ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

MEASURING URBAN ENERGY EFFICIENCY IN TURKEY

M.Sc. THESIS

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Department of Urban and Regional Planning

Urban Planning Programme

JUNE 2015

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Programı : Herhangi Program

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TÜRKİYE'DE KENTSEL ENERJİ VERİMLİLİĞİNİN ÖLÇÜLMESİ

YÜKSEK LİSANS TEZİ

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To my beloved family,

FOREWORD

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May 2015 Cansu İLHAN
(Urban Planner)

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ABBREVIATIONS

APEC	**:** Asia-Pacific Economic Cooperation
BP	**:** British Petroleum
CDD	**:** Cooling Degree Day
CO	**:** Carbon Monoxide
CO_2	**:** Carbon Dioxide
CRS	**:** Constant Returns to Scale
DEA	**:** Data Envelopment Analysis
DEKTMK	**:** Dünya Enerji Konseyi Türk Milli Komitesi
DFA	**:** Data Frontier Analysis
DMU	**:** Decision Making Unit
EEM	**:** Energy Efficiency Measurement
EJ	**:** Exajoule
EMRA	**:** Energy Market Regulatory Board
ESCO	**:** Energy Services Companies
EU	**:** European Union
FDH	**:** Free Disposal Hull
GCC	**:** Gulf Cooperation Council
GDP	**:** Gross Domestic Product
Gt	**:** Giga tonne
GHG	**:** Greenhouse gas
HDD	**:** Heating Degree Day
ICLEI	**:** International Council for Local Environmental Initiatives
IEA	**:** International Energy Agency
MCDM	**:** Multicriterion Decision Making
MENR	**:** Ministry of Energy and Natural Resources
MEU	**:** Ministry of Environment and Urbanization
Mtoe	**:** Million Tonnes of Oil Equivalent
NO_X	**:** Mono Nitrogen Oxide
OECD	**:** Organisation for Economic Co-Opearation and Development
SFA	**:** Stochastic Frontier Approach
SO_2	**:** Sulfur Dioxide
TAEK	**:** Türkiye Atom Enerjisi Kurumu
TFA	**:** Thick Frontier Approach
TFC	**:** Total Final Consumption
TOE	**:** Tonnes of Oil Equilvalent
TPES	**:** Total Primary Energy Supply
UNDP	**:** United Nations Development Programme
UNEP	**:** United Nations Environment Programme
UNIDO	**:** United Nations Industrial Development Organization
UNFCCC	**:** United Nations Framework Convention on Climate Change
VRS	**:** Variable Returns to Scale

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MEASURING URBAN ENERGY EFFICIENCY IN TURKEY

SUMMARY

Energy efficiency is a key component of urban sustainability and also it is a subset of eco-efficiency. In recent decades, energy efficiency has become a hot topic in both academic and policy circles and has gained a strong global commitment by the world leaders that have reaffirmed the critical role that improved energy efficiency can play in addressing energy security, environmental and economic objectives. Today, enhancing energy efficiency represents one of the most important opportunities for countries to expand economic growth and job creation and also it is indispensible to mitigate CO_2 emissions and climate change by reducing energy consumption in cities. Energy efficiency of communities can be defined as a ratio between an input of energy consumption or emissions, and an output of services, such as number of inhabitants and jobs or floor square meters. In general, energy efficiency refers to using less energy to produce the same amount of services or useful output. It is widely assumed that over the coming decades, increased energy efficiency will help the world meet its energy needs and reduce carbon dixoide emissions.

This study aims to measure urban energy efficiency and to evaluate the critical success factors in efficiency by deploying Data Envelopment Analysis (DEA). DEA is a nonparametric method, linear programming model and optimization algorithm which develops efficiency scores for all decision making units (DMUs). kIn DEA method, efficiency of a decision making unit is calculated relative to the group's monitered best practice, efficient DMU's imply that as compared with other DMU's in the group they produce a certain amount of or more outputs while spending a given amount of inputs, or use the same amount of or less inputs to produce a given amount of outputs. The study focuses on 81 provinces, ranks them by their efficiency performance and maps out the patterns of energy use and efficiency in Turkey. Using data and information gathered from Turkish Statistical Institute (TURKSTAT), Turkish State Meteorological Service and The Ministry of Energy and Natural Resources (MENR), National Mapping Agency, Energy Market Regulatory Authority (EMRA) and since there are no official statistics on greenhouse gases emissions, it is taken from the estimated data in Can (2013). The results of Data Envelopment Analysis highlight the critical factors in energy efficiency performances of Turkish cities. Analyzing the energy efficieny of cities will help decision makers to develop energy strategies for further projects line spacing must be set for summaries.

TÜRKİYE'DE KENTSEL ENERJİ VERİMLİLİĞİNİN ÖLÇÜLMESİ

ÖZET

Son yıllarda dünyada artan nüfus ile birlikte insanların ihtiyaçları da artmış ve kıt kaynakları tehdit eder hale gelmiştir. Enerji bir yandan ülkelerin ekonomilerini büyütmek için bir araç iken diğer yandan neden olduğu sera gazı emisyonları nedeniyle çevreleri için de bir tehdittir. Artan enerji tüketimi ile birlikte dünya küresel ısınma, iklim değişikliği, ekosistemlerin tahrip olması gibi problemlerle karşı karşıya kalmıştır. Son yıllarda yapılan çalışmalarda, küresel ısınmaya insanların üretim ve tüketim süreçleri sonucunda oluşturdukları seragazı emisyonlarının neden olduğu kanıtlanmıştır. İklim değişikliğinin başlıca sebebi olan seragazı emisyonlarını düşürmek için enerjiye olan talep azaltılmalı ve fosil yakıtlar yerine yenilenebilir enerji kaynaklarına yönelim arttırılmalıdır. Verimli enerji kullanımı sera gazı emisyonlarının azaltılmasında en etkili, hızlı ve düşük maliyetli çözümdür. Uluslararası Enerji Ajansı'nın tahminlerine göre enerji verimliliği ile 2050 yılına kadar sera gazı emisyonlarını %31-53 oranında azaltmak mümkündür. Bugün dünyada sera gazı emisyonlarının yaklaşık % 77'si petrol, kömür, doğal gaz gibi fosil yakıtların kullanımı nedenlidir. Başlıca sera gazlarından biri olan CO_2, doğada çok yüksek hızla artmakta ve gün geçtikçe daha ciddi zararlara neden olmaktadır. Geçtiğimiz yüzyıl içinde sera gazı emisyonları nedeniyle yeryüzünün ortalama sıcaklığı 0,7 ^{o} C artmıştır. Sera gazlarının yanı sıra, fosil yakıtlarının kullanımına bağlı olarak azot oksit ve sülfür oksit gibi zehirli gazlar da asit yağmuru gibi ciddi çevre sorunlarına neden olmaktadır.

Sürdülebilirliğin hem ekonomik hem de ekolojik boyutunu dengede tutmak için bugün ülkeler hem ekonomiden hem de çevrelerinden taviz vermeden devamlılıklarını sağlamak durumundadırlar. Bu da ancak sınırlı kaynakların verimli, bilinçli ve duyarlı bir şekilde kullanılmasıyla mümkün olacaktır, bu nedenle de enerji verimliliği politikaları son yıllarda pek çok ülkede kilit gündem haline gelmiştir. Günümüzde, enerji verimliliğinin geliştirilmesi, ülkelerin ekonomik büyümelerinde ve iş olanaklarının yaratılmasında önemli olanaklardan birini temsil etmektedir. Geçtiğimiz yıllarda, enerji verimliliği konusu, gerek akademik gerekse politik arenada sıcak gündem maddeleri arasında yer almış ve enerji verimliliğinin çevresel ve ekonomik amaçlara yönelik olarak üstlendiği etkin rol geniş kapsamlı olarak gündeme alınmıştır.

Enerji verimliliği; enerji tüketimi veya emisyonu girdisiyle, hizmet çıktılarının oranı olarak tanımlanmakta ve aynı hizmeti veya çıktıyı sağlamak üzere daha az enerji kullanmayı ifade etmektedir. Kısaca, yaşam standardını, üretim kalitesini ve miktarının düşürmeden, daha az enerji tüketerek aynı miktarda ya da daha fazla işi yapabilmektir. Enerji verimliliğini, kaynakların daha verimli kullanımının yanı sıra gelişmiş endüstriyel süreçler ve enerji geri kazanımları gibi önlemlerle de gerçekleştirmek mümkündür. Gelecek yıllarda enerji verimliliğinin arttırılması ile

dünyanın enerji gereksiniminin karşılanması yanı sıra karbon salınımının da azaltılması hedeflenmektedir.

Gelişmekte olan bir ülke olarak Türkiye'de de enerji talebi hızla artmakta ve ülke kaynakları bu talebi karşılayamamaktadır. Bu nedenle de Türkiye enerji ihtiyacının % 70'inden fazlasını ithal etmek zorunda kalmakta bu da ekonomiye ağır yükler bindirmektedir. Artan enerji tüketimi ile birlikte, Türkiye'de sera gazı emisyonları da 1990 - 2007 yılları arasında % 119 artış göstermiştir ve tahminlere göre 2020 yılında emisyonların 2007 yılının iki katına ulaşması beklenmektedir. Son yıllarda Türkiye'deki temel enerji politikalarına bakıldığında enerjideki dışa bağımlılığı düşürmenin temel çözümü olarak nükleer enerji görülmektedir. Çok geniş yenilenebilir enerji kaynaklarına ve enerji verimliliği potansiyeline sahip Türkiye'de tek çözüm elbette nükleer enerji değildir. Tüm dünyanın kabul ettiği gerçek şudur ki; en ucuz enerji, verimli kullanım sonucu tasarruf edilen enerjidir. Enerji verimliliği, Türkiye'de % 70'in üzerine varan dışa bağımlılığın azaltılması ve iklim değişikliği ile mücadele edilmesinde büyük önem arz etmektedir. Yapılan çalışmalarda Türkiye'de bina sektöründe % 30, sanayi sektöründe % 20 ve ulaşım sektöründe % 15 enerji tasarruf potansiyeli olduğu tespit edilmiştir. Bu potansiyellerin tespiti ile Türkiye'de de enerji verimliliği ile ilgili politikalar son yıllarda artmış ve bu konuda toplumsal farkındalık yaratılmaya başlamıştır. İlk olarak 2007 yılında Enerji Verimliliği Kanunu, 2008 yılında ise Enerji Kaynaklarının ve Enerjinin Kullanımında Verimliliğin Arttırılmasına Dair Yönetmelik yürürlüğe girmiştir. Son yıllarda bu konu ile ilgili artan politikalara rağmen enerji verimliliğinin ölçümüne ilişkin çalışmalar yapılmamıştır. Özellikle enerji tüketiminin ve potansiyelinin yüksek olduğu kentlerde bu konu ile ilgili yapılacak bir çalışma daha sonrasında belirlenecek olan kent düzeyindeki enerji politikaları için de yol gösterici olacaktır.

Bu çalışma, Türkiye'de kentsel enerji verimliliğini ölçmeyi ve ekonomik, sosyal ve çevresel girdi ve çıktılar kapsamında kritik başarı faktörlerini değerlendirmeyi amaçlamaktadır. Çalışmada, Türkiye İstatistik Kurumu, Türkiye Devlet Meteoroloji Enstitüsü, Harita Genel Komutanlığı, Enerji ve Tabii Kaynaklar Bakanlığı'ndan alınan ve istatistiki bilgisi bulunmayan ve hesaplama yöntemi ile elde edilen bir takım veriler kullanılmıştır. Yöntem olarak matematiksel programlama tabanlı, ürettikleri ürün ya da hizmet açısından birbirine benzeyen ekonomik karar birimlerinin göreli etkinliğinin ölçülmesi için geliştirilen parametresiz bir etkinlik ölçüm tekniği olan Veri Zarflama Analizi'nden (VZA) yararlanılmıştır. VZA, çok sayıda girdi ve çok sayıda çıktının ağırlıklı bir girdi veya çıktı setine dönüştürülmesinin zor olduğu durumlarda anlamlı sonuçlar üretebilmektedir. VZA, göreli bir etkinlik ölçüm tekniği olup, her bir karar verme birimini (girdiyi çıktıya dönüştürmekten sorumlu işletme ya da ekonomik kuruluşlardır- literatürdeki adıyla Decision Making Units) "en iyi" birimlerle karşılaştırarak sonuç almaktadır. Geleneksel verimlilik ölçüm yöntemlerinde, çoklu girdi ve çoklu çıktıların değerlendirilmesi için bir bütünsellik sağlanamazken, VZA çoklu girdi / çıktı yaklaşımı ile bunu sağlayabilmektedir. Bu yöntem parametrik yöntemlerdeki önceden belirlenmiş herhangi bir üretim fonksiyonuşlnun varlığına ihtiyaç duymadan ampirik gözlemler yardımıyla ölçüm yapabilmektedir.

Veri Zarflama Analizi yaklaşımı altında 8 değişken ile Türkiye'de 81 ilde enerji verimliliği ölçülmüş ve kentlerin performansını belirleyen kritik başarı faktörleri ortaya konmuştur. Çalışmada 5 girdi (nüfus, yüz ölçümü, enerji tüketimi, ısıtma ve soğutma gün dereceleri) ve 3 çıktı (yıllık gelir, CO_2 emisyonları, ortalama yaşam süresi) kullanılmıştır. Kentlerin enerji tüketimini dolayısıyla da verimliliğini etkileyen kent formu, yoğunluk, kültür, iklim vb. gibi pek çok faktör olmakla birlikte bu faktörlerin hepsini bu ölçekteki bir ölçümde göz önünde bulundurmak öncelikle veri mevcudiyetinin olmamasından dolayı neredeyse imkansızdır. Örneğin; kültür insanların ulaşım tercihlerini etkilemekte bu da ulaşım için harcanan enerji miktarını değiştirebilmektedir. Kent içi ulaşımda bisikletin yüksek olduğu bir kent ile özel araç kullanımın yüksek olduğu bir kentin ulaşım için harcadıkları enerji miktarı bir hayli farklılaşacaktır. Bu alanda yapılacak daha detaylı çalışmalar için il düzeyinde sektörel bazda (ulaşım, konut, sanayi vs.) enerji verilerine ihtiyaç vardır, böylelikle kentlerin enerji verimliliklerini daha hassas bir şekilde incelemek mümkün olabilecektir.

Çalışma, Türkiye'de kentsel enerji verimliliğinin ilk kez ölçülüyor olması açısından oldukça önemli bir katkı sağlamaktatır. Çalışmanın sonuçları, Türkiye’deki kentlerin enerji verimliliği performanslarını belirleyen etkenleri ortaya çıkarmak ve gelecekte enerji verimliliğinin arttırılmasına yönelik geliştirilecek olan stratejilere yol göstermesi açısından önem taşımaktadır.

1. INTRODUCTION

During the last decades, urban areas all over the world have increased in size (Omer, 2008) and today cities are covering more than 3 % of the world's land surface (Schirber, 2005). According to UN Habitat Report (2009) approximately half of the world's population live in cities and for the first time ever, more people live in urban centers than rural. UNIDO (1997) predicted that the world's urban population will double in 38 years with an expected annual growth of 1.8 %. Besides with this growing population, needs of commodities and service demands are incessantly increasing, and concordantly demand for energy is intemperately increasing (IEA, 2004).

With growing urbanization, cities have increased in number, size, population and complexity (Omer, 2008), and this rapid urban growth throughout the world has surpassed the capacity of most cities to provide adequate services for their citizens (IEA, 2011) and many countries have faced with the question of how to supply the growing energy needs of the population (Bilen, et al., 2008). These growing cities also bring forth some problems related with resources and environment, as revealed by Jollands, Kenihan, & Wescott (2008) urban dwellers consume approximately 80% of all commercial energy produced globally. And IEA (2008) report presented that between 1990 and 2005 global final energy use increased by 23% while the associated CO_2 emissions rose by 25%. And it caused to a global challenge of human development, and the transformation of where we live brings to the fore the question of how we live (Worldwatch Institute, 2007).

According to BP Statistical Review of World Energy (2011), global energy consumption has risen by more than 200 percent since 1965, from 3767 million tones of oil equivalent (Mtoe) to 12002 Mtoe in 2010, and according to estimates by the Energy Information Administration's 2011 International Energy Outlook, this trend will continue with industrial energy consumption growing an approximately 50 percent from 2008 to 2035 (Burgoon, 2013). And also according to International Energy Agency (IEA, 2005) predictions, with reference to 2001, in 2030, energy consumption will have enlarged by 60 % and it will become more toilsome to satisfy these demands from fossil fuels. Predictions reveals also that within the next 20 years, petroleum will become so barely and that will lead to risk for those countries which will still be dependent on energy imports in the future (IEA, 2005).

Energy is the essential input for economic and social development (Omer, 2008), it is indispensable to improved quality of life in all over the world (Bilen, et al., 2008). UNDP (2000) says that energy is a vital element for the people to become more productive in their work and to increase their income. But on the other hand, energy consumption causes great problems both economically and environmentally. Today all energy sources are consuming insensibly, and it leads to energy crisis and great environmental challenges. In many countries, energy demand is rising with an increase in industrial and agricultural activities (Omer, 2008), and this growing consumption of energy is threatening the environment and society.

Energy is one of most important development priority for many countries, and today all over the world, governments are increasingly aware of the scarcity and importance of energy resources, and as a result of these concerns, sustainable development has become more important policy in many countries. There is an intimate connection between energy and sustainable development. Especially in 1987 Brundtland Report and in the 1992 Rio Earth Summit have helped to place sustainable development issues on international and national policy agendas. (Keirstead, 2007). For the successful climate protection and sustainable development, environmentally and economically friendly energy policies should be implemented (UNDP, 2000) and it should not be forgotten that the sustainable development relies upon the efficient energy consumption (Hu & Wang, 2006).

Energy consumption is the primary cause of greenhouse gas emissions and other environmental problems (Worrell, 1996), the main areas of environmental problems are major environmental accidents, water pollution, maritime pollution, land use and sitting impact, radiation and radioactivity, solid waste disposal, hazardous air pollutants, ambient air quality, acid rain, stratospheric ozone depletion and global warming (Omer, 2008).

As mentioned above, great challenges in environment and economy have forced governments to decrease to their energy consumption. Approximately 70% of the total worldwide primary energy used is lost throughout the energy supply chain, and this shows that there is a huge energy-saving potential in energy consumption (UNDP, 2000). Improved energy efficiency is a key issue for decreasing energy consumption, and also it is a essential policy goal of many governments around the world (IEA, 2008), and also it has often been accepted as cost-effective way of decreasing carbon dioxide emissions and developing industry competitiveness (Ang, Mu, & Zhou, Accounting frameworks for tracking energy efficiency trends, 2010).

