ECONOMY-WIDE ENERGY EFFICIENCY ASSESSMENT: A CROSS-COUNTRY COMPARISON STUDY IN EUROPE

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Thesis Abstract

Duygu Ceylan, “Economy-wide Energy Efficiency Assesment:

A Cross-Country Comparison Study in Europe”

Energy efficiency has become one of the “twin pillars” of sustainable energy policy along with renewable energy. Improvements in energy efficiency can reduce the need for investment in energy infrastructure, cut fuel costs, increase competitiveness, increase energy security by decreasing the reliance on imported fossil fuels while at the same time help to save the environment by reducing greenhouse gases emissions and local air pollution. Being an energy deficient developing country whose import reliability reached almost 75% in 2008 and whose current account deficit is based primarily on energy imports, Turkey is in great need of an accurate energy efficiency strategy. This study analyzes economy wide energy efficiency performance of Turkey by means of cross-country comparison, benchmarking with European countries for the period of 1995-2007. The nonparametric linear model used in the study considers capital, labor and total R&D expenditure as non-energy inputs, oil, gas, solid fuels, nuclear energy and renewable energy consumption as energy inputs, and considers GDP as the desirable output and greenhouse gases emissions as the undesirable output. The study also aims to trace energy efficiency changes over time by evaluating the contributing factors such as activity mix of the economy, sources of primary energy-use, share of renewables and changes in energy prices. The results indicate an improvement in energy efficiency over time but the efficiency scores and their improvement pace is considerably lower when environmental factors are taken into account. The findings also reveal that Turkey emerges as one of the energy efficient countries among 32 European countries. The empirical evidence also supports that energy mix, the activity mix of the economy and energy prices have significant effects on energy efficiency.

Tez Özeti

Duygu Ceylan, “Ekonomi Çapında Enerji Verimliliği Değerlendirmesi:

Avrupa Ülkeleri Arası Karşılaştırma Çalışması”

Enerji verimliliği, yenilenebilir enerji ile birlikte sürdürülebilir enerji politikasının iki önemli ayağını oluşturur. Enerji verimliliğinin iyileştirilmesi, bir yandan sera gazları emisyonunu ve yerel hava kirliliğini azaltarak çevreyi korurken, aynı zamanda enerjide altyapı yatırımlarına olan ihtiyacı azaltır, yakıt maliyetlerini düşürür, rekabet gücünü yükseltir ve fosil yakıt ithalatına bağımlılığı azaltarak enerji güvenliğini artırır. 2008’de ithalat bağımlılığı %75 ‘i bulan, cari açığı ağırlıklı olarak enerji ithalatından kaynaklanan, önemli enerji açığı olan, gelişmekte bir ülke olarak Türkiye, doğru enerji verimliliği stratejilerine muhtaçtır. Bu çalışma Türkiye’nin ekonomi çapında enerji verimliliğini ülkeler arası karşılaştırma ve 1995-2007 yılları arasında Avrupa ülkeleri ile kıyaslama suretiyle analiz etmektedir. Bu çalışmada yararlanılan parametrik olmayan lineer metot; sermaye, işgücü ve toplam AR-GE harcamalarını enerji dışı girdiler olarak, petrol, gaz, katı yakıtlar, nükleer enerji ve yenilenebilir enerji tüketimlerini enerji girdileri olarak, gayri safi milli hasılayı istenen çıktı ve sera gazları emisyonlarını istenmeyen çıktılar olarak kabul etmiştir. Çalışma aynı zamanda, ekonomik aktivite birleşimi, birincil enerji kaynakları birleşimi, toplam tüketimde yenilenebilir enerjinin oranı ve enerji fiyatlarındaki değişiklikler gibi etki eden faktörleri de değerlendirerek enerji verimliliğindeki değişimi araştırmayı amaçlamaktadır. Sonuçlar, zamanla enerji verimliliğinde artış göstermekle birlikte, çevresel faktörler hesaba katıldığında verimlilik skorları ve bunların gelişme hızının dikkate değer derecede düştüğü görülmektedir. Bulgular, aynı zamanda Türkiye’nin, 32 Avrupa ülkesi içinde enerji verimli ülkeler arasında yer aldığını göstermektedir. Ampirik kanıtlar, enerji birleşiminin, ekonomik aktivite birleşiminin ve enerji fiyatlarının enerji verimliliği üzerine önemli etkileri olduğunu da göstermektedir.

ACKNOWLEDGEMENTS

I would like to thank my thesis advisor, Assoc. Prof. Emine Nur Özkan Günay, for her professional help, invaluable comments and encouraging and tolerant assistance in the preparation of this thesis. I would also like to thank Assist. Prof. Aslı Deniz Helvacıoğlu, Assoc. Prof. Ahmet Faruk Aysan and Assist. Prof. Ayfer Hortaçsu for their participation and contributions.

CONTENTS

CHAPTER 1

INTRODUCTION

Beginning with the world energy crisis in 1993, energy efficiency has been brought into the policy agenda of many countries as a top priority issue. With the more recent understanding of the need to act against global warming and climate change, it has become a much more important concept. Energy efficiency is said to be one of the "twin pillars" along with renewable energy, of sustainable energy policy. Improvements in energy efficiency can reduce the need for investment in energy infrastructure, cut fuel costs, increase competitiveness, increase energy security by decreasing the reliance on imported fossil fuels while at the same time help save the environment by reducing greenhouse gases emissions and local air pollution.

Energy efficiency is one of six broad focus areas of the International Energy Agency's G8 Gleneagles Programme. The International Energy Agency (IEA) has submitted 25 policy recommendations to the G8 for promoting energy efficiency that, if implemented, could reduce global CO2 emissions by 8.2 gt by 2030. But there are some important barriers to energy efficiency, either financial and market barriers such as high investment costs, uninformed investors with little familiarity with energy efficient products, principal agent problems or political and regulatory obstacles such as under funded R&D, bureaucracy and cultural and behavioral barriers. It is important for governments to coordinate policies in a way to address all of these barriers across all sectors. Establishing and maintaining sound policy requires accurate assessment of energy efficiency trends and accurate assessment of the reflections of these policies.

Most of the recent analyses confirm that current energy consumption trends lead to an unsustainable energy future. From 1990 to 2007, global final energy consumption increased by 31%. Electricity consumption increased by 60% on the global scale as well. The associated carbon dioxide emissions rose by 31% during the same period. The IEA projects global primary energy demand could grow by 55% from 2005 to 2030 and the resulting carbon dioxide emissions will increase by 57%. On the other hand, in most world regions the amount of energy use per unit GDP is decreasing steadily: 1.6% per annum on average at the world level between 1990 and 2006. Energy productivity improvements throughout this period resulted in 4.4 Gtoe energy savings and avoided 10 Gt of carbon dioxide emissions only in the year 2006 (World Energy Council, 2008).

The European Union (EU) plays a leading role in improving energy efficiency and it has the lowest energy intensity among all world regions. To illustrate, the average power plant efficiency of the world is 34%, whereas this number is 40% in the EU, and 46% in Spain, the EU best practice. This corresponds to 420 Mtoe of fuel saving and avoiding 1.3 Gt of carbon dioxide only in the year 2006, if the world had the same performance as the EU average (World Energy Council, 2008). In 2008 the EU have made a commitment to transform itself into a highly energy-efficient, low carbon economy. In order to do this they set a series of climate and energy targets to be met by 2020 which became law in June 2009. These are:

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
- 20% of EU energy consumption to come from renewable resources

- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

Collectively they are known as the 20-20-20 targets.

Being an energy deficient emerging country whose import reliability reached almost 75% in 2008 and whose current account deficit is based primarily on energy imports, Turkey is in great need of an accurate energy efficiency strategy. Turkey's energy demand has grown 4.3% per annum throughout the period 1990 - 2008. This is three times that of the world average, and it is one of the highest growth rates among the OECD countries for the last decade. Likewise, since 2000, Turkey's electricity and natural gas demand growth rate has been the second highest worldwide, after China. However, Turkey has started adopting an energy efficiency strategy very late relative to the EU. The first draft of Energy Efficiency Strategy Paper was published in 2003. Turkish Energy Efficiency Law numbered 5627 came in force on 2007 and the Turkish government declared 2008 to be energy efficiency year. According to a study of The General Directorate of Electrical Power Resources, Turkey has a minimum saving potential of 20% in manufacturing, 35% in buildings and 15% in transportation. If Turkey can take determined and successful steps towards improving energy efficiency, the realized level of the predicted consumption level in 2020 can be reduced by 20% corresponding to 45 Mtoe of energy saving. This amount is about 2.5 times Turkey's electrical energy production capacity and is enough to cover around 30 million households' annual energy need.

