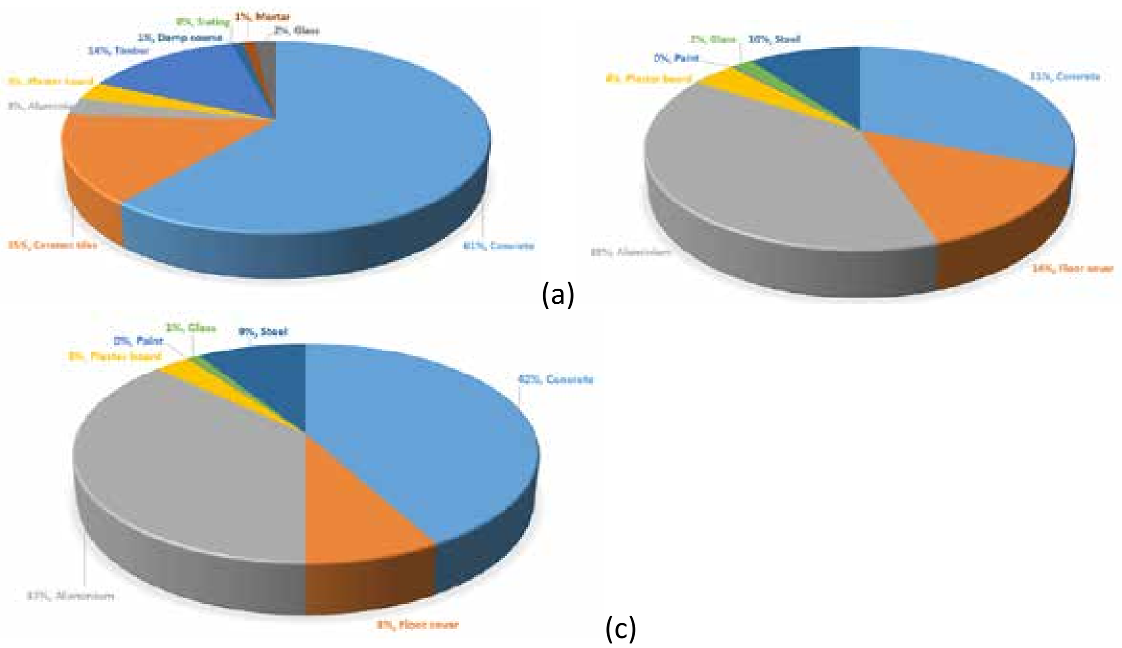

Figure 1 Embodied energy and GHG emissions from construction materials based on their consumption in buildings (a) and (b) embodied energy of two example buildings and (c) GHG emissions from a representative building [26][27]

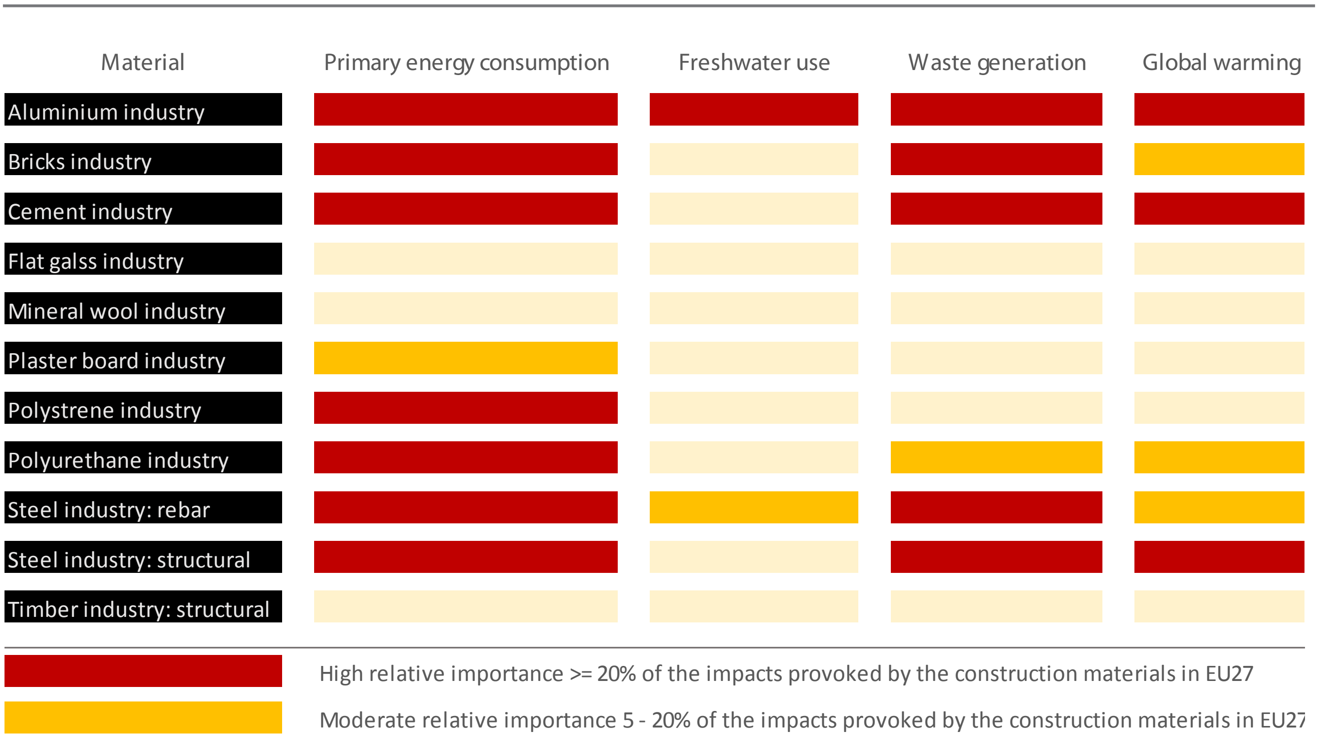

Figure 2 Severity of environmental impacts of construction materials [12]

SUSTAINABLE CONSTRUCTION VALUE CHAIN

Construction value chain, as can be seen in Figure 3, shares similar system boundaries with life cycle of a building. The value chain is complex; from the time of the industrial revolution the number of suppliers related to a building site has increased from 5-10 to a few hundred [28].

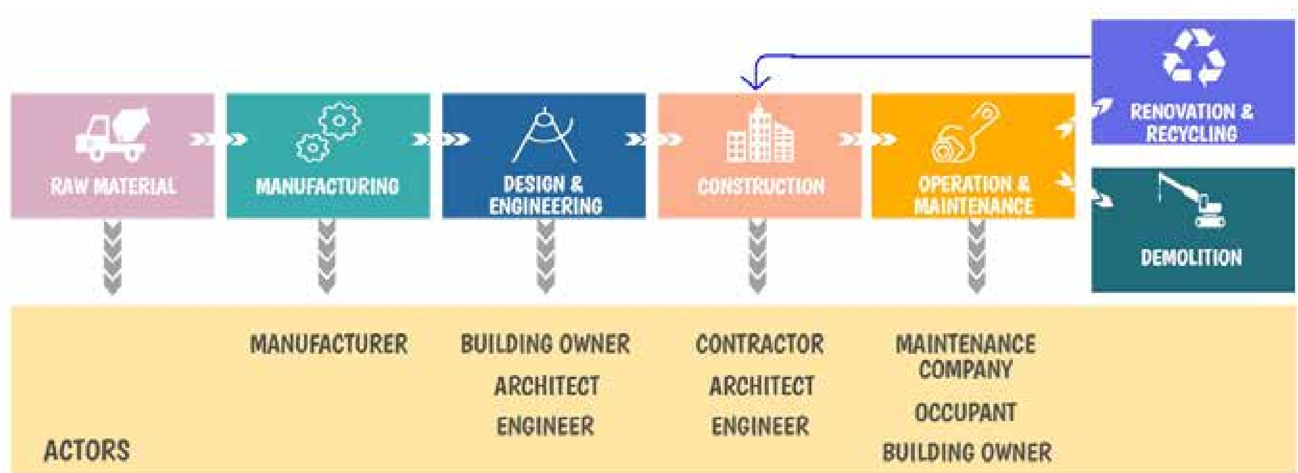

Figure 3 Traditional construction value chain (Adapted from [29])

Consumption of resources and related environmental impacts throughout a building's life cycle can be reduced by:

- o A holistic design approach incorporating user needs and functionality with use of resources under consideration of deconstruction scenarios;
- o Better project planning which ensures a greater use of resource and energy efficient products;
- o Utilization of resource efficient/low footprint construction products including ones that valorize recycled materials and waste as secondary raw materials and/or fuel source;
- o Prevention of construction and demolition wastes (CDW) through waste prevention and recycling/re-using materials and products during construction and renovation [9].

Effective implementation of these strategies, which also applies for the construction value chain, relies on a shift in construction sector towards more sustainable practices through Best Available Techniques (BATs) and development of innovative products as a result of ambitious R&D efforts. Currently, the construction industry can be related to 7% of global CO_2 emissions and the construction and demolition sector accounts for about a third of all waste [12]. According to EEA 2012 report, 61% of total waste streams in the EU-27 is composed of mineral/inorganic waste, which mainly originates from mining, quarrying, construction and demolition activities, as well as industrial sources such as steel slag, aluminum salt slags, glass and ceramic industry waste [30].

The more recent EU legal instruments and strategies including Thematic Strategy on the prevention and recycling of waste, the 6th Environmental Action Programme**,** the EC Communication **"Towards a circular economy: a zero waste programme for Europe"** and the revised Waste Framework Directive WFD - 2008/98/EC) priorities waste prevention according to waste hierarchy principle [31]. Resource efficiency is among the main challenges that construction sector faces in the period up to 2020 [9]. WFD stipulates, "by 2020, the preparing for re-use, recycling and other material recovery….of non-hazardous construction and demolition waste….shall be increased to a minimum of 70 % by weight". Although recycling rates up to 90% are reported for CDW in some EU Member States, EU-wide recycling rates are still below WFD target [32]. Therefore, there is still a lack of solutions, business and economic models, policy instruments, education and communication strategies for more efficient waste management for the process industry through cross-sectoral application of technologies, including industrial symbiosis.

Industrial Symbiosis (IS) refers to the network of product, by-product and waste exchanges that reduce the ecological footprint of industrial areas, and one example of IS are the Eco-Industrial Parks (EIPs), a key concept of industrial ecology for increasing the environmental and economic performance through maximum efficiency of resource utilization and local actors involvement, including citizens. Local co-operation in industrial symbioses can reduce both the consumption of virgin raw material use and waste disposal, thereby closing the material loop of industrial systems and minimizing waste, creating a fundamental feature of the circular economy and acting as a driver for green growth and eco innovative solutions.

FISSAC PROJECT

The overall objective of FISSAC project is to develop and demonstrate a **new paradigm built on an innovative industrial symbiosis model** towards a zero waste approach in the resource intensive industries of the construction value chain, tackling harmonized technological and non-technological requirements, leading to **material closed-loop processes** and moving to a **circular economy**. FISSAC will demonstrate the applicability of the new industrial symbiosis model (FISSAC model) as well as the effectiveness of the innovative processes, services and products at different levels.

The FISSAC model will be comprised of the FISSAC methodology and an IS ICT platform (FISSAC Platform) and will aim to implement the industrial symbiosis model among industrial sectors to move from a linear to a circular economy model by the improvement of material flows. In addition to the material flows, this model will take networks of stakeholders, best available techniques facilitating cross-sectorial synergies, sustainability/eco innovation indicators and social aspects into account.

Within the scope of FISSAC Project, innovative technological and non-technological processes is currently being studied to transform waste into valuable secondary raw materials to be used in the design and manufacturing of eco-innovative construction products. During the development phase, technical requirement of the secondary raw materials will be established along with the critical parameters of waste characterization. Standardization issues will be also addressed. One of the most important aspects of the FISSAC Project is its emphasis on sustainability issues. Environmental impacts of the new value chain and products will be evaluated from a life cycle perspective with ***life cycle assessment (LCA) and life cycle costing (LCC)***. Furthermore, ***eco-design approach*** will be followed to ensure cost-effectiveness of the products and minimize the amount of waste and maximize recyclability of waste and by-products at the same time. Finally, new technologies will be validated through ***Environmental Technology Verification (ETV)*** Procedure.

FISSAC Project aims to deliver ***four new sustainable construction products*** through the IS network scheme shown in Figure 4. These products include two types of eco-cements, new green concrete, two innovative ceramic products, a rubber fusion wood-plastic composite.

Eco-Cement products will be produced via two routes for the synthesis:

1) ***Belite-yeelemite based cements*** will be produced by using aluminum saline slags, glass waste, ceramic waste and ladle furnace slag within the raw meal**.** Compared to ordinary Portland cements, the new cements will have lower CO_2 footprint (up to 10% in comparison with the current patented solutions) and lowed embodied energy cements and high resistance to sulfate attack;

2) ***Blended cements*** will be obtained by using the glass and ceramic waste materials as mineral additives in Portland cements. The main advantage of this route is lowering the clinker content in the blended cement thus reducing the environmental impacts.

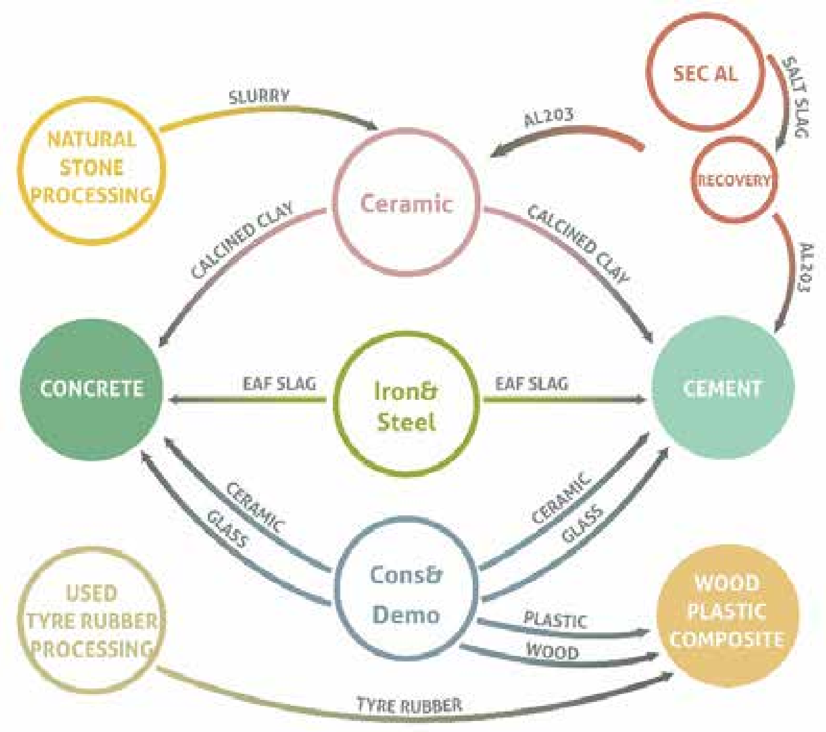

Figure 4 FISSAC IS network scheme

New Green concrete formulations (ready mix concrete and AAC) will contain upgraded electric arc furnace (EAF) and ladle furnace (LF) steel slag aggregates and binder elaborated with compounds extracted from glass waste, ceramic waste and ladle furnace slag. The new products will have improved characteristics related to the density, compressive strength and thermal conductivity.

Innovative ceramic products will include light and urban stoneware tiles:

1) ***Light stoneware tiles*** is a porous porcelain based material to be used in walls and ceilings. Main characteristics of this new products will be related to reduce weight by increasing porosity and to keep the mechanical properties by composition.

2) ***Urban Stoneware tiles,*** on the other hand, is a porcelain based material to be used in sidewalks and high traffic sites. The new tiles will have improved characteristics related to frost resistance, high wear resistance and fracture resistance.

Rubber fusion Wood Plastic Composites would not only reduce production costs by using the used tires, but also achieve additional functionalities (e.g. thermal, impact performance) (partial replacement of 15-25%) of recycled rubber, waste plastic and waste wood as raw material.

Production technologies will be demonstrated both at pre-industrial and industrial level. Furthermore, real applications are planned to investigate the behavior of new products and assess their life cycle impacts.

Replicability of the FISSAC Model will be addressed through ***Living Labs*** in nine different countries represented by the project partners. In order to maximize the potential for replicability, technological and non-technological barriers will be studied. Moreover, necessary steps and changes for transition from linear business models toward more circular ones will be identified through ***Transition Management System and Technological Innovation System Analysis***.

EXTENDED IMPACTS OF A SUSTAINABLE CONSTRUCTION VALUE CHAIN

The impact of FISSAC Project will span both industrial and urban systems. With maximum valorisation of industrial waste in new eco-products, FISSAC model will not only create avoided burdens for industry but also lower the footprint of urban structures by decreasing the embodied energy of construction materials.
Furthermore, reuse of construction demolition waste will lead to significant resource and environmental benefits and contribute to better waste management practices in the EU. For instance, each ton of recycled flat glass (used for windows in buildings etc), results in savings of 1200 kg of virgin material, 25% of energy and 300 kg of CO_2 emissions (directly linked to the melting process) [33]. Apart from environmental benefits, there can be economic opportunities for manufacturers when using recycled material. As an example, the flat glass industry in the EU sees a market price for recycled glass of about €60-80 per ton, sufficiently below the €90 ton necessary to compete with virgin material. In the case of glass, there is thus often an economic benefit for manufacturers to use recycled material. Still, market demand for recycled material is rarely met, which presents further exploitation potential [9].
Quantifiable extended impacts of FISSAC include:

- Reduction of 170,200 ktons of construction and demolition and industrial waste generation each year.
- Beyond 12% gains in productivity for waste treatment which means 30.36 million ton per year of usable waste and approximately € 270 million per year in waste management costs.
- Beyond 20% in energy efficiency and associated GHG savings which will lower the overall embodied energy of the products by energy efficiency improvements in processing recycled materials, reducing the associated GHG emissions of the associated energy use and further improved by replacing fossil fuels with other low carbon energy sources.
- Savings in CO_2 emissions around 0.85 kg/kg of Portland cement replaced by the industrial waste, which can lead to up to 12.66 Mton of CO2 reduction through novel green concrete consumption.
- Avoidance of 4.36*1011MJ of energy and 3.06*106 tons of water consumption each year across Europe as a result of innovative ceramic products.

CONCLUSIONS AND ADDITIONAL RECOMMENDATIONS

Value chain innovation provides a way for it to continue contributing to job creation and retention and GDP growth while reducing its resource footprint. Sustainable building is one of three key sectors identified in the EU's Resource Efficiency Roadmap and it forms a central pillar of the Europe 2020 strategy for growth and jobs [28].
Tangible steps towards sustainability is required not only in operation of buildings but also in construction value chain. These steps need legal framework to be present and a strong commitment from stakeholders associated with construction materials manufacturing, design and operation of buildings.
FISSAC Project introduced in this paper tackles sustainability issues in construction value chain through implementation of an IS network. Main aim is to deliver new sustainable construction materials, a new IS Model for replication and ultimately, contribute to a shift from linear economic models to circular ones. In a circular economy, "the value of products and materials is maintained for as long as possible; waste and resource use are minimized, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value" [34].

In order to lower the environmental footprint of construction sector and buildings, additional tools can be used to support R&D and sustainable design activities:

- ***Life cycle assessment (LCA)*** allow businesses in the building and construction sector to understand and assess how they can improve product or building performance by adopting a cradle-to-grave approach.
- ***Life cycle costing (LCC)*** is an economic evaluation of the total cost of a product, asset (e.g. building) or process throughout its life cycle. Whole life cost (WLC) is often used interchangeably with LCC but specifically includes wider costs which in the content of buildings might include land acquisition costs and income generated from leases.
- ***Environmental Products Declarations (EPDs)*** communicate the environmental performance of construction products, resulting from the use of LCA. EPDs are usually developed by manufacturers to inform their consumers on the environmental performance of their products using selected indicators [24].

LCA and LCC provide the fundamental building blocks of a framework to support whole life thinking, which takes into consideration environmental, economic and social aspects and impacts. A life-cycle framework provides a simple, modular and standardized concept that can support the self-assessment or provide the basis for a third-party assessments, giving stakeholders a clear perception of costs, benefits, impacts, challenges and successes implied in the process. In line with LCA and LCC, EPD process provides a consistent definition of green and resource efficiency, potentially reducing the burden for suppliers and providing a basis for industry transparency and trust.

ACKNOWLEDGEMENT

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REFERENCES

[1] Voytenko, Y., McCormick, K., Evans, J., Schwila, G., 2016. Urban living labs for sustainability and low carbon cities in Europe: towards a research agenda. Journal of Cleaner Production, 123, 45 – 54.

[2] Hunziker, R., 2015. Value Chain Collaboration for Sustainable Construction and Resource Efficiency. Presented at UNEP Symposium "Sustainable Buildings and Cities". URL: http://energies2050.org/wp-content/uploads/2015/04/7_WBCSD-Value-chain-collaboration_HUNZIKER.pdf Date of Access: May 2016

[3] Shi, Q, Yu, T., Zuo, J., 2015. What leads to low-carbon buildings? A China study. Renewable and Sustainable Energy Reviews, 50, 726 – 734

[4] Li, D.H.W., Yang, L., Lam, J.C., 2013. Zero energy buildings and sustainable development implications - A review. Energy, 54, 1 – 10.

[5] Sinha, R., Lennartsson, M., Frostella, B., 2016. Environmental footprint assessment of building structures: A comparative study, Building and Environment, 104, 163 – 171.

[6] Ju, C., Ning, Y., Pan, W., 2016. A review of interdependence of sustainable building. Environmental Impact Assessment Review, 56, 120 – 127.

[7] Chen, Y., Ng, S. T., 2016. Factoring in embodied GHG emissions when assessing the environmental performance of building. Sustainable Cities and Society. Article in press, http://dx.doi.org/10.1016/j.scs.2016.03.015

[8] Horne, R., Moore, T., 2008. Embodied Energy in Buildings: A review. Presented in Melbourne Forum,2008. URL: https://www.airah.org.au/imis15_prod/Content_Files/MelbForum/MelbForumJun08_RH.pdf

[9] European Commission, 2014. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS ON RESOURCE EFFICIENCY OPPORTUNITIES IN THE BUILDING SECTOR. Brussels, 1.7.2014 COM(2014) 445 final

[10] Hakkinen, T., Kuittinen, M., Ruuska, A., Jung, N., 2015. Reducing embodied carbon during the design process of buildings. Journal of Building Engineering, 4, 1 – 13.

[11] IPCC, 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment. Report of the Intergovernmental Panel on Climate Change. Edited by Core Writing Team, R.K. Pachauri, A.Reisinger, Geneva: IPCC, 104pp. URL: http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm , Date of access: August 2013

[12] California Department of Parks and Recreation, 2009. Your Home Technical Manual – Embodied Energy. URL: http://ohp.parks.ca.gov/pages/1054/files/embodied%20energy.pdf

[13] Sartori, I., Hestnes, A.G., 2007. Energy use in the life cycle of conventional and low-energy buildings: a review article, Energy Build. 39 (3), 249–257.

[14] Thomark, C., 2006. The effect of material choice on the total energy need and recycling potential of a building, Building and Environment, 41 (8),1019–1026.

[15] Cole, R. J., & Kernan, P. C., 1996. Life-cycle energy use in office buildings. Building and Environment, 31 (4), 307–317.

[16] Suzuki, M., & Oka, T., 1998. Estimation of life cycle energy consumption and CO2emission of office buildings in Japan. Energy and Buildings, 28 (1), 33–41.

[17] Koroneos, C., Dompros, A., & Loizidou, M., 2007. Life cycle assessment of an office building in Greece. URL: http://www.uest.gr/suscon/LCA%20of%20Building.pdf Date of access: May 2013.

[18] Ayaz, E., & Yang, F., 2009. Zero carbon isn't really zero: why embodied carbon in materials can't be ignored. Design Intelligence. Retrieved from. http://www.di.net/articles/archive/zero carbon/

[19] Adalberth, K., 1997. Energy use during the life cycle of single-unit dwellings: examples. Building and Environment, 32 (4), 321–329.

[20] Winter, B. N., & Hestnes, A. G., 1999. Solar versus green: the analysis of a Norwegian row house. Solar Energy, 66 (6), 387–393.

[21] Humphrey, S., Amato, A., & Frewer, R., 2004. Whole life comparison of high rise residential blocks in Hong Kong. Hong Kong Housing Authority. URL: http://www.housingauthority.gov.hk/hdw/ihc/pdf/wlchrrr.pdf. Date of access: May 2013.

[22] Dimoudi, A., & Tompa, C., 2008. Energy and environmental indicators related to construction of office buildings Resources. Conservation and Recycling, 53(1–2), 86–95.

[23] Fieldson, R., Rai, D., & Sodagar, B., 2009. Towards a framework for early estimation of lifecycle carbon footprint of buildings in the UK. Construction Information Quarterly, 11(2), 66–75.

[24] UNEP, Sustainable Buildings and Climate Initiative, 2014. Greening the Building Supply Chain. URL: http://www.unep.org/sbci/pdfs/greening_the_supply_chain_report.pdf Date of access: May 2016.

[25] Circular ecology, 2015. Embodied energy and carbon – the ICE database. URL: http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html#.V1lASZGLS00 Date of Access: June 2016

[26] Biswas, W., K., 2014. Carbon footprint and embodied energy consumption assessment of building construction works in Western Australia. International Journal of Sustainable Built Environment, 3 (2), 179 – 186.

[27] Horne, R., 2008. Embodied energy in buildings: A review. Presented at Melbourne Forum, 30th June, 2008. URL: https://www.airah.org.au/imis15_prod/Content_Files/MelbForum/MelbForumJun08_RH.pdf Date of access: May 2016.

[28] European Commission, 2012. 12th European Forum on Eco-innovation Scaling-up sustainable construction through value chain innovation Report on summary of the event . URL: http://ec.europa.eu/environment/archives/ecoinnovation2012/1st_forum/pdf/ecoap_12th_report.pdf Date of access: May 2016

[29] BPIE and Industrial Innovation for Competitiveness, 2016. Driving Transformational Change in the Construction Value Chain. URL: http://bpie.eu/wp-content/uploads/2016/01/DrivingTransformationalChangeCVC2016.pdf Date of access: June 2016.

[30] European Environment Agency, 2012. EEA Annual Report 2012. URL: http//www.eea.europa.eu Date of access: May 2016

[31] European Commission, 2016. Circular Economy Strategy. URL: http://ec.europa.eu/environment/circular-economy/ Date of access: May 2016.

[32] Ecologic Institute, Umweltbundesamt Österreich, RIMAS , 2013. Ambitious waste targets and local and regional waste management. URL: http://cor.europa.eu/en/documentation/studies/Documents/2013-waste-target-and-regional-waste-management/waste-target-and-regional-waste-management.pdf Date of Access: June 2016.

[33] Information obtained from unpublished data of FISSAC Project partners.

[34] European Commission, 2015. European Commission – Fact Sheet: Circular Economy Package: Questions and Answers. URL: http://europa.eu/rapid/press-release_MEMO-15-6204_en.htm Date of Access: June 2016.

Paper No: 193

Energy and Data Management in Sustainable Cities through Urban Metabolism

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ABSTRACT

The built environment accounts for two-thirds of all greenhouse gas emissions, making interventions in this area pave the way for meeting climate resilience goals. Solutions have to be thoroughly efficient in improving the environmental impact of the built environment and take into consideration the true impact of that spans time and urban space.

This is possible through an urban metabolism approach that sees urban space as a holistic system of flows, materials and processes that interact and function like a living metabolism combined with analysis spanning the whole life cycle of the subject, revealing hidden costs and effects. Building clusters of any size from block to city can be modelled through innovative software to illustrate cumulative effects such as urban heat islands and pollution on Geographical Information Systems. Intervention scenarios can be developed and analysed for their performance throughout the life cycle of subject buildings and results projected into the same urban metabolism view. R2Cities project will be presented to elaborate this method combining the urban metabolism approach and Life Cycle Assessment over the built environment to achieve nearly zero energy cities. As a result, decisions regarding urban scale retrofitting actions can be optimized for targeted improvements regarding environmental impacts, benefits and avoided burdens.

Keywords: urban metabolism, life cycle assessment, urban sustainability, retrofitting, spatial modelling, low carbon cities

INTRODUCTION

In recent decades, additional concerns have started to arise regarding the impacts of urbanization on environment and public well-being. Present rate of urbanization is faster than ever, as 50% of the global human population living in urban areas as of today is expected to rise all the way up to 70% in 2050 (Goldstein, et al. 2013). This means sustainability issues will be even more pressing in the forthcoming decades. In order to minimize the adverse effects of built environment and urbanization, tangible steps should be taken to incorporate the concept of sustainability in design and upgrading industrial and urban systems. Furthermore, for the success of "sustainable" systems, performance of these tangible steps needs to be monitored with sound and reliable methods. Another important issue is to adopt a holistic point of view during sustainability assessment and consider how individual systems interact with each other at a network level. Complex natural and human systems need quantification methods not only for flows such as energy, water, carbon, and pollutant fluxes but also for related cost and resulting environmental impacts in an integrated approach, based on life cycle thinking to achieve sustainable decision making.

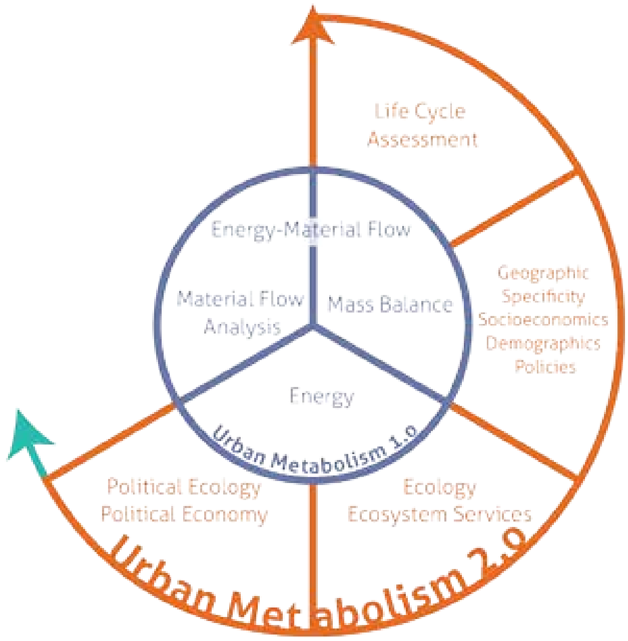

Figure 1 Future trends in application of urban metabo**lism [6]**

To address these issues in urban settings, experts and academics have been conducting research under the term "***urban metabolism"*** that "refers to a broad range of quantitative methods that attempt to conceptualize urban areas as organisms, requiring goods and energy to maintain functionality and support growth, while emitting waste as a by-product" (Goldstein, et al. 2013). As stated by Baynes and Wiedmann (2012), environmental sustainability assessment for urban metabolism may have two general purposes: monitoring and measuring the past or current environmental pressures, states, or impacts of urban areas. Recent studies suggest a need to improve the methods evaluating urban metabolism only through material flow analysis (MFA) and emergy (embodied energy) by integrating life cycle assessment (LCA) to these methods (Baynes ve Wiedmann 2012) (Chester, Pincetl ve Allenby 2012) (Pincetl, Bunje ve Holmes 2012)(Figure 1).Such an approach would bring standardization to urban metabolism studies, enhance communication of results with the stakeholders, enable comparison of different urban systems with each other, and support informed-decision making for planning as well as adaptation and mitigation strategies under sustainable urban development. The quest for analysing bigger scale systems is a research topic under study to serve industrial networks, ecosystems, urban and societal communities. Though there exists no single bullet solution to answer all sustainability conundrums and quantification requirements, a holistic tool is needed to support this methodology.
Although the benefits of this strategy are acknowledged, so far, there is no holistic decision support methodology or tool which couples urban metabolism and life cycle approach in a large-scale such as city-level. The aim of this is study is to provide an overview about the urban metabolism approach for a given urban system and to go beyond the state of art with a sample study.

URBAN METABOLISM AS A HOLISTIC SOLUTION FOR SUSTAINABLE CITIES

The scale of urban issues is constantly increasing with accelerating urbanization and densification. Therefore, efforts towards tackling urban issues should go beyond present conditions and consider future trends. This necessitates temporal aspects to be considered for assessing impacts of urbanization. Only then, urban areas can reduce their footprints and cities can be ready for mitigating large scale impacts of global climate change. Furthermore, urban areas are not homogeneous in terms of population density, infrastructure, transportation or wireless networks etc., which necessitates spatial variances to be considered for understanding the true nature of such areas.

In addition, urban systems are multi-layered and have many sub-systems within. These sub-systems are interconnected with each other and connected to exterior systems such as industrial zones. Finally, urban growth affects economy, humankind and the environment which in turn influence each other. In this sense, an effective approach to answer problems of urbanization should disaggregate grand urban systems but have a holistic point of view at the same time.

Therefore, there is a need of a new methodology that is capable of analysing urban networks in terms of environmental impacts and associated external and embedded costs that will assist stakeholders and decision-makers to develop strategies to reduce urban environmental footprints, to mitigate effects of global climate change and to promote energy & resource efficiency(González, et al. 2013).

In order to cope with urbanization pitfalls, some methods are being used to understand urban systems. Urban metabolism, which is commonly traced back to Karl Marx(Pincetl, Bunje ve Holmes 2012), is one of them and roots from the analogy that associates urban systems with living organisms. Two distinct approaches used for urban metabolism include material flow accounting and Odom's energy methods, both argued to have shortcomings (Goldstein, et al. 2013)(Pincetl, Bunje ve Holmes 2012).

In this study, it is proposed to expand the horizon of urban metabolism by incorporating LCA, geographic specificity, ecosystem services, and political economy. By this means, urban metabolism methods can be more effective in representing complex urban systems. The benefits of understanding urban metabolism are providing suitable measures of resource exploitation and waste generation as sustainability indicators and measures of resource intensity and circularity of resource streams (i.e. circular economy) that may be helpful in identifying opportunities for improvement(Ferrao ve Fernandez 2013).

As an urban metabolism tool, EPESUS, has performed as a web based platform for material and energy flow accounting at both buildings as singular facilities and at the industrial network level, capable of demonstrating life cycle impacts of production processes in addition to simple material flow analysis (MFA).

EPESUS AS AN URBAN METABOLISM PLATFORM

The relation of the urban and industrial ecosystems, especially in the field of energy and waste management has been identified as a major potential by the global policy makers in order to achieve GHG emission reduction targets.

Ekodenge has had the opportunity to develop the EPESUS software within past EU projects and field works into a platform which delivers sustainability analyses for the industrial and built environment. The platform delivers a holistic assessment capacity for the various material and energy flows of the studied systems, in relation with Life Cycle Impact and Life Cycle Cost assessments. Additionally the capacity to analyse these systems in a time series manner with hourly energy and flow data analyses has provided the capacity for the calculation of exact flows

amounts among the system components.
At the urban level, the system components could be individual buildings, building groups or a district of a city. The buildings are assessed both with their whole life cycle flows and processes as well as their hourly breakdowns of energy demand. As shown in the below infographic, this approach enables the system to be addressed both in the 60 year life cycle span of a building and also with the hourly analyses of electricity, fuel and other relevant flows.

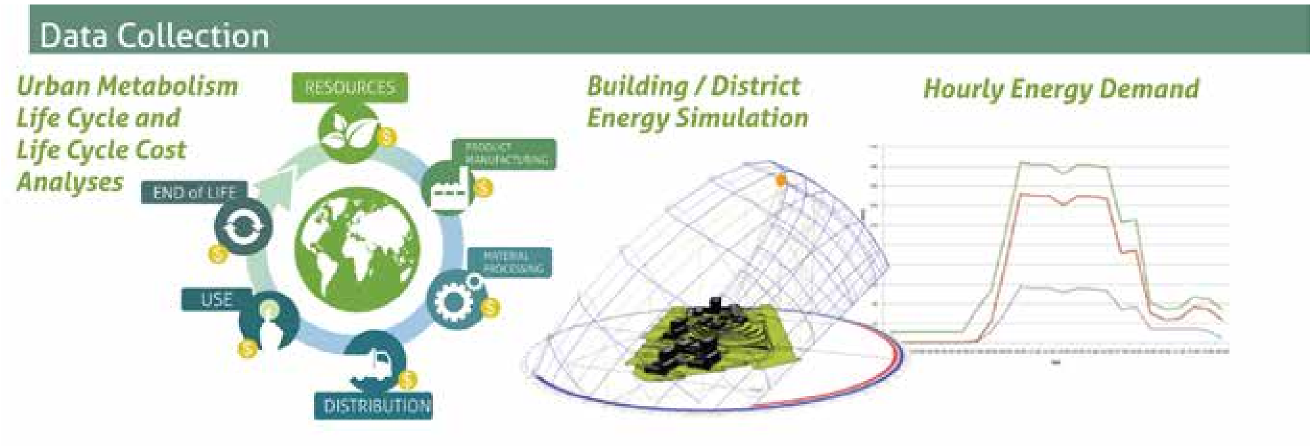

Figure 2 Levels of analyses performed by EPESUS

The ability to integrate temporal and spatial aspects into the analysis of multiple flows in urban space is the basis of EPESUS's urban metabolism capability. By altering parameters one can calculate and visualize changes in these flows and their impact on the overall Life Cycle Impact of the defined spatial zone.

R2CITIES PROJECT AS A CASE STUDY

Funded under European Union's Seventh Framework Programme for research, technological development and demonstration, the objectives of Renovation of Residential and Urban spaces towards: nearly zero energy CITIES (R2CITIES) project are to develop and to demonstrate replicable strategies for designing, constructing and managing large scale district renovations for achieving nearly zero energy cities. This covers a very ambitious renovation plan of three residential districts in Valladolid, Genoa and Kartal, which will involve more than 57.000 m2, 850 dwellings and 1500 users, with a potential of energy consumption reduction close to 60%.

In the design phases of the refurbishment projects of demonstration districts, a holistic methodology is applied with selected district sustainability indicators (consisting of energy, economic, comfort, social, environmental and urban indicators) which provide a similar approach to urban metabolism with a life cycle point of view. Different building retrofitting scenarios have been evaluated through these indicators and the best scenario for the district is selected by Kartal Municipality and other relevant stakeholders.
Retrofitting scenarios of Kartal district have been analysed and evaluated with EPESUS platform by means of economic (LCC), environmental (LCA) and energy performances at district level.

Firstly, the information in building level which consists of floor area, building type, building height, occupant density, building age, has been defined in GIS-based EPESUS platform according to their locations. From the previously defined system model database of EPESUS, the most suitable model is selected according to the energy performance type of the building. This system models includes hourly energy demands, CO_2 emissions, environmental impact categories and life cycle costs per floor area for a year.

By defining all of the R2cities demonstration buildings in Kartal neighbourhood, one can have a district-level model which can display hourly energy demand density and CO2 emissions of Kartal District. By extrapolating this information with the integrated databases of EPESUS platform to the city-level, energy consumptions, CO2 emissions and retrofitting scenarios of the buildings in a city can be analysed and monitored.

This has been an application of the urban metabolism approach to district and building level analyses within the scope of the project goals of R2cities. Integrating other types of energy and material flows such as transportation, industrial activities and public space management to this platform can elaborate the urban metabolism approach within EPESUS' capabilities further to support different types of decision making processes of authorities.

RESULTS

Hourly energy consumption of the selected district or city can be analyzed by the GIS module of EPESUS. Hourly energy consumptions (according to fuel types and end-uses such as heating, cooling, lighting etc.) of the buildings can be defined by the integrated building energy simulation tool (Energy+) or the monitored real-time data (obtained from the energy meters of energy management systems of buildings) in the background of this module. Therefore, one can visualize the energy consumptions in the user-defined district or districts for the selected time interval (hourly, daily and annual). The energy demand in Kartal, Yakacık District is illustrated in Figure 2.

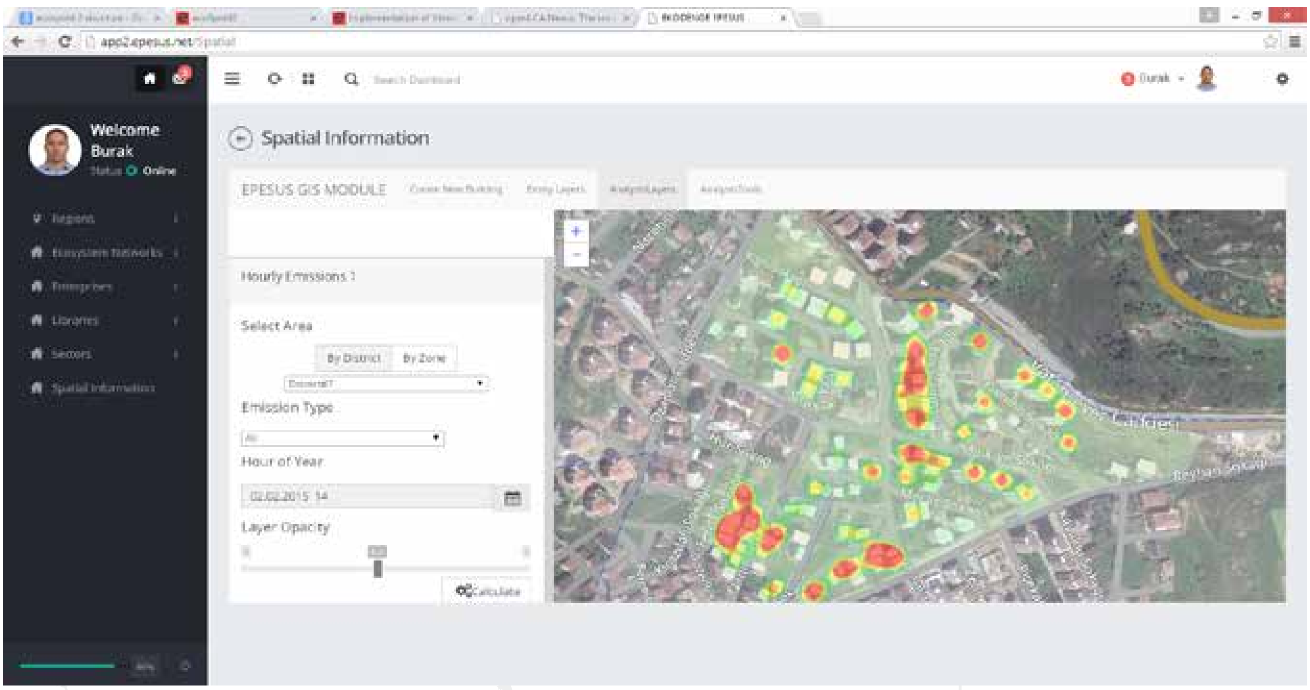

Figure 3 Hourly Energy Consumption Analysis

Previously defined energy efficient retrofitting scenarios of a building or district can be analysed and one can compare different scenarios such as building envelope insulation, HVAC equipment replacements and renewable energy systems integration. The comparison figures of existing scenario, envelope retrofitting scenario and HVAC retrofitting scenario of two different building in Kartal district are illustrated in Figure 3.

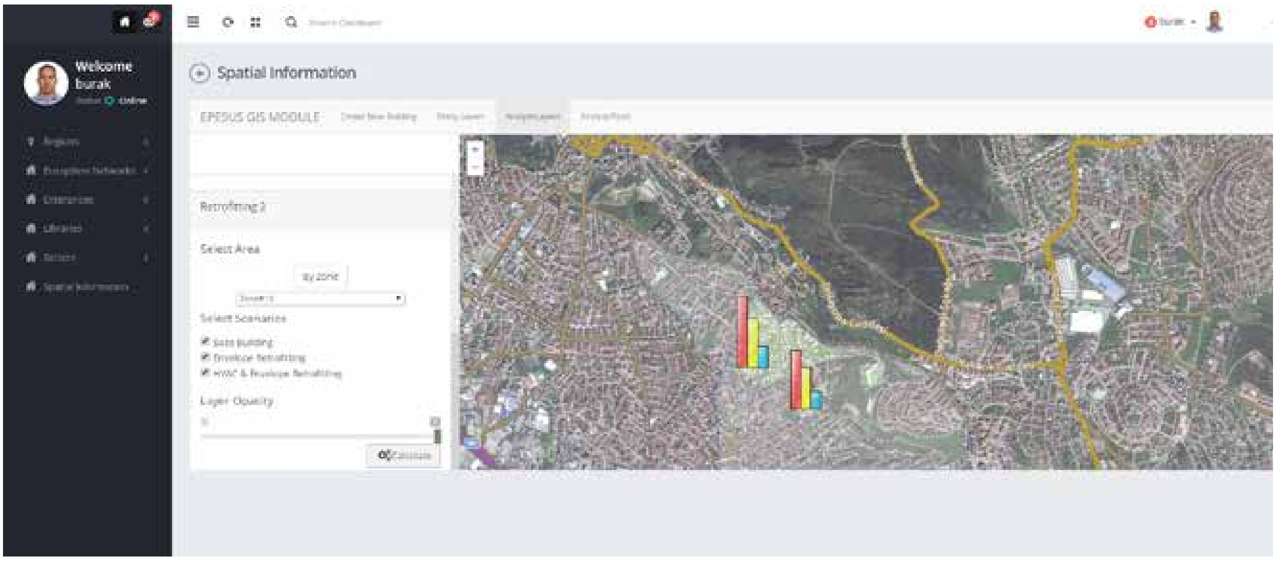

Figure 4 Retrofitting Scenarios Comparison

Flue gas emissions (NOx, SOx) from solid fuels (natural gas, coal, fuel oil etc.) can be shown with respect to the plume dispersion model, which takes into account wind direction and speed, at building or district level as shown in Figure 4.

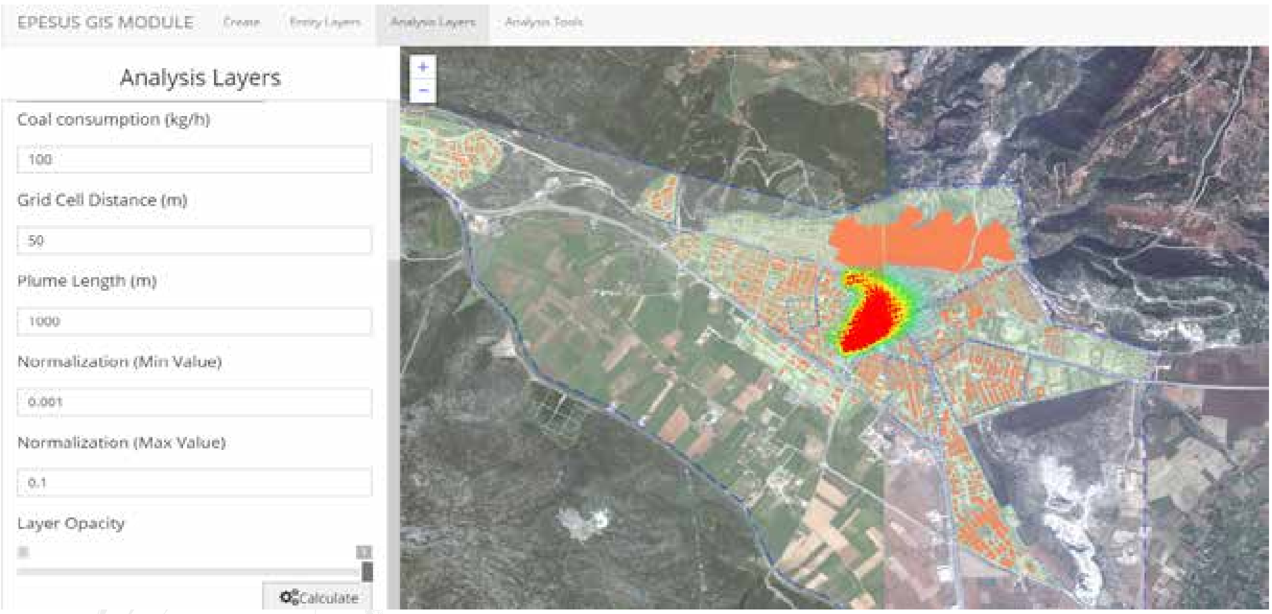

Figure 5 Air Emissions Analysis

Many experts from different fields including municipalities, industrial facilities or zones, buildings and building groups, can benefit from these analyses which can be accomplished with an integrated urban metabolism platform.

As one of the main beneficiaries of an urban metabolism platform, municipalities can find many solutions for their responsibilities in energy management, waste management, water footprint, urban sustainable energy action plans, urban air pollution monitoring and forecasting. For energy management tasks of municipalities, main actions which can be accomplished by the platform can be listed as:

- Retrofitting decisions by analysis and monitoring of fuel and electricity consumptions of municipality facilities
- Improvements in user behaviours and decision making processes by comparing historical and expected energy consumption data
- Energy savings by reactive power compensation method
- Optimization of renewable energy systems integration for maximum usage
- Energy demand management with forecasting by real-time data or simulations

In the scope of waste management activities, main benefits of municipalities can be listed as:

- Integrated waste management by forecasting of the amount of waste and energy saving potentials
- Logistics improvement scenarios modelling and supports for their applications
- System design with waste separation potential forecasting (waste collection and usage modelling)

For water management and footprint activities:

- Water consumption monitoring of public parks and gardens
- Water savings in irrigation with integrated weather forecasting
- Reusing of waste water in irrigation systems

For urban sustainable energy action plans:

- Energy consumption identification of buildings and industries
- Scenario comparisons and feasibility analysis of urban renewal and retrofitting
- Urban performance criteria definitions and monitoring system

For urban air pollution monitoring and forecasting:

- Forecasting of PM1, SOx and NOx emission concentrations of urban resources
- Air pollution forecasting according to weather data
- Decision support and analysis of air pollution reduction and cost scenarios

Other than municipalities, organized industrial zones can use this platform for active /reactive power management, waste management and waste heat valorisation within or between industries. For industrial facilities, the platform can be treated as process data management and can perform decision support for automation systems, measurements of energy improvement potential scenarios, environmental performance monitoring, environmental product declarations.

If has been seen and proven that multiple decision support actions to the urban actors can be provided which include;

- Performance analyses of various scenarios
- Analyses of consumption and flow metrics, delivery of warnings and improvement recommendations
- Analyses on demand forecasts and effects of various external parameters for these scenarios such as weather changes in the short terms and climate change related effects in the mid and long term

Additionally, future research and development topics are provided with the presented platform and methodology. These include;

- Dynamic optimisation of the flows with multiple objectives
- Connectivity to external data and sensor networks
- Involvement of the citizens as agents of the ecosystem and modelling their behaviours, vulnerability and wellbeing with respect to the changes in the urban ecosystem

As a result, an urban metabolism platform tool is a promising technology for many applications in different fields and provides solutions for the problems of dealing with complex urban systems in compliance with recently developed technologies and regulations around the world.

ACKNOWLEDGEMENT

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REFERENCES

[1] Baynes T.M., and Wiedmann T. ***General approaches for assessing urban environmental sustainability.*** Current Opinion in Environmental Sustainability, 2012, pp.458 – 464.

[2] Chester M., Pincetl S., and Allenby B. ***Avoiding unintended tradeoffs by integrating life-cycle impact assessment with urban metabolism***. Current Opinion in Environmental Sustainability, 2012, pp.451 – 457.

[3] Ferrao P., and Fernandez J.E. ***Sustainable Urban Metabolism***. Massachusetts Institute of Technology, 2013.

[4] Goldstein B., Birkved M., Quitzau M., and Hauschild M. ***Quantification of urban metabolism through coupling with the life cycle assessment framework: concept development and case study***. Environment Research Letters, 2013.

[5] González A., Donnely A., Jones M., Chrusoulakis N., and Lopes M. ***A decision-support system for sustainable urban metabolism in Europe***. Environmental Impact Assessment Review, 2013, pp. 109-119.

[6] Pincetl S., Bunje P., and Holmes T. ***An expanded urban metabolism method: Towards a systems approach for assessing urban energy processes and causes.*** Landscape and Urban Planning, 2012, pp.193 – 202.

"Context - Environment"

Paper No: 161

Cut Trees to Save Environment?

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ABSTRACT:

This is the title of an old press release by Ed Pepke, Forest Products Marketing Specialist of UNECE/FAO Timber Branch. It is certainly very obvious that the theme is not about cutting down the trees and destroying the forests. It aims to draw attention to the fact that promoting the use of wood helps to protect our forests and hence the environment.

This paper aims to outline:

1. The properties of wood as a building material: wood is durable, has extra ordinary physical and chemical properties, can be repaired easily, is a perfect material for prefabrication and large span constructions, is safe in a fire, safest material in an earthquakes and that using wood is good for the environment.
2. New developments in timber architecture

Cut trees to save environment is the title of an old press release by Ed Pepke, Forest Products Marketing Specialist of UNECE/FAO Timber Branch. It is certainly very obvious that the theme is not about cutting down the trees and destroying the forests. It aims to draw attention to the fact that promoting the use of wood helps to protect our forests and hence the environment.

Wood has sustained its importance for ages: Wood can be used almost for everything, machine parts, wheels, tableware, toys, furniture, almost anything but the most important mission of wood is to help to build sustainable environments.

Wood has extraordinary physical and chemical properties: Wood does not conduct electricity, does not conduct heat, wooden surfaces are free of condensation and does not corrode.

Wood is durable: Istanbul archaeological museum hosts coffins from the Egyptian pyramids more than 4000 years old. Wood does not decay easily. Wood rotting fungi need water, oxygen and certain temperatures to survive and to be able to digest the cellulose in the wood cell walls - thus cause wood rot

Figure 1 Wooden toy, Gordion [1]

Figure 2 Wooden plate, Gordion [1]

Figure 3 Koç Museum, İstanbul

Gordion tumulus, central Anatolia 800 BC., houses the oldest wooden burial chamber. Wooden furniture from the chamber is exhibited in the Anatolian Civilizations Museum, Ankara. The chamber is a wooden structure; rubble fills the space between the wooden walls and the surrounding earth which makes up the tumulus. Thus rain water is discharged through the rubble, keeping the wood dry. The ancient port of Istanbul (400-700 a.d.) was discovered in 2006 when excavations for Yenikapi metro station construction started. More than 30 wooden ships were found, almost intact. In most underwater excavations the wooden parts are all over the place but the boats of the Istanbul excavations were intact because wooden pegs were used instead of metal nails. A most interesting finding during the Istanbul excavations was a grave: the bones of the body were lying on big timber pieces with a wooden cover. The wood was dated to 6500 B.C. Wood had not rotten away as wood rotting fungi need oxygen to survive and to damage wood cells.

Figure 4 A boat, ancient port of İstanbul

Figure 5 Wooden piles

Figure 6 Grave, 6500 BC P:Serkan Ocak

In Istanbul many seaside mansions are built on timber piles, Dolmabahce palace for example is still standing on timber piles since 1843.

Wood is easily and economically repaired: The Turkish Timber Association restored two timber houses in Zeyrek within the boundaries of the World Heritage Area of Istanbul, to show that timber buildings can be easily repaired. The first building was repaired in 2.5 weeks at a cost of only 15 000 USD. Many practical and easy methods are available to repair timber buildings.

Wood is a perfect material for prefabrication: Hereke silk carpet factory kiosk was built in 1894: manufactured in 3 weeks and assembled in 3 days upon instructions of the Ottoman sultan to host the German emperor who wanted to visit the silk factory.
Another example is houses of the eastern black sea area. These houses are built without using nails or other connectors. You can dismantle them and rebuild them again

Figure 7 Darphane repairs, İstanbul

Figure 8 Silk Factory, P: Önder Küçükerman

Figure 9 A house, Rize P: Cengiz Eruzun

.**Wood is safe in a fire:** Wood is a combustible material but when it starts to burn a layer of char is formed on the surface which protects the inside. Exposed heavy timber constructions can be designed to a fire resistance rating of 90 minutes.

Sibelius hall, Finland: fire resistance: 90 minutes. In this building timber is exposed and untreated and metal connectors are protected inside the wood. Haydarpaşa train station, Istanbul, after the fire the roof was completely burned, November 28, 2010.

Figure 10 Sibelius Hall [2]

Figure 11 Haydarpaşa Station, P: Demet Sürücü, Kudeb

Figure 12 Haydarpaşa, cross section, P: Demet Sürücü, Kudeb

Wood is earthquake safe: The first secret is in the equation: f=ma²: a=acceleration, a measure of how fast the earth moves m=mass, a measure of how heavy the building is, f=the force exerted on the building by the moving earth

Therefore: the lighter the building the less will be the forces acting on it to tear it down. Wood is light but cotton is also light, therefore we need a material which has a high strength/weight ratio. 1 kg of wood can carry more load than 1kg of concrete or steel.

Then the third secret is that a certain amount of stiffness is needed. Timber frame construction can easily meet these criteria. Traditional timber frames from earthquake areas in Turkey have v and x braces for extra earthquake resistance.

1999 Kocaeli earthquakes in Turkey killed 17 000 people, mostly under concrete structures. Reports about the performance of timber houses were usually very positive. Wooden houses with soft story problems and extensive rotten timber survived the shakes.

Figure 13 On the fault line, [3]

Figure 14 National Geographic, 1999, [4]

Figure 15 Timber, soft storey [5]

Using wood helps to protect the enviroment:

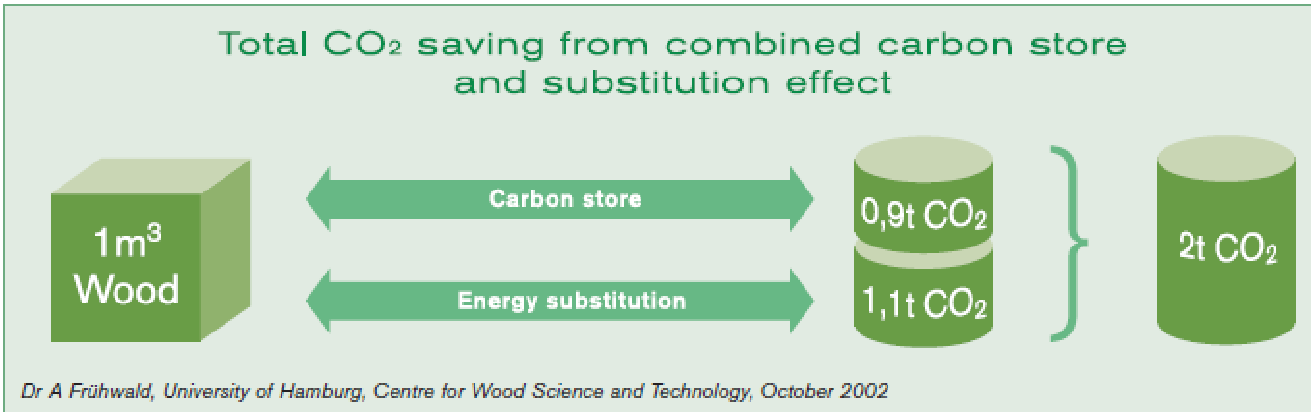


Figure 16 Forests and the carbon sink [6]

The production of one cubic meter of wood, when compared with the production of an equivalent amount of other materials such as concrete and steel, creates roughly about 1,1 tons less carbon dioxide. In addition to this, wood stores 0,9 tons of CO_2/m^3 itself.

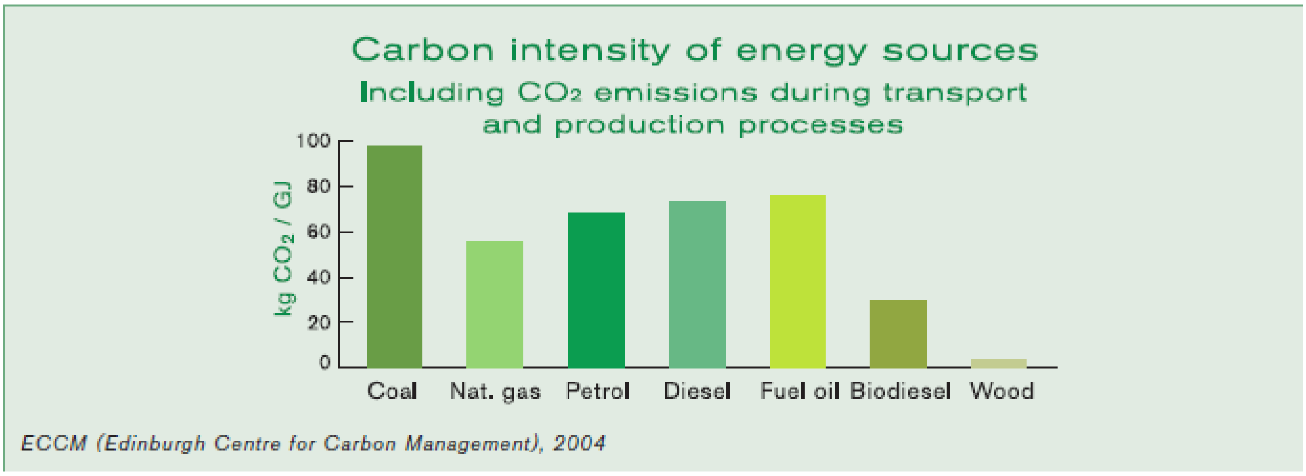


Figure 17 Substitution for fossil [7]

Wood can be burned after it has been used, and as can be seen in figure 2, the cleanest fuel and the only one which has a renewable source.

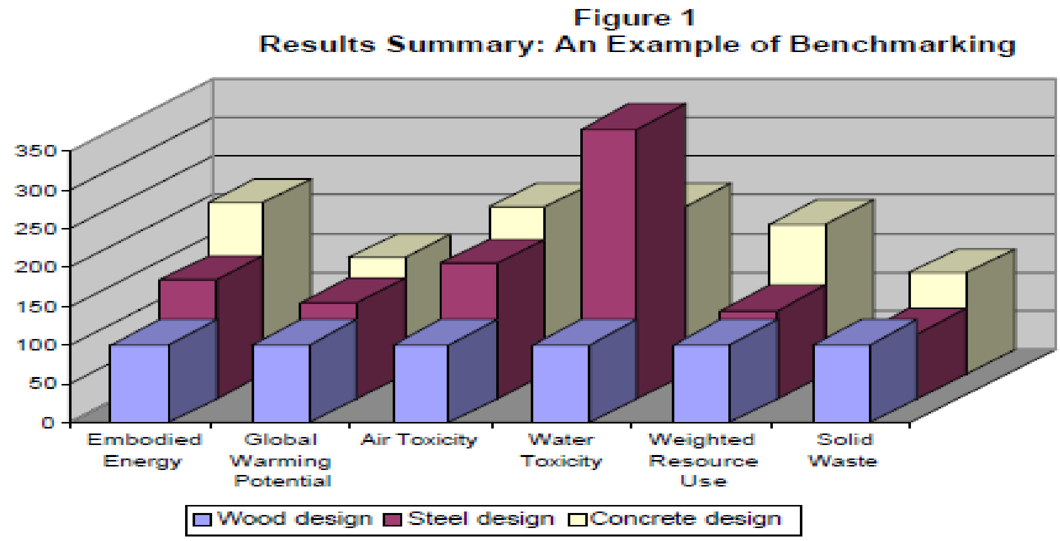


Figure 18 Results summary: An example of benchmarking [8]

Figure 19 And...wood can be reused? A library building in Azkoitia, Spain. It was constructed by Estudio Beldarrain with recycled old railway sleepers [9]

Traditional Turkish timber architecture

Doğan Kuban, in his book titled "Wooden Palaces" comments: If the Turkish soul is to be praised this will be for the timber housing architecture. Unfortunately not much literature is available, except for books with pictures. With a question mark, the origin of American timber frame and timber roof shingles are said to have their roots in Anatolia.

Figure 20 Kemaliye, Elazığ

Figure 21 5 stories, Mudurnu, Bolu

Figure 22 The orphanage, Prince Islands, Istanbul, largest traditional building in Europe

New face of timber architecture

Knowing the virtues of timber together with new worries about environmental problems, it is no surprise that architects and engineers have come together, and in a very short time period we see a boom in emergence of a new timber architecture, new products and new visions.

EXPO 2000 Hannover was probably one of the triggers. For the Swiss pavilion Peter Zumthor stacked 3000 cubic meters of unseasoned standard sized timber to make a maze, without using any connectors or glue. After the exhibition the timber was sold to be used for something else. What was Zumthor trying to point out?

New products [10]

Glue laminated timber:

Glulam is stronger than steel and has greater strength and stiffness than comparably sized dimensional lumber. Increased design values, improved product performance, and cost competitiveness make glulam the superior choice for projects from simple beams and headers in residential construction to soaring arches for domed roofs spanning more than 500 feet

Glue laminated timber was probably the oldest renovation. In fact, similar products date back to the 19th century, the difference being to hold the laminates with metal connectors instead of glue.

Figure 23 Laminated beams without glue Halifax, UK, 1900

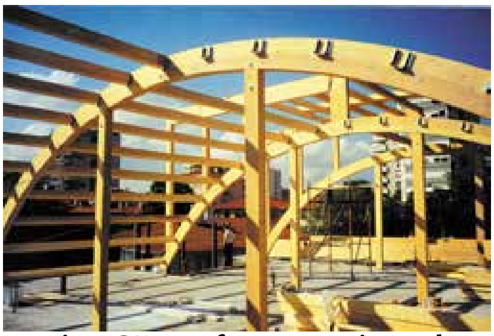
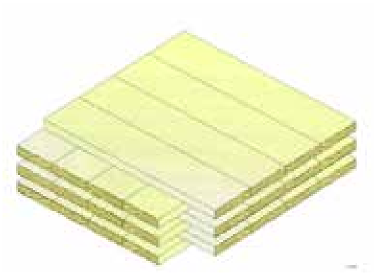


Figure 24 First GLT roof structure in Turkey, 1995, Vedat Tokyay

Cross laminated timber:
CLT-cross laminated timber, is a "solid wood" panel produced from 3-7 alternating layers of lumber, stacked and either glued or fastened orthogonally one to another. ICLT, Interlocking CLT panels are a recent innovation. ICLT utilizes no adhesives or fasteners between layers. The panel is held together using a method of interlocking dovetailed boards.

The fist high rise (9 storey) built with cross laminated timber is probably Murray Grove in London. It is built in 9 weeks, almost no garbage and no disturbing construction noise.



CLT

Figure 25 ICLT cross section

Figure 26 Murray Grove, 9 stories, UK

Figure 27 Bergen, Treet Tower 14 stories, Demet Sürücü

Structural composite lumber (SCL):
SCT is a more recent product, a family of engineered wood products created by layering dried and graded wood veneers, strands or flakes with moisture resistant adhesive into blocks of material known as billets, which are subsequently resewn into specified sizes. In SCL billets, the grain of each layer of veneer or flakes runs primarily in the same direction. The resulting product out-perform conventional lumber, and is a uniform engineered wood product that is sawn to consistent sizes and is virtually free from warping and splitting.

Last word: some very high projects:

Figure 28 For London, 80 stories
PLP Architecture [11]

Figure 29 For Paris, 35 stories,
Micheal Green. [12]

Figure 30 For Stockholm, 34 stories,
CF Møller [13]

From an interview by Architectural Review
Glenn Murcutt, 2002-pritzker prize, 2009 AIA
AR: what about your choice of materials?
GM: again, you have to ask the right questions: how much energy is required to produce the material? How much will the material reduce energy use in the building? One of the few sustainable materials is timber. Steel and aluminium require much more energy to produce. They should be used sparingly.
Murcutt is also fond of quoting the aboriginal proverb: "touch the earth lightly."

REFERENCES

[1] Prof. Dr. Elizabeth Simpson, Prof Krysia Spirydowicz, ***Gordion Wooden Furniture,*** **(**Museum of Anatolian Civilizations), Ankara, 1999, ISBN No. 975-7558-21-4
[2] http://www.sibeliustalo.fi/en/sibelius-hall
[3] www.usgs.gov
[4] National Geographic, December 1999
[5] MCEER, Multidiciplinary Center for Earthquake Engineering Research, Technical Report MCEER-00-0001, March 23, 2000
[6] Frühwald, A., Forests and the carbon sink, European Wood Factsheets 3, European Confederation of woodworking industries http://www.vhn.org/pdf/Eurofact3-Wood_as_Carbon_stores.pdf
[7] ECCM (Edinburgh Center for Carbon Management), 2004, European Wood Factsheets 3, European Confederation of woodworking industries http://www.vhn.org/pdf/Eurofact3-Wood_as_Carbon_stores.pdf
[8] Trusty W.B., Meil J.K., ***Building life cycle assessment: residential case study,*** ATHENA- Sustainable Materials Institute, Canada http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.504.7004&rep=rep1&type=pdf
[9] http://www.dezeen.com/2015/11/26/aizkibel-library-extension-reclaimed-railway-sleepers-spain-estudio-beldarrain/
[10] www.apawood.org
[11] http://www.plparchitecture.com/
[12] http://mg-architecture.ca/
[13] http://www.cfmoller.com/

Paper No: 166

The GIS-Based Earthquake Risk Analysis of Değirmendere

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ABSTRACT

Based on the data derived from former studies about the distribution of building damage in Değirmendere, level and distribution of damage along with the structural behavior during the earthquake on August 17, 1999 have been analyzed.

Geographical Information System (GIS) has been used for the seismic danger and risk analysis regarding the vulnerability of each building on the study area. Each building has been evaluated regarding the static and dynamic effectiveness of the parameters of earth sciences and the total vulnerability has been derived by the weighted sum of each parameter.

However, in order to determine the damage vulnerability of the buildings, all data have been assigned to the attribute value of each building in GIS. Thus, it has become possible to label each building with all its properties.

Demographic data on the habitants of the region has been added to the building attributes in GIS along with other data.

Finally, the total seismic danger and vulnerabilities of buildings have been determined and classified in groups of "High" and "Low." Therefore, the population under high levels of risk has been specified. Based on the information on population and vulnerability, additional knowledge has been produced for direct use in disaster management.

Keywords: Risk Analysis, Disaster Management, Geographical Information Systems (GIS), Hazard Mitigation.

STUDY AREA

Surface rupture of the August 17, 1999 Gölcük earthquake which occurred on the northern branch of the Northern Anatolian Fault Zone (NAFZ), passes through Değirmendere and continues to the sea. The study area is located in the southern part of the NAFZ (Figure 1).

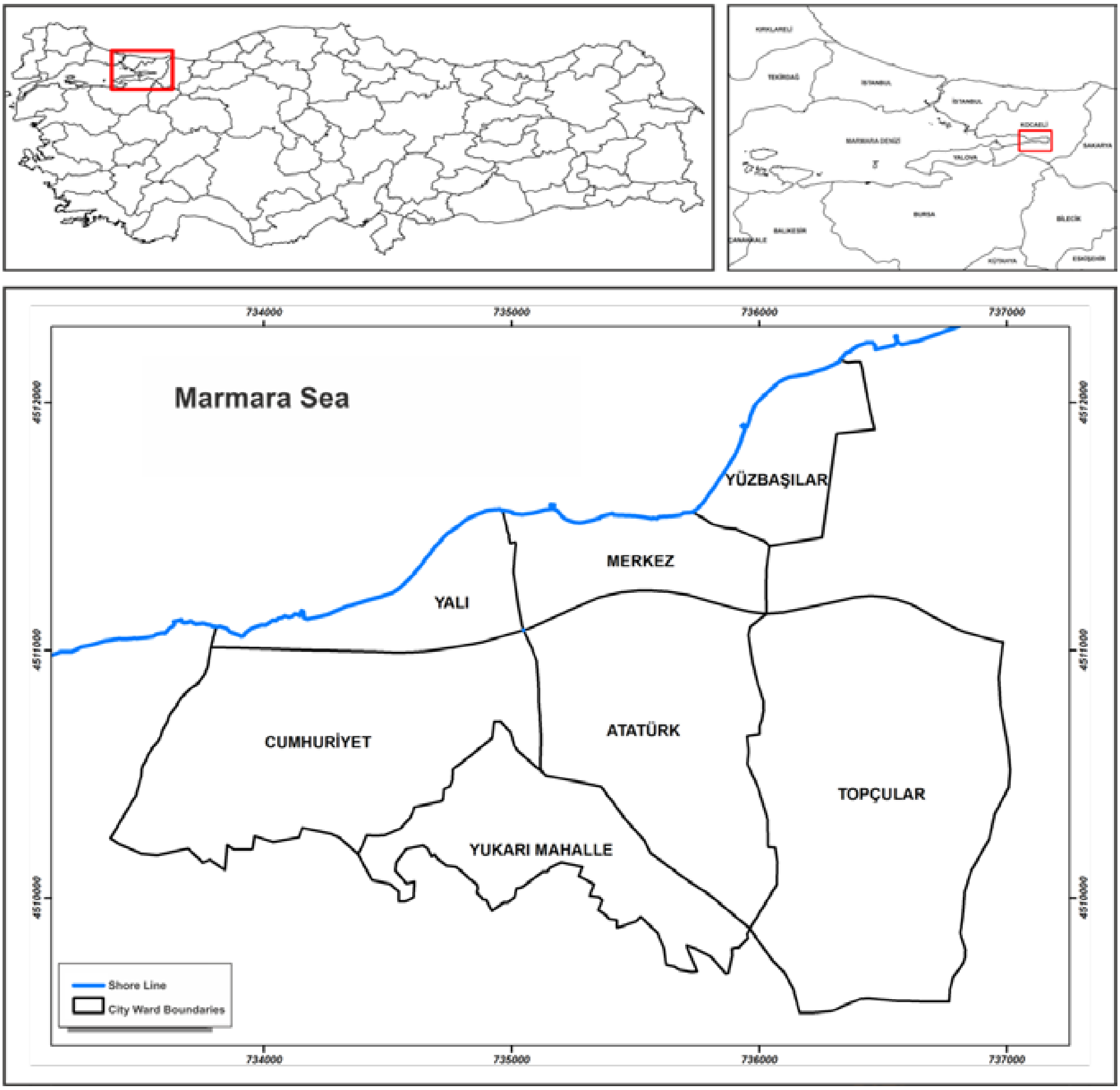

Figure 1. Study area

Değirmendere which is a coastal town consists of 7 districts. There are 3456 buildings in the study area and 2204 of them were damaged in various levels during the August 17, 1999 Earthquake. %64 of the total building stock in the study area was damaged.

ASSESSMENT OF DATA UNDER EARTHQUAKE RISK ANALYSIS

Geoscientific data have been evaluated and 28 specific data were classified and added to the structure attribute in GIS domain (Table 1). These data have been selected independently from the study area and have been compiled in order to create a database for other studies and researchers. The data created in GIS domain is updatable and can be integrated into multi-disciplinary studies. Data obtained from the General Directorate of Civil Registration and Nationality on demographic features is also appended to the attribute values of the system in addition to the geosciences data. In order to see all data about building, Building Hazard Analysis Voucher (BHAV) has been created independently from the GIS program. Also, all visual documents belonging to each building (pictures, static projects, settlement, etc.) were stored with BHAV archiving system.

Table 1. Criteria used in Building Hazard Analysis

Local soil conditions and earthquake effects	**Remarks**
Distance to the fault	Meters or kilometers
Primary axis direction to the fault Perpendicular Parallel Others	1-perpendicular to fault 2-parallel to fault 3-others
Distance to stream bed	m or km
Groundwater level	M
Bedrock depth	Özlaybey et al., (2008) [1]
Consistency Condition	1 – Very soft 2 – soft 3 – stiff 4 – hard 5 – very hard
P velocity	2nd layer P wave velocity
S velocity	2nd layer S wave velocity
Vs(30)	S wave velocity within 30 m
Cohesion (C)	
Internal friction angle (ε)	
Geological Formation effect	Will be entered by using regional geological maps
RQD	For rock sites
Poisson ratio	Elastic parameters from S waves
Bulk modulus	Elastic parameters from S waves
Sliding modulus	Elastic parameters from S waves
T0 (resonance period)	From seismic data
Bed coefficient	From seismic data
Liquefaction	1 – exist 2 – non exist
Carrying power	From borehole data
Soil safety stress	From seismic data

Soil amplification	From microtremor
Resonance period	From microtremor
Soil classification	From microtremor
Residential compliance status according to DEMA terminology	From available studies
Acceleration value	
Damage distribution after the August 17, 1999 earthquake	From observational reports of Ministry of Environment and Urbanisation 1 – no damage 2 – light damage 3 – moderate damage 4 – heavy damage 5 – collapse
Slope/hill-slope effects	% slope data

DATA WEIGHTING USING ANALYTIC HIERARCHICAL PROCESS

Seven data which have higher potential of damage have been selected from available data in the study area (Table 2) to be used in hazard analysis.

Table 2. Geoscientific data effecting hazard analysis

Geoscientific factors
Distance to fault (DF)
Primary axis direction (Perpendicular, parallel, others) (PAD)
Groundwater level (GWL)
Vs(30) (Vs)
Geological formation effects (GFE)
Soil classification (microtremor data) (SC)
Slope/hill-slope effect (larger than 30%) (S)

Analytic Hierarchical Process (AHP), has initially appeared in 1968 in the works of [2] and was developed and completed in [3] as a model to solve problems of decision making [4].

AHP is a decision making process, based on the relative importance of alternative decision criteria values, to be used in complicated problems for the running mechanism of management [5]. Among various approaches of AHP, the methods of [4] and [5] have been compiled and applied in the study. AHP method flow chart is shown in Figure 2.

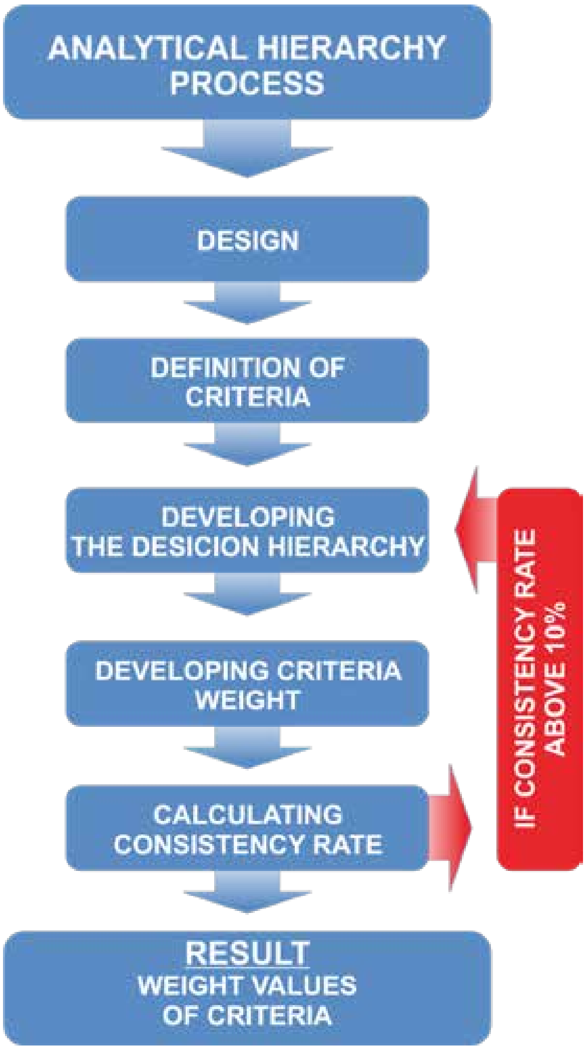

Figure 2. Flow chart for AHP method [6]

AHP method is used to determine the effects of the selected data on hazard analysis. It was decided to use AHP, as one of the multi-criteria decision-making methods, due to the ease of its application for GIS work in solving large-scale problems and its objectivity in problem solving in the fastest possible ways.

AHP is implemented in 4 stages. These;
Decision-making problem identification (Step 1)
Factors establishing inter- comparison matrix (Step 2)
Determining the percentage distribution of important factors (Step 3)
Consistency Factor measurements in comparison (Step 4)

Weights obtained by AHP results shown in Fig 3.