According to International Energy Agency Report (2012), aside from energy savings, wider socio-economic outcomes that can arise from improved energy efficiency. In addition to energy savings, improving energy efficiency provides multiple benefits, it represents great opportunities for the countries to extend economic growth (Lewis, Hógáin, & Borghi, 2013), and it is also great tool to reduce greenhouse gas emissions and local air pollution (IEA, 2008). Briefly, energy efficiency is crucial for tackling with the economic and environmental challenges.

The role of cities is gaining importance in the energy efficiency improvement, since they consume significant amounts of energy (Jollands, Kenihan, & Wescott, 2008). Today, the ecological footprint of cities is larger than the areas they physically occupy (Omer, 2008), this growing consumption of energy in cities leads to great environmental problems. All these discussions have demonstrated that the urban level is very important to reducing environmental pollution and to improving energy efficiency.

Today in contrast with sustainability approach, energy consumption has been growing more and more and it leads to great challenges for economy and environment. The motivation of this study is coming from energy scarcity and sustainability perspective. Like many others, Turkey is facing with great energy scarcity and climate change, and its energy demand rates are expected to accelerate in the future. In Turkey, domestic energy production is very low and has not exceeded 40% of its demand. And as in other cities, Turkish cities are consuming significant amount of energy produced nationally and there is great threat of climate change due to emissions of carbon dioxide. In this regard, energy efficiency appears to be one of the most effective solution to strive with climate change and energy scarcity. This study measures urban energy efficiency in Turkey from multiple input/output model with Data Envelopment Analysis and reveals critical success factors in efficiency.

1.1 Aim

The intent of this study is to measure urban energy efficiency in Turkey and to determine the critical success factors in urban energy efficiency. To determine the patterns of energy use in cities is important to designate the energy and environment policies in cities. Since the increasing awareness about climate change those policies has gained great importance and necessity.

This study discusses urban energy efficiency from multiple input/output perspective, which provides more comprehensive point of view. And the study asks two main questions: which cities are using their sources effectively and what are the factors that cause efficiency/inefficiency situation in cities? The expected results of the study is to address the efficiency or inefficiency circumstance of cities, to define the worst and best performers cities in Turkey and to reveal which factors affect the cities energy efficiency performance.

1.2 Research Objectives

The first objective is to define urban energy efficieny indicators in measurement that is very important to establish of the extent of study. Since there are many different approachs (e.g. parametric or nonparametric) on energy efficiency measurement methods, second objective is specify to best method on urban energy efficiency measurement and to explain why the particular method was chosen. Another and the final objective is measure the urban energy efficiency by chosen method and determine the critical success factors in efficiency.

The research objectives of this study are as follows:

- To measure urban energy efficiency in Turkey
- To compare and to classify the cities within their energy efficiency scores
- To identify the factors associated with energy efficiency performance of cities.

1.3 Methodology and Context

This study is mainly predicated on literature research and empirical survey. In the empirical part, Data Envelopment Analysis has been utilized and the reason why this method was chosen is explained in the related section. This study focuses on 81 provinces of Turkey.

In the first section of the study; the aim, research questions, method and content is explained. In the second section, in the frame of climate change and sustainability that have recently become a hotspot issue in national policies, energy demand and the problem arising from this is mentioned. The importance of energy efficiency which plays key role for the solution of these problems is underlined. In the third section, conceptual framework was presented by defining energy efficiency and urban energy efficieny. Again in this section, energy indicators in the literature is analysed and different approaches in this field is referred. Then, methods of measuring energy efficiency are mentioned and by analysing the advantages and disadvantages of different methods (parametric and non-parametric), the most suitable method is defined for the energy efficiency measurement study at urban level in Turkey. In the fourth section, by stating Turkey's energy policies, country's general energy profile is drawn. In this section, energy policies are explained under three main titles; energy and environment, general energy policy and energy efficiency policy. An empirical study is revealed in the fifth section. The aim, method, scope and data sources are defined and obtained empirical results are set forth. By making a detailed study of emerging results, factors that affects the urban energy efficiency are analysed and interpreted. In the final part, a general frame is drawn regarding the urban energy efficiency in Turkey and the contribution to literature of this study is discussed.

2. CLIMATE CHANGE AND SUSTAINABILITY

2.1 Climate Change and Urban Sustainability

Cities around the world, particularly those in developing countries where urbanization occurs at unprecedented rates, are currently facing the challenges related to climate change, which increases vulnerabilities, destroys economic gains and hinder social and economic development (The World Bank, 2011). Today according to many scientists, the global economy is not on a path toward sustainable development, the Intergovernmental Panel on Climate Change found that the signs of a changing climate, from shrinking glaciers to the decline of some plant and animal populations (Worldwatch Institute, 2007). An international analysis of the world's ecosystems revealed that 60% of the services of nature are being degraded or used unsustainably (Worldwatch Institute, 2007), natural resource degradation, pollution and loss of biodiversity are very damaging since they increase vulnerability and reduce resilience (Omer, 2008). In 2005, Millennium Ecosystem Assessment (MA) warned that "these problems unless addessed, will substantially diminish the benefits that future generations obtain from ecosystems".

Climate change has and will continue to have significant impacts on cities. The health, livelihoods and assets of urban residents are affected by these impacts, and the urban poor, residents of informal settlements and other underprivileged groups are rather vulnerable (The World Bank, 2011). As indicated by the World Bank (2011), the impacts of climate change include to increase in the occurrence rate of extreme weather events and flooding, hotter temperatures, and public health concerns. Environmental sustainability is mainly related with climate change, and today climate change is recognized as one of the most crucial issue for the world (Sioufi, 2010). Besides natural environment, climate change is a global problem with serious consequences for social and economic infrastructure (Bilen, et al., 2008), if climate change impacts does not take into consideration, it will be more difficult for cities to achieve sustainable development (The World Bank, 2011).

Climate change will strike the world from many ways, on the one hand, many developing countries are agricultural so they are extremely vulnerable to rigorous severe weather events and changing climate conditions, these can lead to important economic losses for them. On the other hand, they are lacking the capacities for accommodate to climate change, for example by building protective sykes along their coastlines (Berger, 2002).

Climate policies cannot be defined as a choice between growth and fighting climate change, as a matter of fact, these policies support to enhance development, reduce vulnerability, and finance the transition to low-carbon growth paths (The World Bank, 2011). As an urgent measures with regard to energy and climate policy, EU defined three headline targets; to increase the share of renewable energy sources to 20%, to increase energy efficiency by 20% and to decrease CO_2 emissions by 20% by 2020 (EU, 2013). According to Bilen et al. (2008), most important part of climate policy is investments in improved energy efficiency since there is a huge potential for this both in industrialized and in developing countries.

Since the beginning of the industrial age, growing amounts of gases have been released into the atmosphere (Bilen, et al., 2008), and today greenhouse gas (GHG) emissions are considered as main reason of climate change, and they mainly arise from burning fossil fuels such as coal, oil and natural gas (Bilen, et al., 2008). As an outcome of greenhouse gases, temperature increase will lead to climate changes that have the potential to cause non-reversible impacts on economy and environment (Bilen, et al., 2008) This rapid emission growth throughout the world is becoming more dangerous for the society and environment. Governments across the world need to decrease the their consumption of energy (especially fossil fuels) in order to build a sustainable development. Energy efficiency policies are among the most effective actions to control the greenhouse gases emissions and to fight the climate change.

Until now, cities have always faced with natural hazard events, some which are not climate related (such as earthquakes and tsunamis) and some which are climate related (such as hurricanes and flooding) (The World Bank, 2011). Today and in the future to struggle with global climate change and to ensure sustainable development policy makers should take into consideration the relationship between energy efficiency, energy use and greenhouse gas emissions (Metivie, McIntosh, & Pearson, 1996). As a common principle, the more efficient the complete supply system is, the less power generation capacities is needed (Bilen, et al., 2008). By coursety of increasing awareness of the environmental impact of CO_2 and other gases emissions actuated interest in environmentally friendly cooling, and heating technologies (Omer, 2008).

Briefly, countries must increase and continue their energy efficiency policies as an indispensible part of a global survival strategy (Lemon, 2013). As said in International Conference on Urban Energies (2012); "The sustainable city is climate-conscious and energy efficient, adaptable and socially just, economically efficient and, last but not least, creatively unique and beatiful" (URBACT, 2012: 8).

2.2 Sustainable Energy Action Planning

There are many definitions on sustainable development, most common one is that "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987: 16). And in the future world's energy supply will become more vulnerable, cities will be exposed to many challanges related to today's unsustainable energy systems- from air and water pollution to climate change (Worldwatch Institute, 2007), so it must be used sustainably (Bilen, et al., 2008). Many cities have been striving to reduce their ecological footprints (Byrne, Wang, Lee, & Kim, 1998).

In 2002, The World Summit on Sustainable Development in Johannesburg committed itself to "encourage and promote the development of renewable energy sources to accelerate the shift towards sustainable consumption and production". This aim can be achieved by following:

- Trying to maintain economic growth does not cause environmental contamination
- Improving resource efficiency
- Analyzing the whole life-cycle of a product
- Enabling consumers to receive more information on products and services

- Investigating how taxes, voluntary agreements, subsidies, regulation and information campaigns, can best encourage innovation and investment to provide cleaner technology (Omer, 2008).

Energy resources include both renewables, such as solar energy, wind energy, geothermal energy, bioenergy etc., and non-renewables such as coal, crude oil, natural gas. The supply of energy, whether renewable or non-renewable, is restricted. The aims of sustainable energy action planning are optimal energy efficiency, low or no carbon energy supply and accessible, equitable and good energy service supply to users (UN- HABITAT, UNEP & ICLEI, 2009). Both by a more efficient use of energy and by using of renewable sources of energy contribute to sustainable energy action approach.

As said by Burgoon; "Strategic energy management today creates brighter energy environment tomorrow" (Burgoon, 2013: 14).

Cities play a significant role in struggling with energy scarcity and sustainability challenges, they can moderate climate change by reducing energy consumption in the construction, maintenance and refurbishment of buildings (Lewis, Hógáin, & Borghi, 2013). And also, they are the key players in the reduction of greenhouse gases emissions and in the fighting against climate change (Lewis, Hógáin, & Borghi, 2013), cities mitigate the these problems through urban planning, building design, and choice of end use products and energy resources and technologies (Worldwatch Institute, 2007).

Cities play a crucial role in the reduction of energy consumption and they are ideal to provide sustainability through local action plans (Lewis, Hógáin, & Borghi, 2013). All over the world, many cities are already getting better their energy efficiency performance and producing more of their energy locally and sustainably (Worldwatch Institute, 2007). Cities implement their energy and climate action plans to have less traffic congestion and lower energy input costs, to have cleaner air and low-carbon economies (UN- HABITAT, UNEP & ICLEI, 2009).

As revealed by VTT Technical Research Centre of Finland (2012), the most important facts in sustainable energy action planning are at dwelling area level: location, structure, building density, house types, space heating sytems, at regional level: area density, energy consumption and production systems, location of and distances between dwellings, working places, and services, transportation systems, possibilities of walking and cycling, availability of public transport, and necessity for use of private cars.

Irrespective of size or governance structure, cities can implement sustainable energy planning in three primary ways (UN- HABITAT, UNEP & ICLEI, 2009):

- ✓ First of all, within their operations. Since they are the large consumers of energy in buildings and public facilities, in water systems and in other infrastructure, they can easily control local actions.
- ✓ Secondly, by courtesy of their authoritative role in forming the built environment, they can handily encourage the alternative energy resources and efficient energy use in private sector (e.g. energy efficient buildings and site planning, energy friendly urban design etc.)
- ✓ Thirdly, they can determine the development patterns to decrease the impacts of urbanization on the energy system and the environment.

According to UN- HABITAT, UNEP & ICLEI (2009) report there are many adventages of sustainable energy action planning;

<u>Improvements in local air quality:</u> Local authorities can act some actions -energy management initiatives e.g.- to reduce the air pollution that causes important environmental and health problems within their cities.

<u>Financial savings:</u> For many local authorities, the charm of saving money is the starting point for municipal energy management initatives.

<u>New jobs:</u> Inefficient energy systems stand for important investment opportunities in the community, and these investments are the most effective ways to create new employment.

<u>Local Economic Development:</u> Energy management industry is a growth industry and it can be an useful ingredient of local economy.

<u>New Partnerships:</u> In addition to municipal, utilities, private enterprises, financial institutions and levels of government are all pursuing energy management for various reasons.

These are some of the ways in which local governments play a central role in the energy picture of their cities (UN- HABITAT, UNEP & ICLEI, 2009):

- They plan and control the city development and growth
- They establish and implement building codes and approve building plans
- They are the main providers of basic services such as water, waste management, street lightning and other allied services
- They are responsible for transport planning and management across and within a city
- They are generally responsible for the dissemination of electricity and for billing and may be responsible for some generation capacity
- They are big energy consumers themselves- in their fleets and buildings
- As they are major employers, they can directly affect their emplooyees energy-use patterns
- They provide important procurement of paper, fuel, building materials, light bulbs, vehicles etc.

According to UN- HABITAT, UNEP & ICLEI (2009), these are the key characteristics of sustainable energy and climate action planning:

- Energy sources and energy-related activities are seen as whole a system
- Moderation of carbon emissions is a determining factor in the development of the plan and choice of project options
- Energy conservation, energy efficiency and demand-side management are seen prior to supply-side solutions
- Environmental and social costs are apparently considered
- The demand for energy services, rather than what energy can be supplied, is the essence for planning
- Linkages between energy sector and economy are included
- The plan is flexible and can anticipate and react to change.

3. ENERGY EFFICIENCY

In recent years energy efficiency has gained significant place in the public policy agenda of most developed countries, it has been extensively seen as a hopeful means to cope with environmental problems (Trianni, Cagno, & Donatis, 2014), and as a policy objective energy efficiency is linked to commercial, industrial competitiveness and energy security benefits (Patterson, 1996), and also it is closely connected to enviromental factors seen as a subset of the eco-efficiency (Forsström, et al., 2011).

Recent revision of the European energy targets (2012) showed that a strong boost towards the reduction of energy consumption is needed (European Union, 2012). This refers that tomorrow's policies should be designed to obtain a wider dissemination of Energy Efficiency Measures (EEMs) in any sector (Trianni, Cagno, & Donatis, 2014). Energy efficiency policies will be more indispensible policy for many countries. Improving energy efficiency represents many important openings for the countries to extend their economic growth and job creation (Lewis, Hógáin, & Borghi, 2013), and it is the fastest and cost effective way of mitigating energy security, environmental and economic challanges (IEA, 2011), but it is not enough to overturn global warming and figure out the global energy crisis (Lemon, 2013). And it should not be forgetten that countries can improve their energy efficiency with just a little extra input, such as an upgrade of the turbines (Bilen, et al., 2008).

3.1 Energy Efficiency: Conceptual Framework

3.1.1 Energy efficiency

In recent years, energy efficiency has become an indispensible component of energy strategy in many countries in consequence of high energy prices and the concern about global warming and sustainable development (Ang, 2006). In spite of the continuing policy interest on the matter of 'energy efficiency', little attention has been given to exactly defining the term (Patterson, 1996).

Patterson (1996) says that energy efficiency is a general term, and there is no any certain quantitative measure of "energy efficiency" for all cases. Generally, energy efficiency refers to using less energy to produce the same amount of services or useful output (Patterson, 1996), and in the European Directive (2006) energy efficiency defined as "a ratio between an output of performance, service, goods or energy, and input of an energy". For example, something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input (IEA, 2014).

According to first law of thermodynamics energy can not be created or destructed, it is all the time in some mode and somewhere, and it transforms itself a certain amount between the system and the surrondings (Forsström, et al., 2011).

Energy efficiency is a term that is used in a variety of meanings in different contexts and there is no one unequivocal quantitative measure of energy efficiency for all circumstances. The efficiency of energy transition is commonly measured as the ratio of energy output and the energy input of the process (3.1) (Forsström, et al., 2011):

$$\frac{energy\ output}{energy\ input} \quad \textbf{(3.1)}$$

If we can not measure the output as energy, the issue is more complex. In this case, output appropriately describes the service, process, goods, consumption (Forsström, et al., 2011), USDOE (1995) calls such a measure a demand indicator. Energy efficiency indicators commonly take the form of energy intensity (3.2) (Forsström, et al., 2011):

$$\frac{energy\ input}{demand\ indicator} \quad \textbf{(3.2)}$$

Comparing with equation (3.1) we can conclude that intensity is inversely associated to energy efficiency; the greater the efficiency of a given process, the smaller its energy intensity (Forsström, et al., 2011).

It is widely accepted that energy efficiency is an essential part of sustainable development. Energy efficiency is a primary driver of sustainable development and eco-efficiency. As it can be seen in Figure 3.1, energy efficiency is a component of a wider context, and it can be defined as a part of eco-efficiency. As the mentioned by Forsström, et al. (2011), energy efficiency is closely related to environmental situaiton and seen as a subset of the eco-efficiency, and the amount of the waste related to energy production and use is a main feature arising from the perspective of eco-efficiency. In eco-efficiency perspective, indicators are such as CO_2, NO_x, SO_2. Eco efficiency is ecological efficiency and it measures use of natural resources and negative impacts in relation with results obtained, and it can be defined as a part of sustainability. Sustainability approach encompasses environmental (or ecological), economic and social (including cultural and institutional) sustainability, and today by coursety of climate change, environmental sustainability has become more vital of the whole sustainability target (Forsström, et al., 2011).

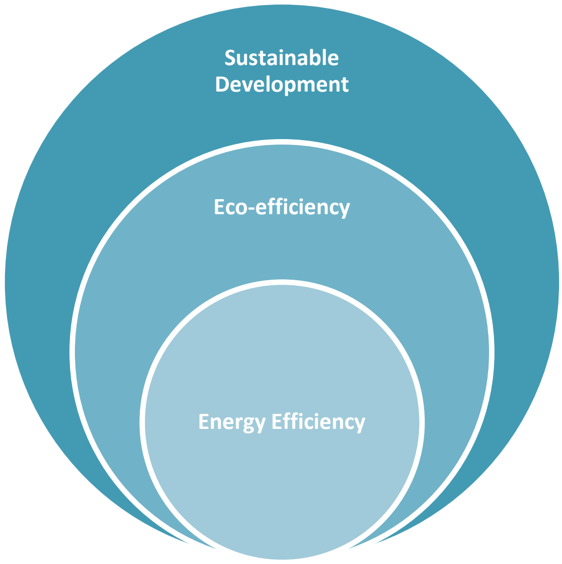

Figure 3.1 : Relationship between energy efficiency, eco-efficiency and sustainable development.