Given such significant importance, the majority of academic energy studies conducted in Turkey is either on Turkey's scarce energy resources, policies on energy trade and energy security issues, or they are associated with Turkey's foreign politics. Energy efficiency studies are very restricted and none at the economy-wide level.

In this study, economy wide energy efficiency performance of Turkey is calculated by means of cross-country comparison and benchmarking with the EU countries for the period of 1995-2007. For measuring economy-wide energy efficiency performance, a non-parametric frontier approach is used in order to make performance benchmarking across multiple entities. Energy consumption data of 32 European countries, namely, EU-27, Switzerland, Norway, Iceland and the candidate countries Turkey and Croatia, over the period 1995-2007 is used. Green house gases (GHG) emissions are also taken into consideration as the undesirable output of energy usage and efficiency scores with and without the environmental concerns are compared. Furthermore, energy efficiency changes over time are analyzed as a second step by evaluating the contributing factors such as activity mix of the economy, sources of primary energy resources, especially the share of renewables, and changes in energy prices. One of the attracting results of the study is that Turkey emerged as one of the most energy efficient countries among the countries included. It is also seen that although energy efficiency has improved over time, the energy efficiency scores are considerably lower when environmental concerns (adding emissions minimization condition) are taken into account. The second step regression analysis results imply that energy mix in the total consumption, the economic activity mix of the country and energy prices have significant effects on energy efficiency.

The study is organized as follows.

Chapter 2 provides a general outlook on the overall trends in energy consumption and energy efficiency in the world, the EU and in Turkey. It also provides some insight on the role of energy trade in Turkey's macroeconomic balances. Energy efficiency literature is presented in Chapter 3 and a thorough review of energy efficiency policies, measures and regulatory framework of the EU and Turkey is explained and illustrated in Chapter 4.

Chapter 5 and 6 compose the empirical chapters. Data envelopment analysis (DEA) is defined, explained and applied on 32 European countries and the findings are presented in Chapter 5, while these results are used to investigate the factors effecting energy efficiency in Chapter 6. Chapter 7 concludes.

CHAPTER 2

ENERGY EFFICIENCY TRENDS AND THE ROLE OF ENERGY TRADE IN TURKEY'S ECONOMY

Energy consumption is the key point of interest in energy efficiency studies. Hence, it is important to evaluate the consumption trends in order to make correct assessments and employ proper policies. Also, in order to understand why energy efficiency improvement is so crucial for a country like Turkey, the role of energy trade, which is vital in satisfying the demand rising from the consumption patterns, in the overall economy and its effects on macroeconomic balances must be comprehended. The first part of this chapter provides a general outlook on the overall trends in energy consumption in the world, the EU and in Turkey. It also provides information on energy efficiency trends in terms of efficiency indicators. The second section of the chapter provides some insight on the role of energy trade in Turkey's macroeconomic balances. The energy consumption data given throughout this chapter is obtained from Eurostat, International Energy Agency, BP Statistical Review of World Energy (BP, 2010) and Turkish Undersecretariat of the Prime Ministry for Foreign Trade (TMFT). Energy efficiency indicators data is obtained from the Odyssee and Enerdata database.

Energy Efficiency Trends

This part constitutes of a brief review of global energy use in order to give an idea about where both the EU and Turkey stand, followed by illustrations of major consumption trends of the EU and Turkey with respect to economic growth, along with its breakdowns to fuel types and regions. Valuable information on energy efficiency trends that are obtained from some widely accepted energy efficiency indicators is also given in this section of the chapter.

Global Energy Consumption Review

Primary energy refers to energy found in nature that has not been subjected to any conversion or transformation process such as fossil fuels including oil, natural gas and coal, nuclear fuels, hydro, solar and wind power. Primary energy consumption has increased in an accelerated way in the past few decades (Figure 1). Primary energy demand has almost doubled since 1980 and reached 11.089 million tons of oil equivalent (Mtoe) in 2007. The average annual growth rate has been 1.9% from 1987 to 2007, 2.2% in the last decade and 2.5% in the last five years which illustrate the rapid acceleration year by year.

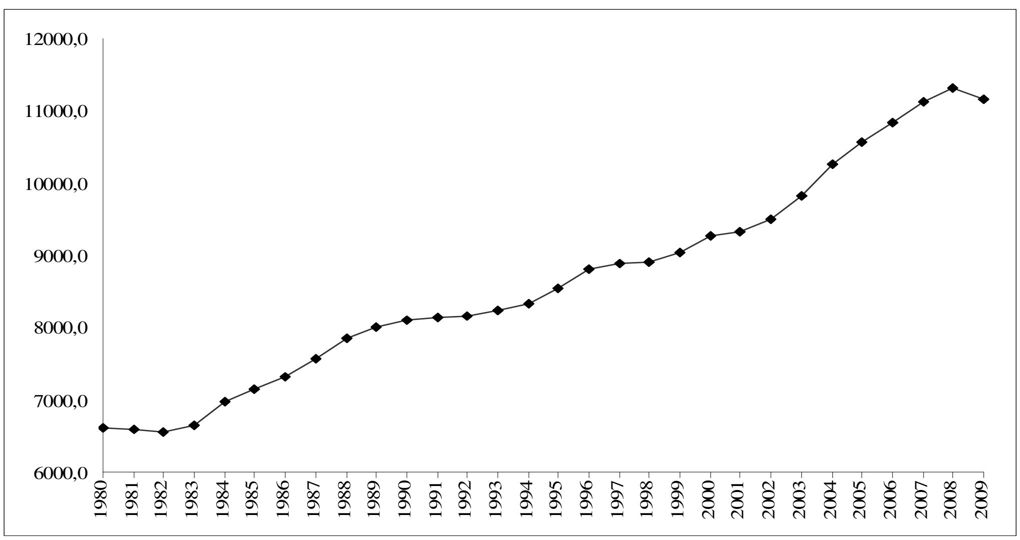

Figure 1. World's primary energy consumption in Mtoe

After the global financial crisis in 2008, however, although out of the scope of this thesis, it is important to note that world primary energy consumption – including oil, natural gas, coal, nuclear and hydro power – fell by 1.1% in 2009, the first decline since 1982 and the largest decline in percentage terms since 1980. Consumption in OECD countries fell by 5%, the largest decline on record and OECD consumption reached the lowest level since 1998.

According to 2009 data, countries in Asia Pacific consumed the majority of the primary energy, which contributed to 37.1% of the world's energy consumption. China has been the major consumer in Asia Pacific region spending 19.5% of the world's total energy in 2009. Japan, India and South Korea followed China in the region with their respective consumption shares of 4.2%, 4.2% and 2.1%.

Table 1. Primary Energy Consumption per Region and Their Shares as of 2009

Regions	Consumption (Mtoe)	Consumption Share (%)
Middle East	659	5.9
Europe and Eurasia	2,770	24.8
Africa	361	3.2
South and Central America	563	5.0
North America	2,664	23.9
Asia Pacific	4,147	37.1
TOTAL WORLD	11,164	100.0
European Union	1,623	14.5
OECD	5,217	46.7

Countries in Europe and Eurasia followed Asia Pacific with a consumption constituting 24.8% of the globe's overall energy consumption. In the region, Russian Federation has been the leading energy consumer with 635.3 mtoe embodying 5.7% shares of the global primary energy consumption.

European Union member countries consumed 1,623 mtoe of primary energy in 2009 and thus contributed to overall consumption by 14.5%. Northern America materialized an almost similar consumption rate to Europe and Eurasia with a total of 2,664 mtoe of primary energy of which 2,182 belongs to United States. United States exhausted 19.5% of the world's energy in 2009. Together with China who spent

2,177 mtoe in the same year with the same share of 19.5%, they are the major energy spending countries of the world. South and Central America and the Middle East spend both around 5% of the total energy whereas Africa's share is only 3.2%.