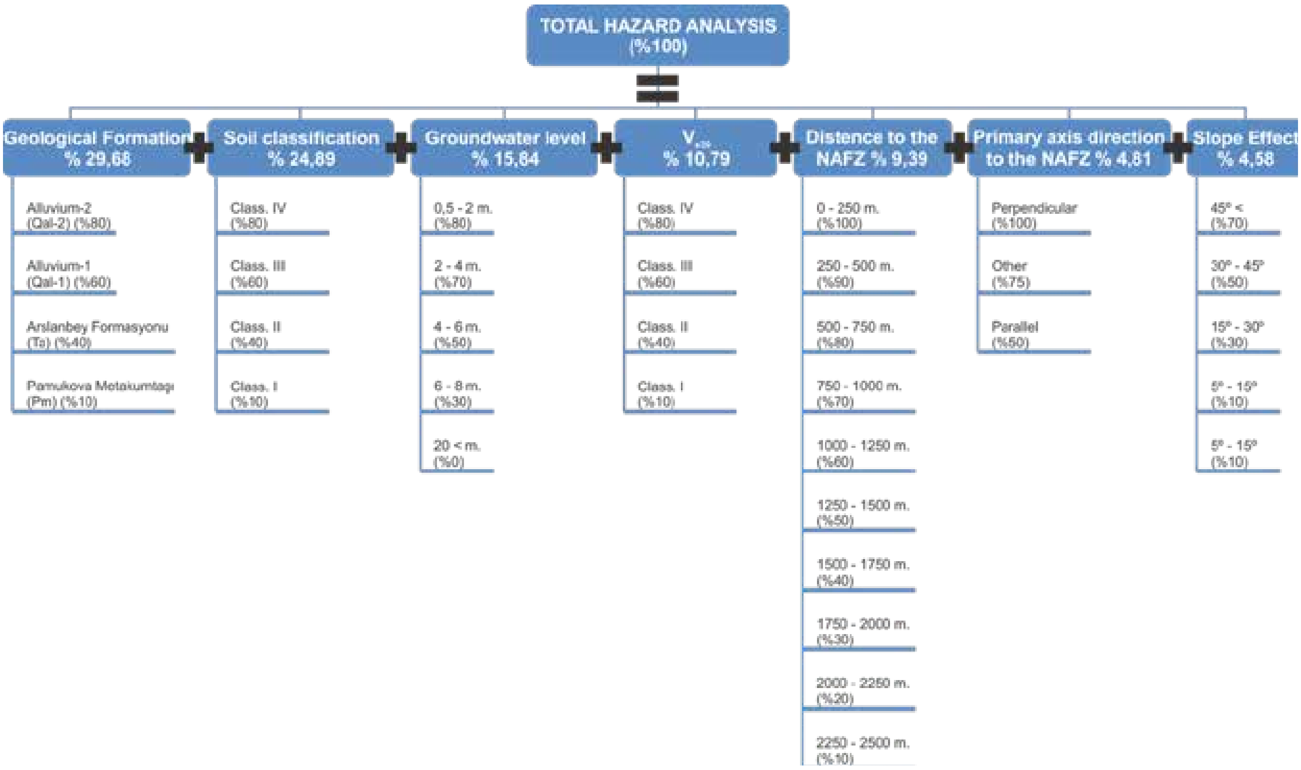

Figure 3. weight data and sub- risk groups used in the analysis of hazards

TOTAL HAZARD ANALYSIS MAP

Weight values obtained by AHP are added to the attribute value of each building in a GIS environment. Hazard Analysis Coefficient (HAC) was calculated for each building by adding the sub-group values of the weight values obtained. Distribution of the HAC values above and below 50% is given in Figure 4. As a result of the hazard analysis evaluation in the working area of 3456 buildings, 1502 of these buildings appear to have a risk of over 50%.

Table 3. Distribution of buildings and population at risk (according to HAC values above 50%)

Classification	Building number	Building number (%)	Male	Female	B65	K15	Population	Population (%)	House
16 – 50,00	1954	56,53	6527	6484	627	3020	13011	40,62	3262
51 – 78,68	1502	43,47	9344	9676	1757	3415	19020	59,38	5571
TOPLAM	3456	100	15871	16160	2384	6435	32031	100	8833

As the results of the analysis, the number of people living in low-risk buildings in the study area is 13011; the total number of houses is 3262; the number of people living in high-risk nature is 19020; the total number of houses is 5571 (Table 3). 59.38 % of the total population is accommodated in buildings that have high risk. Places where there is a large risk are areas where urbanization is also intense. The intervention and rescue work is expected to be experienced with difficulty.

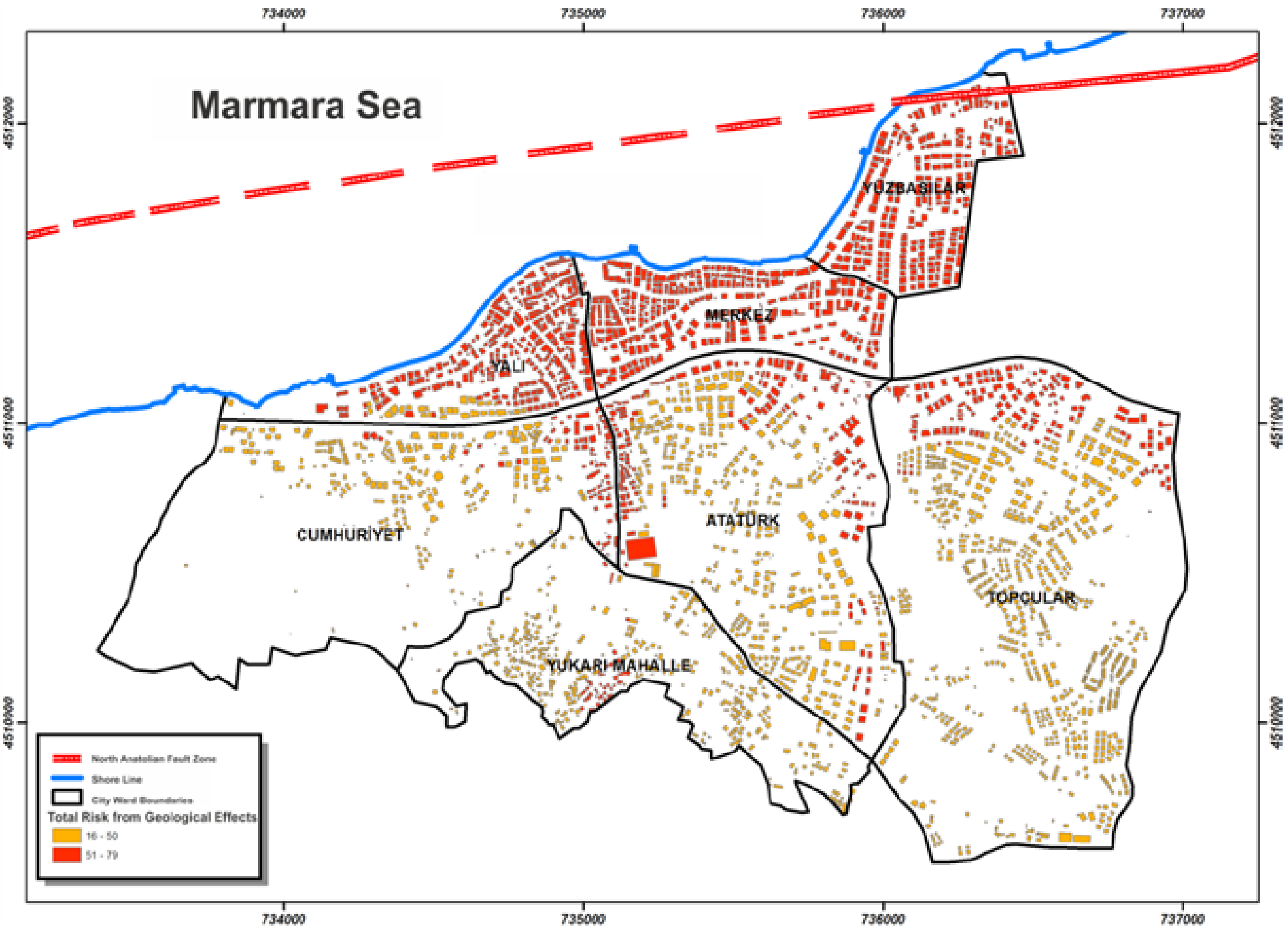

Figure 4. Distribution of the building stock at risk (according to HAC values above 50%)

Evaluating the study area in the neighborhood scale, all of the buildings in Merkez and Yüzbaşılar districts are at high risk. Risk rate is about 90 % at Yalı district. 4204 houses are in high-risk groups within these limits. 75.46% of the total number of houses is in the risk group. Within the three districts, the total affected population is 13621, therefore 42,52% of the total population lives in districts under high risk conditions.

5172 people over 65 or less than 15 years of age –who are considered as the vulnerable population, live at areas of high risk.

BUILDINGS WITH HIGH VULNERABILITY, DISTRIBUTION OF VULNERABLE POPULATION AND AREAS

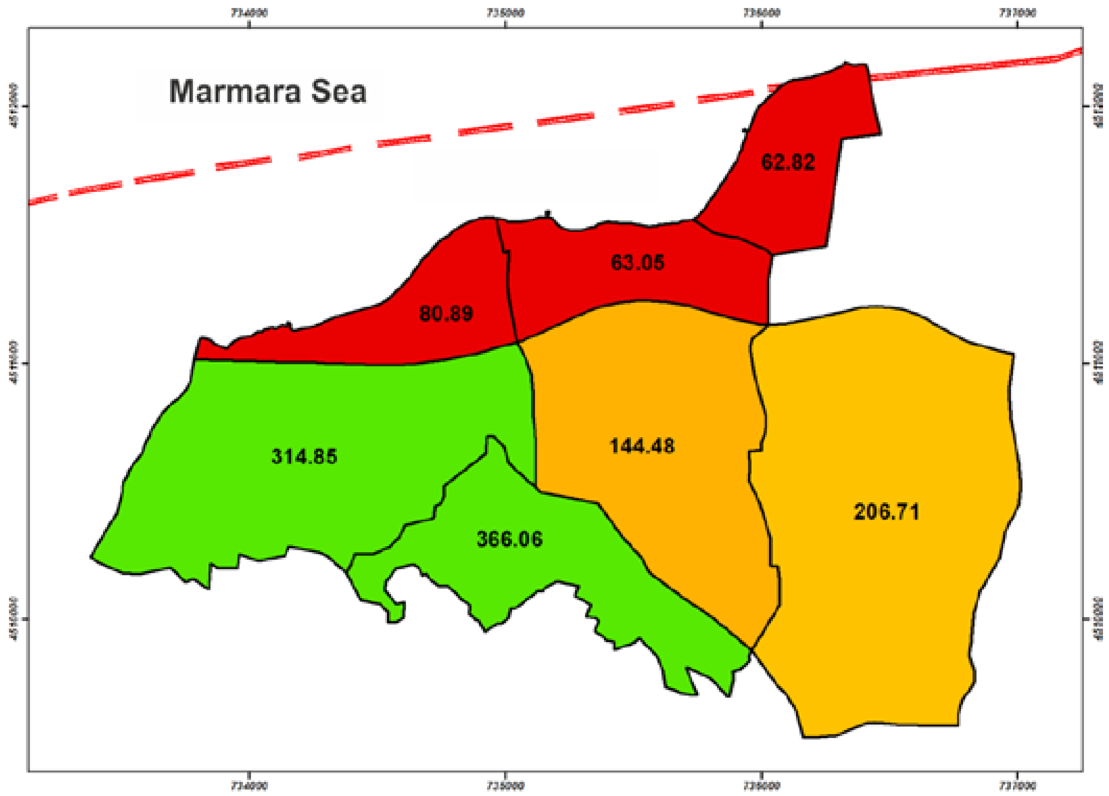

Figure 5. Distribution of unit area per capita in the scale of neighborhood (Area (m2) / Population)

The hazard analysis results indicate that, the most risky districts -Merkez, Yüzbaşılar and Yalı, also contain risks in the classification of area per capita (Figure 5). Close rates are observed at the evaluation of the Building/Space and House/Area criteria (Table 4).

Table 4. Unit area per capita in neighborhood scale

District	Area (m^2)	Building Number	Building/ Area (m^2)	Population	House	House/ Area (m^2)	Population/ Area (m^2)
Atatürk	883.482,85	613	1.441,24	6.115	1515	583,16	144,48
Cumhuriyet	1.055.055,70	349	3.023,08	3.351	898	1174,89	314,85
Merkez	350.302,63	373	939,15	5.556	1745	200,75	63,05
Topçular	1.422.772,40	983	1.447,38	6.883	1715	829,60	206,71
Yalı	313.036,14	437	716,33	3.870	1190	263,06	80,89
Yukarı	556.782,03	449	1.240,05	1.521	359	1551,92	366,06
Yüzbaşılar	297.457,53	252	1.180,39	4.735	1441	206,42	62,82
TOPLAM	4.878.889,28	3.456	9.988,00	32.031	8863	4.808,81	1.238,86

There will be difficulties in first responders and rescue operations in Merkez, Yüzbaşılar and Yalı districts where building and population densities are high. Efforts should be given in order to reduce the building and population densities in this region.

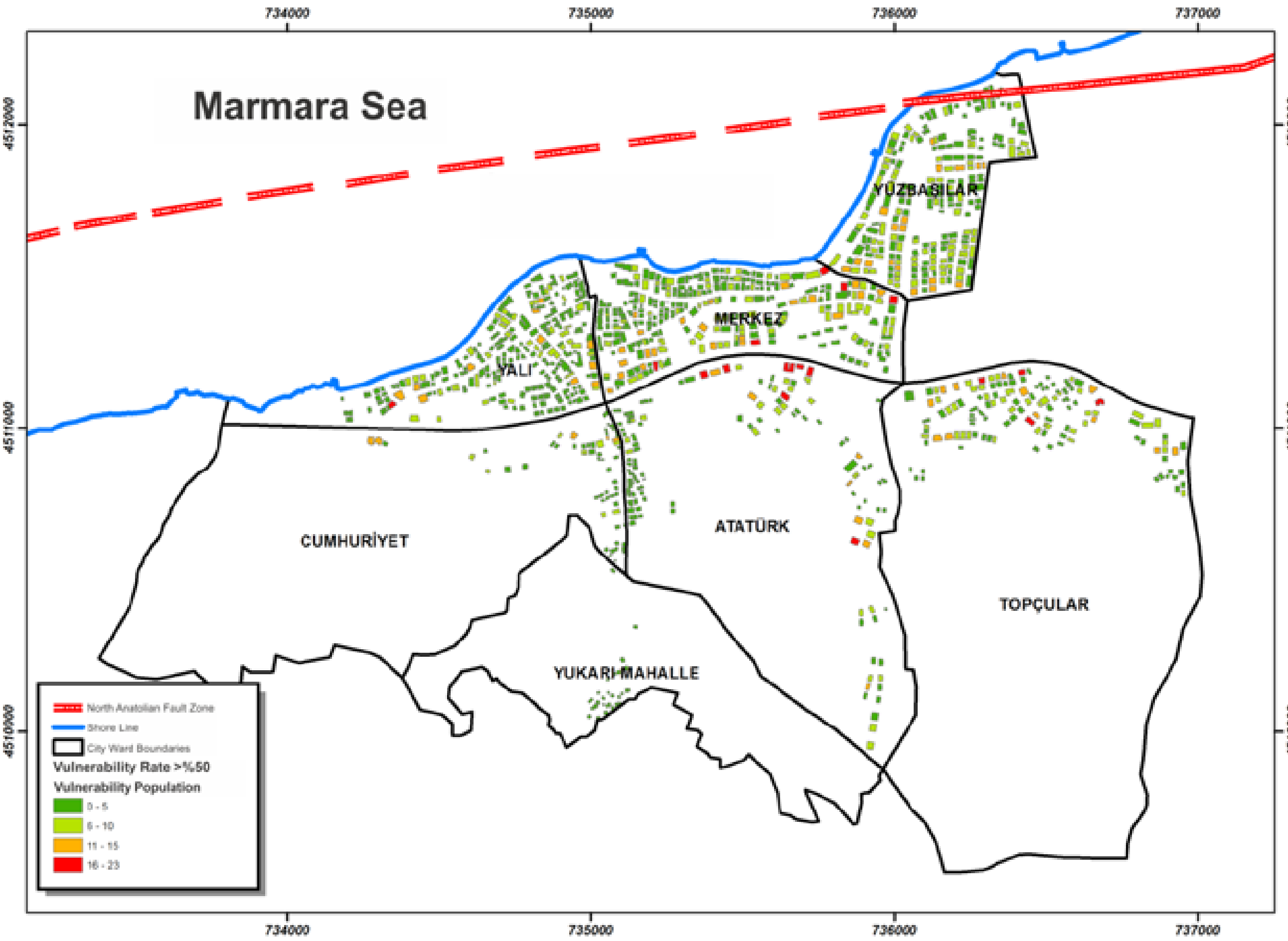

Figure 6. Distribution of Vulnerable Population in Buildings of Risk (according to HAC values above 50%)

As a result of the hazard analysis carried out in the study area, it is derived that -among the 1502 buildings with HAC above 50%, a total number of 1068 buildings are inhabited by members of the vulnerable population (people of age above 65 or below 15) (Figure 6).

CONCLUSIONS AND RECOMMENDATIONS

The study area is under hazard of natural disasters and in particular earthquake risk. To control the damage resulting from this risk, it is essential to know the properties and the reasons of the risk. In this study, the seismic hazard analysis is done for the region Değirmendere, the risk values are determined for each building, and the characteristics of the total population and the vulnerable population are demonstrated.

Taking into account systematic data produced today, disaster management and especially mitigation, it is not enough to carry on the studies only by evaluating the information of the building or the area. Since we need to protect people, in disaster management and mitigation, it is needed to evaluate the emerging risks and their results with a special focus on the population that will be effected by the disaster. In this study, 3456 buildings in the study area are analyzed by using geoscientific data in terms of hazard analysis. According to the obtained results, the number of buildings which have been identified as high-risk units is 1502. 58.10 % of the total population -5172 of whom are members of the vulnerable population- in Değirmendere still live in buildings of high risk levels. As a result, it is required to take urgent measures for the buildings of high risk and also for the people who inhabit these buildings.

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REFERENCES

[1] Özalaybey S., Zor E., Tapırdamaz M.C., Tarancıoğlu A., Özalaybey S. Ç., Erkan B., Karaaslan A., Alpaslan E., Ergin M., Ergintav S., Tan E., Kocaeli İli için Zemin Sınıflaması ve Sismik Tehlike Değerlendirme Projesi, TÜBİTAK, 5057105, 190, 2008.

[2] Myers J. H., Alpert M. I. Determinant buying attitudes: Meaning and measurement, J Mark, 1968, 32, 13–20.

[3] Saaty T. L., A scaling method for priorities in hierarchical structures, Journal of mathematical psychology, 1977, 15(3), 234-281

[4] Yaralıoğlu K., Uygulamada Karar Destek Yöntemleri, İlkem Ofset, İzmir, 2004.

[5] Timor M., Analitik Hiyerarşi Prosesi, Türkmen Kitapevi, İstanbul, 2011.

[6] Güven, İ., T. 2016. “Değirmendere’nin Yer Bilimleri ve Yapı Özelliklerine Göre CBS Tabanlı Deprem Risk Analizi”, Doktora Tezi, Kocaeli Üniversitesi, Fen Bilimler Enstitüsü.

"Material, Building- EPD&LCA"

Paper No: 8

Environmental Product Declarations (EPD) And Comparıng EPD's Through A Building Product

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ABSTRACT

Environmental labels are defined as "claims which indicates the environmental aspects of product or service" in ISO 14020. Environmental labels provide to compare different products with each other and to facilitate to take environmental concerns into account during the selection of products.
Environmental labels are used in many countries around the world. However especially Type III Environmental Label (Environmental Product Declaration - EPD) come forward for building product because having the following characteristics

- They are based on life cycle processes
- They assessed multiple environmental impacts
- They provide detailed information

EPD programs are widely used. However there are not enough studies comparing the EPD's of this programs through a specific building product.
The aim of this study is to identify information about EPDs and EPD Programs that created according to ISO 14025 and compare the EPD's of programs through a specific building material.
The scope of this study is limited to the following three EPD programs;

- The International EPD System-Sweden
- Institute Bauen und Umwelt-Germany
- EPD-NORGE-Norway

due to the fact that both PCR (Product Category Rules) and EPD count is more than other programs. As a result, especially when the functional unit is same, EPDs are facilitating the elections during product decision.
KEY WORDS: Eco-Label, Environmental Declarations, EPD, Building Materials, ISO 14025,

INTRODUCTION

Environmental labels which facilitate the consideration of the environmental concerns during product selection and which enable comparison of different products with each other are defined as the information showing the environmental dimension of the product or the service" in ISO 14020 [1]. Environmental labels are used in various country around the World. However especially Type III Environmental Label (Environmental Product Declaration - EPD) come forward for building product because having the following characteristics

- They are based on life cycle processes
- They assessed multiple environmental impacts
- They are well known because they provide detailed information. EPD programs are widely used. However there are not enough studies comparing the EPD's of this programs through a specific building product.

The aim of this study is to identify information about EPDs and EPD Programs that created according to ISO 14025 and compare the EPD's of programs through a specific building material.

The scope of this study is limited to the following three EPD programs;

- The International EPD System-Sweden
- Institute Bauen und Umwelt-Germany
- EPD-NORGE (Norway)

due to the fact that both PCR (Product Category Rules) and EPD count are more than other programs.

In the first section of our study information related to the all environmental label types created within the ISO 14020 standards. In the second section detailed information especially on Type III environmental label are provided and EDP programs' declaration creation phases are mentioned. Than, information related to the Type III environmental label existing in the World are presented in a detailed table. In the third section programs which EPD and PCR numbers are higher than others are selected. The selected programs are compared through a determined building product. In the fourth and last section the evaluation of the study and prospective propositions are determined.

1. ENVIRONMENTAL LABELS

For the environmental labels which are started to be used in 1970's, The United Nations promised to create a standard in its conference themed "Environment and Development" in Rio De Janeiro in 1992 [2]. Therefore the International Standards Organization (ISO) developed the ISO 14000 series standards in order to create the environmental approach regarding the environmental effects.

The environmental labels are determined in different resources as;

- "Information showing the environmental aspect of a product or service." [1]
- "Labels aiming to provide information to the consumers in order to select the product which is least dangerous for the environment." [3]
- "Labels which are provided at the end of the evaluation of the products which environmental effects are evaluated in accordance with measures determined by third parties and which should be obtained voluntarily" [1].

From these definitions it is possible to define the environmental labels as "**labels which inform the environmental effects during the life cycle of the products or services**".

In order to create a common international definition, criteria and concept substructure GEN, Global Ecolabelling Network is working together with ISO [4]. GEN, is founded in 1994 in order to develop, improve and present all the products and services related to environmental label. Environmental label purposes created by GEN in 2004;

- <u>Protecting the Environment</u>: Supporting the engineering, production, marketing and use of the products which environmental effects are decreased and limiting the use of the resources that are not renewed, during their life cycle.
- <u>Supporting the Environmental Innovations:</u> Promoting the innovative and progressive works in which environmental effects are decreased.
- <u>Increasing the Awareness of the Building Users in Relation To The Environmental Matters: P</u>roviding scientific and reliable information to the consumers in relation to the environmental effects of the products [5].

Benefits of the environmental labels that are also defined as a type of environmental performance criteria in relation to the products are:

- To obtain accessible and sustainable information in relation to the products and environment,
- To provide comparison capability in product selection,
- To provide and increase in consumers' awareness level and their environmental knowledge through the selection of the environmental labeled products
- The development of the new products through the efforts of the manufacturers in manufacturing products with high environmental performance,
- To facilitate the international circulation of the products with an environmental label,
- With the preference of the products with an environmental label, to provide success in product category which is important in certifications systems and thus, to help the creation of a healthy artificial environment,

As there are many different environmental labels and different applications in relation with them ISO classified the environmental label types as following according to 14020 standards:

- Type I
- Type II
- Type III

The Type I environmental label, is a labeling program which evaluate multiple effects and which is inspected by independent institutions. It doesn't contain quantitative data in relation with the environmental performance of the products, it provides only an opportunity for the consumer to compare the environmental performances of the products which are situated within the same category. It is an environmental label which is consumer oriented and easy to understand [6].

Examples of type I environmental labels are, The EU Eco-Label, Der Blaue Engel, The Nordic Swan.
Type II environmental label, ISO 14021 [7] describes the Type II environmental labels as "environment claim declared by manufacturers, importers, distributors, retailers or any other having the possibility of gaining income from these claims, without an independent third party certification". Type II environmental labels that do not take under consideration of the life cycle approach, are only considered as publicity purpose. The institutions choose the variable that they would like to declare and also determine the scope of the environment performance information that they will deliver within this concept.
Examples of the Type II environmental labels are, Philips Green Tick Logo, Siemens SN 36350 standard [8].
Type III environmental label, is a program with third party approval that realize evaluations based on multiple variables according to the life cycle approach. It provides quantitative data in order to allow comparison between the products having the same function. It is a environmental label with a commercial communication approach [9].

- Examples of Type III environmental labels are; The International EPD System (Sweden), IBU-EPD(Germany), EPD-NORGE(Norway)

As most of the Type III environmental label programs which have strong points such as being approved by independent institutions, evaluating multiple effect based on Life cycle assessment- LCA method, including quantitative data and providing detailed information benefit from a building products category, Type III environmental labels will be examined in detail.

2. TYPE III ENVIRONMENTAL LABELS (ENVIRONMENTAL PRODUCT DECLARATIONS-EPD)

The general purpose of the environmental labels and declarations is to promote the supply and demand of the product and services that are associated with certain and sustainable information on causing less effect on the environment. In ISO 14025 [9] TYPE III environmental label and program specifications are provided in detail. According to this standard the purpose of the Type III environmental labels are,

- To provide information based on LCA method in relation to the environmental dimension of the products.
- To help customers and users realize comparison between the products.
- To promote the improvement of the environmental performance.
- To provide information in order to evaluate the environmental effects of the products during their life cycle.

The qualities of the product declarations that allow providing the products' quantitative environmental information in comparing the products having the same functions,

- It is a voluntary program,
- It is based on independently approved systematic data, thus provides the independent institutions to evaluate the validity and the quality of the life cycle based data,
- It provides the environmental product information related to all life cycle of the product and services based on life cycle evaluation according to ISO 14040 (2007) [10] standard series.

- It is determined as the indicative group related to the different effect categories which defined the environmental performance of the products,
- It provide more detailed quantitative information,
- Even though it is oriented in B2B communication, it can be used in communicating with the consumer,
- It is bound to the direction of a program manager [9, 11, 12, 13].

2.1. TYPE III ENVIRONMENTAL LABEL (ENVIRONMENTAL PRODUCT DECLARATION) METHOD

The method which is used in the creation of the environmental product declaration has four phases. These are: the creation of the product category rules, the creation of the environmental product declaration draft, verification and the publication of the declaration.
As showed in Figure 1, the first phase starts with choosing one of the Type III environmental declaration programs. Than the existence or non-existence of a Product Category Rule –PCR is checked. If the product doesn't have a category rule, than this needs to be created. The next phase is to manufacture an environmental products declaration - EPD draft, based on LCA method. This draft should be in accordance with EPD program rules and defined product category rules. Finally, before publishing the EPD, the accordance of the data created through LCA method should be proved in a verification process [11]

Figure 1 Environmental Product Declaration Creation Phases

Product Category Rules: The product category rules that are used in the creation of the environmental product declarations should determine the life cycle phases to be included, variables to be covered and the necessary method. Also, for the product category the LCA should define the purpose and scope of the essential information and also the rules in order to produce the additional information related to the environment for the product category.
The product category rule created for each product should include:

- The description and explanation of the product category
- The purpose and scope description for product LCA
    - Functional unit
    - System Limit
    - Explanation related to the data
    - Criteria related to the inclusion of the inputs and outputs
    - Data quality requirements
    - Units

- Inventory analysis
    - Data collection
    - Calculation methods
    - Material and energy flow and the dispersion of the emissions
- Effect category choice and calculation rules
- Predetermined variables in order to report the LCA data
- Additional information related to environment
- Materials and matters to declare
- Content and format of the Type III environmental declaration
- Regulation in order to provide necessary data to develop the declaration
- Information related to LCA phases not included in the declaration
- Validity period [9].

The content of the environmental product declarations in TS 14025 [9] are,

- The title and description of the institution preparing the declaration
- The definition of the product and its description
- The name of the program, the address of the coordinator and if appropriate their logo and web site
- Product Category Rules definition
- The publication date and its validity period
- Data obtained from LCA and LCIA or the information modules
- Additional information related to the environment
- The content of the declaration which covers the materials and matters to be declared
- Information situating that the phases have not been taken under consideration when the declaration is not based on a LCA which covers all the life cycle
- Explanation situating that environmental declarations belonging to different programs might not be comparable
- Information situating where the descriptive documents can be obtained are explained in detail.

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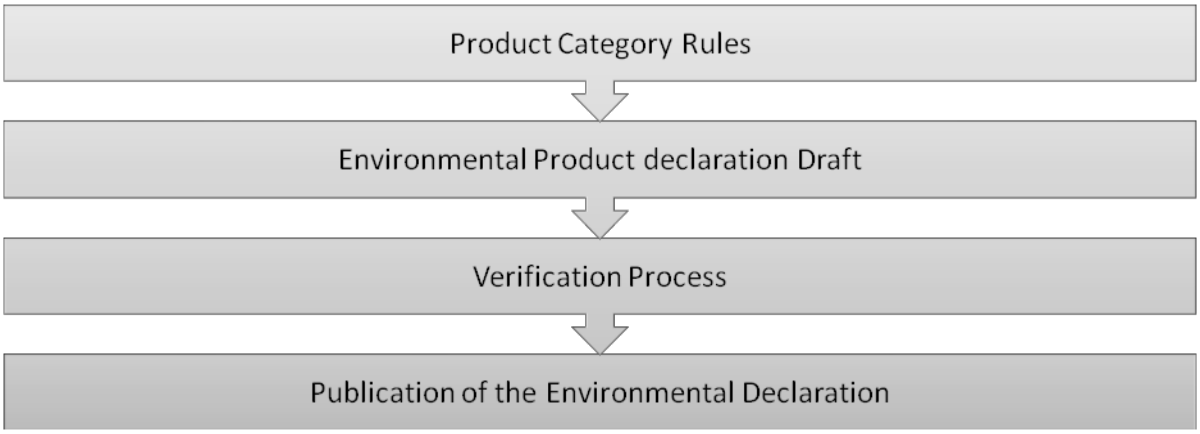

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- Explanation situating that environmental declarations belonging to different programs might not be comparable
- Information situating where the descriptive documents can be obtainedare explained in detail.

2.2. WORLDWIDE EXAMPLES OF THE TYPE III ENVIRONMENTAL LABELS

Today, there are lots of TYPE III EPD programs worldwide. In our study 27 programs are examined as examples of EPD programs. EPD programs are listed according to their foundation years.

The Table 1 that is listing the most important EPD programs around the world contains information such as Name, logo, Foundation Year, Country, PCD number, EPD number, program operator and web site.

As seen on the table the programs with most EPDs are the JEMAI program in Japan, the IBU-EPD program in Germany, The International EPD System from Sweden and PEP Eco-passport and ADEME from France.

According to the market demand the product category rules which form basis of the EPD preparation can be developed by any program. When programs are listed according to the product category rule number, Sweden Program The International EPD System, Taiwan program EDF (Environmental Development Foundation), German IBU-EPD program, Japanese JEMAI and Korean KEITI are within the leaders.

When they are listed according to their foundation year the first five programs are Int. EPD Prog., JEMAI, KEITI, EPD-NORGE and IBU-EPD.

Most EPD programs include building and building material categories. But DAPC from Spain, IBU-EPD from Germany and BRE from UK are mostly created especially for the certification of the building and building materials and/or building systems.

As they have more EPDs and PCRs, as they are older according to their foundation year and they are deep rooted and also to ensure that no language problems would rise during literature scanning in the comparison of the EPD programs in relation to a building product, German IBU-EPD, Sweden Int. EPD System ve Norway EPD-NORGE programs are selected.

Table 1 Worldwide Examples of EPD Programs [16, 17, 18, also are compiled from related website on 30.12.2015.]

NO	LOGO	PROGRAM NAME (SHORT)	PROGRAM NAME (ORIGINAL&ENGLISH)	WEB ADDRESS	FOUNDATION YEAR	COUNTRY	ORGANIZATION TYPE	MARKET POSITION	PCR NUMBER	EPD NUMBER
1		IES	The International EPD System	www.environdec.com	1999	SWEDEN	PUBLIC	INTERNATIONAL MARKET	200	476
2		JEMAI	Japanese Environmental Management Association of Industry	www.ecoleaf-jemai.jp	2002	JAPAN	SEMI-PUBLIC	NATIONAL	80	1250
3		KEITI	Korean Environmental Institute for Technology and Information	www.epd.or.kr	2002	KOREA	PUBLIC	NATIONAL	34	310
4		NEF	Næringslivets miljøstiftelse EPD NORGE (Norwegian EPD Foundation)	www.epd-norge.no	2002	NORWAY	PRIVATE	NATIONAL	18	234
5		IBU	Institut Bauen und Umwelt e.V. (Institute for Construction and Environment)	www.bau-umwelt.de	2004	GERMANY	PRIVATE	INTERNATIONAL MARKET	100	714
6		SCS	SCS Global Services	www.scscertified.com	2005	USA	PRIVATE	INTERNATIONAL MARKET	0	0
7		EAA	European Aliminium Association	http://www.european-aluminium.eu	2005	EUROPEAN UNION	PRIVATE	INTERNATIONAL MARKET	1	0
8		FDES	Fiches de Déclaration Environnementale et Sanitaire (Environmental and Health Declaration Sheets) +AFNOR French Standard	www.inies.fr	2006	FRANCE	SEMI-PUBLIC	NATIONAL	1	248
9		PE	Plastics Europe	www.plasticseurope.org	2006	EUROPEAN UNION	PRIVATE	INTERNATIONAL MARKET	1	12
10		EDF	Environmental Development Foundation	www.edf.org.tw	2006	TAIWAN	PRIVATE	NATIONAL	173	0
11		MVD	Danks Standard (Danish Standard)	www.mvd.dk	2006	DENMARK	SEMI-PUBLIC	INTERNATIONAL MARKET	5	0
12		PEP	PEP Ecopassport	www.pep-ecopassport.org	2007	FRANCE-EUROPEAN UNION	PRIVATE	INTERNATIONAL MARKET	1	407
13		BRE	BRE Global	www.greenbooklive.com	2008	UNITED KINGDOM	PRIVATE	INTERNATIONAL MARKET	1	80
14		DAPc	Sistema Declaraciones Ambientales de Productos por la construcción (EPD System for the Construction Sector)	www.csostenible.net/index.php/es/sistema_dapc	2008	SPAIN	SEMI-PUBLIC	INTERNATIONAL MARKET	3	21
15		BAU-EPD	Bau EPD GmbH	www.bau-epd.at	2009	AUSTRIA	PRIVATE	INTERNATIONAL MARKET	11	5
16		CLF	Carbon Leadership Forum	www.carbonleadershipforum.org	2009	USA	PRIVATE	INTERNATIONAL MARKET	1	0
17		ecospec	Ecospecifier	www.GlobalGreenTag.com	2010	AUSTRALIA	PRIVATE	INTERNATIONAL MARKET	10	39
18		ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie (French Environmental and Energy Agency) + AFNOR French Standard	www.ademe.fr	2011	FRANCE	PUBLIC	NATIONAL	19	347
19		Ift	ift Rosenheim	www.ift-rosenheim.de	2011	DE	PRIVATE	INTERNATIONAL MARKET	11	111
20		TGS	The Green Standard	www.thegreenstandard.org	2011	USA	PRIVATE	INTERNATIONAL MARKET	2	5
21		FP	FP Innovations	www.forintek.ca	2011	CA	SEMI-PUBLIC	INTERNATIONAL MARKET	1	2
22		NSF	NSF International	www.nsf.org	2011	USA	PRIVATE	INTERNATIONAL MARKET	3	0
23		CEPI	Confederation of European Paper Industries	www.paperpfcr.eu	2011	BELGIUM/EUROPEAN UNION	SEMI-PUBLIC	INTERNATIONAL MARKET	1	0
24		UL	UL Environment	www.ul.com	2012	USA	PRIVATE	INTERNATIONAL MARKET	2	59
25		ICC-ES	ICC Evaluation Services	www.icc-es.org/ep	2012	USA	PRIVATE	INTERNATIONAL MARKET	1	9
26		ASTM	ASTM International	www.astm.org/EPDs.htm	2013	USA	PRIVATE	INTERNATIONAL MARKET	9	14
27		NRMCA	National Ready Mixed Concrete Association	www.nmrca.org/sustainability/EPDProgram/	2013	USA	PRIVATE	INTERNATIONAL MARKET	0	1

3. COMPARISON OF THE EPD PROGRAMS IN RELATION TO A BUILDING PRODUCT

In this section, from the Type III environmental label programs,

- The International EPD System (Sweden)
- IBU(Institute Bauen und Umwelt)-EPD (Germany)
- EPD-NORGE (Norway)

which contain the most product category rule and environmental product declaration in relation to the building products will be examined.

The International EPD System

"The International EPD System" is founded in Sweden in 1999. The program operator is EPD Consortium and it is a state institute. The program which is used by Belgium, Greece, Italy, Netherlands, Sweden, Taiwan and United Kingdom, the product category rule number is 2000 and the environmental product information number is 476.

Table 2 "The international EPD System program's PCR and EPD numbers" are compiled from www.environdec.com website on 18.06.2015.

PRODUCT CATEGORIES	PCR NUMBER	EPD NUMBER
Food and Agriculture Products	36	131
Building Products	22	142
Structure and Substructure	6	9
Electricity	9	15
Furniture	7	27
Textile and Leather Products	12	7
Machinery and Equipment	20	46
Transportation Vehicles and Equipment	6	15
Basic Metal and Minerals	3	0
Glass and Plastic Products	7	0
Wood and Paper Products	14	48
Fuel and Chemical Products	12	19
Metal Products	12	9
Services	34	8
TOTAL	**200 PCR**	**476 EPD**

As seen on table 2, the Swedish program has lots of category other than the building products. But as the building products are not detailed under a building products main title, it is difficult to find the EPD belonging to the searched building product. The data situated on Table 2 are from 2015. In the examination realized on 02.06.2016 it is seen that the PCR number for building products title has decreased from 22 to 20 and that the EPDs are increased from 142 to 251.

IBU-EPD (Institut Bauen und Umwelt)

"IBU-EPD" is founded in Germany in 2004. The program operator is Building and Environment Institute and is a non profit organization. It is used in Germany, Switzerland, Austria and Turkey. It contains 100 product category rule and 714 environmental product declarations.

Table 3 "The IBU EPD program's PCR and EPD numbers" are compiled from www.bau-umwelt.de website on 18.06.2015.

PRODUCT CATEGORIES		PCR	EPD
Basic Materials and Precursors		7	22
	Aggregates	2	1
	Cement, Building Limes	1	9
	Other Basic Materials and Precursors	2	5
	Products Related to Concrete Groud and Plastering	2	7
Building Products		83	671
	Engineering Products	1	0
	Adhesives	3	255
	Products related to doors and windows	5	35
	Facades	11	3
	Fire Protection	1	0
	Structure Connectors	2	6
	Glass Products	1	1
	Floor Coverings	1	98
	Plaster Products	1	10
	Indoor Tools	5	6
	Indoor and Outdoor Wall/Ceiling finishing	7	12
	Wall and related products	4	65
	Membranes	4	35
	Metal Products	8	23
	Concrete Products	5	11
	Plastic Products	1	0
	Roof coatings	9	16
	Room Partition Systems	1	0
	Structural Wood Products	2	7
	Tiling systems	1	2
	Heat Insulation Products	7	49
	Wood Based Panels	3	34
Building and Service Engineering		10	21
	Fire Protection and Suppression Products	1	0
	Equipment to Produce Electricity	1	0
	Laboratory Equipment	3	0
	Artificial Lighting Products	1	15
	Sanitary Installation	3	6
	Ventilation and Air Conditioning Technologies	1	0
TOTAL		**100 PCR**	**714 EPD**

As seen in Table 3 German IBU-EPD program is formed only from building and building product categories. But when the classification is examined it is seen that some classes are overlapping. The classification contains groups according to building elements (wall, roof slab products) and also groups according to building material (glass, metal, concrete and plastic). That is one of the week qualities of IBU-EPD. The data situated on Table 3 are from 2015. In the examination realized on 02.06.2016 it is seen that the PCR number for building products title has decreased from 83 to 78 and that the EPDs are increased from 671 to 1398.

EPD-NORGE

"EPD-NORGE" is founded in Norway in 1999. The program operator is Norway EPD Foundation and it is a state organization. The program which is used in Norway has 18 product category rule and 234 environmental product declaration.

Table 4 "The EPD-NORGE program's PCR and EPD numbers" are compiled from www.epd-norge.com website on 18.06.2015.

PRODUCT CATEGORIES		PCR	EPD
Building Products		A TOTAL OF 18 PRODUCT CATEGORY RULE	202
	Concrete Products		50
	Concrete		10
	Building Raw Materials		0
	Building Panels		32
	Doors and Windows		12
	Solid Wood		17
	Insulation Materials		12
	Chemical/Technical Building Products		2
	Steel Building Products		26
	Cement		14
	Roof and Water Insulation Materials		17
	Asphalt		1
	Plaster and Dry Plaster		7
	Natural Stone Products		2
Furniture			24
Electricity			2
Chemical			6
TOTAL		**18 PCR**	**234 EPD**

As seen on table 4, the EPD-NORGE program has other categories other than the building products. Also it is observed that the building product groups are missing and also have a week classification. The data situated on Table 4 are from 2015. In the examination realized in 2016, it is seen that the EPD number in building products increased from 234 to 269 and that there is no change in PCR number.

When EPD programs situated in Germany, Sweden and Norway are examined, it is understood that especially the program in Germany (IBU-EPD) is a program specific to building products. Also, by looking at their EPD number in a year, we can say that IBU-EPD program and The Int. EPD System programs are widely preferred. It is observed that PCR numbers are increased in all programs. But, when the increased EPD number is observed, it is possible to say that generally the same groups are requesting the EPD.

In order to make comparison between the programs, a building product that is evaluated in each program is researched. As stone wool heals insulation material have PCR and EPDs in each program, the comparison is realized in regards of this product. In the literature research it is situated that EPDs should include:

- The description of the product and the manufacturer
- The environmental performance
- Information form the related organization and certificationinstitutions.

Table 5 The comparison of the EPD programs in relation to stone wool building material (are compiled from related website on 30.12.2015.)

		THE INTERNATIONAL EPD SYSTEM	**EPD NORGE**	**IBU EPD**
Logo				
The name of the program, the address of the coordinator and if appropriate their logo and web site		International EPD System , SWEDEN http://www.environdec.com/	Norway EPD Foundation, Oslo, NORWAY www.epd-norge.no	Building and Environment Institue, GERMANY www.baumwelt.de
The title and description of the institution preparing the declaration		The evaluation of the life cycle and Center for Sustainable Design (CADIS) MEXICO, www.centroacv.mx	PE International, GERMANY, www.pe-international.com	PE International, GERMANY www.pe-international.com/ ULG BELÇİKA www.ulg..be
Product Category Rules definition		Multiple un cpc codes, insulating materials 2014:13	CEN Standard EN 15804, NPCR 12 rev1	Mineral İnsulating materials, 07-12
The publication date and its validity period		- / 3 years ??	15.09.2014 / 15.09.2019	08.05.2014 / 07.05.2019
The definition of the product and its description		Stone wool thermal acoustic insulation plate is consisted of mineral fibers connected with thermoset resin. It can be manufactured in 61cm/51mm-152mm/122cm dimension Its density is 38,5 kg/m3 It has 60 years of service life.	Stone wool is consisted of volcanic rocks and recycled materials formed generally from basalt and dolomite. It is a building product used in heat insulation. At least its 96% is consisted of mineral wool and the rest is consisted of connector. Its approximate density is 93 kg/m3. It has 50 years of service life.	It is a stone wool heat insulation material which can be found as a plate or as a roll. Its density is consisted of material changing between 25 - 160 kg/m3 and stone wool with 98% thermoset resin connector. It is consisted of volcanic rocks and recycled briquette materials formed generally from basalt and dolomite.
Functional Unit		**1 m2 product**	**1 m2 product**	**1 m3 product**
Life Cycle Effect Evaluation Results (Manufacturing Process)	Global warming Potential	6,5961 kgCO2 eq	4,20 kgCO2 eq	76 kgCO2 eq
	The thinning of the Ozone Layer	0.0000 kg CFC-11 eq	3.48 kg CFC-11 eq	5.38 kg CFC-11 eq
	Acidization (water and soil)	0.0455 kg SO2 eq	1.83 kg CFC-11 eq	2.68 kg CFC-11 eq
	Eutrophication	0,0070 kg PO4 eq	1,83 kg PO4 eq	1,66 kg PO4 eq
	Photochemical oxidants	0,0032 kg C2H4	2,39 kg C2H4	2,48 kg Ethen
	The decrease in fossile resources	0,0685 kg Sb eq	3,93 kg Sb eq	882 MJ

Also in the content of the Environmental Product Declarations of TS 14025;

- The title and description of the institution preparing the declaration
- The definition of the product and its description
- The name of the program, the address of the coordinator and if appropriate their logo and web site
- Product Category Rules definition
- The publication date and its validity period
- Data obtained from LCA and LCEA or the information modules
- Additional information related to the environment
- The content of the declaration which covers the materials and matters to be declared
- Information situating that the phases have not been taken under consideration when the declaration is not based on a LCA which covers all the life cycle

phases, should be included. In the chart in which EDP programs are compared especially these information are situated.

In Table 5, "The International EPD System", "IBU-EPD" and "EPD-NORGE" are compared in relation to stone wool heal insulation material. Following the information related to the programs and the evaluated product, the life cycle effect evaluation results during manufacturing process are shared. As seen in table 5, in order to compare the functional units have to be equal For that reason "IBU EPD" results can not be compared to other products. Also it is seen that Swedish program The Int. EPD System's effect evaluation result of the evaluated product is less than the one from Norway's EPD-NORGE program. As a result when the functional unit is the same, these declarations that help comparing the environmental effect of the products, make it easier for the decision makers to choose.

4. RESULTS AND CONCLUSION

The environmental product declarations that inform the environmental effects of the product or services during their life cycle help the decision makers to make comparison between the products. These Type III class labels that promote the demand and supply of the product and services that has a verified less impact on the environment, also realized continuous environmental improvement directed by the market. There are lots of EPD programs around the world. In this study specific programs are choosen as,

- The International EPD System
- IBU-EPD
- EPD-NORGE

which have more declarations in relation to building products.

As a common product that is evaluated in all programs, stone wool building material is chosen. In order to compare functional unit should be the same. For that reason the product of IBU-EPD program cannot be compared with the other programs. When the environmental effects of the other programs' products are compared it is seen that The Int. EPD System product has less environmental effect than EPD-NORGE's product. Therefore especially when the functional unit is the same, it would be easier to compare the products in relation with their environmental effects.

Environmental product declarations are programs with third party approval that realize evaluations based on multiple variables according to the life cycle approach. The fact that they contain quantitative data in order to allow comparison between the products having the same function, provide them to be a communication oriented environmental label.

As a result, together with Environmental Product Declarations, **designers and users** have the possibility to obtain accessible and verifiable information related to products and environment and to realize comparisons during product selection. The **manufacturer** companies, have the possibility to obtain transparent information in relation to each of their products. Therefore, the manufacturers work in order to manufacture products with high environmental performance, and new products can be developed. Also, the products with a environmental label will have easy international access possibility and with the preference of environmental label, success will be achieved in a product category which has an important place in **certification systems**. Also, it is possible to say that environmental product declarations will help the creation of a healthy artificial environment. Even though there are standards prepared by ISO in regards of EPDs, there are no places where EPDs and environmental labels are obligatory. The situated benefits of the EPDs will increase when they will be deemed obligatory by society.

REFERENCES

[1] TS EN ISO 14020, (2002). Çevre Etiketleri ve Beyanları – Genel Prensipler, TSE, Ankara.
[2] Agenda 21, (1992), United Nations Division for Sustainable Development, UNCED- Rio de Jenario.
[3] Jönsson, A., (2000) "Tools And Methods For Environmental Assessment Of Building Products -- Methodological Analysis Of Six Selected Approaches" Building and Environment, 35:223-238
[4] GEN (Global Ecolabelling Network), 2004. Information Paper: "Introduction to Ecolabelling" Japan.
[5] Tuna Taygun, G., Balanlı, A., (2007). "Yapı Ürünleri ve Çevre Etkileşimi – Çevre Etiketi" Eko Teknolojiler ve Ekolojik Yerleşimler, YTÜ Basım-Yayın Merkezi, İstanbul.
[6] TS EN ISO 14024, (2002). Çevre Etiketleri ve Beyanları – Tip I Çevre Etiketlemesi – Prensipler ve Yöntemler, TSE, Ankara.
[7] TS EN ISO 14021, (2006). Çevre Etiketleri ve Beyanlar – Çevre İle İlgili İddiaların Öz beyanı (Tip II Çevre Etiketleri), TSE, Ankara.
[8] Erol, P., (2011). "Yapı Malzemelerinde Çevre Etiketi" Ekoyapı, Mart-Nisan:58-66
[9] TS EN ISO 14025, (2008). Çevre Etiketleri ve Beyanları – Tip III Çevre Beyanları – Prensipler ve Prosedürler, TSE, Ankara.
[10] TS EN ISO 14040, (2007). Çevre Yönetimi – Hayat Boyu Değerlendirme – İlkeler ve Çerçeve, TSE, Ankara.
[11] Bovea M.D., Fores V.I., et all, (2014) "Environmental Product Declaration (EPD) labelling of construction and building materials" Eco-Efficient Construction and Building Materials, Woodhead Publishing 7:125-164
[12] Allison, C., Carter, A., (2000). "Study on Different Types of Environmental Labelling (ISO Type II and III Labels: Proposal for an Environmental Labelling Strategy)" Nisan 2013 tarihinde, http://ec.europa.eu/environment/ecolabel/about_ecolabel/reports/erm.pdf, adresinden alındı.
[13] Kaya, U., (2011). "Yapı Sektöründe ve BREEAM' de Çevre Etiketlerinin Kullanımı" Ekoyapı, Mart-Nisan:68-72
[14] TS EN ISO 14044, (2007). Çevre Yönetimi – Hayat Boyu Değerlendirme – Gerekler Kılavuz, TSE, Ankara.
[15] Tuna Taygun, G., (2005). "Yapı Ürünlerinin Yaşam döngüsü Değerlendirmesine Yönelik Bir Model Önerisi", Basılmamış Doktora Tezi, YTÜ, İstanbul.
[16] Borghi A.D., (2013) "LCA and communication: Environmental Product Declaration" International Journal of Life Cycle Assessment 18:293–295
[17] Hunsager E.A., Bach M., et all (2014) "An institutional analysis of EPD programs and a global PCR registry" International Journal of Life Cycle Assessment 19:786–795
[18] Passer A., Lasvaux S., et all (2015). "Environmental product declarations entering the building sector: critical reflections based on 5 to 10 years experience in different European countries" International Journal of Life Cycle Assessment 20:1199–1212
[19] www.environdec.com (The International EPD System official website for EPD & PCR search)
[20] www.bau-umwelt.de (IBU-EPD offical website for EPD & PCR search)
[21] www.epd-norge.com (EPD-NORGE offical website for EPD & PCR search)

Paper No: 50

Environmental Product Declaration Studies for Special Cements in Turkey Case Study: White Cement

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ABSTRACT

This paper states detailed studies on environmental product declaration (EPD) and its scope for white portland cement. EPD certificates are started to gain importance in 2013 when Europe Construction Product Regulations start to demand EPD's which are correlated to EN 15804. Green building certifications as LEED, BREEAM and DGNB give extra points for the materials which have EPD certificates. Product classification is applied consistent with raw material extraction, energy usage and yield, chemical components, emissions to air, water and soil and waste. Another feature of EPD is Life Cycle Assessment (LCA). LCA is based on ecological footprints of the economic activities and different kinds of emission measurement results. White portland cement is fundamental for the formulations of major industries in Turkey, such as Building Chemicals and Precast Industry. Çimsa is also first company that published the sustainability report in Turkish Cement Industry to combine the technical capabilities with the perspective of environmental friendly manufacture. For building chemicals, main usage area is joint fillers and tile adhesives. For precast, terrazzo tile and glass fiber reinforced concrete applications are main usage areas of white cement. Lastly, this study will help white cement users in their products' green building certification processes first time in Turkey._

Keywords: *White cement, portland cement, life-cycle assessment, environmental product declaration, carbon dioxide foot print, green building, ISO 14025, ISO 14040*

1. INTRODUCTION

In order to combine the technical capabilities with the perspective of environmental friendly manufacture. This study states the detailed workings on environmental product declaration (EPD) studies and its scope for the white portland cement. EPD certificates are started to gain importance in 2013 when Europe Construction Product Regulations start to demand EPD's which are correlated to EN 15804 and they are defined under the sustainability norms. Environmental Product Declaration is a certificate defined according to ISO 14025 and this certificate evaluates the environmental performance of a product or service, quantitively. Environmental process evaluation is done according to some predetermined categorical parameters which are defined in ISO 14040 serial.

Moreover; green building certifications as LEED, BREEAM and DGNB give extra points for the construction materials which have EPD certificates. This issue is under the trending topics of the Turkey. Product classification is applied consistent with raw material extraction, energy usage and yield, chemical components of the output, emissions to air, water and soil and left waste. Another significant feature of an EPD is the Life Cycle Assessment (LCA). LCA is based on the ecological footprints of the economic activities and different kinds of emission measurement results. LCA is done under two distinct headers as Cradle to Grave and Cradle to Gate. Cradle to grave method includes all the production, usage and re-cycling processes and the emissions originated from these steps. Cradle to gate method investigates the steps from raw material gathering to factory gate; the transportation, the usage and the end life emissions are not taken into account. The data that should be gathered for LCA studies are; raw material, bulk material, mixtures, energy consumption, water consumption, emissions (Dust, NO_x, CO_2, SO_2, TOC..) and waste material. As a consequence of LCA studies, investigating the environmental effects of the production line and the supply chain becomes possible and developing new polices for the possible environmental hazards becomes more effective. White cement is the fundamental ingredient for the formulations of many major industries in Turkey, such as Building Chemicals and Precast Industry. In building chemicals industry main usage area is the joint fillers and tile adhesives. In precast industry traditional terrazzo tile and Glass Fiber Reinforced Concrete applications are the main usage areas of white portland cement.

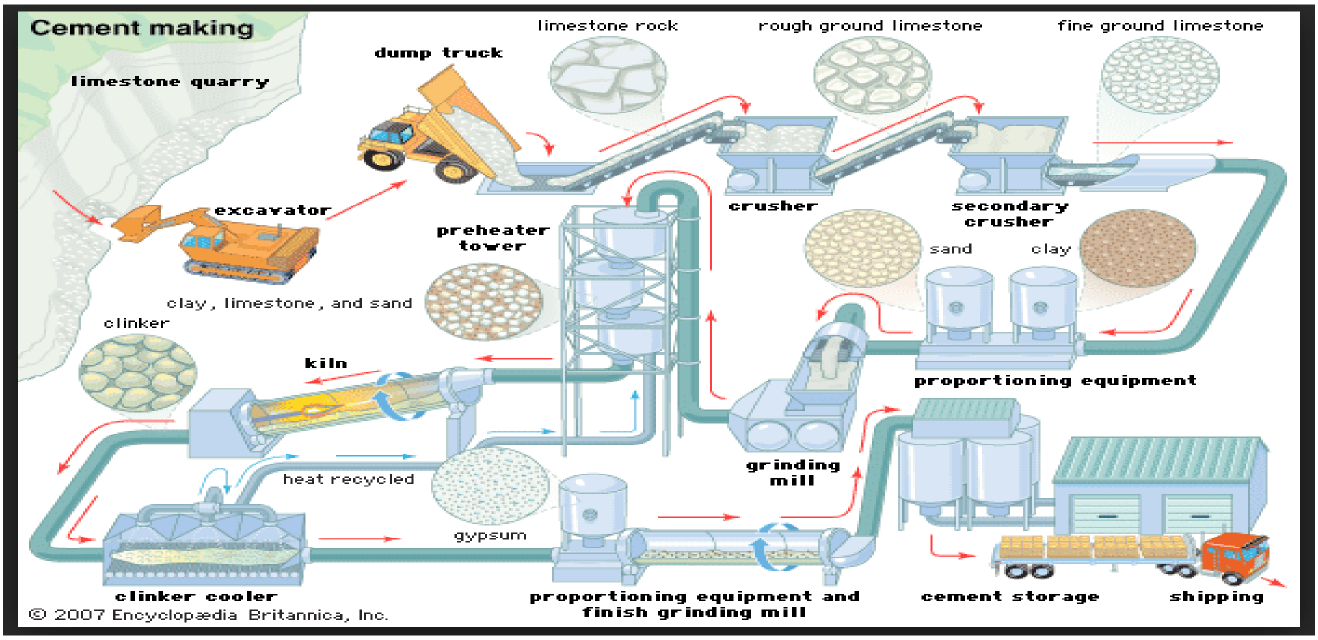

Figure 1.1. Process Flow of Cement Production [4]

2. PROCEDURE:

A road map should have fallowed in order to define the content of declaration studies. The work can be grouped under ten steps.

2.1.Scope of the EPD Studies

Section 0 – Description of the Product: The product is introduced to the system with its qualifications. This step start with the short product description, Application areas, product specifications, product qualification, certificates, standards, quality control mechanisms, quality management certification, geometrical data, physical properties (density, sound insulation, ex-proof properties, moisture balance, compressive and flexural strength, heat insulation and vapor diffusion etc.)

Section 1 – Chemical Composition of Raw Materials: Chemical composition of raw material by weight and the norms that are fallowed while choosing the composition of raw meal are described in this section. Also the source and availability of raw materials are also investigated.

Section 2 – The Production Method: Description of the production stages and the risk management system which analyses the all the stages in terms of environment, occupational health and safety. Also the precautions that the company took for these risks should be stated.

Section 3 – The Process: The preparation and handling of the product should be described in this section. The risks for these steps are specified in terms of environment, occupational health and safety. The ultimate waste materials originating from packing and producing are also defined.

Section 4 – Terms of Use: The indication of product content again and also the identification of health and environmental effects in usage should be stated. Also long-term durability of the material is indicated.

Section 5 –The Effect under Unexpected Accidents: The interactions and effects are stated when the unpredicted issues like fire, flood etc. occur.

Section 6 - Usage Period and After: The identification of recovery and re-cycling processes after usage of the materials is done. Also the disposal methods and alternative methods in order to manage the waste materials are defined.

Section 7- Life-Cycle Assessment: The detailed information is given in 2.2.

Section 8 – Evidence: Includes the documentation of analyzing a specific product in terms of radioactivity, leakage etc.

Section 9 – Product Classification Rules (PCR) – Investigation and Approval: IBU and technical committees evaluate the data.

Section 10 – References: The reference documents (technical reports, norms, databases, software) which are used are listed in this stage.

2.2. Life-Cycle Assessment (LCA) :

Life cycle assessments (LCAs) evaluate the environmental impacts of a product or a process. The use of LCA to understand the embodied energy, environmental impacts, and potential energy-savings of manufactured products has become more widespread among researchers in recent years. Most LCAs evaluate environmental impact over the entire life-cycle (from cradle to grave) of a product or process. The goal of this white cement life cycle assessment (LCA) is to develop accurate data on the inputs and emissions associated with cement production to the gate. These investigations will be used in turn to perform life cycle assessments (LCAs) of concrete products and competing construction materials. The data is available for incorporation into existing LCA models, which are designed to improve a production process and to compare alternative cement manufacture techniques. Cradle to grave assessments are complex. For cement, a cradle to grave assessment is especially difficult because cement has so many end uses, and each use has a unique, often complex life-cycle. Therefore, the assessments reviewed here are "cradle-to-gate" studies. These cradle-to-gate assessments evaluate impacts of producing cement from the raw material extraction process to the factory gate as it can be seen from Figure 2.1.Thus, the end use and disposal of cement are not included in these assessments. All life cycle assessments share the objective of evaluating the impacts that a product or process has on the environment and identifying the resources required to produce, use, and retire that product or process[1]. Despite this common goal, there are a multitude of diverse methodologies used to achieve this objective.

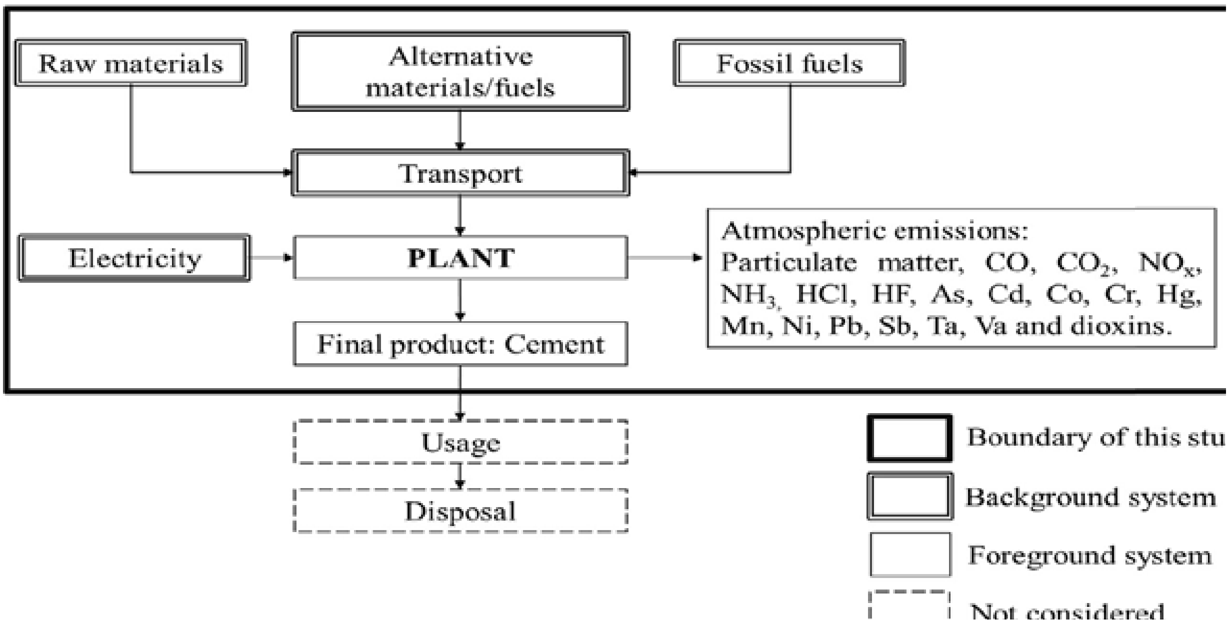

Figure 2.1. System Boundaries of LCA Study of White Portland Cement [3]

Huntzinger et al. performed a cradle to gate LCA of cement and compared traditional processes with alternative manufacturing processes. The LCA used the following methodology: [2]

1) The scope of the cement production process to be evaluated (the control boundaries) was determined.
2) The inventory of outputs and inputs were determined.
3) The environmental impact data is calculated with the help of literature.
4) The results were interpreted and suggestions were made for improvements.

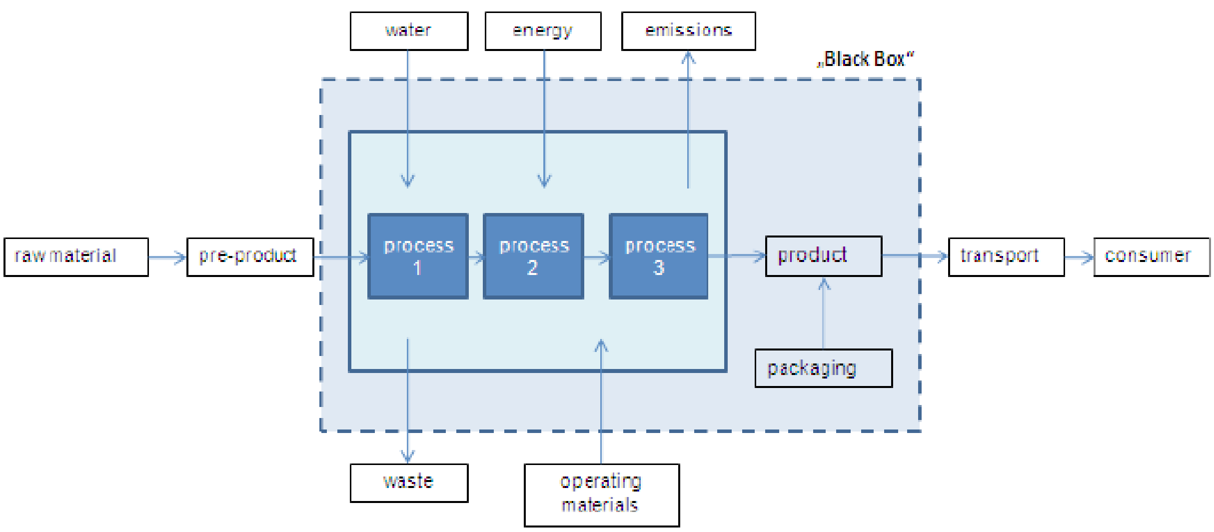

Figure 2.2. The Flow Diagram of the LCA Process

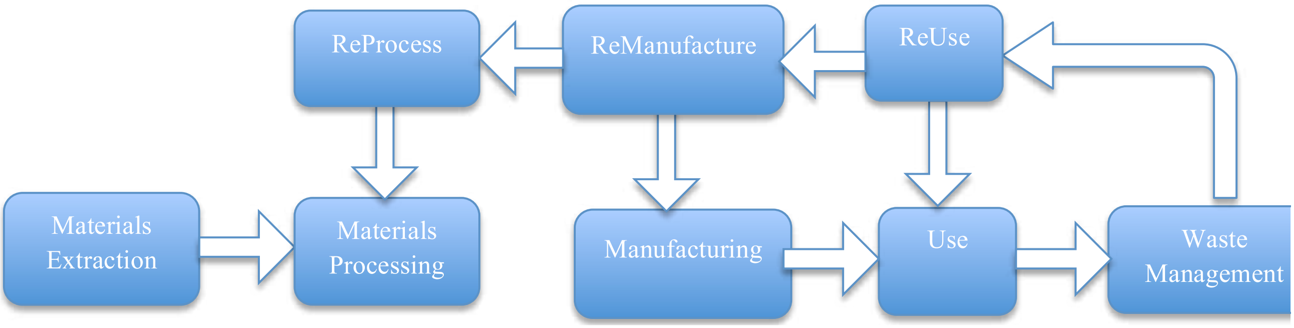

Figure 2.3. The Waste Management Strategy

Moving towards sustainable engineering solutions requires a better understanding of construction activities that affect nature. The LCA structure is a crucial measure necessary to evaluate environmental impact of a product or structure over its useful life. Conventional assessments often overlook one or more of these phases leading to incomplete and indefensible conclusions.

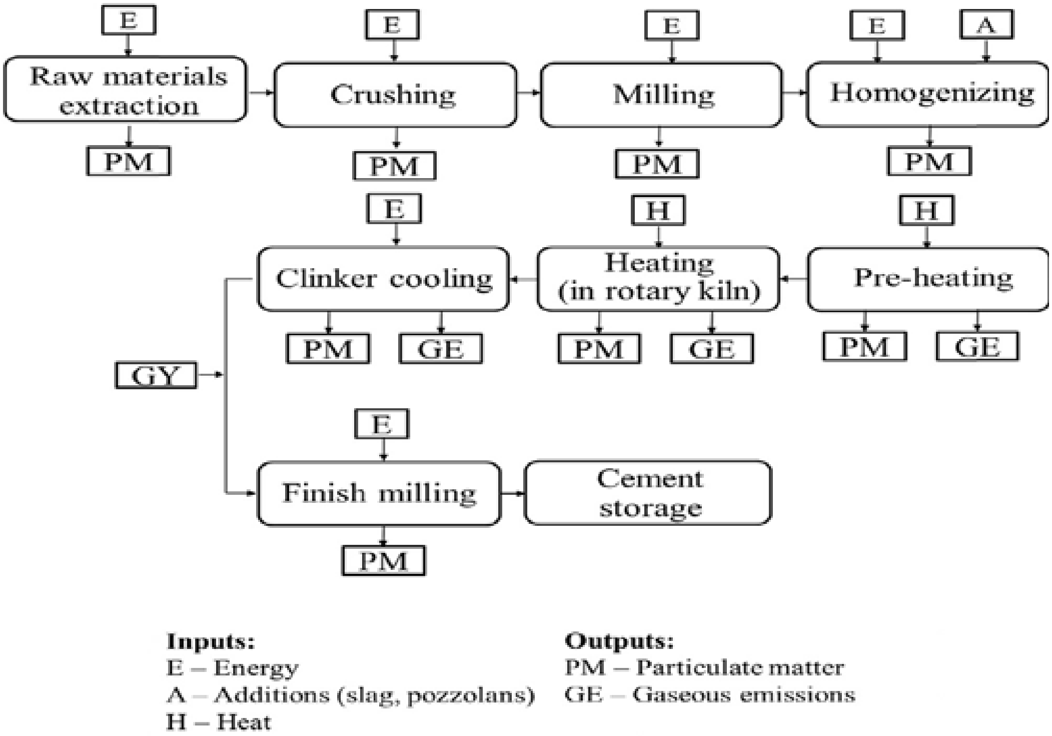

Figure 2.4.Process diagram and the environmental impact for the manufacture of cement [2]

3.Çimsa EPD Certificates:

Çimsa took EPD certificates for; Super White Portland (CEM I 52.5 R) Cement, ISIDAÇ 40 Calcium Aluminate Cement, REFRO 4O Calcium Aluminate Cement, RECIPRO 40 Calcium Aluminate Cement and RESISTO 40 Calcium Aluminate Cement. Thus, usage of these products brings in extra points for green building certification as LEED, BREEAM and DGNB.

3.1. The Validation Systems

- **IBU**

Institut Bauen und Umwelt e. V. (IBU), is a Germany oriented programme operator that decided to support sustainability movements in construction sector. The participants are mostly from construction material producer initiation.

- **The International EPD System**

The International EPD System is linked to IVL Swedish Environmental Research Institute which is a part of Sweden Ministry of Environment. They acknowledge EPD certifications which are valid in all over the world. This is the most comprehensive system in terms of sector variety and market availability in the world.

- **EPD Turkey**

EPD Turkey is managed by the 'Sustainable Production R&D and Design Center' in a similar manner as Italy, Australia, New Zealand and Czech Republic. EPD Turkey is based on The International EPD System and aimed to encourage the sustainable product usage for Turkish consumers and support them in the international markets.

- **ECO Platform**.

ECO Platform is a non-profit establishment that records the EPD Certificates of the products published by LCA experts and nongovernmental organizations. The purpose of ECO Platform is to develop building products that have Type III EPD certificates, especially.
Çimsa Super White (CEM I 52.5 R) and Calcium Aluminate Cement have dual registration for IBU and EPD Turkey

3.2. EPD Content and Calculation Methodology

EPD Certificates include;

- ✓ Firm information,
- ✓ Technical data of the product, relevant standards, application areas,
- ✓ Declaration content, LCA system boundaries,
- ✓ Outputs of LCA: Resource usage, environmental indicators and performance

EPD certification starts with the PCR. PCR (Product Category Rule) is a systematic approach to group the product under a defined category with respect to its specifications. LCA is done under the norms of ISO 14040/44 and PCR. SimaPro; LCA software is used to calculate the final results.
EN15804 adapted Çimsa Super White Cement's system boundaries are defined in Table 3.1. Buiding products should include raw material supply, transport and manufacturing phases in LCA.

Table 3.1. List of Production Stages in LCA Studies

Product Stage			**Construction Process Stage**		**Use Stage**							**End Of Life Stage**				**Benefits And Loads Beyond The System Boundaries**
Raw material supply	Transport	Manufacturing	Transport from the gate to the site	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse- Recovery- Recycling- potential
A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
X	X	X	MND	MND	MND	MND	MND	MN D	MND	MND	MND	MND	MND	MND	MND	MND

(X: Module assessed, MND: Module not declared)

LCA study defines the environmental indicators in defined boundaries and according to PCR calculating methods, these values are computed per unit product. Then the outcomes are grouped under the headlines of environmental impact, resource use and waste categories.

Table 3.2. List of Parameters Calculated in LCA Studies

Results Of The LCA - Environmental Impact	
Parameter	**Unit**
Global warming potential	[kg CO_2-Eq.]
Depletion potential of the stratospheric ozone layer	[kg CFC11-Eq.]
Acidification potential of land and water	[kg SO_2-Eq.]
Eutrophication potential	[kg $(PO_4)^{3-}$-Eq.]
Formation potential of tropospheric ozone photochemical oxidants	[kg ethene-Eq.]
Abiotic depletion potential for non-fossil resources	[kg Sb-Eq.]
Abiotic depletion potential for fossil resources	[MJ]

Results Of The LCA - Resource Use	
Parameter	**Unit**
Renewable primary energy as energy carrier	[MJ]
Renewable primary energy resources as material utilization	[MJ]
Total use of renewable primary energy resources	[MJ]
Non-renewable primary energy as energy carrier	[MJ]
Non-renewable primary energy as material utilization	[MJ]
Total use of non-renewable primary energy resources	[MJ]
Use of secondary material	[kg]
Use of renewable secondary fuels	[MJ]
Use of non-renewable secondary fuels	[MJ]
Use of net fresh water *	[m^3]

Results Of The Lca – Output Flows And Waste Categories:	
Parameter	**Unit**
Hazardous waste disposed**	[kg]
Non-hazardous waste disposed**	[kg]
Radioactive waste disposed	[kg]
Components for re-use	[kg]
Materials for recycling	[kg]
Materials for energy recovery	[kg]
Exported electrical energy	[MJ]
Exported thermal energy	[MJ]

3.3. Software (SimaPro) Usage: SimaPro is software that developed by Holland oriented Pré Consultants firm. Transparency and flexibility are the main reasons for being the most preferred LCA software in worldwide. It is used for LCA studies in over 80 countries. The international companies like Unilever, Heineken and BASF, lots of local establishments, research centers, universities and consultant firms calculate environmental impacts, carbon and water foot print with this software. SimaPro uses Eco invent database and, compatible with ISO 14044-4, PAS2050 and GHG protocols.

4. CONCLUSION

For the white portland cement, produced by Mersin Çimsa factory, this study states the numerical values of global warming potential [1.07E+3 kg CO -Eq], depletion potential of the stratospheric ozone layer [2.24E-5 kg CFC11-Eq.], acidification potential of land and water [1.00E+0 kg SO2-Eq.], eutrophication potential [6.29E-1 kg (PO4)3--Eq.], formation potential of tropospheric ozone photochemical oxidants [4.31E-2 kg ethene-Eq.], abiotic depletion potential for non-fossil resources [1.30E-4 kg Sb-Eq.], abiotic depletion potential for fossil resources [3.07E+3 MJ] renewable primary energy as energy carrier [4.33E+2 MJ], total use of renewable primary energy resources [4.33E+2 MJ], non-renewable primary energy as energy carrier [3.07E+3 MJ], total use of non-renewable primary energy resources [3.07E+3 MJ], use of net fresh water [9.41E-1 m^3], hazardous waste disposed [4.94E-3 kg], non-hazardous waste disposed [6.86E-2 kg]. All in all, compared to other white cement manufacturers the outcome includes relatively low values [5]. The content of the declaration study is renewed every five year to see the progress in the production stages in terms of carbon footprint of the process. Also, it gives the opportunity to declare the improvements for global warming potential whenever the process is directed to a greener way of production. Furthermore, the consumers of the products with EPD certificates have the advantage of declaring the origin of their raw materials and apply it for the constructions that aim to be evaluated under green building norms. This is a good opportunity for tile, precast, any kind of building chemicals and glass reinforced concrete sectors. Understanding the impacts of cement at each stage in its life-cycle is important for putting the future production of cement products into a global perspective. This cradle to gate study will help to provide such an understanding, and may be useful in determining new mechanisms to decrease the environmental impacts of producing cement.

5. REFERENCES

[1] "Environmental Management - Life Cycle Assessment - Principles and Framework," ANSI/ISO 14041, International Organization for Standardization, Geneva, Switzerland, 1997.

[2] Huntzinger, Deborah N., and Eatmon, Thomas D., "A life-cycle assessment of Portland cement manufacturing: comparing the traditional process with alternative technologies" Journal of Cleaner Productions 17 (2009) 668-675

[3] F.N. Stafford 162 et al. / Journal of Cleaner Production 126 (2016) 159-165

[4] Adapted from http://civildigital.com/cement-manufacturing-process-simplified-flow-chart

[5] Çimsa Super White Portland Cement (52,5R) Environmental Product Declaration Certificate

Paper No: 61

Life Cycle Assessment of Glass Fiber Reinforced Concrete (Gfrc) Steel Framed Facade Panels

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ABSTRACT

The activities in construction industry, which is the most polluting and most resource -consuming sector, contribute to climate change. Buildings cause as much as one third of total global greenhouse gas emissions, primarily through the use of fossil fuels during their operational phase. The research was conducted using life-cycle assessment methodology, which is a scientific and systematic environmental management tool that indicates the environmental performance of the construction product of Glass Fiber Reinforced Concrete (GFRC) Steel Framed Façade Panel that is produced by Fibrobeton firm in Duzce. The purpose of this study is to establish GFRC steel frame façade panel's life cycle assessment. Life-cycle assessment results were presented by impact category 2002+ methods. The system boundaries were selected as cradleto gate. Acquisition of raw material, transport, and energy demands are assessed by LCA methodology in the phases of production. Results of the case study demonstrated that they had the highest level of effect on the midpoint modelling, respitory inorganic, global warming and non-renewable energy. At the end point modelling shows that GFRC panel effects human health by the mean of environmental emission.

Keywords: Life cycle assessment (LCA), Glass fiber reinforced concrete (GFRC) façade panel, sustainability building material

INTRODUCTION

Buildings play an important role in energy consumption all over the world. The building construction sector has a significant influence on the cons umption of total natural resource and on the emissions that are released. Buildings are responsible for more than 40 percent of global energy use and one third of global greenhouse gas emissions both in developed and developing countries [1]. Most countries had to decrease their emission of greenhouse gases and their energy consumption by the requirement of legislation, and universal protocols (e.g. Kyoto protocol) [2]. As the construction industry has become increasingly interested in sustainable development, more comprehensive methods are being developed to evaluate and reduce environmental impacts of buildings. Therefore, some kinds of investigation methods are developed by experts. One of them is life cycle assessment (LCA) method, which is based on the assessment of input and output of natural resources and emissions. Life Cycle Assessment (LCA) is emerging as one of the most functional assessment tools, which is accepted by green building certificate systems throughout the world[3].According to International Standard ISO 14040 series, LCA is the "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" [4].Another description of LCAmethod is tracking and reporting the environmental impact as a product or process through its life span[5].

The aim of this study is to determine life cycle impacts of glass fiber reinforced concrete(GFRC) façade panel's. Moreover, the analysis helps one to understand the effects on different impact and damage categories of the GFRC façade panel's life cycle stages. The

GFRC is a composite which consists of high strength fiber embedded in a cementitious matrix. Glass fiber serves as tensile-load carrying; concrete matrix serves as a binder that keeps the fiber together, and transfers loads from fibers to concrete[6]. Moreover, GFRC offers various options to the architect and decision maker for a wide variety of shapes, forms, textures, colours, finishes, and architectural styles [7].

LITERATURE REVIEW

American Institute of Architect (AIA) Guide to building life cycle assessment in Practice **[3]** this publication is a guide for an architect for decision making for building material, construction, use, and end of life phases**[7].**

Goldin et al. (2009) comparesGFRC with fiber reinforced polymer materials as facade covering. They stated that production stage involves the same moulding process, so they don't take care of this process and highlighted the importance for transportation to determine the level of the choosing effect for the local manufacturer**[8].**

Ölmez (2011)'s master's thesis, "Comparison of sub-processes and final products of iron and steel production with life cycle assessment",is of a lot importance for Turkey in that**,** whole life cycle assessment is done for steel products and co-products**[9].**

Gursel (**2014), in her doctoral dissertation called** "Life-cycle assessment of concrete: decision-support tool and case study application", investigates the concrete life cycle assessment in the case of Turkey. She developed a tool for concrete life cycle assessment to find global warming potential factor replacement of Ordinary Portland Cement with supplementary cementitious materials **[10].**

METHODOLOGY

LCA is a tool that allows architects and other building professionals to figure out the energy use and other environmental impacts associated with all life cycle phases of the building: procurement, construction, operation, and decommissioning.

In this study, LCA method was chosen for sustainability assessment, and functional unit was chosen for 1 m^2 steel framed facade panel. The system boundary was chosen as cradle to gate.

MATERIALS AND METHODS

Goal of the study:

The goal of the study is to determine life cycle environmental impacts of steel framed facade panel covering over a 1 m^2 area on a building façade.

Scope of the study: functional unit and system boundaries

The functional unit was defined as the "coverage of one square meter of GFRC steel framed façade panel, for a duration of 60 years in Turkey", aiming to protect a building facade from weather events and to assure thermal insulation. Fibrobeton is a concrete product reinforced with alkali resistant glass fiber produced at a thickness of 10-15 mm. Due to its easy moulding and easily pourable characteristic into any kind of mould, it is a good decorative material as well as being a long - life and high resistant facade cladding material reinforced with a steel frame to form a panel at requested geometrical shape and at demanded dimensions **[11].**

GFRC steel framed façade panel's mechanical properties are as follows: Compressive strength (fc) 50-80 N/mm^2, tensile strength (fct) 5-10 N/mm^2, thermal conductivity coefficient (λ) 0,8-1,2 W/mK for 10-15 mm Fibrobeton GFRC steel framed façade panel**[11].**

The boundaries for façade panel system were defined as the extraction and processing of raw materials in order to form the panel assembly. (Cradle to gate LCA) GFRC steel framed facade panel boundaries are demonstrated in **Figure 1**. Three processes were included in the manufacturing of glass fiber reinforced concrete steel framed panel, which are the preparation of the concrete, moulding, spraying concrete mixture to the mould, waiting for curing and montaging steel frame.