In 2008, International Energy Agency (IEA) developed a set of 25 energy efficiency policy recommendations for seven priority areas to help its member countries execute the benefits of energy efficiency across their economies (IEA, 2011):

- Cross-sectoral
- Buildings
- Appliances and equipment
- Lightning
- Transport

- Industry
- Energy utilities

In spite of the recent amelioration in energy efficiency, there is a still huge potential for more energy savings across all sectors, an analysis of industy shows that on a global scale the application of proven technologies and best practices could save between 25 EJ and 37 EJ per year, which represents between 18% and 26% of current primary energy use in industry (IEA, 2008).

According to IEA estimation, if policies implemented globally without any delay, the proposed actions could save as much as 7.6 gigatonnes (Gt) CO_2/year by 2030, in 2010, this corresponded to energy savings of more than 82 EJ/year by 2030, or 17% of the current annual worldwide energy consumption (IEA, 2011).

Energy efficiency improvements is a vital challange for energy and climate policies for the countries and it needs to be extended considerably to realize high-grade, secure and sustainable future. By coursety of the policies recently initiated, improvement in energy efficiency has been increasing slenderly (IEA, 2008).

3.1.2 Urban energy efficiency

According to UN Report (2006) today approximately 50% of the world's population living in cities and urban sustainability has become a major issue (Keirstead, 2007). As centres of economic and cultural activity, cities offer important life improvements to both developed and developing countries (Keirstead, 2007), and at the same time, they are the biggest consumer of energy. Since the huge consumption of energy, cities are responsible for the largest share of CO_2 emissions (Lewis, Hógáin, & Borghi, 2013), but concurrently they have a comparatively high potential for energy efficiency improvements, these potential seems to be highest in the structures and in transportation (Forsström, et al., 2011). Urban energy consumption is also severely connected with urban form, climate, density and morphology. So it is possible to say that; the urban way of life is both part of the problem and part of the solution (Lewis, Hógáin, & Borghi, 2013). And also in order to increase energy efficiency in cities, urban plans need to be coordinated with local energy efficiency action plans.

Doherty, Nakanishi, Bai, & Meyers (2013) has identified the energy consumption of cities into three categories:

- Embodied energy: This energy is consumed in the manufacture, distribution, construction of buildings and its infrastructure.
- Operational energy: This energy is consumed in the heating and cooling of buildings and in operating the appliances used within them
- Transport energy: This energy (both private and public) is consumed in transportation

According to World Energy Council (2010), there are four key drivers that affect urban energy consumption;

- The level of economic development and the distribution of income

- Urban form and density profiles

- Culture and climate

- Demographic growth, transition and age structure

The level of economic development and the distribution of income: From past to present, household energy type tends to move from traditional ones to modern forms of energy. According to Barnes that transformation is a three-stage process; in first phase, dominant energy source is wood, in the second phase wood is less available by the reason of deforestation, and the dominant energy sources are charcoal and kerosene. In third phase, with increasing income and growing market, LPG and electricity become prominent. According to Barnes, this transformation is not only influenced by local characteristics (nearby forests, climate, etc.) but also national policies on energy prices. Government can influence the speed of that transformation by imposing taxes or subsidies in energy prices.

Household income is another factor that affects the energy consumption. With increasing household income, people tend to buy more appliance and live bigger homes consequently they increase their energy consumption.

Urban form and density profiles: Density is another factor that greatly affects the energy consumption. As revealed by Newman and Kenworthy (2006), high density implies low energy consumption for transportation. While public transportation is more preferred in higly dense cities, private transportation is more common in low density cities (Table 3.1).

Table 3.1 : Urban density and transportation (Newman and Kenworthy, 2006)

Global urban density	**Low** < 25 hab/ha	**Medium** 50 -100 hab/ha	**High** > 250 hab+/ha
Modal distribution	MPT: 80 % PT: 10 % NMT: 10 %	MPT: 50 % PT: 25 % NMT: 25 %	MPT: 25 % PT: 50 % NMT: 25 %
Automobile use (km/pers/year)	> 10 000		< 5 000
Public transport use	> 50		< 250
Petrol consumption for transport (MJ/pers/an)	> 55,000	35,000 - 20,000	< 15,000
Representative positions	North American and Australian Cities	European Cities	Asian Cities

MPT: Motorised Public Transport; PT: Public Transport; NMT: Non Motorised Transport. Density: number of inhabitants and jobs per hectare of net urban surface.

In addition to transportation, urban form also greatly affects energy consumption in infrastructure (water supply, sewage etc.). Compact cities relatively consume less energy for infrastructure. But these cities, on one hand consume less energy for transportation and infrastructure, on the other hand by the reason of high density they cause heat island effect and as a result they increase their energy consumption for cooling. Although it is widely accepted that urban form and density are important factors in the minimizing energy consumption, there is no any defined ideal density and urban form for cities.

<u>Culture and climate:</u> Culture and climate are important factors that affect urban energy consumption. Energy consumption of cities may vary based on their climatic types. Warm climate cities consume more energy for cooling, while cold climate cities need more energy for heating. In addition to climate, home size also has an influence on energy consumption. A comparison between Europe and Japan, who

have similar climates, shows that culture also greatly affects the energ consumption. In Japan people tend to heat the rooms in use, while in Europe they tend to heat all home. In addition to culture, materials and structure also influence energy consumption and efficiency. Culture plays an important role in people's transportation behaviours. Especially in Europe, it is possible to say that people in north more tend to use bicycle as a transportation vehicle compared with south. Compared with the other factors, climate and culture are less influenced factors by public policies.

Demography: Demographic changes is also one of the factors that affect the energy consumption. With increasing old age population, transportation to work or school might be decreased. And the size of city affects the energy consumption pattern, a study carried out by Komives et al. (2005) in 45 cities showed that small cities less depends on electricity than bigger ones.

Basically, cities use energy to builing infrastructure to light, heat and cool buildings, to cook, to manufacture goods, and to transport people (Worldwatch Institute, 2007), that is why energy efficiency in cities must be a combination of energy used during the lifecycle. People's job and shopping behaviours also greatly affects energy consumption, for e.g. working at home and online shopping reduces energy consumption (Forsström, et al., 2011).

As revealed by Forsström et al. (2011); improving urban energy efficiency means reducing energy use needed in production of products and services in energy production, transfer, distribution, and use. For cities, most appropriate energy efficient urban models are based on walking, bicycling, railway transport, effective mass transport and relatively dense building, and the worst (inefficient forms) models show limply structured and disorderly settlement and private transportation.

All these factors mentioned above, can be summarized as follows;

- Location
- Urban sprawl (integration to the urban form)
- Density (building/area/site density) floor-m^2 / land- m^2
- Structure of networks (in transportation, water supply and sewerage, energy, communications)
- Broadness of networks m/floor- m^2, m^2/floor- m^2

- Living space floor- m^2/inhabitant, working place space floor- m^2/ work place
- House types and forms
- Micro climate utilization and solar energy
- Space heating and cooling systems
- Energy production sytems (local energy sources)
- Transportation system
- Modes of transportaion choice (based on private car or mass transport?)

But in general, Forsström et al. (2001) define as energy efficiency of cities with this ratio:

$$\frac{\text{services, products, quality of life}}{\text{kWh,} \quad \text{CO2} - \text{eq. t}} \qquad \textbf{(3.3)}$$

3.2 Energy Efficiency Indicators

Indicator means that "a parameter, or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon/ environment/ area, with a significance extending beyond that directly associated with a parameter value" (OECD, 2003: 5).

Energy indicators have great importance as they can be used at supporting energy efficiency policy development and evaluation (IEA, 2008). Although several studies have attempted to define the energy efficiency indicators, there are no any described accurate and precise indicators. In general, indicators depend on countries' data availability. Today in general, many countries have used aggregate indicators - most common is energy intensity which is the measure of energy consumption per unit of gross domestic product (GDP), but it has a limited usefulness and can be misleading by reason of it is driven by many factors (IEA, 2011).

There are many indicators can be used to monitor changes in energy efficiency. Patterson (1996) has identified into four main groups:

- Thermodynamic: These indicators rely totally on thermodynamic quantities for both inputs and outputs.
- Physical- thermodynamic: These indicators where the energy inputs are measured thermodynamically, but the outputs are measured in physical units.
- Economic - thermodynamic: These indicators where the goods or services (output) of the proces is measured in monertary terms.
- Economic: These indicators measure energy efficiency both inputs and outputs in monetary terms.

All these approaches has its strengthes and weaknesses and in the each category it is possible to meet the alternative indicators. On the other hand, it is so simple to choosing the right indicator, for example in cars, fuel consumption is generally measured as litres per 100 km, but not only distance but also there are many factors that affects fuel consumption which are mass of the car, driving habits, road conditions etc. It is disputatiously impossible to make a perfect comparison unless consider the all factors (Forsström, et al., 2011). All of these indicators mentioned above do not take into account environmental outputs and other related issues, so those are not sufficient for the urban energy measurements.

Eventually, formulating the indicators is a compelling process, and a choice has to be made between a few aggregate indicators with care. Therefore, it is possible to say that choosing of indicators is an continuing process and one indicator can not provide all the sides of energy efficiency (Forsström, et al., 2011), to measure the energy efficiency comprehensively more detailed data are required for the main end-use sectors (industry, residential, services and transport). And all of these sectors are affecting by different factors therefore in the sector analysis diffent informative data is necessiated (IEA, 2011).

According to International Energy Agency indicator approach, there is a hierarchy of energy indicators from most detailed to least detailed, which is illustrated in a pyramid (Figure 3.2). This is an important demonstration because it presents how specific changes (it could be the results of policies, technological progress, structural reform or behavioural change etc) can be connected to higher order, more aggregate quantities. By courtesy of this pyramid, it is more explicit and easy to explain more aggregate changes in energy use in the sense of components. But this pyramid is not appropriate for all the countries, it changes from country to country as it depends on the data availbility (IEA, 2011).

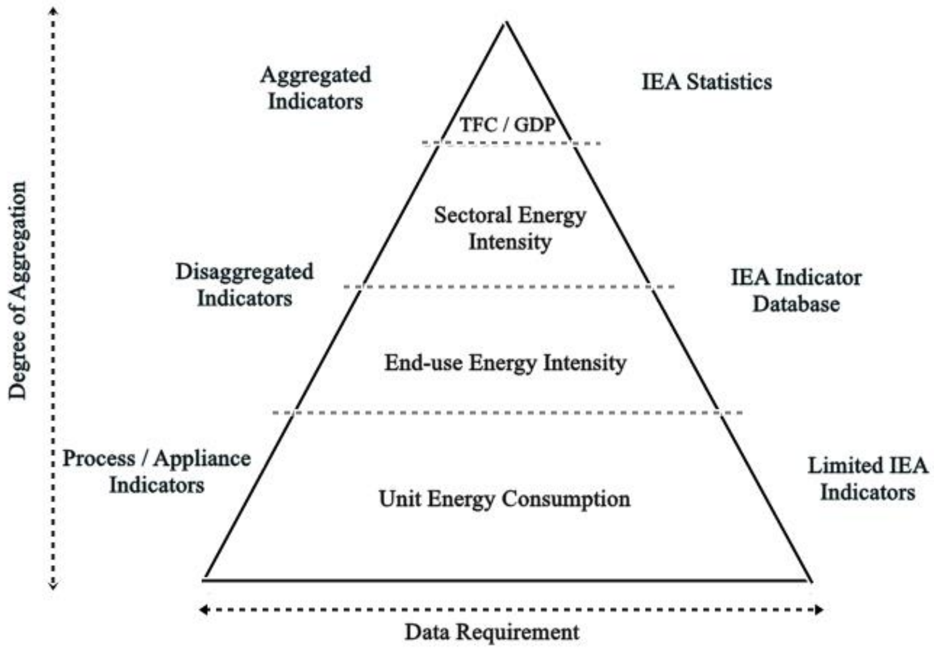

Figure 3.2 : The IEA indicator pyramid (IEA, 2011).

The top row of the pyramid shows the most aggregate indicator which is defined as the ratio energy use to gross domestic product (GDP), but additionally it could be defined as the ratio of energy use to another macro-economic varible, e.g. population. The second row of pyramid displays energy intensity of each sector, as measured by energy consumption per unit activity in each sector. And the lower rows of the pyramid show sub-sectors or end-uses, they give more detail about the process. The lower rows of the pyramid need more data and more complex analysis than the upper rows, as a matter of course lower rows provide a higher quality measure of energy efficiency (IEA, 2011).

Example of indicator pyramid: Industry Sector

The industry sector includes the production of goods, mining and quarrying of raw materials and construction, the pyramid shows that the disaggregation of industrial sector and the different indicators that can be used at each level but it excludes power generation, refineries and the distribution of electricity, gas and water (Figure 3.3) (IEA, 2011).

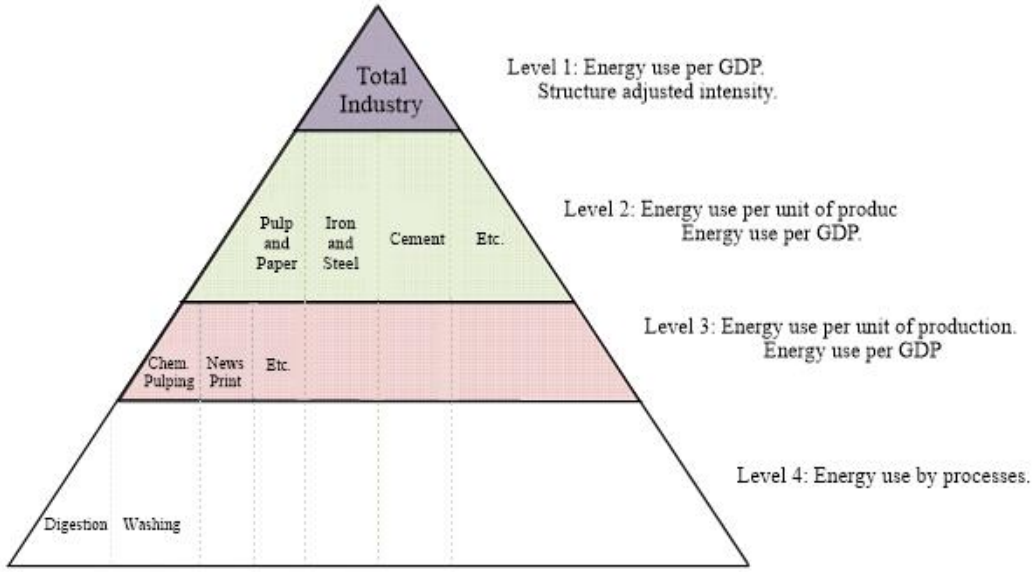

Figure 3.3 : Industrial indicator pyramid (IEA, 2011).

In Level 1, total industry sector shows most aggregate indicator which is energy use per unit of GDP, this ratio implies how much energy is required to manufacture one unit of economic output. Since there are many non-energy efficiency factors (e.g. the structure of the industry, the quality of resources, weather conditions etc.), it would be fallacious to evaluate the energy efficiency based on just this indicator, for this reason, many countries/ organisations enhance structure-adjusted intensity for the more comprehensive evaluation (IEA, 2011).

The industries presented in Level 2 and Level 3 vary by country to country, it depens on their data availability. IEA (2011) reveals that at these levels (Level 2 and 3), the best and commonly used indicator to evaluate energy efficiency is energy use per unit of production, but generally industries are not homogenous and they do not have one measure of production, in situations such as this, GDP (or another monetary value such as gross output) is the second best choice. In Level 4, process indicators provide comprehensive view to energy efficiency. But it necessitates detailed data, unfortunately only a few number of countries have this detailed data for a limited number of industries (IEA, 2011).

<u>Example of indicator pyramid: Residential Sector</u>

The residential sector covers the activities that related to dwellings, it handles all energy consumption activities in apartments and houses, e.g. space and water heating/cooling, lighting and the use of appliances but it does not include personal tranpsort, which is handled in the transport sector. As is the case in industrial sector pyramid, in the residential sector the level of detail depends on data availbility (IEA, 2011).

For instance, Canada is using two pyramid related to residantial sector which are end-uses with energy consumption related to the number of household (Figure 3.4) and end-uses with energy consumption related the floor area (Figure 3.5). These pyramids would not be appropriate for all countries, as mentioned before, it depends on countries' detailed data availability (IEA, 2011).

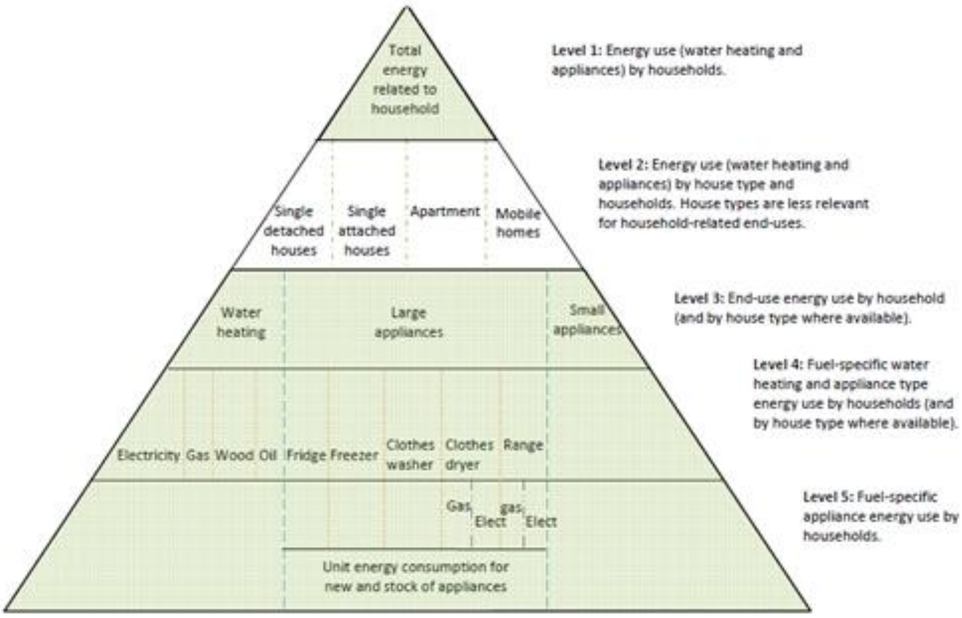

Figure 3.4 : Residential sector pyramid based on household (IEA, 2011).