Table 2. Leading Primary Energy Consumers and Shares as of 2009

Consumer Country	Consumption (mtoe)	Percentage Share
United States	2,182	19.5%
China	2,177	19.5%
Russian Federation	635.3	5.7%
India	468.9	4.2%
Japan	463.9	4.2%
Canada	319.2	2.9%
Germany	289.8	2.6%
France	241.9	2.2%
South Korea	237.5	2.1%
Brazil	225.7	2.0%
United Kingdom	198.9	1.8%
Iran	204.8	1.8%
Turkey	93	0.8%
Others	3427.3	30.7%

The illustrated regional distribution of primary energy consumption reveals that industrialized countries spend the majority of energy. Two enormous emerging economies China and Russian Federation along with India follow United States in the consumption of primary energy and these four countries together form around half of total global energy consumption.

Energy Consumption Review of the EU and Turkey

Although world's primary energy consumption has nearly doubled since 1980 and even gained pace after 1995, both primary and final energy consumption in the EU-27 has increased only slightly in the same period. The primary and final energy consumption increased at approximately the same rate between 1995 and 2007

(0.7%/year on average) in the EU-27 (Figure 2) and amounted to around 1900 Mtoe and 1200 Mtoe, respectively.

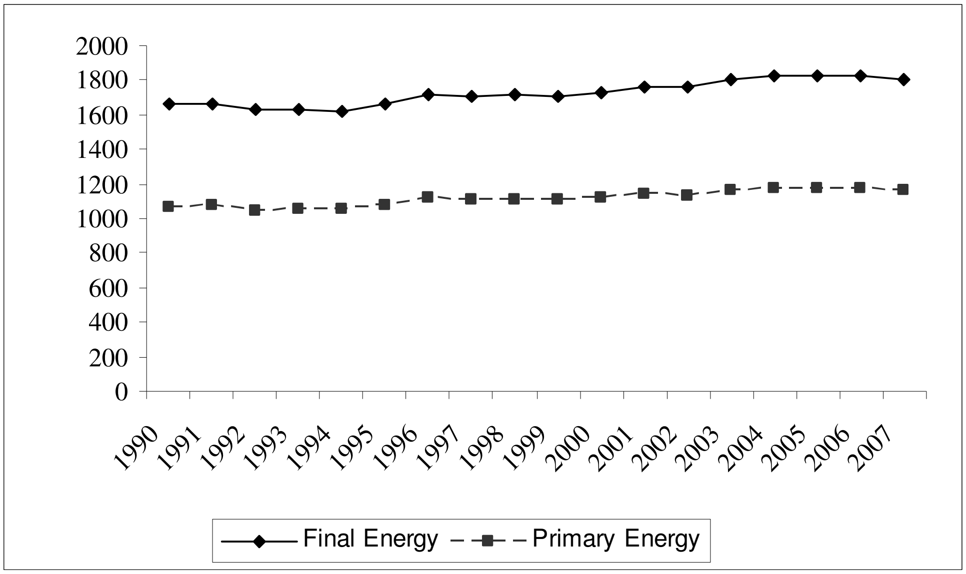

Figure 2. EU-27 primary and final energy consumption in Mtoe

Figure 3 shows the GDP growth rate in the EU between 1995 and 2007 in three different periods.

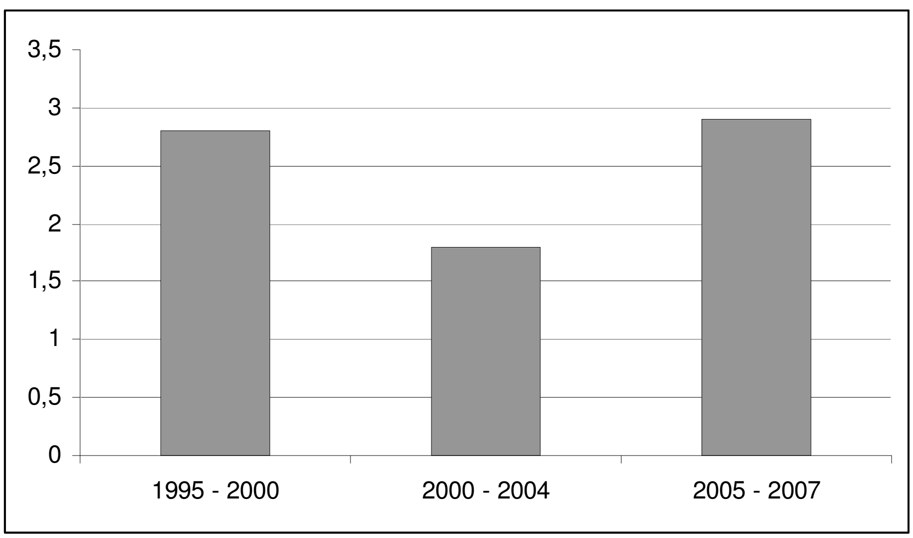

Figure 3. Economic growth in the EU (%/year)

The period 1995-2000 was characterized by a rather low progression of the energy consumption (0.7 %/year) compared to the economic growth of 2.8 %/year (Figure 3). Between 2000 and 2004, the lower economic growth (1.8 %/year) was accompanied by a more rapid evolution of the consumption (+1.3 %/year). Between 2005 and 2007, the energy consumption has decreased -0.5%/year despite a rapid expansion of the economy, (+3 %/year for the GDP).This trend was probably influenced by the rapid increase in international energy prices as well as the energy efficiency and climate policies implemented by the EU Commission and by national governments. On average since 1995, energy consumption has progressed three times slower than the GDP in the EU-27.

On the other hand, like most of the emerging countries, together with increasing industrialization, Turkey's primary energy consumption has increased approximately by 94% from 1990 to 2007 with an average of 4%/year. In fact this would be a continuous increase except for the years 1994, 1999 and 2001 where energy consumption fell by 2%, 1.8% and 7.7% respectively. These years coincide to times of lower economic growth and even economic contraction in 2001 due to economic crises.

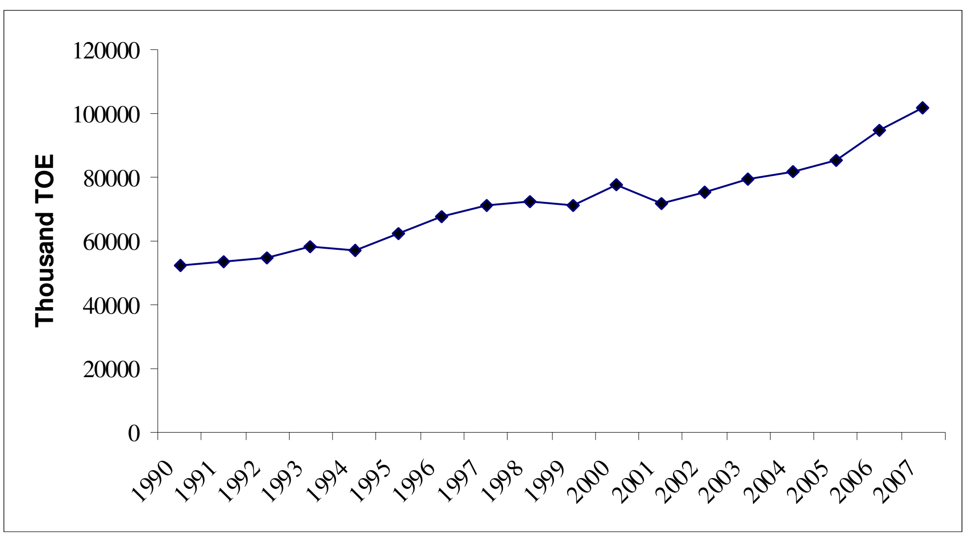

Figure 4. Turkey's primary energy consumption

It is noticeable from Figure 4 that after 2001, energy consumption in Turkey gained a faster pace, 6%/year in average, along with rapid economic growth (6.5% /year on average).