Fibrobeton factory produces different forms and kinds of glass fiber reinforced concrete (GFRC) panels which are generally used at façade cladding. GFRC Concrete façade panel's life cycle assessment to cradle to gate was shown below**(Figure. 1).**

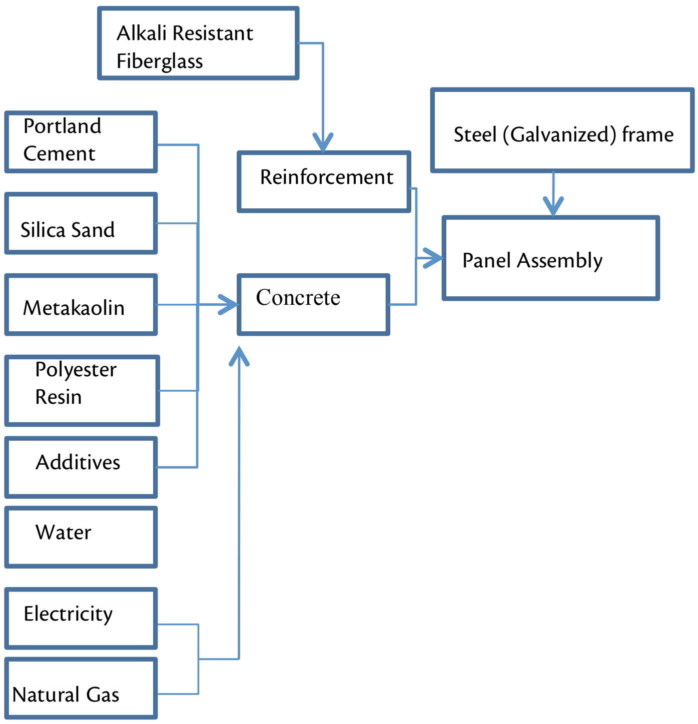

Figure 1 GFRC Steel Framed Façade Panel Flow Chart (cradle to gate) [11]

Materials:

Glass fiber is an alkali-resistant continuous filament fiber developed and formulated to have high strength retention in hydraulic cement environments. Alkali-resistant AR-GFRC is the most widely used system for the manufacture of GFRC products**[12]**.Glass fiber is shipped to İstanbul by ship (8000 km) and by truck to Duzce (250 km).

Fine aggregates: Fine aggregate or sand should be washed and dried in order for removing soluble matter and permitting accurate control of the water/cement ratio. The particle shape should be round or irregular, and should have a smooth surface without honeycombing. In this case, silica sand was used as fine aggregate. (170 km by truck)

Water should be clean and free from deleterious matter, mixing water for concrete. In this case, water was extracted from water wells nearby the factory.

Normal Portland Cement must be used in steel framed facade panel. In parallel to this, Fibrobeton Factory uses Çimsa Eco White- Portland Calcareous Cement material which is obtained from Mersin by ships (İstanbul to Mersin, 1000 km) and trucks (İstanbul to Duzce, 250 km). This cement contains Portland Cement, limestone, and gypsum in deferent ratios. White limestone cement is used as a hydraulic binder for the production of concrete, mortars and grouts. With the highest whiteness level it has, in precast applications, it increases process ability time by its long setting time**[13]**When white limestone cement reacts with water, for instance when making concrete or mortar, or when the White Limestone Cement becomes damp, a strong alkaline solution is produced. Environmental knowledge about Çimsa Eco White- Portland Calcareous Cement material is obtained from Metsims Sustainability Consulting Firm by the Çimsa Firm's permission**[14].**

Metakoalin; high reactivity metakaolin is a manufactured pozzolanic mineral admixture, which significantly enhances many performance characteristics of cement-based mortars, concretes and related products. Derived from purified kaolin clay, which is a white, amorphous, alumina-silicate and it reacts aggressively with calcium hydroxide, a normal cement hydration by product, to form compounds with cementitious value. Metakaolin is a pozzolanic material which is obtained by calcination of kaolinitic clay at temperatures from 700°C to 800°C. In this study, it is assumed that for 1 kg metakaolin, using 1.16 kg pure kaolin and adding gas heating of 2.5 MJ/kg are needed. **[15]**Metakaolin is shipped by lorry from 250 km distance by trucks.

Admixtures are permitted and their use is encouraged as they can enhance the properties of GFRC.

Table 1Materials for GFRC steel framed panel [11]

Materials	**1 m^2 Precast Facade GFRC panel (shell)**
White Portland cement	13-16 kg
Silica Sand	14-19 kg
Metakoalin	0,5-2,5 kg
Additives	1-3 kg
Glass Fiber	1-3 kg
Water	4-7 kg

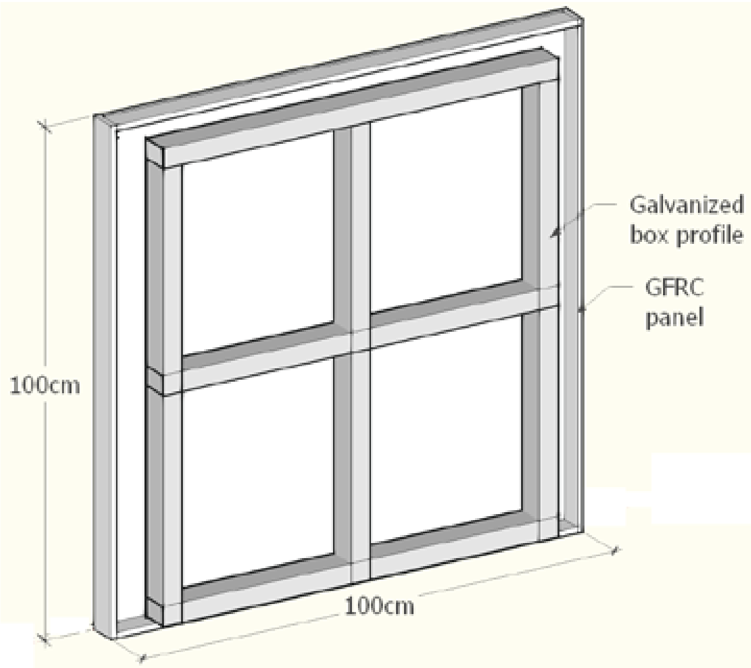

Figure 2. Presentation of GFRC panel with steel frame.

Admixture Super plasticizer (high range water reducing admixture) is a material, which permits a high reduction in the water content of a given mixture without affecting the consistence, or which increases the slump/flow considerably without affecting the water content; or produces both effects simultaneously **[16]**. What is more, creating a strong and lasting bond ensures adherence and elasticity. Its chemical and preventive nature of sudden drying cracks helps to obtain resistance to mechanical attack. Also, it increases the resistance to the freezing and thawing cycle while ensuring water tightness. The biggest effect is increasing the machinability**[17].** Superplasticizer admixture is shipped by lorry from 185 km distance.

A mould must be prepared for giving form to concrete. Moulding types of precast facade panels are: medium density fiberboard (MDF), steel, polyester, styrofoam, rubber these moulding types are selected to reuse a number of the mould which is needed. In this study, it is assumed that MDF mould is used for 1 m^2 façade panel with respect to the other moulding types are generally used for difficult curved forms. MDF mould is calculated by the drawing of the moulding. Wood varnish is used for better surface quality and increase the number of reuse of mould**[18]**.Varnished MDF mould could be used for ten times. MDF is obtained from 273 km distance, by trucks.

Concrete mortar is prepared with glass fiber, cement, metakoalin, admixture, silica sand, and water by mixing machine. This mortar is applied to mould by hand spraying. Direct spray-up method requires experienced workers, expensive equipment, and rigorous quality control. After the mortar spray- up to mould, it must wait for curing for getting enough strength.

The GFRC steel framed facade panel for 1 m^2 is thickness is 10-15 mm and the weight is 35 kg and 4,5 kg of galvanized steel (hot-dip galvanized) must be added**[11].**

Life cycle Inventory data quality and data collection

The study was carried out between 2013-2016 years. Primary data on average GFRC steel framed facade panel production were collected and provided by Fibrobeton. Missing, incomplete or non-accessible data were completed from secondary data, extracted from Ecoinventdataset, an international life cycle database on industrial data, public available databases, literature review and expert judgment.

Road transportation data were obtained from Ecoinvent data and all the trucks were assumed that they were euro diesel 4. The average long distances were taken from the maps on Internet.

The Turkish electricity grid mix used on the calculations is presented on **Table 2**. The ratios of energy were taken from Republic of Turkey Ministry of Energy and Natural Resources. This datum was used specifically for all foreground processes. For background processes, an adapted version of the Ecoinvent database was used.

Table 2Electric mix for Turkey[17]

Primary Energy	**%**
Coal	20
Hydropower	35,3
Natural gas	28,5
Lignite	1,5
Geothermal	1,4
Wind power	6,2

METHOD APPLIED:

SimaPro 8.0 (Pre-consultant, 2015) with ecoinvent 3.0 was used as the tool to conduct the assessment. A number of the aforementioned raw materials and processes were not found directly in the SimaPro database, and therefore surrogates were used, as described below: Metakoalin, a typical filler material for pigments and concrete, was not found in SimaPro.

The alkali resistant glass (AR glass) was used in the GFRC and modeled using the fiberglass material available in the SimaPro database.

Kaolin was found in ecoinvent database and heating energy was added**[13].**Other materials were gained from production managers from Fibrobeton Firm.Additives were not found in ecoinvent database so the major material in it was chosen.

Generally precast GFRC elements are manufactured by hand spraying the GFRC into a mould. With the direct spray-up method, a concentric chopper gun, which is fed by a spool of GFRC roving is pulled into the chopper gun and blended at the nozzle. This mix has a higher fiber content (4 to 6%) than can be achieved with premix and is the recommended method for larger panels**[12].**

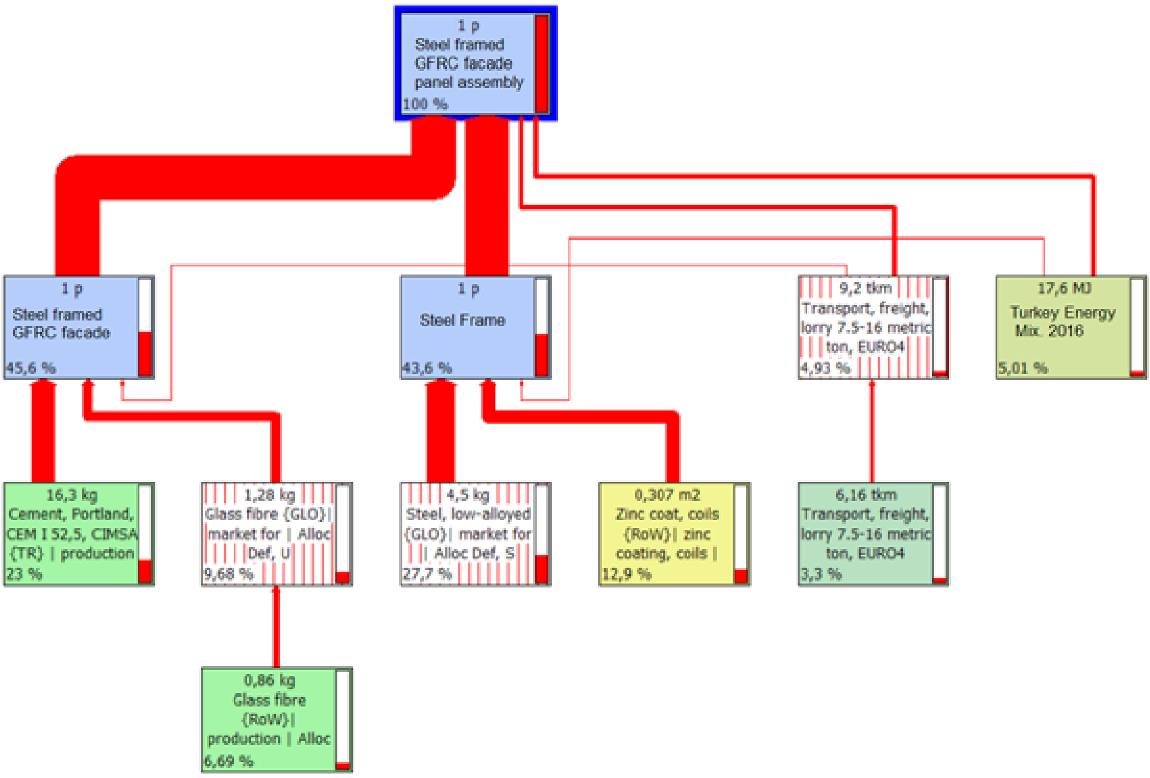

Figure 3.GFRC steel framed facade panelLCA inventory tree single score expressed as percentages.

CONCLUSIONS AND RECOMMENDATIONS

The main purpose of this study is to analyzeLCA of GFRC steel framed façade panels. For this construction material, the biggest potential effect comes from Portland cement and steel low alloyed materials. Zinc coat andglass fiber follow after other materials (**Figure 3**). The environmental impacts of concrete production are significant. In 2011, about 3 Gt of Portland cement were produced globally leading to about 2.6 Gt of CO_2 emissions annually for average production conditions**[18].**Althoughiron and steel production is one of the most resource and energy demanding industries around the world. Throughout the life cycle of iron and steel products, the intensive use of raw materials and energy results in contributions to a wide range of environmental impacts **[9].**

The functional unit choice in concrete LCAs is seen as one of the most influential factors in interpretation of LCA results. Besides concrete material aspects, LCA system boundary (cradle to gate, gate to gate, and cradle to grave) selection is also important. **[18]** This study's boundaries effect results yielded that steel low alloyed has a big embodied energy, but %80-%90 of the waste steel could recycled. If the boundaries were selected as cradle to cradle the CO_2 emissions would decrease.

The life cycle impact assessment methodology IMPACT 2002+ proposes a feasible implementation of a combined midpoint or endpoint, linking all types of life cycle inventory results (elementary flows and other interventions) via several midpoint categories to several damage categories **[19].** Endpoint LCA results shown in**Figure 5.**The results point out that the biggest indictors are respectively human health, climate change, resources, and ecosystem quality.

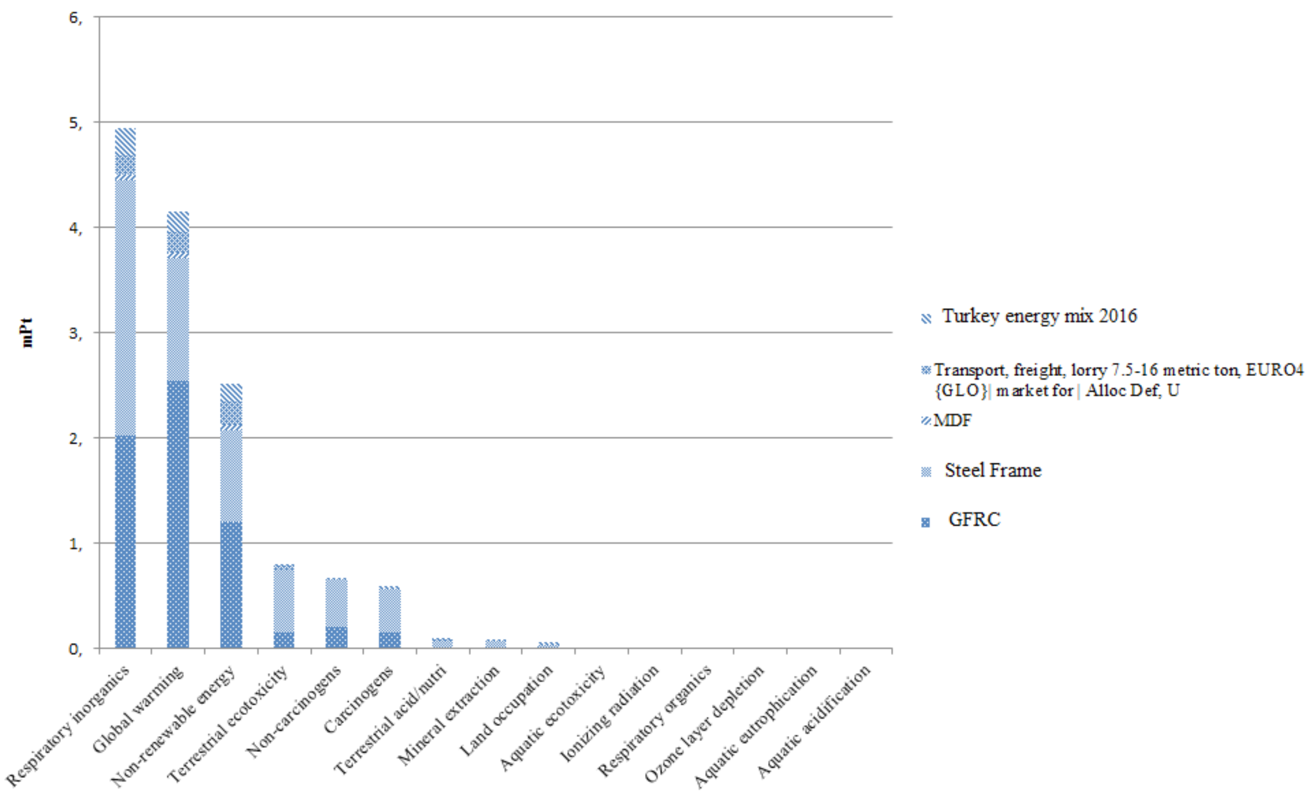

Figure 4 Midpoint LCA results for steel framed GFRC panel. The analysis was carried out with IMPACT 2002+V2.11

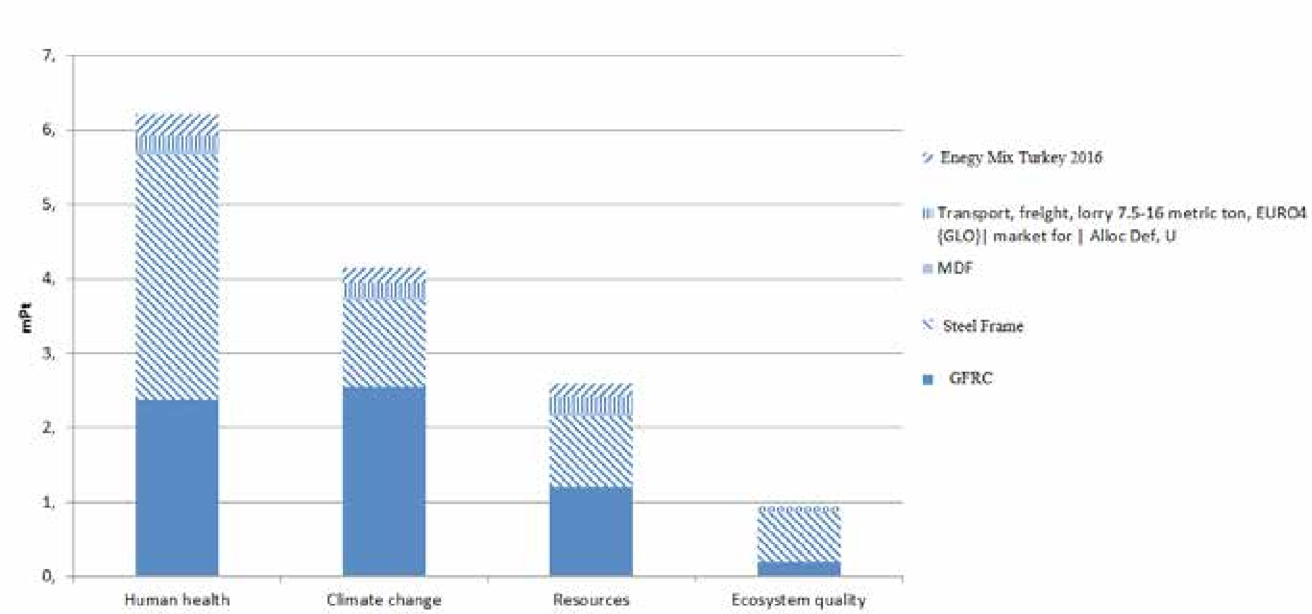

Fig 5. Endpoint LCA results for GFRC steel framed façade panel (cradle to gate). The analysis was carried out with IMPACT 2002+.

Glass fiber reinforced concrete (GFRC) panels were analyzed for assessment for midpoint and endpoint impact indicators **(Figure 3,4).**The results show that biggest indictors are respectively "respiratory inorganics, global warming, non-renewable energy, terrestrial exotoxicity, non-carcinogens, and carcinogens."Other indicators' effectsare so low that to be consider. **(Figure 4).**Biggest effects causes by glass fiber reinforced concrete and steel frame.This figure shows that GFRC steel framed panels has environmental affect focus on respitory and global warming potential.

The information obtained through this LCA can lead to the undertaking of various actions to reduce the life cycle environmental impact associated with GFRC steel framed façade panel production, focusing on the specific leads. For this product, for example, panels' thickness or amount of the steel can be decrease. Moreover due to the manufacturing energy can be used from renewable energy resources. With regard to the cement production, the options of a renewable source of energy during clinkerization process could reduce the CO_2 emissions during this step, improving the indicators' results for Climate Change, Human Health. We expect that this work to be an incentive to the construction sector in Turkey on its role in assessing the environmental impacts of building materials and elements.

ACKNOWLEDGMENTS

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REFERENCES

[1] UNEP SBCI (sustainable buildings and climate Initiative). Building and climate change, Summary for decision makers. 2009; can be downloaded at: http://www.unep.org/sbci/pdfs/SBCI-BCCSummary.pdf

[2] Buyle M, Breat J and Audenaert A. "Life cycle assessment in construction sector: A review". Renewable and Sustainable Energy Reviews. 26 (2013) 379–388

[3] Bayer, C and Gamble, M. (Georgia Institute of Technology) "AIA Guide to Building Life Cycle Assessment in Practice", (The American Institute of Architects, 2010) Can be downloaded at: http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab082942.pdf

[4] ISO 14040:2006Environmental management -- Life cycle assessment -- Principles and framework. Can be ordered from: http://www.iso.org/

[5] Simonen, Kathrina. "Life cycle assessment" pocket architecture: Technical design series, 2014, ISBN-13: 978-0415702423 can be ordered from: https://www.amazon.com

[6] Precast/Prestressed Concrete Institute, Designing with Precast &Prestressed Concrete Can be downloaded at: http://www.pci.org/uploadedFiles/Siteroot/Design_Resources/Building_Engineering_Resources/_Related_Content/PCI_DWP_binder.pdf

[7] Precast/Prestresssed Concrete Institute /Manual for Quality control for plants and production of Glass fiber reinforced concrete products. 2009, ISBN 0-37040-82-7

[8] Goldin, Aaron. Scammell, Adam Lauren, Wise, Cris. Architectural facades for the Heydar Aliyev Cultural Center: A life cycle assessment CEE 226- Term project, Autumn 2009; Can be downloaded at: http://www.kreysler.com/wp-content/uploads/2013/08/CEE-226-Baku-Facade.pdf

[9] Ölmez, Gülnur "Comparison of Sub-Processes and Final Products of Iron And Steel Production with Life Cycle Assessment" Master Thesis inMiddle East Technical University, (Turkey Ankara, 2011)

[10] Gürsel, Ayşegül Petek. "Life-Cycle Assessment of Concrete: Decision-Support Tool and Case Study Application", PhD Thesis, (University of California, Berkeley, 2014)

[11] Interviews with Fibrobeton company officials

[12] Roy, M. Development and Evaluation of High Performance Fiber Reinforced Concrete as a Repairing Material, master thesis, Department of Civil and Environmental Engineering Morgantown, (West Virginia ,2011)

[13] https://www.cimsa.com.tr/tr/urun-ve-hizmetler/cimento/beyaz-cimento/cimsa-eko-beyaz-cem-ii-b-l-42-5-r-portland-kalkerli-cimento/i-102

[14] Interview withMetsimssustainability consulting company

[15] Heath, A., Paine, K. and McManus, M. "Minimizing the global warming potential of clay based geopolymers". Journal of Cleaner Production, 75-83. (September 2014) ISSN 0959-6526,

[16] Schlumpf J., Bicher B., andSchwoon O. Sika concrete handbook, 2012

[17] Cabeza L.F., Rincon L. ·Vilarino V. Perez G.·Castell A. Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review Renewable and Sustainable Energy Reviews 29:394-416 ,· (January 2014)

[18] Puettmann, M., Oneil E. and Wilson J.,Cradle to Gate Life Cycle Assessment of U.S. Medium Density Fiberboard Production,CORRIM, the Consortium for Research on Renewable Industrial Materials. (U.S. August 2013)

[19] Electrical Engineers Chamber of Publication, Electric power installed capacity in Turkey (Turkey, March 2016)

[20] Gursel AP, Masanet E, Horvath A, Stadel A. Life-cycle inventory analysis of concrete production: a critical review. Cement and Concrete Composites 51, 38-48 20 (2014)

[21] Impact2002+_UserGuide_for_vQ2 21_1(November2012)Can be downloaded at: http://www.quantis-intl.com/pdf/IMPACT2002_UserGuide_for_vQ2.21.pdf

Paper No: 147

Planning Sustainable Development Road Map for a Producing Company in Reference to LCA Results of Gypsum Based Building

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ABSTRACT

The Sustainability strategy of Saint-Gobain Group (SGG) is based on equally important three main pillars: financial, social and environmental. For a sustainable future, Rigips, a Saint-Gobain Group company in Turkey, conducts local studies within the scope of building materials and systems produced by Rigips, the company itself and also the construction industry, in line with the group strategy.

One of those studies is the life cycle assessments (LCA) of the 8 different building materials produced locally by the company and the documentation of these assessments by means of environmental product declarations (EPD). In this paper, the LCA process, the assessment results and the future eco-innovation projects developed by using the inferences from these results are explained.

The LCA results clearly indicate that a significant proportion of the environmental impact is originated from the manufacturing of the products and the use of raw materials. By means of additional energy analyses on the manufacturing stage and projects which would provide efficiency and sustainability of this stage, the company is expected to reduce its environmental impact and would be able to realize its sustainability goals.

Keywords: plaster, plasterboard, LCA, EPD, sustainable development.

INTRODUCTION

Built environment is responsible for an inevitable deal of environmental pollution. Buildings account for 40% of global energy use, 38% of global greenhouse gas emissions, 12% of global potable water use and 40% of solid waste streams in developed countries. However, 30% to 70% of reduction in those various environmental impacts can be achieved. That is to say, providing a sustainable built environment has the greatest potential for reducing emissions and resource consumption at the least cost [1], [2]. In this aspect, the global company group, Saint-Gobain, developed a sustainable approach to its business which enables collaboration with its construction industry partners such as architects, contractors and installers.

The vision of Saint-Gobain Gypsum Activity involves, (among others)Limiting the impact on natural resources and biodiversity,

- Minimizing the energy consumption and CO_2 emissions,
- Improving public comfort, safety and health,
- Enhancing circular economy: increase waste recycling and recycled content.

This vision is supported by three values: exemplarity, transparency and innovation. In line with this vision, performing LCA and EPDs for plasterboard and plaster in order to assess environmental impacts for all SGG countries with manufacturing facilities is a part of the local sustainability road maps. The group is aware that EPDs are not only strong marketing tools for green building construction projects, but they are a very important first step of sustainable development.

Saint-Gobain Rigips Alçı Sanayi ve Ticaret A.Ş., which locally manufactures and sells gypsum based building materials, adopted this sustainable approach and performed LCA and EPDs for 4 different types of plaster and 4 different types of plasterboard produced in its two different factories in Bala and Hasanoğlan, Ankara [3], [4] , [5] , [6] , [7] , [8] , [9] , [10].

MATERIAL AND METHOD

Life cycle assessments (LCA) were performed for 8 different plaster and plasterboard types:

- Spray plaster: It is a gypsum-based spray plaster which can be applied by a spray machine on any interior surface such as structural concrete or infill blocks. It should be applied minimum 8mm, maximum 30 mm in thickness [3].
- Lightweight spray plaster: It is a gypsum-based lightweight spray plaster, which can be applied by a spray machine on any interior surface such as structural concrete or infill blocks. It should be applied minimum 8mm, maximum 30 mm in thickness. It provides 25% more coverage with same weight of plaster than traditional spray plasters [4].

- Hand plaster with perlite: It is a hand-applied gypsum-based plaster with perlite which can be used on any interior surface such as structural concrete or infill blocks. It should be applied minimum 8mm, maximum 30 mm in thickness [5].

- Finishing plaster: It is a hand-applied gypsum based finishing plaster for skimming over a wide range of interior surfaces such as dry wall and suspended ceiling systems or under coat applied block walls. It provides a smooth surface and it is also used as an undercoat of paints, with high adhesion. A finishing plaster layer should be maximum 1mm thick [6].

- Standard plasterboard: It is a composite gypsum-filled construction material covered with ivory paper on the front side and grey paper on the other side. This product is used for installing partition walls, shaft walls, dry lining systems and suspended ceilings in interiors [7].

- Moisture resistant plasterboard: It is a composite gypsum-filled construction material with improved moisture resistant core. The board is covered with green paper on the front side and grey paper on the other side. This product is used for installing partition walls, shaft walls, dry lining systems and suspended ceilings in humid interiors where moisture resistance is a required design criterion [8].

- Fire resistant plasterboards: It is a composite gypsum-filled construction material with improved fire resistant core. The board is covered with pink paper on the front side and grey paper on the other side. This product is used for installing partition walls, shaft walls, dry lining systems and suspended ceilings in interiors where fire safety is a required design criterion [9].

- Moisture and fire resistant plasterboard: It is a composite gypsum-filled construction material with improved moisture and fire resistant core. The board is covered with pink paper on the front side and green paper on the other side. This product is used for installing partition walls, shaft walls, dry lining systems and suspended ceilings in humid interiors where both moisture resistance and fire safety are required design criteria [10].

LCAs were conducted by using EN 15804 CPC Division Construction Materials and Construction Services Version 1.0 as the core PCR (Product Category Rules) in accordance with Saint-Gobain requirements. The LCAs were performed on the whole life cycle of the products including raw materials, manufacturing, logistics, installation, building life time, end-of-life and recycling (**Figure 1**). After the completion of the LCA process, Type III Environmental Product Declarations (EPDs) for each product were produced and verified by a third party according to ISO 14025:2010 [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16].

***Figure 1** Life cycle flow diagram of the gypsum based building products [3], [4], [5] , [6] , [7] , [8] , [9] , [10].*

RESULTS

The LCA results show that a significant proportion of the environmental impact of the products originates from the manufacturing process and use of raw materials (**Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, Figure 7, Figure 8** and **Figure 9**). The ratio of energy consumption amount at production stage to the total amount throughout the life cycle is 76% for the spray plaster, 89% for the lightweight spray plaster, 84% for the hand plaster with perlite and the finishing plaster, 92% for the standard plasterboard, 93% for the moisture resistant plasterboard, 92% for the fire resistant plasterboard and 93% for the moisture and fire resistant plasterboard (**Table 1**).

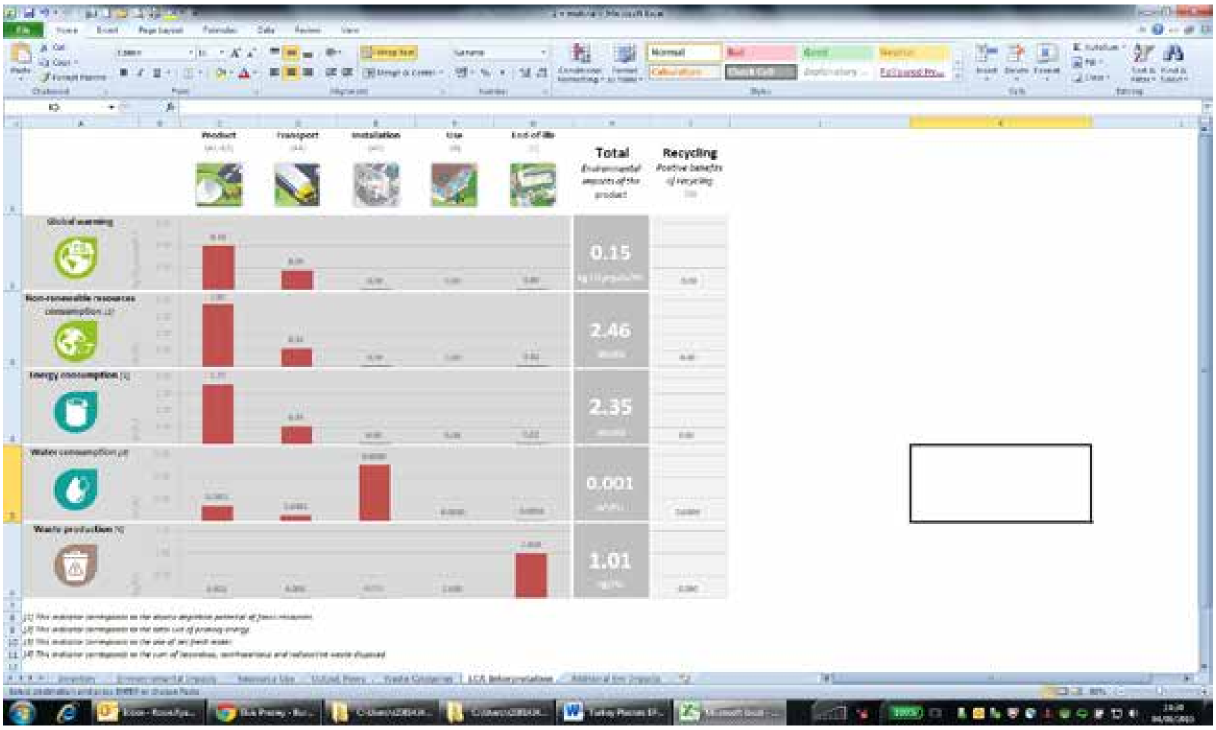

Figure 2 Life cycle assessment results for spray plaster [3].

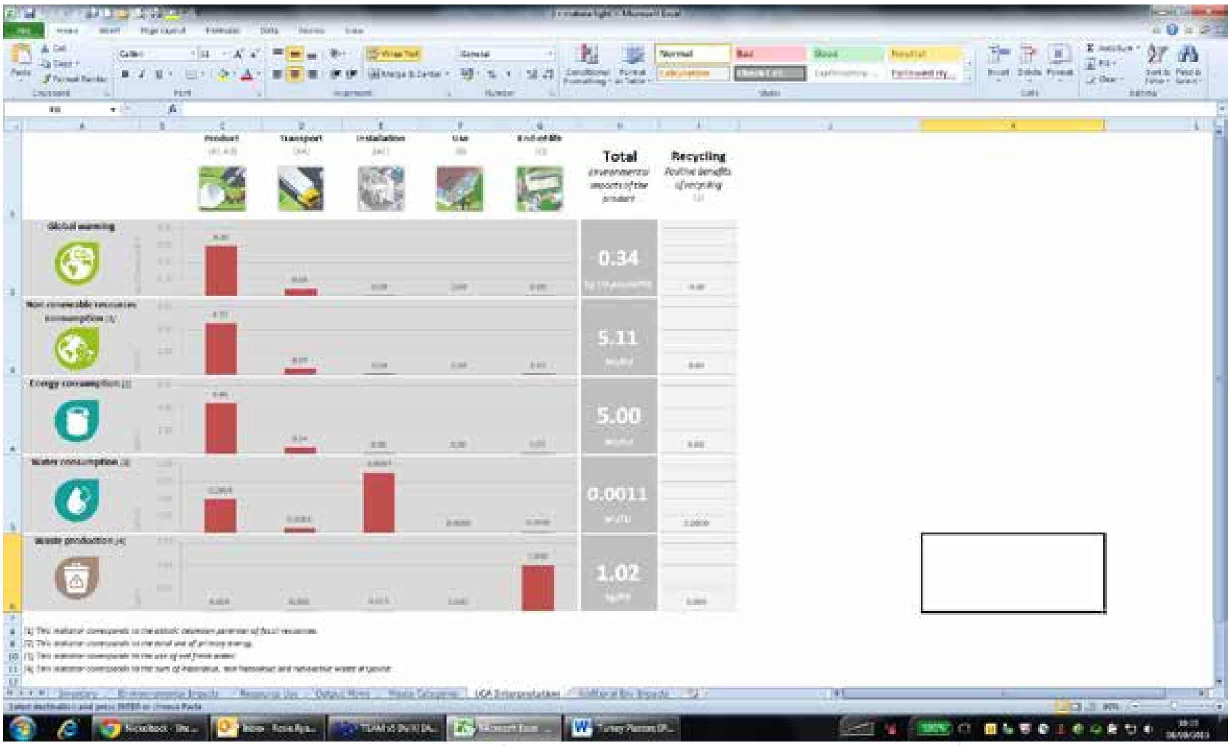

Figure 3 Life cycle assessment results for lightweight spray plaster [4].

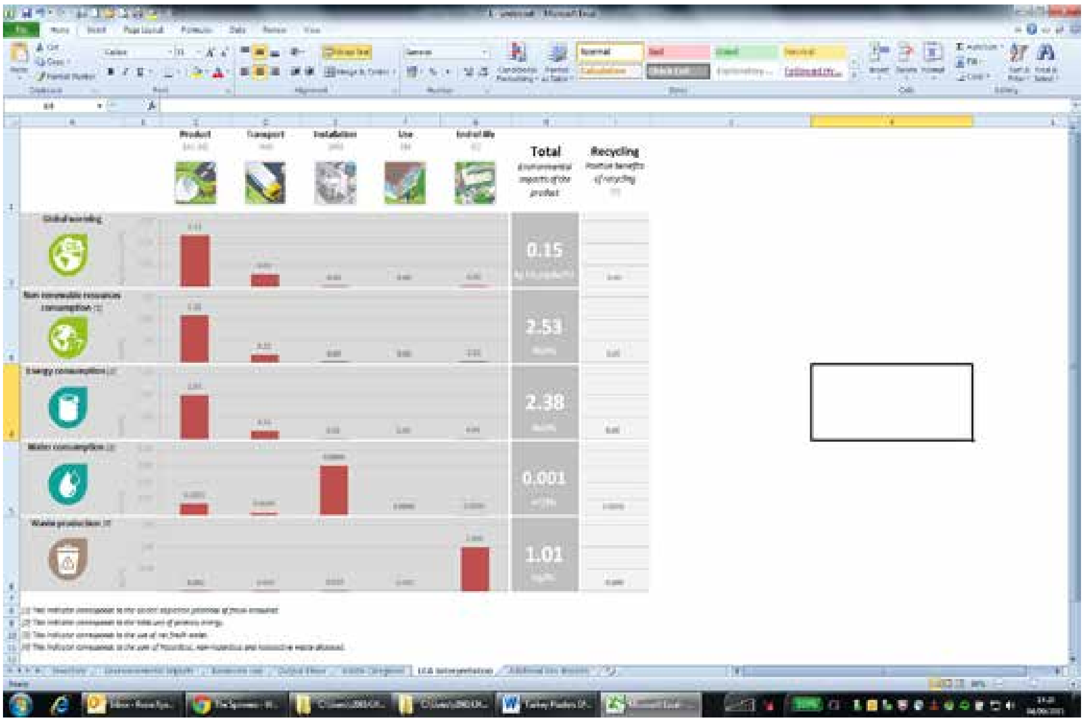

Figure 4 Life cycle assessment results for hand plaster with perlite [5].

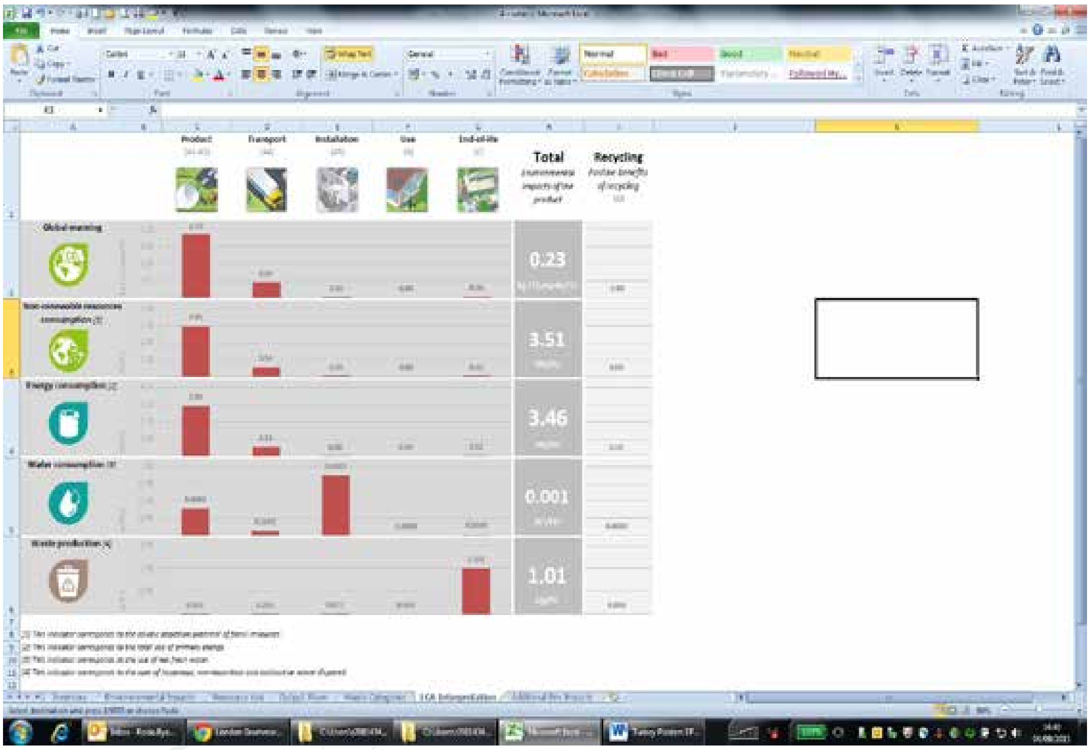

Figure 5 Life cycle assessment results for finishing plaster [6].

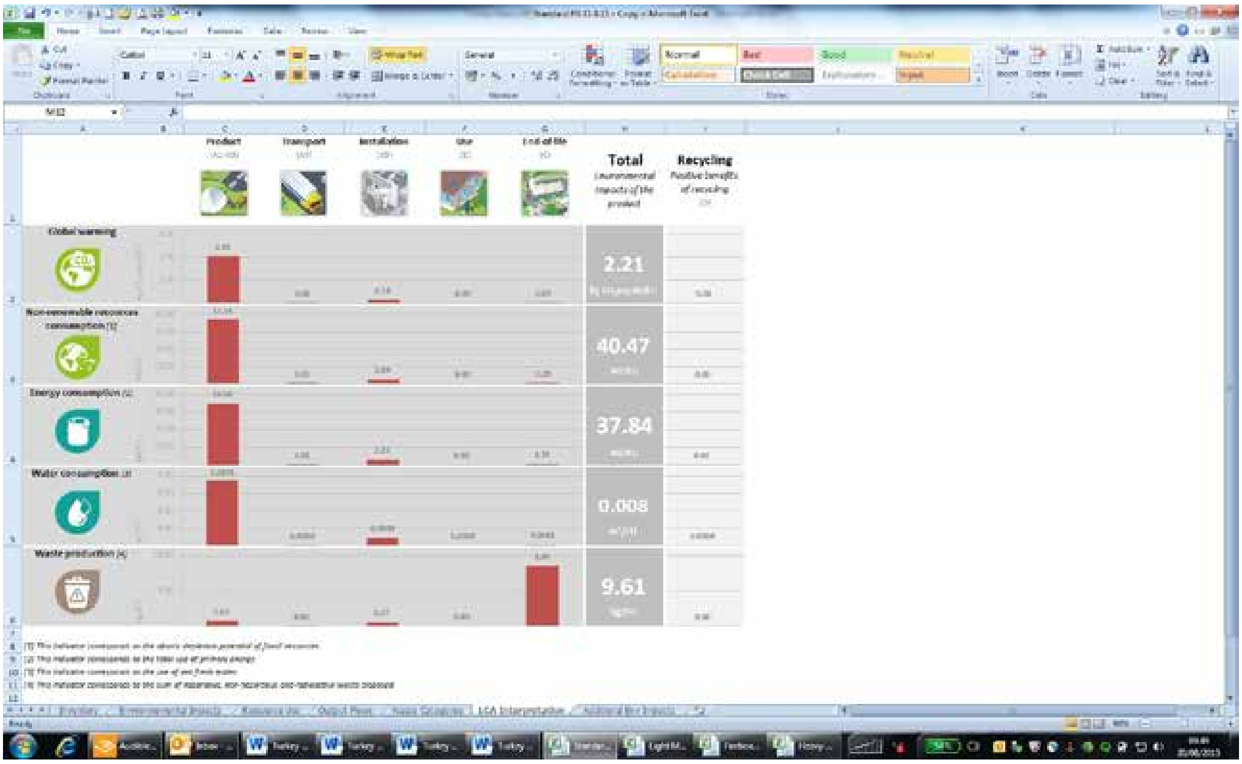

Figure 6 Life cycle assessment results for standard plasterboard [7].

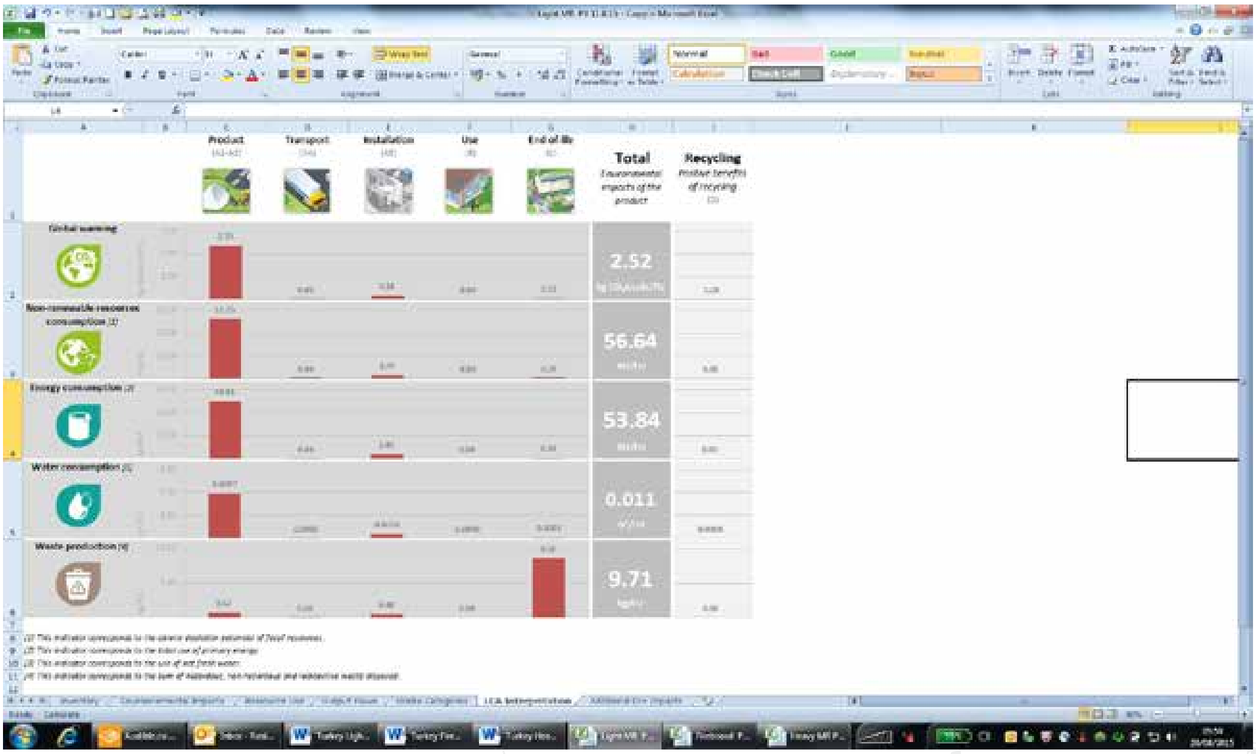

Figure 7 Life cycle assessment results for moisture resistant plasterboard [8].

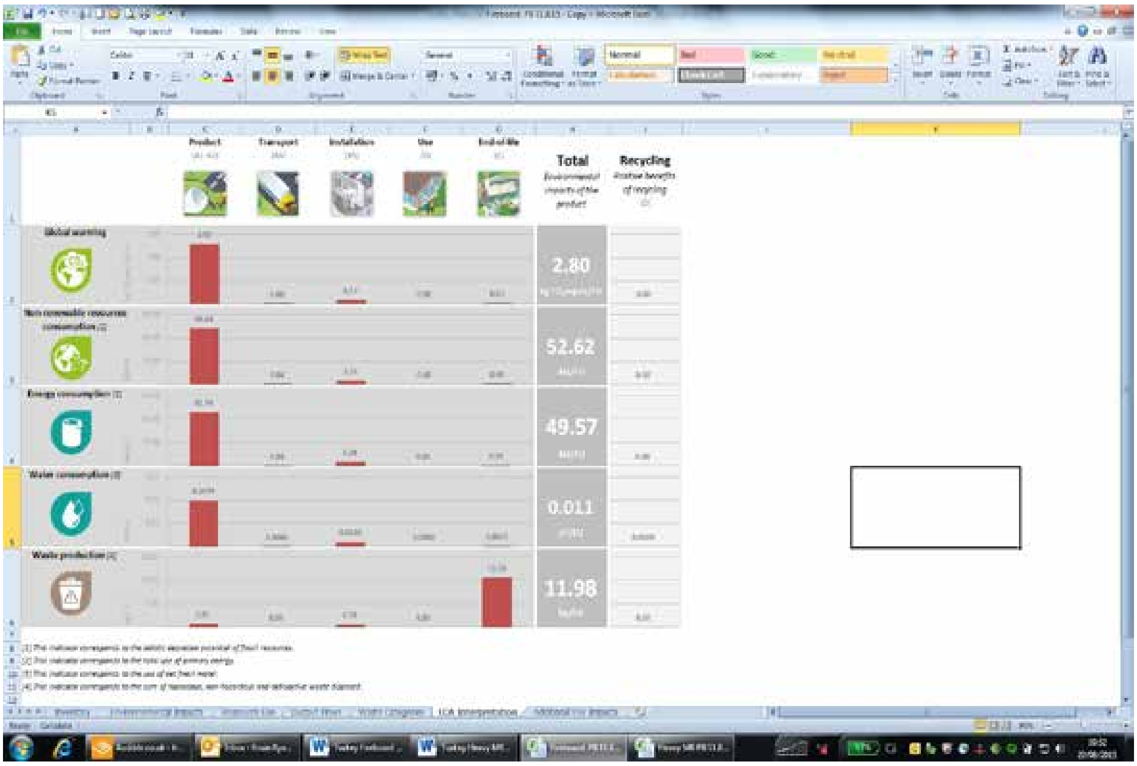

Figure 8 Life cycle assessment results for fire resistant plasterboard [9].

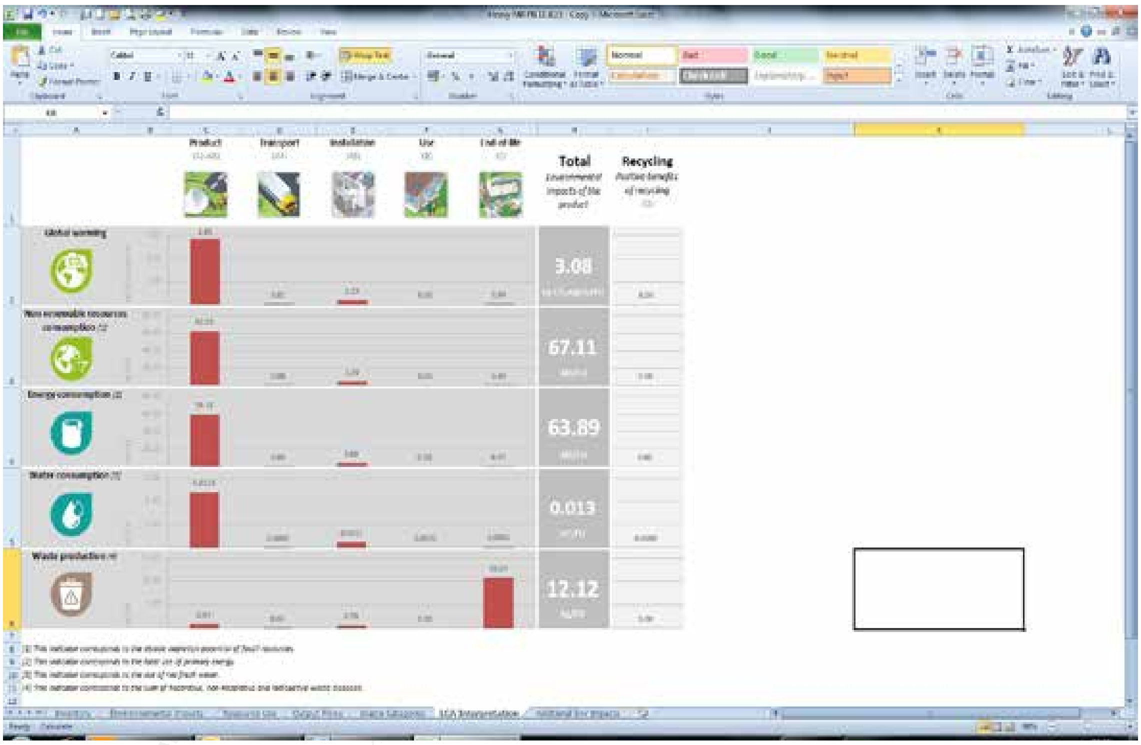

Figure 9 Life cycle assessment results for moisture and fire resistant plasterboard [10].

According to the LCA results, the ratio of CO_2 emission amount at production stage (A1-A3) to the total amount throughout the life cycle is 67% for the spray plaster, 88% for the lightweight spray plaster, 80% for the hand plaster with perlite, 83% for the finishing plaster, 92% for the standard plasterboard, 92% for the moisture resistant plasterboard, 93% for the fire resistant plasterboard and 93% for the moisture and fire resistant plasterboard (**Table 2**).

Table 1 The energy consumption amount at production stage and the total amount throughout the life cycle

	Energy Consumption (MJ/FU)		Ratio (%)
Gypsum Based Product	**At Production Stage**	**In Total**	
Spray Plaster	1.79	2.35	**76**
Lightweight Spray Plaster	4.44	5.00	**89**
Hand Plaster with Perlite	2.00	2.38	**84**
Finishing Plaster	2.90	3.46	**84**
Standard Plasterboard	34.66	37.84	**92**
Moisture Resistant Plasterboard	49.91	53.84	**93**
Fire Resistant Plasterboard	45.76	49.57	**92**
Moisture and Fire Resistant Plasterboard	59.31	63.89	**93**

Table 2 The CO2 emission amount at production stage (A1-A3, raw material use and manufacturing) and the total amount throughout the life cycle

	CO_2 Emission (kg CO_2equiv/FU)		Ratio (%)
Gypsum Based Product	**At Production Stage**	**In Total**	
Spray Plaster	0.10	0.15	**67**
Lightweight Spray Plaster	0.30	0.34	**88**
Hand Plaster with Perlite	0.12	0.15	**80**
Finishing Plaster	0.19	0.23	**83**
Standard Plasterboard	2.03	2.21	**92**
Moisture Resistant Plasterboard	2.33	2.52	**92**
Fire Resistant Plasterboard	2.59	2.80	**93**
Moisture and Fire Resistant Plasterboard	2.85	3.08	**93**

CONCLUSION

This study confirmed that most of the environmental impact of plasters and plasterboards results from the manufacturing process and use of raw materials.

After conducting this study, Saint-Gobain Rigips, the gypsum based building material producer in Turkey, decided to accelerate its energy efficiency studies at the raw material and manufacturing stage of the life cycle of its products in collaboration with an experienced energy efficiency consultancy company, in order to limit its environmental impact by using ISO50001 EnMS (Energy Management Systems) tools. Several short-term and long-term eco-innovation projects are planned in the light of these analyses. This eco-innovative sustainability approach of Rigips is expected to raise also a nationwide awareness and be exemplary for other producers of construction materials in Turkey.

As a result, EPDs are not only marketing tools for the eco-friendly construction market, but also documents with very important information on the magnitude of the environmental impact of a product. Such information is crucial to raise awareness of a producer and it is necessary to set key performance indicators for the prospective sustainable development.

REFERENCES

[1] Levine, M., D. Ürge-Vorsatz, K. Blok, L. Geng, D. Harvey, S. Lang, G. Levermore, A. Mongameli Mehlwana, S. Mirasgedis, A. Novikova, J. Rilling, H. Yoshino, 2007: Residential and commercial buildings. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Can be downloaded at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter6.pdf

[2] UNEP SPCI, Building Design and Construction: Forging Resource Efficiency and Sustainable Development. Can be downloaded at: http://www.unep.org/sbci/pdfs/UNEP_SBCI_PositionPaperJune2012.pdf

[3] Rigips Makina Sıva Alçısı Environmental Product Declaration. Can be downloaded at: http://www.rigips.com.tr/wp-content/uploads/2016/01/Rigips_Makina_Siva_Alcisi_EPD.pdf

[4] Rigips Makina PRF25Sıva Alçısı Environmental Product Declaration. Can be downloaded at: http://www.rigips.com.tr/wp-content/uploads/2016/01/Rigips_Makina_PRF25_Siva_Alcisi_EPD.pdf

[5] Rigips Perlitli Sıva Alçısı Environmental Product Declaration. Can be downloaded at: http://www.rigips.com.tr/wp-content/uploads/2016/01/Rigips_Perlitli_Siva_Alcisi_EPD.pdf

[6] Rigips Saten Perdah Alçısı Environmental Product Declaration. Can be downloaded at: http://www.rigips.com.tr/wp-content/uploads/2016/01/Rigips_Saten_Perdah_Alcisi_EPD.pdf

[7] Rigips Standart Alçı Levha Environmental Product Declaration. Can be downloaded at: http://www.rigips.com.tr/wp-content/uploads/2016/01/Rigips_Standart_Alci_Levha_EPD.pdf

[8] Rigips Suya Dayanıklı Alçı Levha Environmental Product Declaration. Can be downloaded at: http://www.rigips.com.tr/wp-content/uploads/2016/01/Rigips_Suya_Dayanikli_Alci_Levha_EPD.pdf

[9] Rigips Yangına Dayanıklı Alçı Levha Environmental Product Declaration. Can be downloaded at: http://www.rigips.com.tr/wp-content/uploads/2016/01/Rigips_Yangina_Dayanikli_EPD.pdf

[10] Rigips Suya ve Yangına Dayanıklı Alçı Levha Environmental Product Declaration. Can be downloaded at: http://www.rigips.com.tr/wp-content/uploads/2016/01/Rigips_Suya_ve_Yangina_Dayanikli_EPD.pdf

[11] General Program instructions of the International EPD System VERSION 2.5. DATE 2015-05-11

[12] BS 15804: 2012 + A1 2013 Sustainability of construction works, - Environmental Product Declarations Core Rules for the Product Category of Construction Products

[13] Environmental Product Declaration: Saint Gobain Methodological Guide for Construction Products. April 2013.

[14] ISO 14025:2006 Environmental labels and declarations -- Type III environmental declarations -- Principles and Procedures.

[15] CONSTRUCTION PRODUCTS AND CONSTRUCTION SERVICES 2012:01 VERSION 2.0 VALID UNTIL: 2019-03-03

[16] ISO 21930:2007 Sustainability in building construction -- Environmental declaration of building products.

Paper No: 148

Measuring Sustainability in Buildings Using Construction Materials Database Based on Life Cycle Information in Turkey

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SUMMARY

There has been an increase in demanding environmental performance information of building materials and systems (components) from policy makers, due not only to high resource use but also environmental impacts such as climate change, and from the designers of sustainable or high performance buildings through certification systems. Such information requires life cycle impact dataset with multiple impact indicators and are proposed to be used to assess the sustainability of a whole building. Turkish Construction Materials Life Cycle Database is formed including data from Turkish Life Cycle Inventory Database as well as data from products with Environmental Product Declarations. The database includes product and sector specific primary data sets as well as generic data reflecting Turkish manufacturing conditions. Data quality requirements for the database is very high, i.e. mainly primary data.

This database will be introduced and its relevance to Turkish green building sector will be discussed. The use of the database within the context of assessing the environmental impacts of a real building will be demonstrated. The database's relevance to the development of green building assessment schemes in Turkey as well as to the established assessment schemes will be discussed. Potential benefits of using the database in the Urban Regeneration in Turkey to to assess at least greenhouse gas emissions and its contributions to Turkey's commitment for Kyoto Protocol II for reducing such emissions will also be speculated.

Keywords: life cycle, construction materials, database, green building assessment, climate change, environmental impacts

INTRODUCTION

Life Cycle Assessment studies are becoming more important in assessing sustainability of buildings due to the sector's huge impacts on climate change and resource use such as materials, energy and water. Over 40% of carbon emissions, 50% of resource use is attributed to the sector [1]. Embodied energy and carbon, which refers to energy and emissions during manufacturing of materials, becomes important part of building life cycle. Although its effects are reduced over the building life cycle due to long life of buildings, its effects are immediate, i.e. when a built is constructed, and will be even more prominent when energy efficient and/or passive houses becoming more prominent. As such, demolition of a building is also relevant. As the awareness of the topic in the built environment has been increasing and also the environmental concerns have been paid more attention to, the construction sector is led to Kyoto Protocol. The EU regulations are also focusing on resource efficiency [1] and energy performance through Energy Performance of Buildings Directive 2002/91/EC [2].

Several building assessment schemes have been developed in the built environment and construction sector. The well-known schemes are British BREEAM, American LEED, German DGNB. Turkish Green Building Council (ÇEDBİK) also develop the first local scheme for new homes. Each schemes have its own set of methodologies, some common some differs among them, to assess sustainability in a building context. To make such assessment more measurable and comprehensive, Life Cycle Assessment (LCA) is becoming an important element of these assessment schemes.

Embodied energy demand of a building is about one fourth of a total building energy demand. This ratio, however, increases for well insulated homes and for passive houses. As such embodied energy and carbon are becoming an important indicator for the sustainability of buildings. A cradle-to-grave LCA study can present the energy demand, carbon emission for climate change and other midpoint and endpoint impact indicators of a whole building from raw material extraction to manufacturing, construction and the end-of-life phases.

Construction materials with environmental indicators such as embodied energy and carbon is becoming widely available thanks to ISO 14025 Environmental Product Declaration (EPD) for products. An EPD is third-party (external) verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products [3]. LCA is always needed to obtain all the indicators required by EPDs.

Database containing life cycle environmental impacts of construction materials manufactured in Turkey have been developed to facilitate the assessment of environmental impacts of buildings. Compliant to international standards and called Turkish Construction Materials Life Cycle Database, it contains not only branded product specific but also generic datasets relevant to Turkey taken from Turkish Life Cycle Inventory Database (TLCID) [4]. So far with over 200 high quality datasets and growing with daily additions, it is comprehensive enough to become an important element of assessment schemes developed in Turkey. Such database is also useful for international green building assessment schemes that requires calculation of LCA as part of assessment, for example LEED and BREEAM. More importantly for Turkey, the Database will facilitate the calculation of carbon footprint for any Urban Regeneration project to be registered for the Kyoto Protocol II commitments. This paper demonstrates the use of this database to assess the environmental impacts of a multi-storey residential building reflecting the local conditions and makes the assessment relevant to Turkey.

1. BUILDING LIFE CYCLE ASSESSMENT

A four storey residential building with 1200 square meter area constructed in Turkey was used for the case study (Figure 1). All the materials and assembly information of the building was taken from an earlier PhD study [5]. The building is divided into the following components:

- Foundation
- Structure
- Coverings

- Internal Walls
- External Walls
- Profiles
- Glazing
- Roof

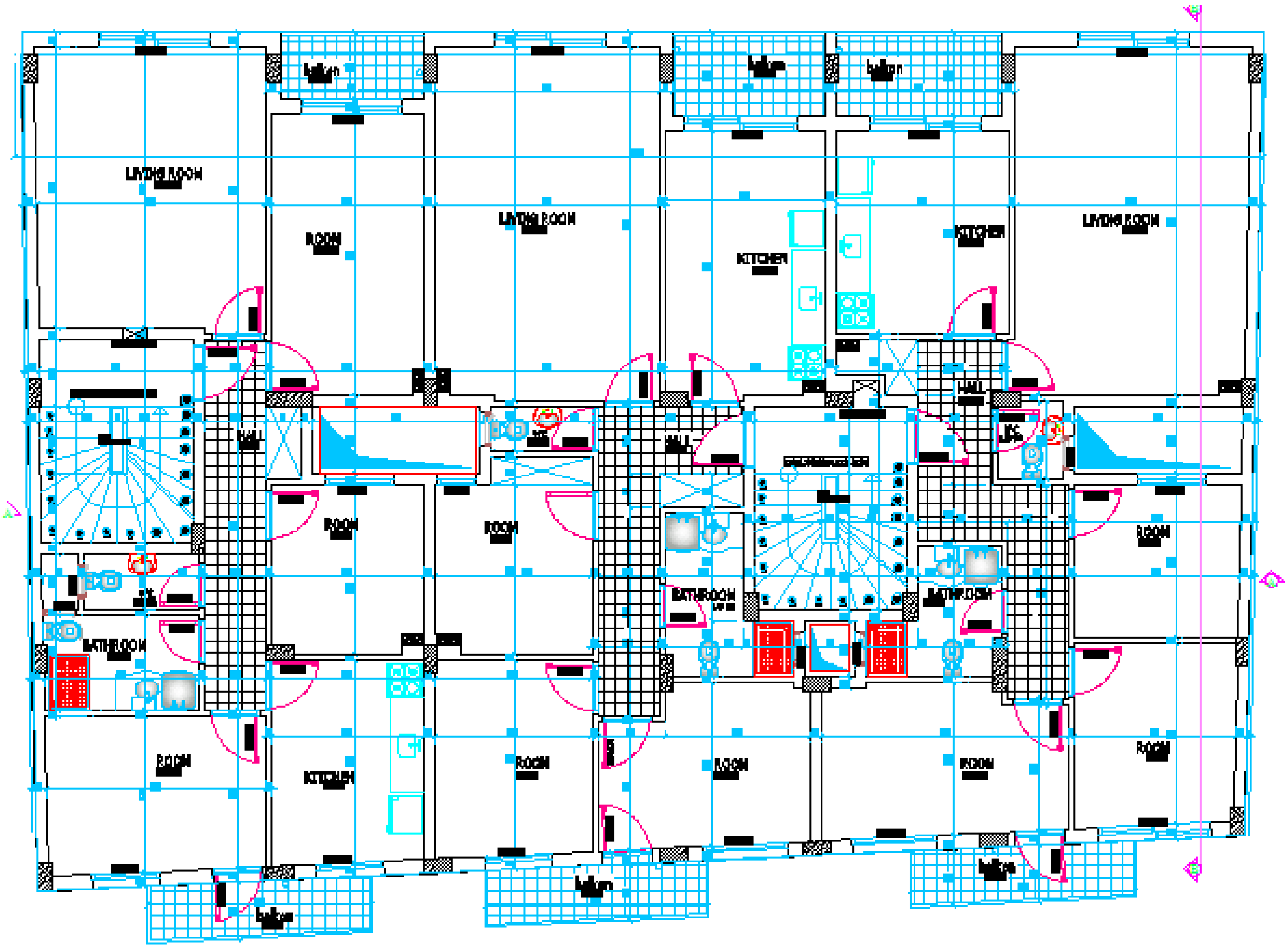

Figure 1 Architectural details of the building design used for the study.

Building inventory involving all of the above components was gathered from the design and insulation reports. The functional unit was considered as the entire building with 1200 gross sq. meters. The system boundary was determined to include the raw materials extraction from the nature, transportation from/to raw material treatment, transportation to production site, manufacturing, fuel and energy consumptions. Datasets for Turkish electricity mix and natural gas mix is part of the Database taken from the TLCID database.

Many combinations area available for the types of components to use. For example, a flat-roof with tile covering but no insulations which was part of the assessment is shown in Figure 2. The following materials are required to assemble 1 m^2 of such roof:

- 12 kg ceramic tiles
- 2 kg cement based adhesives
- 0.1 kg geotextile felt
- 0.8 kg polymeric modified bituminous water proofing membrane
- 154.14 kg screed for inclined purposes (7 cm)
- 364 kg concrete slab (15 cm)
- 12.6 kg steel reinforcement
- 5 kg gypsum plaster (5 cm)

The rood component shown in Figure 2 can be modified to include insulation materials with various thicknesses such as XPS, EPS, Rockwool, Glasswool etc. Other sections of the component can also be modified according to the need of the architectural design. Such flexibility is available for all components of the building highlighted above. Such flexibility gives the designer to do life cycle design study at an early stage of the design and find the best compromise between building cost, environmental impacts and life cycle cost.
All the inputs were inserted into SimaPro LCA software tool with Turkish Construction Materials Life Cycle Database. All environmental impacts are assessed in accordance with EN 15978 norm per total amount and per square meter. Only building materials stage A1-3 (Figure 3) is taken into account in this study. The other stages can easily be included to complete the full life cycle assessment. For the use phase, energy consumption figures from energy certificates can be used and match with the latest Turkish energy specific impacts from the Database.

Inventory for all other remaining building components were also collected to complete the assessment. Indicators per square meter is calculated.

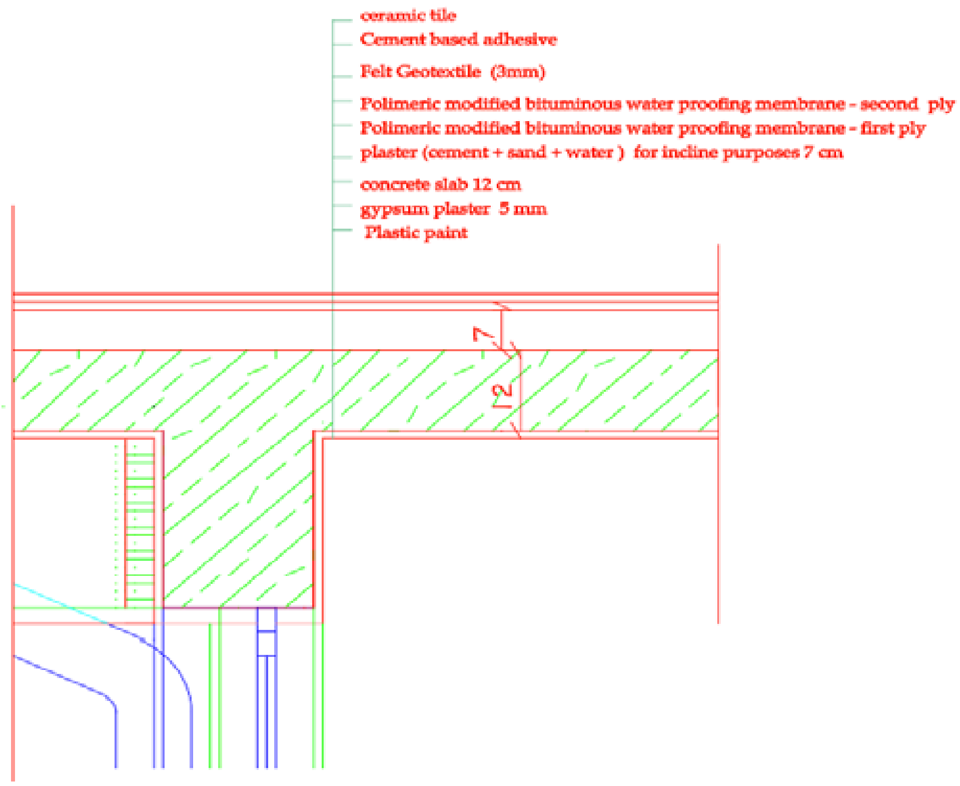

Figure 2 Design details of flat roof component without any thermal insulation

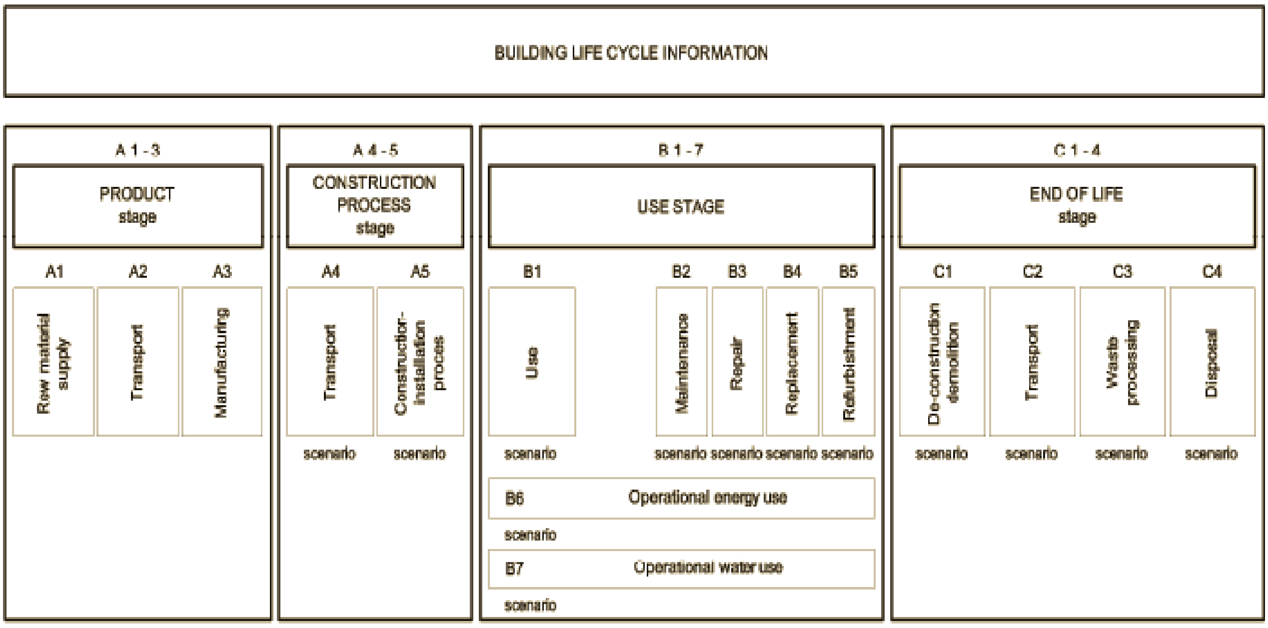

Figure 3: Different stages of the building life cycle assessment according to EN 15978 [6]

Figure 4 represents a system boundary flow from raw materials extraction to end of life stage over a buildings life time in compliance with EN 15978 standard. This LCA study focuses on the Global Warming Potential (GWP) and Energy Demand (CED) as a result of construction materials use, i.e. embodied carbon and energy demand of the construction materials.

The GWP impact is calculated using IPCC 2013 GWP 100a ver. 1.2 methodology that contains the climate change factors with a timeframe of 100 years. For embodied energy, Cumulative Energy Demand ver. 1.09 methodology is used.

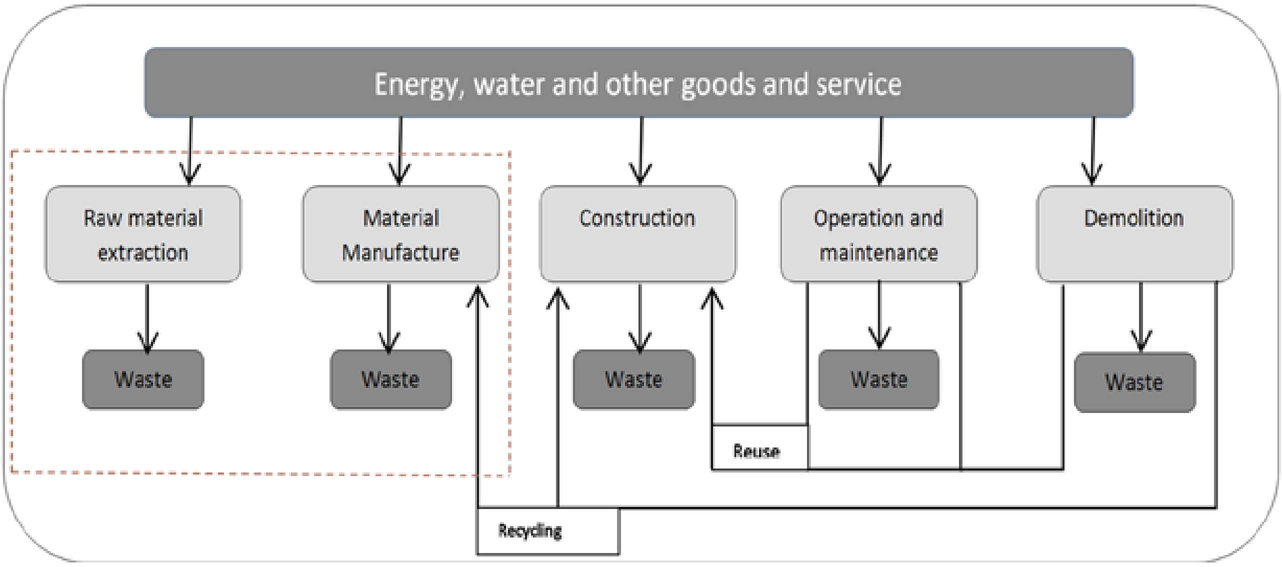

Figure 4 System boundary across the building life cycle [7]

RESULTS

The GWP impact of all building components for 1200 square meter building are shown in Figure 5. As seen, structure and foundations are two building components with about 29% and 28%, respectively, the dominant embodied carbon impacts among all building parts. The total carbon impact of the building as a result of materials use (A1-3) is 476 913 kg CO_2 eq. The values and relative contributions of each building components per one square meter of the building is shown in Figure 6. GWP per square meter is about 397 kg CO2 eq.

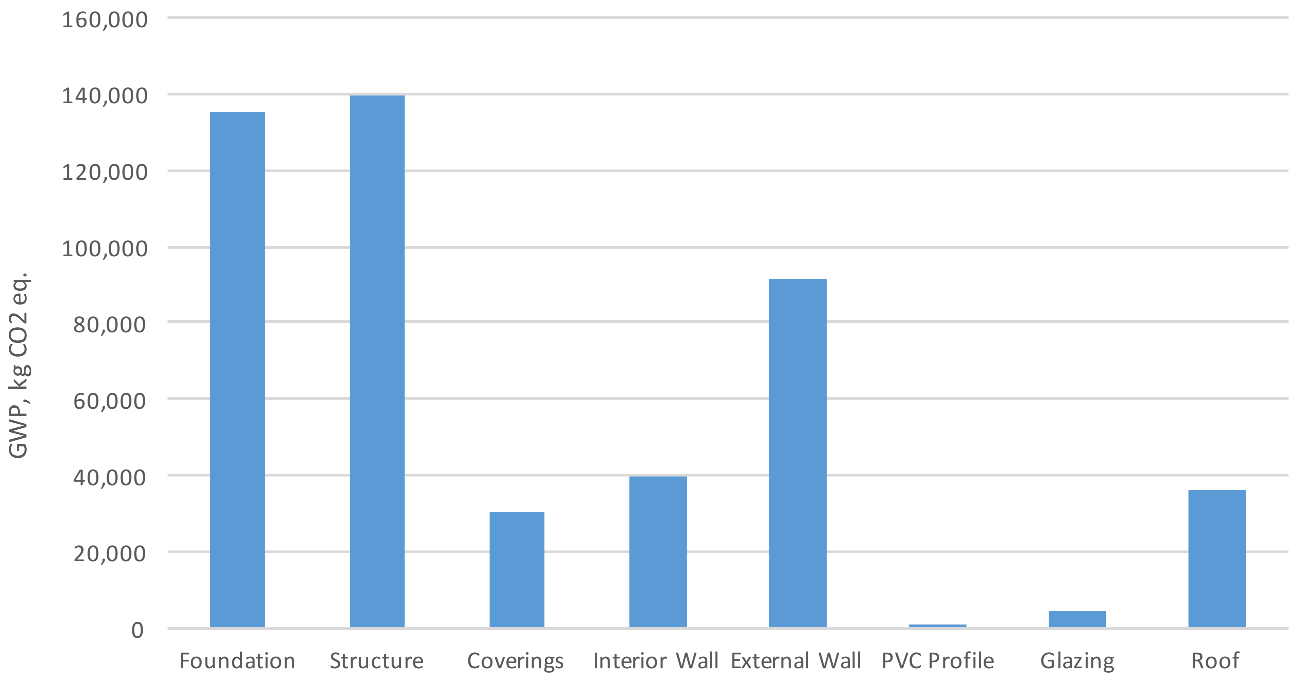

Figure 5 GWP of each building component and their relative contributions to climate change.