Consequently, as it can be seen above, the analysis of energy end-use trends differentiates between there main factors which are aggregate activity, sectoral structure and energy intensities (IEA, 2011).

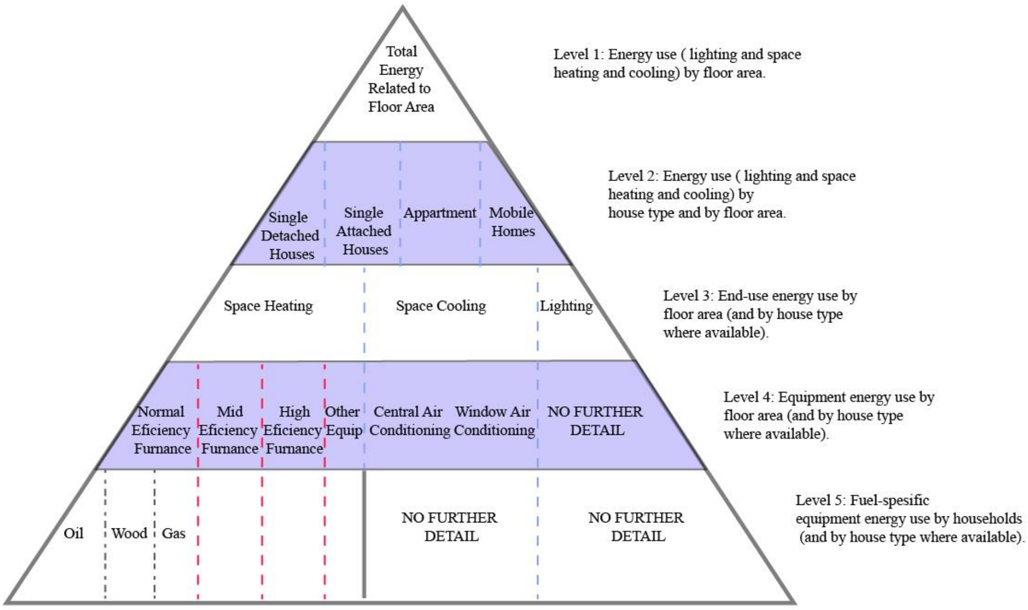

Figure 3.5 : Residential sector pyramid based on floor area (IEA, 2011).

Aggregate activity (A) is measured differently for each sector; for industrial sector it is measured as value added, for residential sector it is measured as population, for transport sector it is measured as passenger- kilometres and for the freight transport sector it is measured as tonne-kilometres.

Sectoral structure (S) presents the combination of activities within sector, it divides into sub-sectors, for instance measures of residential end-use activity or transportation modes.

Energy intensity (I) indicates to energy consumption per unit of activity, to discriminate the effect of different elements over time, IEA uses a factoral decomposition and states as follows (IEA, 2011):

$$y_t = \phi_1 . y_{t-1} + \varepsilon_t \tag{3.4}$$

In this equaiton, the symbols represent the following parameters:

E: Total energy use in a sector

A: Overall sectoral activity

r: Sub-sectors or end-uses within a given sector

S^r: Share of sub-sector or end-use "r" in a sector

I^r: Energy intensity of each sub-sector or end-use "r".

As revealed by IEA (2011), to look for more deeply to energy efficiency in each sector, more detailed data is needed (Figure 3.6), but unfortunately many countries do not have data at this level.

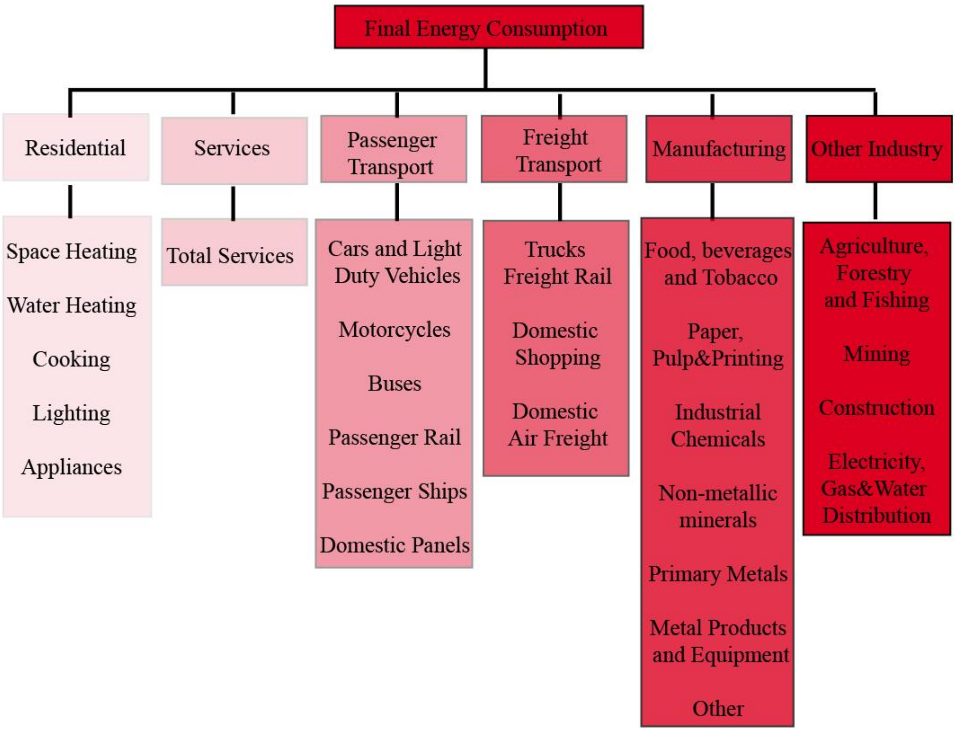

Figure 3.6 : Disaggregation of sectors, sub-sectors and end-uses in IEA energy indicators approach (IEA, 2011)

3.3 Efficiency Measurement Methods

For many companies/firms/cities or organisations, it is very important to examine its efficiency (Vincova, 2005), but unfortunately there has been no accepted and certain methodology on it (Forsström, et al., 2011). Generally, methods of efficiency measurement can be gathered under the three main categories: ratio measure, parametric and nonparametric methods (Vincova, 2005).

Ratio measure is one of the most simple method, which is evaluate small number of indicators and it does not impact total efficiency, e.g. it may cite income per unit of costs. The most common parametric methods of efficiency measurement are

Stochastic Frontier Approach (SFA), Thick Frontier (TFA) and Distribution Free Approach (DFA) (Vincova, 2005), these methods are generally insufficient by the reason of multiple inputs and outputs have connection with to different resources, activities and environmental factors (Bhagavath, 2009), they measure only economic efficiency (Vincova, 2005).

Stochastic Frontier Approach is a econometric modeling (Vincova, 2005) and it is one such method to model producer behaviour (Kumbhakar & Sarkar). SFA models provide to analyse technical inefficiency in the perspective of production function (Mastromarco, 2008), and it produces efficiency scores of individual producers hence it is possible to identify those who need intervention and corrective measures (Kumbhakar & Sarkar). This model is assuming that production units (firms, regions, countries, etc.) produce according to a common technology and when they produce the maximum possible output for a given set of inputs they reach the frontier (Mastromarco, 2008).

Thick Frontier Approach, instead of estimating a frontier edge, compares the average efficiency of a group of firms (Vincova, 2005), it does not impose any distributional assumptions (Tahir & Haron, 2008).

Distribution Free Approach does not require any specific form of distribution or average efficiency of firm, it relies on average variations of a cost function (Vincova, 2005).

And there are two nonparametric methods, these are Data Envelopment Analysis (DEA) and the Free Disposal Hull (FDH). These methods mainly used for technical efficiency, it looks at the level of inputs and outputs. Technically efficient implies that minimum usage of inputs at a given level of outputs or maximum outputs at a given level of inputs (Vincova, 2005).

Free Disposal Hull is a nonparametric and nonstochastic method, it designed as an alternative to data envelopment analysis (DEA) and it can be seen as a generalised DEA model (Vincova, 2005). As compared to other methods, Free Disposal Hull needs minimal assumptions with regard to production technology and the main addition of this method is to relax the convexity assumption DEA models (Borger, Kerstens, Moesen, Vanneste, & Jacques, 1994).

Data Envelopment Analysis is a nonparametric method, linear programming model (Vincova, 2005) and optimization algorithm, which develops efficiency scores for all decision making units (DMUs). In DEA method, efficiency of a decision making unit is calculated relative to the group's monitered best practice (Bhagavath, 2009), efficient DMU's imply that as compared with other DMU's in the group they produce a certain amount of or more outputs while spending a given amount of inputs, or use the same amount of or less inputs to produce a given amount of outputs (Vincova, 2005).

Especially in energy and environmental studies, DEA has been widely applied to measure ecological efficiency (Dyckhoff & Allen, 2001; Korhonen & Luptacik, 2004; Şimşek, 2011; Zhou, Poh, & Ang, 2007), estimate the technical efficiency of energy industries (Thompson, Lee, & Thrall, 1992; Hawdon, 2003; Zhang & Kim, 2014; Al-Najjar & Al-Jajbajy, 2012), assess energy efficiencies of different organizations (Boyd & Pang, 2000; Ramanathan, 2000), measure the energy efficiency of countries/regions/cities (Hu & Wang, 2006; Keirstead, 2013; Zhou & Ang, 2008; Alsahlawi, 2013; Zhang, Cheng, Yuan, & Gao, 2011; Zhi, Pei, & Guoping, 2010; Honma & Hu, 2008).

DEA provides the improving performance of inefficient DMUs by either increasing the current outputs or decreasing the current input levels but both desirable and undesirable factors may be present (Seiford & Zhu, 2002). For example, cities are consuming great amount of energy to provide the services for their citizens but at the same time they are causing great air pollution with CO_2 emissions, in this process CO_2 emissions are considered undesirable output. If inefficiency occurs in a process, the undesirable outputs should be reduced to increase the efficiency (Seiford & Zhu, 2002). Generally accepted that in DEA model, only inputs are allowed to decrease- outputs are not (in a similar way, only outputs are allowed to increase- inputs are not allowed) (Bian, 2008). As revealed by Seiford and Zhu (2002), to improving a DMU's efficiency even if undesirable output (input) needs to be decreased (increased) and it is possible to treat the undesirable outputs as inputs without affecting the production process (Bian, 2008). All these methods mentioned above attain input and output weights in different ways, and they become different (Vincova, 2005).

3.4 Measurement of Energy Efficiency

The measurement of energy efficiency in city, region, country or organisation is precendition to improve the their performance of energy efficiency (Vincova, 2005). But today generally, energy efficiency measurement studies draw a "big picture" of current patterns of energy consumption, many studies in this area use aggregate indicators such as total primary energy supply (TPES) and total final energy consumption (TFC). There are many advantages of aggregate energy indicators - first and foremost they are generally readily widely available and they can be used at cross-country comprasions but at the same time they could generally be misleading and insufficient, and therefore it would be inaccurate (IEA, 2011). Briefly, ratio between GDP and TFC can not explain the energy efficiency performance exactly, there is need of more comprehensive approach.

It should not be forgotten that it is impossible to produce any output with just using energy, in order to produce outputs energy must assemble with other relavant inputs (Hu & Wang, 2006). Traditional energy efficiency measurement approachs take energy consumption into account as a single input that produces an economic output but this approach is very restricted since they ignore some other relevant key inputs, such as capital and labor (Zhang, Cheng, Yuan, & Gao, 2011). Thus, to correctly assess the energy efficiency a multiple model should be used (Hu & Wang, 2006). Total-factor energy efficiency is a new index of energy efficiency which combines energy, labor and capital stock as multiple input so as to produce economic output (Zhi, Pei, & Guoping, 2010).

Although there are many studies in literature on energy efficiency measurements, total-factor energy efficiency approach has been proposed for the first time in 2006 by Hu & Wang (2006). It is developed as an alternative to traditional partial-factor energy efficiency approach. In recent years, there is a growing interest in the field of total-factor energy efficiency, especially in Japan and China which are the the biggest consumers of energy (Dizdarevic & Segota, 2012). As revealed by Honma & Hu (2009), partial-factor efficiency is insufficient and misleading, and can not give the suitable benchmark. In most cases, the use of partial-factor efficiency is insufficiently correct for the evaluation. Total-factor energy efficiency provides an extensive view of indicators (e.g. labor, capital etc). Although total-factor energy efficiency has a more comprehensive a point of view, other relavent inputs and outputs should be integrated into process, e.g. CO_2 emissions which is the inevitable output (undesirable output) of an energy process. For this reason, it does not provide adeqaute view at the urban level studies. Urban energy efficieny studies should consider the other non-energy inputs and outputs such as heating degree day, cooling degree day, CO_2 emission etc. since there are many factors affect the urban energy consumption, for e.g. climate, urban form, density. At the urban level, weather conditions is also one of the most critical factor in energy consumption, as it lead to changes in space-heating and cooling demands, especially in residential and commercial sectors where both heating and cooling demands are significant (Metivie, McIntosh, & Pearson, 1996). Therefore, multiple input/output models should be used at the urban energy efficiency measurement studies.

3.5 Previous Studies on Energy Efficiency Measurement

In 1973**,** world oil crisis has caused a great enthusiasm in applying diffent techniques in energy studies (Loken, 2007), and as a result different methods have been developed to address energy studies (Zhou, Ang, & Poh, 2008). Much of the literature in this area mostly uses Data Envelopment Analysis. For example; Honma & Hu (2009) computed the regional total-factor energy efficiency in Japan by employing Data Envelopment Analysis, they measured 47 prefectures in Japan for the period 1993-2003. They used a new approach that combines the TFEE and the Malmquist productivity index and computed total factor energy productivity index for four representative energy sources (electric power for commercial and industrial use, kerosene, heavy oil and coal) in a multiple-input framework to avoid single-input projudice, hereby, they enabled to compute single-factor productivity under a total-factor framework.

Hu & Wang (2006) analyzed energy efficiencies of 29 administrative regions in China for the period 1995-2002 with a total-factor efficiency index. They accompanied to energy and other relevant inputs (labor and capital stock) to produce real economic outputs. Hereby, by courtesy of TFEE scores they identified that which DMU (region) operates optimally at the efficiency of energy consumption

Zhi, Pei, & Guoping (2010) measured total factor energy efficiency for Chinese cities with constant returns to scale by using 1995-2006 panel data for 210 cities. Their aim was to analyze the differences and causes of urban energy efficiency and get more detailed information and more indepth result. They firstly calculated the urban total-factor energy efficiency, then illustrated regional difference characteristics on Chinese urban energy efficiency, and eventually analyzed impact factors of urban energy efficiency by the help of Tobit model.

Zhang, Cheng, Yuan and Gao (2011) investigated energy efficiency in 23 developing countries during the period of 1980-2005 by using of total-factor framework. They used annual data on the labor force, energy consumption (kt of oil equilvalent) and capital stock as the three input variables and the gross domestic product is the single output. And finally, they used a dynamic Tobit model and found a relationship between total-factor energy efficiency and income per capita.

Keirstead (2013) used and compared the three different methods to investigate urban energy efficiency of 198 local administrative units in UK. He compared three methods which are ratio measures (such as per capita energy consumption), regression residuals and Data Envelopment Analysis, and he found that each method has its positive and negative features (e.g. ease of interpretation, ability to identify outliers, constistent ranking etc.) In DEA model, he used total final energy consumption, land area, population and climate (as measured by the sum of heating and cooling degree days) as an input variables. Life expectancy, carbon dixoide emissions (undesirable output) and access time to services are used as an output variables.

Dizdarevic & Segota (2012) examined economy-wide energy efficiency changes in the EU countries in the period from 2000 to 2010 and compared the results with the traditional energy efficiency indicator. They applied Data Envelopment Analysis CCR multiple input-oriented model in order to investigate the efficiency of the three inputs which are capital stock, labour and energy consumption in producing GDP as the output. And they confirmed that the traditional partial-factor energy efficiency indicator is too plenary and could be deceptive.

And in addition to these above mentioned studies; Ramanathan (2000) used the Data Envelopment Analysis to study the energy efficiencies of transport modes in India, Önüt & Soner (2006) measured building energy efficiency of 32 five-star hotels in Antalya, Hu & Kao (2006) computed energy-saving targets ratios for 17 APEC economies during 1991-2000.

As it can be seen in the literature (Table 3.2) , many energy efficiency measurement studies use the energy intensity as a direct ratio of the energy input to GDP (for example Patterson 1996 and Renshaw 2002) (Honma & Hu, 2008), but this partial-factor energy efficiency is not appropriate and sufficient for the analyze the changing energy use over time (APEC, 2002). Therefore, there is need of more comprehensive approach which will include other relevant inputs and ouputs (Honma & Hu, 2008). Most of the studies mentioned above generally focus on economic features, but very few have taken a comprehensive view.

Table 3.2 : Some of the previous studies on energy efficiency measurement.

Study	***Description***	***Method***
Hu and Wang (2006)	Calculates economic efficiency of Chinese regions	DEA
Keirstead (2013)	Measures urban energy efficiency in UK	DEA
Honma and Hu (2007)	Computes the regional total-factor energy efficiency in Japan	DEA
Zhang, Cheng, Yuan and Gao (2011)	Measures total-factor energy efficiency in developing countries	DEA
Alsahlawi (2013)	Measures energy efficiency in GCC countries	DEA
Zhou, Ang and Q. Zhou (2008)	Estimates economy-wide energy efficiency performance	Parametric frontier approach
Hu and Kao (2006)	Computes energy-saving targets ratios for 17 APEC economies	DEA
Önüt and Soner (2006)	Measures building energy efficiency of 32 five-star hotels in Antalya	DEA
Ramanathan (2000)	Measures energy efficiencies of different transport modes in India	DEA
Keirstead (2013)	Uses three different methods to evaluate the urban energy efficiency	DEA, Ratio measures and Regression

4. TURKEY'S ENERGY POLICY

4.1 Energy and Environment

Environmental problems can be listed among the many consequences of technological progress, and the risks associated with environmental degradation have become more apparent in recent years. Increased human activity associated with the rapid growth in the world population, consumption and industrial activity paved the way to growing evidence of environmental problems. While, in the 1970s, conventional effluent gas pollutants (such as SO_2, NO_X, CO_2, particulates, and CO) were the main parameters taken into account in environmental analyses and legal controls, environmental concerns do now address the control of micro or hazardous air pollutants along with the control of globally significant pollutants such as CO_2 (Omer, 2008).