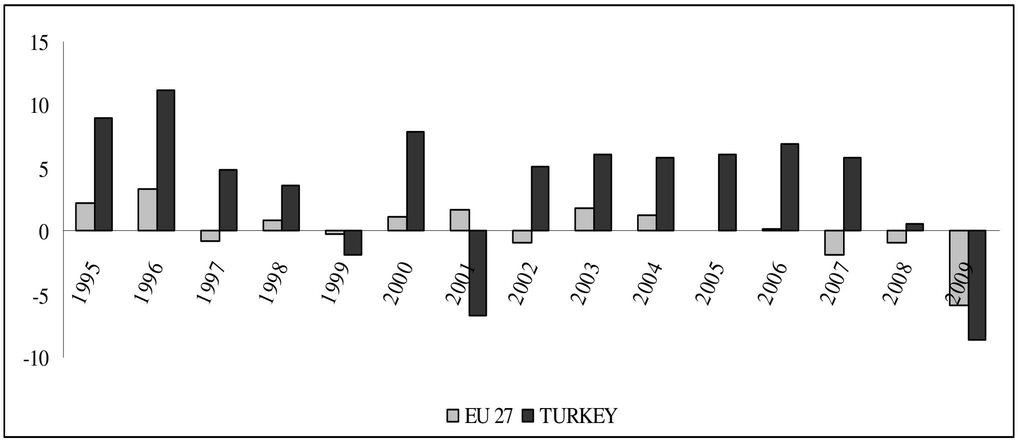

Figure 5. Primary energy consumption trends

Figure 5 illustrates energy consumption change of the EU and Turkey comparatively. It is clearer from the figure that the changes in consumption in Turkey are much more dramatic in Turkey compared to the EU.

A similar figure occurs in electricity consumption as well.

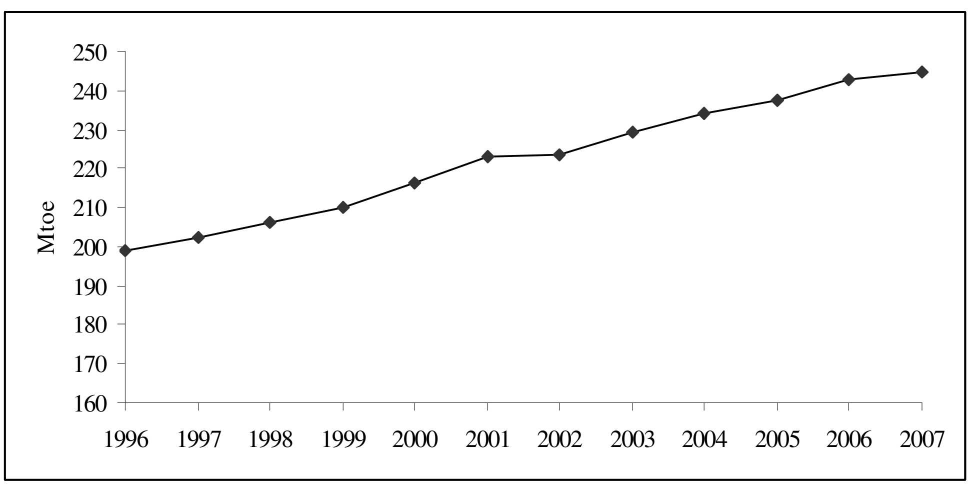

Figure 6. EU-27 electricity consumption

Electricity consumption in the EU underwent a more rapid progression than the total energy consumption (1.9 %/year on average since 1993), slowing down to 1.5 %/year since 2005.

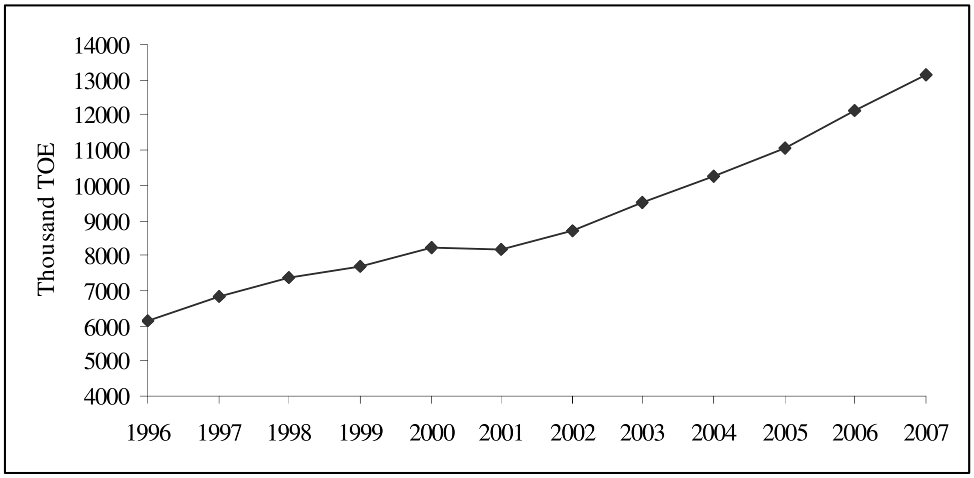

Figure 7. Turkey's electricity consumption

Meanwhile Turkey's electricity consumption increased on the average by 7.1%/year since 1996 (Figure 7). Electricity consumption trend followed the same path with energy consumption as expected and experienced deterioration in 2001 by 0.6% under the influence of the economic crises. Figure 8 is an illustration of the comparison of these trends between the EU and Turkey.

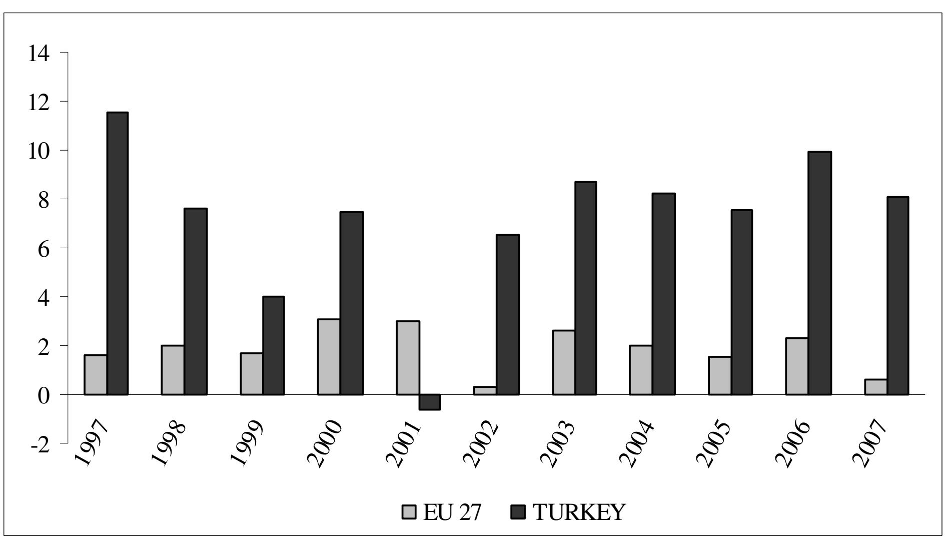

Figure 8. Electricity consumption trends (%)

It is evident that Turkey's electricity consumption growth is essentially higher than that of the EU's except for the year 2001, where there was a decline in Turkish electricity consumption due to the economic crisis while EU's consumption increased by approximately 3%.

Figure 9 and 10 show the trends in electricity consumption, energy consumption and GDP comparatively for the EU and for Turkey respectively.

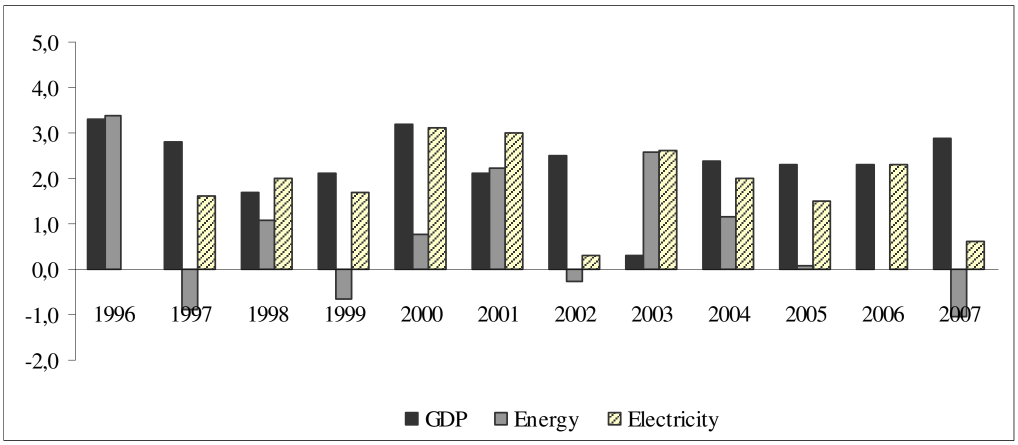

Figure 9. Trends in GDP, primary energy and electricity consumption in EU-27(%)

It can be seen that although energy consumption fell in some years in the EU, electricity consumption increased in all years and with a higher pace than energy consumption.