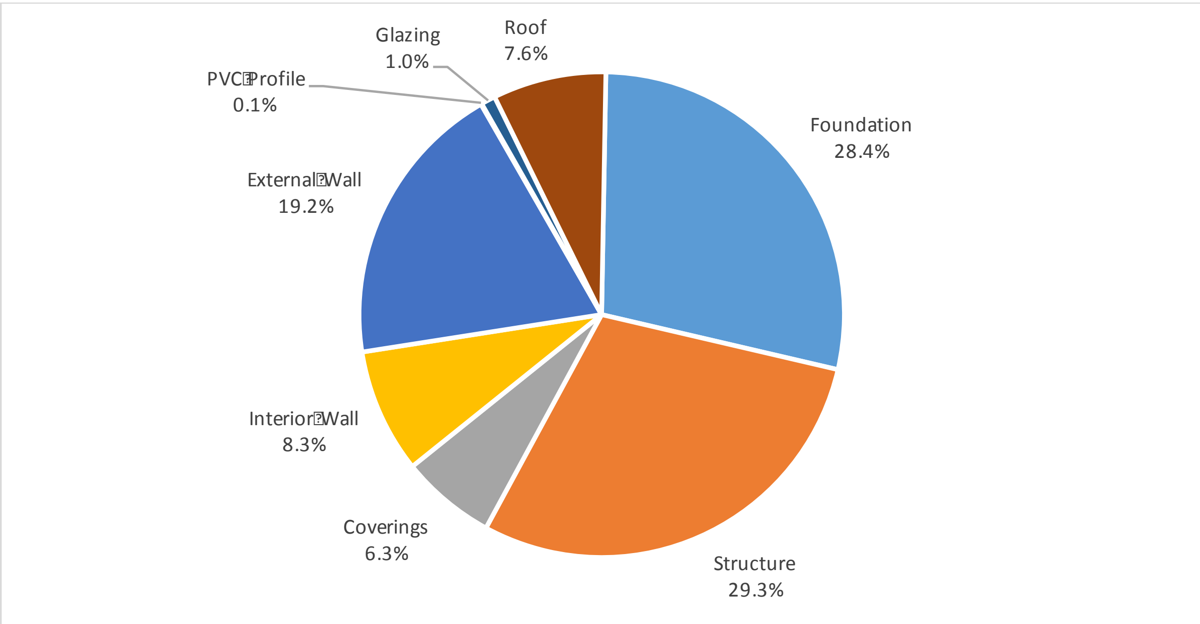

Figure 6 GWP distribution among building components per square meter

When the embodied energy consumption of building was examined, it was found that fossil energy sources are the most prominent (Table 1). Total embodied energy consumption of the building is 5.25E+06 MJ. Per square meter this is calculated to be 4.38E+03 MJ. of which only small fraction of about 315.2 MJ is coming from renewable primary energy resources.

Although this paper is focusing on the embodied carbon and energy, other relevant environmental impacts at building level can also be calculated. This is also the requirement of the EN 15978 building life cycle assessment norm. This is done using a CML-IA baseline methodology (ver. 4.02). The results of the methodology are presented in Table 2.

Table 1 Whole building LCA results for embodied energy

Parameter	**Unit**	**Building Level**	**Per sqm**
Use of renewable primary energy excluding resources used as raw materials	[MJ]	3.78E+05	315
Use of renewable primary energy resources used as raw materials	[MJ]	0	0
Total use of renewable primary energy resources	[MJ]	3.78E+05	315
Use of non-renewable primary energy excluding resources used as raw materials	[MJ]	4.88E+06	4064
Use of non-renewable primary energy resources used as raw materials	[MJ]	0	0
Total use of non-renewable primary energy resources	[MJ]	4.88E+06	4064
Use of secondary material	[kg]	0	0
Use of renewable secondary fuels	[MJ]	0	0
Use of non-renewable secondary fuels	[MJ]	0	0

Table 2 Whole building LCA results for environmental indicators (CML-IA baseline method ver. 4.02)

Parameter	Unit	Building Level	Per sqm
Global Warming Potential	[kg CO_2 eq.]	4.70E+05	391.9
Ozone Depletion Potential	[kg CFC11 eq.]	2.10E-02	0.0
Formation potential of tropospheric ozone photochemical oxidants	[kg ethene eq.]	1.11E+02	0.1
Acidification Potential	[kg SO_2 eq.]	1.49E+03	1.2
Eutrophication Potential	[kg PO_4^{3-} eq.]	5.00E+02	0.4
Abiotic depletion potential for non-fossil resources	[kg Sb eq.]	6.39E-01	0.0
Abiotic depletion potential for fossil resources	[MJ eq.]	4.88E+06	4062.7

CONCLUSIONS

Turkish Construction Materials Life Cycle Database is developed in compliance to international standards and European EN 15804 construction product norm. The Database contains high quality product specific datasets for Turkish construction materials as well as Turkish electricity and natural gas mix. Therefore, any study conducted using the Database will be highly relevant to Turkey and the results will be more precise contrary to studies using generic databases.

Environmental impacts evaluations of four-storey residential building using life cycle information from materials can be calculated to measurable indicators such as climate change effects. Embodied energy and carbon area two indicators that refers to carbon emissions, climate change effects and resource use due to construction materials. Besides, other environmental indicators are also available to measure if necessary such as acidification, eutrophication and so on.

Existing or future green building assessment schemes in Turkey will be able to utilize the Database. Such schemes will be more valuable when environmental indicators per square meter area provided to the end users is communicated. The Database also provides the opportunity to bring life cycle assessment to non-LCA experts such as architects, green building designers and other engineers.

The Database will open up a way to conduct environmental impact assessment of any building type with Turkish specific datasets. As such, measuring carbon impacts from Urban Transformation projects in Turkey will be an excellent opportunity to achieve Turkey's Kyoto II commitments. By doing so, future carbon burden on the industrial sectors will be minimized. This is life time opportunity not to be missed by the policy makers as well as all other stake holders.

ACKNOWLEDGEMENT

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REFERENCES

[1] EU COM (2011) 571, EU Roadmap to a Resource Efficient Europe.

[2] Buyle, M., Braet, J., Audenaert, A. (2013***). Life cycle assessment in the construction*** sector: A review. Renewable and Sustainable Energy Reviews. 26, 379-388.

[3] The International EPD System. (2016). What is an EPD? Available: http://www.environdec.com/en/What-is-an-EPD/. Last accessed 26/07/2016.

[4] Turkish Life Cycle Inventory Database, Turkish Centre for Sustainable Production Research and Design (SÜRATAM), www.surdurulebiliruretimmerkezi.org, 2014-2016.

[5] İlker KAHRAMAN, A Sustainable Building Assessment Model Proposal for New Residential Buildings in Turkey, PhD Thesis, Dokuz Eylül University Graduate School Of Natural And Applied Sciences, March 2013, İzmir, Turkey.

[6] Khasreen, Mohamad Monkiz., Banfill, P.F.G., Menzies, GF. ,. (2009). Life-Cycle Assessment and the Environmental Impact of Buildings: A Review. Sustainability. (1), 674-701.

[7] European Standard. EN 15978 Sustainability of construction works - Assessment of Environmental performance of buildings - Calculation method, European Committee for Standardization, November, 2011, pp. 21.

Paper No: 213

A Life Cycle Assessment Based Decision Support Model for Architecture-Engineering-Construction (AEC) Projects

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ABSTRACT

Environmental evaluation of built-environment has rapidly improved in our decade. As the Architecture-Engineering-Construction (AEC) industry is proved to have the highest share in resource demand, environmental impact of construction activities draws attention of many parties. Starting from high-performance buildings to green certificated examples, optimizing both the performance and profitability of AEC products have been the main goal of researchers and practitioners. Life-cycle assessment (LCA) is considered as the most scientific and comprehensive method developed for this purpose.

In developing countries such as Turkey, the main driving force of economy is AEC industry. Hence, rapid urban expansion dramatically increases the pressure on the existing infrastructure which affects buildings, public transportation, road networks, water quality, waste collection, public health, and overall energy usage. Higher rates in construction require an immediate need for methods of analyzing and controlling the environmental impacts of built environment.

The study aims to develop an LCA model for buildings in Turkey. For LCA studies, national databases are of crucial importance. This model is aimed to provide planners with design solutions depending on the localized life cycle data.

Keywords: Life cycle assessment, construction projects, decision support system

INTRODUCTION

The focus on sustainability is ever increasing in our daily life, in academic research efforts and in AEC industry. As a point of interest, sustainability has been defined numerous times in the literature. One common definition was introduced in the Brundtland Report [1] as: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

At early years of sustainable architecture, the promotions on agents such as green roof, recycling, renewable products and applications such as photovoltaic, geothermal panels had influenced the industry and increased the usage of mentioned components. But, neither the application of these green tools solely implies that the design target is achieved, nor it provides the level of success. As it is stated by Athena Sustainable Materials

Institute (ASMI) [2], above mentioned agents are just the means of sustainable architecture, what really matters is the measurement of embodied energy and greenhouse gas (GHG), consumption of raw materials, emissions, etc.

On the other hand, rating systems have been criticized for low sensitivity in rating categories and not including local priorities. Another major argument is about the consideration of building life-cycle. While, the operational phase of buildings is proved to have the largest effect on environment in most research efforts, without a comprehensive life cycle analysis (LCA), it is difficult to evaluate the total impact that a particular building has on its surroundings. Hence, it may be misleading to brand a product of AEC as "sustainable" without considering every impact that is done upon environment during its expected life-cycle. Even though substantial knowledge on energy-saving strategies for building operations can be found, there is still less information on the upstream (extraction, manufacturing, transportation) and downstream (deconstruction, disposal) impacts of buildings [3]. Moreover, performance of a particular building may be valuable if only the scope of evaluation is limited to building systems. If the scope is enlarged to built-environment, then we can assume that improvement of a single building may have a very little impact on the whole. In this case, impacts of urban scale components such as infra-structure, distance to urban center, means of transportation, etc. must also be included. The meaning of improving building performance should be questioned if the occupant is driving a fossil fueled car for three-hours a day.

The main goal is identified as developing an LCA-based model that is linked to a reference life cycle assessment study which is necessary to represent the material characteristics in Turkey. By building a reference study, it is possible to identify a national index for environmental impact projects. Only when the reference study may represent construction projects implemented in Turkey, it may be utilized as a model that presents output for planners and architects about environmental impact levels of different design scenarios.

On the other hand, there is a lack of research and data on the environmental impact of built environment and industrial products in Turkey. National databases are considered as the most important component of an LCA study. In the end of this study, while LCA of environmental impact of construction projects is performed and interpreted, also a necessary contribution to the literature of environmental impact of built environment in Turkey would be achieved; a three clustered database developed in this study may enable other researchers to conduct similar assessments.

LITERATURE REVIEW

Life cycle assessment studies the environmental aspect and potential impacts throughout a product's life from raw material acquisition through production, use and disposal. While LCA has been a methodology that is mostly developed by the Society for Environmental Technology and Chemistry (SETAC) and EPA, it may be the initial research by Kohler [4] that begins a thorough and comprehensive understanding of life-cycle building impacts. LCA-based assessment is a new approach in environmental assessment of built environment. It is intended as a comprehensive approach and championed for integrating the strengths of LCA and bridging the inadequacies of eco-labeling systems [3]. In the literature, LCA is often acknowledged as a science-based, fairly comprehensive, and standardized environmental assessment methodology [5].

LCA Framework Standards

As stated in ISO [6], there is no single method for conducting LCA studies. But, the International Standards Organization ISO 14040 series on how to conduct an LCA study was released in Geneva as a development of the ISO 14000 Environmental Management Standards. These include the four steps of an LCA study which are: goal and scope definition, inventory analysis (ISO 14041); impact assessment (ISO 14042); and interpretation (ISO 14043). A general introductory framework was also introduced (ISO 14040). According to this framework, an LCA shall include four main phases, such as; goal and scope definition, inventory analysis, impact assessment and interpretation of results.

Life-Cycle Assessment Approaches

In the literature, LCA can be grouped in two conceptually different approaches; process-based LCA (SETAC-EPA approach) and economic input-output analysis based LCA (EIO-LCA) [7] [8]. The major difference between the two approaches is that while process-based LCA focuses on the individual phases that are used to make a product or generate a service, the latter uses a macro economic framework that includes all the monetary changes generated in a country's economy by the production of a product or by the offer of a service.
While a growing body of literature discusses the importance of embodied energy, most studies rely on process analysis for its quantification. Hybrid analysis is the combination of both techniques. It consists of using process data where available and filling the systemic gaps with input–output data in order to assess the entirety of the supply chain of a product [9].

The two approaches above are integrated to provide a more accurate or cost-effective LCA or to provide alternative estimates for comparison purposes. In particular, the EIO-LCA can be applied for the materials extraction and manufacturing-stage assessments to advantageously use an economy-wide boundary; and to advantageously use its focus on specific processes, the SETAC-EPA LCA approach can be utilized in product-use and end of- life phase assessments [7].

Related Studies

In literature, there are some distinct approaches to research studies regarding LCA methodology. Most of studies put emphasis on a few components of buildings with a detailed life-cycle analysis or attempt to perform a whole building LCA with limited impact categories. At another perspective, the scale of research studies differs from building specific to urban scale. As the scale of the study expands, consequently the assumptions and uncertainty of the results tend to increase, though they present a greater picture on the environmental evaluation. Some researchers investigate the potential of LCA as a decision-making tool.

LCA as a Decision-Making Tool

Adoption of LCA methods in AEC projects has been limited due to features such as uniqueness of buildings, their very long lifespan, multi-functionality and being locally assembled. In addition, LCA methods typically require significant time and effort for implementation. The difficulties in applying LCA to the AEC industry have been noted by others, including obtaining complete environmental impact data for building components, tracking material flows, and clearly defining system boundaries. Building information modeling (BIM), which is increasingly used by AEC designers to digitally represent a facility during the early design stages, currently lacks interoperability with LCA software. Another challenge of performing LCA of a building project is the complexity and large number of decisions that a designer faces. Balancing between completeness and simplicity of use is one of the challenges in developing an effective and efficient environmental building assessment tools. Moreover, numerous researchers have shown that the earlier decisions are made in the design process and the fewer the changes to these decisions at later stages, the greater is the potential for reducing the building's environmental impact. In the literature, there are studies which imply that simplified LCA may be utilized as a decision-making tool.

Mereb [10] presented a tool to measure and subsequently improve the sustainability performance of a building over its entire life-cycle while still at the conceptual design stage. In their study, Tsai ***et al.*** [5] aimed to adopt life cycle assessment (LCA) in order to assess CO_2 emission costs at bidding stage and apply a mathematical programming approach to allocate limited resources to maximize profits for construction companies. Basbagill ***et al.*** [11] introduced a method for applying LCA to early stage decision-making in order to inform designers of the relative environmental impact importance of building component material and dimensioning choices.
Peuportier ***et al.*** [12] also put emphasis on the fact that decisions having the largest influence on building performance are made in early design. The authors claimed an eco-design tool should therefore be usable in this phase and also have a user-friendly interface which is essential to professional use.

METHODOLOGY

In this section, the LCA framework and methodology which is developed for this study is given in details. First, LCA framework development within ISO 14040 standards is introduced. Beginning with goal and scope definition (including system function and unit, boundaries, life cycle assessment method, etc.) and followed by life cycle inventory analysis (including necessary data, means of data collection and management), the whole life cycle analysis is explained. At the end of the analysis, an environmental impact database with three main clusters on construction projects in Turkey is to be achieved. By grouping the inputs and outputs according to the clusters, it is aimed to evaluate construction projects at different scales. These three main clusters are:

- Environmental impact by building typology
- Environmental impact by urban context
- Environmental impact demanded by sustainable solutions

At the next stage, the development of the model for decision support system is explained. The model is going to be presented in idef0 language, and possible feature of user-friendly software is going to be introduced. According to the results of a specific number of analyses, a reference model is to be established for the utilization of user-friendly software for aiding planners and designers at different stages of construction projects, and supporting clients in their decision-making.

In the following sections, the proposed framework for LCA of construction projects at differing scales is going to be defined. According to the necessities and purpose described above, the proposed framework is going to be explained in following sub-headings as depicted in ISO 14040.

Definition of the goal and scope

The aim and scope of an LCA study must be put forward clearly at the beginning. In this study, the goal is to analyze construction projects including urban context and develop a decision support system including possible sustainable solutions appropriate for the project typology. The main framework is given in Figure 1. Therefore, the main objective is to evaluate three construction projects and build a reference database of three main clusters which are (i) building typology, (ii) urban context and (iii) sustainable solutions.

Secondary objective is to form scenarios depending on the identified parameters for each cluster and build a decision support model. The parameters are going to be identified for each phases of architectural project flow, but initially schematic design phase is going to be included in this study.

At the first stage of LCA, the goal and scope is to be initially defined, including subsets as;

- The function of the system and functional unit
- The system boundaries
- Data requirements and quality
- Limitations and assumptions

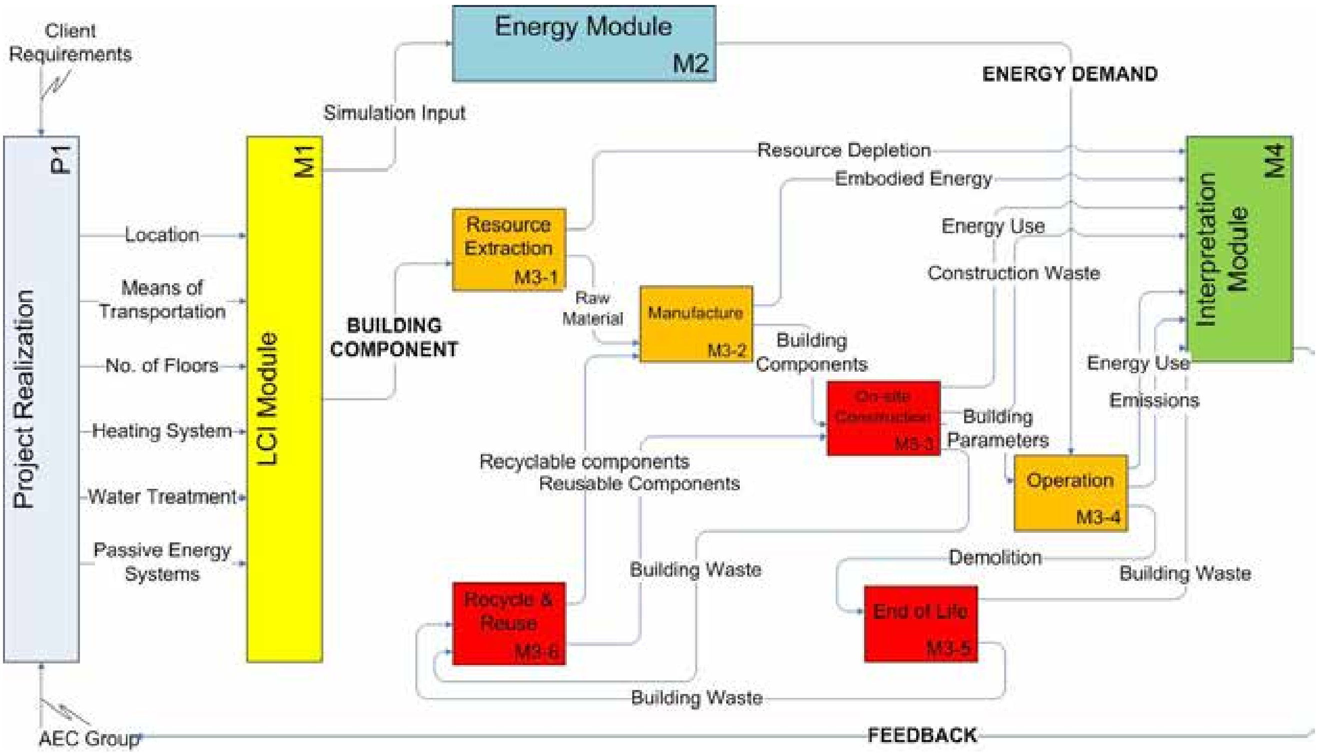

Figure 1 Framework Scheme

Function of the System and Functional Unit

Function of the system is defined as the total of all energy and resources that is extracted from nature in facilitating a construction project which includes several types of building material, along with the necessary infrastructure, and the total of all emissions that are produced during 50 years of service life.

Functional unit is proposed as two different units as; (i) living space (m^2) and (ii) parameters per capita. The living space is to be utilized for comparison of projects, while number of resident is to be used for assessing the relative effect of population density on the output of LCA.

System Boundaries

In the system boundaries, following factors not directly related to building LCA are omitted. These omissions are common practice for such study and are unable to be modeled. Construction of buildings and infrastructure, maintenance and end-of-life processes are excluded due to lack of data. Additionally, effect of traffic on transportation is ignored, as seen in Figure 2. The parameters derived from projects goals above are given in detail in the Life Cycle Cluster Databases section.

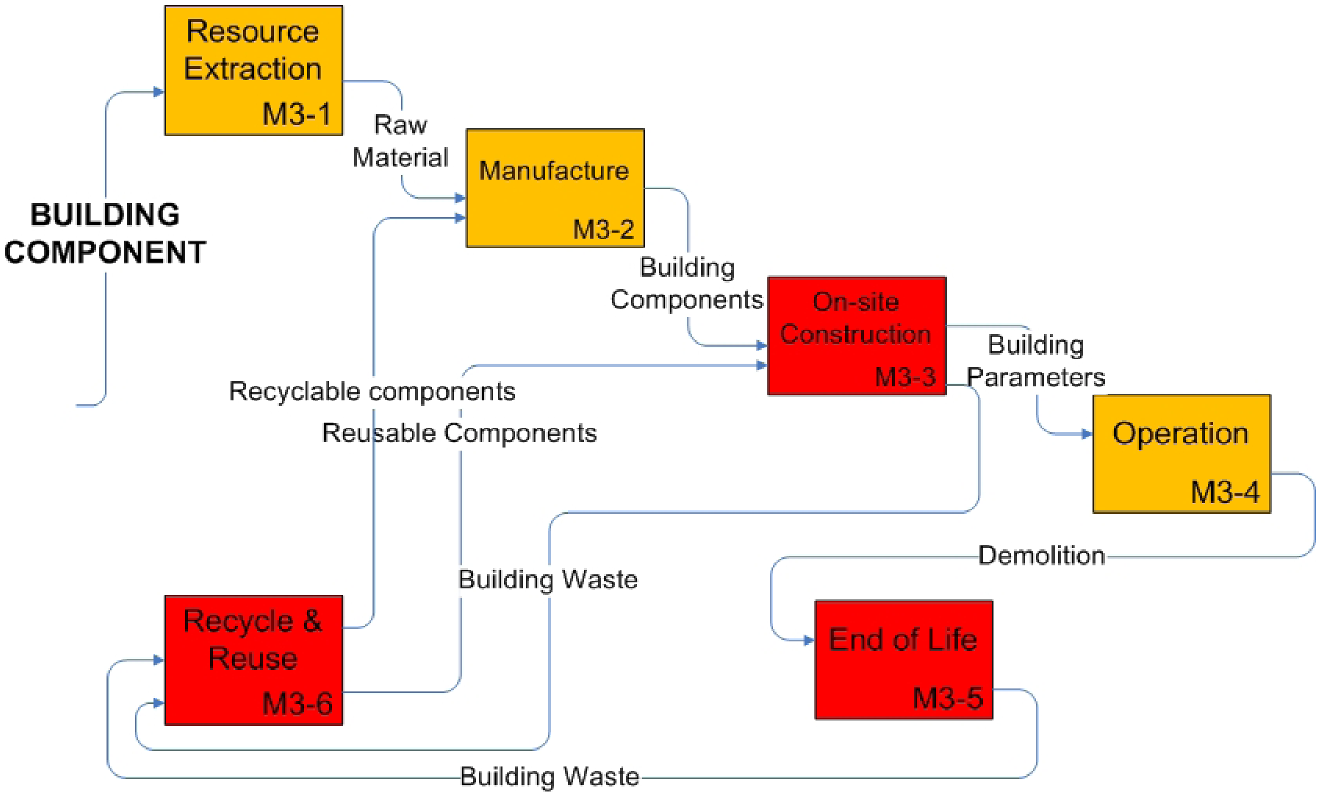

Figure 2 LCA phases included in proposed framework

Limitations and Assumptions

LCA methodology has its limitations, which are important to recognize while initiating the study and interpreting the results. Generally, the inventory analysis stage is considered to have the least uncertainty. The most of the weaknesses are related to the scope definition, impact assessment, and interpretation stages of the LCA.
General limitations are listed in ISO 14040 [6] as following: There are subjective choices (e.g., system boundaries, selection of data sources, and impact categories), the models used in inventory and impact assessment are limited (e.g., linear instead of nonlinear), the local conditions may not be adequately represented by regional or global conditions, the accuracy of the study may be limited by the accessibility or availability of relevant data, and the lack of spatial and temporal dimensions introduces some uncertainty in impact assessment.

Life Cycle Inventory Analysis (LCI)

After the life cycle framework is created, data management process is facilitated in order to build up a database which LCA framework will retrieve necessary quantitative input. The projects are evaluated through major elements defined in LCA, such as;

- Construction materials (including buildings, utilities and roads)
- Building operations (operational energy) and,
- Transportation (private automobiles and public transit).

Bill of quantities, architectural drawings and interviews with responsible staff (construction manager, site architect, etc.) are going to be utilized for necessary data. Statistical data for energy consumption and GHG emissions are going to be retrieved from TURKSTAT.

Construction materials for buildings are categorized as substructure, shell, interiors and services according to the Uniformat II framework. Equipment and furnishing, and demolition categories are excluded in this framework. For building operations, e-Quest energy simulation software is to be used for calculating energy demand. National statistical data and user data from questionnaires are to be utilized for defining different scenarios.
In this stage, beyond gathering statistical data for all items included in LCA, it is aimed to determine which components of projects in Turkey have the most significant environmental impact. By doing so;

- System boundaries can be redefined and less significant components can be omitted for the sake of simplicity and efficiency of the framework.
- Parameters are to be created for significant components for sensitivity analysis and for different user/ building scenarios.

In the end of prepared LCAs, average values on the basis of per square meter of living area will be achieved. By defining variables on these values; cost, operational and transportation expenses, total energy demand and CO_2 emissions can be calculated for varying scenarios. Parameters are going to be grouped under main clusters of the LCA framework are further explained in following section.

Life Cycle Cluster Databases

For LCA studies, national databases are of utmost importance [13]. In the scope of this study, proposed methodology can be customized according to the accessibility of data; information is to be stored on processes and materials that have significant environmental impact. By performing this study, a new environmental impact database with three main clusters for construction projects analysis is going to be created. The main clusters are as follows and can be seen in Figure 3;

Cluster-I: Environmental impacts based on Project Typology

According to the typology of the construction project, parameters are going to be altered. Height and heating system are set as varying features of this typology. The structural system with varying building height is going to have differing environmental loads. Heating system is going to have a crucial impact when combined with user behaviour. This database cluster is going to be beneficial for planners to compare the loads creating by low, medium and high building; central and individual heating system options during the design stage.

Cluster-II: Environmental impacts based on Urban Context

Buildings are going to have different environmental loads depending on the available means of transportation and location. Defining LCA parameters and creating a database for private/public transportation will enable the planners to compare the environmental loads of urban planning options.

Cluster-III: Environmental impacts based on Sustainable Solutions

Sustainable solutions for buildings are widely used for lowering energy demand and utilizing renewable energy sources. It is possible to integrate a holistic sustainable system for projects at larger scales. Photovoltaic panels, grey water treatment systems, biogas energy are several options that can be utilized in this study and their environmental impact may be analyzed as well.

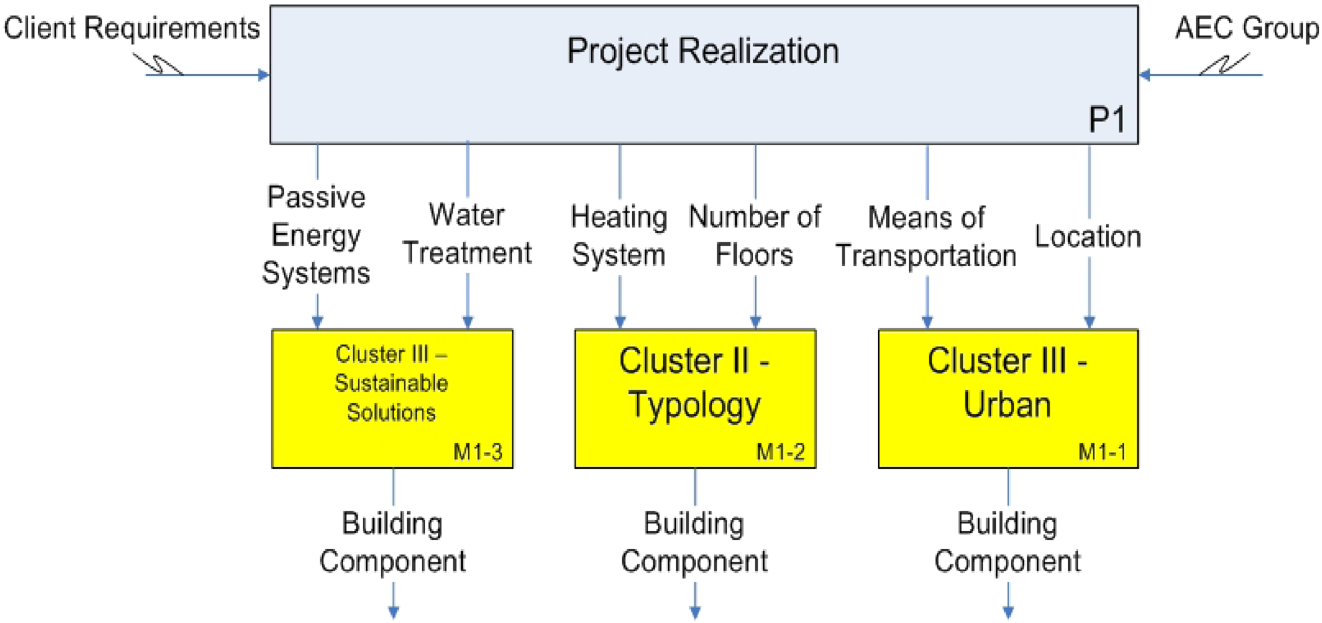

Figure 3 LCI Database Clusters

Life Cycle Environmental Impact Assessment (LCIA)

As the necessary data is prepared and parameters are defined, impact assessment is to be performed. The initial output of the assessment is going to be used to refine the LCA framework and for defining significant components of high environmental load. The output data is going to be integrated with decision support system. In Figure 4, assessment framework for this study can be seen.

Impact assessment methodologies are configured specifically for each primary categories that are construction materials (buildings, services and infrastructure/roads included), building operations and transportation (private and public).

For construction materials, hybrid LCA methodology is preferred for enhancing the accuracy of the analysis where available data is to be utilized in detail whereas missing data is to be compensated with economical generic data. The significant components of the construction projects are to be defined at initial steps of data collection stage, and these main components are focused as the points of attraction of the study. If possible, process data is to be used for all significant components.

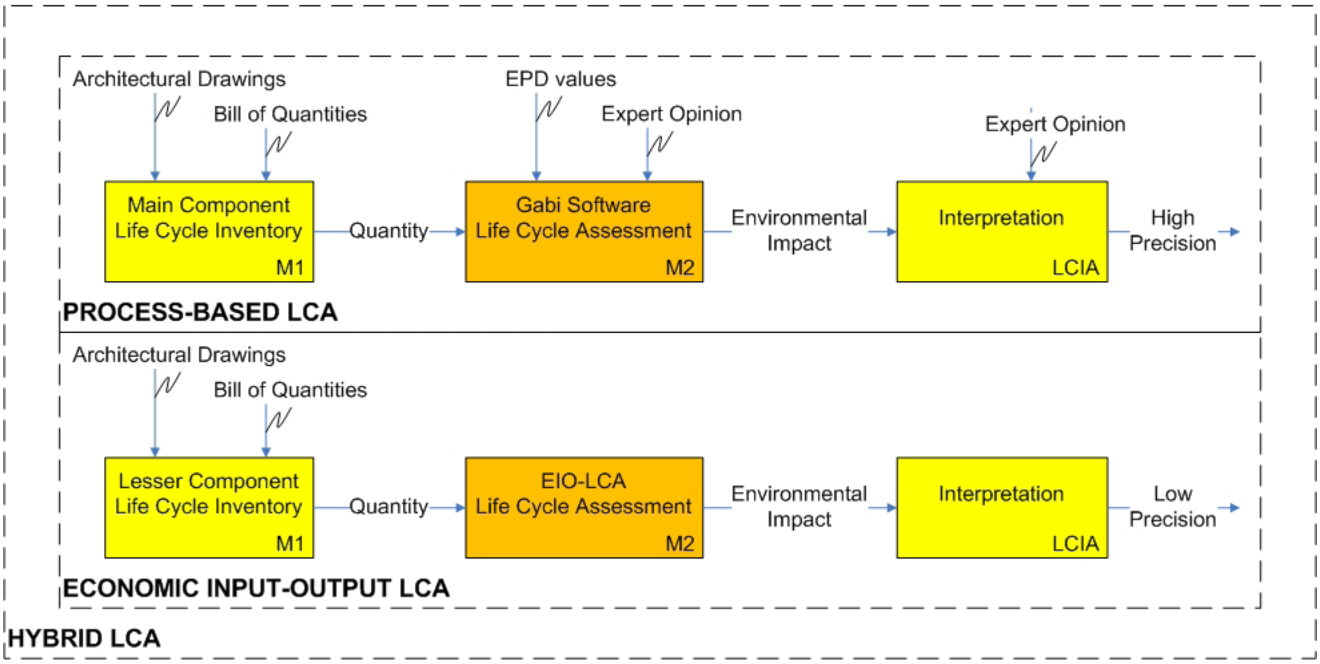

Figure 4 Hybrid LCA Methodology

Interpretation

Interpretation of the life cycle inventory analysis (LCIA) is going to be conducted through the main clusters as well. By altering parameters, different scenarios can be built and compared for achieving an optimized design solution. By separating environmental solutions, net impact decrease can be seen clearly. Different solutions can be compared and results can be analyzed with ease. The framework in detail can be seen in Figure 5.

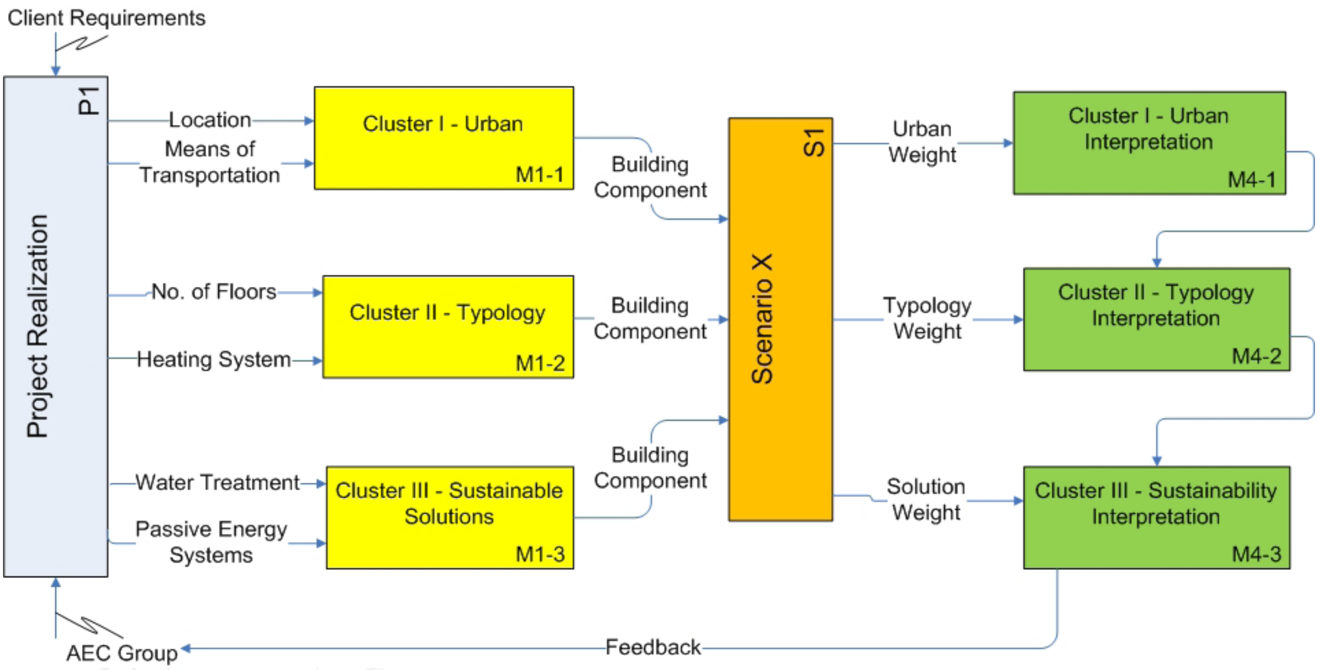

Figure 5 LCI-LCIA to Interpretation Module

CONCLUSION

Decision-based support systems require a solid and representative data set for providing healthy outputs. LCA studies have the potential to be the strongest method in which holistic databases can be utilized for taking decision. For such studies, local databases are of crucial importance. Development of databases should be conducted according to the local/national data in order to have a representative knowledge-base.

This study may provide an initial framework to develop a decision making model while also comprises a step for developing a national database on construction industry. Further studies may be conducted for different building typologies on various scales.

REFERENCES

[1] WCED. Our Common Future, Brundtland Report, United Nations World Commission on Environment and Development. 1987

[2] Athena Sustainable Materials Institute (ASMI) .Technical Details. [Online]. Available from: http://www.athenasmi.org/resources/about-lca/technical-details/ [Accessed at 10 September 2013]

[3] Ragheb, A. F. Towards environmental profiling for office buildings using life cycle assessment (LCA). 2011. (3476786, University of Michigan). ProQuest Dissertations and Theses, 185. Retrieved from http://search.proquest.com/docview/896355684?accountid=13014. (896355684).

[4] Kohler, N. The relevance of Green Building Challenge: an observer's perspective. Building Research & Information, 27:4-5, 1999, pp.309-320.

[5] Tsai, W-H., Lin, S-J., Liu, J-Y., Lin, W-R., Lee, K-C. Incorporating life cycle assessments into building project decision-making: An energy consumption and CO2 emission perspective. Energy, Volume 36, Issue 5, 2011, pp.3022-3029.

[6] ISO International Standard 14040. Environmental management – Life Cycle Assessment – Principles and framework. International Organization for Standardization (ISO), 1997E, Geneva.

[7] Hendrickson, C, A. Horvath, S. Joshi and Lave, L.B. Economic Input-Output Models for Environmental Life Cycle Analysis. Environmental Science & Technology, Volume 32, No. 7, 1998, pp. 184A-191A.

[8] Hendrickson, C. T., Lave, L. B. and Matthews, H. S. Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach. Resources for the Future Press, 2006.

[9] Stephan, A., Crawford, R. H., Myttenaere, K. Towards a comprehensive life cycle energy analysis framework for residential buildings. Energy and Buildings, Volume 55, 2012, pp. 592-600.

[10] Mereb, M. M. GREENOMETER-7: A tool to assess the sustainability of a building's life cycle at the conceptual design phase. 2008. (Order No. 3309246, Cleveland State University). ProQuest Dissertations and Theses, 380. Retrieved from http://search.proquest.com/docview/250785741? accountid= 13014. (250785741).

[11] Basbagill, J., Flager, F., Lepech, M., Fischer, M. Application of life cycle assessment to early stage building design for reduced embodied environmental impacts. Building and Environment, Volume 60, 2013, pp.81-92.

[12] Peuportier, B., Thiers, S., Guiavarch, A. Eco-design of buildings using thermal simulation and life cycle assessment. Journal of Cleaner Production, Volume 39, 2013, pp. 73-78.

[13] Trusty, W. B., and Horst, S. Integrating LCA Tools in Green Building Rating Systems. The Athena Sustainable Materials Institute. Merrickville, Ontario, Canada. 2003.

Building - Rating Tools/Best Practices

Paper No: 42

A Critical Review of Green Building Certification Systems Regarding Historic Buildings

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ABSTRACT

This paper investigates the leading green building certification tools and the weakness of these tools when applied to historical context. Existing and historic buildings can be refurbished through proper retrofitting that allows buildings use less energy as well as produce less waste, use environmentally friendly products and innovative techniques to be more sustainable. Global carbon problem also requires building owners new ways of doing refurbishments. The authors are aiming to draw a roadmap for professionals who are in cultural heritage preservation for the usage of green building certification systems. Green building certification systems are tools used to define the environmental rating of the buildings and communities. A critical review of BREEAM **(**Building Research Establishment Environmental Assessment Method**),** LEED (Leadership in Energy & Environmental Design) and GBC (Green Building Council) Italy's recently formed green building system tailored to be used for historical buildings are examined. The analysis shows that existing tools need to be tailored to historical building projects and need to incorporate credits for cultural preservation and sustainability. Newly formed GBC Italy may be a good start for those countries which want to create their own tools.

INTRODUCTION

The building industry's full range of impacts on the environment — including product manufacturing, site preparation, construction activity, and building occupancy and operations — accounts for 40% of natural resources consumption, 40% of total primary energy consumption, 15% of the world's fresh water resources, 25% of all waste generation, and 40-50% of greenhouse gas emissions [1, 2]. The larger source of emissions results from the operating emissions from the 300+ billion square feet of buildings we already have. Emissions from existing building operations are about 2.2 billion metric tons/year [3].

A building owner/manager can use existing green building certification systems in order to green existing buildings. Historical buildings have their unique requirements and preservation standards which are set by the governments. This paper focuses on using established green building rating systems like LEED, BREEAM and GBC Italy to compare their approaches to the historical context.

Even though historical buildings consist of a significant part of the existing building stock in many countries, leading green building rating systems do not take into account the requirements of traditional and historical buildings to be sustainable, as much as they do for new buildings. Yet, these buildings have to be investigated carefully apart from the "existing" category due to their cultural and architectural value. Their authenticity and integrity should not be sacrificed to the existing regulations and solutions that are not acceptable and revisable for their structures. Also, successful and innovative retrofits by the accurate conservation approach will enhance the historical buildings and settlements while supporting the energy consuming policies and protecting the natural environment. The evaluation of specific criterias is needed to the historical buildings' remarkable role in the existing building stock for a sustainable conservation.

SUSTAINABILITY AND HERITAGE CONSERVATION

Historical properties can be conserved in such a way so that they can be environmentally sustainable and contribute to the sustained growth of metropolitan areas. National Institute of Building Sciences of US suggest to employ Energy Star and/or a green building rating system for existing buildings like LEED for Existing Buildings: Operations and Maintenance (LEED EBOM) or Green Globes for Existing Buildings to gage the building›s level of performance. For historic buildings, updating systems appropriately to maintain a balance between the need for energy and water savings with the character of the original building fabric is recommended [4].

Preservation maximizes the use of existing materials and infrastructure, reduces waste, and preserves the historic character of older towns and cities. The energy embedded in an existing building can be significant of the embedded energy of maintenance and operations for the entire life of the building. Sustainability begins with preservation [5]. A recent report "The Greenest Building: Quantifying the Value of Building Reuse (2011)" delved into the question of how green an existing building truly is. The Preservation Green Lab, a part of the National Trust for Historic Preservation, with the assistance of building constructors, sustainability consultants and life cycle analysts, established a set of case studies of recognizable building types; both renovated existing and new construction, in order to quantify the benefits of building reuse against that of new construction. Part of understanding how heritage protection and environmentally sustainable design can work together is in recognizing and understanding the shared challenges the two areas face when dealing with the impacts of climate change. Numerous studies that have been completed on the topic of retrofitting historic buildings to make them more energy efficient. The methods and techniques are most practical and sensitive when dealing with historic structures. This information is often hard to come by in an area which is still emerging – the concept of 'greening historic buildings' gained momentum in the past 5-10 years [6].

More and more of the projects involving heritage buildings are being assessed using the LEED, GB Tools, Green Globes, and other assessment systems. This information should be assembled and reviewed as case studies to determine whether there are other general conclusions that can be reached about sustainability-assessment systems for heritage properties [7].

SUSTAINABILITY AND HERITAGE PROPERTIES

Part of understanding how heritage protection and environmentally sustainable design can work together is in recognizing and understanding the shared challenges the two areas face when dealing with the impacts of climate change. Numerous studies that have been completed on the topic of environmental sustainability and heritage properties. The methods and techniques are most practical and sensitive when dealing with historic structures. This information is often hard to come by in an area which is still emerging – the concept of 'greening heritage properties' really only having gained momentum in the past 5-10 years [6]. The importance of promoting energy conservation and sustainability during heritage conservation is studied by several researchers [7]. However the large body of research on building retrofits available is in the public domain. But existing buildings continue to be upgraded at a very low rate [8]. For instance, the existing commercial building stock is currently being retrofitted at a rate of approximately 2.2% per year only [9]. Among these retrofits which are certified with systems like BREEAM and LEED, used these systems without adapting to local conditions. For heritage conservation, national and regional priorities and conditions may be hurdles to overcome while using these systems as is. The emphasis on quantifiable values provides a difficult field for the integration of the more qualitative issues associated with community and cultural sustainability [7].

INTERNATIONAL GREEN BUILDING CERTIFICATION SYSTEMS

The negative effects of climate change and the increase in the public's environmental awareness are creating pressures on every industry to come up with creative solutions to reduce GHGs. Stakeholders of the construction industry are demonstrating their commitment to solve environmental problems by building in a more environmentally friendly way through using environmental standards for their buildings [10].

Green building certification systems can be used to provide design and operations guidance, document progress toward a design or operational performance target, compare buildings using the certification systems structure, and document what design and operations outcomes and/or strategies are being used in the building. An "apples-to-apples" comparison of the certification systems is challenging because the development basis is different for each system [11].

International Green Building Certification tools have been transforming the market place through design, construction and maintenance practices since 1990s.
LEED and BREEAM are the most used of international systems. BREEAM of UK was the first system developed for New Construction by BRE Global. LEED followed BREEAM. Other systems started being used in the market in the past 25 years. LEED-EBOM rating system is the longest established and most widely used existing building system. BREEAM-In-Use is the BRE's existing building certification system. These certification systems provide a framework and they are tiered. They require a minimum number of points or credits to be achieved for a base level of certification, with higher levels of certification available based on accumulation of additional points or credits. Their rating process is conducted through benchmarking the assessed building against prescribed performances indicators. Even though BREEAM-In-Use and LEED-EBOM exist in the market over 20 years, there was no demand from the industry for their use in historical restoration.

BREEAM SYSTEM

BREEAM of UK aims to work for all types of buildings including homes, offices, hospitals, schools, warehouses, data centers etc. including historical buildings. Based on the screening completed from BRE Global web page, the BREEAM systems used by practitioners for assessing the environmental sustainability of heritage properties are BREEAM UK Refurbishment and Fit-Out and 2014-Non Domestic. Historical buildings are defined as listed buildings – Grade I, Grade II* and Grade II (England and Wales), Grade A, B and C (Scotland) and A, B1 and B2 (Northern Ireland), existing buildings situated in conservation areas (where the existing building itself has conservation status and contributes to the status of the conservation area), existing buildings which are of architectural and historical interest and which are referred to as a material consideration in a local authority's development plan and existing buildings designated as being of architectural and historic interest within national parks, areas of outstanding natural beauty, and world heritage sites.

HISTORIC BUILDINGS

For the purpose of assessing historic buildings under the BREEAM Refurbishment and Fit-out scheme, historic buildings are defined as building's or monuments that are formally listed and protected under international, national or local laws or schedules and therefore subject to local planning and building regulations, including buildings that are in a conservation zone. Such buildings will normally require consent from the local, national or international historic buildings authority (e.g. UNESCO, Architects des Batiments de France (ABF), the National Heritage Board of Poland etc.). Within this scheme document, there are a number of Compliance notes that should
be referred to where undertaking an assessment of a historic building.

TABLE 1 Assessment Parts

Project Type		**Assessment parts typically applied**		
	Part 1 Fabric and Structure	Part2 Core Services	Part3 Local Services	Part 4 Internal Design
	✓	✓	✓	✓
First fit-out		✓*	✓	✓
Secondary fit-out		✓*	✓	✓
Shellonly	✓			
Shelland core	✓	✓		
Upgrade of central M&E plant		✓		
Upgrade of local services			✓	
Changeofuse	✓	✓	✓*	✓*
Heritage building refurbishment	✓*	✓	✓	✓
Internal refresh/remodeling				✓

NEWLY CONSTRUCTED BUILDINGS

Newly constructed buildings cannot be assessed under the BREEAM Refurbishment and Fit-out scheme and should be assessed under the BREEAM International New Construction scheme [12]. The exception is the assessment of a fit-out being undertaken in an existing but newly constructed building. There are however other situations where a building may be defined as a new build while incorporating existing building elements. This includes:

- Where there is no more than one façade (or two on a corner site) of a pre-existing building being retained as an explicit condition as part of Planning Permission, incorporated as part of the new shell,

- Where there is more than one façade and/or party walls of a pre-existing building/s retained and a new shell is being constructed behind the retained façade.

A building is being extended to create additional floor area that is contained entirely within the extension with no internal access between the two buildings. The structural elements of an existing building are stripped back to its frame, for example removal of the external walls, roof and all services, leaving the structural frame and floor and ceiling slab. This is a positive approach to the protection that distinguish the real restoration projects from some projects called as “restoration”, for instance some renewal projects protecting only the facade.

The credits where conservation parameters are discussed are follows:

Environmental section weightings: Environmental weightings are fundamental to any building environmental assessment method as they provide a means of defining, and therefore ranking, the relative impact of environmental issues. BREEAM uses an explicit weighting system derived from a combination of consensus based weightings, ranking by a panel of experts and where necessary an adaptation process to reflect local conditions in a country (or region if the country has a significant land mass with varied climates or environmental issues). These are then used to determine the relative value of the environmental sections used in BREEAM and their contribution to the overall BREEAM score.

Adaptation of weightings for local conditions: In order to provide weightings that are adapted for local conditions, the weightings are reviewed for the first project that registers for assessment in a country or region. These weightings are then set as appropriate for that project and all other projects thereafter in that country or region for the life of the current BREEAM International Refurbishment and Fit-out version. The development of these weightings is based on robust and independent information forwarded from ‘local experts’ who have an understanding of local conditions. This may be a member of the design team if they can demonstrate sufficient knowledge of the environmental conditions of the region or country, or another individual or organization with the relevant expertise. The weightings are tailored based on the ten technical categories, with categories being considered ‘Global’ or ‘Local’. Global categories are those defined as having a universal impact, independent of the local context. Local categories are those defined as being variable locally, due to social, environmental, political or economic factors. BRE Global will take account of these factors when determining the relative importance of the technical sections.

The influence of location: As well as having an impact on the weightings attributed to BREEAM sections and assessment issues (see section weightings above), the culture, economy, climate and work practices can also affect the development of criteria and the method of assessing certain BREEAM issues.

One example involves the opportunity for rainwater recycling in BREEAM issue. Wat 01 Water consumption. In this instance the higher performance benchmarks vary according to amount of precipitation available. The assessor can determine the climatic zone in which the building is located using the map provided in BREEAM Manual and consequently use this climatic zone to establish the appropriate water consumption benchmark for a building in that location.

Use of local codes and standards: Certain criteria in BREEAM, require compliance with specified standards and/or best practice documents. In some countries there may be local equivalents of these standards and in these cases BREEAM International allows BRE staff, with support from assessors and the project team, to review the local standards against BREEAM specified requirements and confirm their equivalence. If BRE Global approves the standard as equivalent, the local standard will form part of the approved named standards for that country, region or area. The individual requirements for a particular local standard and a list of approved standards are provided in the Approved standards and weightings list for the BREEAM International Refurbishment and Fit-out scheme.

Every BREEAM International assessment must include a completed (project specific) version of the Approved standards and weightings list to inform BRE Global which standards the project team have worked to and complied with. This may involve the use of a 'New country worksheet' or, where assessments have already been undertaken in that country, an 'Existing country-specific worksheet' that is amended to suit the specific project. Confirmation is required that previously approved standards remain valid and up to date.

CREDITS RELATED TO HISTORIC BUILDINGS

In the energy section, Ene 01 Reduction of energy use and carbon emissions there are two additional credits are available for Historic buildings, up to a maximum of twelve or fifteen depending on whether option 1 or option 2 is being used respectively as detailed in criteria 1 and 2, where:

- A specialist study has been undertaken by a Suitably Qualified Heritage Conservation Specialist at the Concept Design stage (equivalent to RIBA Stage 2), to investigate the implications of improving building fabric and services performance while minimizing the potential negative impacts of both the historic character of the building, the condition of the building fabric and indoor air quality.
- The study includes looking at the potential for improving ventilation, air tightness and moisture control within the building, ensuring that these are considered in balance with that of the welfare of the historic building fabric. This includes considering materials specified, impacts on breathability of the building, paying attention to additional ventilation that may be required e.g. roof, wall and floor voids.

For Ene 04 Low carbon design (Credit Number (CN) 21 Historic buildings) under some circumstances a feasibility study may be undertaken however due to listed building consent and/or planning conditions in a conservation area, there may be no recommendations that can be implemented. In this situation, this is still compliant provided it can be demonstrated that a wide range of options have been considered with consultation input from the local authority conservation officer, e.g. locating LZCs out of public view, use of screens etc. and the report contains evidence to support these findings.

In materials section Mat 05 Designing for durability and resilience (CN Historic Buildings) for listed buildings and buildings in a conservation area, measures to protect vulnerable parts of the building from damage (criterion 1) and to limit material degradation (criteria 2 and 3) should be based on the measures that are feasible within the scope of any heritage requirements that may be explicitly required by the relevant conservation authority (e.g. The local authority heritage office).

In Management section, Man 02 Life cycle cost and service life planning (CN6 Heritage building) where there are conservation requirements that set an explicit requirement from a relevant conservation or heritage authority (e.g. UNESCO, a national or local heritage body, local authority conservation or heritage officer) regarding the selection of components and materials. The Elemental life cycle cost and component level LCC plan should be based upon the range of materials and components that are allowable within the heritage restrictions in order to identify the option that provides the lowest life cycle cost. Where there are components or materials where only one product type is allowable as a result of heritage requirements, this can be excluded from the study.

In Health and Wellbeing section Hea 01 Visual Comfort credit (CN5 Historic buildings; lighting zoning and controls) an explicit requirement from the relevant historic buildings conservation authority (e.g. local authority conservation officer) may require the retention of heritage features which prevents zoning of lighting in accordance with criterion 13 in some cases. In such cases, evidence should be provided from the conservation officer and measures should be considered to ensure that adequate control is provided for existing retained lighting zones and measures adopted for the provision of task lighting as relevant for the function type and as is feasible within the constraints as applied by the conservation officer.

For credit Hea 02 Indoor air quality (CN5 National best practice standards/relevant industry standards) it is recommended to refer to the country specific reference sheet to locate the appropriate national best practice standards in the country of assessment. Alternatively, the minimum requirements as set out in the Approved standards and weightings list are covered by the proposed documents. Where appropriate standards do not exist for a country, the design team should demonstrate compliance with the British or European standards as listed in each relevant country reference sheet

For CN12 Paints and varnishes in historic buildings, an exemption is provided for historic buildings where there is an explicit requirement from the Local Authority conservation officer or the national conservation body to use specific paints and varnishes that may contain a high level of VOCs In all cases procedures should be in place to ensure the building is flushed out for a sufficient period prior to occupation and ventilated adequately in order to reduce risks with VOCs in accordance with criteria 1 and 2.

Credit Hea 04 Thermal comfort (CN9 Meeting Criterion 3 in Historic Buildings) the thermal comfort requirements must still be in accordance with criteria 1-5 in order to demonstrate compliance), except where alternative performance standards are required by a local or national conservation body or authority. Heating systems should be modeled for continuous heating rather than intermittent.

Hea 05 Acoustic performance (CN12 Historic buildings) For historic buildings, full credits available can still be achieved where full compliance has not been met where confirmation is provided from a SQA(Suitably qualified acoustician) that the design has improved the acoustic performance as much as possible taking into account the restrictions as detailed in a report from a conservation officer.

For Mat 05 Designing for durability and resilience (CN1 Historic buildings) for heritage buildings and buildings in a local/national conservation area, measures to protect vulnerable parts of the building from damage (criterion1) and to limit material degradation (criterion2) should be based on the measures that are feasible within the scope of any heritage requirements that may be explicitly required by the relevant conservation authority (e.g. the local authority heritage office). This should consider the range of options that may be feasible in order to demonstrate compliance with justification provided, including reference to documentary evidence to verify any restrictions that are in place that prevent compliance with any durability measures (including those specified in CN1.1)

BREEAM UK Refurbishment – domestic where the dwelling is a historic building and sound testing results demonstrate existing separating walls and floor meet the historic building credit requirements, up to four credits may be awarded as shown in Table 2 and described in CN10.

CN10 Historic Buildings credit requirements for attached dwellings within Historic Buildings, the following credit requirements apply: Pre-completion testing should be carried out before and after refurbishment by a suitably qualified acoustician to determine whether the sound insulation values for historic buildings have been met as found in the Table 2 covering Sound insulation values for historic buildings.

TABLE 2 Sound Insulation Values

Credits	**Airborne Sound Insulation Values**	**Impact Sound Insulation Values**
1 credit	No worse than the values determined pre-refurbishment	
2 credits	3dB higher than before refurbishment	3dB lower than before refurbishment
3 credits	5dB higher than before refurbishment	5dB lower than before refurbishment
4 credits	8dB higher than before refurbishment	8dB lower than before refurbishment

For Hea 05 ventilation, one credit can be awarded where the following whole dwelling is brought up to the following ventilation requirements:

- A minimum level of background ventilation is provided (with trickle ventilators or other means of ventilation) for all habitable rooms, kitchens, utility rooms and bathrooms compliant with section 7, Building Regulations Approved Document Part F, 2010.
- A minimum level of extract ventilation is provided in all wet rooms (e.g. kitchen, utility and bathrooms), compliant with section 5, Building Regulations Approved Document Part F 2010.
- A minimum level of purge ventilation is provided in all habitable rooms and wet rooms, compliant with section 7, Building Regulations Approved Document Part F, 2010.
- The building is a historic building (CN4) and meets the requirements for historic buildings below.

Two credits can be awarded where:

- Ventilation is provided for the dwelling that meets the requirements of Section 5 of Building Regulations Part F in full.
- Where the building is a historic building and meets the requirements for historic buildings (CN4).

CN4 requirements for historic buildings are the majority of historic buildings are constructed of porous materials that both absorb moisture and allow it to escape. Ventilation stops this moisture building up in any one place and causing damage and problems with condensation and mould. However, historic buildings typically have high levels of air infiltration leading to discomfort and heat loss. Historic buildings also typically require a higher level of infiltration to remove structural moisture in the absence of impermeable damp proofing. The refurbishment should be designed to meet the requirements of Building Regulations Part F section 3.11–3.16 and reference is made to the guidance provided in: The guide to building services in historic buildings, CIBSE, 2002

BS 7913: Guide to the principles of conservation in historic buildings. Building Regulations and Historic Buildings, English Heritage 2004 Guide for Practitioners, conversion of traditional Buildings, application of the Scottish Building standards, Historic Scotland, 2007.

One credit is awarded where an assessment is carried out to establish the current levels of air tightness and structural moisture prior to the specification of fabric measures and heating systems. The assessment should establish the appropriate level of ventilation for the building, based upon: The minimum ventilation requirement to meet that set out in Building Regulations Approved Document Part F.

Ventilation rates in all habitable and inhabitable spaces are sufficient to allow structural moisture to be dealt with effectively. This may be required by Building Regulations Approved Document Part F where the structure or fixtures needs higher levels of ventilation in order to deal with moisture levels. Two credits are awarded where the first credit is achieved and where the following testing was also carried out in order to develop the ventilation and air tightness strategy for the building: Pressure testing was carried out before and after refurbishment in accordance with the appropriate standard. Temperature and humidity is monitored before and after refurbishment.

ITALIAN SYSTEM

Italian Green Building Council decided to develop GBC Historic Building™ [14], a new LEED®-based rating system for the voluntary certification of the sustainability level in restoration, recovery and integration of historic buildings, with the ultimate purpose of recognition, enhancement and transmission to the future of cultural heritage in its usefulness, historic interest and significance [13]. The system consists the same topics as LEED NC (new construction): sustainable sites, water management, energy and atmosphere, materials and resources, indoor air quality, innovation and design and regional priority. GBC added an extra topic "historic content" to be used in historical buildings as can be followed from TABLE 3.

TABLE 3 Green Building Council Italy Historic Buildings Score Card

Historical Content	**To**	**Points**
Prerequisite-1	Preliminary Conceptual Assessment	**Max points:20**
Credit 1.1	Advanced Conceptual Assesment: Energy Assessment	**1-3**
	First Level Assessment	**1**
	Comprehensive Assessment: Thermal Imaging	**1**
	Comprehensive Assessment: Thermal Imaging on site	**1**
Credit 1.2	Comprehensive Conceptual Assessment: Defining material and Shape distortions	**2**
Credit 1.3	Comprehensive Conceptual Assessment: Diagnostic research of the building and structural monitoring	**1-3**
	Diagnostic Research of the Building	**1-2**
	Structural Monitoring	**1**
Credit 2	Reversibility of preservation inititave	**1-2**
Credit 3.1	The suitability to the purpose of building's function and	**1-2**
Credit 3.2	The chemical/physical suitability of the mortar used to renew the building	**1-2**
Credit 3.3	Resemblance to the existing building	**2**
Credit 4	Sustainable renovation site	**1**
Credit 5	Planned maintenance level	**2**
Credit 6	The expertise in architecture and landscape design	**1**

LEED SYSTEM

LEED is the most widely used third-party certification for green buildings. LEED aims to work for all types of buildings including homes, offices, hospitals, schools, warehouses, data centers etc. including historical buildings. LEED does not have a specific certification type for historical buildings. However, historical buildings can pursue LEED BD+C (New Construction & Major Renovation) certification if they go through a major renovation or LEED EBOM (Existing Buildings Operation Maintenance) certification. More than 100 historical buildings around the world achieved LEED BD+C or EBOM so far. The oldest LEED certified building is Sede Centrale - a Venetian Gothic palazzo built in 1453 -. Also, other historical buildings such as Fay House in

Harvard University built in 1807 and Empire State Building built in 1931 are LEED certified [16]. LEED has a set of environmental criteria which is used worldwide in all types of buildings. Since LEED is not specifically designed for historical buildings, it doesn't include any additional credit for preservation of the historical building. LEED BD+C "Materials & Resources Category Credit 1: Building Re-use" focuses on maintaining the existing building structure (including structural floor and roof decking) and envelope (the exterior skin and framing, excluding window assemblies and non-structural roofing material) in order to extend the lifecycle of existing building stock. This credit awards 4 points out of 110 total points in LEED [17].

Implementing LEED in a historical renovation may be challenging since both the preservation and LEED standards must be applied in the project. According to a survey of professionals who involved in LEED certified historical building projects, 25 of 33 professionals agreed that it was difficult to fit a historical building into one LEED rating system [18]. The survey also shows that some LEED credits are easier to obtain in historical buildings such as Sustainable Site (SS) credit 5.1 Site Development – Protect and Restore Habitat, MRc1.1 Building Reuse – Maintain Existing Walls, Floors and Roof, MRc1 Building Reuse – Maintain Existing Walls, Floors, and Roof, MRc1.2 Building Reuse – Maintain Interior Nonstructural Elements, and MRc3 Recycled Content. On the other hand, some credits are harder to get such as EAc1 Optimize Energy Performance. The EA category relates to the building envelope, which includes the standards for insulation and energy efficiency. In order to install the insulation or other energy efficiency strategies properly it would require the removal of the historic finish, which can be damaged in the process. The restoration of a 19th century Italianate farmhouse has achieved LEED Gold certification. Despite the fact that some preservationists don't believe that historic restoration can be accomplished sustainably, the Hardman Farm house restoration demonstrates that historic restoration and green building principles go hand-in-hand and actually complement one another [19].

CONCLUSIONS

There is a need to re visit to define methodological principles for the development and use of green building certification systems for heritage properties. Existing green building certification systems have performance rating scale at the levels of indicators and buildings. But heritage conservation, needs qualitative issues integrated into the scoring system. Social values and environmental benefits of preserving historical structures need to be addressed better in existing systems like LEED and BREEAM. There is more engagement needed for the preservation, sustainability, and the way construction is handled. There is a need for special codes according to the regions of countries and local preservation experts has to assess historical buildings going through preservation work. Italian GBC's adaptation of LEED and addition of historical content to LEED NC is a beneficial start. This system needs to be used on pilot projects to see the best outcomes in other countries.

REFERENCES

[1] http://www.worldwatch.org/node/866

[2] Architecture 2030

[3] Energy Information Administration – CBECS database (2012) and RECS database (2009)

[4] https://www.wbdg.org/resources/retro_sustperf.php 7.7.2016

[5] https://www.wbdg.org/resources/sustainable_hp.php?r=historic_pres 7.7.2016

[6] Ruth Redden, Greening Historic Buildings: A study of Heritage Protection and Environmental Sustainability ISS Institute Inc. December 2014

[7] A. Powter, S. Ross, Integrating Environmental and Cultural Sustainability for Heritage Properties , APT Bulletin, Vol. 36, No. 4 (2005), pp. 5-11, Association for Preservation Technology International (APT), URL: http://www.jstor.org/stable/40003157 Accessed: 08-12-2015 09:03 UTC

[8] Zhenjun Ma, P. Cooper, D. Daly, L. Ledo, Existing Building Retrofits, Energy and Buildings 55 (2012) 889-902

[9] V. Olgyay, C. Seruto, Whole-building Retrofits, a gateway to climate stabilization, ASHRAE transactions 116 (Part 2) (2010) 244-251N

[10] Erten D., Henderson K, Kobas B. (2009) A Review of International Green Building Certification Methods: A Roadmap for a Certification System in Turkey, 5th International Conference on Construction in 21st Century, Istanbul, Turkey

[11] Wang KM Fowler RS Sullivan, Green Building Certification System Review, March 2012 Prepared for the U.S. General Services Administration under Department of Energy Contract DE-AC05-76RL01830 with Battelle Memorial Institute

[12] www.breeam.org

[13] M. M. Sesana, M. Grecchi, G. Salvalai, C. Rasica, Methodology of Energy Efficient Building Refurbishment: Application on two university campus-building case studies in Italy with engineering students. Journal of Building Engineering 6 (2016) 54-64

[14] Paola Boarina , Daniele Guglielminob , Anna Laura Piselloc , Franco Cotana, Sustainability assessment of historic buildings: lesson learnt from an Italian case study through LEED® rating system, The 6th International Conference on Applied Energy – ICAE2014

[15] GBC Italia, GBC Historic Building - Short Version – Part 1, v.0.2, (2013)

[16] www.usgbc.org

[17] LEED 2009 NC (2010). MRc1. Washington, D.C., U.S.

[18] Jacqueline F. Stephens, Khalid Siddiqi (2013). LEED Rating Systems for Historical Restorations. 49th ASC Annual International Conference Proceedings. Southern Polytechnic State University, Georgia, U.S. Retrieved July 20, 2016

[19] Meyers, G. (2012, January 12). Marrying Historic Preservation with LEED Gold Certification. Green Building Elements, Reporting on Sustainably Built Environments from Bricks to Cities. Retrieved July 20, 2016, from http://greenbuildingelements.com/2012/01/12/marrying-historic-preservation-with-leed-gold-certification/

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General View on the Green Building Certification Programs and Evaluation for Turkey

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ABSTRACT

Climate change, depletion of energy resources, environmental pollution and also the prominence of the concept of sustainability has necessitated the consideration of the solutions and number of measures in the building sector as it happened in many other sectors. The concept of green building, certification programs and labeling has emerged as a solution in the building sector. In recent years voluntary green building certification has become popular also in Turkey. Therefore professional organizations get involved in developing their own schemes. The government decided to regulate these activities.

In general, certification programs allow buildings to be evaluated from the life cycle analysis perspective starting from the selection of the site, design, selection of building materials, water use, energy consumption and waste management on the basis of certain criteria.

In this study, firstly green building concept and the evaluation criteria are elaborated, then the green building certification programs used in developed countries like LEED, BREEAM, DGNB, CASBEE are given, also the studies to develop a national green building scheme in Turkey are looked through and finally the criteria to be included in the national certification system is evaluated.

Key Words: *Sustainability, green building certification programs, green building criteria, life cycle assessment.*

1. INTRODUCTION

Climate change, global warming, depletion of energy resources and sustainability concept have come to the forefront recently. The objective of sustainability, as stated in the United Nations Brundtland Report, is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs [1]. Each sector finds its own solution to combat climate change and support sustainability. A green building concept stands out in the building sector.

A green building is a building that is designed and constructed according to specific standards in order to minimize its environmental, economic and social impacts. In the green building, reducing its lifelong consumption of resources and avoiding damage to the environment is targeted.

Green Building:

- ✓ Compatible with nature,
- ✓ Evaluated according to life cycle assessment,
- ✓ Suitable for climate and region,
- ✓ Consuming less energy and water,
- ✓ Using renewable energy resources,
- ✓ Designed with integrated approach

It is evident that buildings have significant effect on resource consumption and environmental damage. The buildings are responsible for using the 1/3 of the natural sources, consumption of the 12% of the drinkable water and 40% of solid waste generation [2]. From the life cycle perspective, most of the total energy is consumed in the building usage stage. The efficiency of the building in its usage stage and the potential harm to the environment depends on the design, materials used for its construction and the way a building is operated. The surveys done on green buildings show that the buildings that are constructed and operated according to the green building concept have proven potential savings as 24 – 50% energy, 33 - 39% carbon percent reduction and 30 - 50% saving of water use and 70% solid waste and 13% reduction in the operation costs [2]. Certified buildings not only minimize negative impact on environment but also building owners gain prestige and increase a market value of the building.

In the context of sustainable development the buildings that use fewer natural resources, consume less energy and pollute the environment less are supported in many countries, particularly in developed ones. To do so, environmentally friendly green building standards have been established and certification is carried out.

Certification systems are usually developed by non-profit green building councils, building research centers in order to raise awareness among designers, contractors, owners, occupiers and operators. Some of them are also supported by the states; DGNB in Germany and the Japanese CASBEE system are among them.

Most recognized and most often applied certifications worldwide are BREEAM developed by UK Building Research Establishment and LEED developed by the US Green Building Council. The other widely recognized systems are DGNB in Germany developed by German Sustainable Building Council, CASBEE by Japanese Green Building Council, HQB in France and Greenstar in Australia. In the Table 1 certification systems used in various countries are listed.

Table 1 Green Building Certification Systems used in various Countries

Country	Name of the certificate
USA	LEED
ENGLAND	BREEAM
GERMANY	DGNB
JAPAN	CASBEE
AUSTRALIA	Green Star

FRANCE	HQB
UNITED ARAB EMIRATES	ESTIDAMA
CANADA/INTERNATIONAL	SBTool
ITALY	ITACA
HONGKONG	HK-BEAM, CEPAS
DENMARK, NORWAY, SWEDEN	SWAN ECO
SINGAPORE	Green Mark for Buildings
NORWAY	EcoProfile
SWEDEN	Environmental Status
FINLAND	PromisE
SOUTH AFRICA	SBAT
TAIWAN	EEWH

Even though it is clear that voluntary green building certification systems will only to very limited extent contribute to minimizing environmental burden of buildings, evidently there is a market for green buildings certification in Turkey. At least two professional organizations got involved in developing its own schemes – ÇEDBİK and Turkish Standard Institute. The Turkish government decided to regulate these activities. In this study, in order to benefit from experiences of other countries the green building concept and the evaluation criteria of number of certification programs are overviewed. Also elements which could be included in the national certification system and weak points which should be avoided have been identified.

2. GENERAL INFORMATION

2.1 Certification Procedures:

In every certification system there is a certification body. Certification body develops a rating system and certification guides for the evaluation of buildings. In most of the systems qualified experts are accredited according to specified criteria to evaluate buildings in line with certification system rules. The final evaluation is done by the certification body. The certification body checks and evaluates the documents provided by qualified experts. However in some certification systems involvement of accredited experts to do on-site checks is not obligatory eg. in LEED. In this case the documents are prepared by building owners. In all cases a relevant certificate is issued according to the scoring result.

The green building certification systems are typically voluntary based. However, in some countries, like Japan, local governments request certification in the public building procurement procedures.

In all certification systems the applications, assessment and certification procedures are carried out at a specific price. Certification fee varies depending on type and size of building and the evaluation criteria. For example, to obtain the LEED certificate, the building owner must pay a fee ranging from $ 4,200 to $ 31,200.

2.2 Certification Criteria

In general certification systems determine whether buildings are designed, constructed, renovated, maintained and operated in line with a given set of criteria. The criteria are defined according to the environmental, economic and social impacts. Each criterion has a certain weight in the rating system. After the assessment, buildings are certified on the basis of score received. For marketing purpose each certification program offers various certification levels like gold, silver and bronze. It must be noted that materials and products are not certified by certification systems.

Majority of certification systems offer specific rating schemes for various types of buildings. The typical schemes mainly include new buildings, existing buildings and major renovations. The other are more developed and include criteria for houses, healthcare and educational buildings and also for urban areas. The criteria vary according to the building types. In order to be certified a building must fulfil the criteria that are determined having in mind improvement of its environmental, social and economic performance. Typical criteria categories of certification systems include:

- Land planning (construction period is included),
- Life cycle assessment of building and building components
- Design of the building and innovation properties,
- Construction materials, the use of recyclable materials,
- Water usage and waste management,
- Energy usage,

Some of the criteria are treated as a prerequisite that must be met; therefore no points are given for meeting them. Compliance to national legal requirements is an obligation and remains out of scoring as well.

In all certification systems the criteria are periodically reviewed and revised by the evaluation of the feedbacks from applications and developments in emerging technologies. Feedback, provided by all actors in the sector, including designers, material producers, real estate agents and building users, is taken into account and integrated to enhance the validity of the certification system. Amendments are made accordingly also to prioritization and scoring of specific criteria. That makes certification systems self-developing and renewed. For example, in case of LEED which has started in 1994 the 4th version was introduced for use in 2015.

1. COMPARISON OF WIDELY USE CERTIFICATION SYSTEMS

1.1 **BREEAM Certification System**

BREEAM (Building Research Establishment's Environmental Assessment Method) is a method of assessing, rating and certifying the sustainability of buildings, masterplans and infrastructure developed by the Building Research Establishment (BRE) based in England. It has been developed as first one in the world. The first studies about BREEAM began in 1988 and in 1990 BRE launched first version for assessing new office buildings. This was followed by versions for other buildings including superstores, industrial units and existing offices.

BREEAM allows for assessment of sustainability values ranging from energy to ecology in different categories of buildings as new construction, refurbishment and in-use. Every category is determined according the most influential factors on the bases of social, economic and environmental impact.

BRE develops and operates a number of BREEAM schemes, each designed to assess the environmental performance of buildings at various stages in the life cycle, such as:

- BREEAM Communities: for the master-planning of a larger community of buildings
- BREEAM Infrastructure: for the sustainability assessments for civil engineering works (like airports, cross rail, London 2012 Olympics, etc.)
- BREEAM New Construction: for new build, domestic and non-domestic buildings
- BREEAM In-Use: for existing non-domestic buildings in-use
- BREEAM Refurbishment: for domestic and, from summer 2014, non-domestic building fit-outs and

refurbishments [3]
The BREEAM assessment process evaluates the procurement, design, construction and operation of a development against targets that are based on performance benchmarks. Assessments are carried out by independent, licensed assessors and developments rated and certified on a scale of Unclassified (<30), Pass (≥30), Good (≥45), Very Good (≥55), Excellent (≥70) and Outstanding (≥ 85) [3].

The scoring is done according to the weightings for each of the nine environmental sections included in the BREEAM New Construction scheme:

Table 4 Scoring in BREEAM

Category	New Construction (NC)
Building Management	12
Health and well-being	15
Energy	19
Transport	8
Water	6
Materials	12,5
Waste	7,5
Land Use & Ecology	10
Polution	10
Innovation (additional)	10
TOTAL	110 (100+10)

3.2 LEED Certification System

LEED (Leadership in Energy and Environmental Design) was developed by U.S. Green Building Council to promote buildings to be environmental friendly from design stage to demolishment stage and to identify high-performance buildings that are healtier to live in and more economic with less operating costs compared to conventional buildings.

LEED sets the benchmark and provides criteria for all buildings everywhere and for all building types. There are ten rating schemes for the design, construction and operation of buildings, homes and neighborhoods and these are grouped under five programs:

- Green Building Design and Construction: LEED for New Construction (NC), Core and Sheel (C&S), Schools, Retail-New Construction and Major Renovations, Healthcare
- Green Interior Design & Construction: LEED for Commercial Interiors, LEED for Retail- Commercial Interiors
- Green Building Operations & Maintenance: LEED for Existing Buildings- Operations & Maintenance (EBOM)

- Green Neighborhood Development: LEED for Neighborhood Development
- Green Home Design and Construction: LEED for Homes

The maximum score in LEED is 110. In order to obtain a certificate prerequisites must be fulfilled and at least 40 points must be gained in total. Based on the number of points achieved, a project then receives one of four LEED rating levels: Certified (40-49), Silver (50-59), Gold (60-79) and Platinum (80+).

USGBC's Green Building Certification Institute (GBCI) accredits people according to their knowledge on LEED certification system as LEED Green Associate, LEED Accredited Professional (LEED AP) and LEED Fellows. But for the assessment of the project it is not obligatory to use a LEED Accredited Professional, but using a LEED AP adds 1 point to the final score.

LEED set down reference values based on standards according to the environmental performance of the building. Water and energy consumption of the building is compared with the benchmark values and efficiency of the building is determined. The building doesn't have to comply with all criteria except the prerequisites. The scoring is done according to the total points gained in every criterion. Every criterion is scored according to the severity [4]. The scoring is done under 8 categories as shown in Table 5:

Table 5 Scoring in LEED

Category	New Construction (NC)	Core & Shell (C&S)	Schools
LT Location and Transportation	16	20	15
SS Sustainable Sites	10	11	12
WE Water Efficiency	11	11	12
EA Energy and Atmosphere	33	33	31
MR Materials and Resources	13	14	13
IEQ Indoor Environmental Quality	16	10	16
ID Innovation	6	6	6
RP Regional Priority	4	4	4
TOTAL	**110**	**110**	**110**

LEED is the most popular certification system In Turkey. According to the GBCI there are 578 buildings registered in LEED system [5].

3.3 DGNB Certification System

DGNB (Deutsche Gesellschaft für Nachhalties Bauen) Certification system is developed by the German Sustainable Building Council – DGNB- that was founded in 2007 by number of actors in the construction and real-estate sectors to promote sustainable and economically efficient buildings. DGNB Certification system was launched in 2009.

DGNB certification system allows for assessing the quality of buildings over their entire life cycle. The 50 assessment criteria are grouped in 5 sections: environmental, economic, socio-cultural and functional, technical and process related issues. In addition site quality is assessed separately as it is included in the commercial viability criterion. For urban districts, on the other hand, the site quality is included in all criteria.

DGNB developed various schemes in the certification program. At the moment the schemes for new offices, existing offices, residential buildings, dwellings, healthcare, education facilities, hotels, retail, assembly buildings, industrial, tenant fit-out are available. Also further schemes are constantly being developed in working groups, e.g. for hospitals.

The scheme for new offices called CORE 14 has been developed in English language for international use. It is based on international standards and requirements and can be adapted to local requirements in various countries.

Since 2011 also districts can also be certified in the DGNB program. Four schemes for districts have been developed: urban districts, office and business districts, industrial locations and event areas.

DGNB System offers different types of certificates for both the buildings and urban districts. Firstly pre- certificate may be obtained in the planning phase. It remains valid until the project is completed. After that a final certificate may be obtained. In case of existing buildings the certificate is valid for 3 years, while for new constructions it has unlimited validity.

As urban districts are being developed in several phases over a long period of time, there are three certification stages – the pre-certificate and two other types of certificates. The first of these, with a term of five years, can be awarded when 25 per cent of access and services have been completed. The second has an unlimited validity and is awarded after completion of 75 per cent of the buildings.

In case of final certification, the performance measured as a percent of the maximum level. Certificates are issued in the following categories: bronze (35%), silver (35-50%), gold (50-65%) and platinum (65-80%). In case of pre-certification in the planning phase there is only one level system.

In order to be certified in the DGNB system the project must get a score in the mentioned above 5 sections and separately, in relation to site quality. The final score is calculated as a combination of the evaluation points with the relevant weighting.

The assessment process is carried out by the independent experts who are registered in DGNB system as DGNB auditors. Expert details can be found by contractors on the DGNB Website. The contractor enters into a contract with the expert and, separately, with DGNB. There is no contractual relationship between DGNB and the expert in order to guarantee the greatest possible degree of objectivity and independence.

The expert supports the contractor and supervises the process from registration to the certification. Certification cost consists of the expert service fee and certification fee to the DGNB. To date more than 850 projects have been certified or registered for certification by the DGNB [6].

Table 6 Scoring in DGNB

Quality Sections	**Scoring**
Ecological quality	**%22,5**
Economic quality	**%22,5**
Social, cultural and functional quality	**%22,5**
Technical quality	**%10**
Process quality	**%22,5**
TOTAL	**%100**
Site quality	**Assessed seperately**

3.4 CASBEE Certification System

CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) is a building environmental assessment system, which was developed by the Japaneese IBEC (Institute for Building Environment and Energy Conservation) in 2004. CASBEE is a joint industrial/government/academic project established under the support of the Japanese Ministry of Land, Insrastructure, Transport and Tourism.

CASBEE allows for evaluating and rating of buildings according to their environmental performance. Buildings features, including inside amenities and landscape, materials used energy-saving and/or low environmental load are considered.

CASBEE has been developed for the purpose of objective evaluation of buildings on the basis of the following three principles:

a) Evaluation through the lifecycle of buildings

b) Evaluation by both "Q;Quality of building performance" and "L;Environmental load"

c) Evaluation by using the index of Built Environment Efficiency (BEE) based, on the concept of environmental efficiency

Assessment results in categorisation of a building into one of evaluated by five classes: Class S: Excellent, "Class A: Very good", "Class B+: Good", "Class B-: Slightly poor", "Class C: Poor".