Fossil fuels have been the primary means to provide for the energy demand in the world. BP (2004) states that 77% of the energy is generated by burning fossil fuels, while the remainder is provided from traditional biomass (9%), large hydropower (6%) and renewable energy (2%). Provision of energy from fossil fuels have major consequences such as acid rains, water and soil acidification, forest die-off, increased occurrences of human respiratory diseases, increased health costs, and decreased agricultural productivity (Masters, 2004). According to Bilen et al. (2008), increase in the rate of illnesses, disruptions in the ecosystem and the increasing threat to society are among the side-effects caused by the consumption of energy generated by using fossil fuels.

According to Martinot (2006), lead emissions to the atmosphere from human activities are on the order of 0.2 million tons per year, 40% of that from fossil fuels and 18 times the natural baseline flow. In addition, every year, approximately 2 million tons of oil are discharged into the oceans, and this figure which is 10 times the baseline of natural oil flow. While the concentration of CO in the atmosphere was 280 parts-per-million (ppm) in the pre-industrial period, it has reached up to 380 ppm today. Also, burning fossil fuels produce 75% of the human-caused emission of CO_2 (Martinot, 2006). Global warming as well as air pollution, acid precipitation, ozone depletion, deforestation and radioactive emissions are among the problems that are associated with the supply and use of energy. If humans continue degrading the environment at the same rate, it is quite apparent that the future holds many challenges (Omer, 2008).

Turkey meets the great amount of its energy needs with fossil fuels and will probably continue to do so. Turkey has been a Party to the United Nations Framework Convention on Climate Change (UNFCC) since 2004 and to the Kyoto Protocol since 2009, but still it does not have effective policy for emissions reduction and environment. In 2010, government published National Climate Change Strategy (2010-2020) in order to promote to facilitate the impacts of climate change. This strategy paper includes a set of objectives to be implemented in the short-term (within one year), the mid-term (undertaken or completed within 1 to 3 years), and long-term (undertaken over a 10 year period). After this strategy document, in 2011, Turkey's National Climate Change Adaptation Strategy and Action Plan has been prepared in the context of United Nations Joint Programme on Enhancing the Capacity of Turkey to Adapt to Climate Change that has been executed under the coordination of Ministry of Environment and Urbanization.

4.1.1 Local air pollution related to energy consumption

Today all the nations are facing with a great environmental pollution. Although humans have caused air pollution from the moment they achieved to control fire, the beginning of industrialization marked a dramatic increase in the rate of air pollution caused by human activities, which lead to the emission of many volatile organic compounds and trace metals into the atmosphere. The pollutants in the atmosphere can diffuse over large areas and result in environmental problems not only at the local scale but also at the regional and global scales (Omer, 2008). And current energy consumption trends pose serious problems to the air quality and human health.

Industrialization and other human activities led to about 30% increase in the rate of CO_2 in the atmosphere. Over the last 100 years, great amounts of coal, petroleum and natural gas were burn particularly in the industrialized countries leading to considerable increase in the CO_2 content in the atmosphere (Berger, 2002). A significant amount of greenhouse gas emissions is produced due to the long-distance transactions that occur in the global networks through which cities are linked for the provision of their food, energy, raw materials, consumer goods and economic output (UN- HABITAT, UNEP & ICLEI, 2009). Martinot (2006) points out that sulfur emissions to the atmosphere from human activities are on the order of 80 million tons per year, 85% of which is from burning fossil fuels. As UNDP (2000) indicates, CO_2 is a greenhouse gas that leads to higher temperatures near the earth's surface. Over the past 100 years, an average increase of 0.6 ^{o}C in temperatures was observed. In addition, the occurrence rate of severe weather events (such as storms, floods and droughts) has considerably went up. In the event that these trends persist, CO_2 content at the end of the century may be triple the rate in the period before industrialization began. Based on the predictions of the Intergovernmental Panel on Climate Change, the increase in temperatures may reach 5.8 ^{o}C over the next 100 years (Boyle, 2012).

Various environmental issues at the local, regional and global levels are the inevitable consequences of the rapid increase in the amount of energy produced and consumed (Kaygusuz & Sari, 2011). Within this context, both the carbon dioxide (CO_2) emissions and the energy consumption in Turkey have increased significantly. As IEA (2005) claims, emissions in 2000 reached 211 metric tons. The direct greenhouse gas emissions in Turkey between 1990 and 2000 by sector are presented in Table 4.1 and Table 4.2 (Akçasoy, Önder, & Güven, 2000).

In order to achieve reduction in the greenhouse gas emissions and enable cities to adapt to the climate change, it is necessary to take certain measures and actions. Out of these, energy efficiency is a common strategy to reduce the greenhouse gas emissions and decrease electricity consumption, and thus, reducing vulnerability to grid overload and outages (The World Bank, 2011).

Table 4.1 : GHG emissions of Turkey in years.

Greenhouse gases (GHG)	Years					
	1990	**1995**	**1997**	**2000**	**2005**	**2010**
Total Direct GHG	200,720	241,717	271,176	333,320	427,739	567,000
CO_2 (%)	88.67	87.42	88.93	90.93	92.90	94.53
CH_4 (%)	10.77	10.05	9.42	7.68	5.97	4.52
N_2O (%)	0.56	2.53	1.65	1.40	1.14	0.95
Emission fractions generated from fuel consumption						
Direct GHG	146,735	172,933	195,591	258,314	352,733	491,995
CO_2 (%)	97.3	97.8	98.0	98.2	98.6	98.9
CH_4 (%)	2.1	1.6	1.5	1.4	1.0	0.7
N_2O (%)	0.6	0.5	0.5	0.4	0.4	0.4
Emission fractions generated from industrial processes						
Direct GHG	35,424	47,251	52,929	52,929	52,929	52,929
CO_2 (%)	99.5	89.1	93.5	93.5	93.5	93.5
CH_4 (%)	0.1	0.1	0.1	0.1	0.1	0.1
N_2O (%)	0.4	10.8	6.4	6.4	6.4	6.4
Emission fractions generated from the burning of agricultural residues						
Direct GHG	591.05	550.25	578.5	578.5	578.5	578.5
CH_4 (%)	76.92	76.90	76.96	76.96	76.96	76.96
N_2O (%)	23.08	23.10	23.04	23.04	23.04	23.04

Table 4.2 : Total CO_2 emissions by sector in years (million tones of CO_2 equivalent).

	1990		1995		2000		2005		2011	
	Emis. (a)	% (b)	Emis. (a)	% (b)	Emis. (a)	% (b)	Emis. (a)	% (b)	Emis. (a)	% (b)
Energy	132,13	70,6	160,79	67,7	212,65	71,6	241,75	73,3	301,25	71,3
Industry	15,44	8,3	24,21	10,2	24,37	8,2	28,78	8,7	56,21	13,3
Agriculture	29,78	15,9	28,68	12,1	27,37	9,2	25,84	7,8	28,83	6,8
Waste	9,688	5,2	23,83	10,0	32,72	11,0	33,52	10,2	36,13	8,6
Total	**187,03**	**100**	**237,51**	**100**	**297,01**	**100**	**329,9**	**100**	**422,42**	**100**

(a) Tonnes of CO_2 equivalent
(b) Percentage in total

4.1.2 Turkey's national climate change action plan

The number of countries that prepare specific plans to plan for climate change or that adapt their existing plans, policies and projects to address climate considerations presents an upward graph (The World Bank, 2011). Although major steps have been taken in Turkey towards the protection of the environment, it is still required to take further action. Turkey was able to adhere to the United Nations Framework Convention on Climate Change (UNFCCC) in May 2004 - ten years after the convention became effective, and in 2010 government published the first National Climate Change Adaptation Strategy and Action Plan. This plan mainly have focused on five important areas which are Water Resources Management, Agricultural Sector and Food Security, Ecosystem Services, Biodiversity and Forestry, Natural Disaster Risk Management and Public Health.

Decreasing greenhouse gases is one of the important objectives of this plan and it is critical to ensure that all market operators (including those owned by the state) comply with the current air quality and emissions legislation. The investments made in order to increase security in the congested tanker traffic through the Turkish straits are promising. However, the authorities are still required to take further action, such as seeking alternative transport routes, continued cooperation with other Black Sea nations and increased involvement of large oil and gas importing countries (IEA, 2005; MENR, 2005; MEU 2010).

It is very likely that the environmental damage, such as severe air and water pollution, destruction of certain ecosystems in large regions, pervasive losses of natural habitat and the reduction of plant and animal diversity, will continue over the next decades. The environment in Turkey was significantly affected by the booming economic growth in the mid-1990s where economic growth and energy consumption together led to increased air pollution, particularly in cities where pollution levels were already alarming. Despite being lower than the advanced European countries, the per capita carbon emissions in Turkey are increasing. Turkey adopted the Kyoto protocol in order to help gain membership in the EU; however, the country does not have a formal emissions reduction target (Kaygusuz & Sari, 2011; Akçasoy, Önder, & Güven, 2000).

4.2 Turkey's Energy Policy

4.2.1 Country overview

Over the last years, Turkey has been undergoing major economic changes and its population has reached 77 million. Also its economy expanded and as a growing consumer, its energy demand has increased largely, and it is expected to will continue to grow in the future. Under favour of increase in its energy demand, Turkey is expected to become one of the most dynamic energy economies (MFA, 2015). In Turkey, a huge increase of energy consumption throughout the all cities is causing a growing pressure on the environment and economy.

Under the sustainability perspective, Turkey has made important efforts with related to energy and environment, an independent regulator (EMRA) has been established, an ambitious privatization programme has been announced, the United Nations Framework Convention on Climate Change (UNFCCC) has been ratified (MENR, 2005; WECTNC, 2003).

4.2.2 Energy trading in Turkey

As it can be seen in Figure 4.1, Turkey's energy export has increased from 2,46 mtep in 1990 to 10,32 mtep in 2012. In 2010 total energy export was 8,4 mtep, in 2011 it was 9,15 mtep. And Turkey's energy import has increased from 31 mtep in 1990 to 98,7 mtep in 2012. In 2011 total energy import was 90, 3 mtep.

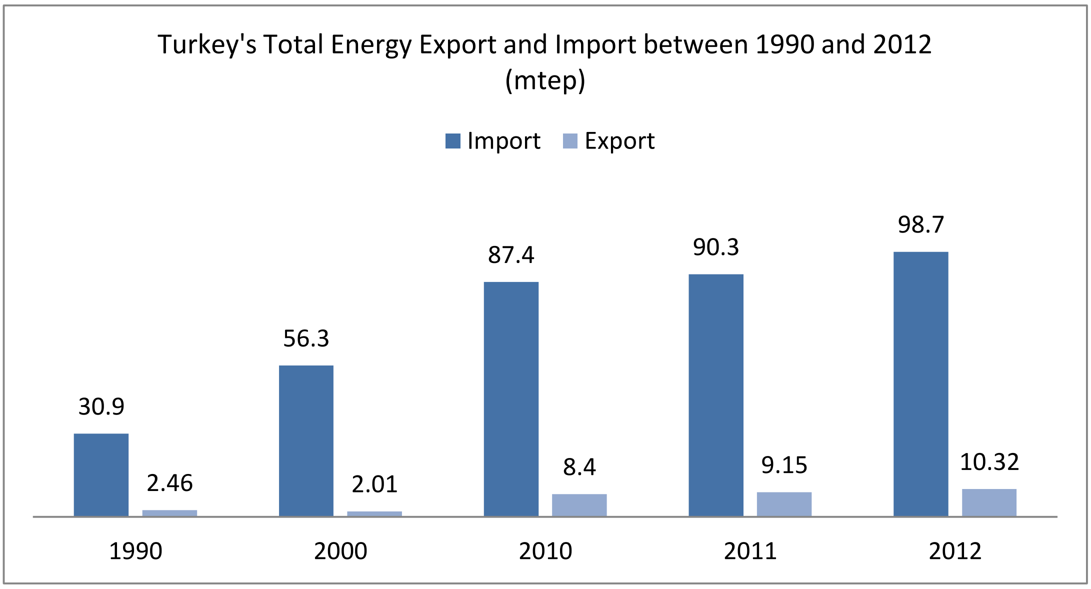

Figure 4.1 : Turkey's total energy import and export between 1990 and 2012 (ETKB).

When analyzed the development of Turkey's growing energy import on the basis of sources between 1990 and 2012 (Figure 4.2); it can be clearly seen that natural gas has enlarged substantially and it has increased approximately thirteen times, from 3 mtep to 37,9 mtep. In 2011 and 2012, import of petrol and natural gas are seen in similar levels. The import of petrol has increased by 62 % in 2012 when compared with 1990, from 23,4 mtep to 37,9 mtep. And from 1990 to 2012, the import of hard coal has increased approximately five times, from 4,2 mtep to 19,5 mtep (DEK-TMK, 2014).

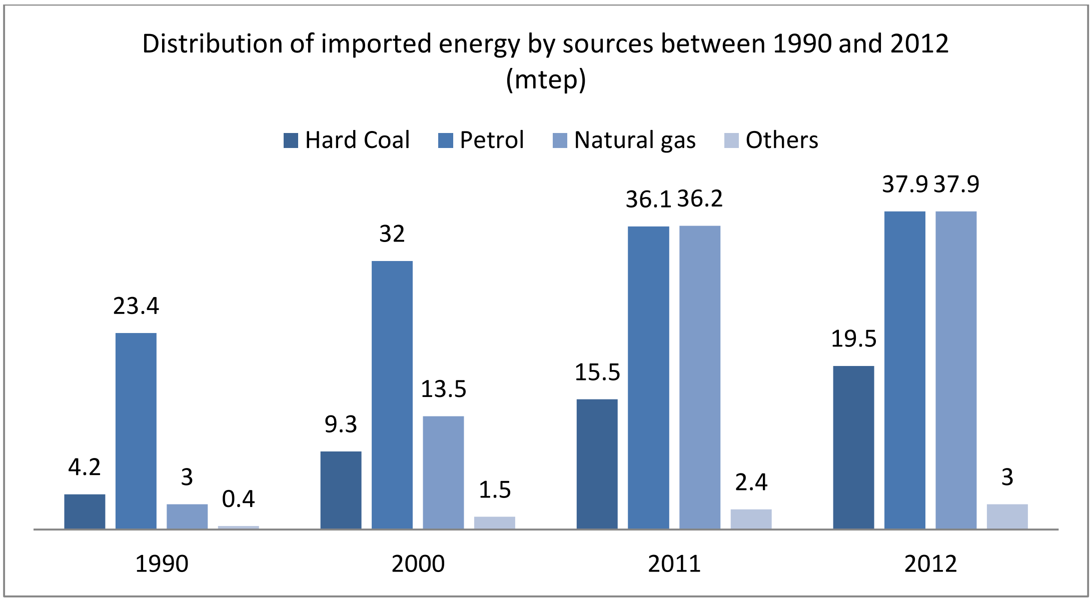

Figure 4.2 : Distribution of imported energy by sources between 1990 and 2012 (ETKB).

4.2.3 Energy production, supply and demand in Turkey

From 1990 to 2012, Turkey's energy production has increased by 35 %, from 25.478 bintep to 34.3467 bintep (Figure 4.3). And in this period, total primary energy supply has increased by 128 % (DEK-TMK, 2014).

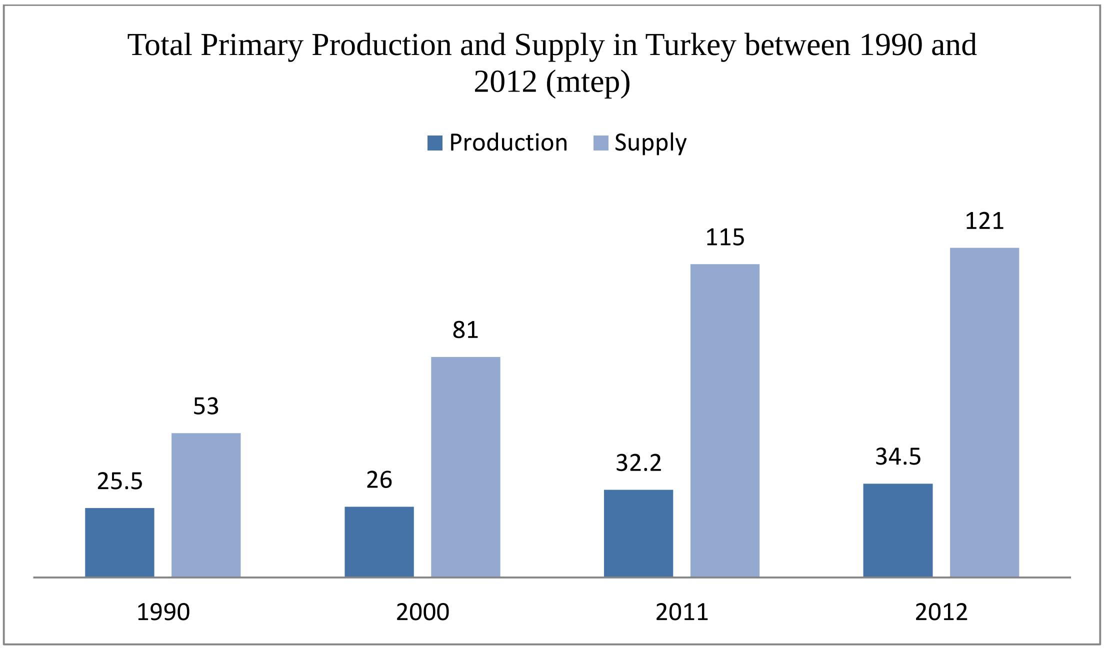

Figure 4.3 : Total primary production and supply in Turkey between 1990 and 2012 /mtep) (DEM-TMK, 2014).

Table 4.3 shows Turkey's primary energy consumption by souces between 1990 and 2012 years. And the Figure 4.4 shows the changes in supply and demand of energy in years of Turkey.