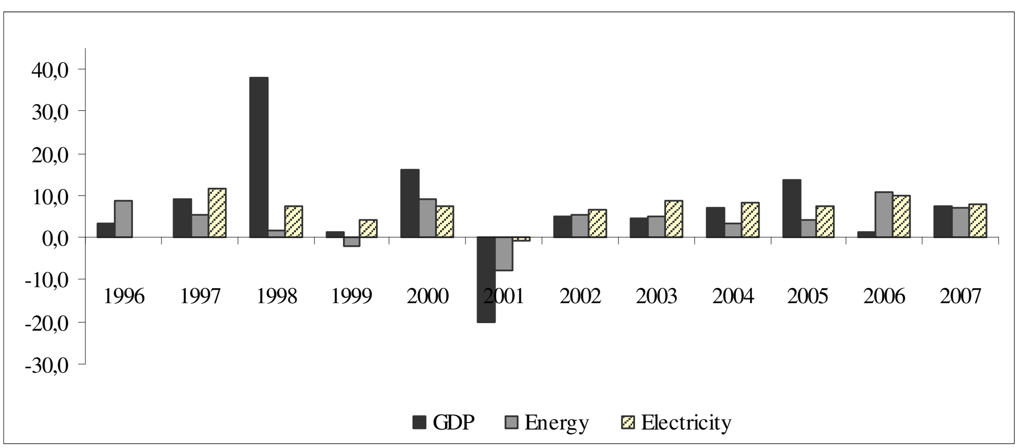

Figure 10. Trends in GDP, primary energy and electricity consumption in Turkey(%)

Figure 11 shows the primary energy consumption trends and GDP growth rates of the EU countries.

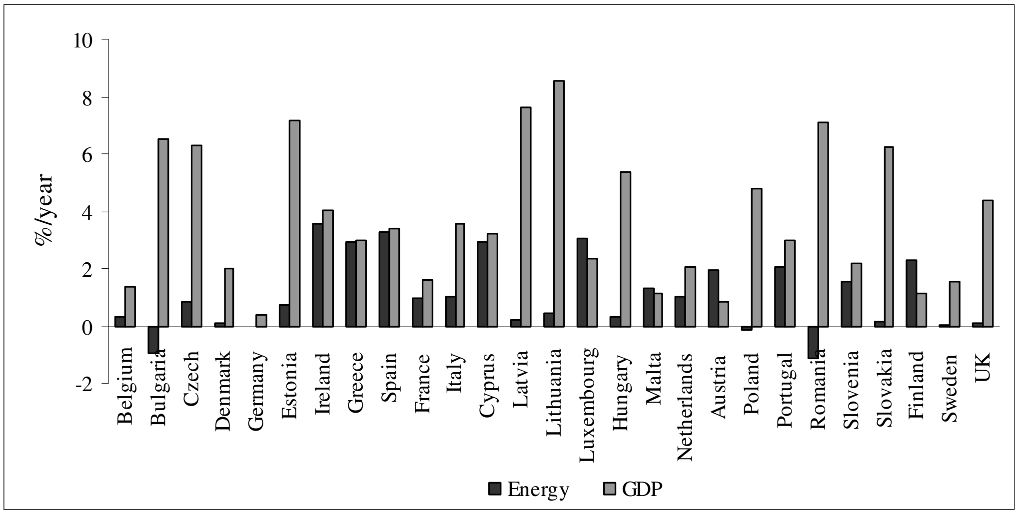

Figure11. Primary energy consumption and GDP in EU countries (1995-2007)

The trends by country show a large decoupling between the primary energy consumption and the economic growth in the EU (Figure 11). In most countries, the high economic growth was possible with a low progression in energy consumption (UK, Lithuania, Latvia, Belgium, Estonia) or even a reduction in some countries (Romania, Germany, Poland, Bulgaria). In some countries, however, there is a rapid progression of energy consumption.

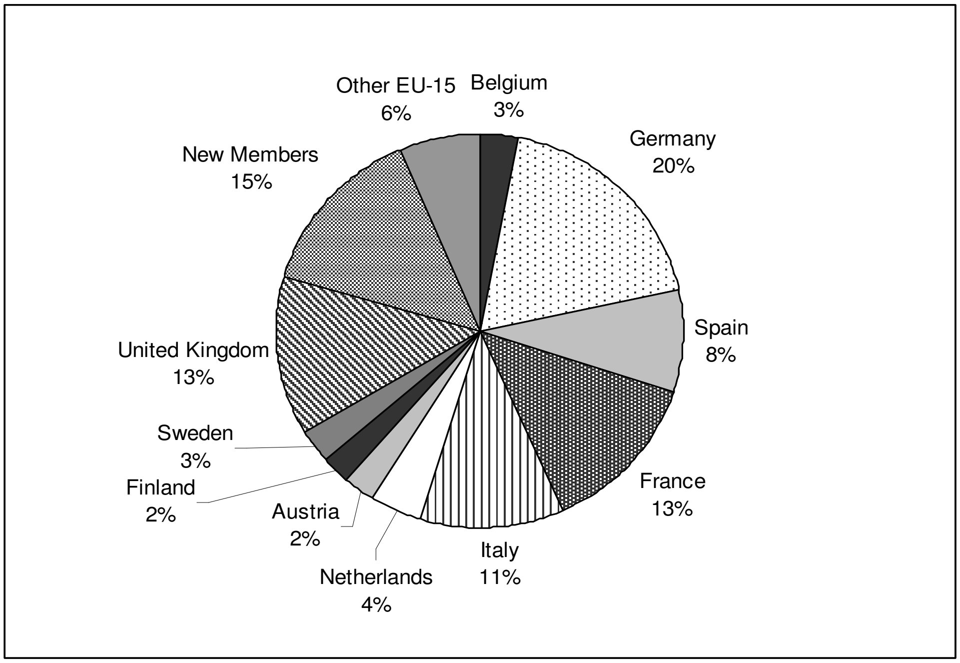

Figure 12. Final energy consumption by country in the EU

Around 50 % of the final energy is consumed by three countries (Germany, France and UK) and almost 60 % by four countries if Italy is added and around 70% with two more countries (Spain and Poland). EU-15 countries plus Poland represent around 90% of the total final energy consumption of the EU (Figure 12).

Table 3. Final Energy Consumption by Energy Source in the EU

	Consumption			Percentage Share (%)		
	1990	1997	2007	1990	1997	2007
Solid Fuels	125.523	79.773	56.542	11,50	7,04	4,71
Oil	445.340	476.010	484.000	40,80	42,01	40,36
Gas	227.403	256.366	268.496	20,83	22,62	22,39
Electricity	184.067	202.497	244.502	16,86	17,87	20,39
Heat	47.348	42.942	45.593	4,34	3,79	3,80
Renewable	61.806	75.559	100.082	5,66	6,67	8,35

Oil is the dominant energy source in the final energy consumption of the EU and its contribution remained almost stable, around 41 %, over the period 1990 -2007 (Table 3, Figure 13). Although it has been substituted by gas and other fuels in industry, households and services, this substitution was offset by a rapid increase in motor fuel demand which was 1.6 %/ year on average over the period 1990-2007 (Odyssee, 2009).