CASBEE offers various criteria for evaluation of buildings, housing, cities and urban development and these are categorised under house scale, building scale and for urban scale. Corresponding to the building lifecycle, CASBEE includes four assessment tools to serve at each stage of design process: CASBEE for Pre-design, CASBEE for New Construction, CASBEE for Existing Building and CASBEE for Renovation. Evaluation criteria are grouped in 6 large categories focusing environment quality of the building and environment load reduction of the building.

CASBEE has developed various versions of the system for specific purposes such as for detached houses, for temporary construction, brief versions, local government versions, for heat island, for urban development, for cities and for market promotion.

Other than the other certification systems CASBEE has developed also brief versions of the assessment schemes in order to reduce assessing time and to meet needs from local governments (like Nagoya city, Osaka city and Yokohama city etc.), owners and designers. Simplified versions are available for new constructions, for existing buildings, for renovations.

CASBEE establish an Accredited Professional (CASBEE-AP) Registration System. In order to become the accredited professional it is obligatory to attend the relevant training and pass an exam [7].

Table 7 CASBEE Assessment Items [7]

CASBEE Assessment Items		
	Large Category	Middle Category
Environment Quality of the Building	Q1. Indoor Environment	Noise, Thermal Comfort, Lighting & Illumination, Air Quality
	Q2. Quality of Service	Service Ability, Durability & Reliability, Flexibilty & Adaptability
	Q3. Outdoor Environment on Site	Preservation &Creation of Biotope Townscape & Landscape Local Chracteristics & Outdoor Amenity
Environment Load Reduction of the Building	L1. Energy	Building Thermal Load Natural Energy Utilization Efficiency in Building Service System Efficient Operation
	L2. Resources&Materials	Water Resources Reducing Usage of Non-Renewable Resources Avoiding the Use of Materials with Pollutant Content
	L3. Off-site Environment	Consideration of Global Warming Consideration of Local Environment Consideration of Surrounding Environment

Table 8 Comparison of Green Building Certification Systems [8]

Name of Certificate	BREEAM (Building Research Establishment's Environmental Assessment Method)	LEED (Leadership in Environmental and Energy Design)	DGNB (Deutsche Gesellschaft für Nachhalties Bauen)	CASBEE (Comprehensive Assessment System for Built Environment Efficiency)
Origin country/ Certification body/ Establishment year/	England BRE - Building Research Institute 1990 (supported by the state and construction sector)	USA U.S. Green Building Council 1994	Germany The German Sustainable Building Council 2009	Japan IBEC (Institute for Building Environment and Energy Conservation) 2004 (supported by the Japanese Ministry of Land, Infrastructure, Transport and Tourism)

Criteria topics and rating	10 Topics: (110 points)	8 Topics: (110 points)	6 Topics: (100 points)	6 Topics:
	1. Energy	**1.** Location and transportation	**1.** Ecological quality	**1.** Q1. Indoor Environment
	2. Health and well-being	**2.** Sustainable sites	**2.** Economic quality	**2.** Q2. Quality of Service
	3. Innovation	**3.** Water Efficiency	**3.** Social, cultural and functional quality	**3.** Q3. Outdoor Environment on Site
	4. Land Use	**4.** Energy and Atmosphere	**4.** Technical quality	**4.** L1 Energy
	5. Materials	**5.** Materials and resources	**5.** Process Quality	**5.** L2. Resources & Materials
	6. Building management	**6.** Indoor Environmental Quality	**6.** Land quality	**6.** L3.Off- site Environment
	7. Pollution	**7.** Innovation		
	8. Transport	**8.** Regional Priority		
	9. Waste			
	10. Water			
Data requirements for certification	Construction reports Architectural drawings, Engineering calculations, Energy modelling and reports, BREEAM documents, Reports of building Site visits	Construction reports Architectural and engineering drawings, Engineering calculations, Energy modelling and reports Reports and explanations of building by building owner, LEED Score sheet Site visits	Up-to-date experts´/ survey reports and simulations	-Assessment of design/ actual specifications and performances realized at the time of assessment -Assessment on the base of operation records and measured values for at least one year after completion (for existing build.) -Detailed environmental measurement and detailed energy consumption analysis -Score and Calculation sheets
Certification Rating levels	- Pass - Good - Very Good - Excellent - Outstanding	- Certified - Silver - Gold - Platinum	- Bronze - Silver - Gold - Platinum (option of simple pre-certification in the planning phase)	- Class S: Excellent - Class A: Very good - Class B+: Good - Class B-: Slightly Poor - Class C: Poor
Expert	BREEAM Assessor	- LEED AP (Accredited Professional)	- DGNB Auditor	- CASBEE AP (Accredited Professional)

4. GREEN BUILDING PRACTICES IN TURKEY

In recent years green building certification systems are becoming popular in Turkey. There are many buildings, mostly in İstanbul having green building certificates. The most popular certificates are respectively LEED, BREEAM and DGNB.

Still investors and contractors in Turkey have a demand for the certification of the country-specific green building certification system. The main reasons for that are:

- some criteria in certification systems do not comply with the Turkish national standards and the national conditions as these systems reflect the conditions of the origin country,
- certification fees charged abroad are seen as very high.

Apart of setting up minimal requirements for energy performance of buildings, the government of Turkey has taken an initiative to lay down foundations for the national voluntary certification system by publishing "The Regulation about the Principles and Procedures of Sustainable Green Building and Sustainable Settlement". (Published in the Official Gazette on 08.12.2014) The regulation identifies responsibilities, qualifications and duties of the bodies that will take role in the certification procedures [9]. The Regulation covers environmental, social and economic performance and sustainability assessment and certification of new and existing buildings and settlements.

The development of "Basic Assessment Guidelines" is underway. The document will be announced by the Ministry of Environment and Urbanization. It will be used for certification of sustainable green buildings and sustainable settlement. "Basic Assessment Guidelines" will contain mandatory performance indicators and assessment criteria grouped in the following headings; integrated building design, land use, energy use and efficiency, water use and efficiency, local and environmentally friendly materials, health, comfort and function, waste management, operation and maintenance and innovation. The idea behind the guidelines is that any voluntary certification system in this area should include these criteria as a minimum.

It has to be noted that currently other country-specific green building certification systems are being developed independently from the government initiative. Their basic characteristics are given below. Compliance of these two systems with the governmental initiative will need to be evaluated.

"ÇEDBİK Green Housing Certification System" is developed by the Turkish Green Building Council (ÇEDBİK) for residential buildings. The guide document was published on the web page of ÇEDBİK (http://www.cedbik.org/) [10]. It has been prepared with the help ÇEDBİK members and also certain elements of the international certification systems like LEED, BREEAM and DGNB are overviewed and incorporated. The assessment is done under 8 main criteria including integrated green project management, land use, water use, energy use, health and comfort, materials and resource use, life in resident, operation and maintenance.

Table 9 Scoring in ÇEDBİK

Category	**Scoring Weight (%)**
Integrated Green Project Management	%6
Land Use	%13
Water Usage	%12
Energy	%25
Health and Well-being	%10
Material and Resouce Usage	%14
Living in residential	%13
Operation and Maintenance	%5
Inovation	%2
TOTAL	**%100**

"Safe Green Building Certification System" is developed by Turkish Standards Institute (TSE). The root document for the system is "Safe Green Building Certification Procedures and Principles" which was issued on 05/05/2014. This document aims to implement the national and international green building certification activities and to regulate the use of the brands associated with them [11]. In this system the buildings are evaluated by a scoring system in the following categories of criteria: sustainability, accessibility, security and so on and certifications are given in different categories. It has to be noted that this document is related only with the procedures of the system. However the evaluation principles and main criteria are not given in this document.

Tablo 10: Scoring in TSE Safe Green Building Certification

Category	Scoring
Pre-design Safe Green planning	12
Vital Site Design	32
Site Selection	8
Health – security - comfort	38
Efficient use of water	33
Material and resource usage	39
Carbon foot print	5
Energy Efficiency	120
Award score	25
Operation manegement	13
Total	325

5. CONCLUSION

The assessment criteria in all presented certification systems cover a broad spectrum of environmental, social and economic aspects. The importance of specific criteria varies according to prioritization.

Examination of numerous certification systems allows for conclusion that the Turkish national certification system should include the following categories of assessment criteria:

- Integrated building approach and life cycle analysis
- Energy and global warming: A target must be set for building energy consumption. Criteria must be set also for monitoring and verification of energy consumptions.
- Water usage: Water consumption of the building must be reduced, waste water must be used as grey water and for landscape irrigation,
- Resource usage and materials: according to life cycle assessment
- Earthquake resistance, Reliability
- Bio diversity and land protection: the determination of building site is important to protect the bio diversity
- Indoor air quality: Operation and management criteria for health, daylight, natural ventilation

In order to be certified a building should meet the minimum criteria in each of these categories, as it is demanded in BREEAM.

In general green building certification systems are voluntary systems and they are mainly developed by non-governmental and independent bodies. Most of them are maintained as commercial schemes. In order to maintain a market position certifiers balance cost and effort needed for application with wide recognition and reliability issues. While developing the schemes certifiers take into consideration views of the all actors in the sector and feedback from applications. Intervention of governmental agencies may have result in influencing that balance thus it should not go too far and evidently as there is a market for green buildings everyone in the sector wants to have its own certification system like ÇEDBİK and TSE to make a business out of green building.

When reliability issue comes to the question it must be noted that in some of the certification systems presented there is no monitoring or verification of the building performance on site. Certification can be taken by filling a score chart and sending some test reports. Lack of involvement of an independent and qualified assessor may negatively influence reliability of the system. Therefore the national system should ensure that the assessors are competent and not biased. As the certification body gives the certificate according to the expert's reports, the experts assessing the building must be sufficient enough to guide the project team and to evaluate the building according to the sustainability aspects. Besides the assessment criteria the qualification and training issues of these experts should be determined.

Compliance with regulatory requirements should be a sine qua non condition for certification. Likewise in other certification systems minimal threshold for certification should be laid down significantly higher than these requirements. As a result, the number of certified buildings will never reach a high percentage of all buildings in the country. Turkish green building certification system should contribute to the sustainability rather by awareness raising and providing a good example then directly by minimizing the overall negative impact on environment. Thus, enforcement of regulatory requirements still remains the main issue.

REFERENCES

[1] Our Common Future, Brundtland Report, United Nations World Commission on Environment and Development (WCED), 1987.

[2] Erten, Duygu., Yeşil Binalar, Sürdürülebilir Üretim ve Tüketim Yayınları, Çevre ve Şehircilik Bakanlığı, 2011

[3] http://www.breeam.com

[4] http://www.usgbc.com

[5] http://www.gbig.org/places/899

[6] http://www.dgnb.de/en/council/dgnb/

[7] http://www.ibec.or.jp/CASBEE/english/

[8] Erten, D., Henderson, K., Kobaş, B., 2009: A review of International Green Building Certification Methods: A roadmap for a certification system in Turkey. Fifth International Conference on Construction in the 21st Century (CITC-V) "Collaboration and Integration in Engineering, Management and Technology". Mayıs 20-22, 2009, İstanbul, Türkiye.

[9] Sürdürülebilir Yeşil Bina ile Sürdürülebilir Yerleşmelerin Belgelendirme Usul Ve Esaslarına Dair Yönetmelik, T.C. Resmi Gazete 8.12.2014 Tarih ve 29199 sayı,

[10] www.cedbik.org/

[11] Güvenli Yeşil Bina Belgelendirme Usul Ve Esasları, TSE Yönetim Kurulu Kararı, 29.04.2014 tarih ve XIX/50/236 numara

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Brief Discussion of Energy Certification Systems for Buildings

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ABSTRACT

All certification systems should emphasize four key principles, i.e., energy, environment, ecology and economy. The leading building certificates such as LEED, BREEAM, DGNB refer to these concepts in various degrees of importance. Yet, none of them emphasizes the aspects of energy cost and efficiency in depth. Four other ones, Energy Star, Effinergie, Minergie, and Passivhaus, have a more clear emphasize on energy. Many parameters considered for these certification systems show a great variety among themselves and are considered very complex by the end user, making them unattractive to users and owners of buildings. There is a need to have a comprehensive set of guidelines for design, construction and operation of sustainable buildings, particularly with emphasize on energy cost and efficiency. Here, we provide a review of certificate systems with particular emphasize on Energy Star, Effinergie, Minergie, and Passivhaus. Our objective is to identify the strengths and weaknesses of these systems, which help us to develop a new set up of guidelines for high performance buildings of future from energy cost and efficiency points of view, in line with the ongoing NEED4B Methodology, we are working on.

KEY WORDS: Energy Performance, Energy Certification Systems, Sustainable Energy, Buildings

INTRODUCTION

Certification systems for buildings date all the way back to Romans, as documented by Vitruvius, in "De Architectura", widely known today as "The Ten Books on Architecture" [1]. During the first century BC, Vitrivius explored structures in terms of their solidness, usefulness and beauty (firmitas, utilitas and venustas), and suggested a series of guidelines for both buildings and cities. Most Roman cities were built on these premises, many of which are still in tact and beautiful, although most are not in use by public. In recent times, more comprehensive certification systems were offered by different organizations in different countries. One of the first organizations for this was the American Society for Heating, Refrigeration and Air Conditioning (ASHRAE) founded in 1894, to focus on energy efficiency, building systems, refrigeration, indoor air quality and sustainability within industry [2]. In recent times, additional certification systems for buildings were introduced by British (Building Research Establishment Environmental Assessment Methodology (BREEAM [3]) and by Germans (Passivhaus [4]). Since then many other certification systems have been introduced to the market reaching to hundreds of different systems in use [5, p.8]. Today most of certification systems are implemented at national levels, with only a few being considered at the international level.

We can break down and analyze these certifications into holistic or specific approaches. A holistic approach considers a wide range of aspects of the building performance, beginning with the building materials until the availability of the nearest public transportation. These certificates also emphasize on environment, as in the cases of Leadership in Energy and Environmental Design (LEED) [6], Building Research Establishment Environmental Assessment Methodology (BREEAM); Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) [7], Indian Green

Building Council (IGBC) [8]. The certificates with specific approach on energy issues are limited, although they have started gaining more importance in recent years. They are namely Energy Star [9], Effinergie [10], Minergie [11], Passivhaus, which will be our focus in this paper.

The most notable, developed and ambitious system among all certification systems is based on the legislatively binding document Energy Performance of Buildings Directive (EPBD) established by the European Union (EU) [12]. On the other hand, most EU member countries have been developing their versions of the EPBD according to their regulations; climatic challenges and market need [5, p.9]. Even the associated countries, like Norway, Israel, Switzerland and Turkey, have established working groups for their versions of such certification systems. The "Enerji Kimlik Belgesi" (EKB; Energy Identification Document) is the version of the EPBD developed for Turkey since 2010 [13].

Whether national or international, the most widely known and credible certificates are influenced by the EN 15978, EN 15804 and ISO 21930 standards in the fields of building and construction [14].

In Figure 1, we outline different aspects of twelve selected certification systems. All these systems are evaluated under different categories with different weights and contain different parameters with different weights. These details are given by a guide, Simply Green [14], prepared by Swegon Air Academy, describing twelve certification systems – from environmental to energy-based classification systems for energy-efficient buildings worldwide. On the other hand, we are currently working on a new methodology based on several demonstration projects funded under a European Union Framework Program 7. The project, NEED4B [New Energy Efficiency Demonstrations for Buildings] [15], is based on tools and procedures that already exist or are under development, like Integrated Project Delivery, Building Information Modeling, Life Cycle Assessment, Life Cycle Cost, Occupants' Behaviors on Building Energy Use and Energy Performance Simulation Software. The advantage of this methodology is that it gives the same importance to operation phase of the buildings, besides the design and construction phases and real-time monitoring becomes an instrument for re-evaluating the energy performance of the buildings, in order to correct any discrepancies of the original targets set during the design phase and/or upgrade the systems within the building.

Certification systems with holistic approach provide a larger overall objective of a building's impact on the environment and they suggest different credits to different parameters according to type and usage of buildings. These credits are mainly based on the standards of the origin country, requesting a minimum of the set standards and targeting higher rankings within the system, according to how far the standards would be carried out. Their ranking varies from 3 up to 5. The certification systems with focused approach on energy listed in Figure 1 are Energy Star, Effinergie, Minergie and Passivhaus. The energy performance expectations in each certificate system is listed in third column in Figure 1. Important parameters under this category are power demand (heating/cooling), type of energy (renewable or fossil-fuel based), and environmental impact parameters. Among them, power of demand (heating/cooling) is the focus only in Effinergie and Green Building certifications. In Passivhaus the type of energy is equally important as the power demand (heating/cooling). Minergie certificates include a third parameter, the environmental perspective, and the three parameters are equally weighted in this system. A similar weight is being adapted in NEED4B as well.

As we have analyzed the most outstanding certification systems with focused approach on energy in the following chapters in detail, we briefly summarize in the following paragraphs the certification systems with holistic approach. We note that all eight holistic certification systems contain different categories. Among all, BREEAM contains most of the categories with 10 plus additional "others" category and CASBEE the least with 7 plus additional "others" category. All eight certification systems contain energy performance, indoor environment, material and water categories. Yet, the share of each category varies in itself: the difference in energy performance category ranges from 5% to 32%; the difference in indoor environment category ranges from 13% to 53%; the difference in material category ranges from 1% to 13% and the difference in water category ranges from 1% to 19%.

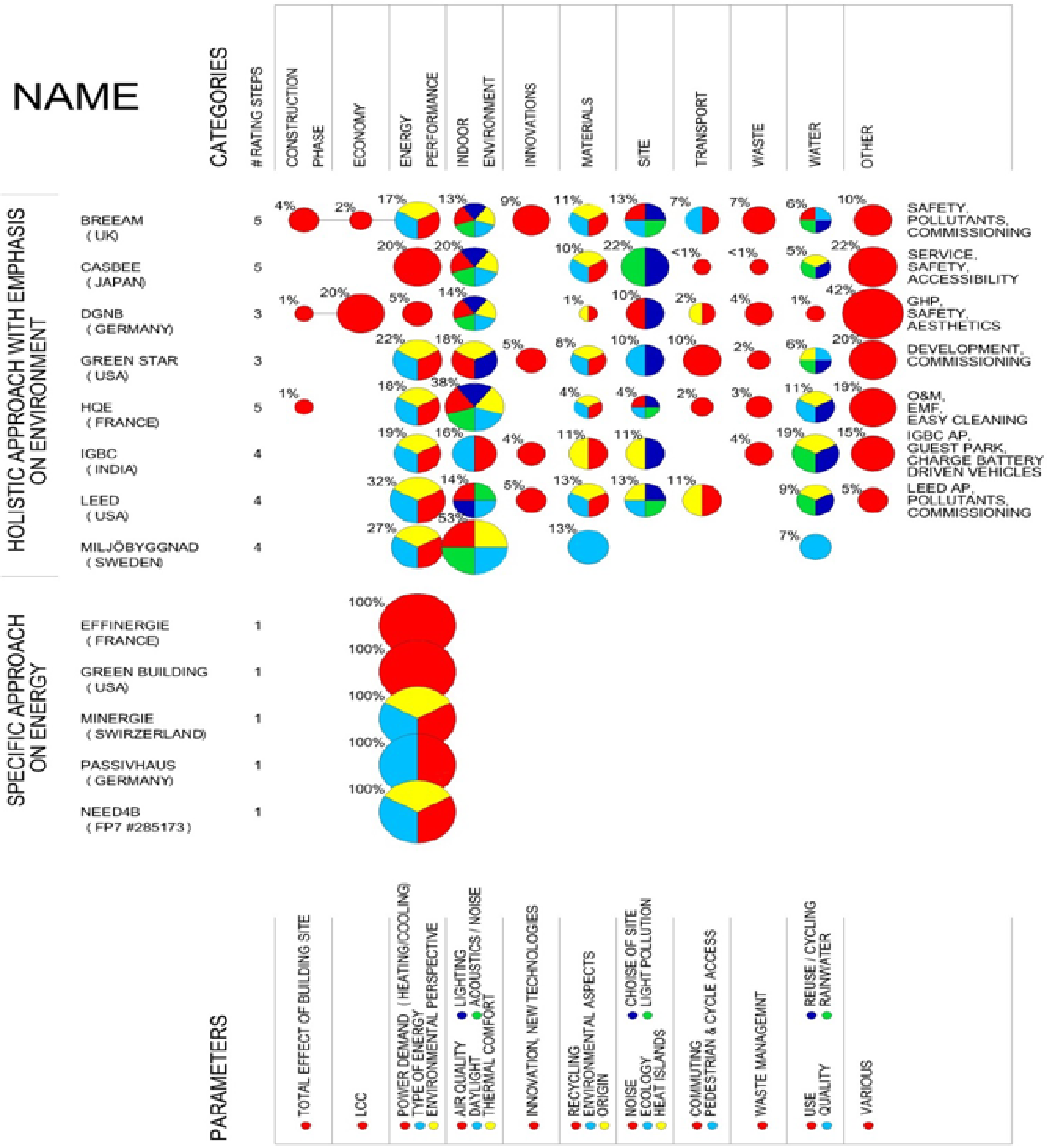

Figure 1 Comparison of various certificates in alphabetical order. Each certification system is evaluated under different categories, which consist of many sub-categories. The weights of each certification systems vary [5].

If we compare the three most notable certification systems in this figure in further depth, we note that BREEAM has 10 categories and 38 parameters, LEED 9 categories and 27 parameters, and DGNB 6 categories and 20 parameters. The complicated differences in demarcation of categories and main parameters are obvious in these and, also, at the other certification systems. This complexity and variety makes it difficult for anyone to find out which of these certification systems would be better and more comprehensive for their specific circumstances, needs and expectations.

The efforts on discussing the certification systems have indeed a clear motivation: On an economy front, certified buildings with reduced energy use have the potential of higher property value and rents, being distinguished in highly competitive real estate markets. On an energy front, efficiency is promoted to reduce the carbon emissions related with buildings and decrease operational costs. On a health front, sustainable materials selection through certification process can improve the quality of the indoor environment by eliminating materials with toxic substances. Research carried out by the USA-based Pike Research Institute in 2010 on Green Building Certification Programs presents a very clear picture of the impact of certification systems. In this report, it is stated that certified building spaces in the USA will grow from 5,5 billion square meter to 49 billion square meter from 2010 to 2020 [16].

Our goal in this paper is to discuss the most prominent of these certifications from energy efficiency point of view. Only in few cases certification systems concentrate basically on energy use and energy density. In Swiss certification system Minergie, comfort and cost are considered as well. Below, we provide a set of detailed comparisons for Energy Star, Effinergie, Minergie and Passivhaus certification systems. We chose these four as they are the most notable certification systems with specific approach on sustainable energy selections.

SCOPE OF CERTIFICATION SYSTEMS WITH ENERGY EMPHASIS

In this section we review the existing certification systems and identify good practice. The study concerns both new buildings and existing buildings and different typologies. By facilitating the evolution of the outstanding existing certification systems, we will later discuss a generic process by using Turkey as a case sample.

1. Energy Star (USA)

Energy Star certification system has originated in USA in 1992 [9]. The Energy Star labeled buildings are scored by the software called the Rate Home Energy Analyses (REM) [17]. This software allocates a Home Energy Rating System (HERS) index to the buildings, in which 0 represents a net-zero building, 100 represents a reference building condition corresponding to the 2006 International Energy Conservation Code and 130 represents a typical resale home determined by the U. S. department of Energy [18]. There are no units assigned to the HERS index; it is a relative scale, in which the lower the number is, the more energy efficient is the building. A home upholding a HERS Index Score of 70 is 30% more energy efficient compared to a RESNET Reference Home [18]. A home upholding a HERS Index Score of 130 is 30% less energy efficient compared to a RESNET Reference Home.

1.1 Residential Buildings:

The necessary recommendations and guidelines to obtain energy star label for residential buildings have been provided at the official website of the Energy Star [9]. Among many stringent requirements, the heat transfer coefficients for obtaining the label are very high compared to the heat transfer coefficients of the European energy certification systems. We provide the U values in Table 1 by using the previously described conversion factors. The requests for airtightness parameter are more ambitious according to the European energy certification systems. Most industry standards and building codes require a value of 0,091 $m^3h^{-1}m^{-2}$, as the industry is favoring the mantra of "***Build Tight – Ventilate Right***". Although no national regulation has been set for airtightness, many authorities, regulatory bodies, associations for standards and codes are considering requirements for envelope limitations. These limitations often count on climate, as they are driven by energy reduction.

Currently, there is a set of allowable leakage levels, which are not identical, depending on the referred code or standard. Yet, USA is arriving to unanimity on minimum ventilation rates given by ASHRAE 62.2. Present airtightness testing of homes is restricted to homes obtained energy ratings. Yet, this situation is aimed to increase significantly in the future, mainly due to modifications in the International Energy Conservation Code (IECC). IECC is a building code formed in 2000 by the International Code Council, adopted by many municipal governments and states in the USA for setting up the minimum design and construction requirements for energy efficiency) [19].

1.2 Commercial Buildings:

The ENERGY STAR scores evaluate the energy performance of the entire building, reflecting actual metered energy consumption. During the evaluation, equatable accounting of variant energy sources; normalizing for building operation and a comparison of a peer group are required. Once developed, the score is programmed into ENERGY STAR Portfolio Manager. This is EPA's online measurement and tracking tool and is described in detail in their website [17].

The peer group for comparison is obtained from the national population of buildings with the same fundamental activity, such as an office, a classroom in a school from kindergarten through the 12th grades, schools, and others. Nationally provided actual (billed) whole building data is the core of the ENERGY STAR score, enabling EPA to account for business activity, to understand the full distribution of energy performance, and to establish a peer group comparison. Once the national data set is clarified, the EPA applies a series of filters. These filters refine the peer comparison group and eliminate any technical limitations. Specifically, some or all of the following four filters are applied by the EPA: building type filter, program filters, data limitation filters and analytical filters.

1.2.1 Accounting for Primary Energy use in Terms of Fuel Mix:

The EPA utilizes the source energy, in order to combine all of the different forms of energy, like natural gas, electricity, fuel oil or district steam. Source energy includes the site energy, traced on the energy bills, and the energy required to generate and delivered to the building.

The document titled "Methodology for Incorporating Source Energy Use" provides the technical details about how to incorporate source energy into the national energy performance ratings maintained by the EPA ("Energy Star Portfolio", 1998). Energy Star has studied and included the source-site ratios for each type of fuel into the Portfolio Manager. This conversion enables an equitable assessment of energy efficiency at building level, as source energy incorporates all transmission, delivery and production losses, accounting for whole primary fuel consumption. The site energy metric provides a tribute for buildings that buy energy generated off site by a utility, for example electricity. The source-site energy ratios are then applied to convert each on site energy unit into the total equivalent source energy consumed [21]. The source-site ratios for electricity is 3,34, when purchased from the grid and 1 when on site solar or wind installation is performed; for natural gas 1,047; for fuel oil, propane and liquid propane 1,01; for steam 1,45; for hot water 1,28; for chilled water 1,05; for wood, coal and other fuels 1,00. The EPA source energy multipliers do not vary with season, day or hour and are static.

2. Effinergie (France)

Effinergie was first released in France in 2007 [10]. One of the outstanding features of Effinergie is its approach towards particular regions' climatic and geographical differences. Just like France, Turkey is divided geographically into climatic zones and has an altitude range of 5,166 meters (lowest spot: Mediterranean Sea 0 m and the highest spot: Mount Ararat 5,166 m). France has a less altitude difference of 4810 meters (lowest spot: Rhône river delta -2 m and the highest spot: Mont Blanc 4,808 m). In that sense, a similar altitude and climate type demarcations can be used in both countries.

In Effinergie, whether the building is newly constructed or is refurbished, the primary energy of a building refers to the energy lost while it is being transformed. The primary energy complies with the energy purchased from the energy distributor (final energy) which should be multiplied by a factor of 2.58 for electricity, factor of 0.6 for wood and factor of 1 for other energies. The 2.58 factor for electricity considers the heat provided by the power station. This unused heat is evacuated in the natural surroundings, like sea, river, and others. There is neither clear scientific argument nor clear algoritm report on the base of the factor. Yet, in practice, the factor calculation may be based nearly on the electricity mix and coefficient of 3 for nuclear, which is more or less the internationally established standard, according to Molenbroek, Striker and Boermans [22].

The energy consumption goals of Effinergie are formulated as follows:

The consumption value of the new building is expected not to exceed 50 kWh/m²/year of primary energy of the Net Floor Area (NFA), taking into consideration the geographical (a) and altitude (b) factors:

Energy Consumption (new) = $(50\ kWh/m^2)/year)*(a+b)$

The consumption value of the refurbished building is expected not to exceed 80 kWh/m²/year of primary energy of the Net Floor Area (NFA), taking into consideration the geographical (a) and altitude (b) factors. Then, 50 kWh/m^2 in above equation becomes 80 kWh/m^2.

The coefficients ***a*** and ***b*** are obtained due to the diversity of climates and altitudes of the country. The coefficients are derived from eight climatic zones, corresponding to the administrative borders of ***department*** and three altitude ranges. As a result, the consumption values fluctuate: 1. between 40 and 65 kWh/m²/year of primary energy of NFA for new residential buildings; 2. between 64 and 104 kWh/m²/year of primary energy of NFA for refurbished residential buildings.

In order to obtain an Effinergie label for non-residential buildings, the primary energy shall be 50% less than that defined in the RT 2012 code [10]. In the situation of renovations of non-residential buildings, the primary energy is to be 40% less than the RT 2012 code [10]. The RT 2012 is the latest national building regulation of France, which is a step towards nZEB buildings. The regulation is applied through the mandatory evaluation of an official software program stemming from the official rules Th BCE-2012 of the Centre Scientifique et Technique du Batiment (CSTB). At a glance, the RT 2012 building regulation includes three major requirements to be taken into tandem [23, p.29].

The first requirement considers the essence of the structure and the envelope of a building, while disregarding the HVAC system and other technical services. These features are summarized with a variable called the B_{bio} Factor (bioclimatic needs factor). This is a dimensionless number obtained from the following expression, where cooling, heating, and lighting requirements of a building are computed with an hourly dynamic analysis software program and the energy consumption of ventilation system and lighting services are obtained from conventional values in the program, using:

$$B_{bio} = 2x(\text{Heating needs} + \text{Cooling needs}) + 5x(\text{Artificial lighting needs})$$

The second requirement is about the maximum allowed annual consumption of the primary energy of the building by incorporating the HVAC system, the domestic hot water production, besides the artificial lighting. These features are represented by C_{ep} (Conventionelle d'energie primaire / Conventional primary energy) Factor. The C_{ep} coefficient embodies the conventional annual consumption of the primary energy of a building, reduced to floor surface. Only two primary energy factor values are used: 2,58 is used for electricity and 1 is for all other fuels [23, p.32].

The final requirement is about the thermal comfort during the summer season based on the agreement to a maximum comfort temperature level (indoor operative temperature). This requirement is only applicable to buildings without any air conditioning systems.

The building air tightness has to be less than or equal to 0,6 m^3/hm^2 under 4 Pascal pressure differential for a detached house. It has to be less or equal to 1 m^3/hm^2 for apartment buildings. There are no regulations for the non-residential buildings for air tightness, whether new or refurbished. In the case of refurbishment of residential buildings, there are no fixed limits, but measurement is compulsory. The reference area for the air tightness measurement is the difference between the envelope area and the floor area.

3. Passivhaus (Germany)

Passivhaus has originated in Germany in 1990 [24]. This is a design methodology which can be applied by anyone and anywhere. In this methodology heating losses due to transmission and ventilation losses are aimed to be minimized through the following actions: the technology required for an idealized passive house requires airtight and well-insulated climate building envelopes, windows and doors with low transmission losses; the remaining heat demand is often supplied by the supply air using heat recovery from the extract air. In general, this concept is best applicable to climate zones with very low winter temperatures, such as Northern Continental Europe or Eastern Anatolia.

In order to earn a certificate, all data and calculations carried out in the Passivhaus Planning Package (PHPP) have to be reported, including U-values, preventive design of thermal bridges, types of windows and heat demands. The PHPP contains a check list, a calculation program and handbook, which can be bought at the website. The certification criteria are adapted to cool and temperate climates and would need revision for other climates. The area referred to in the criteria indicates the usable area (net living area within the building envelope). In order to obtain this certificate for different building conditions, a number of criteria have to be fulfilled. The criteria for heating and cooling vary among demand and load, yet we focus on the demand criteria in this paper.

In order to obtain Passivhaus certificate for residential buildings, specific annual heating demand excluding domestic hot water can be at most 15 kWh/m^2 and the total specific yearly primary energy demand can at most be 120 kWh/m^2. Airtightness rate at testing pressure of 50 Pa (n_{50} measurement) is set to maximum 0,6/h [25].

For obtaining Passivhaus certificate for non-residential buildings, specific annual heating demand excluding domestic hot water can be at most 15 kWh/m^2, specific yearly energy demand for cooling can be at most 15 kWh/m^2 and total specific annual primary energy demand can be at most 120 kWh/m^2. This limit value applies for schools and similar utilization patterned buildings. These values are used as a basis and in cases with very high thermal internal heat loads; the Passivhaus Institute requires proof of efficient electrical enery use for exceeding the basis value. Airtightness rate at testing pressure of 50 Pa (n_{50} measurement) is set to maximum 0,6/h [26].

For Passivhaus certificate for refurbishment, specific annual heating demand or heat power demand excluding domestic hot water can be at most 25 kWh/m^2, specific yearly energy demand for cooling is calculated automatically at the PHPP verification sheet; total specific annual primary energy demand can be at most 120 kWh/m^2. This limit can be implemented at residential buildings, office buildings, schools and other buildings having matching utilization patterns. These values are used as principles and in cases with very high energy demand; the Passivhaus Institute requires proof of efficient electrical energy use for exceeding the basis value, with the exception of uneconomical solutions in terms of upgrading and lifecycle for existing electricity uses. Airtightness rate at testing pressure of 50 Pa (n_{50} measurement) shall be maximum of 1,0/h^{-1}, although the target value expected to be maximum 0,6/h [27].

The PHPP includes tools for calculating: 1. Transmission losses through windows and the solar heat contribution; 2. Heat power demand; 3. Heating demand (annual and monthly use); 4.Heating systems using primary energy factors and assessing them; 5. Air flows, different operating conditions and degrees of heat recovery; 6. Heat distribution losses and domestic hot water use.

4. Minergie (Switzerland)

Minergie is the energy certification system of Switzerland released in 1995 [11]. The Minergie certification system combines energy efficiency with better indoor comfort and added value. In addition to focusing on energy efficiency, it is emphasized as a way of improving the indoor living environment by enforcing high quality building envelope/thermal insulation and systematic renewal of air/fan-assisted, balanced ventilation system. Architects, building owners and planners are free in their design, selection of materials and in the internal and external structure of their building [28].

There are several modules developed in the Minergie certification system:

(1.) Minergie defines buildings with energy consumption at most 75% relative to average buildings and with fossil-fuel consumption at most 50% of the consumption of such buildings. (2.) Minergie-P describes buildings consuming very low energy, mainly considering heating energy demand. This standard is similar to the Passivhaus standard. (3.) Minergie-A defines buildings with Nearly Zero Energy. The requirements include thermal insulation, air tightness, annual energy demand, auxiliary energy, embodied energy, lighting and household appliances. (4.) Minergie-ECO defines buildings with additions considering ecological requirements for additional occupant comfort. Some examples for these additions are noise protection, indoor air quality, recyclability, etc., on top of the regular Minergie requirements. Measurements carried out to verify the indoor environment include TVOC, formaldehyde, CO_2 and radon gas measurements. Note that “ECO” specification is possible for all first three types of Minergie modules.

The first requirement regarding the building envelope for obtaining a Minergie certificate is the heating demand calculated according to the Swiss standard SIA 380/1, which regulates the thermal energy in buildings. The maximum value is defined according to the building function. The final energy consumption referred to in Minergie does not include energy used in production or lost during transportation. The limit value depends on the building category and the building shape. Taking into consideration that 100% limit value corresponds with the Swiss regulations, Minergie and Minergie-A are a step tougher than the Swiss regulations with 90% and Minergie-P requests much thicker insulation with 60%. The air change has to be controlled whole year round. The renewal of the air is provided through a ventilation system.

The second requirement is the weighted energy demand index calculated with the national factors. This value is a measure of the total net energy delivered yearly relative to the reference "energy surface". The building's energy performance is based on weighted energy use per square meter heated gross floor area (GFA). Weighted Energy Index for Minergie is < 38 kWh/m²; for Minergie-P < 30 kWh/m² and for Minergie-A < 0 kWh/m² (15 kWh/m² when biomass plant is used). The weighting factors for the different energy sources used in Minergie are 0 for solar and ambient heat; 0,7 for biomass (biogas, wood); 0,6 for waste heat (incl. sewage treatment plants, industry and waste incineration); 1,0 for fossil fuels and 2,0 for electricity.

Another requirement is the provision of thermal comfort during summer time. The fourth requirement is that the additional costs must not exceed 10% compared with conventional building systems for a Minergie certificate and must not exceed 15% compared with conventional building systems for a Minergie-P certificate. Depending on the modules of the certification system, further requirements are expected as indicated below:

Minergie: There are five standard solutions valid for only residential buildings, which can be described as: 1. Ground-source heat pump to be used for hot water and heating the whole year round; 2. Thermal collectors for hot water in summer season, wood-fired systems for hot water and heating in winter season; 3. Automatic wood-fired systems for hot water and heating the whole year round; 4. Usage of waste heat (waste incineration, sewage treatment plants and industry) for hot water and heating the whole year round as single source); 5. Air-to-water heat pump for hot water and heating the whole year round [28]. Additional conditions to be fulfilled for Minergie module are: 1. A fan-assisted balanced ventilation system with a heat recovery unit having an efficiency of at least 80% is to be built. An AC motor or a DC motor should be used for the ventilation system; 2. A group of U values to be used at the building envelope are not to be overrunned, such as for floor, walls and roof 0,15 W/m^{2}K, for windows 1,0 W/m^{2}K and for doors 1,2 W/m^{2}K [29].

Minergie-P: In addition to Minergie requirements, Minergie-P requests a maximal specific heating power, airtight building envelope and household appliances with A-label. Furthermore, airtightness must be proven by test (limit value being $\eta_{50} \leq 0{,}6h^{-1}$). Typical thickness of insulation for Minergie envelopes are 20 to 25 cm and for Minergie-P envelopes are 25-35 cm [29].

Minergie-A: The requirements for the building's envelope are the same as for the Minergie and lower than the Minergie-P. The main focus is the weighted energy demand index. Non-renewable energy is not considered in this module. The requirements include thermal insulation, air tightness (proven by test and limit value being $\eta_{50} \leq 0{,}6h^{-1}$), annual energy demand, embodied energy (limit value being 50 kWh/m²), lighting and household appliances. Household appliences should have a minimum label of A [30].

EVALUATION OF CERTIFICATION SYSTEMS AND ADOPTION OF NEED4B METHODOLOGY

The certification systems studied in this paper do not only fulfill the national requirements of the country they originate, but they go beyond the national borders. All systems promote designing and retrofitting buildings using less energy, while promoting better services. They request high performing building envelopes and lowered energy demands for heating and cooling. Yet, a direct comparison among the certification systems and their standards is not possible. Almost all the calculation methods are focusing on the calculation of the primary energy consumption of the buildings, while the processes conversion of energy demand into primary energy is varying from country to country [31]. Taking into account that the energy certification systems have different scopes, different calculation methods, different norms and different units, we can still suggest a very basic scheme by breaking down the certification systems according to their energy consumption scopes.

The "energy use per year" and "energy use per unit of area" are the standard energy performance determinants in all certification systems. Yet, the definition of area reflects variations in all the studied certification systems as floor area including the exterior walls, floor area excluding the exterior walls, net floor area and gross floor area. This situation leads us to careful justifications during assessments.

In all studied systems and modules the inclusion of energy services varies among heating, domestic hot water, auxiliary equipment services, ventilation and lighting. Only Passivhaus includes all the mentioned energy services for the calculation of the targeted energy consumption of the building, whereas the others have different applications. In the European certification systems primary energy is the main calculation medium, whereas in the USA based Energy Star the total amount of raw fuel is the main calculation medium.

As different building types provide different building services, request different usage patterns and different building envelopes and forms, their energy performances cannot be compared sheerly. All aspects should be considered and studied carefully, prior to declaration of target energy performance for each building type. Hence, Energy Star specifies the performance limits for each building type, whether new or refurbished, without any intrinsic units. Minergie-A certification module specifies the performance limits for each new building type with conjugated limits on heating and domestic hot water. Effinergie certification system specifies the performance limits for each new and refurbished building type with conjugated limits on heating, domestic hot water, auxiliary equipment and ventilation, except for the single family dwellings and apartments. In the cases of single family dwellings and apartments the limit is 12% less. The other certification systems and modules have also detailed limits for different building types, yet not covering each different type.

In all certification systems analyzed in this paper, the energy performance is calculated according to nationally derived and described major climate zones. Effinergie takes this practice one step further and includes altitude factor in the energy performance. None of the energy certification systems nore modules suggest any ranking, compared to the variety of the certification systems with holistic approach. Their objective is pretty clear and straightforward. Yet, a ranking system could open the doors for achieving near zero energy buildings in quicker time, fulfilling the EU 20-20-20 energy targets of having a 20% (or even 30%) reduction in CO_2 emissions compared to 1990 levels, 20% of the energy, on the basis of consumption, coming from renewables and a 20% increase in energy efficiency by year 2020.

The Energy Star program uses a 1-100 scoring technique, in which a building is expected to score a minimum of 75 points in order to obtain an Energy Star certificate. This technique is based on normalization methods of statistical analysis and models implemented to the EIA data base. The data base information, Energy Star uses, is a crucial issue, yet technically complex and expensive to set up. In this sense, the success of the Energy Star in the USA has not been achieved by many countries, so far. At the EU level, many intermediary projects have taken place in order to establish an EU-wide database, like Euroclass, EPLabel, ENPER-EXIST, studying the complexity of creation of a database [32]. Yet, all EU certification systems arise from CEN Standard EN ISO 15217 "Energy performance of buildings – Methods for expressing energy performance and for energy certification of buildings"; briefly defining reference values for energy use, density and CO_2 emissions.

At this point, we would like to mention that these suggestions are being implemented to the NEED4B Methodology we are currently developing. NEED4B (New Energy Efficient Demonstration for Buildings) is a an EU-FP7 Project, and applied to one of the campus buildings, SCOLA, at Özyeğin University in Istanbul. SCOLA is the Turkish demonstration building in NEED4B project, along with the four other buildings in Belgium, Italy, Spain and Sweden, with different climates and usage purposes. The measurements over the last two years reveal that SCOLA has very low energy density, only 45 kWh/m²/year, which is lower than the project expectation of 60 kWh/m²/year. Note that a typical academic building in Turkey uses 255 kWh/m²/year in the 2. heating zone [33]. The real-time measurements of the SCOLA building indicate far better results compared to the different buildings in the university campus, which have been rewarded with LEED Gold or Silver certification.

We also want to emphasize the following to place certification systems within the framework of UNDP sustainable development goals ("Sustainable Development", 1991). We must interpret certificates as a protocol among different levels of stakeholders. Whatever the approach is or whichever country the certification system originates from, energy certifications should be considered based on the following four key modalities: the cost of energy production systems and installments (α); energy efficiency of all sub-units as well as the overall system (β); local and wide-spread availability of materials used for energy production and conservation measures (γ); reliability of all sub-components as well as total installments (δ). A more detailed description of these four modalities is given as:

α is the cost of all components and the operation of them within the system, starting at the project level to the completion of construction, and daily operation. The return on investment (RoI) is to be included in this modality, along with the cost of operations and their financing. The building user, owner and/or investor are the focus group of this modality. Here,

β refers to any type of energy, renewable or conventional, to be used in the most efficient way in a building. The operational costs are also included in this modality with emphasis on efficient operation of the system. It focuses on the impact of the energy selections to the welfare of the society. The third parameter,

γ is for the cost of all types of materials used for energy production and conservation. It is naturally tied to more general life cycle analysis (LCA) and the industrial impact. The sustainability in a more general sense, for the earth and the businesses is the focus of this modality. Finally,

δ refers to the end comfort of users. The human touch and the social consciousness are the main drivers of this modality and it focuses on the occupants.

These four concepts need to be considered hand in hand. In this paper our focus was limited to the energy efficiency modality only (β aspect). The details of these concepts are outlined by Menguc [34].

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REFERENCES

[1] Vitruvius, I, Howe T. N., Rowland D. ***Ten Books on Architecture*** (Cambridge University Press, 2001)
[2] ASHRAE Web site. Retrieved May 4, 2016 from http://www.ashrae.org/about-ashrae
[3] BREEAM. Retrieved May 5, 2016 from http://www.bre.co.uk
[4] Passive House Institute Documentation, "About Us". Retrieved February 20, 2015 from http://www.passiv.de
[5] Heincke, C., Olsson, D. ***Simply Green*** (Falköping: Conny Nilsson, Swegon Air Academy, 2012).
[6] LEED Documentation. Retrieved May 5, 2016, from http://www.usgbc.org/leed
[7] German Sustainable Building Council (DGNB) Documentation. Retrieved May 5, 2016, from http://www.dgnb.de/en/
[8] IGBC Documentation. Retrieved May 4, 2016, from https://igbc.in/igbc/
[9] About Energy Star. Retrieved May 4, 2016 from http://www.energystar.gov
[10] Effinergie Booklet. Retrieved May 4, 2016 from http://www.effinergie.org
[11] Minergie. Retrieved May 5, 2016 from http://www.minergie.ch
[12] Buildings - European Commission. Retrieved May 1, 2016 from https://www.ec.europa.eu
[13] Binalarda Enerji Performansı. Retrieved March 3, 2016 from https://www.bep.gov.tr
[14] Swegon Air Academy. Retrieved August 10, 2016 from https://www.swegonairacademy.com
[15] NEED4B (New Energy Efficiency Demonstration for Buildings) Project Documentation. Retrieved August 10, 2016 from https://www.need4b.eu.
[16] Bloom, E. ***Energy Efficient Buildings***: (Global Outlook. Colorado: Pike Reasearch LLC, 2011).
[17] Tools and Resources. Retrieved February 23, 2016 from https://www.energystar.gov
[18] Understanding the HERS Index. Retrieved February 23, 2016 from https://www.hersindex.com
[19] Sherman, M. & Walker, I. Philosophy and approaches for airtightness requirements in the USA, ***Proceedings of International Airtightness Workshop***, (Brussels, 2012).
[20] Energy Star Portfolio Manager. Retrieved February 23, 2016 from https://www.energystar.gov
[21] Taylor, Z. T., Mendon, V. ***Identification of RESNET HERS Index Values Corresponding to Minimal Compliance with the IECC Performance Path.*** (US Department of Energy, Pacific Northwest, National Laboratory, May 2014).
[22] Molenbroek, E., Stricker, E., Boermans, T. ***Primary Energy Factors for Electricity in Buildings - Toward a Flexible Electricity Supply***. (Utrecht, 2011).
[23] Feldmann, C. "French building regulation sets 50 kWh/(m²a) a limit for primary energy", ***REHVA Journal***, (2013): 29-32.
[24] Passivhaus Institute Documentation. Retrieved May 5, 2016 from https://www.passiv.de
[25] Feist, W. ***Certification criteria for residential Passive House buildings*** (Passive House Institute, Darmstadt, 2013).
[26] Feist, W. ***Certified Passive House - Certified Passive House - Criteria for non-residential*** (Passive House buildings, Passive House Institute, Darmstadt, 2013).
[27] Feist, W. ***EnerpHit: Certification criteria for retrofits*** (Passive House Institute, Darmstad, 2013).
[28] Practical Tips for Residents. Retrieved May 5, 2016 from https://www.minergie.ch
[29] The Minergie - Standard for Buildings. Retrieved May 5, 2016 from https://www.minergie.ch
[30] Huber, H. ***The Energy Standard and the Label MINERGIE*** (Praha, 2012).
[31] Towards Very Low Energy Buildings. Retrieved July 5, 2016 from https://www.isover.com
[32] Nikolaou, T., Kolokotsa, D., Stavrakakis, G. (2011). Review on methodologies for energy benchmarking, rating and classification of buildings, ***Advances in Building Energy Research***, 5:1 (2011) 53-70.
[33] Ek-4a. Retrieved July 5, 2016 from https://www.resmigazete.gov.tr/eskiler/2008/12/20081205-9-1.doc
[34] Menguc M.P. (2016). ***Layers of Responsibilities for Energy Efficiency Measures.*** (in preparation).

Urban/Building - ICT

Paper No: 211

A Bluetooth Low Energy Based Framework Approach for Real-Time Occupancy Detection

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ABSTRACT

Buildings account for about 40% of total energy use in the world and it is estimated that building energy use will grow 45% over the next 20 years. However, a huge amount of this consumption is caused by the waste of operating unoccupied buildings' services. With the drive towards improved occupant comfort as well as reduction in energy consumption, building automation systems are currently the leading technology for regulating building operations in a sustainable manner. However, since current building automation systems lack real time input of dynamic occupancy factor and they rely on predefined occupant comfort ranges, they cannot adjust themselves according to occupants' comfort needs and do not operate with full efficiency. Although there are many studies on occupancy detection systems in the literature, a reliable and precise detection framework is still missing due to certain shortcomings of current approaches including uncertainties in detection, privacy and time-delay issues, inability for multiple detection, and high expense of deployment and maintenance. Considering the importance of occupancy detection and the drawbacks of currently available technologies, the aim of this study is to propose a wireless based framework for real-time occupancy detection that will be accurate, multi-occupant aware, punctual, and reasonable in expense.

1. INTRODUCTION

Reducing CO_2 emissions by 20% compared to 1990, and increasing renewable energy use by 20% by the year 2020 were put as future objectives for '20-20-20 targets' by the European Commission. Since buildings use 40% of total energy in the world, Soucek and Zucker [1] argue that nearly-zero energy buildings should be the only choice for built environments in the future. Benezeth *et al.* [2] listed three solutions for economizing energy consumption, which are utilizing renewable energy sources, providing passive solutions like insulation, and managing the active energy consumption in buildings. Soucek and Zucker [1] indicated that employing technological tools like comprehensive Building Automation Systems (BAS) is the prerequisite for the third solution. It is claimed that, while energy efficiency requires the building architecture and its systems to be designed accordingly, with a focus on the very early stages of construction, the operation and maintenance of buildings are the stages where BAS is responsible for minimizing energy consumption.

Commonly, what BAS refers to is the arrangement of computer-based systems to monitor and administrate buildings' physical environments and operations such as heating, ve ntilation and air conditioning, electricity control, and water systems controls [3] . Wang [3] listed the main logical subsystems that compose BAS as HVAC, fire, security, lighting, hot water, and shutter controls. As it is obvious in the Figure 1, the operations of all major subsystems are based on the occupancy.

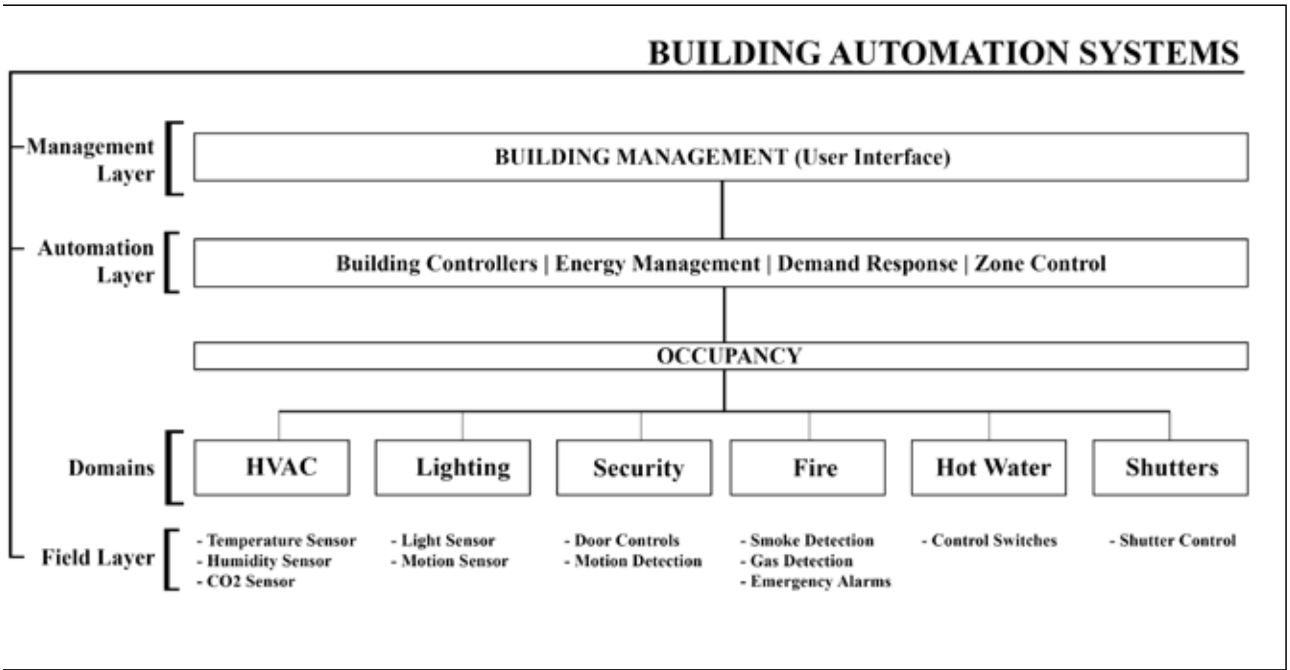

Figure 1 Breakdown of Building Automation Systems [4]

In the current approach of the industry, facility management technologies like BAS are operated through a reliance on assumption models and pre-defined occupancy profiles [5]. Yet, considering the excessive uncertainty in the nature of occupancy and unpredictable variations over numerous time-scales, fixed occupancy profiles for buildings are not very reliable and real-time monitoring is necessary to gain instant occupancy information [5].

The definition of occupancy information is made by Li *et al.* [5] as "the number and identities of occupants in a thermal zone and the resulting activities from occupant being present (*i.e.* associated plug, lighting, and HVAC loads)". In dynamic environments especially, having real-time occupancy information, including the number of occupants and their locations in the building, as Li *et al.* [5] claim, may be very useful both in building energy management and applications areas including security, safety, and emergency response. Yang and Becerik-Gerber [6] revealed that if occupancy profiles are personalized through real-time location monitoring and used instead

of conventional assumption models in HVAC control of a multi-story office building, energy consumption can be reduced by 9%. Likewise, the research of Lo and Novoselac [7] showed that a reduction of 30% in cooling energy consumption is possible with the utilization of occupancy control in an open plan office, through considering occupied and unoccupied zones separately in providing facility services. Furthermore, as Erickson *et al.* [8] affirm, the energy consumed for air conditioning annually in an office building can be reduced by 42% through sensing the location of people in the buildings, while keeping the comfort standards optimum for occupants.
In order to understand the influence of dynamic occupancy information on energy usage, Dong and Andrews [9] simulated the energy consumption of an office zone with both static occupancy profiles and dynamic occupancy data. Their research shows that, sensing occupancy in real-time could remarkably reduce the energy consumption to a level of 30%. As using fixed design assumptions are not that efficient in terms of energy consumption, obtaining reliable real-time occupancy information with the combination of raw sensor data and advanced algorithms has become an area of interest for many researchers lately [10].

There are some existing approaches for detecting the occupancy in indoors, such as simulation models, image detection systems, passive infrared sensor based systems, CO_2 sensors based systems and radio frequency based (wireless) systems. However, a reliable and precise location detection framework is still missing due to certain shortcomings of the current technologies including uncertainties in detection, time latency and privacy issues, inability for multiple detection and high expense of deployment and maintenance.

The aim of this research is to assess the possibility of establishing a mobile device integrated framework for building occupancy detection and to investigate the usability of Bluetooth Low Energy (BLE) technology for indoor localization. BLE technology is already embedded in most of the mobile devices and its properties such as ultra-low power consumption, low cost and low latency in data exchange make it a viable alternative to currently available technologies.

2. WIRELESS SYSTEMS FOR OCCUPANCY DETECTION

In this section, it is intended to overview the wireless (radio frequency based) systems for occupancy detection with their principles and shortcomings given in the literature. Radio frequency identification (RFID), wireless local area networks (WLAN), and ultra-wide band (UWB) will be analyzed with their technical frameworks.
Despite the popularity of Global Positioning System (GPS) for locating people and positioning objects in outdoor environments, the system does not work for indoors properly due to attenuation of electromagnetic waves by the walls and obstacles since the line of sight between the satellites and receiver tools is obstructed [11]. Since radio waves has the capability of penetrating walls, obstacles and human bodies, radio frequency based technologies are suitable for indoor localization with their wide coverage area and less hardware necessity [12]. Radio Frequency (RF) based localization systems are generally composed of transmitters and receivers, which interact with each other through radio signals.
The very first RF based occupant localization system was named RADAR that is developed by Bahl and Padmanabhan [13]. The goal of the authors was to locate and track occupants in indoor built environments through gathering RSSI data at multiple receiver locations and using collected information for position estimation. In the light of the research of Bahl and Padmanabhan [13], many other studies have been conducted for establishing a reliable and accurate real-time indoor localization solution based on RF technologies including radio frequency identification (RFID), WLAN, Ultra-wideband (UWB), and Bluetooth.

■ RFID

One of the most popular methods studied for detecting occupancy is RFID sensor based models. An RFID system composed of a number of readers and generally a large number of tags adjusted according to intended building size. What separate RFID from the other sensor technologies are its benefits such as RFID tags' features of having unique identity numbers and light, portable designs, its effectiveness in non-line of sight and longer detection range compared to infrared, ultrasound, and WLAN technologies [14]. A detailed technological review of RFID technology for indoor localization purposes can be found in the research paper of Pradhan *et al*. [14].
Despite the capability of RFID sensors based detection systems to provide comprehensive fine-grained occupancy information for demand driven applications in buildings [5], there are some obstructions. The multipath effect for signal propagation, changing environments' negative effects on RSSI, and unwillingness of occupants to wear RFID tags [10] can be listed as the main limitations for the deployment of this technology.

■ WLAN

As the infrastructure of WLAN is already deployed in many indoor environments including office buildings, educational facilities and public areas, the interest towards using WLAN for detecting occupancy has become a popular issue for researchers [15]. In WLAN based location detection models, position of every Wi-Fi compatible mobile device can be located through using existing Wi-Fi infrastructure with the aid of a positioning server. In this application line of sight is not required between access points and the target units [11]. Moreover, the coverage area of a WLAN based localization system is expandable since it can bear additional access points, and any mobile target can be tracked unless it goes out of the covered range [15].

Despite its potential for gaining occupancy information, WLAN based systems have their shortcomings and limitations, such as the negative effects of possible changes (i.e. moving furniture) in the environments on RSS, high initial deployment cost, variations in Wi-Fi signal strength by time and possible interferences with other appliances [16]. However, WLAN based occupancy detection solutions are still preferred over Passive Infrared (PIR) based or ultrasound based systems since they need fewer transmitters and provide higher confidence in real-time positioning accuracy [14].

■ UWB

Ultra-wideband technology is based on data transmission technique through sending and receiving ultra-short radio pulses. For an UWB based detection system, multiple unique tags for target units, stationary receivers covering signal map of the area, and a location management platform are required [17]. UWB system has the capability of high accuracy indoor localization with low power consumption even in non-line-of-sight conditions [17]. Since signals transmitted from UWB tags use a wider radio spectrum than the other RF-based tools, it does not effected by the interference of other signals in the environment and it has resistance to multipath effects [16]. In addition, large bandwidth of UWB provides high resolution in both time and location for positioning and tracking, and it is suitable for utilizing positioning techniques including time of arrival and time difference of arrival [16].
There are several studies in the literature for developing an applicable UWB based localization and tracking system, yet there is not a widely accepted solution. Although UWB based location detection models have the highest accuracy and precision (with a location error of 15 cm) among all other indoor localization solutions, a comprehensive receiver-transmitter infrastructure is required and the necessary initial deployment is so expensive that it is not in wide-scale use [16].

3. OVERVIEW OF BLUETOOTH LOW ENERGY TECHNOLOGY

Bluetooth technology was invented in the year of 1994 with the purpose of replacing data cables with a wireless communication for exchanging data using radio transmissions [18]. Bluetooth can be described as a wireless standard for wireless personal area networks (WPANs), which has zero dBm maximum power output [16]. Although the main aim of the creation of Classic Bluetooth was to unite distinct worlds of computing and communications tools, ***i.e.*** laptops and cell phones as Heydon [19] explains in his book, the technology was used widely and primarily as an audio link between cell phones and headsets. Enabling communication between cars and cell phones, file transfer between devices, and wireless printing are some of the uses that were generated as the technology was improved in years.

In 2010, the latest version of the technology, Bluetooth Low Energy (BLE), which is also called as Bluetooth Smart, or Bluetooth 4.0, was created by Bluetooth Special Interest Group Incorporation [18]. The core objective of BLE is claimed by Collotta and Pau [20] as to run with an ultra-low power consumption. While former versions of Bluetooth are mostly used for transmitting huge amount of data such as audio or files, BLE is designed to exchange small data pieces such as humidity readings (Figure 2), which makes this technology convenient for devices requiring long battery life rather than high data rates [21]. Latencies in connection and data transfer is also much smaller in BLE when it is compared with former technologies. Another feature of BLE is that it enables internet connection for different devices in an efficient way with its server architecture [20]. In order to connect to the Internet, BLE devices can use other BLE embedded devices such as tablets, smartphones or PCs that have a direct internet connection as a gateway. The primary benefit of this approach is achieving simpler, lower cost and lower power wireless devices.

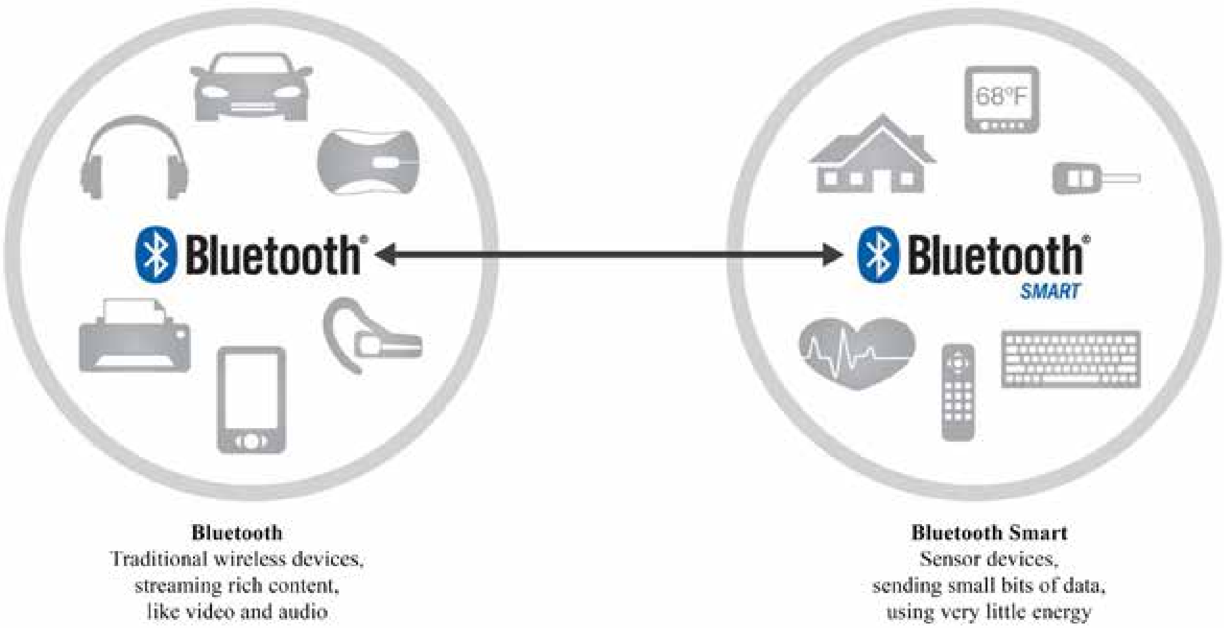

Figure 2 Scope of Classic Bluetooth via Scope of Bluetooth Low Energy [18]

BLE has adapted itself into the mobile device industry very rapidly and most of the smart device producer companies, as Townsend *et al.* [22] observe, including Apple, Samsung and Google are putting significant efforts into embedding this technology into their products and publishing design guidelines around it. The reason behind this uncommonly rapid adoption rate is that it is an extensible framework for exchanging data and it allows little task-specific and innovative devices to talk to smartphones or tablets, which potentially open the gates for new ideas and improvements in the market [22]. Another driver for the rapid adoption rate is the concept of Internet of Things (IoT). The visionaries of the IT sector propose a future where every tool, device, component will have the ability to connect to internet and form a network of devices. Easy-to-deploy, cost efficient and low power wireless solutions are the key requirements for the IoT concept, and BLE was shown to be a well-suited technology with its ultra-low power sensors and low-cost deployment needs [23].

Table 1 Comparison of Localization Technologies' Features [24]

	RFID (active)	WLAN	UWB	BLE
Accuracy	2 m	4 m	15 cm	2 m
Coverage	30 m	30 m	10 m	30 m
Battery Consumption	i-CARD CF350 interrogator 250 mW (milliwatt)	WSN802GX 3.3 V*200 700 mW	Transceiver(19) 500 mW	nRF51882 3V*10 30 mW
Device Cost	300 pounds	50 pounds	10 pounds	10 pounds
Privacy	Medium	Medium	Medium	Medium

Although BLE technology is not specifically designed for indoor positioning and occupancy detection, it has a significant potential [25]. As it is shown in Table I, BLE technology is more efficient than existing localization technologies in power consumption, while ensuring good accuracy, coverage and cost features [24]. BLE uses tiny chips, widely known as Bluetooth tags, in which radio frequency and microchip technologies are combined for creating a robust system and this system can be used for both identification, monitoring and maintenance of building assets, and indoor positioning of people through communicating with a tag reader [26]. As this low energy and low latency data exchange technology is increasingly popular in the device industry, almost all mobile devices such as smartphones, smart watches, tablets, or laptops equipped with BLE are able to communicate with Bluetooth tags and can be used as readers. These Bluetooth tags can send small data pieces to the readers, which can be any mobile device, and the distance can reach up to 50 meters [25]. Besides its pervasive availability in mobile devices (which people readily own and carry), relatively low cost of and ultra-low power consumption of BLE tags when compared to other technologies can be claimed as the main advantages for utilizing it for locating people in indoor environments.

4. PROPOSED FRAMEWORK

As reviewed in the literature, occupancy detection is an important area of research for the energy optimization in built environments and no proposed solution for gaining occupancy information is widely accepted due to the constraints of existing approaches. It is also inferred from the literature that properties of BLE technology such as ability to penetrate through walls, ultra-low power energy consumption, low cost, low latency in data exchange and uniqueness of its tags make it a potentially appropriate technology for utilization in occupancy detection

[26]. Moreover, as mobile devices such as smartphones, tablets or smart watches became essential objects in today's daily life of people and shows a rapid evolvement, there is a potential for using them as an enabler for the integration of BLE in occupancy detection systems. According to the research carried out by Smith and Page [27], 90% of people use a cell phone whereas 64% of them are smartphones in United States. Considering this, an occupancy detection framework that is accurate, punctual, reasonable in expense and easy to be implemented in current building systems can be developed for location detection using Bluetooth Low Energy technology and employing mobile devices.

Mainly, materials of the proposed system is composed of BLE tags as signal transmitters and mobile devices as readers. In the framework, first, BLE tags are deployed in the test bed environment in a way that whole indoor area is in the coverage zone. Then, intended area is divided into non-physical grid cells in two dimensions and radio signal data was collected at all defined locations, which creates the radio map of the area. Afterwards, in real operating conditions of the buildings, when an occupant gets inside the building with his mobile device, it starts to collect radio signal data from the deployed BLE tags. After the mobile device records radio signal data for a defined period of time (*i.e.* one minute), it sends the recorded data to the building automation server. Here, it is assumed that the mobile device is equipped with the application to record radio signal data. When recorded data comes from the occupant to building automation server, the data is searched in the pre-established radio map with the employment of defined classifier and the positon of the occupant is determined in the predefined coordinates (Figure 3).

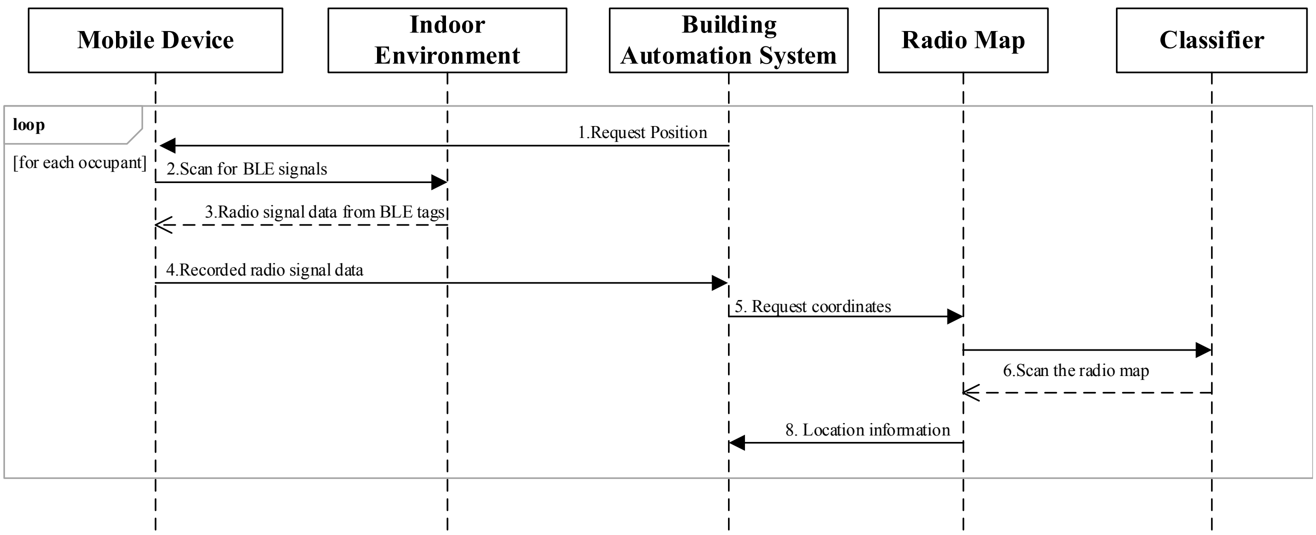

Figure 3 Proposed Occupancy Detection Framework

For that purpose, a series of experiments are organized and being conducted at MATPUM Research Center building at Middle East Technical University, Ankara. MATPUM building is selected as the test bed environment considering the fact that it has a gallery space, metallic interior structure, many walls and obstructions that may affect the proposed system's performance. The defined area consist of six personal offices, two restrooms and a corridor, with an approximate size of 240m². The results of the experiments were not established at the time of writing.

4. CONCLUDING REMARKS

In this study, an occupancy detection framework based on BLE is proposed. While the proposal itself may be highly technical in nature, its implications in the built environment is tremendous. Current approaches to facility design are based on the assumptions of occupation, with little control over the running of energy consuming systems. In most facilities, the heating is either on, or off. The distribution and thermal capacities of indoor heating/cooling devices are mostly based on a constant running regime. Compartmentalization of air-conditioned spaces and internal/external insulation strategies are also based on the assumption of a consolidated occupancy across the whole building. However, the existing research shows that most buildings are under-occupied, leading to the fact that most energy is wasted for nothing. With a simple, reliable, and cheap monitoring of occupancy, the authors propose that the mindset for designing the facilities will also change.

At the home-level, the problem of solving occupancy detection is a trivial one due to the limited number of occupants and ease of dealing with their needs, privacy concerns, and their relatively regular use patterns. There are many new upstarts targeting this market, *i.e.*, Google Nest. For larger facilities, such as offices, or hospitals, the problem is much more complex. This study aims to propose a solution for the complex problem.

Once a simple and reliable occupancy detection solution is provided, the designers can focus on space heating, ventilating, and air conditioning instead of building-wide system. With the collected occupancy data, using artificial intelligence, the use patterns of occupants can be guessed at a high accuracy and the spaces they need can be readied in advance. Other sources such as calendars, social networks, and scheduling systems can also aid in improving these services. As a result, the wasted energy consumption in facilities can be reduced dramatically, leading to a much lower environmental impact in the future.

5. REFERENCES

[1] Soucek, S., Zucker, G. Current developments and challenges in building automation, Elektrotechnik und Informationstechnik 129 (4) (2012) 278-285.

[2] Benezeth, Y., Laurent, H., Emile, B., Rosenberger, C. Towards a sensor for detecting human presence and characterizing activity, Energy and Buildings 43 (2-3) (2011) 305-314.

[3] Wang, S. Intelligent Buildings and Building Automation, Spon Press, New York, 2010.

[4] Vasseur, J.-P., Dunkels, A. Building Automation, Interconnecting smart objects with IP, Morgan Kaufmann Publications, Burlington, 2010, pp. 361-372.

[5] Li, N., Calis, G., Becerik-Gerber, B. Measuring and monitoring occupancy with an RFID based system for demand-driven HVAC operations, Automation in Construction 24 (2012) 89-99.

[6] Yang, Z., Becerik-Gerber, B. The coupled effects of personalized occupancy profile based HVAC schedules and room reassignment on building energy use, Energy and Buildings 78 (2014) 113-122.

[7] Lo, L.J., Novoselac, A. Localized air-conditioning with occupancy control in an open office, Energy and Buildings 42 (7) (2010) 1120-1128.

[8] Erickson, V.L., Carreira-Perpiñán, M.Á., Cerpa, A.E. Occupancy-based system for efficient reduction of HVAC energy, 10th International Conference on Information Processing in Sensor Networks (IPSN), Chicago, IL, USA, 2011, pp. 258-269.

[9] Dong, B., Andrews, B. Sensor Based Occupancy Behavioral Pattern Recognition for Energy and Comfort Management in Intelligent Buildings, Eleventh International IBPSA Conference, International Building Performance Simulation Association, Glasgow, Scotland, 2009.

[10] Ekwevugbe, T. Advanced Occupancy Measurement Using Sensor Fusion, Institute of Energy and Sustainable Development, De Montfort University, 2013.

[11] Farid, Z., Nordin, R., Ismail, M. Recent Advances in Wireless Indoor Localization Techniques and System, Journal of Computer Networks and Communications 2013 (2013) 1-12.

[12] Vorst, P., Sommer, J., Hoene, C., Schneider, P., Weiss, C., Schairer, T., Rosenstiel, W., Zell, A., Carle, G. Indoor Positioning via Three Different RF Technologies, RFID Systems and Technologies (RFID SysTech), 2008 4th European Workshop on, 2008, pp. 1-10.

[13] Bahl, P., Padmanabhan, V.N. RADAR: An In-Building RF-based User Location and Tracking System, IEEE INFOCOM 2000 (2000).

[14] Pradhan, A., Ergen, E., Akinci, B. Technological Assessment of Radio Frequency Identification Technology for Indoor Localization, Journal of Computing and Civil Engineering 23 (2009) 230-238.

[15] Ismail, M.B., Fathi, A., Boud, A., Nurdiana, W., Ibrahim, W. Implementation of Location Determination in a Wireless Local Area Network (WLAN) Environment, Advanced Communication Technology, 2008. ICACT 2008. 10th International Conference on, Vol. 2, 2008, pp. 894-899.

[16] Mautz, R. Indoor Positioning Technologies, Civil, Environmental and Geomatic Engineering, ETH Zurich, 2012.

[17] Torrent, D.G., Caldas, C.H. Methodology for Automating the Identification and Localization of Construction Components on Industrial Projects, Journal of Computing in Civil Engineering 23 (2009) 3-13.

[18] SIG. Bluetooth, Vol. 2016, Bluetooth Special Interest Group Inc., 2016.

[19] Heydon, R. Bluetooth Low Energy: The Developer's Handbook, Pearson Education Inc., United States, 2013.

[20] Collotta, M., Pau, G. Bluetooth for Internet of Things: A fuzzy approach to improve power management in smart homes, Computers & Electrical Engineering 44 (2015) 137-152.

[21] Andersson, T. Bluetooth Low Energy and Smartphones for Proximity-Based Automatic Door Locks, Department of Computer and Information Science, Linkopings Universitet, 2014.

[22] Townsend, K., Cufí, C., Akiba, Davidson, R. Getting Started with Bluetooth Low Energy, O'Reilly Media Inc., United States of America, 2014.

[23] Andersson, M. Use case possibilities with Bluetooth low energy in IoT applications, u-blox, 2014.

[24] Basiri, A., Peltola, P., Silva, P.F., Lohan, E.S., Moore, T., Hill, C. Indoor Positioning Technology Assessment using Analytic Hierarchy Process for Pedestrian Navigation Services, International Conference on Location and GNSS (ICL-GNSS), Gothenburg, 2015.

[25] Ionescu, G., Osa, C.M.d.l., Deriaz, M. Improving Distance Estimation in Object Localisation with Bluetooth Low Energy, Eighth International Conference on Sensor Technologies and Applications - SENSORCOMM, Lisbon, Portugal, 2014.

[26] Lodha, R., Gupta, S., Jain, H., Narula, H. Bluetooth Smart Based Attendance Management System, Procedia Computer Science 45 (2015) 524-527.

[27] Smith, A., Page, D. U.S. Smart Phone Use 2015, Pew Research Center, 2015.

Paper No: 72

Evaluation of Thermal Radiation and Conduction Transfer in Sustainable Building Materials

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ABSTRACT

In this study, selected building materials are evaluated numerically and experimentally to explore their radiative and conductive heat transfer characteristics. The purpose for radiation part is to evaluate sustainable materials for buildings with desired spectral and directional performances to decrease the heating loads. For situations where a surface is to be kept cool while exposed to the sun, the objective is to have maximum reflection of solar energy with maximum radiative emission from the surface (radiative cooling). Such materials are called "spectrally selective." Spectrally selective materials can also be useful where it is desirable to cool an object exposed to incident radiation from a high-temperature source. Conduction heat transfer through these materials was also investigated since the main objective in choosing materials for roofs is to come up with high-resistance, low-cost insulation materials which also are of low density for the sake of reduced weight. Reverse heat leak method is used in determination of R-values of all samples. Materials for this purpose were developed and fabricated. They were tested using an insulated test chamber which was built for this study. The characteristics and the details of these materials are discussed for optimization of both radiation and conduction transfer through them.

Keywords: Building materials, Radiation transfer, Conduction transfer, Sustainable materials.

1. INTRODUCTION

Sustainable development through climate action and resource efficiency is crucial for the welfare of the planet and the humanity. This focus could have being an opportunity for the development and commercialization of eco-efficient construction and building materials. Such an effort should include eco-efficient thermal insulators, materials for mitigating building cooling needs, materials with reduced embodied energy, materials capable of reusing a high waste content and nanotech energy efficiency building materials and development of construction materials capable of reusing a high waste content is an important research line related to the management of waste as a resource [1]. One of the most effective way of reducing heat losses in buildings thus reducing heat energy needs is the use of thermal insulation materials constitutes with a thermal conductivity factor, k (W/m-K) lower than 0.065 and a thermal resistance higher than R=0.30 (m^2·K/W) [2]. Suitable materials for the production of these insulating products are lightweight materials with cellular structures. These materials can be categorized into the groups of pumice and perlite materials [3]. Perlite is an amorphous aluminosilicate volcanic glass which has the potential to be utilized as a raw material in geopolymerization technology [4], and pumice is a well known lightweight concrete aggregate that by combining with Portland cement and water produces a lightweight thermal and sound insulating, fire-resistant lightweight concrete for roof decks, lightweight floor fills, insulating structural floor decks, and a variety of other permanent insulating applications [5].
Determination of R-value for insulating materials is significant for quantification of insulation properties. One of the reliable techniques to evaluate these is the reverse heat leak method (RHLM), which is a major thermal testing method extensively used in the refrigeration industry to test U values of refrigerators [6]. Numerous

studies [7-11] exist on employing RHLM. While the technique is same, different types of heating elements for simulating the heat load is being used in these studies.

The process by which the surface of the Earth (and the air in contact with it) cools by the emission of longwave radiation is radiative cooling. The Earth's atmosphere has a transparency window for electromagnetic waves between the wavelengths of 8-13 μm that coincides with peak thermal radiation wavelengths at terrestrial temperatures. Creating an unbalance between the heat radiated outwards through the transparency window, and the absorbed radiation from the environment is key to achieving radiative cooling. The purpose of radiative cooling is control of emission by paints and coatings or using new materials [12, 13].
Fourier transform infrared spectroscopy (FTIR) is a technique which is used to obtain an infrared spectrum of absorption or emission of a solid, liquid or gas. An FTIR spectrometer simultaneously collects high spectral resolution data over a wide spectral range [14].
This study involves design and experimental study of potential new building insulation materials (Perlite pumice based materials). R-value determination tests conducted on the samples prepared in the lab, using the RHLM. Meanwhile radiative properties of the materials were measures by an FTIR Spectrometer.