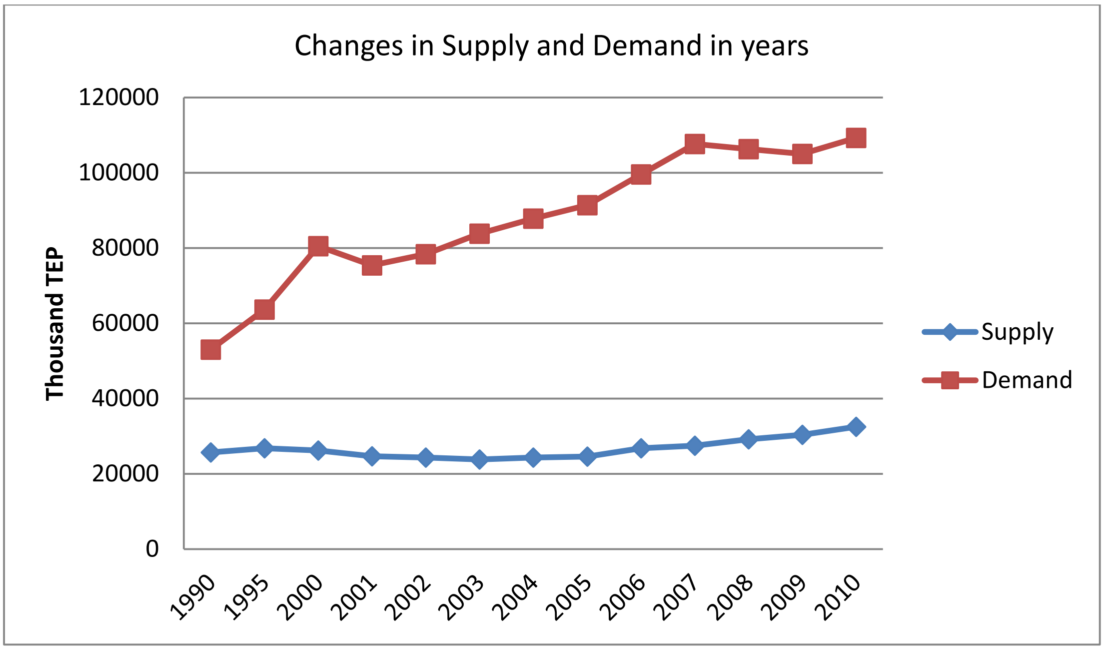

Figure 4.4 : Changes in supply and demand in years.

Table 4.3 : Primary energy consumption by souces between 1990 and 2012 years.

Years		**1990**	**2000**	**2011**	**2012**
Coal	bintep	16.110	22.928	33.879	37.977
	%	**30**	**29**	**30**	**31**
Petrol	bintep	23.901	32.297	30.499	30.614
	%	**45**	**40**	**27**	**25**
Natural gas	bintep	3.110	13.729	36.909	37.373
	%	**6**	**17**	**32**	**31**
Hydrolics	bintep	1.991	2.656	4.501	4.976
	%	**4**	**3**	**4**	**4**
Odun, çöp, vb.	bintep	7.208	6.457	3.537	3.465
	%	**14**	**8**	**3**	**3**
Jeotermal, Güneş, Rüzgar	bintep	461	978	3.096	3.508
	%	**1**	**1**	**3**	**3**
Diğer	bintep	206	1.456	2.071	3.071
	%	**1**	**2**	**2**	**3**
Primary Energy Consumption	bintep	**52.987**	**80.500**	**114.490**	**120.984**
	%	100	100	100	100

Respectively, in 1990 48% of , in 2000 32 % of, in 2011 28 % of and the in 2012 28,5 % of total supply has been met by total energy production (Figure 4.5). Hence, between 1990 and 2012, it is possible to say that production has decreased by 20 % or dependence on foreign sources has increased by 20 %.

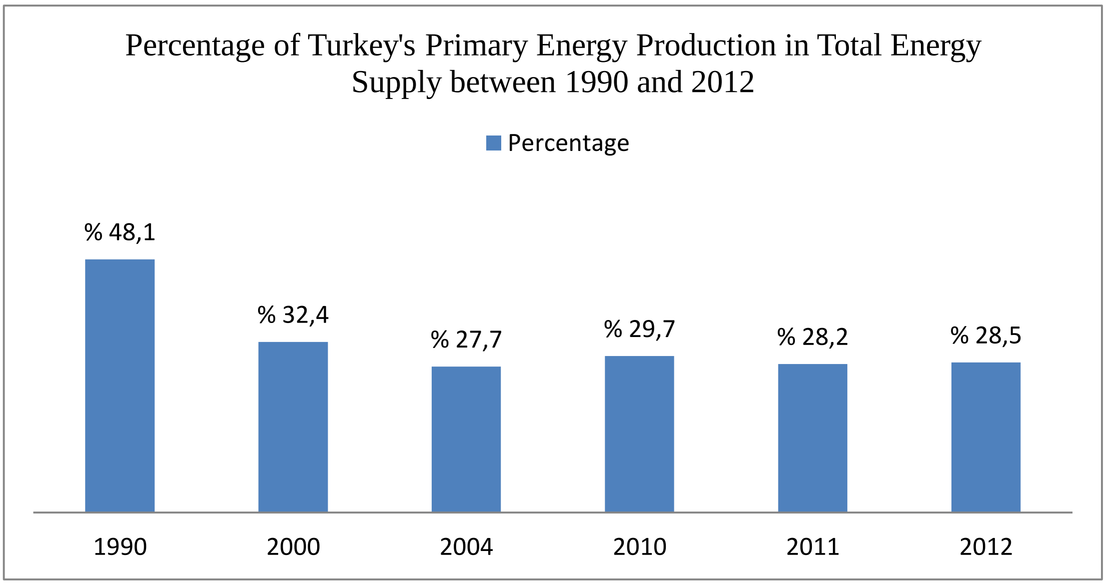

Figure 4.5 : Percentage of Turkey's primary energy production in total energy supply between 1990 and 2012.

In 2011, Turkey's total primary energy production was 32,32 mtep, in 2012 it has increased by 7% and reached 34,47 mtep. In 2012, 57 % of total energy production was generated from hard coal, followed by with 14 % hydrolics, with 10% geothermal, wind and solar (renewable energy sources), with 10 % wood and trash, with 7 % petrol and with 2 % natural gas (Figure 4.6).

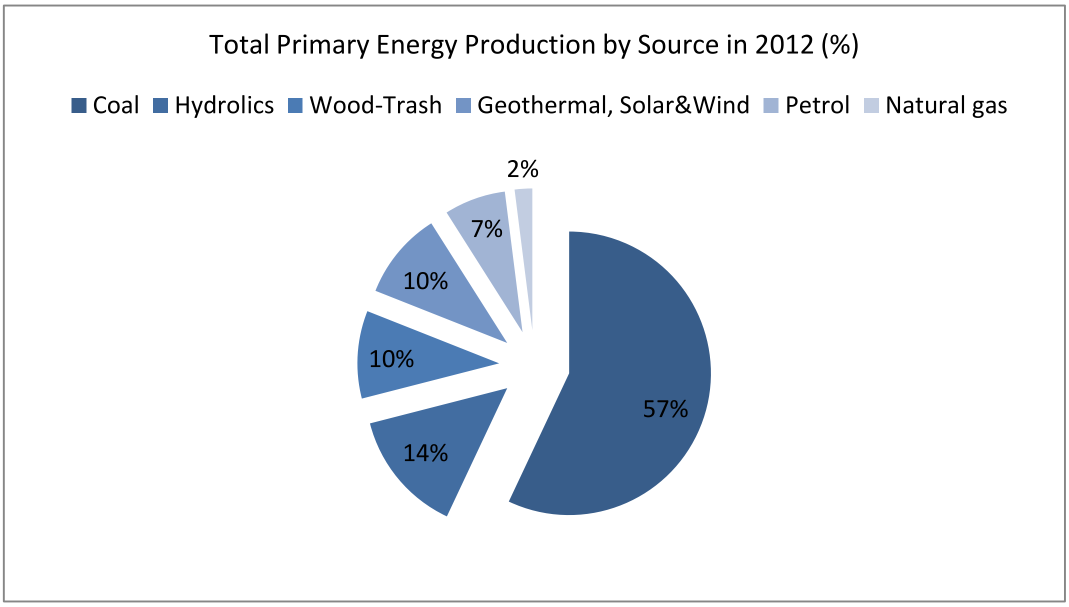

Figure 4.6 : Total Primary Energy Production by Source in 2012 (%) (ETKB).

4.2.4 Energy efficiency policies

- Energy Efficiency Law 2007; aims to increase efficiency in using energy sources with the intent of decrease waste, reduce the burden of costs on the economy and environment.
- Energy Efficiency Strategy Document 2012; Aims are as follows:

- To reduce energy intensity and energy losses in industry and services sectors

- To decrease energy demand and carbon emissions of the buildings and to promote sustainable environment friendly buildings using renewable energy sources

- To provide market transformation of energy efficient products

- To increase efficiency in production, transmission and distribution of electricity; to decrease energy losses and harmful environment emissions

- To reduce unit fossil fuel consumption of motorized vehicles, to increase share of public transportation in highway, sea road and railroad and to prevent unnecessary fuel consumption in urban transportation

- To use energy effectively and efficiently in the public sector

- To strengthen institutional structures, capacities and collaboration; to increase use of state of the art technology and awareness activities and to develop financial mechanisms except public.

- Energy Efficiency Strategy Paper for Turkey 2012-2023; purposes are as follows;

  - To reduce energy intensity and energy losses in industry and services sectors

  - To decrease energy demand and carbon emissions of the buildings; to promote sustainable environment friendly buildings using renewable energy sources

  - To provide market transformation of energy efficient products

- To increase efficiency in production, transmission and distribution of electricity, to decrease energy losses and harmful environment emissions

- To reduce unit fossil fuel consumption of motorized vehicles, to increase share of public transportation in highway, sea road and railroad and to prevent unnecessary fuel consumption in urban transportation

- To use energy effectively and efficiently in public sector

- To strengthen institutional capacities and collaborations, to increase use of state of the art technology and awareness activities, to develop financial mechanisms except public financial institutions

- Regulations

  - Increasing efficiency in energy resources and consumption 2011

  - Energy performance of buildings 2008

  - Cost sharing at central heating systems 2008

  - Energy efficiency in transportation 2008

  - Energy efficiency supports for SMES 2010

  -Energy managers assignment in public schools 2009

  - Efficiency requirements of gas or liquid fuel boilers 2008

  - Energy Labeling for Air Conditioners 2006

  - Energy efficiency requirements for refrigerators and freezers 2006

  - Labeling for refrigerators and freezers

  -Energy Efficiency requirements for lightning 2006

- Notifications

  - Labeling for dishwashers, washing machines, drying machines, ovens

- Circulars

- Related Strategy Papers

  - National Climate Change Strategy Document 2010

- National Climate Change Action Plan
- Industrial Strategy and Action Plan
- TAEK Strategy
- TÜBİTAK Strategy
- SMES Strategy

4.2.5 Critique

Comparing to IEA contries, Turkey is expected to have the fastest growth in energy demand in medium to long term. In Turkey the young population is high, urbansation is fast and still TFC per capita is low. In coming years, the popularity of automobiles and electronic devices will increase and Turkey will undergo new construction. Recently assuring sufficient energy is primary concern of government's energy policies especially for growing economy. It seems to remain its importance in the future. Turkey has become more concerned about energy efficiency and its benefits. It also started to work on energy supplies security, pollution redution and money saving (IEA, 2010).

2007 Energy Efficiency Law in Turkey is appriciated by IEA. It supports Turkey about enforcing energy law by mobilizing all the resources needed. The best practices of other countries can be advantage for Turkey to more sustainable energy usage instead of unsustainable energy concumption pattern. Turkey's roadmap on energy efficieny future can lead other developing countries as an example. Therefore IEA ecourages Turkey to share the learnings on the road to increasing energy efficiency. Turkey is working on improving energy efficiency comprehensively. It has plans for future improvements such as decreasing energy intensity at least 15% below the scenario projections by 2020. Also, energy efficiency service market, supporting sectors' energy efficiency projects and increasing public awareness are within its prior policies. Those policies and measures should be analised and conformed by government. In this context, statistics on sector-spesific energy consumption and efficiency keep importance for government which are emboldened by IEA for improvements (IEA, 2010).

Turkey needs to update the Energy Efficiency Strategy prepared in 2004 immediately for its further works on energy efficiency. Another important point is revising the energy efficiency legislation regularly in order to enhance and adapt the policies for transparency as well. The more ambitious targets should be considered by government. In the meantime Turkey should close the gap on its technical knowledge and qualified staff about energy efficiency. Also it should improve its financial resources. Turkey also needs economic encouragements in order to expedite the improvements on energy efficiency. That will support to improve energy security, save money and mitigate to climate change (IEA, 2010).

Turkey has achived energy efficiency on building sector with minimum performance standards execution. Those standards should be updated for the coming years by government in order to sustain more efficient and cos-effective solutions. Also, for new and existing buldings high-efficiency should be sustained by government with the help of incentives. High living standards will come with the more appliances. Turkey can set energy performance standards examining the best practice internationally if it is applicable for appliances and lighting instead of seting the minimum standards of EU which it is likely to follow (IEA, 2010).

Climate change impacts are likely to increase the demand energy for air-conditioning and this should considered especially. It is possible to decrease demand for cooling with low-cost measures such as natural shading and using light colours for roofs and pavements. Those measures are helpful for both reducing energy consumption for cooling and saving money which government would spend for energy generation and consumption. 2007 Energy Efficiency Law specifically focus on industry becouse it is the largest sector that consume energy while it is the important for efficiency. An energy management system for industry which is the largest consuming sector with 39% was established. Many certified energy managers have been educated. Government encouraged industry to effort energy efficiency measures which have short-term payback adventage. For that purpose Energy Services Companies (ESCOs) as third-party financed and trained the industry. This is a new approach for Turkey which need to be supported by government and awareness should be rised on energy efficiency in industry and finance sector (IEA, 2010).

The passenger and freight transportation is also important issue since they are transported by inefficient vehicles by road in most of IEA member countries. The number of people having car is not high however, it increasing. The fright transport by road will also continue correlated with GDP. This situation reveals that Turkey has unsustainable transportation trends which is oil and car based as other IEA contries have. However, Turkey has adventage with its low car ownership ratio to avoid the dependance on unsustainable transport. The current transportation system of Turkey is unsustainable and the government is aware of it. The IEA appriciates Turkey's plans on expanding railway network, using high-speed trains and increasing the use of railways. Those plans are important and beneficial to decrease the demand for car and sustain environmental protection and energy security. For a sustainable transportation system the more effort is needed. Fast growing urban areas should be considered specifically by governments. Policies on land use planning, parking and pricing, road pricing, public transportation and non-motorised transportation should be developed fot those urban areas. Railway transportation shold be improved more and dominated over road in freight and long distance passenger transport. Turkey also needs fuel economy standards for vehicles and regulations on non-motor integral that impact vehicle energy efficiency (e.g. tyre rolling resistance and tyre pressure). In order to encourage for efficient vehicles, taxation can be used. Transportation is the largest oil-based and consuming sector with current trends. Changing those trends would be beneficial for saving money, avoiding congestion, improving air quality, increasing oil security. For more sustainable transportation system Turkey should develop a comprehensive transportation strategy and implemented ambitiously (IEA, 2010).

5. MEASURING URBAN ENERGY EFFICIENCY IN TURKEY

5.1 Prefatory Remarks

For many countries energy is the vital component to provide social and economic development but at the same time reckless energy consumption brings great challenges like climate change and energy scarcity. As a policy objective energy efficiency helps countries to respond to the challenges of climate change and energy scarcity.

Turkey imports vast amount of energy (especially gas and oil) it uses, according to TURKSTAT (2013), in 2012, Turkey has paid more than 60 billion dollars for energy import. This great amount of energy import is causing diffuculties for the economy. So there is a urgent need of energy efficiency improvement but firstly it should be measured on a urban/region/country level.

This study provides empirical evidence on measurement urban energy efficiency in Turkey and it contributes to the existing energy efficiency literature by presenting an assessment of energy efficiency applying the DEA[1] methodology.

5.1.1 Aim objectives

The aim of this study is to measure urban energy efficiency in Turkey by determining critical success factors in efficiency. The study is focusing 81 provinces of Turkey. For the economic and social development energy efficiency is an essential for the cities, and the study mainly asks these questions; which cities are the best and worst performers in Turkey, which cities are using their sources effectively and what are the factors that cause efficiency/inefficiency?

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[1] MaxDEA Pro 6, Beijing Realworld Research & Consultation Company Ltd.

5.1.2 Methodology

The methodology of this study is based on linear programming technique which is Data Envelopment Analysis (DEA). In recently, DEA has gained great popularity in measuring energy and environmental efficiency (Zhang & Kim, 2014), it identifies the best practice among a sample of units (Al-Najjar & Al-Jajbajy, 2012). DEA is a useful method to take into account energy related emissions (e.g. undesirable outputs- *CO_2 emissions*) (Zhang & Kim, 2014).

Data Envelopment Analysis (DEA) is a multi-factor productivity analysis model for measuring the relative efficiencies of a homogenous set of comparable entities - often called decison making units (DMU'S) (Yılmaz & Harmancıoğlu, 2007), these DMU's could be organisations, divisions, or entities, that use similar inputs and produce similar outputs (Al-Najjar & Al-Jajbajy, 2012). DEA methodology originally introduced by Charnes et al in 1978, and the main purpose of this method is to construct a non-parametric envelopment frontier over all sample data (Coelli, Rao, O'Donnel, & Battese, 2005), and it is a great tool to estimate "relative" efficiency of a chosen entity in a given group of units and criteria (Vincova, 2005). Since DEA only measures efficiency relative to best practice within the specific sample, it is not meaningful to compare the results between different studies (Bhagavath, 2009). Data Envelopment Analysis derives input and output weights by means of an optimising calculation, thanks to this, it can be classify to units into efficient and inefficient (Vincova, 2005).

Vincova says that "efficient DMU's are those that produce a certain amount of or more outputs while spending a given amount of inputs, or use the same amount of or less inputs to produce a given amount of outputs, as compared with other DMU's in the test group" (Vincoca, 2005; 24).

Data Envelopment Analysis (DEA) has gained great popularity in many studies in recent years by courtesy of their advantages. As Raju & Kumar (2006) reveal there are many advantages of DEA, these are; (1) It is possible to effectively use multiple inputs and multiple outputs while ascertaining efficiency and a specific production function is not required (2) Decision Maker doesn’t need former information about weights of the inputs and outputs (3) Each Decision Making Unit (DMU), efficiency is compared to that of an ideal operating unit, rather than to the average performance (4) On the contrary of Multicriterion Decision Making (MCDM) techniques, DEA does not require numerous parameters, which are difficult to be determined precisely requiring extensive sensitivity analysis.