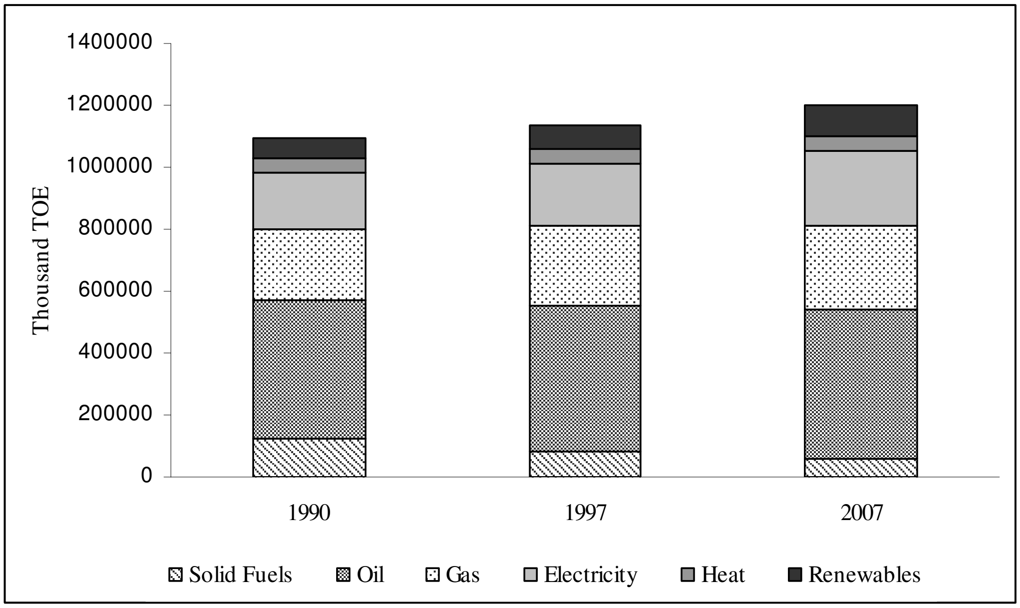

Figure 13. Final energy consumption by energy source in the EU

The share of gas increased slightly between 1990 and 1996 and remained stable since then. The market share of electricity also increased by 4 points and reached almost 21 % in 2007 compared to 17 % in 1990. Renewables, which consist of solar energy, biomass and wastes, geothermal energy, industrial wastes, hydro energy, wind energy and biofuels as specified in the Eurostat database, play a minor but increasing role in EU's final energy consumption (6 % in 1990, 8 % in 2007).

The contribution of each energy source varies quite a lot among countries depending on their energy resources and climate. For some countries such as Cyprus, Greece, Luxemburg, Ireland and Malta, oil represents around 70 % of the energy consumed, due to a high share of transport (2007). On the opposite, in Nordic countries (Sweden, Finland, Norway) and some Central European countries (Slovakia, Czech Republic, Hungary and Romania), oil is no longer a dominant source of energy (20-30 %), and is replaced by gas or electricity (Odyssee, 2009).

The breakdown of Turkey's energy consumption is not only different than that of the EU's but it is also more dynamic.

Table 4. Final Energy Consumption by Source in Turkey

	Consumption			Percentage Share (%)		
	1990	1997	2007	1990	1997	2007
Solid Fuels	8.040	9.361	14.648	19,82	17,43	19,24
Oil	17.919	22.539	23.480	44,17	41,96	30,84
Gas	1.158	3.985	14.407	2,85	7,42	18,92
Electricity	3.865	6.851	13.125	9,53	12,75	17,24
Heat	0	0	1.032	0,00	0,00	1,36
Renewable	9.589	10.985	9.445	23,64	20,45	12,41

Oil again is the leading source of energy in the final consumption but although its usage has increased since 1990, its contribution to the total fell from 44% in 1990 to 31% in 2007. This is mainly due to its substitution with natural gas. Gas consumption increased enormously in the given period changing from 3% to 19% of all energy consumption. Solid fuels, in which coal is the dominant source, kept its contribution around 19% throughout the years. Turkey's electricity consumption has been rising continuously since 1990, as a secondary form of energy, electricity consumption rised to 17% of total energy consumption in Turkey in 2007 (Table 4).An integral portion of Turkey's overall energy production is designated by coal (mineral and lignite) and renewable energies involving hydro, biomass, geothermal and solar. Since the absolute production of renewable energy did not increase in the period of analysis but the energy demand has increased, the share of renewable energy in Turkish consumption have declined from 23% in 1990 to 12% in 2007.

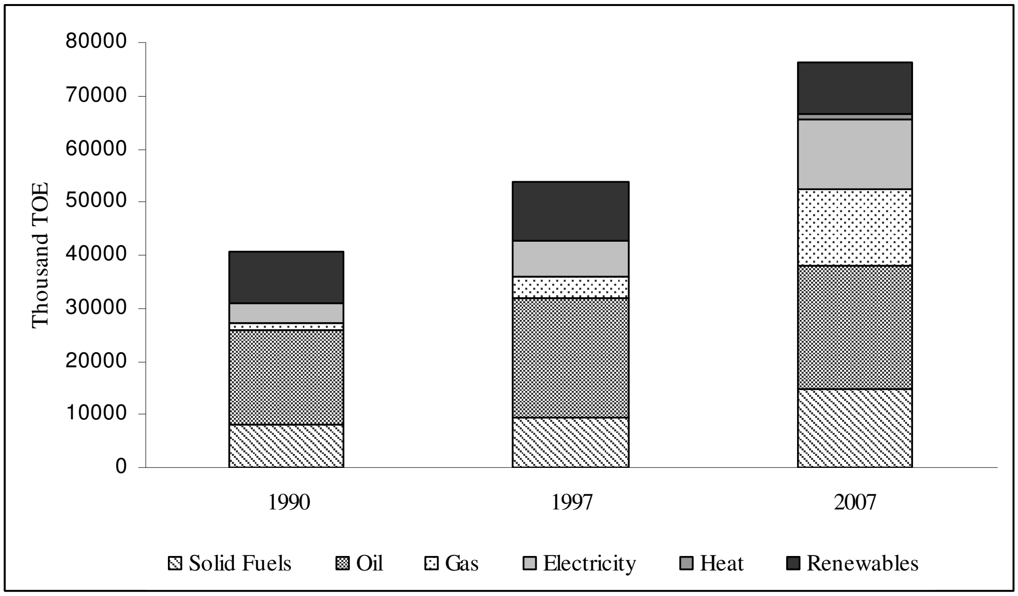

Figure 14. Final energy consumption by source in Turkey

Within the renewables, the share of biomass has fallen but hydro and solar have surged. Neglecting the contribution of wind power which was only 30 thousand Toe in 2007, total renewable energy production and hence consumption has stayed rather stable from 1990 to 2007.

Figures 15 and 16 show the breakdown of energy consumption into the highest energy consuming sectors which are industry, households and services and transportation.

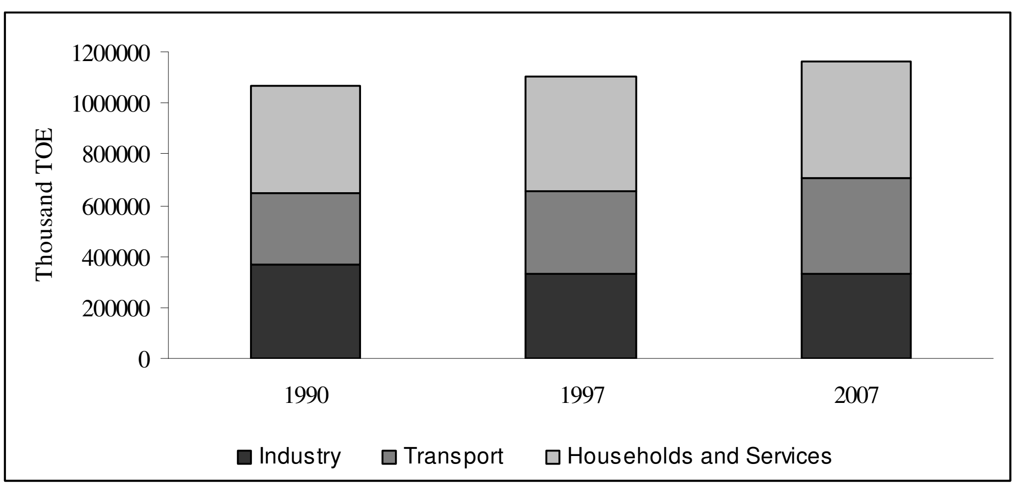

Figure 15. Final energy consumption by sector in the EU

Buildings (households and service sector) absorb around 40 % of the final energy consumption in the EU. The share of industry has decreased from 34% to 28% contrary to transport which represents nowadays 33 % of the final consumption (up from 26 % in 1990). The sector mix between countries is quite diverse with a share of industry ranging from more than 50% in Finland and around 25% in Latvia and Cyprus.