2. EXPERIMENTAL METHODS

2.1 Radiation

All FTIR (Fourier transform infrared) spectroscopy spectra were recorded as direct (specular) absorbance or transmittance. Diffuse absorbance and transmittance spectroscopy measurements in the UV/ Vis/ near IR region were carried out on a Nicolet iS10 FTIR Spectrometer equipped with an integrating sphere that is shown in Figure 1. Spectra were recorded at room temperature between 4000 and 400 cm^{-1}.

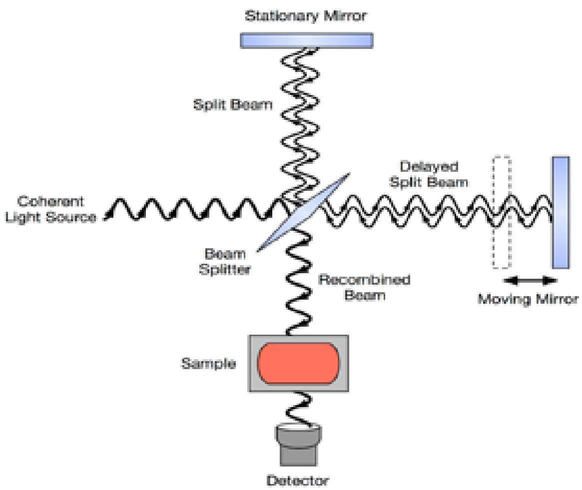

Figure 1 Thermo-Nicolet iS10 FTIR

(Sabanci University, [15].)

Figure 2 Schematic of the FTIR device [16].

In Figure 2 a schematic of the FTIR device operation principles are shown.

FTIR is the technique used to obtain spectrum of absorption, emission and the main aim is to measure the amount of light absorbed by a sample each wavelength [17].

In infrared spectroscopy, IR radiation is passed through a sample, so some of the infrared radiation is absorbed by the sample and some of it is passed through (transmitted). The resulting spectrum represents the molecular absorption and transmission [18].

2.2 Conduction Experiments

In conduction part, the experimental setup consists of the insulation box (made of XPS or extruded polystyrene and the top is left open as the test surface for testing the fabricated prototype panels whose R-values are to be determined), test surface, heat load, and the data acquisition system which is composed of thermocouples, a multiplexer and a data logger. A commercial software was used for achieving the raw data and real-time monitoring of temperature values. In Figure 3 a schematic of the experimental setup is shown.

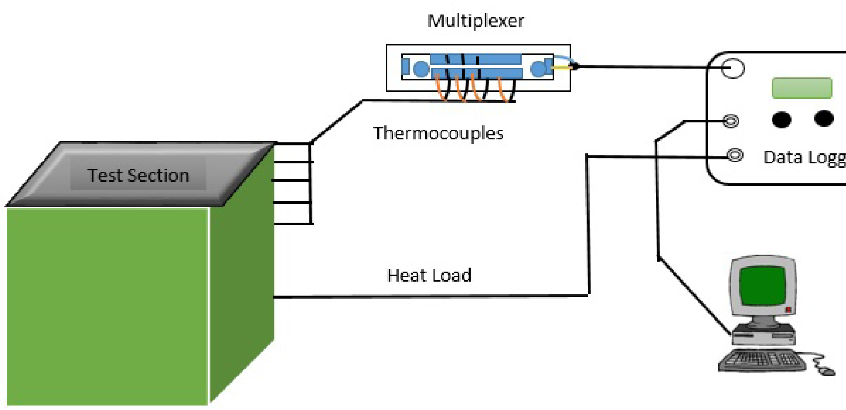

Figure 3 Schematic of the conduction test setup at Ozyegin University.

At first, all T-type thermocouples were calibrated (Eighteen thermocouples), and implemented at selected locations for measuring temperatures of surfaces, inside air, and ambient air. Surfaces temperatures were measured both on the inner and outer surfaces of each face of the box, centered symmetrically. All thermocouples measuring surface temperatures were covered with 2×2×0.5 cm XPS foam to isolate the thermocouple tips from the surrounding affects. Inside air temperature was measured at two levels (at one quarter and three quarters of the inner height) within the box, to get an average inside temperature. Outside air temperature was measured at four sides of the box. The test box was placed on a hollow galvanized steel stand to ensure that the bottom surface is also completely exposed to outside air. To block the flow of heat through the metal stand, XPS separators were placed between the stand and the box, and rubber strips were used underneath the legs of the stand. Figure 4 illustrates the reference (XPS) box, along with the heat load (10.5 W light bulb) and thermocouples. Sampling frequency of temperature data collection was one minute. For each test, it was first assured that steady-state was assured, followed by at least one hour of data collection to get at least sixty data at steady state conditions for minimizing the standard deviation. Three prototype samples of dimensions 58×58×2 cm were developed. All of these panels had perlite, pumice, and cement common in their composition with mass fractions of 24%, 6%, and 70%, respectively. One sample had a painted upper surface, and the other one had 0.5 cm soil and 0.5 cm high moss on top of it, representing the green roof system.The initial test was performed with the XPS panel at the test section. PPC is the plain sample with perlite, pumice, and cement of mass fractions of 24%, 6%, and 70%, respectively. The last two samples on the table are another PPC sample with white colour paint, and one more PPC covered with moss as a green roof system. Figure 8 plots the experimental and theoretical results, along with the illustration of experimental uncertainties.

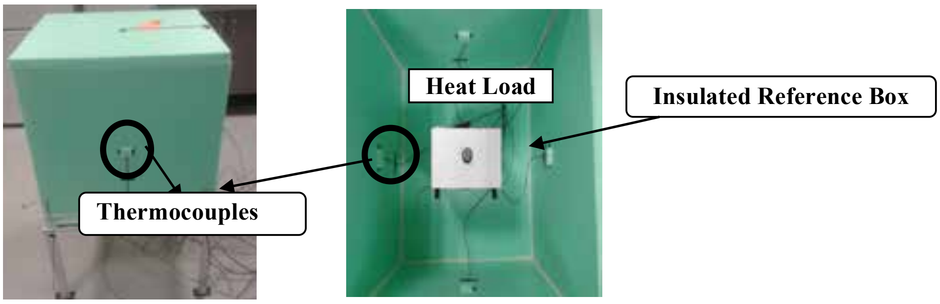

Figure 4 Heat load and thermocouples of the insulated XPS box for conduction experiments.

3. THEORY

3.1 Radiation Transfer

To be able to explain radiative cooling, we need to write down the equations for radiative energy balance on a surface.

$$Q_{in} = Q_{solar,absorbed}(T_{Sun}) + Q_{atm,absorbed}(T_{amb}) \quad (1)$$

$$Q_{out} = Q_{emitted}(T_s) + Q_{convected} \quad (2)$$

$$Q_{in} = G_{Sun}(T_{Sun})\alpha_s(T_s) + G_{atm}(T_{amb})\alpha_s(T_s) \quad (3)$$

$$Q_{out} = \varepsilon_s \sigma T_s^4 + h_c(T_s - T_{amb}) \quad (4)$$

$$Q_{net} = Q_{out} - Q_{in} \quad (5)$$

In day time if $Q_{out} > Q_{in}$ so we have radiative cooling. Figure 5 represents day time radiative cooling.

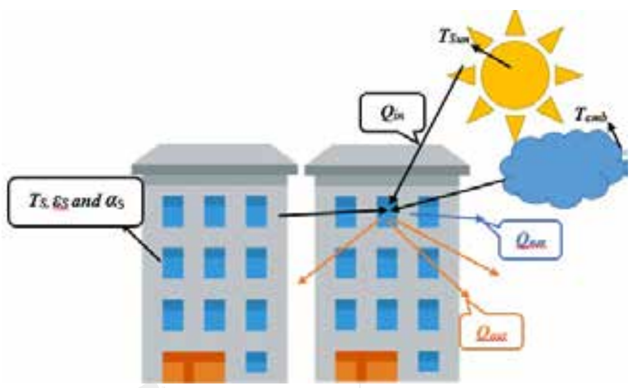

Figure 5 Schematic for day time radiative cooling.

One of the other situations is night time radiative cooling that we have to consider it in two states of clear sky and dusty or humid sky. In clear sky, we assume clear night with no dust and humidity so we have night time radiative cooling generally as showed in equation (6).

$$Q_{in} < Q_{out} \tag{6}$$

But if we have dust and humidity in night time, so it will be like and equation (7) and therefore we do not have night time radiative cooling in this case.

$$Q_{in} \approx Q_{out} \tag{7}$$

The important thing is considering the net cooling power in different wavelengths because by changing the wavelength, this value will be changed too. So the radiative cooling equations by considering that it varies with wavelength has been rewritten in the following equations. We briefly review the spectral energy balance below. We consider a structure at temperature T, with a spectral and angular spectral emissivity $\varepsilon(\lambda,\Omega)$. The structure is exposed to a clear sky and is subject to solar irradiance and atmospheric irradiance corresponding to an ambient temperature T_{amb}.

All the equations can be written in rate format in terms of Watt so Q=P.Δt

$$P_{rad}(T) = Q_{emitted}(T_s)/\Delta t \tag{8}$$

$$P_{rad}(T) = \int d\Omega cos\theta \int_0^\infty d\lambda I_{BB}(T,\lambda)\varepsilon(\lambda,\Omega) \tag{9}$$

is the power radiated by the structure per unit area, Ω is the angular integral over a hemisphere, and

$$I_{BB}(T,\lambda) = (2h_c^2/\lambda^5)/\left[e^{h_c/(\lambda K_B T)} - 1\right] \tag{10}$$

is the spectral radiance of a blackbody at temperature T,

$$P_{in} = P_{atm}(T_{amb}) + P_{Sun} \tag{11}$$

$$P_{atm}(T_{amb}) = \int d\Omega cos\theta \int_0^\infty d\lambda I_{BB}(T_{amb},\lambda)\varepsilon(\lambda,\Omega)\varepsilon_{atm}(\lambda,\Omega) \tag{12}$$

is the absorbed power per unit area emanating from the atmosphere, and

$$P_{Sun} = \int_0^\infty d\lambda \varepsilon(\lambda,0) I_{AM1.5}(\lambda) \tag{13}$$

is the incident solar power absorbed by the structure per unit area, and for obtaing equations (12) and (13), Kirchhoff's law ($\alpha_\lambda=\varepsilon_\lambda$) has been used to replace the structure's absorptivity with its emissivity $\varepsilon(\lambda,\Omega)$ and the angle-dependent emissivity of the atmosphere is given by

$$\varepsilon_{atm}(\lambda,\Omega) = 1 - t(\lambda)^{1/cos\theta} \tag{14}$$

where $t(\lambda)$ is the atmospheric transmittance in the zenith direction.

h, c, k_B, and k, are the Planck constant, the velocity of light, the Boltzmann constant, and wavelength, respectively. In equation (13), the solar illumination is represented by AM1.5 Global Tilt spectrum with an irradiance of 964 W/m^2, which represents the average solar conditions of the continental U.S. We assume that the structure is facing the sun. Hence, the term P_{Sun} is devoid of an angular integral, and the structure's emissivity is represented by its value in the zenith direction, θ=0.

3.2 Conduction Heat Transfer

3.2.1 Theoretical R-value

Theoretical thermal resistance calculation is done based on the homogeneous mixture thermal conductivity determination. This is performed employing mass fraction average of the pure species' thermal conductivity values.

$$k = \sum_i Y_i k_i \tag{15}$$

For the green roof case, thermal resistance of the whole system was calculated using both composition-dependent thermal conductivity (for the perlite, pumice, and cement based panel) and the composite layer thermal conductivity (panel with soil and plant on top). Energy balance for the soil and the plant layer is fairly complicated as it accounts for all possible sources of energy flow such as radiative heat exchange between the soil and the foliage, sensible and latent heat flows through both layers, and precipitation heat flux which was assumed to be zero as no rain or irrigation event existed in the lab environment [19]. Equation 16 lays out the energy balance which was solved using MATLAB.

$$\begin{aligned}&\left(1-\sigma_f\right)\left(1-\alpha_f\right)I_s^{\downarrow}+\left(1-\sigma_f\right)(\varepsilon_g\,\mathrm{I}_1^{\downarrow}-\varepsilon_g\sigma\mathrm{T}_g^4)-\frac{\sigma_f\sigma\varepsilon_f\varepsilon_g}{\varepsilon_1}(\mathrm{T}_g^4-\mathrm{T}_f^4)+\rho_{ag}C_{p,a}C_{hg}W_{af}(\mathrm{T}_{af}-\mathrm{T}_g)+\\&\mathrm{C}_{e,g}\,l_g W_{af}\rho_{ag}(\mathrm{q}_{af}-\mathrm{q}_g)+\mathrm{k}\frac{dT_g}{dz}=0\end{aligned} \tag{16}$$

In a similar fashion, energy balance equation for the plant layer on top of the soil layer is illustrated below, where LAI is the leaf area index of moss.

$$\begin{aligned}&\left(1-\sigma_f\right)\left(1-\alpha_f\right)I_s^{\downarrow}+\left(1-\sigma_f\right)(\varepsilon_g\,\mathrm{I}_1^{\downarrow}-\varepsilon_g\sigma\mathrm{T}_g^4)-\frac{\sigma_f\sigma\varepsilon_f\varepsilon_g}{\varepsilon_1}(\mathrm{T}_g^4-\mathrm{T}_f^4)+\\&(1.1\mathrm{LAI}\,\rho_{af}\,\mathrm{C}_{P,a}\mathrm{W}_{af}\mathrm{C}_f)(\mathrm{T}_{af}-\mathrm{T}_f)+1_f\,LAI\rho_{af}C_fW_{af}r^{''}(\mathrm{q}_{af}-\mathrm{q}_{f,sat})=0\end{aligned} \tag{17}$$

3.2.2 Experimental Measurement of R-value

Determination of thermal resistance via experimentation is done based on conservation of energy. Under steady-state condition, all the heat from the light bulb should be leaking through the insulated box which is composed of five reference walls and one test wall.

$$q_{panel} = q_{heatload} - \sum q_i \tag{18}$$

where i indicates any wall but the test wall (i = 1, 2, …,5). Heat leaking through these five walls is calculated employing Fourier's law. The difference, according to Equation 18 gives the heat leak through the sample wall that is being tested. This tested sample panel with a varying cross-sectional area along the path of heat flow is given in Figure 6.

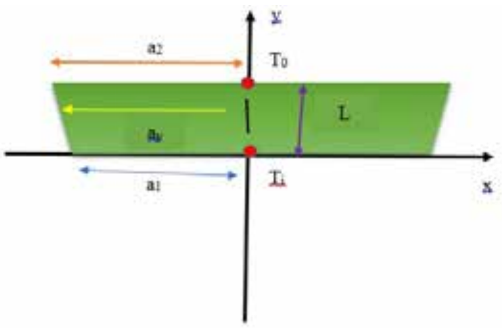

Figure 6 2-D view of the tested panel with varying cross-sectional area in the direction of heat flow.

Applying Fourier's law to the 2-D geometry, a set of following equations are obtained, leading to the R -value of the prototype panel.

$$\int_{y=0}^{y=L} q\frac{dY}{A} = -\int_{T_i}^{T_0} kdT \qquad (19)$$

For the sake of simplicity, theory can be applied on one quadrant of the panel, which can be reflected as one half of the drawing in Figure 6 with respect to y-axis. The width of this quadrant is a function of y.

$$a(\mathrm{y}) = a_1 + \frac{a_2 - a_1}{L} y \qquad (20)$$

$$A(y) = (2a)^2 \qquad (21)$$

$$A(y) = 4\left(a_1 + \frac{a_2 - a_1}{L} y\right)^2 \qquad (22)$$

Implementing Equation 22 into Equation 18 and integrating over the thickness of the sample gives the heat flow rate through the panel (Equation 23). Thermal resistance expression can be derived from this relation (Equation 24).

$$q = 4k\frac{a_1 a_2}{L}(T_i - T_0) \qquad (23)$$

$$R_{panel} = \frac{4a_1 a_2 (T_i - T_o)}{q_{panel}} \qquad (24)$$

3.2.3 Uncertainty analysis

Uncertainty analysis for the experimental part was performed at 95% confidence level (2σ). Temperature, power (heat transfer rate of the heat load), and area measurements were considered in the analysis per the relation given in Equation 25.

$$R = \frac{(A)(\Delta T)}{q}$$

(25)

Total errors from all quantities measured were calculated as in Equation 26:

$$U = \pm\sqrt{U_{\mathrm{Pr}^2} + U_{Bi^2}} \tag{26}$$

where UPr and UBi are the precision and bias errors, respectively. Uncertainties of the R-value measurements for all samples were then calculated by using Equation 27.

$$\frac{U_R}{R} = \sqrt{\left(\frac{U_A}{A}\right)^2 + \left(\frac{U_T}{T}\right)^2 + \left(-\frac{U_W}{W}\right)^2} \tag{27}$$

4. RESULTS

4.1 Radiation Heat Transfer

In Table 1, we introduced the materials that have been analysed by heir thermal conduction and radiation behaviour and the spectral specular absorbance of the materials are shown in Figure 7. **From spectral specular absorbance, we can see the position of the two critical-points structures at A** and B that is the atmospheric window range (8–13 μm or 1250-769.23 1/cm). It is shown that painted PPC (white paint) is a good "atmospheric-window material", it has low IR band absorbance (below and above of atmospheric window) and high IR band absorbance (over 0.3) across the 8–13 μm or 1250-769.23 1/cm band by considering the Equation 28). Plant sample and PPC one have the second and third rank after painted PPC and in this case XPS shows the worst behavior for being used in radiative cooling.

$$\alpha_{total} = \int_{0}^{8\mu m} \alpha_\lambda d\lambda + \int_{8\mu m}^{13\mu m} \alpha_\lambda d\lambda + \int_{13\mu m}^{\infty} \alpha_\lambda d\lambda \tag{28}$$

Table 1 Materials introduction.

Abbreviation	Material
XPS	Extruded Polystyrene Foam
PPC	Perlite Pumice Cement Composite Materials
Painted PPC	Painted Perlite Pumice Cement Composite Materials
Plant	Plant sample

4.2 Conduction Heat Transfer

Table 2 shows the experimental and theoretical results for all samples including the uncertainty in experimental analysis and the error between experimental and theoretical findings.

The initial test was performed with the XPS panel at the test section. PPC is the plain sample with perlite, pumice, and cement of mass fractions of 24%, 6%, and 70%, respectively. The last two samples on the table are another PPC sample with white colour paint, and one more PPC covered with moss as a green roof system. Figure 8 plots the experimental and theoretical results, along with the illustration of experimental uncertainties

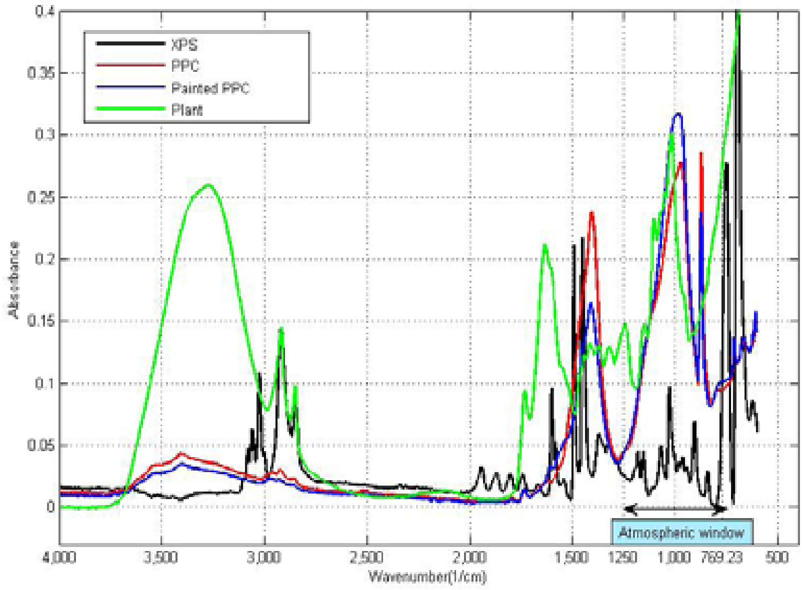

Figure 7 Spectral absorbance of the samples.

Table 2 Results from all samples.

Sample	**Thickness (mm)**	**Experimental R-value (m^2K/W)**	**Experimental R-value per cm ($m^2K/W/cm$)**	**Uncertainty (%)**	**Theoretical R-value per cm ($m^2K/W/cm$)**	**Error (%)**
XPS	25	0.826	0.330	±3.19	0.324	1.82
PPC	20	0.222	0.111	±3.32	0.105	4.95
Painted PPC	20	0.282	0.141	±3.25	0.149	5.32
Plant Sample	30	0.261	0.087	±3.72	0.080	7.66

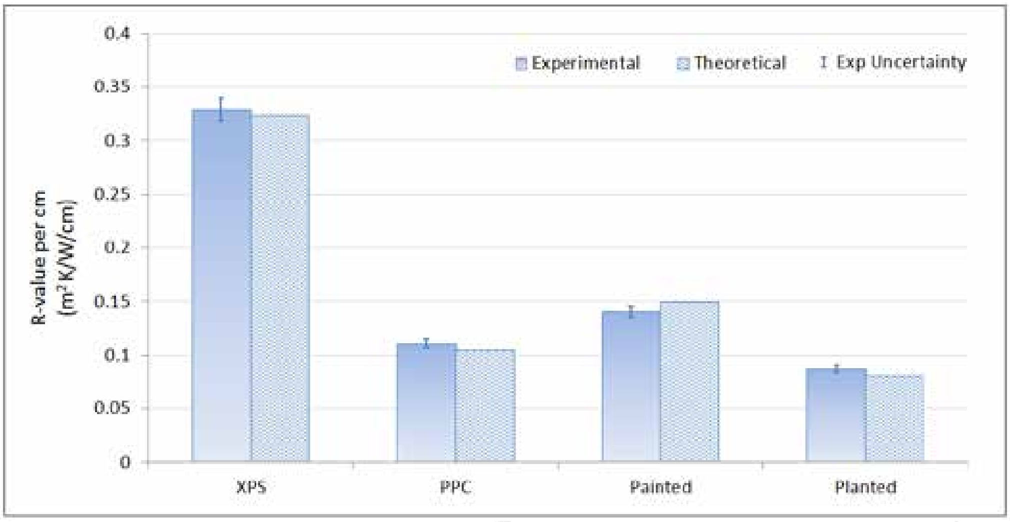

Figure 8 Experimental and theoretical R-values of samples per unit thickness [20].

Although planted sample seems to have lower R-value per unit thickness, it should be noted that when the soil-plant coupling is laid on top of the reference PPC sample, R-value of the system is increased by approximately 18%. Figure 9 plots the daily heat flux values through a bare flat built-up roof (R-value = 0.83 m^2K/W), as opposed to the scenarios of having PPC only, painted PPC, or planted PPC sample laid on top. Istanbul is selected as the test location and the analysis is conducted for a randomly selected date (August 22nd, 2014). Indoor design condition is assumed to be 24°C dry bulb temperature and 45% relative humidity. Negative heat flux between 6:20-6:50AM in the morning is due to outside air temperature falling below the indoor set temperature resulting in heat loss instead of heat gain. Peak period for the heat flux is between 2:30-7:00PM which would be accompanied with a peak load period slightly shifted clockwise, due to the transient behavior of the cooling load.

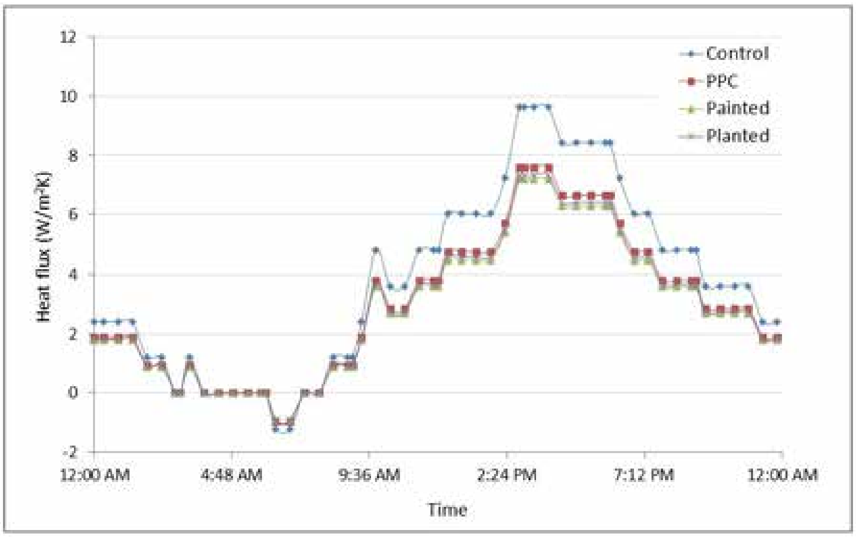

Fig. 9 Hourly heat flux through the roof (Istanbul, August 22nd, 2014) [20].

5. CONCLUSIONS

In this study thermal radiation and conduction heat transfer in building materials have been evaluated. Perlite pumice cement composite materials (bare, painted and planted) and XPS have been chosen as materials in this study. For radiation part, bare PPC, painted, plant sample and XPS were analyzed by FTIR for evaluating their spectral absorbance in using them for radiative cooling and results showed that painted PPC with white paint has the best property and plant sample and bare PPC followed it as the second and third one and XPS sample had the worst property for using in radiative cooling for the roofs of the buildings.

For conduction part, the roof of the building was modeled by fabricating building insulation panels composed of PPC and XPS and using RHLM. Effects of paint or vegetation over the panel surface were studied. Painted sample, with a paint penetration depth of approximately 0.5 mm demonstrated the best performance in terms of the R-value, followed by the plain PPC sample. Although the planted sample seemed to have yielded the lowest R-value per unit thickness of the sample, it is noted that reflectivity and evapotranspiration effects are not considered in this analysis due to the sole purpose of focusing on the conductive properties of the developed materials.

At last, in conclusion of both thermal radiation and conduction transfer behavior of our sustainable materials, perlite pumice composite material with white paint showed both good property as an insulating material in conduction and spectrally emitter in radiation followed by the plain PPC sample.

NOMENCLATURE

$I_l^{\downarrow}$	net longwave radiation, Wm^{-2}	α_f	surface albedo at foliage
$I_s^{\downarrow}$	net shortwave radiation, Wm^{-2}	ε_g	emissivity of soil
LAI	leaf area index	σ_f	foliage cover ratio
r″	surface wetness factor	Waf	wind speed within foliage, ms^{-1}

REFERENCES

[1] F. Pacheco-Torgal, "Eco-efficient construction and building materials research under the EU Framework Programme Horizon 2020," ***Constr. Build. Mater.***, vol. 51, pp. 151–162, 2014.

[2] J. S. Pacheco-Torgal F, Fucic A, "Toxicity of building materials," 2012.

[3] A. Benk and A. Coban, "Possibility of producing lightweight, heat insulating bricks from pumice and H 3PO 4- or NH 4NO 3-hardened molasses binder," ***Ceram. Int.***, vol. 38, no. 3, pp. 2283–2293, 2012.

[4] V. Vaou and D. Panias, "Thermal insulating foamy geopolymers from perlite," ***Miner. Eng.***, vol. 23, no. 14, pp. 1146–1151, 2010.

[5] L. Gündüz, "The effects of pumice aggregate/cement ratios on the low-strength concrete properties," ***Constr. Build. Mater.***, vol. 22, no. 5, pp. 721–728, 2008.

[6] G. Huelsz, F. Gomez, M. Pineirua, J. Rojas, M. de Alba, and V. Guerra, "Evaluation of refrigerator/freezer gaskets thermal loads," ***HVAC&R Res.***, vol. 17, no. 2, pp. 133–143, 2011.

[7] C. Hermes, C. Melo, and F. Knabben, "Alternative Energy Test Method for Frost-Free Refrigerators and Freezers," ***Int. Refrig. Air Cond. Conf.***, pp. 1–9, 2012.

[8] L. A. T. Goncalves, J.M., Melo, C., Vieira, "Experimental study of 'frost-free' refrigerators, Part I: Heat transfer through the cabinet walls (in Portuguese)," in ***1st National Congress of Mechanical Engineering, Natal-RN Brazil***, 2000.

[9] J. M. Goncalves, C. Melo, C. J. L. Hermes, and J. R. Barbosa Jr., "Experimental Mapping of the Thermodynamic Losses in Vapor Compression Refrigeration Systems," ***J. Brazilian Soc. Mech. Sci. Eng.***, vol. 33, no. 2, pp. 159–165, 2011.

[10] V. Parenti and H. Kramer, "PASCAL TM Technology: A Novel Breakthrough Polyurethane Foaming Technology for Domestic Appliance Insulation.

[11] C. Melo, L. Silva, and R. Pereira, "Experimental Evaluation of the Heat Transfer Through the Walls of Household Refrigerators," 2000.

[12] L. Zhu, A. Raman, and S. Fan, "Color-preserving daytime radiative cooling," ***Appl. Phys. Lett.***, vol. 103, no. 22, p. 223902, 2013.

[13] J. R. Howell, M. P. Mengüç, R. Siegel, Thermal Radiation Heat Transfer, 6th ed. CRC Press, Taylor and Francis, 2016.

[14] P. Griffiths, J. A. de Hasseth, "Fourier Transform Infrared Spectrometry," ISBN: ***0-471-19404-2***2, 2007.

[15] https://www.thermofisher.com/order/catalog/product/912A0760

[16] https://commons.wikimedia.org/wiki/File:FTIR_Interferometer.png.

[17] http://www.slideshare.net/DebomitraDey/application-ftir-and-nir-in-food

[18] Thermo Nicolet Corporation, "Introduction to fourier transform infrared spectrometry, "

[19] D. J. Sailor, "A green roof model for building energy simulation programs," ***Energy Build.***, vol. 40, no. 8, pp. 1466–1478, 2008.

[20] S. Celik, R. Family, M. P. Mengüç, "Thermal Evaluation of Perlite and Pumice Based Building Insulation Materials Using Reversible Heat Leak Method, " First Thermal and Fluids Engineering Summer Conference, 2015.

Paper No: 88

Analysis of Restoration Mortars Used For Strengthening of Historical Buildings in the Context of Sustainability Criteria

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ABSTRACT

Turkey is built on a land with thousands of years of history and hosts many historical buildings reflecting the sociological, economic, cultural, religious and political aspects of the history. However, many historical buildings located in Turkey have been subjected to natural disasters, adverse environmental conditions, material deterioration and anthropogenic impacts. It is of utmost importance to preserve these historical buildings with their structural integrity intact in terms of social sustainability. This study focuses on the restoration-strengthening methods used in order to preserve and hand down the damaged historical structures to the next generations. Strengthening methods are limited with restoration mortar used for structural damages, especially cracks. It is important to define the physical and chemical properties of the restoration mortar to be used in the historical building restoration in order to make decisions about the preservation applications. In addition, the material used in the mortar mix will be decisive for the durability of the mortar in the face of environmental conditions. In this context, this paper presents the environmental, economic and social sustainability criteria in a contextual framework while investigating the physical and chemical properties of repair mortars in terms of their environmental impacts.

Keywords: Restoration Mortars, Historical Buildings, Strengthening of Historical Buildings, Sustainability.

1. INTRODUCTION

Historical buildings, acting as a bridge between the past and today, are the reflection of social and cultural features of societies. Given their unique role, it is only possible to sustain their value and unique nature with better maintenance and protection. A shared heritage for the humanity as a whole, maintenance and protection of historical buildings and historical artifacts are considered a measure of civilization today. Therefore, maintenance and restoration of historical buildings is of utmost importance if we are to retain our history and reveal our cultural development [1].

Turkey had been a home to several civilizations and artifacts from these civilizations abound on these lands. Restoration and strengthening efforts made in order to ensure these artifacts are protected for the future must be conducted by specialists. The main purpose of maintenance and restoration of historical cities must involve historical and cultural sustainability, and protection of the identity of such historical structures for the generations to come. Thus, large scale protective efforts are important for the sustainability of physical and social structure in a historical environment where change and transformation are underway. In this regard, protection of the historical areas must be ensured with various dimensions of sustainability. The purpose of sustainable protection today with sustainability dimensions is the protection of the cultural identity and spatial quality of a city. Restoration and strengthening is essential for protecting historical structures with their original properties as a cultural and historical milestone for the generations to come. In this context, this study investigates the repointing mortars used in the restoration and strengthening of historical buildings with respect to sustainability.

2. SUSTAINABILITY IN HISTORICAL STRUCTURES

2.1. The Concept of Sustainability

The concepts of globalization and sustainability emerge as two important subjects of discussion with the concept of sustainability emerging in almost every field in the last decade. Considered as a necessity of society, sustainability is being the focus of several industries such as agriculture, tourism, technology, etc. [2]. It is defined as an ethics principle which has emerged from the environmentalist movement to become a widespread practice; and which is continuously redefined in the political process [3]. As a multifaceted concept, sustainability involves different aspects and it aims to find a balance between protecting and utilizing rather than only protecting. This is possible through the features of the concept of sustainability such as being a long-term commitment, being concerned about the future, and being involved both in nature/environment and the society. It is noted that the concept of sustainability involves conceptual measures as qualities and that these measures make it possible for the sustainable development to include social, ecologic, spatial and cultural aspects [4].

2.1.1. Components of Sustainability and the Concept of Sustainable Development

The planning approach sustainable development adopts based on the principle of development should be furthered without ignoring the environmental values requires the efficient use of resources, respect for the cultural heritage, and being environmentally-friendly in agriculture.

It was noted that it is a shared duty to fulfill our responsibilities associated with economic development, social development, and environmental protection, the three pillars of sustainable development at local, national, regional and global levels [5].

The components which play an important role in the sustainable development are as follows [6]:

• *Environmental sustainability* which focuses on a balanced housing and settlement between urban and rural areas,

• *Economic sustainability* which focuses on the investment and consumption balance with minimal input,

• *Cultural sustainability* which focuses on development of protective policies to ensure the protection of cultural values.

2.1.2. The Concept of Sustainable Protection

Culture is a whole which involves the knowledge, beliefs, arts, ethics, law, traditions and others as perceived by the individuals who are the society [7]. In this context, cultural heritage can be defined as the ongoing shaping of the aforementioned whole in time. In other words, cultural heritage can be defined as a landscape, an event of knowing, a name on a map, a street, a square or a structure, or a time restrained in a place [2].

The fact that the variety of the cultural heritage elements and awareness of the society about this kind of a variety contributes to the society's development is of importance. Nevertheless, it is stated that protection of cultural, historical, archaeological values available in a city will be a remarkable aspect for that city in the globalization process.

Uniting the society with these features, shared cultural heritage as an indispensable part of a city must be addressed with increased cultural benefits in mind. Cultural heritage items however they are protected are prone to be pressurized by the prospective income opportunities due to changing urban economic conditions. In this context, the balance between the concepts of change, development and protection must be realized in order to avoid such pressures which may lead to the devastation of areas under protection.

The main purpose of maintenance and restoration of historical cities must involve historical and cultural sustainability, protection of the identity of such historical structures for the generations to come, assessment of historical structures in the structure stock, and maintenance of the traditional settlement model. Thus, large scale protective efforts are important for the sustainability of physical and social structure in a historical environment where change and transformation are underway. In this regard, protection of the characteristics and features of the urban texture in historical areas must be ensured with a holistic approach and policies focused on sustainability. The purpose of sustainable protection as a common matter of discussion today is the protection of the cultural identity of a city and its spatial quality [8].

2.2. Historical Structures

Historical buildings, acting as a bridge between the past and today, are the social and cultural heritage of the lands they are built on. Protection and maintenance of such heritage is an indication of the civilization level of nations. It is of utmost importance to protect and ensure they are safely offered to the generations to come in order to maintain the data for the development of the humanity. These structures offer information on the building techniques used, their culture, beliefs and sociologic structure of that period. It is important for the humanity to further such information flow [9].

Turkey had been a home to several civilizations such as Romans, Byzantines, Hittite, Ottomans, etc. and artifacts from these civilizations abound on these lands. Protection of these artifacts for the future generations is a major concern which deserves considerable attention. The main focus of maintenance efforts conducted on historical buildings is keeping the data about the historical periods available with the structure intact [10]. However, it is clear that this rule is overlooked in many maintenance projects conducted in Turkey in the recent years. This kind of a lack of direction is leading to irreversible damages to historical buildings instead of protecting the history and cultural heritage through maintenance and restoration.

2.2.1. Materials Used for Historical Buildings

Natural materials such as rocks, bricks and mortar types, wood were used in historical masonry buildings. Human beings have been constructing structures using such materials since the ancient ages known to us. Among these materials natural rocks and bricks are most commonly preferred for their durability properties.

2.2.2. The Causes of Damages in Historical Buildings

In general, the following factors lead to damages in historical buildings which lead to failure:

Inaccurate restoration practices: False utilization of historical buildings leads to devastation and a number of applications are required to rehabilitate such a devastation. The historical structure to be restored must be thoroughly evaluated and explored. The use of a different material than the original material during the maintenance practice will lead to adverse effects in time failing to provide consistency [9].

Damages due to the ground: Impaired or heterogeneous soil strength leads to movement of the structural elements in time which result in visible failures in the structure. Damages in historical buildings due to soil strength may be categorized under six groups, namely, collapses, dislocations, swelling, broken parts, cracks and slides [11].

Ground movements such as earthquakes: Generally only able to carry compression stress, historical buildings are subjected to extensive thaw stresses and they collapse when the compression stresses due to vertical loads exceed the threshold.

Fires, wars and vandalism: However fire's impact on stone or brick buildings is limited when compared to wooden buildings, fire impairs the architectural properties of the structure while high temperatures during fire lead to cracks and collapses affecting the material properties. Historical buildings are receiving extensive damage during wars as the destructive power of modern warfare increases. This kind of damage may even lead to complete destruction of a historical building. Vandalism is an intentional act of destruction and is commonly used to define destruction of monuments by random people. Considered as a symbol of an ideology or a trace of past domination which people do not want to remember, monuments may intentionally be destroyed in accordance with the state policy or by upheaval of the people [11].

Air pollution and traffic: A number of polluting gasses and solutions damage the facades of buildings resulting in wear and loss of properties in time. Any vibrations due to vehicle traffic and their impact on the structure's foundation lead to damages in the historical buildings.

Long-term natural causes: Any interruption in the routine maintenance of historical buildings triggers the damages induced by several natural causes. The materials wear and tear due to temperature differences and freeze-thaw cycles; materials subjected to higher temperatures in hot summer days are then subjected to freeze in cold winter days.

Structural design faults: If there are any dimensional faults in the carrier systems of the buildings due to their original design, in other words, if carriers such as walls, pillars, supports, etc. are not able to carry vertical and horizontal loads, then serious damages may occur. A wall yields when unable to support cross-sectional loads, and when this is the case for the pillars, it may lead to dislocation of arches, vaults, and domes it supports which may result in collapse. Istanbul Hagia Sofia Museum is one of the most remarkable examples of this kind of a design fault.

Building material losing its strength: Deterioration of the structures accelerate when the materials used (stones, bricks, adobe bricks, wood, etc.) are not of good quality. For example, wear of the material is accelerated when the clay content of the stones used in construction increases. In the case of brick structures, structural strength increases when the bricks used are cured properly. Damages such as rapid wear, breaking off, indent formation, surface losses, disintegration, etc. occur when poor quality bricks are used.

Poor Workmanship: The combination of proper construction technique and good workmanship along with good quality materials is ideal. Any faults such as using insufficient amounts of binding material and use of faulty techniques used in bonding may lead to damages in masonry buildings.

2.2.3. Restoration/Strengthening of Historical Buildings

Restoration/strengthening of historical buildings is in fact a part of the concept of protection which has cultural, economic, and social dimensions requiring cooperation of several disciplines. The best decision regarding the additions and/or changes to be made in order to protect a building can only be made with the cooperation of specialists from fields such as architecture, engineering, restoration, art history, etc. The problem is not only about protecting historical buildings against earthquakes but is about protecting them with their original properties as a cultural and historical milestone for the generations to come.

The “Venice Charter” which is adopted in the Second International Congress of Architects and Specialists of Historical Buildings held between 25th and 31st May, 1964 must be taken into consideration for any process to be made in historical buildings. In this context, it is necessary to abide by a number of principles if it is aimed to preserve cultural and symbolic values in any effort made regarding historical buildings in Turkey. One of the most significant of these principles is the Decision No. 660 of the Cultural and Natural Heritage Preservation Board.

It is necessary to assess a historical building regarding its historical, aesthetic and technical aspects before conducting the restoration; to develop a building survey; and to detect any deterioration in order to conduct due diligence and restoration on a scientific basis. Among the techniques used are strengthening, completion, renovation, reconstruction, refinement and transportation as illustrated in Figure 1. The level of the intervention during the restoration effort increases from the strengthening to rebuilding. It would be ideal to limit these efforts with strengthening from a protection perspective.

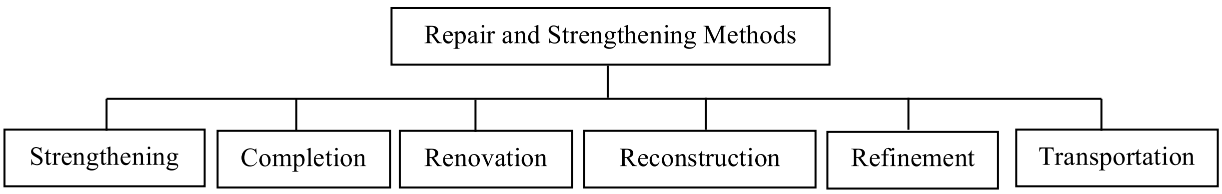

Figure 1. Methods used for the repair and strengthening of historical structures

Materials with similar properties with the original materials used in historical buildings must be considered in restoration- strengthening work done for such monuments. However, materials listed in Figure 2 are also commonly used in such efforts along with materials with similar properties. According to the Venice Charter, insufficiency/ineligibility of the traditional materials must be established before using the materials listed in Figure 2 [12].

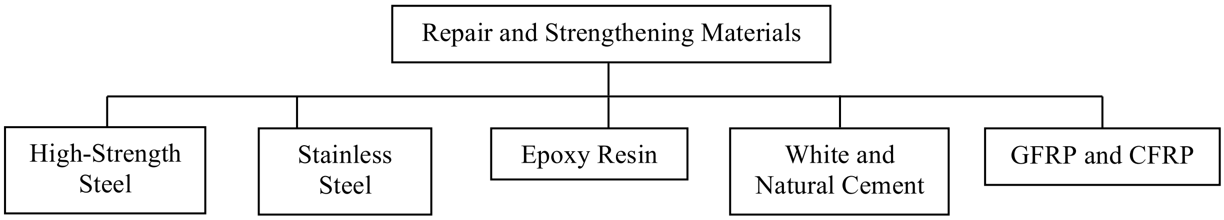

Figure 2. Materials used in the repair and strengthening of historical structures

This study investigates the mortars used in the restoration/strengthening of historical buildings. In this context, restoration and repointing mortars used are explored in terms of their environmental sustainability.

3. RESTORATION MORTARS USED FOR STRENGTHENING OF HISTORICAL BUILDINGS IN THE CONTEXT OF ENVIRONMENTAL SUSTAINABILITY CRITERIA

Before determining the mortar mix to be used in the restoration of a historical building, the reasons behind the damages occurred in the original building material must be understood first. Among the reasons behind the damages in the historical buildings are freeze-thaw, acid rains and crystallization of salts due to changes in humidity levels, etc. Materials used in the restoration of a historic building are of utmost importance in terms of sustainability. Mortar and stucco will affect the sustainability of the historical building when they are prepared considering the reasons behind damages.

Understanding the reasons behind deteriorations and faults observed in the original mortar and stucco is a necessity for appropriate maintenance and for preventing further devastation of the structures [13]. However, damage analysis is the essential step of a fine restoration practice providing the necessary information for the appropriate repointing mortar to be used, it is most commonly ignored. This kind of a negligence may lead to inconsistency between the repointing mortar and the original mortar [14].

Traditional brick dust (khorasan) mortar and hydraulic lime mortars are the main mortar groups used in historical building restorations. Repointing mortars are usually prepared in the field using natural hydraulic lime and slaked lime. The preferable properties of hydraulic lime mortars are as follows [15];

- Availability of adherence forces at the bottom surface;
- High ability to breathe;
- Involving limited amount of soluble salts;
- Resistant against blooming;
- Having limited capillary water absorption;
- Must meet the mechanical property needs.

Lime-based stucco and mortars may be subjected to deterioration due to climate-related and biological impacts. In addition, rain and sunlight have an impact on the deterioration of the mortar. Fire has an extensive adverse effect on the historical buildings. High temperatures may lead to surface failures as it changes the chemical structure of the lime mortars. A masonry wall which was exposed to fire will lose its strength observably as the mortar is damaged [16].

A low quality mortar mix, substandard material selection and poor workmanship will lead to deteriorations in a short while. And this will adversely affect the sustainability of the historical building. After defining the material properties of a historical building, reasons behind the damages must be confirmed. Following this process, appropriate method and materials must be selected for the restoration works [17].

Preliminary tests must be conducted with the application of the stucco and mortar prepared for the restoration of the historical building (sustainable restoration) to a small part of the structure. For example, pigments to be used in the mortar mix must meet the requirements when mixed with lime or when exposed to the sunlight; they should be water resistant, etc. [18].

The essential criterion in the selection of repointing material is that the properties of material such as physical/chemical properties and color/texture must be similar to the original material. Nevertheless, it is possible to make a selection in order to improve the durability properties of the structure without impairing the aesthetical value of the building [14].

Traditional mortars may include several materials such as lime and aggregates along with brick pieces and dust, old mortar or stone pieces, seashells, wood coal or fibers. The properties of mortar or stucco may differ with the amount and size of its ingredients. In this context, the repointing mortar to be prepared must have similar properties with the original mortar.

Standard tests must be conducted for the repointing mortars without exception. For example, pozzolanic activity tests must be conducted beforehand for natural pozzolanic additives in order to see if there is pozzolanic activity. The use of natural puzzolan with lower pozzolanic properties will adversely affect the properties of lime mortar. It is preferable for the lime to be used in lime mortar to be staked and stored at least one year before use. It is important to ensure the fibers to be added to the mix to be dry and clean and that they are not covered with grease. The water to be used must be clean and free from acids, alkali and other soluble organic matter [18]. It must be ensured that the paints to be used in restoration provide a permeable layer and not a film layer on the surface.

During the selection of the repointing material, it is possible to use materials offering similar properties with the original mortar or materials to improve the durability performance in the light of the current research into material technologies. Current research focuses on the additives which aim to improve the durability of lime-based materials against degradation factors. For example, it was found that sodium oleate ($C_{18}H_{33}O_2Na$) addition to lime-based mortars improves the durability against environmental factors and freeze-thaw tests [20]. In addition, the use of high-performance polypropylene with brick dust mortars improves the freeze-thaw and abrasion resistance. With the recent developments in nanotech, the use of nano Si and nano Al is expected to contribute to the mortar performance.

Leslie and Gibbons (2000) outlines the essential information to be obtained for repointing mortars as hydraulic properties of the binder, percentages of binder and aggregate by weight, and size distribution of the aggregate. Charola and Henriques (2000) draws attention to the porosity and mechanical strength properties while the research into the stucco and mortar analyses for the past 20 years shows a shift towards the amount of hydraulic additives available in the mix instead of their definitions. Briefly, it would be fair to say that the information on porosity ratio and mechanical strengths of the proper repointing mortar is more useful than the detailed definition of the hydraulic additives [21].

Assumptions are made for the chemical, physical and mechanical properties of non-hydraulic lime mortars, lime-puzzolana mix or mortars with hydraulic lime as a result of the studies on historical mortars. Moropoulou et al. (2005) outlines the chemical properties of different mortars in Table 1. Physical and mechanical properties of these mortars are shown in Table 2.

Table 1. Chemical properties of a number of mortars

Mortar type	Hygroscopic water (%)	Relative water (%)	CO_2 (%)	CO_2/H_20
Lime mortar	<1	<3	>32	7,5-10
Lime mortar (portlandit)	>1	4-12	18-34	1,5-9
Hydraulic lime mortar	>1	3,5-6,5	24-34	4,5-9,5
Lime-natural puzzolana mortar	4,5-5	5-14	12-20	<3
Lime-artificial puzzolana mortar	1-4	3,5-8,5	22-29	3-6

Table 2. Physical and mechanic properties of a number of mortars

Mortar type	Density (g/cm^3)	Porosity (%)	Tensile Strength (MPa)	Binder: aggregate ratio
Lime mortar	1,5-1,8	30-45	<0,35	1:4-1:1
Lime mortar (portlandit)	1,8-1,9	20-43	0,06-0,7	1:2-1:1
Hydraulic lime mortar	1,7-2,1	18-40	0,35-0,55	1:4-1:1
Lime-natural puzzolana mortar	1,6-1,9	30-42	>0,60	1:4-1:5
Lime-artificial puzzolana mortar	1,5-1,9	30-40	>0,55	1:3

Regarding the mechanical properties of repointing mortars, it was found that compressive strength increases with the increasing binder ratio for the samples. Increasing binder ratio also increases the porosity. Increasing porosity, on the other hand, accelerates the carbonation [22].

Regular maintenance and restoration is a must if it is aimed to preserve historical structures for future generations. However, the first step of any maintenance/restoration work must involve determining the reasons behind the damages and the structure of the original mortars. In terms of environmental sustainability, material selection, mix ratios, and application of the mortar or stucco to the surface appropriately are among the most important aspects.

4. RESULTS AND RECOMMENDATIONS

Recently we have witnessed the use of cement-based repointing mortars in restoration of historical structures. Since cement-based mortars are incompatible with the original mortar, it was observed that they can cause damage to the historical buildings. As cement-based mortars include high levels of soluble alkali salts, and that they offer lower porosity when compared to traditional mortars and they offer a higher compressive strength when compared to lime-based mortars, they cause degradations in historical monuments.

As lime-based mortars are prone to the adverse impact of climate and environmental conditions (poor durability properties), and that lime-based mortars as repointing mortar lead to adverse results such as hardening and carbonation, they are not preferable for restoration works of historical buildings.

When identifying the materials to be used as repointing mortar, it is recommended to use resources offering similar properties with the historical structure. Modern material technologies must be used when preparing repointing mortar mix compatible with the original composition. Especially, nano and fiber technologies will contribute extensively to the repointing mortars.

Regular maintenance and repair efforts will help preserve the original mortar and stucco available in a historical structure. Identifying the reason behind the degradation of stucco and mortar will contribute to economic applications and environmental sustainability.

The environmental conditions and physical effects must be considered for environmental sustainability. Among the chemical and physical factors adversely affecting the historical buildings are freeze-thaw effect and fire, acid rains and sulfate effect. In order to ensure environmental sustainability these effects must be considered and appropriate repointing mortars must be used. It is commonly known that cultural sustainability plays an important role in the restoration of historical monuments in order to ensure the durability of cultural values.

REFERENCES

[1]. Ünay, A.,İ., 1997, Method for the Evaluation of the Ultimate Safety of Historical Masonry Structures, Ph.D. Dissertation, METU, Ankara.

[2]. Büyükoksal, T. 'Kentsel Korumanın Sürdürülebilirliğinin Olabilirliği Üzerine Bir Yaklaşım Önerisi Eskişehir Odunpazarı Örneği' Dissertation, Ministry of Culture and Tourism, Ankara, 2012

[3]. Tekeli, İ., Sürdürülebilirlik Kavramı Üzerinde İrdelemeler, Ankara: Mülkiyetler Birliği Yayınları, 2001, p. 25.

[4]. Beyhan, S. G., Kültürel Süreklilik ve Çağdaş Gereksinmeler Bağlamında Sürdürülebilir Turizm ve Kimlik Kavramsal Modeli: Pamukkale Modeli, İstanbul Technical University Institute of Science and Technology, Doctoral Dissertation, İstanbul, 2004, p.35- 72.

[5]. Özlüer, F., "Sürdürülebilir Kalkınmanın Ekonomik Politiği", Ankara Chamber of Architects, Bulletin 51, File 05, Sürdürülebilirlik: Kent ve Mimarlık, 2007, p. 4-14.

[6]. Kural, N., "Sürdürülebilir Kentlesme Bir Dosyanın Düsündükleri", Ankara Chamber of Architects, Bulletin 51, Dosya 05, Sürdürülebilirlik: Kent ve Mimarlık, 2007, p 22-25.

[7]. Altay, C., "Kentsel Sürdürülebilirlik Açısından Kültürel Planlama ve Mekânsal İcraatlar" Ankara Chamber of Architects, Bulletin 51, Dosya 05, Sürdürülebilirlik: Kent ve Mimarlık, 2007, p. 25-30.

[8]. Özil, A., Türkiye'de Kentsel Koruma Kent Tarihleri ve Koruma Yöntemleri İstanbul: Tarih Vakfı Yayınları, 2001, p. 47- 90.

[9]. Çavuş, M. 'Tarihi Yapılarda Üst Örtülerin Çelik Malzeme ile Sağlamlaştırılmasının Sonlu Elemanlar Yöntemiyle Modellenmesi' Doctoral Dissertation, Gazi University-Institute of Science and Technology, Ankara, 2011.

[10]. Venice Charter**,** "The Venice Charter for the Conservation and Restoration of Monuments and Sites", Second International Congress of Architects and Specialists of Historic Buildings, Italy, 1964.

[11]. Ahunbay, Z., "Tarihi Çevre Koruma ve Restorasyon", ***YEM yayınları***, İstanbul, 1996, p.23-45.

[12]. Sesigür H., Çelik C. and Çılı F., Yapı Dergisi Februrary-2007, p. 10-22.

[13]. Ingham, J.P., Diagnosing Defects in Lime-Based Construction Materials, Journal of Architectural Conservation, 2009, p.15, 3, 59-80.

[14]. Van Hees, R. P. J., Binda, L., Papayianni, I. and Toumbakari, E. RILEM TC 167-COM: Characterisation of Old Mortars with Respect to their Repair , Characterisation and Damage Analysis of old mortars, Materials and Structures / Materiaux et Constructions, 2004, Vol. 37, p.644-648.

[15]. https://assets.master-builders solutions.basf.com/Shared%20Documents/PDF/Turkish%20(Turkey)/Tarihi%20Yap%C4%B1%20Onar%C4%B1m%20ve%20G%C3%BC%C3%A7lendirme%20Rehberi.pdf

[16]. Ingham, J.P., Foensic Engineering of Fire-Damaged Structures, Proceedings of the Institution of Civil Engineers, Civil Engineering, 162, Special issue-Forensic engineering, May 2009 ,p.12-17.

[17]. Polat-Pekmezci, I. and Ersen,A. "Characterization of Roman Mortars and Plasters in Tarsus (Cilicia-Turkey), 2nd Historic Mortars Conference HMC2010 and RILEM TC 203-RHM Final Workshop, 22-24 September, Prague, Czech Republic, 2010, p.317-324.

[18]. BS EN 13914-1 (2005). Design, Preperation and Application of External Rendering and Internal Rendering", Part 1: External Rendering.

[19]. Ashurst J. (1998b). Mortars for stone building, Conservation of Building and Decorative Stone, (ed.) J.Ashurst, F.G. Dimes, 1998. Part 2, p.78-96.

[20]. Izaguirre, A., Lanas, J. vand Álvarez J.I. Ageing of Lime Mortars with Admixtures: Durability and Strength Assessment, Cement and Concrete Research, Vol. 40, 7, 1081-1095. doi:10.1016/j.cemconres.2010.02.013

[21]. Groot, C. , Ashall, G. , Hughes , J.J. and Bartos, P.J.M. (2004). Characterisation of Old Mortars with Respect to their Repair: A State Of The Art, Characterisation of Old Mortars with Respect to their Repair - Final Report of RILEM TC 167-COM, Editor(s): C. Groot, G. Ashall and J. Hughes, RILEM Publications SARL,1-10, doi: 10.1617/2912143675.001

[22]. Lanas, J. and Alvarez,J.I. (2003). Masonry Repair Lime-Based Mortars: Factors Affecting the Mechanical Behavior, Cement and Concrete Research, 33, p.1867–1876.

Building - Design Requirements

Paper No: 35

Sustainable Facade System : Types of Vegetated Façade Systems Designed and Constructed in Turkey

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ABSTRACT

Average air temperature on earth has increased by 0.75 ° C from the beginning of the 20th century until today. Urban heat island effect (UHIE) and greenhouse effect lead to an increase in ambient air temperature. Use of vegetated surfaces and materials with high albedo value play an important role in reducing UHIE. It is essential to use renewable energy sources instead of fossil fuels and/or reduce energy consumption in order to decrease the greenhouse effect. There are various experimental studies in some countries examining the contribution of vegetated façade systems (VFS) used as sustainable systems on improving thermal performance of building envelope. However, in Turkey there is not any empirical study, which has measured thermal performance of VFSs. Therefore, a PhD thesis has being conducted at Istanbul Technical University to measure thermal performance of VFS under Kocaeli climate (temperate humid) conditions. In the present study commonly used VFS types used in Turkey will be determined. Aim of this study is to determine the VFS type whose thermal performance will be measured in the PhD study by means of determining widely used VFS type in Turkey and different VFS types whose thermal performance has been measured under Csa climate conditions.

Key Words: Vegetated Facade Systems (VFS), Green Facades, Living Walls, Building Envelope, VFS Assemblies

INTRODUCTION

Fourth Assessment Report of IPCC (Intergovernmental Panel on Climate Change) indicates that average air temperature on earth has increased by 0.75 ° C from the beginning of the 20th century until today [1,2]. Additionally, it is predicted that average air temperature on earth will increase by 1.8-4°C at the end of 21th century [2]. There are several adverse effects of air temperature increase on human health such as respiration, cardiovascular diseases and infections [3,4]. Urban heat island effect (UHIE) and greenhouse effect are main reasons of ambient air temperature increase. Use of roof, façade and pavement materials with high albedo value and vegetated surfaces play an important role in reducing the urban heat island effect [5,6]. In order to decrease the greenhouse effect it is essential to use renewable energy sources instead of fossil fuels and/or reduce energy consumption. In literature, there are various numerical and experimental studies investigating the contribution of vegetated façade systems (VFS) used as energy-efficient and sustainable façade systems on improving the thermal performance of building envelope. However, in Turkey there is not any empirical study, which has measured and evaluated the thermal performance of VFSs. Therefore, a PhD thesis is being conducted at Istanbul Technical University to measure thermal performance of vegetated facade systems under Kocaeli climate (temperate humid) conditions. For the study, it is essential to determine the type of VFS, which thermal performance will be measured.
Aim of this paper is to determine the type of VFS, which thermal performance will be measured under Kocaeli climate (temperate humid) conditions. Initially, review of various definitions and classifications that are given in

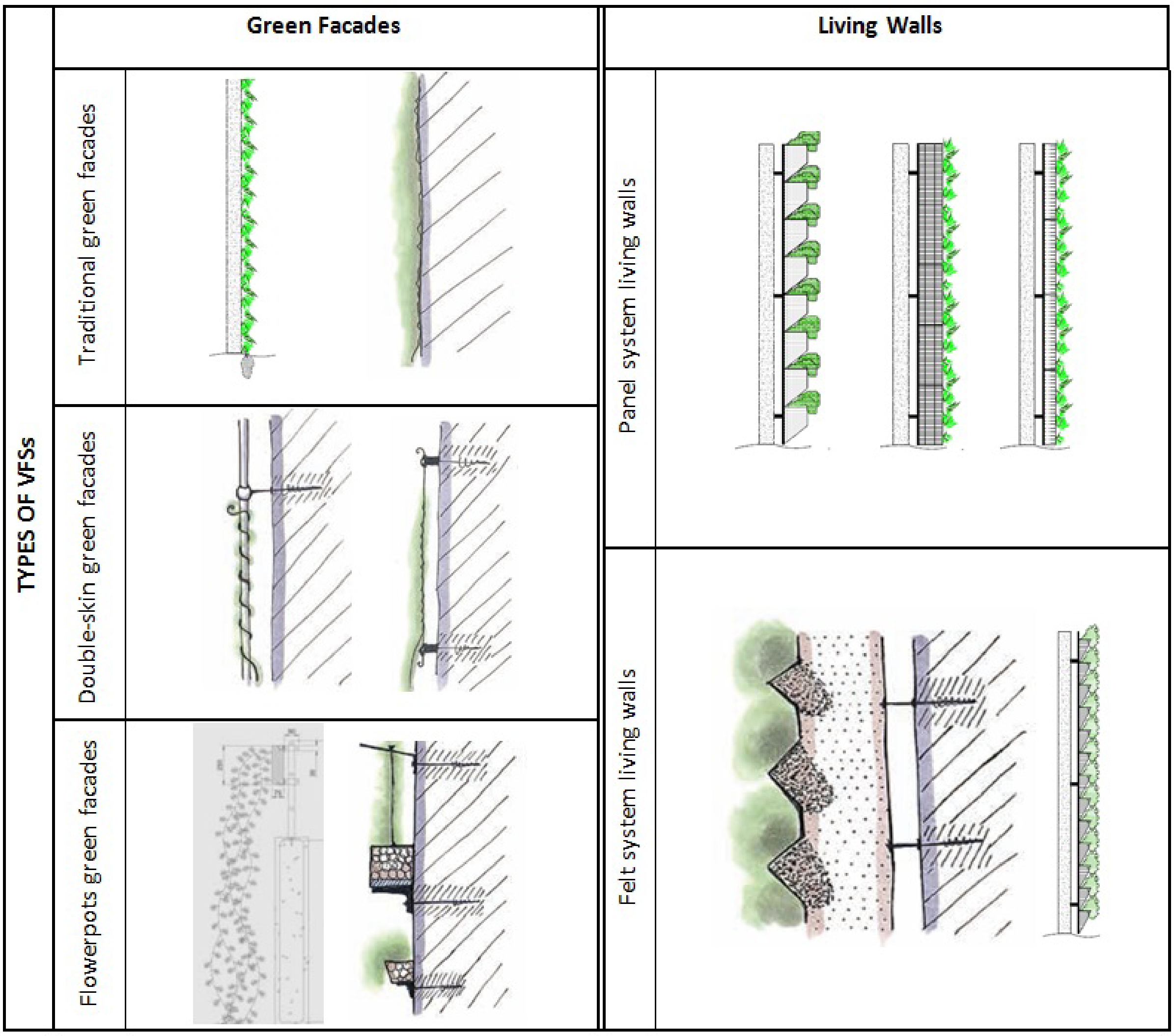
literature for VFSs are presented. Subsequently, literature review of the types of VFSs, which thermal performance has been measured experimentally under different climatic conditions are presented. Finally, most common types of VFSs that are designed and constructed in Turkey that are derived from face to face interviews of several companies located in İstanbul, İzmir and Antalya, are presented.

DEFINITION & CLASSIFICATION OF VEGETATED FACADE SYSTEMS

Vegetated facade systems are living and therefore self-regenarating cladding systems that are attached to the building exterior walls and partially or completely cover the exterior building walls with vegetation [7,8,9]. There are various classification and nomenclatures of vegetated facade systems in literature. Plants grown on vertical surfaces such as building exterior and interior walls and landscape and retaining walls are called vertical greenery system, vertical garden, green vertical system, vertical landscaping, green wall, bioshader etc. There are various terminologies used for these systems, however "vertical greenery system" is a comprehensive and widely used term [10,11,12,13]. In the present study, "vegetated facade system" will be used as thermal performance of building envelope is effected directly through implementation of vegetation on building facade.

There are different classification for VFSs. One of them classifies VFSs in two main categories as green facades and living walls (Figure 1). Location of growing media plays an important role in this type of classification [12]. In green facade, climbing plants are rooted on the ground or in planter boxes which include soil [9,12]. Green facades can be divided into three categories such as traditional, double skin and perimeter flowerpots systems [14,15]. As well, green facades can be divided into two categories as direct and indirect systems [16]. Traditional (direct) green facades are systems, where climber plants use the facade material as a support and attached to the building wall directly [14,16]. Double skin (indirect) green facades include a supporting structure for climbing plants to grow vertically, thus a green curtain seperated from the wall is created [14,16]. Perimeter flowerpots are type of green facade that hanging shrubs are planted around the building [14,15]. In living walls shrubs or various plant species are grown in pre-vegetated or in-situ panels that are attached to frame or to building wall directly [9,12]. There two main types of living walls such as felt system and panel system. Felt system is a type of VFS where plants are supported by a continous geotextile felt [15]. Panel systems are composed of panels made of plastic, metal, concrete etc. that are fixed to a structural wall or frame. These panels consist of holes in which substrates and plants are located [14,15].

Figure 1 Classification of VFSs [9,17]



In literature, there are also different terms used for green facades and living walls. Green facade is also called as green vertical system, support system, bio facade and facade greening [12,14,18,19,20] Living wall is called as green wall, vertical garden, carrier system and biowall [12,15].

THERMAL PERFORMANCE OF DIFFERENT TYPES OF VFSs UNDER DIFFERENT CLIMATE CONDITIONS

Literature review indicates that there are several experimental studies in which thermal performance of various type of VFSs such as felt system, panel system, modular trellis sytem, shading by trees in front of facade and traditional (direct) system has been measured under different climatic conditions. Results of empirical studies in equatorial/ tropical and megathermal climates that are located in the Köppen A group (according to Köppen climate classification regions located in A group have equatorial/ tropical and megathermal climate) show that vegetated facade systems decrease the maximum exterior surface temperature of building facade about 4.4°C-16°C in comparison with exterior surface temperature of referance building facade [21,22,23]. Also experimental studies conducted in arid and semi-arid/ dry climates that are located in the Köppen group B show that vegetated facade systems decrease the maximum exterior surface temperature of reference building

facade about 13°C-18.7°C [21,24]. Results of experimental studies conducted in warm temperate/ mesothermal climates that are located in the Köppen group C show that vegetated facade systems decrease the maximum exterior surface temperature of reference building facade about 1.7°C-25°C and increase the exterior surface temperature of reference building facade 0.6°C-3.9°C [25,26,27,28,29,19,30,31,32,33,34,35,36]. Empirical studies in snow/ continental and microthermal climates that are located in the Köppen D group show that vegetated facade systems decrease the maximum exterior surface temperature of reference building facade about 0.9°C-16°C [37,21,38,39]. To sum up the most dramatic results in terms of decreasing the surface temperatures of building facade are obtained in temperate-hot climates, arid climates, tropical climates and continental climates respectively [40].
Independent of variables of climatic conditions and different orientations of VFS, the most effective types of VFS is panel system, felt system and system of trees in pots in front of the facade respectively. Traditional (direct) system and modular trellis system are less effective systems in terms of enhancing thermal performance of building envelope [40].
As Kocaeli region is located in Köppen Csa group, it is important to determine the types of VFSs, which thermal performance has been measured under Csa climate. Table 1 shows the results of the literature review.

Table 1 Experimental Studies and Types of VFS Measures in Csa Climate [32, 33, 21, 29,34]

KÖPPEN CLIMATE GROUP/ LOCATION	AUTHOR, YEAR OF PUBLICATION	TYPE OF VFS
Csa California, USA	Akbari, 1997	**Shading by trees in front of facade**
Csa Athens, Greece	Papadakis vd., 2001	**Shading by trees in front of facade**
Csa Athens, Greece	Alexandri vd., 2008	**no information**
Csa Pisa, Italy	Mazzali vd., 2013	**Panel System**
Csa Madrid, Spain	Olivieri vd., 2014	**Panel System**

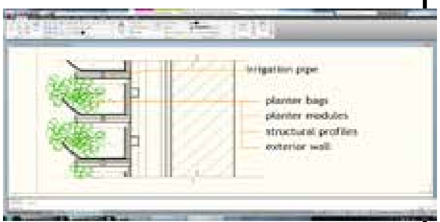
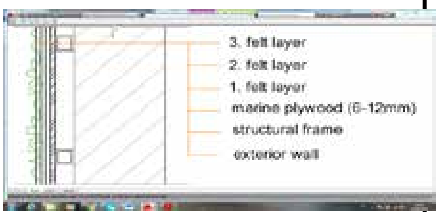
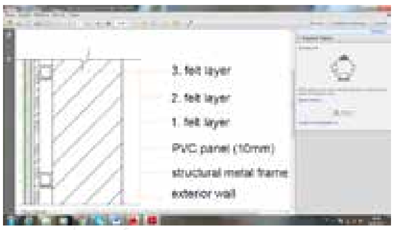
TYPES OF VEGETATED FACADE SYSTEMS DESIGNED AND CONSTRUCTED IN TURKEY

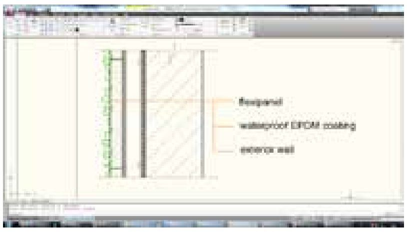
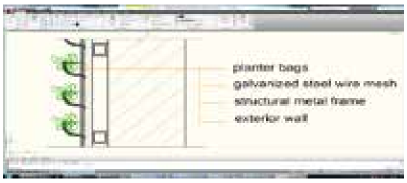
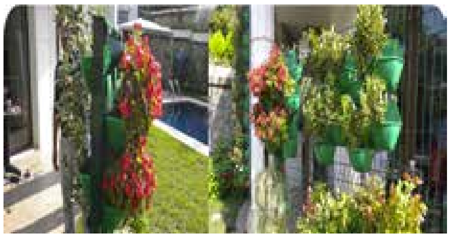
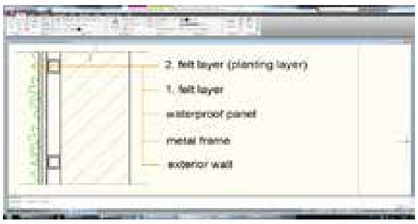
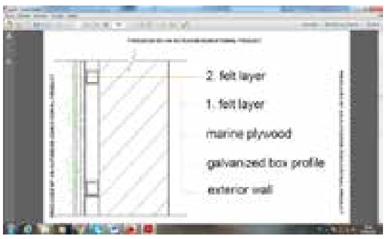
Different types of VFSs designed and constructed by Turkish companies has been determined through face to face interviews with the companies. In Turkey there are about 18 companies which implement vegetated facade systems on building walls and/or retaining and landscape walls. Five of them use panel system vertical vegetation, nine companies use felt system vertical vegetation, two of these companies use both panel and felt system vertical vegetation, one of them use cable system and information hasn't been received from one of these companies (Table 2). Different types of VFSs being designed and constructed by companies and images of the vegetated facade systems that have been implemented by these companies are given in Table 2. Table 2 indicates that the most commonly designed and constructed type of VFS is felt system followed by panel system.
Felt system vertical vegetation consist of six main components such as metal frame, waterproof panels, geotextile felt elements, irrigation pipes, drainage elements and various plant species. Aluminium or galvanized steel frame which supports the waterproof panels is mounted on the wall. After installation of PVC and plywood waterproof panels, geotextile felt elements are mounted on these panels. Companies in Turkey use two or three layer of felt. For instance in the VFS example which was implemented on the exterior walls of "Swissotel" in Bodrum two layer of felt was used (Table 2). First layer of felt was used as covering layer and second layer of felt was used as planting layer in this example. İrrigation pipes are mounted on the first layer of felt. Automated drip irrigation system allows regular water, nutrients and fertilizer flow internally from one felt pocket to another felt pocket and reach to the roots of each plant. Also excess irrigation water is allowed to drain through drainage channels. Various plant species

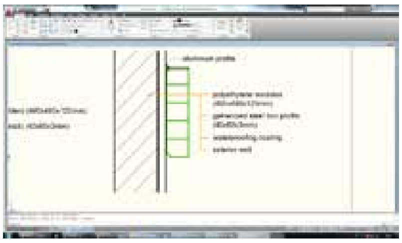
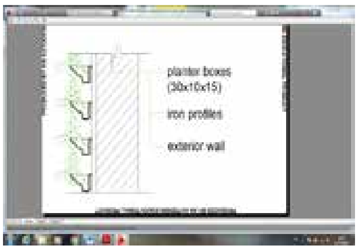
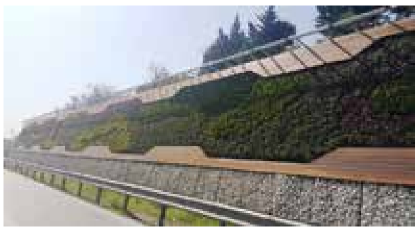
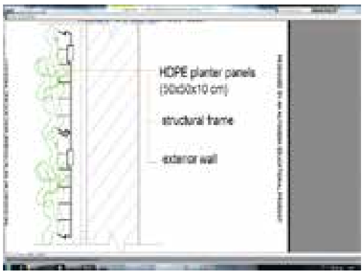
like evergreen shrubs, groundcovers and seasonal plants can be used for planting.

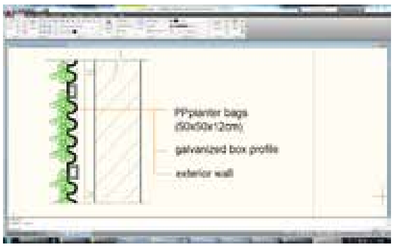
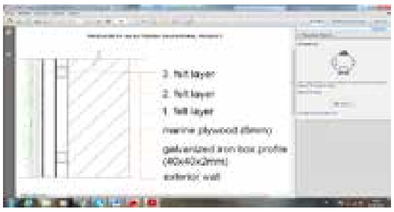
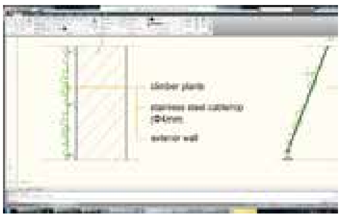
Plant system vertical vegetation which used by Turkish companies usually consist of six main components such as structural metal frame, plastic modules/panels (polyethylene, polypropylene etc.) growing media (soil, perlite, pumice, aminoplast resine foam, mineral wool etc.), various plant species, irrigation system elements and drainage system elements. As it can be seen in Table 2, exterior wall of "Erasta Shopping Mall" was vegetated by using type of panel system. In this example, galvanized steel frame which carries polyethylene modules was mounted directly to the building exterior wall. Plants are growing in these polyethylene modules which contain soil. There are irrigation pipes on each modules and regular water can be reached to each plant through the automated drip irrigation system. Panel system vertical vegetation allows also to grow various plant species such as evergreen shrubs, groundcovers, climbers and annual plants. Types of assemblies and dimension of modules and planter bags can differ according to companies. For example panel system used by the company named as "Company H" consist of 49.5x49.5x12.5 cm modules. Another VFS example implemented by the company named as "Company L" is composed of 30x10x15 cm modules (Table 2).

Table 2 Different types and assemblies of VFSs using by companies in Turkey *(assemblies of VFS has been drawn accordingly images, subdrawings and technical information sent from the companies)*

COMPANY	TYPE OF VGS	ASSEMBLIES OF VFS	IMAGES OF VFSs IMPLEMENTED BY COMPANIES	
COMPANY A	**PANEL SYSTEM** Called by Company as:GRO-WALL 4		Erasta Shopping Mall/ Antalya	
COMPANY B	**FELT SYSTEM** Called by Comp. as: Vertical Garden			
COMPANY C	**FELT SYSTEM** Called by Comp. as: Vertical Garden		Dikey Bahçeler/ Bodrum	

<table>
<tr>
<td>COMPANY D</td>
<td>PANEL SYSTEM
Called by Comp. as: FlexiPanelVertical Garden</td>
<td>
</td>
<td>Shangri La Otel/ Beşiktaş</td>
<td>
(There is not any VFS example applied on a building exterior wall)</td>
</tr>
<tr>
<td>COMPANY E</td>
<td>PANEL SYSTEM/ POTS SYSTEM
Called by Comp. as: Modular Vertical Garden Pots Sys.</td>
<td>
</td>
<td colspan="2">
(There is not any VFS example applied on a building exterior wall)</td>
</tr>
<tr>
<td>COMPANY E</td>
<td>FELT SYSTEM
Called by Comp. as: Vertical Garden</td>
<td>
</td>
<td>Swissotel/ Bodrum</td>
<td>
</td>
</tr>
<tr>
<td>COMPANY F</td>
<td>FELT SYSTEM
Called by Company as: Vertical Garden</td>
<td>
</td>
<td colspan="2">no information</td>
</tr>
<tr>
<td>COMPANY G</td>
<td>FELT SYSTEM
Called by Company as: Vertical Garden</td>
<td>no information</td>
<td colspan="2">no information</td>
</tr>
</table>

<table>
<tr><td rowspan="2">COMPANY H</td><td>PANEL SYSTEM</td><td rowspan="2"></td><td colspan="2" rowspan="2"></td></tr>
<tr><td>Called by Company as: Vertical Garden</td></tr>
<tr><td>COMPANY I</td><td>FELT SYSTEM</td><td>no information</td><td colspan="2">no information</td></tr>
<tr><td rowspan="2">COMPANY K</td><td>-</td><td rowspan="2">no information</td><td colspan="2" rowspan="2">no information</td></tr>
<tr><td>-</td></tr>
<tr><td rowspan="2">COMPANY L</td><td>PANEL SYSTEM/ POTS SYSTEM</td><td rowspan="2"></td><td rowspan="2">TEM Highway, Altunizade, Vegetated Wall App.</td><td rowspan="2">
(There is not any VFS example applied on a building exterior wall)</td></tr>
<tr><td>Called by Company as: Wall Garden</td></tr>
<tr><td rowspan="2">COMPANY L</td><td>FELT SYSTEM</td><td rowspan="2"></td><td rowspan="2">E-5 Highway, Küçükyalı, Veg. Wall Application</td><td rowspan="2"></td></tr>
<tr><td>Called by Company as: Vertical Garden</td></tr>
<tr><td rowspan="2">COMPANY M</td><td>PANEL/ SYSTEM</td><td rowspan="2"></td><td rowspan="2">Emirgan Park, Emirgan, İstanbul</td><td rowspan="2"></td></tr>
<tr><td>Called by Company as: Vertical Garden</td></tr>
</table>

COMPANY N	**FELT SYSTEM**	no information	no information		
COMPANY O	**PANEL SYSTEM** Called by Company as: **Green Wall/ Vertical Garden Pots Sys.**		 *(There is not any VFS example applied on a building exterior wall)*		
COMPANY P	**FELT SYSTEM**	no information	no information		
COMPANY R	**FELT SYSTEM** -	no information	no information		
COMPANY S	**FELT SYSTEM** Called by Company as: **Vertical Vegetation**		Ege Vadisi Sales Office Building, Ankara		
COMPANY T	**CABLE SYSTEM**	 	Şişli Municipality Building		

A typical detail of felt system used by companies in Turkey illustrated in Figure 2. Cable, wire and mesh systems are not used widely in Turkey.

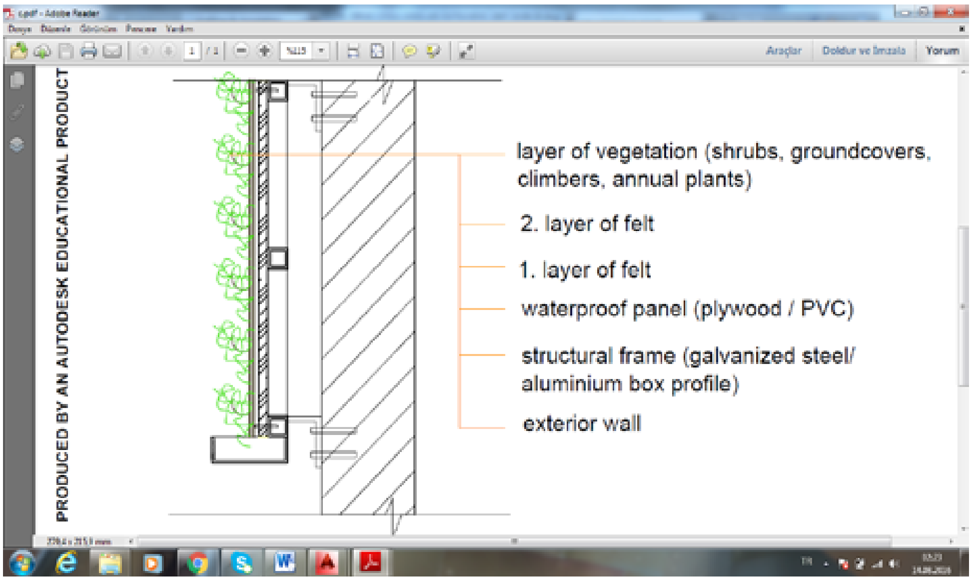


Figure 2 A typical detail of felt system widely used by Turkish VFS companies

RESULTS

Both literature review and face to face inteviews indicate that there are 18 companies which design and construct vegetated facade systems in Turkey and ten of them use felt type vegetated facade system. This result indicates that felt type vegetated facade systems is the commonly used type in Turkey. Additionally, literature review of experimental studies conducted in regions located in Csa climate group indicates that there are only five studies which have been conducted in these climate group and two of these studies has measured thermal performance of panel type vegetated facade system and the remaining two has measured vegetated facade systems that are created by trees in front of facade. And this indicates that in literature there is not any experimental study, which measures and evaluates thermal performance of felt type vegetated facade system in Csa climate conditions.