Raju & Kumar (2006) also define one main disadvantage of this method, that is; standard formulation of DEA creates a separate linear program for each DMU, and this will be computationally intensive when the number of DMUs is large. In addition, another disadvantage is that the DEA method is based on extreme points, and it compares each unit to the best performers, therefore, DEA analysis more sensitive to data noise and measurement errors (Vincova, 2005). Results are especially sensititive to measurement error. As Bhagavath (2009) reveal; DEA results are sensitive to input and output specification and the size of the sample. And Vincova (2005) highlights that DEA is not completely faultless, it calculates "relative" efficiency of a selected unit within a group, but stops short of estimating absolute efficiency.

There are two models in Data Envelopment Analysis which are constant returns to scale (CRS) and variable returns to scale (VRS). CRS model supposes that output will change by the same ratio as inputs are changed (for example; reduplicating all the inputs will reduplicate the outputs), on the other hand VRS model suggests that output (production) may show increasing, constant or decreasing returns to scale (Pascoe, Kirkley, Greboval, & Morrison-Paul, 2003). If it is suspected that an increase in inputs does not show in a same ratio in the ouputs, VRS model should be used. It is well-known that cities are not showing constant returns to scale and they are demonstrating superlinear scaling for indicators of social and economic activity and sublinear scaling for infrastructure condition (Bettencourt, Lobo, Helbing, Kühnert, Christian, & West, 2006). As a consequence, it is possible to say that for urban studies CRS model is unsuitable, variable returns to scale (VRS) should be used (Keirstead, 2013). This study measures energy efficiency of Turkish cities with variable returns to scale (VRS) data envelopment analysis.

5.2 Indicators, Data Sources and Statistics

Literature on the measurement of energy efficiency shows that no single indicator framework is appropriate for all cases, many professionels agree that "there are no indicator sets that are universally accepted, backed by compelling theory, rigorous data collection and analysis, and influential in policy" (Parris & Kates, 2003). As a result, researchers must carefully choose their indicators to maximise their relevance and effectiveness (Keirstead, 2007). Besides the selecting of indicators, the availability of good quality data is also important to the production of high quality analysis (Metivie, McIntosh, & Pearson, 1996).

In this study, five input variables and three output variables are used for urban energy efficiency measurement. Input variables include land area, population, total energy consumption (per capita), heating degree days (HDD) and cooling degree days (CDD). HDD and CDD are required to identify energy consumption arising from climate, these are very important inputs which affect to energy consumption considerably and with regard to climate and latitude amount of heating and cooling varies (Doherty, Nakanishi, Bai, & Meyers, 2013). HDD and CDD highlight the energy usage for heating and cooling. As noted by Metieve, McIntosh & Pearson (1996), a colder winter or a warmer summer can both cause to more energy energy consumption. The outputs variables considered for the study annual income, life expectancy and CO_2 emissions. As a matter of fact, CO_2 emission is an input in the production process but it be approved as an undesirable output of a process. It should not be forgotten that even if some are considered more or less significant, all indicators mentioned above have an impact on energy efficiency performance of cities (Vincova, 2005).

Total energy consumption includes different energy sources which are electricity, nonleaded 95 octane petrol, extrinsic 95 octane petrol, diesel oil, fuel oil 3, fuel oil 4 (heating oil), fuel oil 5, fuel oil 6 and natural gas. All these energy units are transformed into the one unit- tonne of oil equivalent (See Appendix 1). Table 5.1. presents the summary statistics of the inputs and outputs used in the DEA model.

Data on land area, population, life expectancy, energy consumption are taken from Turkish Statistical Institute (TURKSTAT). Heating and cooling degree days are taken from Turkish State Meteorological Service. Since there are no official statistics on carbondixoide emissions, it is taken from the estimated data from Can (2013). The data regarding the energy consumption is acquired from electricity, natural gas,coal and oil separately and is used by converting to one unit which is tonnes of oil equilvalent (TOE). Energy chart is attached (see Appendix A.1). The content of oil consumption is comprised of: unleaded 95 octane fuel, unleaded 95 octane fuel, kerosene, diesel, rural diesel (gasoil), fuel oil 3, fuel oil 4 (heating oil), fuel oil 5, fuel oil 6.

Table 5.1 : Summary statistics of data used in the analysis (n=81 cities).

Variable	**Unit**	**Mean**	**Std. Dev.**	**Min.**	**Maximum**
Inputs					
Land Area	Km^2	9695,641975	6555,4532	850	41001
Population	person	933671	1668005,158	75797	13854740
Energy Cons. (per cap.)	TOE	0,437075432	0,216622995	0,06672	1,04518
Heating Degree Days	C^o	2259,96296	825,381888	824	4708
Cooling Degree Days	C^o	357,85185	301,38883	0	1188
Outputs					
Life expectancy	years	76,8	1,131	74,6	79,8
Annual income	dolar	13284	6324,513997	2595	33620
CO_2 Emissions	tonnes	1423428,809	2277578,878	71630	15743834

In addition to the these indicators, urban density and form have a great effect on the energy consumption. For example, low density implies low public transportation and high private transportation and that increases energy consumption for transportation. And loose urban form causes widen infrastructure system (Forsström, et al., 2011). It is possible to add more indicators that provide more comprehensive view to urban energy efficiency. To evaluate more comprehensively urban energy efficiency data of sub-sectors and end-uses are necessitated.

5.3 Empirical Results

Data Envelopment Analysis VRS model has been applied to measure urban energy efficiency. Under the assumption of Variable Returns to Scale, it was found that average technical efficiency score for cities is 0.9038 which means that on average cities could have used 9,62 % fewer resources to produce the same amount of output. Thirty six cities are found efficient, which means they operate at most productive scale size. Table 5.2 presents the summary of DEA results.

As it can be seen in the energy efficiency map of Turkey (Figure 5.1), most of the cities along the Black Sea coast, eastern region and the Mediterranean coast of Turkey are almost all energy efficient. And the central anatolia region and its eastern side region has most of the inefficient cities. And in addition to these regions, independently of their regions, Edirne, Muğla and Balıkesir are inefficient. The probable reason why the cities along the Black Sea coast, eastern region and the Mediterranean coast of Turkey are efficient, is that they consume less energy and produce more output. Generally, it is not possible and accurate to evaluate energy efficiency performance of cities by their regions since they can be efficient or inefficient independently of their regions. Certainly regional differences (climate, culture - especially energy consumption behaviours, industrial production of cities etc.) greatly affect the energy consumption and in turn energy efficiency in cities but this map should not be interpreted at regional scale. Therefore, to make a more accurate interpretation, each city or each catergory should be analyzed deepestly (section 5.4).

Table 5.2 : Distribution of the clusters.

Ranking Cluster	**Efficiency Score**	**Quantity**
Least efficient	0,6336 - 0,7251	5
Less efficient	0,7252 - 0,8167	17
Average	0,8168 - 0,9083	11
More efficient	0,9084 - 0,9999	12
Most efficient	1	36

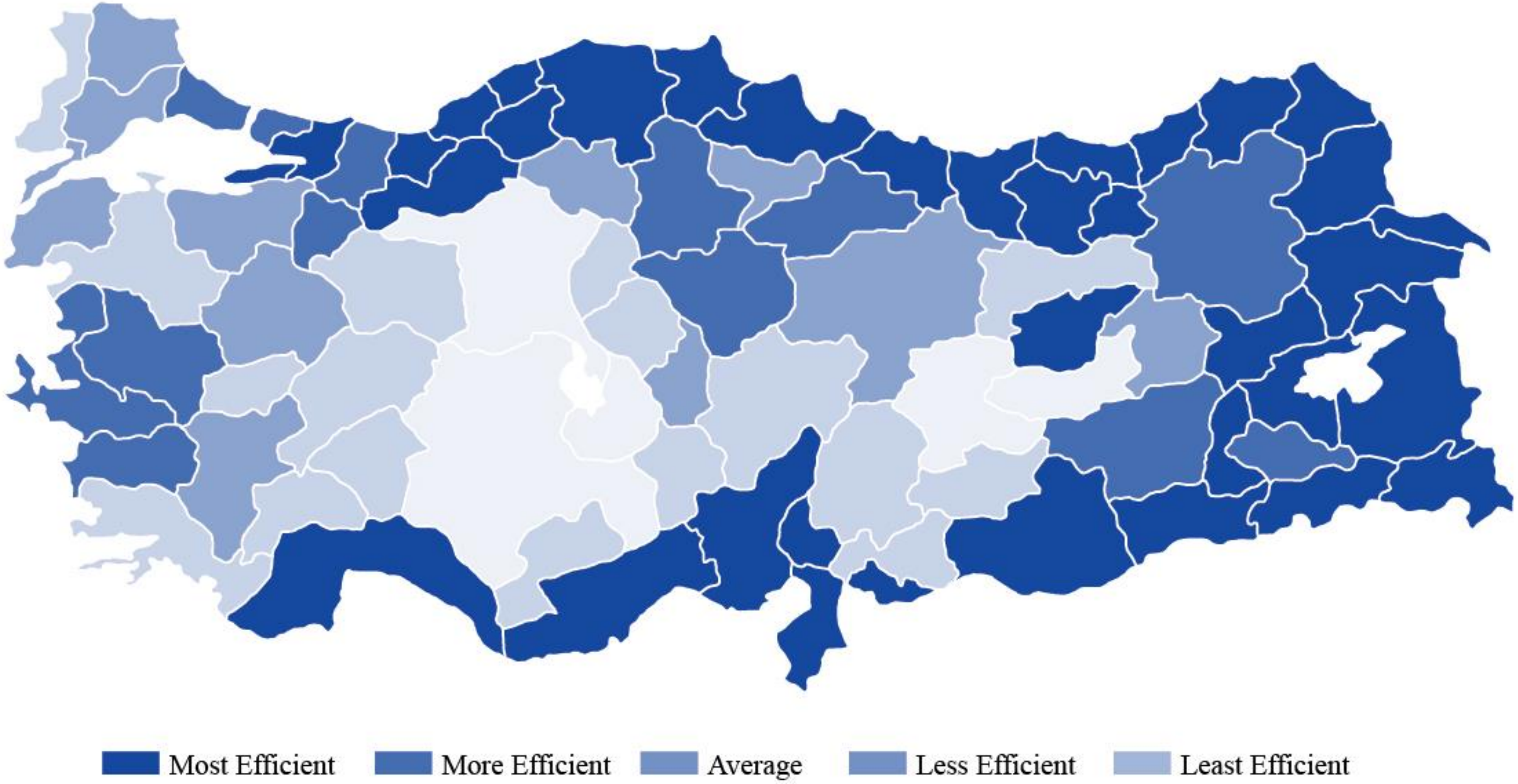

Figure 5.1 : Geographic distribution of efficient and inefficient cities in Turkey.

5.4 Analyzing Critical Success Factors in Efficiency

5.4.1 Least efficienct cities

As it can be seen on the map (Figure 5.1), the cities of Aksaray, Ankara, Elazığ, Konya and Malatya have arisen with least energy efficieny. When the common traits of these cities are analysed, similarities are seen in the heating and cooling degree days (see Appendix A.2). Especially, when the heating day levels are studied, it is possible to state that similar levels of energy is consumed for heating in winter. When the cooling day levels are studied, in summer months Elazığ and Malatya consume approximately same level of energy for cooling. Yet, Aksaray, Ankara, and Konya show less necessity of energy consumption when compared with the other two cities. Although Ankara has high population density and higher income level, the underlying reason of showing less energy activity is that per capita energy consumption is high and CO_2 emissions are excessive.

5.4.2 Less efficienct cities

When we consider the cities in this group, when compared with other cities, Gaziantep has high population density, per capita energy consumption at average level and low per capita emissions, it is considered that the underlying reason of showing less energy efficiency is that low income and life span.

When we study Erzincan having rather low density, although it has low emission, it is considered that the underlying reason of energy efficiency is that low annual income and low density.

Again in the same group, when Burdur, Karaman and Kırşehir are considered that show similar densities, they all need the similar levels of energy for both heating and cooling. Among these three cities, although Burdur has higher per capita energy consumption; it has less CO_2 emission. It is conceived that the reason is the energy is generated less frequently from the fossil fuels in Burdur.

When Edirne, Muğla and Uşak are considered that show similar densities, although Muğla has the lowest per capita energy consumption, it has highest emission rates. The reason beneath is that Muğla relies on fossil fuels more when compared with other two cities. Again, annual income in Muğla is very low when compared with other cities. Although Muğla's annual income and CO_2 emissions show relatively poor performance, it is thought that Muğla's having approximately same level of energy efficiency score relies on its low per capita energy consumption.

When Afyonkarahisar, Isparta and Niğde are discerned, it is observed that they all approximately have similar density and spend similar amount of energy for heating and cooling. Even though Isparta and Niğde have same per capita energy consumption, Niğde's CO_2 emission is higher. It is thought that the possible reason is the energy is generated largely from the fossil fuels in Niğde. Although Afyonkarahisar stays behind of Isparta and Niğde in terms of annual income with small differences, it surpasses Isparta and Niğde in terms of less energy consumption and higher life expectancy.

When Eskişehir and Kırıkkale are taken into consideration, they nearly have same density, annual income and efficiency score. While Eskişehir spends more energy for heating than Kırıkkale, Kırıkkale spends more energy than Eskişehir for cooling. With its lower per capita energy consumption, Kırıkkale causes higher emission levels than Eskişehir. Because of the less energy consumption gives rise to more emissions, it is discerned that the distinguishing factor among these two cities is that the use of fossil fuels.

When it comes to Kayseri and Kahramanmaraş, which both have similar densities and annual income, Kahramanmaraş leads to higher emission with its low energy consumption. So, it is possible to say that Kahramanmaraş has higher fossil fuel rate. Even though Kayseri has nearly similar income rates with Kahramanmaraş and higher life expectancy and emission rates, the reason of these cities' having similar efficiency score is that the high per capita energy consumption in Kayseri.

When Adıyaman and Balıkesir are taken into account, Adıyaman spends more energy for cooling and Balıkesir spends more energy for heating. With its high energy consumption of Balıkesir; life expectancy, annual income and emission levels are higher. Yet, when the efficiency studies are examined, it is possible to see that Adıyaman has higher score by courtesy of its less energy consumption and emissions per capita (see Appendix A.2).

5.4.3 Average cities

When the cities in this group are studied, it is clear to see that Bursa distinguishes itself considerably from the group with its high density. Even though it has high density, when compared to the other cities, Bursa has an average rank on energy efficiency possibly because of having an higher stance on energy consumption. The average values in other variables supports the assumption that the defining factor in efficiency is energy consumption.

Although Tekirdağ has lower density than Bursa, it has high density relatively to other cities. When compared to other cities in the group, although Tekirdağ has relative high income and low emission, it is regarded that the underlying reason of low efficiency is high energy consumption. With its less energy consumption, Denizli has similar characteristic with Tekirdağ.

When Çankırı and Sivas which have the lowest density in the group are regarded, it is possible to say that Çankırı consumes more energy in summer for cooling and Sivas consumes more energy in winter months. Even though Sivas has low per capita energy consumption, it has more CO_2 emissions. The reason of this is the usage of fossil fuels more. It is possible to say that the generally these two cities have similar energy efficiency characteristics. Bayburt also has similar density with Çankırı and Sivas, but it has low energy consumption, low CO_2 emissions and low annual income. This relatively low energy consumption increases Bingöl's energy efficiency score.

When Amasya, Çanakkale, Kırklareli, Kütahya and Nevşehir are taken as a group having similar densities, Amasya, Çanakkale and Kırklareli have higher efficiency when compared with other two cities. Even though it has the lowest annual income in regarded as an outcome of low energy consumption. It is possible to say that Kırklareli which has relatively very high CO_2 emissions, meets its energy needs from fossil fuels more. In a similar way, although Kütahya has low energy consumption, it has very high CO_2 emission. Even though Çanakkale has highest per capita energy consumption, it has relatively low CO_2 emission. This situation points that Çanakkale is less dependent on fossil fuels. In spite of Kırklareli has higher income, the reason why it has average energy efficiency score is that it has high energy consumption and high CO_2 emission (see Appendix A.2).

5.4.4 More efficient cities

The most salient city in this group is certainly İstanbul. Its performance becomes more of an issue on energy efficiency since Istanbul is the biggest metropol and the centre of the economy. Among the 81 cities, İstanbul has largest population and population density. When the results are studied, though its density is making it non-comparable to other cities, its per capita energy consumption is not low. Also, in the city which is regarded as the centre of the economy, the annual income is better than average but not at expected level. Additionally, when CO_2 emission levels are taken into account, it can be say that the emissions are low in relation to energy consumption. Comparing with İzmir which has same rate of energy consumption per capita, it is possible to say that İstanbul uses less fossil fuels than İzmir. And also it is observed that Istanbul spends less energy for cooling and heating when compared to other cities in this group.

When İzmir which is second largest in this group, and third largest city is studied, it has a relatively higher density than the cities other than İstanbul. In relation to the cities in this group, İzmir consumes less energy for heating and more energy for cooling. It shows more CO_2 emissions than Istanbul even though they have same per capita energy consumption.. İzmir's having more annual income explains having more energy efficiency score.

Erzurum and Yozgat which have the the lowest density in this group have similar per capita energy consumption. In comparison with Erzurum, Yozgat has very high CO_2 emission. This points out to use of fossil fuels. When these two cities are regarded in terms of their efficiency scores, Yozgat has a higher score because of its higher annual income and longer life expectancy.

When Bilecik and Çorum which have similar densities are taken into account, Bilecik has higher energy consumption and annual income than Çorum. In terms of their energy consumption levels, their CO2 amounts are in relation to each other. Among these two cities, the possible reason why Çorum has higher energy efficiency score is that it consumes less energy.

When Siirt and Tokat are regarded, Siirt steps forward by its lower per capita energy consumption. Siirt's low energy consumption plays role in its higher energy efficiency score.

Although Manisa and Diyarbakır have similar densities, the energy consumption in Diyarbakır is pretty low and consumes more energy than Manisa for heating in winter months. In spite of its high energy consumption and CO_2 emission, the reason why Manisa has high energy efficiency score is that it has higher annual income.

When Sakarya and Aydın are taken into account, it is observed that although Sakarya has higher density, it consumes more energy. While Aydın spends more energy for cooling in summer months, Sakarya spends more energy for heating in winter months. Reasons why Aydın has higher energy efficiency score is its low energy consumption, relatively high annual income and low CO_2 emission (see Appendix A.2).