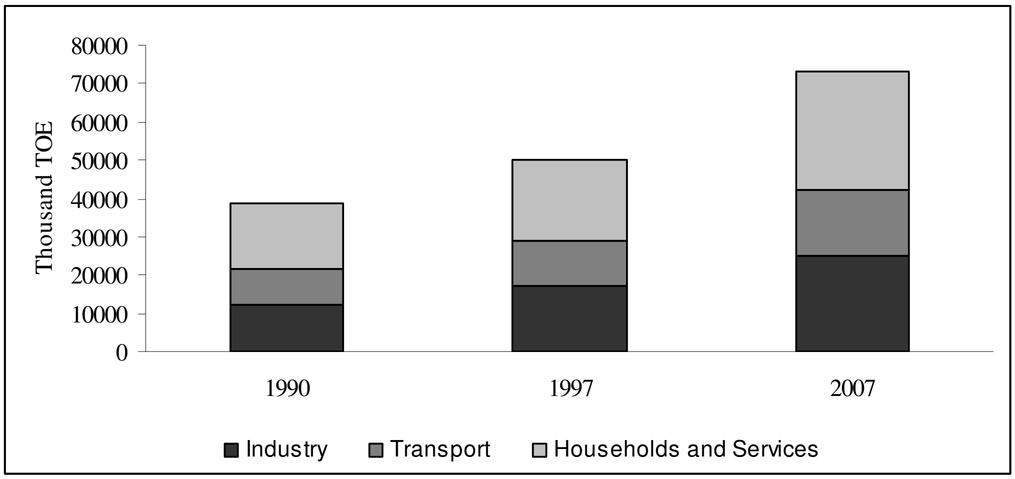

Figure 16. Final energy consumption by sector in Turkey

As in the EU, households and services is the leading energy consuming sector in Turkey but its share decreased from 44% in 1990 to 42% in 2007. On the contrary, the share of industry has risen from 31% to 34% over the years. Transport sector has been consuming around 23% of the final energy since 1990 (Figure 16).

Energy Prices

It is notable to mention the trend of energy prices throughout the considered period. The average prices of imported fuels (oil, steam coal, natural gas) in the international energy market remained quite stable until 1999. A first increase in prices occurred in 2000: respectively 59 % for oil (from 18 $/barrel to 28 $/barrel) and 48 % for gas. After a period of relative stability from 2000 to 2004, international fuel prices started to rise sharply in 2004. Between 2004 and 2008, these prices have been multiplied by a factor 2 for gas, 3 for oil (97 $/barrel) and 4 for coal (Odyssee, 2009).

Figure 17 is an illustration of the Brent oil prices in Europe throughout the period 1987 and 2009.

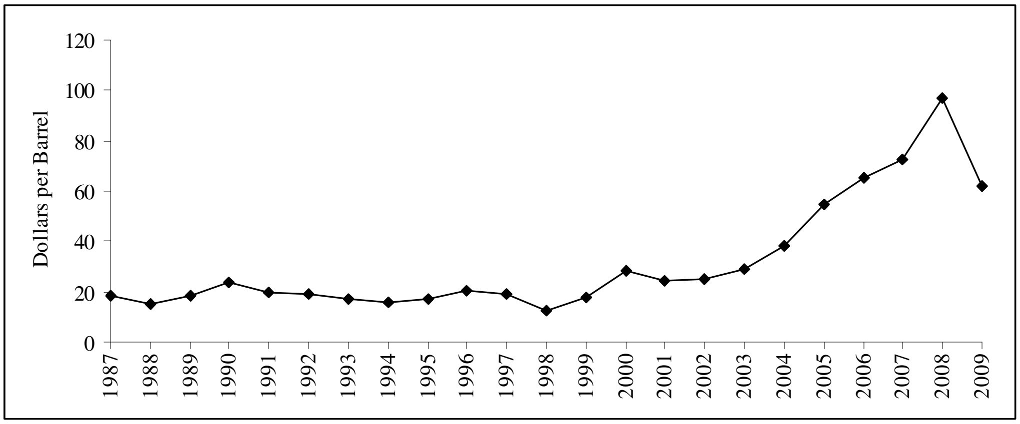

Figure 17. Annual Brent oil spot FOB price in the EU (EIA, 2010)

For final consumers, fuel prices have strongly increased especially for oil products (+113 % for fuel oil in industry, +68 % for heating oil for households) and natural gas (+89 % in industry, +31 % for households). Electricity prices, both in industry and for households have been stable in the EU (Odyssee, 2009).

Table 5 is a consumer price index retrieved from OECD, considering 2005 prices as 100.

Table 5. Consumer Energy Price Index (2005=100) (OECD, 2010)

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	65,8	67,2	68,4	65,9	67,2	78,7	80,5	81,0	85,1	90,7	100,0	109,7	111,1	125,2	115,7
Austria	73,4	78,0	80,4	77,8	78,1	86,4	86,9	84,8	85,6	91,1	100,0	106,2	110,7	122,1	110,5
Belgium	70,5	74,5	76,8	74,1	75,5	86,5	86,9	84,2	84,1	89,7	100,0	107,5	107,7	129,1	111,1
Czech Republic	..	51,9	58,8	70,2	74,6	85,3	88,9	89,3	90,1	93,8	100,0	108,7	110,4	119,7	122,4
Denmark	65,4	69,7	71,8	72,8	77,6	87,0	88,3	90,2	91,0	93,1	100,0	105,3	105,7	113,7	108,6
Finland	68,4	75,4	76,7	75,7	78,6	88,4	86,9	86,1	90,2	93,6	100,0	105,9	107,7	122,3	112,1
France	74,9	78,5	80,0	77,8	78,1	87,6	86,2	84,9	86,9	91,0	100,0	106,4	108,4	120,2	106,3
Germany	66,7	67,2	69,1	66,9	69,6	79,2	83,9	84,1	87,4	91,0	100,0	108,5	112,7	123,5	116,9
Greece	71,7	77,6	74,6	72,1	69,4	81,2	79,8	79,6	82,8	87,6	100,0	109,0	111,2	126,1	111,2
Hungary	30,8	39,6	49,3	56,3	63,7	74,7	77,8	79,5	84,3	93,0	100,0	106,5	121,0	135,3	138,7
Iceland	68,6	71,7	75,0	73,3	75,4	84,3	87,8	85,9	87,6	94,2	100,0	108,0	109,8	133,6	144,5
Ireland	63,5	65,9	67,9	67,5	68,7	78,1	76,1	78,7	81,9	88,8	100,0	108,2	113,2	123,1	113,4

Italy	75,6	78,0	79,5	78,4	79,0	88,2	89,6	87,2	90,0	92,0	100,0	108,1	109,3	120,5	110,8
Luxembourg	64,3	68,0	70,5	66,9	68,7	82,3	81,0	77,7	79,5	86,8	100,0	110,0	112,5	128,5	110,7
Netherlands	58,7	58,2	62,7	62,5	64,6	74,3	79,3	81,1	84,7	89,4	100,0	107,5	111,5	116,5	112,1
Norway	66,3	68,7	72,2	69,3	71,1	79,3	85,8	83,8	100,2	97,7	100,0	117,8	105,8	125,0	120,2
Poland	38,6	45,9	53,9	61,9	67,8	78,1	82,6	86,2	90,0	94,6	100,0	105,1	109,0	118,5	126,2
Portugal	70,4	72,0	74,9	75,5	74,0	78,2	82,2	83,0	87,0	91,4	100,0	107,6	111,4	118,5	110,3
Slovakia	25,1	26,5	27,5	28,5	40,6	58,1	66,2	67,7	81,1	92,7	100,0	112,4	113,4	117,9	117,0
Spain	73,2	75,8	77,7	74,7	77,1	87,4	86,6	85,9	87,0	91,2	100,0	108,0	109,8	122,9	111,8
Sweden	63,6	67,5	70,8	70,7	70,9	76,9	81,7	82,5	91,3	94,4	100,0	107,1	107,5	118,8	116,8
Switzerland	74,2	77,2	79,7	75,0	77,4	91,1	90,0	85,5	86,6	90,6	100,0	107,1	109,0	123,0	104,0
Turkey	1,5	3,1	5,6	9,2	16,1	25,2	48,4	70,4	83,3	87,2	100,0	111,3	118,2	144,7	152,1
UK	72,1	73,9	76,3	76,6	79,9	85,6	83,3	82,6	84,8	90,1	100,0	114,7	120,9	141,4	141,6
Estonia	..	..	..	58,0	64,2	69,3	74,6	79,5	81,4	88,1	100,0	108,2	116,6	143,7	140,1
Slovenia	..	38,9	45,0	50,2	55,1	68,9	77,6	80,8	83,6	89,4	100,0	108,2	111,6	123,4	119,1

It is important to notice that although all countries experience an increase in energy prices, Turkey is the only country to undertake such a drastic rise, from 1.5 in 1995 to 152.1 in 2009. Turkey has experienced a 52% increase in energy consumer prices only in four years since 2005.