CONCLUSION

Integration of vegetation and building facade is not a new approach, however the ecological benefits of vegetation for building facades has been analyzed for last three decades. Covering walls with vegetation has began popular for half a decade in Turkey. Nevertheless, there is not any empirical study, which put forward cooling and insulating effect of VFS in Turkey. Therefore, a PhD thesis is being conducted at Istanbul Technical University to measure thermal performance of vegetated façade systems under Kocaeli climate (temperate humid) conditions. Type of VFS which will be used in the PhD thesis has been determined based on the results of literature review and inteviews with Turkish companies. It has been concluded that the thermal performance of a felt system will be measured in the PhD study as it is the widely used vegetated facade system in Turkey and that there is not any experimental study in which thermal performance of felt system under Csa climate region has been measured in literature.

ACKNOWLEDGEMENT

Authors gratefully acknowledge to Istanbul Tecnical University (ITU) Scientific Research Department for funding the research project.

REFERENCES

[1] IPCC (Intergovernmental Panel on Climate Change), Climate Change 2007: Working Group I: The Physical Science Basis, can be downloaded at: https://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-3.html, access date: 12.11.2015.

[2] MCCAR (Massachusetts Climate Change Adaptation Report), ***The Changing Climate and Its Impact,*** can be downloaded at: http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-chapter-2.pdf, Access date: 12.11.2015.

[3] WHO (World Health Organization), ***Climate Change and Human Health: Risks and Reponses,*** McMichael A.J., Campbell - Lendrum,D.H., Corvalán C.F., Ebi K.L., Githeko A.K., Scheraga J.D., Woodward A., Geneva, 2003, can be downloaded at: http://www.who.int/globalchange/publications/climchange.pdf, access date: 13.11.2015.

[4] EPA (United States Environmental Protection Agency), ***"Climate Change Science Overview",*** can be downloaded at: http://www3.epa.gov/climatechange/science/overview.html, access date: 12.11.2015.

[5] Nuruzzaman M. ***Urban Heat Island: Causes, Effects and Mitigation Measures - A Review***, International Journal of Environmental Monitoring and Analysis, 2015, 3(2): 67-73.

[6] Taha H. ***Urban Climates and Heat Islands: Albedo, Evapotranspiration, and Anthropogenic Heat***, Energy and buildings, 25(2), 1997, 99-103.

[7] Dunnet N., Kingsbury. N**. *Planting Green Roofs and Living Walls,*** Timber Press, London, 2008.

[8] Ottele M. ***The Green Building Envelope Vertical Greening***, Phd Thesis, Technische Universiteit Delft, , 2011.

[9] Mir M.A. ***Green Facades And Building Structures***, Master Thesis, Delft University of Technology, 2011.

[10] Loh S. and Stav Y. ***Green A City Grow A Wall.*** Proceedings of the subtropical cities 2008 conference: from fault-lines to sight-lines: subtropical urbanism in 20–20. Centre for Subtropical Design, Australia: Queensland University of Technology; 2008; 1–9.

[11] Shiah K., Kim J.W., Oldridge S. ***An investigation into the application of vertical garden at the New SUB Atrium***. Vancouver, Canada: The University of British Columbia; 2011.

[12] Safikhani T., Abdullah A.M., Ossen D.R., Baharvand M. ***A Review of Energy Characteristic of Vertical Greenery Systems***, Renewable and Sustainable Energy Reviews 40, 2014, 450-462.

[13] Safikhani T, Baharvand M, Abdullah A, Ossen DR. ***A Review On Vertical Greenery Systems Heat Reduction İn Tropical Climate.*** In: Proceedings of the 4th international graduate conference on engineering, science and humanities. Johor Bahru, Malaysia:UTM; 2013. p.5.

[14] Perez G., Rincon L., Vila A., Gonzalez J.M., Cabeza L.,F. ***Behaviour Of Green Facades in Mediterranean Continental Climate***, Energy Conversion and Management 52, 2011, 1861-1867.

[15] Perez G., Coma J., Martorell I., Cabeza F.L. ***Vertical Greenery Systems (VGS) for Energy Saving in Buildings: A review,*** Renewable and Sustainable Energy Reviews 39, 2014, 139–165.

[16] Manso M., Gomes, J.C. ***Green Wall Systems: A Review of Their Characteristics***, Renewable and Sustainable Energy Reviews 41, 2015, 863-871.

[17] ÖkoKauf Wien, Arbeitsgruppe 25, Grün- und Freiräume, ***Leitfaden Fassadenbegrünung***, Jürgen Preiss, accessed May 13, 2016, can be downloaded at: https://www.wien.gv.at/umweltschutz/raum/pdf/fassadenbegruenung-leitfaden.pdf

[18] Sunakorn P., Yimprayoon C. ***Thermal Performance of Biofacade with Natural Vantilation in the Tropical Climate,*** Procedia Engineering 21, 2011, 34 – 41.

[19] Perini K., Ottele M., Fraai, A.L.A., Haas E.M., Raiteri R. ***Vertical Greening Systems and the Effect on Air Flow and Temperature on the Building Envelope,*** Building and Environment 46, 2011, 2287-2294.

[20] Perini K., Ottele M., Haas E.M., Raiteri R. ***"Greening The Building Envelope Façade Greening And Living Wall Systems",*** Open Journal of Ecology, Vol.1, No.1, 1-8, 2011.

[21] Alexandri E., Jones P. ***Temperature Decreases inan Urban Canyon due to Green Walls and Green Roofs in Diverse Climates***, Building and Environment 43 (2008) 480-493.

[22] Rahman A.M.A., Yeok F.S., Amir A.F., ***The Building Thermal Performance and Carbon Sequestration Evaluation for Psophocarpus tetrogonobulus on Biofaçade Wall in the Tropical Environment,*** World Academy of Science, Engineering and Technology 76 2011.

[23] Wong N.H., Tan A.Y.K., Chen Y., Sekar K., Tan P. Y., Chan D., Chiang K., Wong N.C. ***Thermal Evaluation of Vertical Greenery Systems for Buildings Wall***, Building and Environment 45, 2010, 663–672.

[24] Haggag M., Hassan A., Elmasry S***. Experimental Study on Reduced Heat Gain Through Green Facades in a Heat Load Climate***, Energy and Buildings 82, 2014, 668-674.

[25] Hoyano A. ***Climatological Uses of Plants for Solar Control and the Effects on the Thermal Environment of a Building,*** Energy and Buildings, 11, 1988, 181-199.

[26] Eumorfopoulou E.A., Kontoleon K.J. ***Experimental Approach to the Contribution of Plant Covered Walls to the Thermal Behaviour of Building Envelopes***, Building and Environment 44, 2009, 1024-1038.

[27] Kontoleon K.J., Eumorfopoulou E.A. ***The Effect of the Orientation and Proportion of a Plant-Covered Wall Layer on the Thermal Performance of a Building Zone,*** Building and Environment 45, 2010, 1287–1303.

[28] Koyama T., Yoshinaga M., Hayashi H., Maeda K., Yamauchi A. ***Identification Of Key Plant Traits Contributing to the Cooling Effects of Green Façades Using Freestanding Walls***, Building and Environment 66, 2013, 96-103.

[29] Mazzali U., Peron F., Romagnoni P., Pulselli R.M., Bastianoni S. ***Experimental Investigation on The Energy Performance of Living Walls in a Temperate Climate,*** Building and Environment 64, 2013, 57-66.

[30] Sternberg T., Viles H., Cathersides A. ***Evaluating the Role of İvy (Hedera Helix) in Moderating Wall Surface Microclimates and Contributing to the Bioprotection of Historic Buildings***, Building and Environment 46 (2011) 293-297.

[31] Cameron R.W.F., Taylor J., Emmett M. ***A Hedera Helix Green Facade- Energy Performance and Saving Under Different Maritime-Temperate, Winter Weather Conditions***, Building and Environment 92, 2015, 11-121.

[32] Akbari H., Kurn D.M., Bretz S.E., Hanford J.W. ***Peak Power and Cooling Energy Savings of Shade Trees***, Energy and Buildings 25, 1997, 139-148.

[33] Papadakis G., Tsamis P., Kyritsis S. ***An Experimental Investigation of the Effect of Shading with Plants for Solar Control of Buildings***, Energy and Buildings 33, 2001, 831-836.

[34] Olivieri F., Olivieri L., Neila J. ***Experimental Study of the Thermal-Energy Performance of an Insulated Vegetal Facade Under Summer Conditions in a Continental Mediterranean Climate***, Building and Environment 77, 2014, 61-76.

[35] Jim C.Y. ***Estimating Heat Flux Transmission of Vertical Greenery Ecosystem***, Ecological Engineering 37, 2011, 1112-1122.

[36] Cheng C.Y., Cheung K.K.S., Chu L.M., ***Thermal Performance of a Vegetated Cladding System on Facade Walls,*** Building and Environment 45, 2010, 1779-1787.

[37] Di H.F., Wang D.N. ***Cooling Effect of Ivy on a Wall,*** Experimental Heat Transfer, 12:235-245, 1999.

[38] Susorova I., Angulo M., Bahrami P., Stephens B. ***A Model of Vegetated Exterior Facades for Evaluation of Wall Thermal Performance,*** Building and Environment, 2013.

[39] Susorova I., Azimi P., Stephens B. ***The Effects of Climbing Vegetation on the Local Microclimate, Thermal Performance, and Air İnfiltration of Four Building Facade Orientations*** Building and Environment 76 (2014) 113-124.

[40] Yüksel E., Türkeri A.N. ***Bitkilendirilmiş Cephe Sistemlerinin Farkli İklim Bölgelerindeki Isıl Performanslarinin Değerlendirilmesi***, 2.Ulusal Yapı Fiziği ve Çevre Kontrolü Kongresi, 04-06 Mayıs 2016, İstanbul.

Paper No: 102

PASSIVE HOUSES AS AN INNOVATIVE APPROACH IN BUILDING DESIGN and ITS CONTRIBUTION TO THE ECONOMY

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ABSTRACT

The most important problems in our world's sustainable future are global warming, accelerating with greenhouse gas emissions, and disasters with increasing intensity and frequency, expected future hunger and impoverishment caused by climate change which global warming triggers. Due to the increase in demand against limited energy reserves, it is essential for the future of our world to use energy effectively, turn to sustainable sources and make friends with environment. Buildings that minimize energy use and harmful emissions gained more importance with the effect of urbanization, accelerating in parallel to the development. Passive Houses, becoming popular rapidly in Europe since 1991, lead the development of Zero Energy, Energy Plus, Zero Carbon building concepts and shape the construction of the future. "Passive Houses" can be defined as very well designed and insulated buildings which are planned with annual heating demand of maximum 15 kWh/m² in a new building, and 25 kWh/m² in energy efficient renovation of existing building. These buildings that offer multi comfort and are applicable for all-purpose and all kinds of buildings, are a significant leverage in achieving a low-carbon future with its special approach from design to implementation. 94% of our need in energy consumption is met from imported fossil fuel. Energy import, generated 18% of total import of 207.2 billion dollars in 2015, and has an important effect on our current account deficit with 37.9 billion dollars. This means, savings in low-carbon power independence, and comfort with energy efficiency are everyone's responsibility. When we look at the data about annual energy consumption, while 150-200 kWh/m² energy is used in average in non-insulated buildings, 60% savings are done in buildings projected with TS 825 Thermal Insulation Standard for Buildings. And in a Passive House, heating demand compared to old buildings or buildings with deficient insulation decreases 90%, quite high amount of energy is saved. In this report, we analyze Passive Houses which have multi comfort and have at least two applied examples in our country. And also innovative opportunities for the future of our country are highlighted in terms of national energy efficiency action plans.

INTRODUCTION

Today we have to be more sensitive to sustainable development because of global warming caused by the rapid depletion of energy sources that come from fossil fuels and greenhouse gas emissions, and climate change. Increasing population and its needs, urbanization in parallel to sheltering and development, global warming threatening the future of all living, require developing and executing unusual politics with determination. Therefore, especially developed countries continue their studies with determination for practices to minimize greenhouse gas emissions while also focusing on sustainable production and consumption, energy efficiency actions, and heading for renewable energy sources on the other hand. They try to realize their international commitments which they transfer to national goals, with national action plans they determine, and zero their impact on the world while continuing their growth based on low-carbon economy.

OVERVIEW

86% of World Primary Energy Consumption which has been realized 13.15 billion dollars TOE in 2015, is generated from fossil fuels. Similarly, 85.6% of Turkey Primary Energy Consumption which has been realized 131.3 million TOE is generated from fossil fuels, and CO_2 emission reached 336.3 million tons. [1] World population which has reached 7.3 billion from 2003 to 2015 with 1 billion increase, is expected to exceed 8.5 billion in 2030, and 9.7 billion in 2050. Growth is predicted in developing continents, Africa and Asia. Population in Turkey which is currently 78.7 million is expected to reach 87.7 and 95.8 million with the same order. [2] Cities in which 54% of the population lives according to 2014 data are expected to shelter 66% in 2050, and urbanization which is currently 40% and 48% in Africa and Asia is expected to reach 56% and 64%. In 2050, world city population is predicted to reach 6.3 billion people with 2.5 billion increase and 90% of the increase is expected to actualize in Africa and Asia. Turkey city population which is currently 73% is predicted to reach 84%. 488 cities with a population of over 1 million, including 28 mega cities with a population of over 10 million, are expected to reach 662 cities including 41 mega cities which will host 50% of world population in 2030. [3] In this context, policies which will ensure the sustainable development in cities, and design future's energy efficient, multi comfort, environmental-friendly cities are gaining importance.

Turkey, where the rate of domestic production to meet demand has decreased to 25%, is ranked #5 for natural gas, #13 for oil, and #8 for coal in world energy sources import in 2015. 35% of final energy consumption is actualized for heating and cooling purposes in housing and service industries. The share of electricity consumption is approximately 26%. In MENR's "Strategic Plan" including 2015-2019 period, there are sixteen objectives with eight thematic titles. Active demand management and energy efficiency in Turkey defined enhanced capacity objectives for energy efficiency and savings, targets in line with these objectives, and strategies to be implemented to achieve these objectives are also included in this Strategic Plan [4]

According to TUIK's housing census in 2000; the number of the buildings has reached 7.8 million in 2000 with 78% increase while it was 4.3 million in 1984. The number of housing has reached 16.2 million with 129% increase according to the data of the same year. The most important precaution in buildings are strengthening the buildings for heat loss and heat gain in warm regions, and ensuring rapid dissemination of energy efficient, integrated design primarily starting from thermal insulation. The most efficient precaution is TS 825 Thermal Insulation Standard for Buildings, forming thermal insulation rules to be applied in residential and commercial buildings which will be constructed or which requires renovation considerably, and it is designed in anticipation of 60% savings compared to the practices that do not comply the rules. This standard began to be implemented in all new buildings after 14.06.2000 as a compulsory standard with Thermal Insulation Regulation for Buildings. In this context; with 9.4 million buildings and 22.7 million houses by the end of 2015, it is acceptable that 13.9% of total building stocks and 28.5% of house stocks in our country meet TS 825 Thermal Insulation Standard for Buildings, with an optimistic forecast. [5]

Energy Performance of Buildings Regulation which has been prepared based on EU's 2002/91/EC Energy Performance of Buildings Directive, for the purpose of limiting new or existing buildings energy consumption and greenhouse gas emissions, is enforced in 2009 and thus, a new step was taken to increase energy efficiency in buildings and meet more energy efficient building stocks. The aim of EPBD is to regulate the identification of the calculation rules that will ensure the evaluation of all energy consumption of a building, considering external climate conditions, interior requirements, local conditions and cost-effectiveness, classification according to the primary energy and carbon dioxide (CO_2) emission, identification of minimum energy performance requirements for new and current buildings that requires renovation considerably, identification of applicability of renewable energy sources, controlling heating and cooling systems, identification of the performance criteria and application guidelines in buildings. Due to Regulations, classification for buildings have started according to energy consumption and greenhouse gas emission with an energy performance certificate and energy performance class A, B, C, D, E, F and G. Classification of current buildings according to energy consumption and greenhouse gas emissions, with increasing their energy performances, and creating energy performance certificates, is expected to be completed until the end of 2017. Also new buildings need to be C class or higher. [6]

The energy amount that buildings will use is limited with EPBD but, projected energy efficiency limits for new buildings is still low in our country compared to EU countries with similar weather conditions based on thermal transmittance coefficients of building components and energy consumption limits. While maximum energy demand for climate zones except first climate zone is in average 90-100 kWh/m^{2}year in our country, many EU countries have enforced the standards aiming low energy demand much lower than 100 kWh/m^{2}year. This limit value is 60-40 kWh/m^{2}year in Austria, 51-97 kWh/m^{2}year in Czech Republic and depending on climate and altitude, primary energy demand is 40-65 kWh/m^{2}year for new buildings and 80 kWh/m^{2}year for existing buildings renovations in France. Thermal insulation and allowable energy usage limits stated in current legislation are insufficient in our country compared to developed countries' legislations and future needs, and should be revised according to sustainable future needs. [6]

Building sector in developed countries is assigned as the priority action area, because for "Low Carbon Economy Transition Strategies", easier and more cost-efficient precautions can be taken in this sector compared to industrial and transportation sectors. EU, aiming decreasing greenhouse gas emissions 20% by 2020, reaching 20% renewable energy share in energy supply and increasing energy efficiency by 20%, expects "0" emission in new public buildings in 2018 and all other new buildings in 2020. USA aims zero energy buildings with total of renewable energy production and energy consumption is zero, by 2020, with ZEB-Zero Energy Buildings program (Building America). It is also expected to reach this objective for commercial buildings until 2025. [6]

And with Energy Efficiency Strategy Document enforced in 2012, it is aimed to provide participatory approach and cooperation with public sector, private sector and civil society organizations during 2012-2023 with introducing a set of policies supported by objectives to activate energy efficiency, and the identification of responsible institutions to fulfill the mandatory actions to be taken to meet objectives in line with defined strategic goals. Minimum 20% decrease in the amount of energy (energy density) per Gross Domestic Product is projected for Turkey according to 2011 value. [6]

"Decreasing buildings' energy demands and carbon emissions; increasing the number of sustainable, environmentally friendly buildings that use renewable energy sources" has been set as the strategic objective for building industry. Actions for the first target "***Having thermal insulation and energy efficient heating systems providing the standards in force by 2023, in all third or higher class houses in adjacent metropolitan area which are excluded from urban transformation, and commercial and service buildings with 10.000 m^2 or higher total usage area."*** for this objective are as follows: Revising the current legislation in parallel to EU practices, Determination of maximum annual energy demand including the topics as heating, cooling and lighting depending on the construction of the buildings according to buildings' functions (i.e. hotel, hospital, residence, school, shopping mall), climatic conditions of the region, architectural design and current mandatory standards, with bringing the limitation of maximum energy needs for buildings, Determination of maximum CO_2 emission for buildings and not allowing new constructions that exceed these limits, Encouraging to get close to these limit values by improving existing buildings, Applying administrative sanctions as of 2017 for those who are above the minimum value defined in current legislation about carbon dioxide emission. Actions for the second target ***"Transforming at least one-fourth of building stocks in 2010 into sustainable buildings as of 2023"*** are as follows: Searching for sustainability quality for licensing commercial buildings, detached luxury housing and residences with 10.000 m^2 or higher usage area as of August 2013, Dissemination of this practice as of 2017 covering third or higher class houses, Asking for sustainability certification for buildings, Encouraging cogeneration and micro cogeneration renewable energy sources from renewable energy, central and regional heating and cooling, and heat pump systems in housing projects. [6]

On the other hand, with European Parliament's republished Energy Performance of Buildings Directive No: 2010/31/AB and 2012 Energy Efficiency Directive; a comparative methodology has been created for calculation of optimal cost level of minimum energy performance conditions, and improvement of energy performance of buildings within the European Union has been disseminated considering external climate, local conditions and cost efficiency. Main conditions within Energy Efficiency Directive are as follows; Energy performance certificate will be added to all building sales and rental ads, Audit systems will be created for heating and cooling systems or precautions will be taken which will show the same effect, All new buildings will be nearly zero-energy buildings as of 31st December 2020 (public buildings-as of 31st December 2018), minimum energy performance conditions will be defined for new buildings, big building renovations and replacement or improvement of building elements (heating and cooling systems, roofs, walls, etc.), National financial measures list will be prepared to improve buildings' energy efficiency, Energy performance certificate that has been given previously, will be hung somewhere visible in big commercial buildings larger than 500 m². [7]

Specially for "Nearly Zero-Energy Buildings" mentioned here, Member States are required to provide the following; All new buildings as of 31st December 2020 and public buildings or buildings used by public should be nearly zero-energy buildings as of 31st December 2018, national plans which may include objectives that differ according to building category should be prepared to increase the number of nearly zero-energy buildings. Regulation on Increasing the Efficient Use of Energy Sources and Energy, prepared by Ministry of Energy and Natural Resources, has been published in Official Gazette No: 28097, 27 October 2011; "energy usage of the buildings and businesses owned by the public sector, is decreased minimum twenty percent as of 2023 compared to 2010" provision is included. With the execution of Draft National Energy Efficiency Action Plan by transferring the EU Building Directive into the National Legislation and practices in Turkey services and housing sector building stock, 6 million TOE/year savings in 2023, and total 54.97 million tons CO_2 reduction is expected in 2016-2023 period. [7]

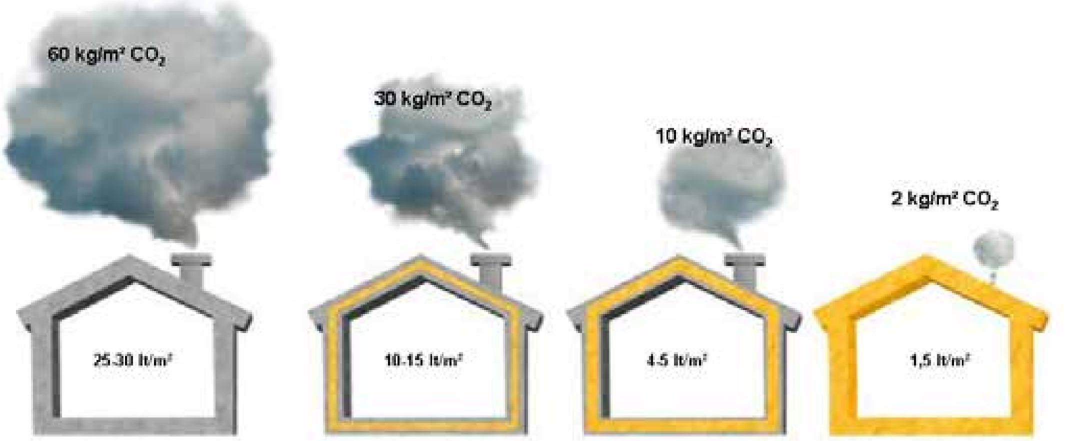
Paris Climate Change Agreement that limits carbon budget with 1.5^{0}C target, which representatives of 195 countries agreed on, at 21st Conference of the Parties of the United Nations Framework Convention on Climate Change, held in Paris in December 2015. In this agreement, it is stated that it is essential to decrease fossil fuel usage rapidly and switch to renewable energies that do not cause carbon emissions. This historic agreement to combat global climate change which means resetting the net emissions in the second half of 21st century, makes energy efficiency and renewable energy practices essential. In accordance with decisions 1/CP.19 and 1/CP.20, the Republic of Turkey has declared a reduction target of up to 21% on greenhouse gas emissions by 2030 according to the Reference Scenario, within the framework of the intended nationally determined contribution (INDC) in order to ensure the ultimate objective which is set out in Article 2 of Paris Agreement (Agreement under the UNFCCC), and the plans and policies to be implemented. Within the framework of plans and policies for Buildings and Urban Transformation to be implemented in line with this target; Constructing new residential buildings and service buildings as energy efficient in accordance with the Energy Performance of Buildings Regulations, Creating Energy Performance Certificates for new and existing buildings so as to control greenhouse gas emissions and to reduce energy consumption with years, Reducing the consumption of primary energy sources of new and existing buildings by means of design, technological equipment, building materials, development of channels that promote the use of renewable energy sources (loans, tax reduction, etc.), Dissemination of Green Building, passive energy, zero-energy house design in order to minimize the energy demand and to ensure local production of energy. [8]

Nearly in all countries, construction industry has started a process/period which can be called sustainable transformation to combat climate change. Passive houses with a design that uses passive solar energy in an optimum way, and with heating energy ≤ 15 kWh/m^{2}year, or sustainable buildings has begun to be commonly taken into account in the new building design in the world. Designs that vary according to local climate conditions in order to ensure maximum U value of 0.15 W/m^{2}K for structural elements in these buildings, and a high level of insulation practice has been made. Although these practices are not yet common, there are two newly constructed and energy efficient renovation made, certified examples in Turkey. Turkey should increase existing standards as soon as possible and quickly implement the road map for “0” emission buildings, and should not miss urban transformation opportunity in order to create the cities of the future.

Integrated building design that offers energy efficiency and multi comfort is the first step of the process and accessibility to nearly zero-energy buildings. Multi comfort design buildings based on passive houses will be the most important leverage in implementation of the cities of the future formed from energy efficient, with high quality interior environment, fire-safe zero carbon, nearly zero-energy and also energy plus buildings. Nearly zero-energy buildings mentioned in EU Directive use 0 kWh/(m^{2}year) primary energy in theory and if it is associated with the cost efficient guidance; it can be proposed that cost efficient energy usage is higher than 0 kWh/(m^{2}year) primary energy usage nationally. [9]

PASSIVE HOUSES FOR DEFINING NEARLY ZERO-ENERGY BUILDINGS

New approaches that have been developed based on Passive Houses, which may include technology and solutions offering high energy efficiency and multi comfort instead of energy inefficient, uncomfortable technology designs, constitutes the basics of low or zero carbon sustainable urbanization. The objective of Passive Houses is to minimize the energy consumption, and the starting point of the idea is building houses with zero energy needs. [10]



1950-1975	**Today**	**Energy Efficient Building**	**Passive House**

Figure 1 The relation of fuel consumption and emissions with better insulation and developing building standards [10]

"Passive Houses" can be defined as buildings that are very well insulated, planned not to exceed 15 kWh/m²year annual heating energy need, thereby have no need for the traditional heating systems, and make renewable energy applications accessible. These buildings may be designed to serve many different purposes such as residence, office building, school and gym that were built with classic or modern design wood, brick and reinforced concrete systems. Heating energy need in energy efficient renovation projects can be implemented not to exceed 25 kWh/m²year as in new buildings. Considering the heat load within the construction, building can be heated with a few candles and light bulbs. A burning candle has 30 W, a bulb has 100 W, a person has 100 W heating power. Considering this domestic load, it is smarter to construct buildings with minimum heating (and/or cooling according to the climate) energy need instead of trying to design zero-energy buildings at high costs. Passive House idea has started to develop at this point. [10]

A house should provide below reference values to comply with "Passive House" definition. Principles prepared for Central Europe climate conditions are valid for other climates too.

- The U-value must be lower than 0.15 W/m²K on the external envelope of the buildings.
- There should not be any thermal bridges on the outer shell.
- Airtightness must be demonstrated with DIN EN 13289 pressure test; uncontrolled leakage can not exceed 0.6 air changes per hour at 50 Pascals pressure.
- The U-value of all windows must be lower than 0,8 W/m²K, also total solar energy transmission must be minimum 50% according to EN 410 in order to make heat gain during winter time.
- The windows should have a total U-value of no more than 0.8 W/m²K.
- Mechanical ventilation system with heat recovery must be designed with at least 75% efficiency to provide the highest energy conversion efficiency and minimum electricity use.
- Heat loss in central hot water supply must be reduced, high efficiency in electricity use must be provided. [10]

Five basic principles to be followed in buildings with Passive House design can be aligned as in Figure 2.

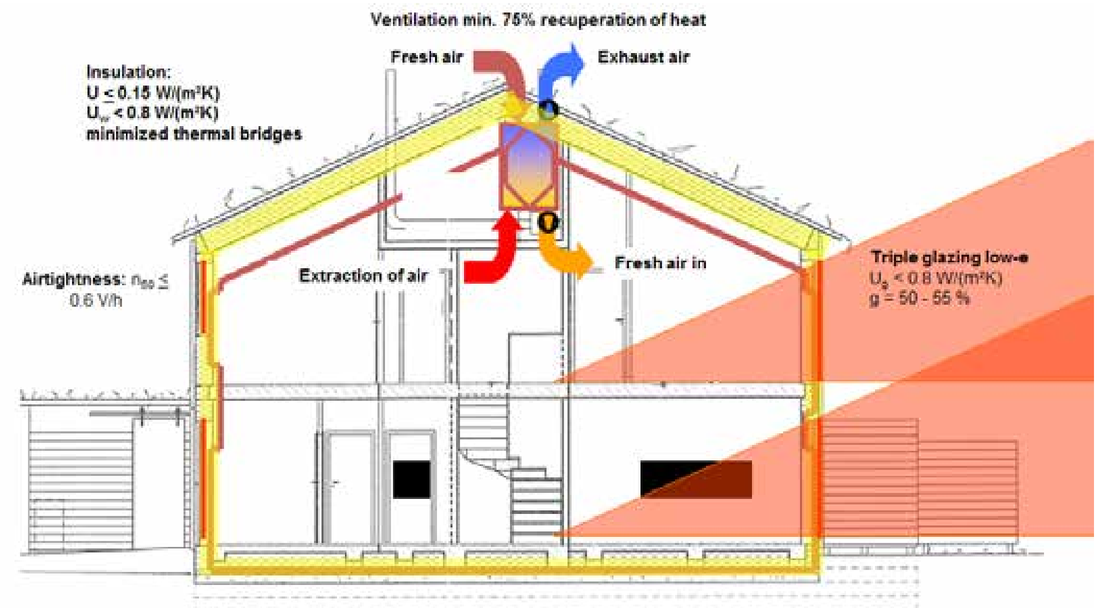


Figure 2 Passive House Principles (thermal insulation without gap, avoiding thermal bridges, triple glazing, airtightness, heat recovery) 10]

"Passive House" idea that has been developed to require a minimal energy in our world where sustainable future is more and more valuable day by day, disseminated rapidly and generated the basis especially in EU countries' energy efficient building developments. In European Commission Energy Efficiency Action Plan in 2006, although performance requirement in kWh/m² have been targeted to be brought to passive house and low energy level in new buildings and the buildings that will be renovated from 2015, European Parliament forced European Commission to give an earlier date as 2011 in Building Performance Requirements in 2008. [10] For EU, who decided with 2010 EPBD Directive all new buildings to be nearly zero-energy efficient as of 2021 and agreed on reducing 40% emission with cost efficient methods as of 2030 (according to 2007 baseline scenario) and reaching 27% or more energy efficiency, nearly zero-energy buildings based on passive houses will be an important leverage. [11]

Not to exceed 15 kWh/m²year energy consumption which is the first condition of a "Passive House" to reduce energy use for heating purposes to zero, is the most important principle and the most important criterion for minimizing the energy use in all buildings, residential or commercial building without distinction is providing sufficient and uninterrupted thermal insulation on the external surfaces. In buildings targeted 20 ^{0}C indoor temperatures as a condition of comfort, outdoor temperature change regionally and can be accepted -10 ^{0}C for cold climates. In Passive Houses, U-value (thermal conductivity) must be equal to or lower than 0.15 W/m²K in structural elements, and 0.8 W/m²K in windows. [10]

Considering the limiting U-values of 0.7-0.4 W/m²K for wall, 0.45-0.25 W/m²K for roof, 0.7-0.4 W/m²K for flooring, 2.4 W/m²K for windows, it turns out that insulation performance of structural elements must be increased and regulations must be improved.

Examples of Passive House Applications

A series of house block in Hannover was renovated with a Passive House base featuring additional insulation and ventilation system with heat recovery. 18 cm additional insulation was performed on the roof, 15 cm on exterior walls and 20 cm on the floor while the windows were replaced by 3-layer qualified windows, pressure test compliance was investigated and a mechanical ventilation system with heat recovery was added. Before such improvements, the annual heating energy need was 12.500 kWh. In conclusion, it was reduced by 88% to 1.500 kWh/year.

Figure 3 Energy-efficient renovation of an existing building in Hannover using passive house principles [10]

There are two Passive Houses in Turkey, one new and one renovated building, designed by based on passive house principles and certified following project implementation. In energy-efficient renovation project of the existing building to be used as the ESCO Incubation Center after renovation in Gaziantep; 24 cm glass wool (0,035 W/mK) on the roof and the wall, and 20 cm extruded polystyrene (0,035 W/mK) on the floor were used for insulation as well as triple layer windows and joinery, mechanical ventilation system with thermal recovery, a heat source thermal pump and a photovoltaic panel.


Figure 4 Energy-efficient renovation of an existing building in Gaziantep using passive house principles

Following the application, heating energy need was reduced from 143 kWh/m² per year to 19 kWh/m² per year and cooling energy need declined from 180 kWh/m² per year to 28 kWh/m² per year, achieving total savings of 86%. Compared to the existing standards, changes in U-values of the building elements are summarized in Table 1.

Table 1 Comparison of U-values in energy-efficient renovation of the existing building

	Compliance with TS 825	Compliance with the Passive House principles
U- wall (W/m²K)	0,50	0,14
U- roof (W/m²K)	0,30	0,13
U- floor (W/m²K)	0,45	0,14
U- window (W/m²K)	2,4	0,75

New Ecologic Building project in Gaziantep used 30 cm extruded polystyrene on the green roof, 40 cm glass wool on the wall, 30 cm extruded polystrene on the floor with insulation materials having a thermal conductivity of 0.035 W/mK as well as triple layer windows and joinery, mechanical ventilation system with heat recovery, a ground source heat pump and a photovoltaic panel. Heating energy need is fixed at 7 kWh/m^{2}year while cooling energy need is achieved as 13 kWh/m^2 per year.

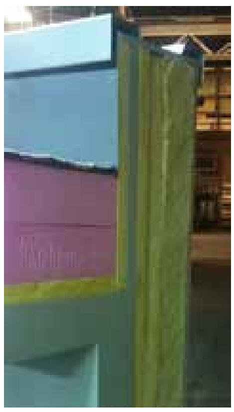



Figure 5 New building built by using passive house principles in Gaziantep

CONCLUSION

Passive Houses, a design approach enabling interior comfort with very little heating and cooling energy need, are an important tool to achieve nearly zero-energy buildings by integrating highly efficient devices and renewable energy technologies.

It is aimed in Belgium to reach Nearly Zero Energy Building rate of 75% of all new buildings by 2020 and 100% of all new buildings by 2021, starting from the public buildings by 2019. Similarly, the Netherlands aim to reach 100% in all new public buildings by 2018 and all new buildings by 2020; Cyprus and Italy to reach 100% in all public buildings by 2019 and all new buildings by 2021. Germany has agreed to propose regulations to include standards for public buildings in late 2016 and for other buildings in late 2018. Having calculated the technical potential of 81% energy saving in energy-efficient renovations of the existing buildings using the passive house standartds, Czech Republic stated in its National Energy Efficiency Action Plan that it will support additional costs in new building constructions to reach nearly zero energy buildings and passive house standards for the period of 2014-2020. Similarly, Croatia offers loans to finance real-estate purchase in high-energy segment, land purchase or construction for low-energy passive houses and energy effective improvement of the existing buildings according to this standard. [12]

Updating the existing standards to the minimum extent of passive house standards, projecting reduction of heating energy need by 60% compared to heating energy consumption of inadequately designed buildings will not only reduce the need of overall heating and cooling energy needs by 90%, but also decrease carbon emissions and energy import while adding value and creating employment. In the National Energy Efficiency Action Plan Draft in which the existing EU Building Directive will be transferred to the National Legislation; a total of 16.6 million savings on TOE and a total of 54.97 million tons of CO2 reduction are projected in the period of 2017-2023 by achieving nearly zero energy buildings in all new buildings by 2021 and all public buildings by 2019 in Turkey and translating this initiative into service and housing industry. [7]

In Turkey, over 100.000 new buildings are given occupancy permit and construction permit, over 700.000 new buildings are given occupancy permit and over 800.000 new buildings are given construction permit. This should be considered as an opportunity to transform into low-carbon 100% renewable energy society with the contribution of quick construction abilities, nearly zero energy buildings including the existing building stock. [5] Considering the country needs, climate conditions and production competences from product to service, having passive house-based nearly zero energy buildings in Turkey is an easily achievable goal which would create a leverage effect in low-carbon high growth with this synergy created in the urban transformation projects. Transferring the EU directive, the public will lead in passive house-based nearly zero energy buildings and offer more effective incentive mechanisms which will in turn significantly decrease the import-based energy consumption in buildings.

REFERENCES

[1] Statistical Review of World Energy, BP, 2016
[2] World Population Prospects, UN, 2015
[3] World Urbanization Prospects, UN, 2014
[4] Ministry of Energy and Natural Resources, 2015
[5] www.tuik.gov.tr
[6] Energy Efficiency in the World & Turkey, MMO/589, TMMOB Chamber of Mechanical Engineers , 2012
[7] National Energy Efficiency Action Plan (Draft), MENR Renewable Enegy Directorate, 2015
[8] Republic odf Turkey Intended Nationally Determined Contribution, 2015
[9] Kurnitski J., Allard F., Braham D., Goeders G., Heiselberg P., Jagemar L., Kosonen R., Lebrun J., Mazzarella L., Railio J., Seppänen O., Schmidt M., Virta M., ***How to define nearly net zero energy buildings nZEB***, REHVA Journal, 2011
[10] Subaşı Türkan Z., ***Energy efficiency and passive houses***, Yapı, Sayı 341, 2010
[11] EU, ***Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy***, 2014
[12] https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive/national-energy-efficiency-action-plans

Paper No: 150

A QFD based sustainable building framework: Application for University Buildings

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ABSTRACT

A good building design depends on what its end users will expect from it. Systematic incorporation of end user requirements for buildings can improve building designs and make them more sustainable by reducing operating and maintenance costs, minimizing construction waste and energy consumption and increasing occupant health and safety. However, little research has been conducted to explore how such considerations can be integrated into sustainable building (SB) design processes. For this purpose, Quality Function Deployment (QFD) approach can be applied to translate customer needs into design parameters. This article analyzes end user preferences in SB design and integration of sustainability benefits in existing literature and proposes a QFD-based SB framework for determining design requirements for achieving an effective SB structure. The presented approach is then applied in a real case study for a sustainable university building design. Findings revealed that according to the user preferences; building orientation, the building forms and dimensions are most important technical requirement for a sustainable university building.

Keywords: *Sustainability; Green Building Design; Sustainable University Building; Quality Function Deployment*

INTRODUCTION

The world faced numerous technological achievements, enormous natural resource usage and population growth since the industrial revolution. Nowadays, we start to see the after-effects of this gigantic growth of human species. As a consequence of this effect, awareness for our planet earth has started. Sustainability has entered our lives.
In parallel to population increase all over the world, the concept of resource efficiency is entering local agenda. One of the fields where resources are intensively used is buildings. Humans affect the environment they live in and construct spaces to dwell and work. Buildings considerably affect their environment and are responsible for roughly one-sixth of fresh water use, one-quarter of its wood harvest, and two-fifths of its material and energy flows. The impacts caused by buildings are not limited to the location where they are located and directly or indirectly affect soil, water and air quality, ecosystems and transportation patterns, beside others [1].

In a world where awareness about sustainability continues to rise rapidly in every industry, investigating sustainable building (SB) is a very promising area of work. This area is ready for new developments to achieve high-level green technologies aiming at the comfort and health of the stakeholders. Stakeholder expectations provide valuable data for the design of a building. These expectations are like a customer requirement for a product design. At this point, the most important issue is making the design according to customer expectations. To realize this goal, a very well-known approach, called QFD, can be useful, which is available for translating customer needs into design parameters.

The main objective of this article is to analyze end user preferences for sustainable building with QFD approach. Normally, the QFD approach is a way to gain insight about customer expectations to uncover the positive quality requirements for the product. As a result, seller's satisfaction level will be increased and new values can be created for the product. The design and construction of a new building is similar to product development and manufacturing and overlapping themes are present [2].

In our case, customer requirements are buildings' stakeholder's desires and the design parameters are our technical requirements. The main idea is to have a user-friendly SB design. To accomplish a QFD-based SB design approach, it will be applied to a real case university building, which will be given in the next sections.

SUSTAINABLE BUILDING

In the construction industry, SB has still not become the norm across countries, with low rates of adoption despite the increased need for it [3].One reason is technical challenges for managing environmental and economic issues related with buildings.

SB requires a new architectural approach that seeks to reduce the overall adverse impacts of buildings by aiming at better resource efficiency, such as lower use of materials, energy, and development space over the lifetime of buildings. Sustainable architecture, in this sense, considers a variety of parameters for a more conscious design and planning that conserves energy, water and other natural resources within the built environment [4].

It is possible to achieve these goals by using these principles [5]:

- Reducing the demand for energy and consumption of materials,
- Use of reusable or recyclable construction materials,
- Designing buildings to extend their useful lives,
- Return of materials to the natural cycle,
- Protection of habitats and space-saving building design.

When we talk about sustainable building; economical, environmental and social aspects of the construction projects must be evaluated. At this point environmental evaluation phase is one of the important parts of the assessment.

In the environmental evaluation phase, we face with the "green building" notion, which can be perceived as sustainable buildings that include only environmental parts rather than economic and social ones.

LITTERATURE SURVEY ABOUT SUSTAINABLE BUILDING

In this study, main purpose is to detect the end-user preferences and their technical requirements with a detailed literature review then choose important technical requirements with a QFD method. For this purpose, first an academic literature survey was made to see what kind of works have done recently in this area. Then a complete research was made to see applied cases about SB and especially sustainable university buildings. According to all these academic and applied cases, requirements in the QFD method have evolved.

Academic Literature Review

In the literature, the concept of SB is a part of studies that deal with sustainable materials for the design in 2005

[6]. Another field is eco-cities in also 2005 [7]. Through the following years, studies about material selection have been an important part of SB literature [8][9][10][11]. Subsequently, mobile rating systems have started in related research, where rating systems are introduced to standardize SB design and retrofit processes. There are various mobile SB assessment models in different forms, including models introduced by renowned architecture and engineering firms. Well-known models in this genre can be described as 'private governance' initiatives. Some of the widely recognized examples of these SB design systems are the Building Research Establishment Environmental Assessment Model (BREEAM), the Leadership in Energy and Environmental Design (LEED), ASHRAE Green Guide, GreenCalc, Green Star and GB Tool [12].
With all of these different rating systems, studies tackled with the question of which one to use or how to evaluate them [13][14][15][16]. Following the concept of rating systems, other models seeking SB retrofit cases start to emerge. Designing new buildings still have their importance; but on the other hand turning existent buildings into "green" structures have become an important subject in the literature [17],[18],[19],[20].
Designing new SB has a particular importance throughout the years and a lot of studies and analyses are carried out about this subject [21], [22], [23], [24], [25], [26], [27], [28], [29]. With designing SB, new works have done in recent years about specific areas such as indoor design and daylighting for buildings [30], [31], [32], [33].
Yet, no studies have been done about end-user requirements in a university building where it has many everyday occupants. That is why a university case is chosen to apply in this study.

Research About Applied Cases of Sustainable University Building

Considerable amount of academic studies has been done about SB, a lot of them helped us to distinguish the end-user preferences about sustainable university building. However, to decide their technical requirements it is needed to make a deep research on applied SB cases especially on university buildings. Their applied green policies are a guide for this study to detect technical requirements of end-user requirements.
Green building certification systems for buildings and communities are important in order to communicate the owner's aims and progress on "greening", as a result; universities who made commitments to sustainability are following green building certifications more than ever now [34]. Detailed research has been conducted to find university buildings, which are gained LEED certifications. LEED, an SB system, is one of the very well known, widely used certificates for green building standards. A rating system is developed for this certificate and different ratings are assigned for different levels of certificates, which are; "Certified", "Silver", "Gold" and "Platinum". The highest level is the Platinum certification, the lowest being simply called 'Certified'. Points to be achieved under these different levels differ, where each qualification for the building has its own score, determined in the LEED scorecard [35].
A list has been found from LEED certification website [36] and universities have been studied carefully to detect technical requirements of demand qualifications.

QUALITY FUNCTION DEPLOYMENT

QFD was first introduced by Shigeru Mizuno and Yoji Akao at the end of 60's. Then Kiyotoka Oshiumi made the first detailed application for Bridgestone in 1966. Later in 1972, Mitsubishi Company had started to use this technique in their businesses. In 1984 this technique had become an accepted, useful approach all around the world.
In the field for consumer requirements (CR),QFD is a famous approach[37]. Various studies discussed QFD and its applications in different areas. The main idea of QFD approach is how to balance CR. Prearranging CR is the

main and first step for QFD and Analytical Hierarchy Process (AHP) is the most commune way to it. In this paper, the QFD approach will be used for SB design. The table 1 summarizes literature that combine SB and QFD.

Table 1 Works done about SB and QFD

Year	Writer	Application Area	Analytical Technic
2013	N. Singhaputtangkul et al.[38]	Building envelope design	House of Quality(Interview)
2014	L. C. Wood et al.[25]	Green Hospital Design	QFD (house of quality)
2014	C.C. Menassaa et al.[39]	SB retrofit decisions	QFD (house of quality)
2015	N. Singhaputtangkul et al.[40]	Building sustainable envelopes	QFD combined with fuzzy set(House of quality)
2015	GhadaElshafei et al.[41]	Review	Fuzzy QFD-MCDM approach

CASE STUDY: UNIVERSITY BUILDING

The design and construction phases constitute the most important stages in a green building's life cycle. Problems that occur during the construction phase can lead to significant corrective measures, in particular when environmental damages are concerned [25]. Examination of variables at an earlier stage permits earlier recognition of potential complications in projects. QFD is based on a matrix known as the house of quality (HOQ). HOQ determines the CR of the project and then defines the priorities of these design requirements [42]. Today, the construction industry is moving towards a strong environmental agenda, which underlines the growing need to adopt new quality approaches. Therefore, there is more pressure on construction managers for applying conscious practices that minimize environmental effects of their projects.

Creating a house of quality model for green design

HOQ is founded on the idea of quality charts with two main elements: a set of Demand Qualities (or customer requirements) and a set of Quality Elements (or technical requirements**)** [25]. In the case of sustainable university building design, end user preferences become demand qualities. A matrix is developed for complying with demand qualities that allows users to incorporate technical requirements in the evaluation. In this approach, columns are ranked according to the sums at the bottom.
The highest scoring item is then prioritized for further improvement.
In our case study, first of all the demand qualities are determined by an extensive literature research; then they are grouped according to their properties. In addition to demand qualities, technical requirements for demand qualities are also determined by this detailed literature research.
The list of all requirements detected for HOQ of this study is given in Table 2. According to the requirement pairings in Table 2, QFD for sustainable university buildings will be designed in the case study.
As the first step in the QFD, importance of demand qualities must be detected. To decide on their importance levels, some research is conducted about SB requirements and their importance in the sustainability rating systems, also an expert is consulted[43, 44].

A study with an expert on SB was done to detect the importance of the demand qualifications. Expert scored demand qualities from 1 to 9 according to their ratings, where 1 is the lowest and 9 is the highest importance.
Based on expert's knowledge on SB, the criteria of "Natural ventilation", "Less usage of water" and "Natural lightings" and six more requirements are chosen as the most important demand qualities. On the other hand, "influence on job market" is chosen as the less important one. Other importance points are listed in the QFD in Figure 1.

Table 2a Demand qualifications and their technical requirements

Demand Qualifications		Technical Requirements
Environmental Protection	Natural ventilation [45, 25]	Building orientation[45] Window typologies[45] Slot diffusers[45] Restroom Exhaust /Fan[45] Types, shape and size of openings[45]
	Temperature [45]	Heat emitting windows[45] Building orientation[46, 25]
	Less usage of water [44]	Low flow plumbing fixing[46] Rain water storage[25] Native plants for landscaping
	Natural lighting [2, 47, 25]	Fixed light windows for skylight[47] Building orientation[48] Building forms and dimensions[48] Concrete building envelop[49]
	Less solid waste [44]	Waste generation areas[43]
	Recycling [2]	Waste generation areas[43]
	Lighting system[35]	Occupancy Sensors[50] LED lightings[50] Daylight Sensors[47]

Table 2b Demand qualifications and their technical requirements

Demand Qualifications		Technical Requirements
Construction and Design	Acoustic [51]	Concrete building envelop[49] Site selection [43, 44, 51]
	Accessibility [43,25]	Site selection[43, 44]
	Safety [25]	Environmentally material use[25] Perform proper building operations and maintenance[50]
	Sunlight Direction[35]	Fixed light windows for skylight Building orientation [48, 25] Building forms and dimensions [48]
	Openness Space [52]	Building forms and dimensions [48] Concrete building envelop [49]
	Indoor air quality [2]	Concrete building envelop [49] Slot diffusers[50] Restroom exhaust/Fan[50]
	Complete air distribution [35]	Building form [48] Types, shapes and size of openings [48] Slot diffusers[50]
Social	Occupants productivity[50]	Window typologies [45] Fixed light windows for skylight [47]
	Thermal comfort[2]	Heat-emitting windows [45] Building orientation [48] Types, shapes and size of openings [48]
	Influence on job market[43]	Regional/local supplier use[2, 43]
Economic	Reducing construction time [40]	Reducing lead times[40] Regional/local supplier use [2, 43]
	Reducing construction costs[40]	Reduce material cost[40] Reduce labor cost[40]

RESULTS AND DISCUSSIONS

It is well known that the most important trick in building design is the comfort of its occupants, especially for a university building with high numbers of occupants. It is not easy to please all occupants with a building design and this task becomes even more challenging when the sustainability dimensions are considered. This study proposed a QFD approach for sustainable university building design to address this difficulty.

As indicated in QFD for sustainable university buildings; "building orientation" and "building forms and dimensions" have the biggest percentage of technical importance according to the demand qualifications. After them, "slot diffusers" and "types, shapes and forms of openings" follow in second place. In accordance with results of QFD, these four technical requirements must be well met in order to achieve a sufficiently user-friendly university building.

	Importance	Low-flow plumbing fixtures	Restroom exhaust /Fan	Fixed Light Windows for Skylight	Slot Diffusers	Concrete Building Envelop	Occupancy Sensors	Heat Emitting Windows	Environmentally material Use	Waste generation areas	Native plants for landscaping	Window typologies	Building forms and dimensions	Building Orientation	Perform proper building operation and maintenance	Types, shapes and sizes of openings	Site Selection	LED Lightings	Daylight Sensor	Reducing lead times	Reduce labor cost	Reduce material cost	Regional/local supplier use	Rain water storage	
Natural Ventilation	9		○		△							○		□		□									
Temperature	9							□						△											
Less usage of water	9	□									○													□	
Natural Lighting	8			□		○							□	□											
Less solid waste	6									□															
Recycling	7									□															
Lighting system	9						□											△	□						
Acoustic	9					△											○								
Accessibility	9																□								
Safety	9								□						□										
Sunlight Direction	6			△									□	□											
Openness Space	7					□							□												
Indoor air quality	9		□		□																				
Complete air distribution	8				□								□			□									
Occupants productivity	8			△								△													
Thermal comfort	9							□						△		△									
Influence on job market	1																						□		
Reducing construction time	2																			□					
Reducing construction costs	3																				○	□			
																									Total
Technical importance (TI)		81	90	114	180	98	81	162	81	117	9	33	261	261	81	180	90	27	81	18	3	27	9	81	2165
Normalized TI (%)		3,74	4,16	5,27	8,31	4,53	3,74	7,48	3,74	5,40	0,42	1,52	12,06	12,06	3,74	8,31	4,16	1,25	3,74	0,83	0,14	1,25	0,42	3,74	100

□	Strong relation (9)
△	Medium relation (3)
○	Low relation (1)

Figure1 Quality Function Deployment for sustainable university building design

On the other hand, the relation between the technical requirements must be investigated in order to decide which one to prioritize or eliminate due to their relations to each other. A roof matrix for HOQ is a best way to see all these relations between the technical requirements. This roof matrix is shown in the Figure 2.

Following the QFD results, a roof matrix of a HOQ is evaluated and the correlations between technical requirements are detected with another literature research. According to these correlations, the most important technical requirements "building forms and dimensions" (12,06%) and "building orientation" (12,06%) are found to be strongly correlated with "types, shapes and sizes of openings" and "daylight sensor". So both three technical requirements should be evaluated together during the designing of a sustainable university building.

In this case study, after applying QFD and HOQ roof matrix, ranking indicated in Table 3 is obtained.

Therefore, the results show that, "building orientation", "building forms and dimensions", which are related to design qualification of building, are the most important ones according to end-user preferences.

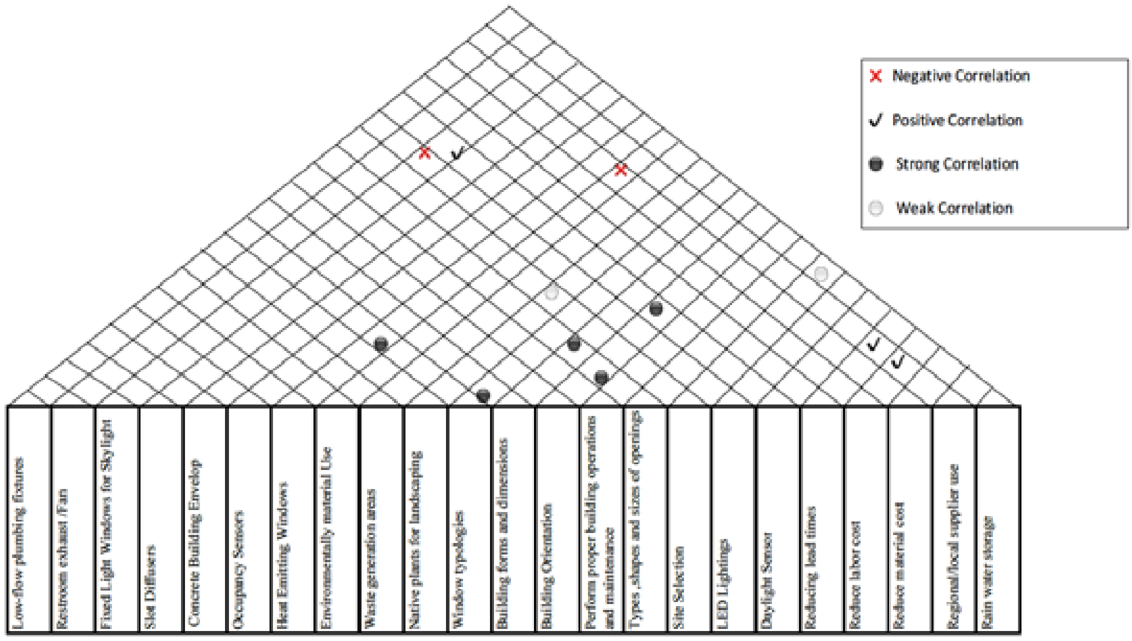

Figure 2 Roof matrix for house of quality for a sustainable university building design

On the other hand, before using QFD approach for a sustainable university design, we asked an expert, who has a very wide experience on designing sustainable university buildings in Turkey, to rank top 5 technical requirements according to her knowledge on sustainable university design.

Table 3 Ranking of the technical requirements

1	Building forms and dimensions
1	Building orientation
2	Slot diffusers
2	Types, shapes and sizes of openings
3	Heat emitting windows
4	Waste generation areas
5	Fixed light windows for skylight
6	Concrete building envelop
7	Restroom exhaust /Fan
7	Site selection

8	Low-flow plumbing fixtures
8	Occupancy sensors
8	Environmentally material use
8	Daylight sensor
8	Rain water storage
9	Window typologies
10	LED lightings
10	Reduce material cost
11	Perform proper building operations and maintenance
11	Reducing lead times
12	Native plants for landscaping
12	Regional /local supplier use
13	Reduce labor cost

Expertise ranking was as indicated in the following list:

1. Site selection
2. Building orientation
3. Building envelop
4. LED lightings
5. Environmentally material use

When it is compared to QFD approach, it is easy to see the similarities such as building orientation, but also the differences like environmental material use and LED lightings' ranking.
This direct evaluation of expertise shows the "must have" requirements for a sustainable university building, but with the QFD approach, with all correlations between requirements; it is easier to see the whole picture together and the results are more reliable than direct evaluation. In a case where too many experts or designers exist, QFD method will bring further technical advantages in designing phase than the direct evaluation due to its partly similar results as direct evaluation.

In addition, when we compare our results with LEED certificated universities, it is easy to see that they all have these qualifications in their university design [36]. In addition to these qualifications, retrofitting old buildings with a smart design also have a great importance in sustainability of university in other countries; but in Turkey the number of universities, which contain historical buildings, is very low. Due to that reason, we do not have that requirement even in our HOQ evaluation. Therefore, it also shows that; all the requirements for a sustainable university design may vary from country to country.

Moreover, in general, while comparing the results with other studies about SB design, we see parallel conclusions. For example, in a sustainable hospital design end-user preference also lead to design parameters like sufficient layout or innovative design [25]. Also LEED system emphasize the indoor environmental quality in SB like hospitals and schools, which is also a design qualification [35]. In addition, "Types, shapes and size of openings" is a strong qualification to have good indoor environmental quality in a SB.

On the other hand, in other sectors like logistics, design parameters begin to be in second place; accessibility and location take the first step in SB design [53]. It is obvious that, results may vary from sector to sector in studies, but in this case study, QFD method gave the parallel results to similar sectors like healthcare.

CONCLUSIONS

In this study, a QFD based method is proposed to design a sustainable university building. Following an extensive research, user requirements for a sustainable building are gathered from literature. These requirements are grouped by their different properties first, then by their scores according to their importance with expert's knowledge for building design and construction for schools. Consequently, their relations with technical requirements are determined with a detailed literature research. Technical qualifications are gathered from applied sustainable university cases.
Later, QFD method has been applied and according to the matrix, the results are gathered. Then their inter-

relations are investigated with a HOQ roof matrix.
Following, all the results have been discussed and compared to other studies on SB designing area.

In this study, the requirements are determined with a literature research and with the help of the LEED rating system. The QFD approach is used for ranking the technical requirements.
In the future, requirements can be evaluated by multiple experts and end user requirements can be evaluated with real university occupants, by surveys, for example. The proposed QFD approach can also be used in the construction and remodeling of sustainable neighborhoods in further studies.

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REFERENCES

[1] L. Abraham, S. Agnello, S. Ashkin and e. al., Sustainable Building Technical Manual,Green building Design, Construction and Operations, Public Technology, 1996.
[2] W. L. Gillis, "Development Of An Integrative Commissioning Methodology For New-Building Construction," ProQuest, 2013.
[3] H. J. Kang, "Development of a systematic model for an assessment toolfor sustainable buildings based on a structural framework," ***Energy and Buildings ,*** vol. 104, pp. 287-301, 2015.
[4] Wikipedia, 2016. [Online]. Available: https://en.wikipedia.org/wiki/Sustainable_architecture#cite_note-1.
[5] B. F. Verkehr, Guideline for Sustainable Building, 1st reprint ed., F. O. f. B. a. R. Planing, Ed., 2001.
[6] G. John, Clements-Croome and G. Jeronimidis, "Sustainable building solutions: a review of lessons from the natural world," ***Building and Environment,*** vol. 40, pp. 319-328, 2005.
[7] L. Crabtree, "Sustainable Housing Development in Urban Australia: exploring obstacles to and opportunities for ecocity efforts," ***Australian Geographer,*** vol. 36, no. 3, pp. 333-350, 2005.
[8] C.Thormark, "The effect of material choice on the total energy need and recycling potential of a building," ***Building and Environment,*** vol. 41, pp. 1019-1026, 2006.
[9] P. O. Akadiri, P. O. Olomolaiye and E. A. Chinyio, "Multi-criteria evaluation model for the selection of sustainable materials for building projects," ***Automation in Construction,*** vol. 30, pp. 113-125, 2013.
[10] M. Marzouk and e. al., "Selecting sustainable building materials using system dynamics and ant colony optimization," ***Journal of Environmental Engineering and Landscape Management,*** vol. 21, no. 4, pp. 237-247, 2013.
[11] D. Castro-Lacouture, J. A. Sefair, L. Florez and A. L. Medaglia, "Optimization model for the selection of materials using a LEED-based green building rating system in Colombia," ***Building and Environment,*** vol. 44, pp. 1162-1170, 2009.
[12] J. Faulconbridge, "Mobilising sustainable building assessment models: agents, strategies and local effects," ***AREA,*** vol. 47, no. 2, pp. 116-123, 2015.
[13] A. Haapio and P. Viitaniemi, "A critical review of building environmental assessment tools," ***Environmental Impact Assessment Review,*** vol. 28, pp. 469-482, February 2008.
[14] S. Pushkar and E. Shaviv, "Using shearing layer concept to evaluate green rating systems," ***Architectural Science Review,*** vol. 59, no. 2, pp. 114-125, 2016.

[15] A. Z. Kibert and J. Charles, "Informing LEED's next generation with The Natural Step," ***Building Research & Information,*** vol. 35, no. 6, pp. 681-689, 2007.

[16] D. Erten, "International Green Building Certification Systems: A Comparative Approach To LEED And BREAM," in ***International Sustainable Buildings Symposium*** , Ankara, 2010.

[17] S. Olander, "Sustainable Building Adaptation: Innovations in Decision-making," ***Construction Management and Economics,*** vol. 33, no. 9, pp. 777-778, 2015.

[18] P. Xu, EdwinHon-WanChan and Q. K. Qian, "Success factors of energy performance contracting (EPC) for sustainable building energy efficiency retrofit (BEER) of hotel buildings in China," ***Energy Policy,*** vol. 39, pp. 7389-7398, September 2011.

[19] Y.-K. Juan, P. Gao and J. Wangc, "A hybrid decision support system for sustainable office building renovation and energy performance improvement," ***Energy and Buildings,*** vol. 42, pp. 290-297, 2010.

[20] P. Xu, E. H. Chan, H. J. Visscher, X. Zhang and Z. Wu, "Sustainable building energy efficiency retrofit for hotel buildings using EPC mechanism in China: analytic Network Process (ANP) approach," ***Journal of Cleaner Production,*** vol. 107, pp. 378-388, January 2015.

[21] T.Häkkinen, "Assessment of indicators for sustainable urban construction," ***Civil Engineering and Environmental Systems,*** vol. 24, no. 4, pp. 247-259, 2007.

[22] Gram-Hanssen and J. O. J. &. Kirsten, "Ecological modernization of sustainable buildings: a Danish perspective," ***Building Research & Information,*** vol. 36, no. 2, pp. 146-158, 2008.

[23] G. Simmon, "Pragmatic ecologies: situating sustainable building," ***Architectural Science Review,*** vol. 53, no. 1, pp. 21-28, 2010.

[24] J. Zhou and Y. Chen, "A review on applying ventilated double-skin facade to buildings in hot-summer and cold-winter zone in China," ***Renewable and Sustainable Energy Reviews,*** vol. 14, pp. 1321-1328, 2010.

[25] L. C. Wood, C. Wang, H. Abdul-Rahman and N. S. J. Abdul-Nasir, "Green hospital design: integrating quality function deployment and end-user demands," ***Journal of Cleaner Production,*** vol. 112, pp. 903-913, 2014.

[26] K. Fujita and I. Takewaki, "Sustainable building design under uncertain structural-parameter environment in seismic-prone countries," ***Sustainable Cities and Society,*** vol. 1, pp. 142-151, 2011.

[27] O. E. Mansour and S. K. Radford, "Rethinking the environmental and experiential categories of sustainable building design: a conjoint analysis," ***Building and Environment,*** pp. 47-54, December 2016.

[28] M. H.Wu, T. S. Ng and M. R. Skitmore, "Sustainable building envelope design by considering energy cost and occupant satisfaction," ***Energy for Sustainable Development,*** vol. 31, pp. 118-129, 2016.

[29] A. Shafaghat and e. al., "Methods foradaptive behaviors satisfaction assessment with energy efficient buildingdesign," ***Renewable and Sustainable Energy Reviews,*** vol. 57, pp. 250-259, 2016.

[30] W. Wei, O. Ramalho and C. Mandin, "Indoor air quality requirements in green building certifications," ***Building and Environment,*** vol. 92, pp. 10-19, 2015.

[31] J. Li, Y. Song, S. Lv and Q. Wang, "Impact evaluation of the indoor environmental performance of animate spaces in buildings," ***Building and Environment,*** vol. 94, pp. 353-370, 2015.

[32] X. Yu and Y. Su, "Daylightavailabilityassessmentanditspotentialenergy savingestimation –A literaturereview," ***Renewable and Sustainable Energy Reviews,*** vol. 52, pp. 494-503, 2015.

[33] A. Shafaghat and e. al., "Enhancing staff's satisfaction with comfort toward productivity by sustainable Open Plan Office Design," ***Sustainable Cities and Society,*** vol. 19, pp. 151-164, 2015.

[34] D. Erten, "Green Campus Development And Greening Existing University Campuses: Case Studies From Turkey," in ***International Sustainable Building Symposium***, Ankara, 2015.

[35] USBC, "Leed v4 For Building Design And Construction," USBC, 2016.

[36] H. Wilber, "10 schools leading the way in Princeton Review Guide to Green Colleges (photos)," USGBC, 2014 April 2014. [Online]. Available: http://www.usgbc.org/articles/10-schools-leading-way-princeton-review-guide-green-colleges-photos. [Accessed 11 August 2016].

[37] Y. Akao, "QFD: Quality Function Deployment – Integrating Customer Requirements into Product Design," ***Productivity Press,*** 2004.

[38] N. Singhaputtangkul and e. al., "Knowledge-based Decision Support System Quality Function Deployment (KBDSS-QFD) tool for assessment of building envelopes," ***Automation in Construction,*** vol. 35, pp. 314-328, 2013.

[39] C. C. Menassa and e. al, "A framework to assess the role of stakeholders in sustainablebuilding retrofit decisions," ***Sustainable Cities and Society,*** vol. 10, pp. 207-221, 2014.

[40] N.Singhaputtangkul and e. al, "Modeling a Decision Support Tool for Buildable and Sustainable Building Envelope Designs," ***Buildings,*** vol. 5, pp. 521-535, 2015.

[41] G. Elshafei and e. al, "Optimization of Strategies and Models Review for Optimal Technologies - Based On Fuzzy Schemes for Green Architecture," ***International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering,*** vol. 9, no. 4, pp. 429-434, 2015.

[42] J. Hauser and D. Clausing, "The house of quality," ***Harvard Buiseness Review,*** vol. 3, pp. 63-73, 1988.

[43] I. William Leroy Gillis, "Understanding The Design Impacts Among LEED Certification Credits," in ***Industrial and Systems Engineering Research Conference***, 2013.

[44] USGBC, "Green Building Design and Construction With Global Alternative Compliance Paths," USGBC, Washington, 2009.

[45] G. B. Tech, "Natural Ventilation," [Online]. Available: http://gbtech.emsd.gov.hk/english/utilize/natural.html. [Accessed 11 June 2016].

[46] WBDG Sustainable Committee, "Protect and Concerve Water," 11 December 2015. [Online]. Available: https://www.wbdg.org/design/conserve_water.php. [Accessed 12 June 2016].

[47] G. D. Ander, "Daylighting," 23 October 2014. [Online]. Available: https://www.wbdg.org/resources/daylighting.php. [Accessed 12 June 2016].

[48] P. Crisman, "Form," 14 March 2014. [Online]. Available: https://www.wbdg.org/resources/form.php. [Accessed 12 June 2016].

[49] Portland Cement Association, "How Does Concrete Help Achieve LEED Certification?," [Online]. Available: http://www.concretethinker.com/solutions/LEED-Certification.aspx. [Accessed 12 June 2016].

[50] M. Maytum and G. Fuertes, "Finding the Balance Point : A case study Sweetwater Spectrum," ***High Performence Buildings,*** pp. 14-22, Winter 2016.

[51] R. Paradis, "Acoustic Comfort," 23 October 2014. [Online]. Available: https://www.wbdg.org/resources/acoustic.php. [Accessed 12 June 2016].

[52] WBDG Sustainable Comitee, "Optimize Site Potential," 11 December 2015. [Online]. Available: https://www.wbdg.org/design/site_potential.php. [Accessed 12 June 2016].

[53] M. Napolitano, "7 Trends in Sustainable Warehouse Design," 15 November 2013. [Online]. Available: http://www.supplychain247.com/article/7_trends_in_sustainable_warehouse_design/green. [Accessed 3 August 2016].

Paper No: 66

Transportation, the Requested Architecture Designs For Future Transportation Systems

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ABSTRACT

Transport policies were changed over time, in response to, for example, transport planning strategies. Objectives have changed from fully satisfying demands for transport to a more objective oriented, transport planning. Travel behaviour of people in urban areas will have to change so that the new requested architectural designs will be necessary as a station for a new kind of transportation system. Before designing these structures, we will take into account this new transportation system. For instance an example maybe the transportation from the 50th floor of a building to another maybe with this new transportation system. Some ideas which are being discussed nowadays are described below:

Parallel Gravity Train, Speedy lanes, Straddling bus, Hyperloop system.

These new transportation ideas shall be always adapted to current developing urban cities. In the following chapter, some transportation ideas which can be adapted to urban development will be shown. These examples shown in the following chapters are:

- Application of Parallel Gravity Train for Bostanli seaside;
- Speedy lanes used on sustainable bridges;
- Straddling bus solution applied for Vatan Street in İstanbul;
- Passing Bosphorus Strait by future Hyperloop system *(close to Yavuz Sultan Selim Bridge).*

INTRODUCTION:

We know that technology is developing day by day and it's affected by the above future transportation. Smart transportation solutions focus on railway, vehicle, aero and marine. In addition, smart transportation helps to improve efficiency during the journey or time spent while waiting for the buses, trains, planes or ships, and for accommodation. This paper summarizes basic principles for transportation planning. It describes a conventional transport planning, which tends to focus on railway, vehicle, aero and marine conditions, and evaluation with technology. In the future, how to evolve transportation hubs; which new methods can be used in future transportation; how to interrelate between architecture and smart city transportation by taking into account the adaptation of these smart transportation solutions to current metropolitan cities.

THE REQUESTED ARCHITECTURE DESIGNS FOR FUTURE TRANSPORTATION SYSTEMS

Transportation acts an important role in our daily lives. People need to earn money to survive. So, when people find a job, they need to get there on time because time is so significant. No one wants to waste time. Human population is also increasing and capacity of job opportunities are decreasing day by day. This is why the distance is usually considerable between workplace and home.

Figure 1 Transportation [1]

Figure 2 Trade [2]

Figure 3 Roller coaster technology [3]

Moreover, this issue will be worsened in the future. When we look at the transportation issue, currently it is not sufficient. It is time that we solve this insufficiency with new architectural designs and reduce this problem to a minimum. First, architecture typology is the comparative study of the physical characteristics of the built environment into different types. Erstwhile, throughout history, people have always traded with each other. For example, when one person produced a new product which he wanted to sell, these products were carried with horses or camels and when the distance was far away to provide access to the buyer, ships were used to arrive in time. In this process, port typology occurred. In addition, if seller wanted to rest while selling his/her products for more than one day, hans and caravanserais were built. Through such examples we can talk about architecture typology that is everywhere.

For example, let's imagine that a passenger is staying in a hotel and he wants to safeguard his money. This situation has created the human need for banks. From past to present, according to human needs, various typology is born and has affected social, cultural, political institutions. When we combine typology and future technology, its suitable to improve life standards or to make life easier. Some ideas which are being discussed nowadays are described below to make life easier. The **'Parallel Gravity Train'** is shown as an example. This name comes from train systems and roller coasters technology.

[1] A steady parallel movement will allow a safe ride and also, it has got ergonomic design. Using roller coaster technology into a single system creates the necessity of keeping the parallel movement of the train-car to the ground at all times. Parallel gravity trains are highly beneficial and have advantages,

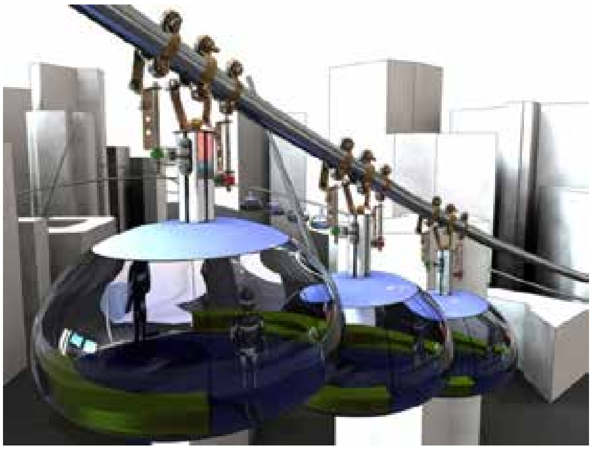

Figure 4 Parallel Gravity Train [4]

particularly in the field of energy consumption. In the future, it can have a place in our lives. For instance, many people prefer highways for transportation, but many vehicles spread carbon emissions which are very unhealthy for human lives. This is why we need to choose another kind of transportation. **Parallel Gravity Train** provides human access from one place to another place in a very short time. This transportation provided through an airway. In this process, as there are lesser crowds of people, its displacement adds energy to the general cycle, and compensates for the lost energy through the frictions within air and rail.

Figure 5 Example for application of Parallel Gravity Train for Bostanli seaside

In the following example you can see how 'parallel gravity train system' can be effectively useful for Bostanli seaside. Increasing traffic problem of city centres are always creating problems for people living in the metropolitan cities. In this example you can see that using this kind of transportation system people can go to city centre (Kadiköy area) easily instead of waiting hours in traffic. And besides, convenient free areas could be used as stops which will need particular architectural designs respecting urban city centres.

[2] The yellow travellator reaches from 3mph to 9 mph, then the orange or red walkways, which would move at 12mph and 15mph respectively. The yellow travellator represents the 'slow lane', the orange travellator represents the 'middle lane' and the red one is the 'fast lane'. It reduces time wasted by stopping at stations.

Shops could be located either side of the travellator. When people travel anywhere, they can easily rest or buy something when necessary. Transportation system is located from above ground to underground. Through this method, business life can be more efficient and many people will prefer it. When the population reaches a higher level, life can continue there. Crowded concentration of people will be reduced this way. Also, carbon emissions are reduced to a minimum level so people are healthier. In addition, this subterranean network of pathways will generate electricity as people walk and cycle through them. In a statement, people can produce energy with their energy. When they walk, they create electricity from these travellators. It provides a better sustainable city.

Figure 6 Underground's Circle Line Giant Travellator [5]

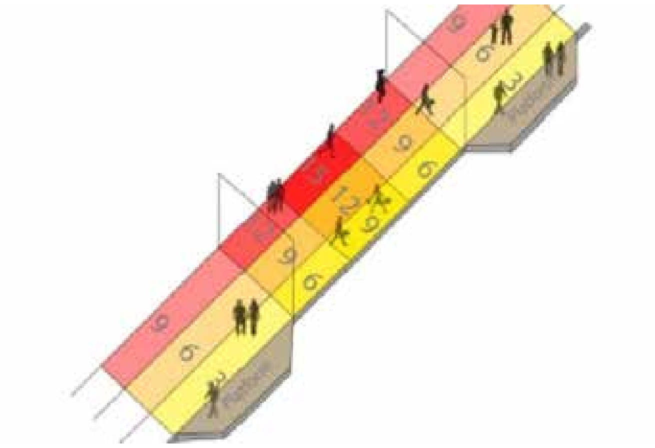

Figure 7 Speeds of lanes [6]

Figure 8 Speeds of lanes [7]

These speedy lanes can be also applied on bridges used daily for people who pass from one side to other side of city. Thanks to able to produce electricity, the illumination system of bridge could be provided by this system. This could be a good example for sustainability both saving time and producing energy without carbon dioxide emission. The photo no.3 shows the illumination system used for new 3rd bridge called Yavuz Sultan Selim.

Straddling bus

One example is a solution in China's transportation systems. As we know, China has the highest population in the world. When we focus on transportation in China, traffic jams have reached the maximum level. Air pollution, crowded population are dangerous factors in Chinese cities. China may have a new and cheap solution in the form of a vehicle which is named the 'Straddling Bus'.

Figure 9 Straddling bus   [8]

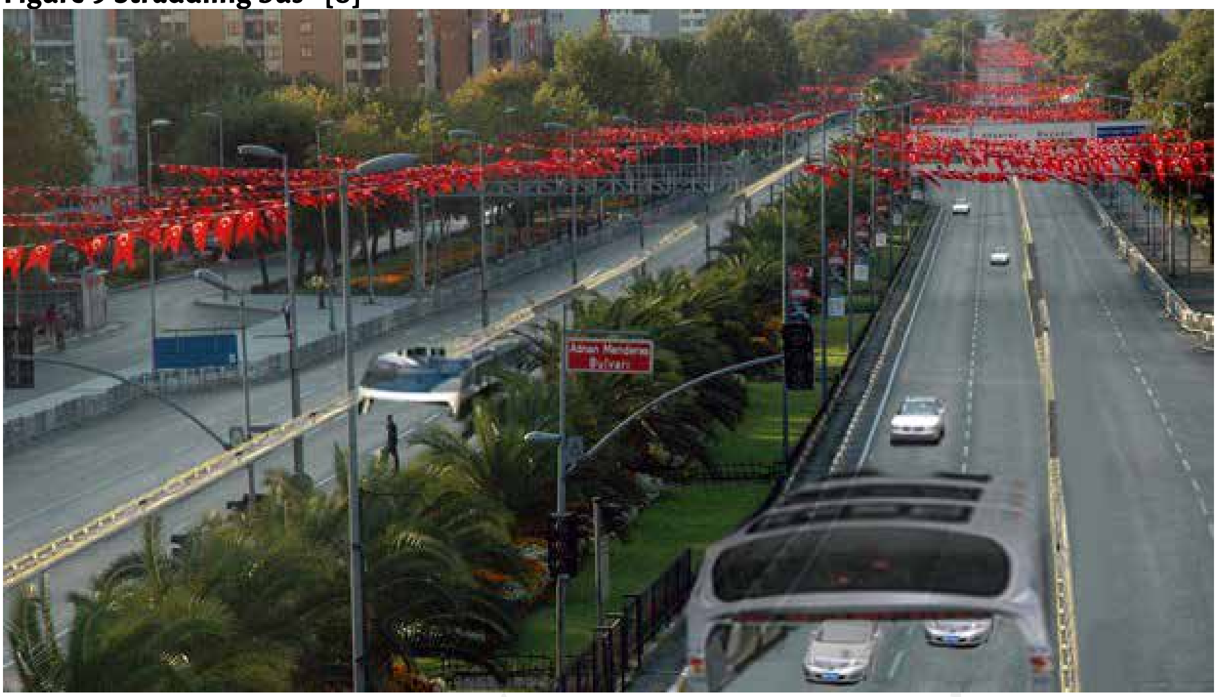

Figure 10 Straddling bus solution applied for Vatan Street in İstanbul

This bus is a rail-based vehicle that goes over street traffic. [3] Approximately 1,400 people can board a full-size bus. The proposed straddling buses would be all-electric, travel approximately 40mph. This transportation method will not contribute to air pollution. High carbon emission levels are the reason to create these straddling buses. [4] According to City Lab reports, through these buses, it is estimated that each one will cut fuel consumption by 800 tons and carbon emissions by 2,500 tons.

Figure 11 Straddling Movement Method [9]

Also, this design will improve and protect Chinese people's budgets. These tickets will be inexpensive and if the passengers want to go anywhere, they do not need to wait in traffic, so we can say that with these busses people will spend less time travelling. These buses pass over the vehicles and passengers can arrive on time anywhere. Straddling buses are powered by solar power and large parking spaces aren't required. The bus itself is a conductor to create electricity. When the bus's electricity is charging, or capacity of speed limit is decreasing, its charge allows the energy to run the bus. In addition, solar power contributes to the charge and it is done when bus stops at stations.[5] The stations are built so that the passengers can go up and over through the ceiling doors. They can use ladders for access between train and station.

Stations can be establish at every 2 km. Also, in these stations there are resting places, cafes and toilets for human needs. When technology and transportation combine to work with each other, problems can be solved easily. A group of engineers from both Tesla and Spacex worked on the conceptual modelling of Hyperloop. Nowadays, Hyperloop is of big importance because it provides [6] the high speed transportation of passengers and goods in tubes and also, has reintroduced using the updated technologies, designed by Elon Musk.

Figure 12a Hyperloop Tubes [10]

Figure 12b Hyperloop Connection [11]

Hyperloop provides a shorter journey time and is not affected by adverse weather conditions [7] Also, it reaches 760 mph speed limits, so the Hyperloop is faster that planes, [8] thus enabling passenger and freight transportation at high speeds with low energy consumption. This transportation ensures inexpensive tickets for the passengers. This improves personal and social lives as well as economic development. In this structure, pylons are designed to be earthquake resistant for safety.

Figure 13 Passing Bosphorus Strait by future Hyperloop System (close to Yavuz Sultan Selim Bridge)

And these tubes not only go aboveground, they can go anywhere. For example, they can go underwater and the hyperloop teams aim to connect the world. [9] Testing the Hyperloop is expected to begin inside a two mile tube by the end of this year in the City of North Las Vegas, Nevada. If you are travelling between cities by car, the journey generally takes 3 to 4 times the time the Hyperloop would take, also drivers will need to pay for expensive gasoline costs. These tubes can be a solution because of time saving and financial reasons. In a short time you can access to anywhere, very comfortably and cheaply. Hyperloop teams are searching for application areas. For natural areas, these hyperloops avoid damage to nature as air pollution and carbon emissions are not an issue. In this system linear induction motors and air compressors are used.