5.4.5 Most efficient cities

It is possible to say that the cities in this group converts inputs into outputs in most efficient way. When Kocaeli which has the highest density is regarded, it is seen that Kocaeli's energy consumption is very high when compared with the average. Yet, Kocaeli converts its consumed energy into output efficiently and shows this in its annual income clearly. In Kocaeli, annual income is very high and is first among 81 provinces.

When Tunceli which has the lowest density is studied, it is seen that Tunceli's annual income is above average. It is possible to say that in Tunceli, which has relatively low energy consumption, inputs are converted to outputs efficiently (see Appendix A.2).

Generally for this group, it is possible to say that these cities can convert inputs to outputs efficiently. For a city, an efficiency frontier is reached by evaluating different variables. So, it is not correct to point out some variables for the cities. For example, while the reason of high efficiency (most efficient) in Ağrı may be the low energy consumption and low emission, it may be high annual income in Kocaeli. Additionally, there are many factors that cause higher energy consumption in the cities. These factors are climate (heating and cooling degree days), too much industrial production or low density. So, to define a city as "efficient", one needs to assess and analyse the weight of inputs and outputs and reach a verdict; not by discerning one input or output. The main reason of utilizing Data Envelopment Analysis in this study is this.

5.5 Evaluation of Urban Energy Efficiency Performance of Turkey

Cities have a high potential for energy efficiency improvements, according to Yang and Fang (2008), there are many factors affect urban energy efficiency and it is very difficult to find out the quantitative relationship (Zhi, Pei, & Guoping, 2010). Density is one of the most important factor in energy efficiency in cities. In literature, most studies show that; there is a compelling relationship between density and energy consumption. Holtzclaw, Clear, Dittmar, Goldstein, & Haas (2010) say that high density is associated with less energy consumption per capita. And it can be seen most apparently in transportation, highly sprawled cities need more energy for transportation and infrastructure. As reveal by Cervero & Guerra (2011), reasonably dense urban development implies a successful public transportation system. On the contrary this, low density causes high private transportation, more consumption of fossil fuels and therefore low energy efficiency performance. And in addition to this, low density means single family homes, fewer stories, more expensive infrastructure (because of distance) as a result more energy consumption. Briefly, the density of urban areas are having importance to more energy efficient forms of housing, transport and service provision (Lewis, Hógáin, & Borghi, 2013).

In this thesis study, multiple inputs and outputs were used to measure energy efficiency; and therefore, it is not possible to suggest a specific relation between the population density of a city and its energy efficiency. Density is certainly one of the most important factors in how energy efficient a city is; however, it is not a decisive variable. For example, according to the results of this study, Tunceli, which has the lowest population density in Turkey (11 persons/km^2), is the most energy efficient city. It is possible to explain this result by the relatively higher income and lower energy consumption in the city. Although, the low population density in Tunceli leads to a higher amount of energy consumption, the amount of outputs (relatively higher annual income, relatively higher average life expectancy and relatively lower CO_2 emissions) is higher.

The correlations calculated between the variables and the efficiency scores also verify the influence of density on the energy efficiency performance. Higher density leads to higher energy efficiency scores.

Additionally, urban energy efficiency depends on urban form and other relevant factors, such as buildings, networks and other structures (infrastructure), and transportation between functions (Forsström, et al., 2011).

It is possible to say that there is a complex relationship between energy consumption and morphology, urban form, density, climate etc. For example, energy consumed in transportation is closely connected to density and urban form (Doherty, Nakanishi, Bai, & Meyers, 2013). Urban form affects the energy consumption and greenhouse gas emissions directly by way of amount and location of structures, it is possible to say that buildings, networks, other structures, transportation between functions, changes linked with living standard, motorizing, and amount of transport etc. affect the energy consumption in cities (Harmaajärvi, Heinonen, & Lahti, 2004; Harmaajärvi, Huhdanmäki, & Lahti, 2001; 2002). And the climate is the another important factor in energy consumption, and it affects the energy efficiency. For example; if City X has more heating degree days than City Y, so it needs more energy for heating, on the contrary if City X has more cooling degree days than City Y, it needs more energy for cooling. Energy efficiency of cities can be equal in different ways which depends on their social and economic circumstances (Keirstead, 2013).

6. CONCLUSION AND DISCUSSION

Uncontrollable population growth poses the big threat to the environment as it leads to significant increase in the demand for energy. Overuse of energy puts both economy and environment at risk. Energy must be managed to ensure that it is utilised carefully. With this respect, it is quite critical that governments adopt new policies on energy in addition to improving their existing policies, and they should also stand firm as they put these policies in practice. Increasing energy efficiency is indispensible to mitigate CO_2 emissions and climate change by reducing energy consumption in cities. All over the world energy efficiency policies and actions must be taken in order to fight climate change and energy scarcity.

Over years, energy demand in Turkey, which is among the developing nations in the world, has increased at significant rates, and it is apparent that the upward graph will persist under the current conditions. Currently, more than 70% of the energy demand in Turkey is imported, and this brings a heavy burden on the national economy.

In order to reduce the dependency of Turkey to foreign countries and to ensure both economic and ecologic sustainability, it is necessary to improve projects, set targets and introduce regulations in energy efficiency, and to effectively implement these projects, targets and regulations. When projects related to energy and energy efficiency are put in practice, a comprehensive approach that not only addresses energy conservation but also encapsulates the issues about climate, environment and competitiveness should be adopted. In addition, the heavy burden that the import policy puts on the economy should be reduced, the amount of investments in renewable energy resources should be increased, and the amount of energy produced by burning fossil fuels should be decreased. Also, further precautions should be taken to address the climate change caused by the high emissions that originate from the heavy use of fossil fuels.

The policies on energy efficiency in Turkey should not be considered in isolation from domestic and international energy security. Turkey currently imports a significant portion of its energy demand from the Middle Eastern countries, and the problems in the international relations with these countries in recent years made it evident that dependency to foreign countries may give rise to problems. In this respect, not only ensuring energy efficiency but also the diversification of energy suppliers is critical issues (Koç University, 2012).

It should be kept in mind that energy efficiency will enable Turkey to increase its political and economic competitive edge in the long run, and the short-term economic burden that will arise from the implementation of the projects related to energy efficiency should not overshadow the long-run benefits that these projects will provide. Necessary actions to should be taken to establish conscience in society about the importance of the activities related to energy efficiency, which carry great importance in the implementation of the government policies and which will provide great benefit to individuals, consumers and national economy (Koç University, 2012).

In addition, while strategies on energy provision and energy efficiency are drawn up, the main purpose should be to preserve the high growth values while achieving transition to a green economy. It should be kept in mind that any steps taken today to achieve energy efficiency will be critical in shaping the future of the economy and environment in Turkey. In summary, energy efficiency plays a key role in enabling energy security, economic development and competitiveness as well as preserving the delicate equilibrium between environment and sustainability and ensuring significant gain in all these spheres (Koç University, 2012). Therefore, a priority for Turkey is to implement its energy policies and regulations as soon as possible.

In order to increase energy efficiency, cities present great opportunities in transportation, buildings, infrastructure etc. Local authorities need to develop strategies on energy efficiency. Urban energy system consist of many sectors and sub-sectors which are residential, services, transportation (passenger transportation and freight transportation), manufacturing and other industry. Decision makers should be attention on urban form choices and location in order to improve energy efficiency since these factors affect transportation need and modes and in consequence of energy consumption for transportation.

Measuring urban energy efficiency performance takes various forms, purposes and applications. And as it can be seen in literature, there is no ideal and definite technique for measuring energy efficiency on urban scale. This thesis study, which measures the urban energy efficiency in Turkey, revealed that only 36 of the 81 provinces in Turkey have relatively made it close to the efficiency frontier. This result implies to the potential that the cities in Turkey hold in terms of energy efficiency; in other words the cities in Turkey are capable to produce more output by consuming the same amount of energy. In this thesis, the relative urban energy efficiency in the cities in Turkey was measured by using the data envelopment analysis (DEA) method. Other methods can be employed in future studies on the same topic. The results presented in this study reflect the relative efficiency values. Therefore, these results on the 81 provinces in Turkey should not be compared with other figures, and they should be evaluated with a holistic approach for the 81 provinces analyzed.

This thesis is the first study on the measurement of urban energy efficiency in Turkey, and it will take the lead in providing insight to future studies in this field. In order to conduct studies that provide further detail, more data at the urban level is required. Especially sectoral energy consumption of cities (as shown in Figure 3.6) should be analyzed seperately to develop policies for each sector without harming the economy and environment. It is quite important that the number of studies on energy efficiency at the urban, regional and national scales increases as we face escalated danger of energy shortage in the world.

In order to carry out more detailed and accurate studies in this field, action is needed on;

- Collection of high-quality and detailed energy data for each sector in each city
- Prevention of informal economy and recording of all economic output
- To prodive regular measurements of CO_2 emissions in each city
- Determination of energy efficient buildings in each city

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APPENDICES

APPENDIX A: Energy conversion table

APPENDIX B: Detalied data of cities

APPENDIX A.1 : Energy conversion table.

	MJ	KWH	TOE	SM3 NATURAL GAS	BARREL CRUDE OIL
1 MJ, Megajoule	1	0.278	0.0000236	0.0281	0.000176
1 kWh, kilowat hour	3.60	1	0.000085	0.0927	0.000635
1 TOE, tonne oil equilvalent	42300	11788	1	1190	7.49
1 Sm^3 natural gas	40.00	9.87	0.00084	1	0.00629
1 barrel crude oil (159 litres)	5650	1569	0.134	159	1

APPENDIX A.2 : Detalied data of cities.

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAP.)	CO_2 EMISSIONS (PER CAP.)	SCORE
Aksaray	7997	379 915	48	0,4821	2364	262	76,3	5912	1,24	**0,7038**
Ankara	25437	4 965 542	195	0,63529	2421	308	78,3	18009	1,43	**0,6875**
Elazığ	9313	562 703	60	0,42095	2480	470	76	10097	0,92	**0,6337**
Konya	41001	2 052 281	50	0,52024	2645	221	74,7	11637	1,62	**0,6768**
Malatya	12146	762 366	63	0,36832	2355	560	74,9	12054	0,69	**0,6565**
Adıyaman	7644	595 261	78	0,3308	1698	992	76	7554	0,61	0,8153

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Afyonkarahisar	14772	703 948	48	0,36841	2595	156	77	11199	1,63	0,7938
Balıkesir	14272	1 160 731	81	0,50023	1913	350	77,1	14527	1,60	0,7893
Burdur	7174	254 341	35	0,5579	2235	341	76,2	12933	1,34	0,7479
Erzincan	11746	217 886	19	0,42474	2856	200	76,6	9922	1,02	0,7506
Edirne	6119	399 708	65	0,84166	2017	477	77,9	17150	1,79	0,7518

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Eskişehir	13925	789 750	57	0,75495	2799	118	78	20435	1,73	0,7499
Gaziantep	6887	1 799 558	261	0,4347	1852	658	74,6	9843	0,43	0,7526
Isparta	8913	416 663	47	0,46366	2524	195	75,1	12447	1,13	0,733018
K.Maraş	14525	1 063 174	73	0,39546	1657	835	76,4	10681	4,80	0,7586
Karaman	8924	235 424	26	0,40758	2348	194	76	14392	1,38	0,7954

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Kayseri	17170	1 274 968	74	0,49676	2817	133	77,6	10847	1,36	0,7313
Kırıkkale	4575	274 727	60	0,68041	2585	265	78,3	20170	2,82	0,7463
Kırşehir	6544	221 209	34	0,43863	2658	196	76,8	10060	1,82	0,7758
Muğla	12974	851 145	66	0,35476	1796	556	75,8	2743	5,19	0,7798
Niğde	7400	340 270	46	0,46591	2639	156	76,4	13210	1,85	0,7525

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Uşak	5382	342 269	64	0,55592	2399	242	76,9	9905	1,17	0,7347
Amasya	5702	322 283	57	0,4613	2064	236	78,3	10000	1,212444436	0,9001
Bingöl	8277	262 507	32	0,1289	2842	400	75,2	4374	0,550976666	0,9028
Bursa	10882	2 688 171	247	0,67876	1764	337	77,7	17990	1,26841	0,8639
Çanakkale	9955	493 691	50	0,97361	1635	443	76,7	18206	2,175767374	0,8928

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Çankırı	7490	184 406	25	0,51536	2804	138	77,6	12465	1,946766639	0,8311
Denizli	11861	950 557	80	0,60071	1544	710	77,3	19162	1,202800571	0,8307
Kırklareli	6304	341 218	54	0,84347	2109	336	79,3	26828	11,19823087	0,8858
Kütahya	12043	573 421	48	0,48183	2724	89	74,7	15119	8,074243436	0,8460
Nevşehir	5407	285 190	53	0,51738	2748	106	78	15811	2,027073879	0,8425

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Sivas	28619	623 535	22	0,44437	3230	68	77,1	12164	2,608013404	0,8283
Tekirdağ	6339	852 321	134	0,96759	1764	354	77,7	18178	1,169826445	0,8584
Aydın	7943	1 006 541	126	0,39291	1240	723	76,2	15784	1,074046812	0,9672
Bilecik	4310	204 116	47	0,92768	2280	180	78,9	24758	2,48599106	0,9302
Çorum	12797	529 975	41	0,46593	2799	56	77,5	14591	1,3025622	0,9629

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
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APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Diyarbakır	15272	1 592 167	104	0,18716	2040	842	76,4	8029	0,389961813	0,9089
Erzurum	25355	778 195	30	0,33485	4650	9	77	7255	0,874005732	0,9127
İstanbul	5313	13 854 740	2607	0,60141	1757	255	77,8	18101	1,13635006	0,9094
İzmir	12007	4 005 459	333	0,60648	1119	712	77,7	21479	1,428183126	0,9746
Manisa	13269	1 346 162	101	0,43263	1505	707	76,4	21843	3,217350115	0,9897

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Sakarya	4878	902 267	184	0,52442	1500	382	76,6	14064	1,296178204	0,9561
Siirt	5499	310 879	56	0,16917	1859	905	76	7423	0,691947876	0,9880
Tokat	10073	613 990	60	0,29065	2303	150	75,3	12645	1,113765403	0,9125
Yozgat	14097	453 211	32	0,34688	3128	46	77,7	9376	7,675430627	0,9954
Adana	14125	2 125 635	150	0,36231	945	800	76,5	15521	0,781355054	1

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Ağrı	11520	552 404	48	0,10747	4273	39	75,2	4118	0,510298981	1
Antalya	20909	2 092 537	100	0,50628	945	781	77,6	15231	0,484123179	1
Ardahan	5156	106 643	21	0,23287	4562	0	76,8	10583	0,859012019	1
Artvin	7359	167 082	23	0,34456	2149	84	78,1	20320	1,483388626	1
Bartın	2076	188 436	91	0,3034	2055	125	77,7	5944	1,615101346	1

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Batman	4680	534 205	114	0,21436	1846	854	76,9	6562	0,255825499	1
Bayburt	3741	75 797	20	0,35791	3720	23	77,7	14998	0,945034781	1
Bitlis	8855	337 253	38	0,13546	3618	68	76,9	3394	0,611764379	1
Bolu	8341	281 080	34	0,70836	2559	61	77,3	24689	1,025722917	1
Düzce	2574	346 493	135	0,58059	1964	176	79,1	9900	0,925394945	1

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Giresun	6831	419 555	61	0,25344	1583	220	77,6	13309	1,057348954	1
Gümüşhane	6440	135 216	21	0,35173	3089	47	76,6	8610	0,99069051	1
Hakkari	7228	279 982	39	0,06672	3023	230	75	4441	0,45870518	1
Hatay	5867	1 483 674	253	0,17472	1079	773	76,7	12060	4,331985632	1
Iğdır	3546	190 409	54	0,13202	2501	381	76,9	6051	0,430954772	1

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Karabük	4103	225 145	55	0,65843	2145	85	77,6	29419	12,3856955	1
Kars	9939	304 821	31	0,19827	4708	0	76,6	7396	0,71275153	1
Kastamonu	13136	359 808	27	0,40503	2936	40	77,2	12358	1,224746847	1
Kilis	1444	124 320	86	0,20957	1497	787	75,4	18126	0,608672856	1
Kocaeli	3623	1 634 691	451	1,04518	1631	342	77,7	33620	3,047125956	1

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Mardin	8858	773 026	87	0,16103	1722	848	74,9	7494	0,613379412	1
Mersin	15620	1 682 848	108	0,44602	824	893	77,1	18285	1,204521061	1
Muş	8090	413 260	51	0,27009	3213	260	77,4	20477	0,576583245	1
Ordu	5952	741 371	125	0,26383	1619	197	76,7	10862	0,88223099	1
Osmaniye	3215	492 135	153	0,57596	1098	742	76,2	6986	0,567433254	1

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Rize	3919	324 152	83	0,37491	1678	230	77,1	13966	1,610155343	1
Samsun	9352	1 251 722	134	0,41062	1581	200	77,1	13363	0,951439122	1
Şanlıurfa	19451	1 762 075	91	0,17585	1437	1188	74,9	7380	0,340483329	1
Sinop	5805	201 311	35	0,31934	1664	185	76,1	11009	1,057010054	1
Şırnak	7203	466 982	65	0,17585	1518	1149	76	2595	0,191020827	1

APPENDIX A.2 : Detalied data of cities (continued).

CITIES	LAND AREA	POPULATION	POP. /LAND AREA	ENERGY CONS. (PER CAP)	HDD	CDD	LIFE EXP.	INCOME (PER CAPITA)	CO_2 EMISSIONS (PER CAP)	SCORE
Trabzon	4662	757 898	163	0,34848	1526	251	78,1	13151	1,042151643	1
Tunceli	7705	86 276	11	0,21525	2676	439	75,8	14550	0,881733223	1
Van	21334	1 051 975	49	0,15828	3137	56	76,7	4311	0,452485518	1
Yalova	850	211 799	249	0,82724	1675	248	79,8	27388	1,089126658	1
Zonguldak	3306	606 527	183	0,53885	1800	115	78,7	16208	1,495260129	1

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List of Publications and Patents:

- İlhan, C., Baycan, T., "Measuring Urban Energy Efficiency in Turkey" Regional Science Association 54th European Congress, CD-ROM, 2014, 26-29 August, Saint Petersburg, Russia.