In the concept of urban development, adaption of the hyperloop connection to current metropolitan system maybe is difficult but in the near future this system will able to connect big metropolitan city centres.

CONCLUSION:

In short, cities and communities have many problems regarding transportation. As population of the world and needs of humans increase day by day, traffic jams are becoming inevitable. People are becoming a bigger threat to the natural environment. As a solution, we need to associate between human needs and better transportation systems. ***For the future transportations systems, these examples given in the previous section provide an interrelation between architecture and smart cities transportations.***

Smart cities need to develop an architecture in which technology can evolve, providing space to create value and start-ups to innovate. Citizens need to see the value in these transportation systems which will save them time and money and then they can focus on how they can access from one place to another. Architecture and transportation can be designed together. Transportation systems should not be harmful to nature, transportation problems should be reduced to a minimum. It may be difficult to predict the architecture of the future, as it is strongly connected to the societies' social, cultural and political future. Architecture aims to meet the needs of the present epoch, with its time-specific reality, such as social, cultural, political, and environmental issues. I am certain that architecture will be more adaptable, and sustainable for designing future transportation systems and will serve every need of humanity in the near future.

ACKNOWLEDGEMENT:
Thanks to Serkan ÇAKIR (Sws Engineering S.P.A) for helping me learn about the above mentioned topics. I am also thankful to Lale BAŞARIR (Izmir University of Economics Faculty of Fine Arts and Design part-time lecturer) for her suggestions and I would like to thank Filiz Keyder ÖZKAN (Izmir University Of Economics Faculty of Fine Arts and Design part-time lecturer) for helping me gather information.

REFERENCES:

[1] https://helixator.wordpress.com/2011/02/16/parallel-gravity-train/
[2] http://www.independent.co.uk/news/business/news/an-architecture-firm-wants-to-turn-the-london-undergrounds-entire-circle-line-into-a-three-lane-10491340.html
[3] http://www.popsci.com/straddle-bus-drives-over-cars
[4] http://www.techinsider.io/what-are-chinese-straddling-buses-2016-5
[5] http://www.slideshare.net/RamKrishnaJagali/straddling-bus-presented-by-rk
[6] https://en.wikipedia.org/wiki/Hyperloop
[7] http://hyperlooptransp.com/
[8] http://www.mithyperloop.org/about.html
[9] https://www.engadget.com/2016/01/29/what-you-need-to-know-about-hyperloop/

Building - Renewable Energy

Paper No: 121

Renewable Energy Technologies - Economic Analysis Tool (RET-EAT) for Turkey

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ABSTRACT

Turkey has developed legislation to improve energy efficiency in buildings and promote the uptake of renewable energy sources (RES). The Renewable Energy Technologies Economic Analysis Tool is developed to assist building designers and developers. This tool aims promoting and enhancing the effective and rational utilization of renewable energy resources in buildings and thereby to reduce the final external energy consumption and associated greenhouse gas (GHG) emissions in the buildings sector of Turkey. For this purpose, the tool aims to demonstrate the feasibility and benefits of renewable energy technologies (RET) in a more quantitative and comparable manner by:
• Calculating the economic, energy savings potential and environmental benefits from RET for buildings,
• Calculating associated investment costs of the renewable energy technologies for economic analysis and also to check if it complies with the minimum investment costs of the current regulations and bylaws of Turkey, and
• Comparing possible RET implementation scenarios and base building scenarios.

INTRODUCTION

As populations expand, living standards improve and consumption rises, total demand for energy is expected to increase by 21% by 2030 [1]. At the same time, growing concerns over climate change are prompting governments worldwide to seek ways to supply energy while minimizing greenhouse gas emissions and other environmental impacts. Renewable energy benefits therefore play a critical role in informing policy decisions and tipping the balance in favor of low-carbon investments. Renewable energy resources are inexhaustible and offer many environmental benefits compared to conventional energy sources. Each type of renewable energy also has its own special advantages that make it uniquely suited to certain applications [2]. Turkey has developed legislation to improve energy efficiency in buildings and promote the uptake of renewable energy sources (RES). To assist building designers and developers meet their obligations, developing of "Renewable Energy Technologies Economic Analysis Tool (RET-EAT)", which will identify the feasibility of technology options, and evaluate the economic, environmental and efficiency benefits of technologies and their combinations [3].
The RET-EAT is developed to promote and enhance the effective and rational utilization of renewable energy

resources in buildings and thereby to reduce the final external energy consumption and associated greenhouse gas (GHG) emissions in the buildings sector of Turkey. For this purpose, the tool aims to demonstrate the feasibility and benefits of renewable energy technologies (RET) in a more quantitative and comparable manner by:

- Calculating the economic, energy savings potential and environmental benefits from RET for buildings,
- Calculating associated investment costs of the renewable energy technologies for economic analysis and also to check if it complies with the minimum investment costs of the current regulations and bylaws of Turkey, and
- Analyzing possible RET implementation scenarios and base building scenarios.

Two different calculation approaches with very different data requirements are used in the tool:

- **The Detailed Approach** requires hourly inputs of different forms of energy demand (space heating, space cooling, domestic hot water, and electricity), which are exogenous user-inputs obtained through the use of a third party software.
- **The Simplified Approach** calculates different forms of hourly energy demand of the building using limited user inputs (compared to the Detailed Approach) and is likely to be more suitable for preliminary design work and other situations in which hourly energy demand data is lacking and a detailed assessment of renewable energy options is not desired.

MODELLING METHODOLOGY and SCOPE

The establishment of the baseline energy demand can be done in two modes: a more complex 'Detailed Approach' and a simpler 'Simplified Approach'. The detailed flow-charts are presented in figure 1 and 2 respectively.

The modelling analysis is based on the energy demands of a single building, including electricity, space heating, space cooling and domestic hot-water demands. Industrial processes (e.g. energy/steam demand for industrial processes, power plants, etc.) are not in scope. The user defines a mixed set of renewable and conventional technologies each of which will partially satisfy the building's energy demands.

The model calculates the fuel, CO_2 and financial breakdown of meeting the user energy requirements for a suite of user specified technology installation options, which can then be compared to determine return on investment and levelised costs of energy. It is as such concerned only with the energy supply and end uses, and is not a point-to-point, or building spatial simulation model.

For the Simplified Approach where hourly energy demand is modelled within the tool, heating and cooling gains/losses are assumed to be only through the building envelope exposed to outside air and for meeting ventilation requirements. This means that walls shared with neighboring buildings are assumed to be in thermodynamic equilibrium and therefore no heat transfer is assumed through them. Furthermore, only space heating / cooling and hot water energy demands are calculated in this approach, with annual lighting and equipment electricity demands being provided as a user input. Annual electricity demands for lighting and equipment are broken down into approximate hourly values based on a simplified algorithm. For the Detailed Approach, hourly inputs of energy demand (heating, cooling, hot water and electricity), are an exogenous user-input, calculated through the use of a third party software, such as EnergyPlus etc. For the heating, if the building has steam demand for space heating purposes, steam demand should be included as "heating demand" and an appropriate technology (e.g. boiler) should be selected to meet the required heating demand.

The conventional and renewable energy technologies included in the model are as follows:

- Combined Heat and Power (CHP), including micro CHP and Combined cooling, Heating, and Power (Tri-generation) based on, turbine or engine
- Heat pump (air source, ground source, water source)
- Heat driven chillers (absorption and adsorption),
- Solar PV,
- Solar thermal,
- Combined: Solar PV-thermal or thermo-electric systems,
- Wind Turbine
- Hot water storage,
- Cold water storage,
- Ice storage
- Space heating storage
- Electricity storage (battery),
- Gas and biogas Boilers,
- Direct heat and hot water sources (e.g. geothermal, district heat or waste heat)

The detailed method or the simplified method is used to calculate the utilisation of user-selected technology mixes for each scenario and for the counterfactual "base" scenario. Based on these, the following metrics can be calculated. Mathematical functions used to calculate these outputs are presented in the next chapter.

- Annual energy demand met by the selected technology mix scenario
- Annual fuel savings (kWh) by the selected scenario including exergy analysis (optional)
- Annual CO_2 savings (tCO_2) by the selected scenario
- Energy efficiency of the system
- Rational Exergy Management Efficiency (optional)
- Increase in initial investment compared to baseline (% fraction of total building cost)
- Annual fuel/bill savings (TRY) by technology
- Payback duration by technology (years)
- Net annualised cost over lifetime by technology (TRY/y)
- Levelised cost of CO_2 reduction over lifetime by technology (TRY/tCO_2)
- Levelised cost of CO_2 reduction over project lifetime for building (TRY/tCO_2)
- Net present value of scenario

Detailed Approach

The detailed hourly approach uses pre-calculated energy demand profiles from third-party software, output and converted as needed to produce hourly electricity, heating, cooling, and hot water use figures.

This approach requires fewer user inputs regarding the building performance as hourly energy demand does not need to be calculated by the tool. It should be noted that, the user will need detailed data on the building to generate the input file using a third-party software such as EnergyPlus.

Dispatching algorithms determine the order in which the technologies are deployed to meet the electrical and thermal (heating, cooling and hot water) demands based on a technology 'ranking'. This ranking defines the preference order in which technologies are used and therefore the share of the energy demands met by renewables. As a general principle, renewable generation in the form of heat, hot water and/or electricity from solar and wind is always used first. Any residual demand is reduced by storage, heat pump, CHP and if still required the conventional technologies such as boilers. The main objective constraint is the minimum required RET investment cost as a fraction of the total building cost. RET mix scenarios may be included in the tool but can be created or amended by the user.

Compared with the Simplified Approach, the Detailed Approach produces a more accurate assessment of the dispatch of the available technologies and therefore provides a more accurate feasibility assessment. Where an accurate assessment is desired, and data is available, this will be the preferred approach.

Simplified Approach

This approach calculates hourly energy demand using limited user inputs. The hourly heating and cooling demands are calculated using a simplified analysis of heat losses through fabric for exposed walls and resulting from ventilation. The degree hours are calculated based on occupancy (The use of only degree hours and U values results in overestimation of the heating loads as it does not include some of the heating gains such as appliance, metabolic and solar gains. Furthermore, it will not be able to distinguish different occupancy patterns for different buildings - e.g. commercial buildings might not be heated or cooled over the weekend, schools might be unoccupied for more than 2 months), internal design temperature and hourly outside air temperature data. In our proposed methodology, using hourly temperature data, and default occupancy timings (based on the type of buildings) will enable a more accurate calculation of heating and cooling loads.

The internal gains are estimated based on occupancy, lighting and appliance use, while solar gains are calculated using the glazing ratio and the dimensions of the exposed walls. The hot water demand is also based on the occupancy and typical requirements per person based on building type. The annual electricity consumption, split by lighting and other appliance use, is a user defined input. Electricity consumption will be broken down into hourly demand in the tool using a simplified algorithm.

Similar to the detailed approach, dispatching algorithms determine the order in which the technologies are deployed to meet the electrical, heating and cooling demands. This ranking defines the merit order of preference in which technologies are used and therefore share of the energy demands that are met by renewables.

The proposed simplified approach is "simplified" compared to detailed engineering simulation tools; however, it still provides relatively accurate and robust energy demand data. Although the algorithm performs an internal hourly calculation, it will be straight-forward for the user to use the model. Some of the required inputs will be included in the "Default building parameters database", and the user will only need to choose the simplified building type. Target heating and cooling temperatures will also be included in the database [4].

Simplified approach (i.e. performing an internal hourly calculation) also results in better estimates of utilization of renewable technologies. Even in the preliminary design work, the user will be able to apply a dispatching algorithm for the bundling scenarios.

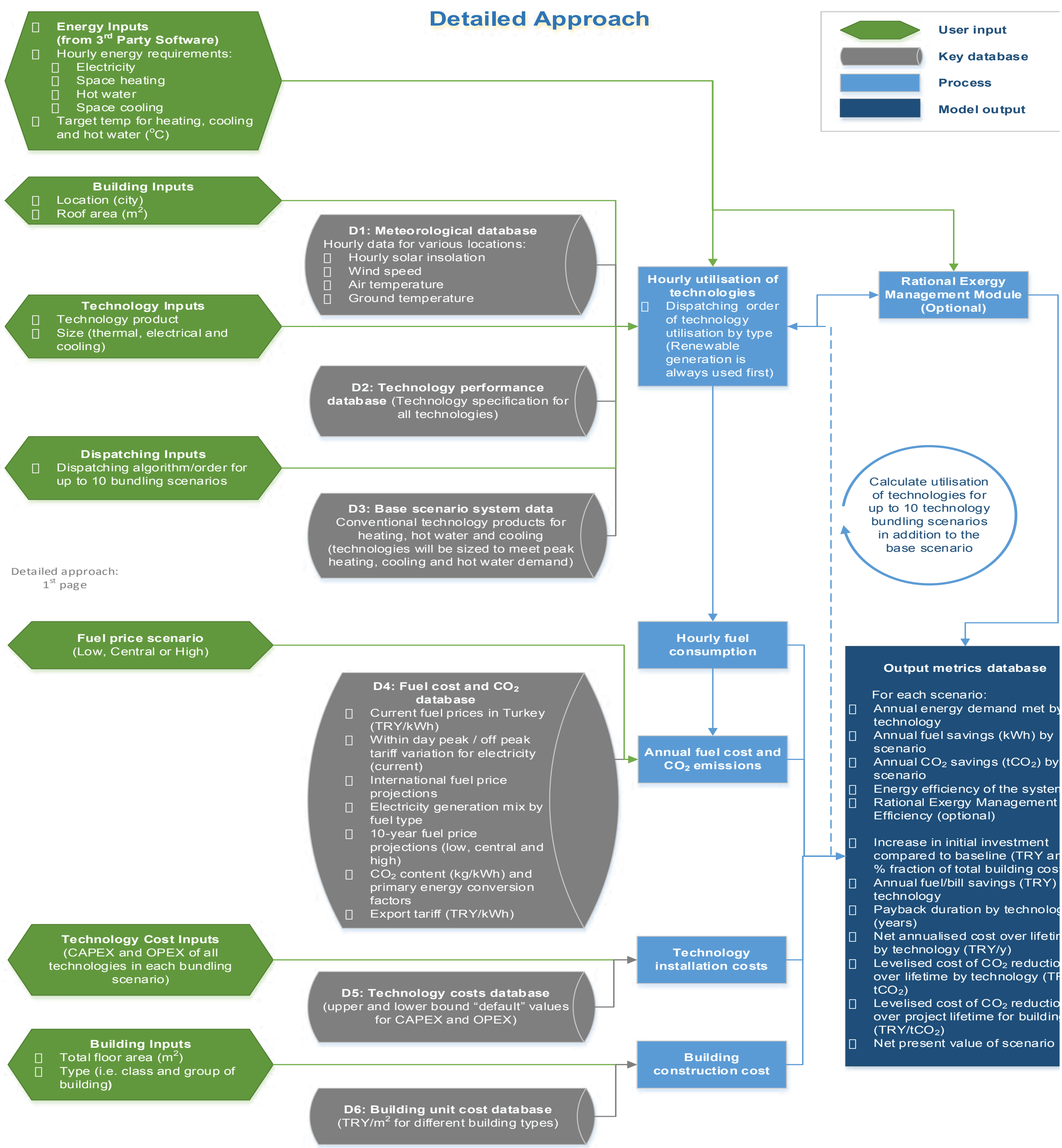

Figure 1. Flowchart for the detailed approach

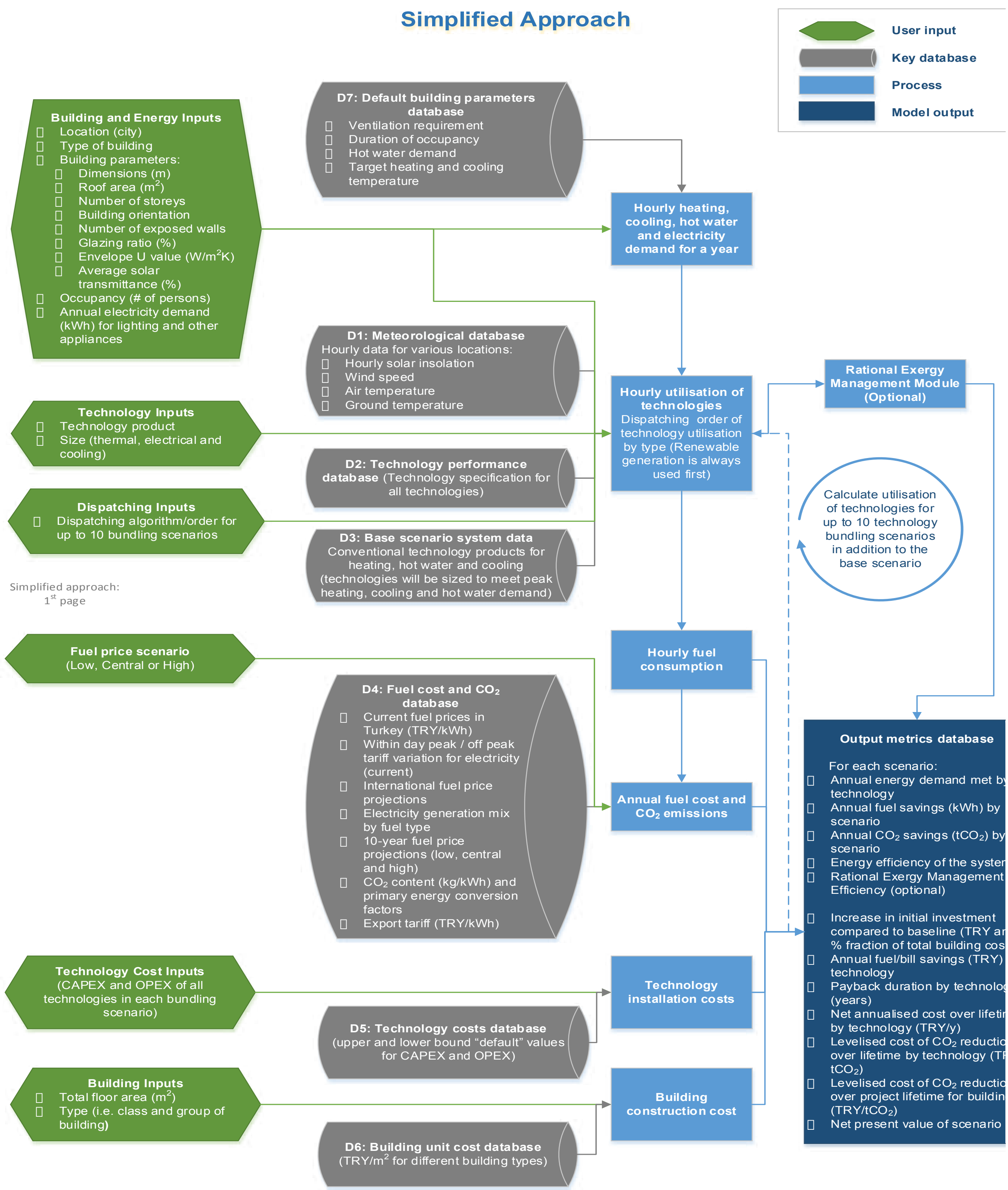

Figure 2. Flowchart for the simplified approach

CONCLUSION

REAT-EAT methodology developed as a subpart of **"Promoting Energy Efficiency in Buildings in Turkey"** Project. A national software will be obtained by using this methodology. This web-based software can be used as a decision support tool for designers and investors about the cost optimality of the renewable energy technologies. Renewable energy technologies diversify the nation's generation portfolio away from fossil fuels. The magnitude of the renewable energy can play depends role on how much cost reduction projections materialize. Investments in renewable energy systems should result in comparable reductions of investments in traditional energy technologies. Although incorporating costly renewable resources into the generation portfolio mix might increase the expected costs, fuel price risk is lower and will offset by increased export of petroleum and less consumption of natural gas. Exergy is a way to a sustainable development. In this regard, exergy analysis is a very useful tool, which can be successfully used in the performance evaluation of renewable energy resources as well as all energy-related systems.

ACKNOWLEDGEMENTS

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REFERENCES

[1] IEA, World Energy Outlook Special Report 2015: Energy and Climate Change

[2] A key review on exergetic analysis and assessment of renewable energy resources for a sustainable future Arif Hepbasli Renewable and Sustainable Energy Reviews 12 (2008) 593–661

[3] UNDP Turkey Renewable Energy Technologies - Economic Analysis Tool (RET-EAT)model guide, 2016

[4] Binalarda Enerji Performansı Ulusal Hesaplama Yöntemine Dair Tebliğ (Tebliğ No: YİG/2010-02)

Paper No: 163

Examination of Solar Comb Integrated Multifunctional Façade Systems

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ABSTRACT

More than 40% of the overall energy consumption and 36% of the overall CO2 emissions are produced by buildings in Europe. Looking through the European building stock, only 1% -1.5% of it is the newly built each year. An important adaptation strategy to comply with future legislation to an economically viable approach is to adapt the building stock to future energy standards.

In refurbishment projects high energy savings and reductions of greenhouse gases can be achieved by using multifunctional facade systems. One of their main applications is for fast thermal refurbishment of the existing building stock.

They provide high thermal requirements and make use of the advantages of prefabrication. Avoiding thermal bridges, achieving high air tightness targets, and its compactness are its outshine specifications on energy efficiency. Also, Large-scale innovative renewable energy sources can be integrated. Another focus lies in considering different technical solutions and integration of new "smart-materials" which subsumes solar comb also.

This paper investigates multifunctional facade systems whose smart material is used as solar comb. Some applied examples are also examined to understand effectiveness of these systems. In conclusion role of multifunctional façade system on refurbishments and energy save rates of them are discussed and evaluated.

Key words: Energy, energy efficiency, new materials, sustainable systems, refurbishment, sustainable refurbishment.

1. INTRODUCTION

The building sector is a large energy end-use sector that accounts for a larger proportion than both the industry and transportation sectors in many developed countries in terms of total energy consumption [1]. Many countries are aware of the essential role of the building sector in energy consumption and take precautions against it in their energy policies, one of which is the European Union's Nearly Zero Energy Buildings Directive that requires all new buildings to be designed as nearly zero energy by the end of 2020. Even though this target is ambitious, it is possible to significantly decrease the energy requirements of buildings by the use of appropriate design and technologies [2].

In European Union countries, buildings presently account for some 45% of carbon emissions and it has been estimated that 80% of the buildings that will being occupied in 2050 have already been built [3]. When it is handled as building stock on Europe, 1% -1.5% of the European building stock is newly built each year [4]. Looking through those data, it is clearly can be said that not only building energy efficient buildings but also energy efficient refurbishment of existing buildings is important for both energy efficiency and reducing CO_2 emission.

Residential buildings constitute 75 percent of the total building stock on a European average [5]. Due to their quantity, residential buildings are the clear leader in energy consumption; hence the greatest contributors to CO_2 emissions, 61 percent of CO_2 emissions are tied to residential buildings [6]. The concern for the energy use of residential buildings started after the energy crisis in the 1970's and led to actions and programs aiming to rationalize the energy consumption of dwellings [3].

High rated energy savings and CO_2 reductions can be achieved in refurbishment projects by using multifunctional facade systems. One of their main aids is for fast thermal refurbishment of the existing building stock. These façade systems accomplish high thermal requirements, keep clear of thermal bridges and achieve higher air tightness goals compared to "on site" construction.

This paper aim to investigate solar comb integrated multifunctional façade systems which is solar active façade system. It is structurally evaluated from wood façade systems and contains solar comb in it as smart material. Both multifunctional façade systems were examined as their structural and physical specialties. Two successful refurbishment projects which were applied solar comb integrated façade system, Linz Apartment Buildings and Dieselweg-4 Apartment Buildings were also examined.

2. MULTIFUNCTIONAL FAÇADE SYSTEMS

Multifunctional Façade Systems are designed to be used in modular construction methods with the highest possible level of prefabrication. The main application is for new development of large-scale residential and office buildings and for a fast thermal refurbishment of the existing building stock which were built in 1960's and 1970's. Unlike traditional façade systems; multifunctional façade systems not only focus on one of the ventilating, shading, insulation or moisture control aims but also care about them all. They accomplish high thermal requirements and make use of the advantages of prefabrication, such as preventing thermal bridges and decreasing on site construction time. High air tightness targets are achieved easily compared to "on site" construction. By having windows, ducting, cabling integrated, they prevent thermal bridges or air leaks. Additionally, large-scale innovative renewable energy sources can be integrated as like; solar thermal, photovoltaics, hybrid-technologies that combine all. Another focus lies in considering different technical solutions and integration of new "smart-materials".

Multifunctional façade systems can be divided into five categories looking through integration of materials, renewable energy or solar energy concepts [4]. These are;

- Wood façade systems
- Solar-active façade systems
- Energy façade systems
- Hybrid façade systems
- Green façade systems

Solar active façade systems category contains solar comb integrated multifunctional façade system but before it is exterminated deeply wood façade systems should be understood structural basis of solar comb integrated multifunctional façade system. Because of that, wood façade systems will be explained first.

3. WOOD FAÇADE SYSTEMS

Wood façade systems' main aim is spreading and making common of timber and modern timber technologies' usage on energy refurbishment field. Before wood façade systems assembled, some number of measurements and calculations are done. As a result of this calculations and measurements thickness of layers, wideness and length of façade units and materials that are used in layers are decided. Giving these decisions helps to make simulation. Façade units are prepared on atelier due to this simulation and they are assembled after being delivered to construction field. Façade units are a flat height and a façade wide unless they don't over a transporter's wideness. Because they are binged to the construction field by them. Making use of advantages of prefabrication increases the production speed and decreases the construction time.

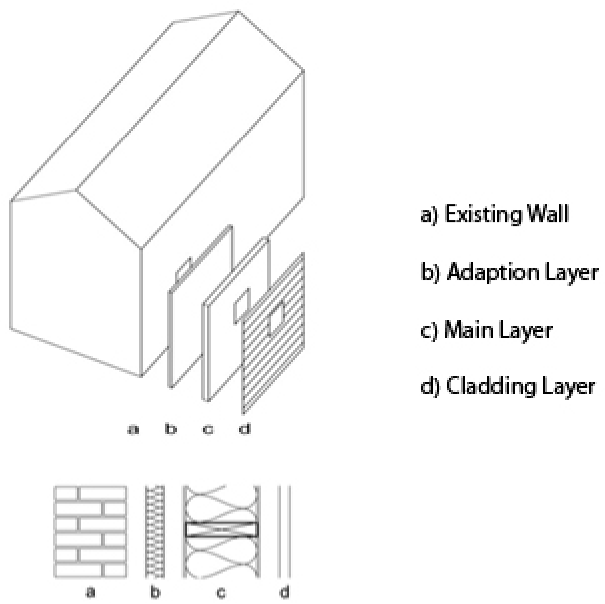

Figure1 Layers of wood façade system. [7]

Wood façade systems consist of three layers which are; adaption layer, main layer and cladding layer. It is attached to the existing exterior wall from its outer surface. Adaption layer is in between the existing wall and the main layer to level unevenness of the existing façade. The gap between the existing wall and the woo façade system needs to be filled to serve the requirements regarding fire safety and building physics. Any unevenness of the façade can be levelled using insulation. The choice of insulation material depends on fire safety requirements and building regulations. Generally organic insulation materials are used in this layer.

Main layer contains timber framework and a secondary insulation layer. The dimension of the insulation is dependent on the requirements rely on the required standards for thermal protection in their current version. Main layer also could contain the components like solar heating system, photovoltaic panels and solar collectors. Some successful examples has been obtained about heat conservation and cooling interior space by using smart-materials in this layer. Cladding layer is the last layer of the wood façade system. It protects the layers and exterior wall from physical and external factors. The variety of materials that can be used in cladding layer is so wide. Wood panels, glass, cement fibre board and their combinations lead the variation of materials used in cladding layer. [7]

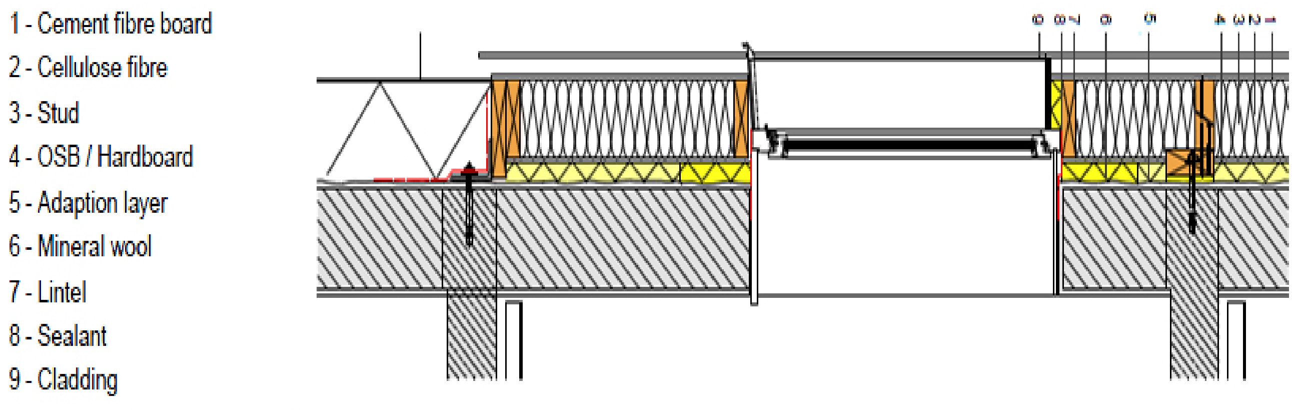

Figure2 Section of the wood façade system. [7]

Wood façade systems fix important thermal requirements as prevent thermal bridges and lets to reach air tightness goals easily. It contains parts and components as like windows, vents, HVAC installations, cables integrated in it. This integration prevents division of insulation layer and thermal leaks due to formation of thermal bridges while these components and parts are set up or added. Air tightness of the building envelope is kept by this method also.

Made of completely timber and organic materials, wood façade systems can be easily recycled when the building finishes its life or client wants to remove the façade system. This specification of the façade system contribute positive effect on CO_2 emission by saving CO_2 that is used production of façade system with recycling in addition to energy conservation and thermal insulation.[8]

4. SOLAR-ACTIVE FAÇADE SYSTEMS

Multifunctional façade systems which are included in this category use the solar radiation and store it in passive energy concepts. They store solar radiation by using existing wall, smart materials or phase change materials. When it comes to cooling and shading they use reflecting shading plates or smart materials and phase change materials which are already mounted for store heating and additionally helps for cooling and shading.

Solar comb integrated multifunctional façade systems (SCIMFS) is a solar active facade system too. It has the same physical, structural and prefabrication specialties with wood façade systems. Also its layer arrangement and materials that are used in the layers also the same. In main layer of SCIMFS, smart material called "solar comb" is used. This smart material is protected from weather and physical damages with a back-ventilated glazing on the cladding layer. Differences on main layer and cladding layer make SCIMFS separated from wood façade system.

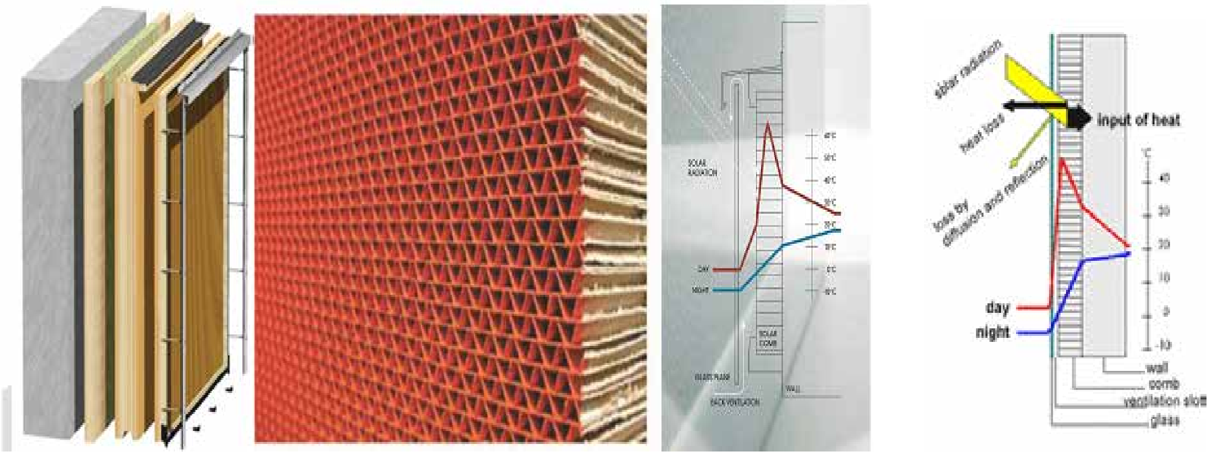

Figure3 Layers of solar comb integrated multifunctional facade system and working mentality of solar comb. [4]

Honeycomb is a comb shaped stable, smart, innovative component whose structure made of natural materials (cellulose). Being smart component is lies on storing heat, shading and cooling in passive way. The low radiated rays of the winter sun penetrate deep into the honeycomb and increase their temperature. This autonomous zone reduces heat loss to almost zero and reduces thermal bridges and heat leaks. During summer, most of the high radiated sun rays are reflected due to the comb structure itself. Shape of the comb also provides shading on existing external wall without needing mechanical sun shading on summer period. That keeps wall and interior space cooler. Depending on the orientation the improvement of the U-value of the exterior wall is up to 90% or more. [4]

Its thermal improvement a side, SCIMFS is supply sound proof, aesthetic improvements and user satisfaction during refurbishment process.

5. APPLIED EXAMPLES OF SOLAR COMB INTEGRATED MULTIFUNCTIONAL FAÇADE SYSTEMS

Linz Apartments and Dieselweg-4 Apartment Buildings have been examined and compared in this section. Both of these apartments are located in Austria. The reason of choice of these apartments as example is being successful on their field and reaching nearly 90% of energy saving with applied refurbishments.

Linz Apartments

Figure 4 Linz Apartments before and after refurbishment [9]

Five floored apartment buildings are situated on the Makartstraße, a main route into the center of Linz, which is capital city of Upper Austria state. They are built in the year of 1957. They have an east/west alignment, with a south side attached to the neighbor building and an open northern front. The walls of these apartments are poured concrete and have a U-value of 1.4W/m²K [9]. On account of a high volume of traffic on the building's east side, the Windows were hardly opened due to the noise level. The loggias were not used.

In this refurbishment project, leading refurbishment movement on Austria is aimed for the refurbishments that are made in the year 2005. In refurbishment project, thermal insulation was applied, SCIMFS has been attached, decentral mechanical ventilation system has been added, balconies have been added to interior space then closed with SCIMFS, existing Windows have been changed and previously gas boiler heated apartment buildings have been added to district heating web.


Figure 5 Preparation of SCIMFS units and attaching them to the existing wall [10]

With SCIMFS a great amount of thermal insulation was applied continuously around the building envelope without thermal bridging. This reduces the heat losses of the envelope like a warm coat. It is considered important as envelope to be airtight. Nearly 30 cm thick rock wool thermal insulation is applied with SCIMFS [10]. Mechanical ventilation system with counter flow heat exchanger was set up to the holes which reach to the outdoor and opened each room. By this system, no heated air is lost from in door to outdoor while ventilation. This ventilation system has a heat recovery rate of %70 [10]. Both holes of the system and mechanical parts included by SCIMFS. Windows of the apartments are changed into new, triple glazed ones with a U-value of 0.86W/m²K and an integrated sun protection. The layers of the triple glazing window are double glazing glass, sun protection and single glazing glass from inside to outside [9]. Windows were integrated to SCIMFS unit on the atelier then mounted to de façade.

After all these refurbishments heating energy demand of the buildings decreased from 179kWh/m² to 14,4 kWh/m². Their Expected savings of about 444.000 kWh/a will decrease carbon dioxide emissions from about 160.000 kg/year to 18.000 kg/year. Before modernization heating costs for a flat of 59 m² was € 40.80/month. After modernization it decreased to € 4.73/month. That means Money of saved energy is nearly 20% of a 59 m2 flat's rent [10].

Dieselweg-4 Apartment Buildings

Figure 6 Before and after refurbishment of Dieselweg-4 Apartment Buildings [11]

Dieselweg is a residential district, which is located in the southern suburban area of Graz. There are five free standing buildings which are built in the 1960s and 1970s and one 1950 made, long building in this residential district. Totally 204 apartments included. Dieselweg-4 is a free standing building with 4 stories, including a basement. 4 apartments are grouped around the staircase in each floor. The apartments are in the size of about 90 to 100 m². [11]

Since the time of construction of the buildings, no improvements have been made. The 204 apartments were in extremely poor condition with exterior walls that were not insulated, windows were in extreme need of repair, a mix use of oil or solid fuel fired single ovens and electricity for heating and hot water were used.

Refurbishment project has been started in 2008. Envelope of the apartment was insulated, windows and ventilation system integrated SCIMFS mounted on the façade. Balconies also have been closed with same system and volumes of the existing balconies were kept. Heating and hot water system changed into a system that works with SCIMFS. Additionally PV panels were added on the roof.

Thickness of the eat insulation that is applied on building (with SCIMFS) is overall 22cm. U value of the exterior wall pulled down to 0.2 W/m²K with SCIMFS and heat insulation. Balconies of the building have been closed with SCIMFS and total volume of the existing balconies kept. This composition, a buffer zone that separates living space from exterior space was made. [11] Old windows of the apartment were removed and 0.85W/m²K U valued, triple glazed windows which are integrated to SCIMFS added [12].

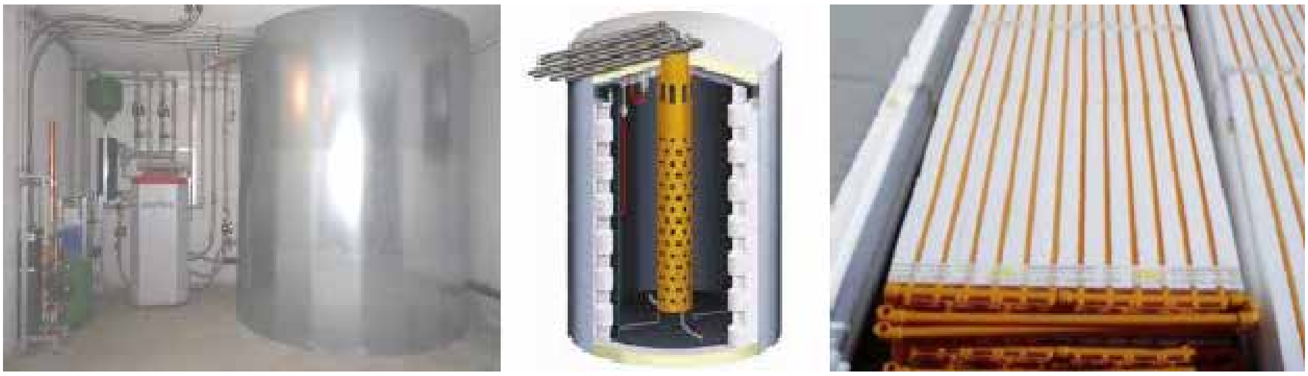

Figure 7 Heat counter and pipe system. [11]

Not exactly known heating system of the building was replaced with a heating system which is supported by SCIMFS. This heating system includes pipes between SCIMFS unit and insulation layer. The heat which is formed in solar comb is vacuumed and used from here when it is needed. Heat is kept in counters that are 3 m3 and placed on every flat. These counters are made of insulation bricks and a special film covered it. Feeding this system with underground water, hot water demand can be supplied. All this heating and hot water traffic is organized by a memory unit which stands near heat counter unit. [12]

After all these refurbishments yearly heating demand decreased from 184kWh/m2 to 12kWh/m2 [13]. This mean rating of the saving is %93. OC2 emission of the building decreased from 700 tons to 80 tons. Applied refurbishments also affected the electricity bills. Before refurbishment 2€ were paid per m2 and after refurbishment it is pulled down to 0.11€ per m2 [12].

6. CONCLUSION

This study focused on solar comb integrated multifunctional façade system which is included by solar active façade system branch of multifunctional façade systems and its structural system with functional specialties. Also energy performances of the system exterminated. Lastly two successful examples are examined that are located on Austria. Some other issues like fire protection, hygienic or costing is no considered. These issues can be handled in another work.

Energy efficient refurbishment of existing buildings takes very important place catching both reducing CO2 emissions and energy saving goals. According to UK Energy Trust (2010), if a well thermal insulation is done to envelope of the building which integrates these parts of the buildings, near %67 of energy lose can be saved. In this point energy efficient rehabilitation of existing building envelop stands a very critical point. In addition to thermal insulation; with windows, mechanical components, solar comb, (sometimes) ventilation systems integration to solar comb integrated multifunctional façade systems fulfills this requirement.

Made of cellulose smart material, solar comb acts an important role on energy efficient refurbishment of existing wall. It doesn't only helps decreasing heating demand of the building but also cooling demand on summer by shading and reflecting over radiation of sun rays. Coming with glass cladding layer and different color possibilities, it gives a positive aesthetic value to building.

Looking through the given examples Linz Apartment Buildings and Dieselweg-4 Apartment Buildings it can be seen that a great energy saving that hits near %93 can be reached with using solar comb integrated façade system on refurbishment projects. Also U value of the existing exterior walls significantly decreased. Different usages of solar comb on Dieselweg-4 Apartment Buildings as like supporting heating system and hot water demand, lure the attention.

Fulfill the energy efficient refurbishment field's necessities, solar comb itself and solar comb integrated multifunctional façade systems are successful applications of innovative, smart materials and energy façades.

REFERENCES

[1] Yang L., Yan H., Lam J.C., Thermal comfort and building energy consumption implications – A review, Applied Energy, 115, 164–173 (2014).

[2] Cabeza L.F., Rincón L., Vilariño V., Pérez G., Castell A., Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review, Renewable and Sustainable Energy Reviews, 29, 394– 416 (2014).

[3] Xing Y., Hewitt N., & Griffiths P., Zero carbon buildings refurbishment–A Hierarchical pathway. Cardif University (2011).

[4] Treberspurg, M. and Djalili M. New technical solutions for energy efficient buildings. SCI-Network, (2010)

[5] Economidou M., Europe's buildings under the microscope. Buildings Performance Institute Europe, (2011).

[6] Voss K., & Musali E., Net zero energy buildings: international comparison of carbon-neutral lifestyle. Munich:Birkhauser (2011).

[7] Heikkinen P., Kaufmann H. and Winter S. Tes energyfaçade –prefabricated timber based building system for improving the energy efficiency of the building envelope. Woodwisdom net. (2009).

[8] Strahl E. TES EnergyFacade – der Massanzug für Wohngebäude in der Grüntenstrasse, Augsburg, 10. Internationales Branchenseminar für Frauen des Holzbaus und Innenausbaus, (2012).

[9] Rennerweg K. Reconstructıon into a passıve house. Architektenschule Aarhus. (2007).

[10] Domenig-Meisinger I. and Mach T. 5-Storey Apartment House in Linz –Makartstraße A. International Energy Agency –SHC Task 37, (2008).

[11] Gao W. and Zhang P. Sustainable renovation projects of residential buildings 5 examples in Austria. Chalmers University of Technology. (2011).

[12] Geier S. Redevelopment residential area "Dieselweg", Graz (Austria). AE –Institute for Sustainable Technologies. International Energy Agency ecbcs Annex50, (2009).

[13] Höfler K., Geier S. and Venus D. Prefabricated Systems for Low Energy Renovation of Residental Buildings, IEA ECBCS Annex 50, (2011), p. 49-56. ISBN 978-3-905594-61-4

Paper No: 214

Influence of Wind-Catcher on the Energy Performance of the Buildings in Hot & Arid Climate of Iran: Case study of Boroujerdi House

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ABSTRACT

A glimpse into the past of ancient countries, there is prominent traditional buildings, which are worth full throughout the generations in and these heritages have significant roles regarding sustainability. The climate has a significant impact on the related architecture. As a result, constructors tried to use feasible strategies regarding natural climatic for coping with harsh conditions. To exemplify, in a hot and arid climate of Iran where the main difficulties is encountering with the deficiency of water and humidity, severe climate enforced architects to build their houses with special measures to encounter. The most significant strategies include proper layout orientation, the distance between buildings, building' orientation & form, climatic elements such as Windcatcher, central courtyard, etc. In the ancient architecture of Iran and the most of the middle east countries, windcatchers play a crucial role to provide thermal comfort for occupants, especially in hot climates.

The paper aims to focus on the traditional housing in hot and arid climate of Iran. It is a country with different climatic zones, and, traditional builders have presented several logical climatic solutions to improve human comfort and energy efficiency of the buildings. Kashan, which is located in the province of Isfahan, is selected to be a representative city. To evaluate different strategies, the case study building' energy performance was calculated by the aid of dynamic simulation tools, DesignBuilder V4.3, and EnergyPlus 8.2. Different scenarios are applied on the windcatchers, windows and different thickness of the materials to analyze the energy performance of building in various circumstance.

Keywords: *Traditional building, Windcatcher, Natural ventilation, Hot and arid climate, Energy performance*

1. INTRODUCTION

The climate is the principal item that has a significant influence on the energy performance of the building and its energy consumption.To reduce energy consumption requirements of building, using renewable sources in the environment could be helpful in providing the comfortable level and healthier for occupants [1]. From another point of view, in climatically responsive design, selection of proper materials and building procedures must be evaluated simultaneously, and the final product should perform well during its whole service life. When sustainable design and construction strategies of Iran's traditional architecture are under analysis, then it is possible to observe how traditional buildings and settlements in this region were designed in harmony with the local cultural, topographical and climatic conditions and how their design and construction could be integrated into today's design practices [1].

In hot, arid regions, in particular, the forms of the traditional buildings have been shaped according to the available natural sources of energy, which help reduce humidity and create natural ventilation. There are some architectural elements which help provide cooling in internal spaces, including an inner courtyard, local materials, and wind-catchers. Throughout history, a wind catcher was introduced as an architectural element, which achieves thermal comfort for occupants [2]. Site and orientation of the building, space between buildings, building form and optical and thermophysical properties of the building envelope are the most critical design parameters affecting indoor thermal comfort and energy conservation in the building scale. All of the parameters are related to each other, and the best values of each parameter should be determined depending on the values of the others, and their best combination should be determined according to the climatic qualities of the region [1].

In this study influence of the windcatchers on the energy performance of one of an ancient building in Iran as the case study building in hot and dry climate is evaluated and examined by the modeling in the dynamic simulation program.

2 METHODOLOGY

The method of this investigation is based on simulation and calculation of a virtual model. The case study building has three wind catchers, which are used for cooling of the building. In order to encounter the harsh weather climate, these wind catchers are used during the year. To assess and analyze the energy performance of the building and influence of wind catcher during a year, different scenarios are applied through the wind catchers, windows that are opened to the courtyard and skylights on the top of the roof. By definition of a different schedule for wind-catchers and opening during the day and night, it is possible to define various scenarios for model's analyzing. In this research, some of these alternatives, which have more influence on the energy efficiency of the building are applied. Heating and cooling energy consumption [kWh/m^2] and Total energy consumption [kWh/m2] are compared with each other to achieve the optimum scenario.
There are some assumptions related to the assessments that are indicating in the followings:

The wind catcher schedule is planned according to the heating and cooling demand of the building. The building demands have defined by simulation of the model using the weather data of Kashan. The heating demand period is from 15 October until 15 April and the cooling demand period is 15 April until 15 October. By applying a seasonal schedule to the wind catcher, it was supposed to use the wind catchers at different hours of day and night. During the day and night, the schedules of wind towers are defined as quarter open- half open, open and closed. Furthermore, it is assumed that during the day and night, there are three scenarios existed for the windows openings which are done manually by the occupants. The different style of the openings includes half-open, open and closed.

3. DESCRIPTION OF THE CASE STUDY: BORUJERDI HOUSE IN KASHAN

There are different climatical regions in Iran. Dr. H. Ganjee divided Iran based on Koppen's method. Iran is divided into four climatic regions: Mild-Humid Climate, Cold Climate, Hot-Humid Climate, and Hot-Arid Climate [3]. Kashan is a city which is located in the central region of Iran and is in the province of Isfahan. This part represents the arid and hot area with a high-temperature difference between diurnal and nocturnal [4]. Another features of this climate are cold winds and dust; sandstorms prevail in winter. The solar radiation intensity is high and enhanced by the radiation reflected from the ground. Besides, the air humidity is low, and this climate is healthier than those of warm-humid lands. The temperatures are highest on average in July, at around 33.2 °C. January has the lowest average temperature of the year. It is 5.0 °C. The air is driest around July 17, which is 15% (dry) and it is most humid around January 17, exceeding 65% (humid). Precipitation is most likely around February 5, occurring in 19% of days. Precipitation is least likely around August 13, occurring in 0% of days. Moreover, prevailing wind during the year is blown from North East and South [5,6].

The traditional building, Borujerdi House, chosen for the evaluation, was built during the middle of the 18th century. This building is a typical traditional four-season house in the hot, arid climate of the central plateau of Iran. The city has cold winters and hot and dry summers, with frequent dusty winds from the deserts on the eastern side of the city [7]. The Borujerdi House is located in the old neighborhood of the city. All of the old houses in this area are detached or semi-detached, with central courtyards. Borujerdi House is an excellent sample of a sustainable traditional house in Iran. The house took eighteen years to build using 150 craftsmen. This house was designed for a wealthy local merchant. It was renovated about 30 years ago.

This building has three stories with an underground floor detached and terraced one family house. The courtyard on the ground floor is isolated from the street and surrounded by high walls. The main entrance is located in the building north; especially because the connection created between the house and the street is contributing to the splendor of the building. The vestibule is following main entry and through the same door, which is located across it finds a way to the yard. More than half of the floor area devotes to the courtyard [7].


Figure 1 South view (left side) and North view (Right) of the Borujerdi House [8].

The house was built on a land area of approximately 1678.2 $m^{2;}$ the roof area is 1595.60 m2. It consists of two main and side entrance, vestibule, hallway, yard, the summer settlement, the winter settlement, kitchens, roofed courtyards around and a large basement [9,10]. The physical properties of the case study building is indicated in Table 1.
Table 1 Physical Properties of case building

Location	Kashan-Iran
	33°59'6.13"N __ latitude , 51°24'35.87"E__ longitude
Orientation	348∘ (CW normal angle of north facade)
Environment	➢ The Urban area surrounded by narrow and irregular alleys.
Floor area (m^2)	1628.75 m^2
Facade surface area (m^2)	3986.89 m^2
Roof area (m^2)	1595.60 m^2
Glazing area (m^2)	332.62 m^2
Glazing ratio (%)	8.34 %
Number of stories	Three stories (basement+Ground+First floor)

The main porch is located on the symmetry axis of summer–settlement, which it is the second factor in the division of space and use of residents in the summer after the yard. The western part of winter–settlement joins the northern and southern parts of the building with two small rooms and a roofed chamber. Large kitchen with shelves and closet and storage room is located in the north [9,10].

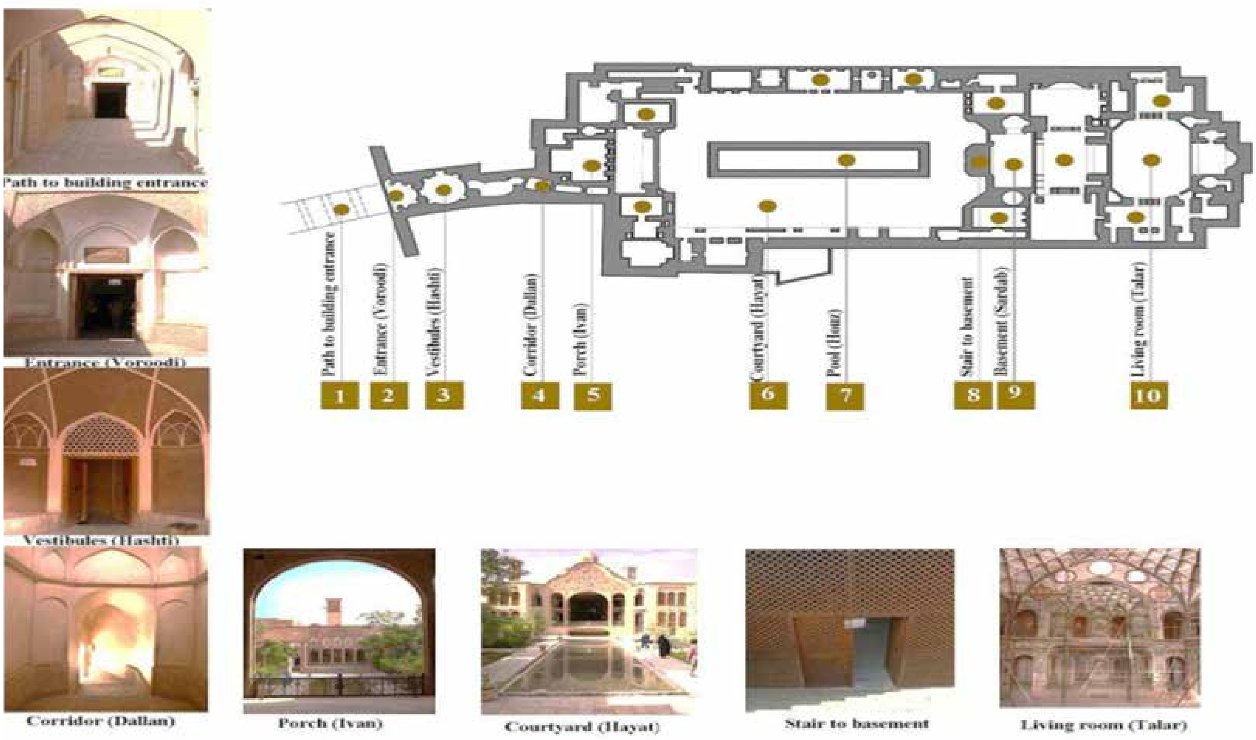
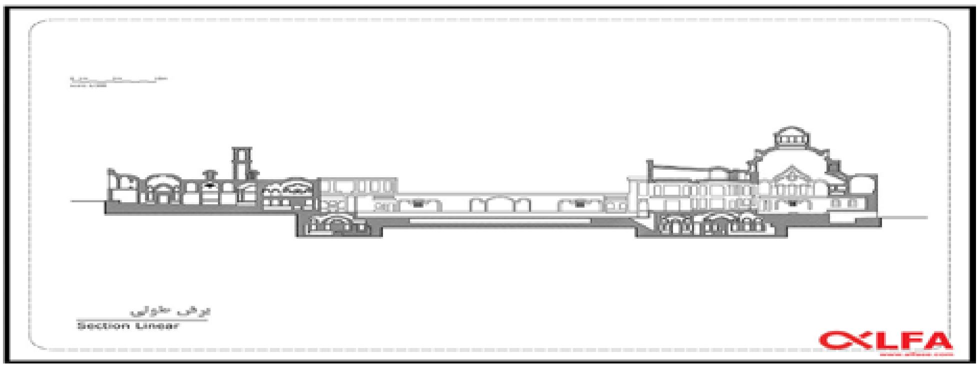


Figure 2 Ground Floor plan of Borujedi House and views of places [9,10].

The basement is located in the following three sections: North, South, and West, which are more used as a cellar, storeroom, and the service space. The basement is usually used during summertime, especially in the afternoons, especially during the evening it is cooler compared to the ground floor [9,10].



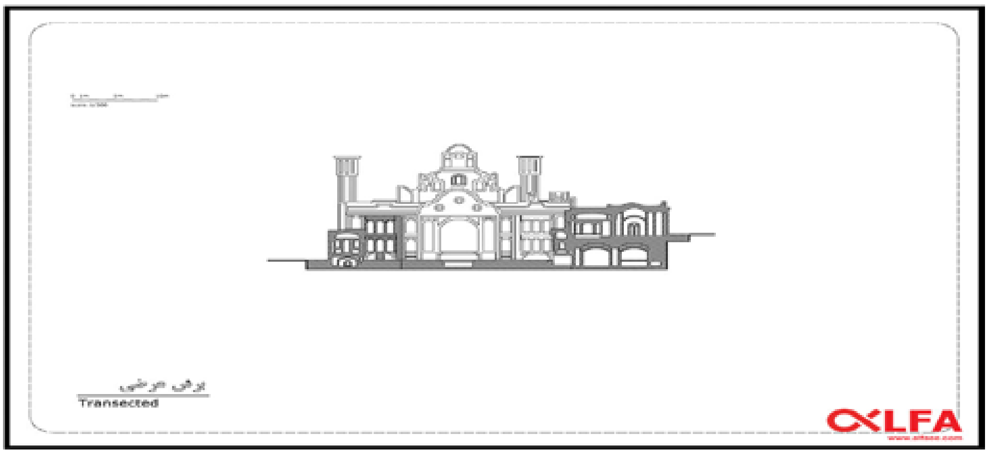


Figure 3 Longitudinal and Transect sections of Borujerdi House [9,10].

The building is principally divided into two parts:

Summer–settlement (summer-living), which is the main part of Boroujerdiha's house, is located in front of the main entrance and back to qibla (South) side. Summer– settlement consists of two rooms, the main hall, two roofed substations, a main roofed house, two quenches, an alcove and Tenby chamber. Winter–settlement is located in the North near the doorway and is consists of one room, an alcove of five-door and a large and sunlight recipient porch. In the west, it contains three rooms, between summer– settlement and winter–settlement, which are related together through a common hallway [9].

The building is made with load-bearing walls, vaults, and domes. The building material is adobe and brick, which can be easily reused for new constructions. The outside surface of the building is exposed brick and inside it is stuccoed with plaster. Internal partitions thicknesses are almost 60 cm. The walls are approximately 100 cm thickness and act as a thermal mass, minimizing the house's temperature fluctuations between day and night.

1.1. Case Study Building's Ventilation System

Since the building has only one opening (the entrance door) to the outside, summer cross-ventilation is provided through the three wind catchers, as well as through the openings on the dome on top of the summer residence and the openings around the courtyard. When there is the wind, it is directed inside through the wind catchers. When there is no wind, the wind-catchers act as chimneys, providing vertical ventilation through the chimney effect. The building is thus kept cool during the summer time [7].

The wind catchers play a useful role in modifying heat, adjusting the temperature of internal spaces as it uses the convection created by a wind flow and clean energy system [11]. Windcatcher, as a name implies, is ventilation techniques for natural cooling. They have been needed for centuries in several countries of hot-arid and hot-humid climates, especially in the middle east countries. The house is prominent for its unusual wind towers, The primary material of this which are made of stone, brick, sun-baked bricks and a composition of clay, straw and mortar. Three tall wind towers help cool the house to unusually cool temperatures. Even the basements consistently benefit from the flow of cool air from the wind towers [12].

The tower head have some vents on only one side facing the predominant wind direction. However, two or four sides of the tower might be open to accommodate the wind in all directions. The tower would be subdivided, respectively, into two or more groups of shafts. This subdivision allows air to move separately up and down the tower at the same time and provides more surface area in contact with the air. Consequently, the roof-top breeze is drawn and is diverted to the summer living zone indoors drawn and is diverted and, vice versa. The incoming air would be cooled by the mass of this structure and effect of the microclimate indoors in regions; the air temperature rises to 25 centigrade in summer from time to time and heat mixed with humidity provide a very adverse condition [3].
The function of the wind-catcher is that the air is thick on the windward side, so in this direction there is a positive pressure, but a negative pressure on the other side. In the wind catchers, according to this principal, the opening facing the wind takes the air into the room at the base and the air in the chamber, with its negative pressure on the opening opposing the wind is drawn out. The temperature difference is caused by carrying out of the function of windcatcher [13].

1.1.1. Wind-catcher features during the day and night

The function of a wind-catcher regarding temperature difference. When there is no wind, the wind-catcher acts according to this action. During the day, since the sun hits on the southern face of the wind catcher, the air heats in the south face of the wind catcher and goes up. This air taken makes a kind of proportional vacuum inside the porch, and takes the fresh air of the inner court into itself, so the existing air in the northern opening is pulled down too[14]. During the night, it becomes cold outside, and the cold air moves down. This circle continues until the temperature of the walls and outside temperature become equal. Before it arrives at the point, the night is usually over, once again the wind catcher functions as mentioned above [13].

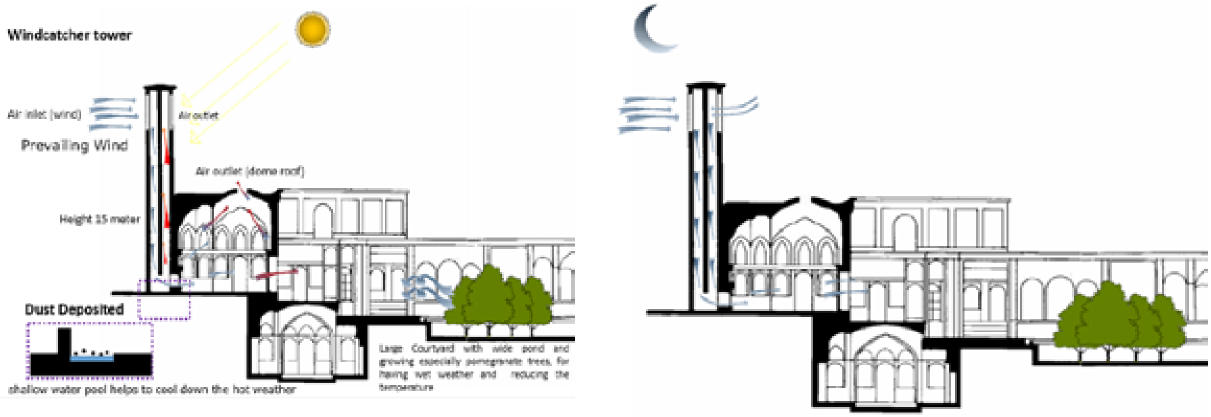


Figure 4 Wind-catcher functions during the day and night in Borujerdi House.

4. APPLICATION OF THE METHODOLOGY IN THE CASE STUDY BUILDING

In essence, the case study building is calculated for a full year with dynamic simulation programs; DesignBuilder and Energy plus. The family members occupied this residential building. The occupancy time for the building is all days during a year but the occupancy hour is varied for different zones. By the modeling of the building by the simulation program, there are existed 56 different thermal zones in the building.

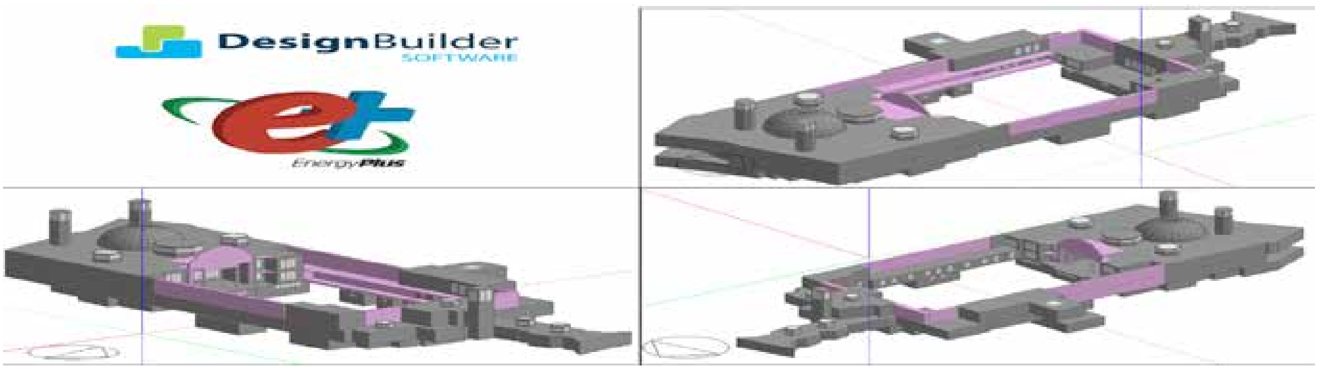


Figure 5 Axonometric views of the case study building in DesignBuilder program.

The Occupancy rate, activity, and activity rate of case building during Weekdays & Weekends are represented in Table 2. For instance, it was assumed the bedrooms was occupied from 23:00 until 07:00 a.m. The activity level in theses zones are sleeping, and activity level is 40 w/m^2 according to ASHRAE Handbook of Fundamentals 2009 [16].

Table 2 Occupancy and activity rate of the case building for weekdays & weekends.

Hours	Number of Occupants Person/m²	Activity	Activity Level (W/m²)	Used Space
00:00 - 07:00	0.4	Sleeping	40	Bedrooms
07:00 – 07:30	0.4	Breakfast	60	Kitchen
07:30 -12:30	0.2	Home works	115	Whole Spaces
12:30 – 15:30	0.2	Reclining	45	Living Room
15:30 -16:30	0.1	Home works	115	Whole Spaces
16:30 – 19:00	0.3	Home works & Reclining	115, 45	Whole Spaces
19:00 – 20:00	0.4	Home works & Sitting, quiet	115, 60	Kitchen, Living Room
20:00 – 20:30	0.4	Dinner	60	Kitchen
20:30 – 23:00	0.4	Sitting, quiet	60	Living Room or Bedrooms
23:00 – 24:00	0.4	Sleeping	40	Bedrooms

Other important is an issue is the thermal comfort of the case study building. The building demands have defined by the weather data of Kashan. The heating demand period is from 15 October until 15 April and the cooling demand period is 15 April until 15 October. The Thermal comfort ranges for the residential buildings are 20°C and 26°C. Heating setpoints during occupied times are assumed 20 °C and during Unoccupied times is 0 °C. Cooling setpoints during occupied times is assumed 26 °C and during Unoccupied times is 50 °C. The heating and cooling systems are used from 15 October until 15 April and 15 April until 15 October respectively. HVAC system is used during occupancy hours. The heating fuel type for this building is coal. The windcatchers provide the cooling system for this building, and the ventilation system of this building is Natural ventilation. Moreover, the lighting amount is varied in different zones which are provided according to the ASHRAE 90.1-2013 amount for reference building.

Table 3 Parameters of the case study building.

Parameter of case building	Values
Occupancy time	All days on, during occupancy hours
	Heating Demand Period =15 October until 15 April Cooling Demand Period =15 April until 15 October
Heating Setpoint	Winter period: During Occupied times = 20 °C , During Unoccupied times = 0 °C
Cooling Setpoint	Other periods: During Occupied times= 26 ° C , During Unoccupied times = 50 °
HVAC Schedule	All days on, during occupancy hours
Cooling System	Windcatcher
Ventilation system	Natural ventilation
Lighting	ANSI/ASHRAE/IES Standard 90.1-2013 [15].

The total glazing surface area of this school is 332.62 m2 and transparency ratio is 8.34 %. Glazing components of this building consist of Small wooden mesh panel frames. Total solar transmission (SHGC) of this type glazing and U-value are 0.676 and 2.16 (W/m2 K). Also, the skylight roof ratio is 2.21%.

Table 4 Transparency ratio of the case building envelope.

	Total	North (315 to 45 deg)	East (45 to 135 deg)	South (135 to 225 deg)	West (225 to 315 deg)
Window-Wall Ratio					
Gross Window-Wall Ratio [%]	8.34	14.61	5.72	8.78	5.58
Skylight-Roof Ratio					
Skylight-Roof Ratio [%]	2.21				

From another point of view, North part of the building has the most window wall ratio in contrast to other facades. The north part have used in winter times. To use the solar utilization of the sun, the transparency of the ratio is higher than another façade. The heat gain in the summer should be the minimum amount. Using small mesh windows protect from ground radiation.

Table 5 Thermophysical properties of glazing system of case study building.

Envelope Components	Thickness (m)	U-value (W/m^{2}K)	(SHGC)	Light transmission
Single glazing	0.006	2.16	0.676	0.739
Window frames	0.08	0.68	Small wooden mesh panel	

The building exterior wall material is adobe and mud-brick. The U-value of exterior walls are 0.63 (W/m^2.K), and the total thickness of the exterior wall with inner and outer gypsum is 105 cm. The below grade wall U-value is 0.62 (W/m^2 .K). on below grade wall there is an extra layer of stone is existed on the wall which is 10 cm. The flat roof and basement floor U-values are 1.07 (W/m2.K) and 0.96 (W/m^2.K) respectively.

Table 6 Thermophysical properties of opaque components.

	U-value (W/m^{2}K)	Total Thickness (m)	Material layers (outer layer -inner layer)
Exterior Wall	0.63	1.05	Cement plaster+ Mudbrick+ Gypsums plaster
Below Grade wall	0.62	1.15	Cement plaster+ lime Stone+ Mudbrick+ Gypsums plaster
Flat Roof	1.07	0.60	Sandstone+ Mudbrick+ Gypsums plaster
Basement floor	0.96	1.20	Brick tiles +Cement+ Stone-Marble+ Earth Gravel

5. IMPLEMENTATION OF THE POSSIBLE IMPROVEMENT SCENARIOS ON THE CASE STUDY BUILDING

In essence, this case study building is calculated for a full year in Hot and arid climate zone of Iran. As before argued, the case study building has three wind catchers, which are used for cooling of the building. In order to evaluate the energy performance of building and influence of wind catcher during the year, Different strategies are applied through the wind catchers, windows that are opened to the courtyard and skylights on the top of the roof. The windcatcher schedules are divided to according to the heating and cooling demand of the building. The building requirements have defined by the weather data of Kashan. The heating demand period is from 15 October until 15 April and the cooling demand period is 15 April until 15 October. By applying a seasonal schedule to the windcatcher, it was supposed to use the windcatchers at different hours of day and night. During the day and night, the schedules of wind towers are defined as semi open, open and closed. It is assumed that during the day and night, there are three scenarios existed for the windows openings which are done manually by the occupants. The different style of the openings includes semi-open, open and closed.

By definition of a different schedule for windcatchers and opening during the day and night, it is possible to define various scenarios for analyzing models. In this paper, some of these alternatives, which have more influence on the energy efficiency of the building are applied., which is represented by Table 7.

Table 7 Improvement options regarding to the wind-catchers and windows opening.

No.	Wind catchers schedule		Windows Opening
	15 October until 15 April	**15 April until 15 October**	
AL.1	23:00- 07:00 - Semi open	23:00- 07:00 - Semi open	Semi-Open
	07:00-23:00 - Open	07:00-23:00 - Open	
AL.2	23:00- 07:00 -Open	23:00- 07:00 -Open	Semi-Open
	07:00-23:00 - Open	07:00-23:00 - Open	
AL.3	23:00- 07:00 - Semi open	23:00- 07:00 - Semi open	Closed
	07:00-23:00 - Open	07:00-23:00 - Open	
AL.4	Closed		Closed
AL.5	Closed		Semi-Open
AL.6	All Days/ Until 24:00 - Open		Semi-Open
AL.7	All Days/ Until 24:00 - Open		Open
AL.8	Closed	23:00- 07:00 - Closed	Closed
		07:00-18:00 - Semi-Open	
		18:00-23:00 - Quarter-Open	
AL.9	Closed	23:00- 07:00 - Closed	Closed
		07:00-18:00 - Open	
		18:00-23:00 -Semi-Open	

AL.10	Closed	23:00- 07:00 - Closed 07:00-18:00 - Open 18:00-23:00 -Semi-Open	Semi-Open
AL.11	Closed	23:00- 07:00 - Open 07:00-18:00 - Open 18:00-23:00 - Open	Semi-Open

Figure 6 presents different scenarios heating and cooling energy consumptions. Total lighting and another equipment energy consumption is 10.40 kWh/m2. As for all alternatives total lighting and equipment consumption are same, alternatives' heating and cooling are compared to each others. By comparison of various scenarios' heating and cooling energy consumptions, in AL.4, there is not used windcatchers and windows for natural ventilation.The cooling energy consumption is 165.71 kW.h/m2, and the heating energy consumption is 8.79 KWh/m2. On the contrary, in scenario 7, the windcatchers and windows are open for all days until 24:00. The cooling energy consumption is 122.04 kWh/m2 and also heating energy consumption is 21.47 KW.h/m2. By comparison of these two scenarios, cooling energy consumption of alternative 7 is having 26% energy saving to the AL.4. However, the heating energy consumption of AL.7 has increased approximately 60% in contrast to the AL.4. By comparison of total Heating and Cooling energy consumption of different scenarios, the most energy consumer belongs to the Alternative 7 , which does not utilize the natural ventilation, and the least energy consumer scenario belongs to the option 11, which is 140.15 kWh/m2. The heating and cooling energy consumption of this scenario is 129.62 kWh/m2 and 10.53 kWh/m2 respectively. By the evaluation of alternative 11, windcatcher is closed from 15 October until 15 April. It is used only from 15 April until 15 October for all days and hours it will be open. Moreover, half of the windows are open during the year for natural ventilation.

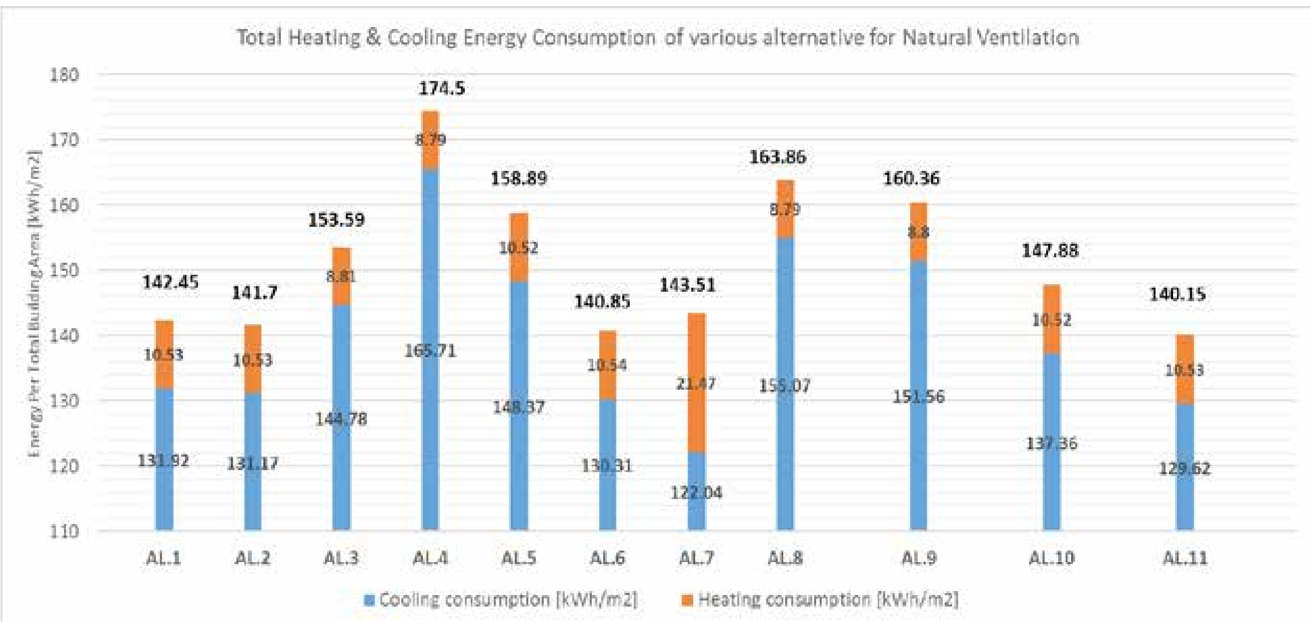


Figure 6 Comparison of the different scenarios' heating and cooling energy consumptions

By comparison of AL.8, AL.9, AL.10, and AL.11, in related scenarios, the windcatchers only used from15 April until 15 October. In winter period, the windcatchers are assumed to be closed. The only difference among these alternatives is using in different hours of day and variation on the amount of windows and opening during the year.

In alternate 8, the daily schedule will be as following: the windcatcher is Closed between 23:00- 07:00, from 07:00 until 18:00, it will be half Open and between 18:00-23:00, the windcatcher schedule is Quarter-Open. Also, the windows and other opening are closed. The cooling energy consumption is 155.07 kWh/m^2. By the only changing windcatcher strategy in alternative 9, the windcatcher is closed from 23:00 until 07:00, between 07:00-18:00, it is Open, and the windcatchers are half Open from 18:00-23:00. The cooling energy consumption has reduced 3%. In AL.10 the cooling energy consumption reaches to 137.36 kWh/m2, by comparison to the scenario 8, the cooling consumption has 10% saving. Furthermore, by comparison of alternative 8 and 11, there is dramatic changing of the total heating and cooling energy consumptions between two scenarios , which are varied from 163.86 kWh/m^2 to 140.15 kWh/m2. There is 14.5% saving in cooling energy consumption. However, the heating energy consumption is increased from 8.79 kWh/m^2 to 10.53 kWh/m$^{2.}$ Consequently, alternative 11 is the optimum situation by comparison of the total heating and cooling energy consumptions. Alternative 4 is the most energy consumption by contrast to other scenarios. In this scenarios; there is not any natural ventilation through windcatchers and openings.

6. CONCLUSIONS

The climate has a significant impact on the architecture of the old buildings. Various measures had been implemented in different climates to compete with the divers climatical conditions. In the ancient architecture of Iran and the most of the middle east countries, windcatchers play a crucial role to provide thermal comfort for occupants, especially in hot climates. The characteristics including height and opening size of the windcatchers were different according to the humidity of the region. The wind catchers in hot, dry regions were higher than those in hot, humid regions. When the air current is closer to the land surface, it is warm because of the effect of the sunshine on the ground. Thus, in a hot and dry region, because of the low temperature and a higher wind velocity at greater heights, wind catchers are built higher to enable them to trap such currents. Heating and cooling loads depend on not only to the climate but also depends on the design strategies of the climate. In the past, some of the architectural techniques devised for not only reducing the energy consumption of the buildings but also providing comfort levels for the occupant. In a hot and arid climate where the case study building is located, various architectural strategies had been taken to the account to encounter with the harsh climate.

In this study, by taking several strategies, the influence of the windcatchers, natural ventilation on the energy performance of the case study building have examined. The dynamic simulation program is used to evaluate the case building in different conditions. By analyzing various alternatives for the windcatchers and openings, it is defined that the alternative 11 is the optimum situation taking into account of the total heating and cooling energy consumptions. In this scenario, the windcatchers are only used from15 April until 15 October, and the daily schedule will be as following: the windcatchers are open till 24:00, also, the windows and opening are half open. Alternative 4 is the most energy consumer compared to the other scenarios. In this scenarios; there is not any natural ventilation through windcatchers and openings. Moreover, the least cooling consumption belongs to alternative 7, when the windcatchers and windows are open until 24:00 every day, in spite of having less cooling consumption it is the most heating energy consumer.

REFERENCES

[1] Kamyar Tolou Behbood, Mohammad Taleghani and Shahin Heidari, ***Energy Efficient Architectural Design Strategies in Hot-Dry Area of Iran: Kashan***, Emirates Journal for Engineering Research, 15 (2), 85-91 (2010).

[2] Dr. Abdel-moniem El-Shorbagy, ***Design with Nature: Windcatcher as a Paradigm of Natural Ventilation Device in Buildings***, International Journal of Civil & Environmental Engineering IJCEE-IJENS Vol:10 No:03

[3] Farzaneh soflaee, ***Natural Cooling Systems in Sustainable Traditional Architecture of Iran., "Passive and Low Energy Cooling 715 for the Built Environment",*** May 2005, Santorini, Greece.

[4] http://www.gapatour.com/en/iran-history/cities-and-attractions/kashan.html

[5] http://en.climate-data.org/location/715146/

[6] http://www.gaisma.com/en/location/kashan.html

[8] http://www.360cities.net/image/iran-kashan-khaneh-borujerdi-house-old-persia

[7] Richard Hyde, 2008, Bioclimatic Housing: Innovative Designs for Warm Climates, chapter5, pp.182-184.

[9] Mohammad Reza Leylian, Aryan Amirkhani, Mohammad Reza Bemanian, Mahdieh Abedi***, Design Principles in The Hot and Arid Climate of Iran, The Case of Kashan,*** International Journal of Academic Research Vol. 2. No. 5. September 2010.

[10] Payam Eskandari, ***Analysis of Traditional Iranian Houses of Kashan, Iranin Terms of Space Organization and Access Design***, Master thesis, September 2011.

[11] Mahnaz Mahmoudi Zarandi, ***Analysis on Iranian Wind Catcher and Its Effect on Natural Ventilation as a Solution towards Sustainable Architecture (Case Study: Yazd),*** International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering Vol:3, No:6, 2009.

[12] http://www.iranreview.org/content/Documents/Boroujerdi-Historical-House-UNESCO-Top-Choice-in-2015.htm

[13] B. Ahmad khani Maleki, ***Improve Ventilation by Wind Tower (Badgir) Modified in Iranian Hot and Arid Region,*** IJTPE Journal, December 2013 Issue 17 Volume 5 Number 4, pp. 124-129

[14] Azami, A. ***Badgir in traditional Iranian architecture.*** 5th international conference on Passive and Low Energy Cooling for the Built Environment. (2005) Santorini, Greece.

[15] ANSI/ASHRAE/IES, ***Energy Standard for Buildings Except Low-Rise Residential Buildings,*** Standard 90.1-2013

[16] American Society of Heating Refrigerating and Air-Conditioning Engineers, 2009, ASHRAE Handbook—Fundamentals.

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