Energy Efficiency Indicators

For measuring energy efficiency changes over time at the economy-wide level, and to be able to make cross-country comparisons and benchmarking, various efficiency - related indicators have been developed. These indicators are developed for various sectors, sub-sectors and end-uses and give an idea on efficiency developments on each of these levels. Table 5 summarizes some selected energy efficiency indicators from the Odyssee project, which is a joint collaboration between ADEME, the SAVE programme of the General Directorate of the European Commission in charge of energy and all energy efficiency agencies in the EU-27, Norway and Croatia. The data is gathered from Enerdata, the technical coordinator of Odyssee, who compiles the data provided by all the energy agencies through Europe in a single database.

Energy intensities (energy consumption/GDP) are the most widely accepted energy efficiency indicators. Both primary and final energy intensities of the world, the EU-27 and Turkey have decreased since 1980, but the decrease in Turkey was not as significant as the others. While Turkey's energy intensities were far lower than that of the world and EU average in 1980, EU-27 had the lowest energy intensity in 2007.

At the sectoral level, as energy consuming sectors are specified as industry, transport, households, services, and agriculture, the energy intensities of these sectors are chosen to be useful indicators. Energy intensity of industry, service sector, and agriculture is given as the ratio of energy consumption to total value added; energy intensity of transport is given as energy use of transport sector to GDP and energy intensity of households is given as a ratio of energy consumption to total private consumption. As another indicator for the households sector, average electricity consumption per household is also considered. It is known that one of the most important energy losses in an economy occurs while transformation, specifically electricity generation. Hence the efficiency of transformation and electricity generation are also important efficiency indicators at the economy wide level.

Table 6. Key Energy Efficiency Indicators (Enerdata, 2009)

Key Energy Efficiency Indicators		1980	1990	2000	2007
Primary energy intensity (PPP)	World	0.271	0.240	0.200	0.180
	EU-27	0.201	0.173	0.146	0.129
	Turkey	0.147	0.151	0.158	0.148
Final energy intensity (PPP)	World	0.192	0.161	0.130	0.113
	EU-27	0.138	0.112	0.095	0.086
	Turkey	0.123	0.110	0.112	0.106
Energy intensity of industry (to value added) (PPP)	World	0.228	0.178	0.133	0.116
	EU-27	0.184	0.138	0.111	0.098
	Turkey	0.142	0.118	0.145	0.128
Energy intensity of transport to GDP (PPP)	World	0.047	0.042	0.038	0.033
	EU-27	0.029	0.030	0.029	0.028
	Turkey	0.027	0.028	0.025	0.024
Energy intensity of households (to private consumption)	World	n.a.	n.a.	0.060	0.053
	EU-27	0.067	0.051	0.041	0.037

	Turkey	0.029	0.057	0.049	0.046
Average electricity consumption per household (kWh/hh)	World	n.a.	n.a.	2460	2834
	EU-27	n.a.	3676	3860	4042
	Turkey	n.a.	n.a.	1446	2011
Energy intensity of service sector (to value added) (PPP)	World	n.a.	n.a.	0.021	0.020
	EU-27	0.027	0.020	0.018	0.016
	Turkey	0.003	0.004	0.011	0.022
Energy intensity of agriculture (to value added) (PPP)	World	0.083	0.060	0.047	0.043
	EU-27	0.109	0.127	0.110	0.094
	Turkey	0.020	0.038	0.050	0.056
Overall efficiency of energy transformations (%)	World	73.8	70.9	68.8	67.4
	EU-27	74.2	70.5	71.4	72.9
	Turkey	82.4	74.6	73.5	75.6
Efficiency of total electricity generation (%)	World	43.4	37.0	38.7	38.4
	EU-27	36.4	35.4	39.1	40.0
	Turkey	49.7	44.8	45.0	48.2
Share of renewables in electricity generating capacity (%)	World	23.2	23.4	23.6	23.4
	EU-27	20.5	20.8	23.0	28.1
	Turkey	42.8	41.6	41.2	37.0

Energy intensities of all sectors have decreased throughout the years in the EU and in the world. But the case in Turkey is different. Energy intensities of all sectors was lower than both the world and EU average in 1980 which is mainly due to the low level of industrialization and development in those years. But by 2007, energy intensity of households, service sector and agriculture has experienced a sharp increase in Turkey. This may be the effect of economic growth and the rise in income levels. In industry, households and services, the energy intensity of the EU-27 average is lower than Turkey's, but in transportation and agriculture Turkey's intensity levels are lower in 2007. Average electricity consumption per household is in a rising trend and Turkey's levels are lower than the world and EU average.

Overall efficiency of energy transformations and efficiency of total electricity generation was higher in Turkey in all years but has deteriorated over time.

Efficiency of energy transformations and energy generation of the world has fallen to 67% and 38%, respectively, by 2007 from 74% and 44% in 1980.

Not being directly related to energy efficiency but being one of the twin pillars of sustainable energy along with energy efficiency, renewable energy is also considered among the indicators, as an indicator of diffusion of energy. The share of renewables in electricity generating capacity has remained stable worldwide throughout the years, but has risen in EU-27 and fallen in Turkey. Although renewables' share has been falling, as seen before the production capacity remains unchanged in Turkey and it is higher than both the world and EU average which are 23% and 28% respectively, whereas Turkey's is 37% in 2007.

Table 7 shows the energy intensities of 32 countries subject to study. As the unit is koe (kilogram of oil equivalent) per 1000 euro (vs. koe per dollar) and the denominator GDP is calculated at constant prices (1995=100) (vs. purchasing power parities), the results are different from the previous table.

Table 7. Energy intensities of 32 European countries (Primary energy divided by GDP (at constant prices, 1995=100) - koe per 1000 euro)

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Belgium	259	256	256	252	244	238	227	237	230	224	215	199
Bulgaria	1.790	1.663	1.585	1.399	1.361	1.359	1.275	1.249	1.138	1.127	1.090	1.016
Czech Republic	721	725	704	649	659	659	655	686	660	613	588	553
Denmark	147	133	127	120	112	115	113	118	112	106	110	106
Germany	186	181	177	171	166	169	166	167	166	163	159	151
Estonia	1.220	1.084	961	895	819	778	701	719	693	624	551	581
Ireland	162	152	150	143	137	135	130	122	123	110	107	103
Greece	214	208	211	204	205	202	201	193	187	185	178	182
Spain	192	194	197	197	196	195	195	196	198	195	187	184
France	201	191	191	185	180	182	180	181	180	177	171	165
Italy	147	147	149	150	145	143	143	151	149	151	147	143
Cyprus	249	238	243	237	237	231	228	243	216	209	212	212
Latvia	675	604	563	498	441	446	411	409	387	357	328	307
Lithuania	905	792	774	665	571	616	612	577	547	478	434	433
Luxembourg	205	191	175	170	165	167	170	176	185	180	169	159
Hungary	608	569	539	515	481	471	460	460	431	438	417	401
Malta	248	286	243	241	191	219	195	214	217	212	195	198
Netherlands	218	207	198	188	184	186	187	191	192	185	175	177
Austria	157	154	151	146	140	147	148	155	153	152	149	141

Poland	684	632	565	526	489	483	469	463	442	433	427	400
Portugal	197	201	205	212	205	202	209	206	209	212	196	197
Romania	1.079	1.083	1.039	935	920	865	858	853	774	736	706	656
Slovenia	358	346	331	313	300	306	299	294	290	285	270	253
Slovakia	896	854	804	800	796	845	810	769	728	680	620	539
Finland	286	286	276	261	246	244	255	265	257	231	241	229
Sweden	225	214	208	198	180	191	185	180	180	171	160	156
United Kingdom	164	155	155	149	145	142	135	134	131	129	123	115
Croatia	406	409	411	411	392	382	375	382	367	354	339	336
Turkey	267	261	258	262	268	262	260	260	245	236	244	251
Iceland	318	309	310	341	343	343	346	337	323	311	359	360
Norway	145	145	148	151	143	145	129	143	143	158	120	129
Switzerland	102	102	101	100	95	100	96	97	95	93	94	87

Energy intensity has fallen in all countries from 1996 to 2007. Countries with lowest energy intensity are Norway, Switzerland, Denmark and Ireland and with highest energy intensity are the new members, Bulgaria, Romania, Slovakia and Estonia; but they are also the countries that experienced the highest improvement. Turkey remains as one of the lower energy intensive countries in Europe.

Table 8. Energy intensities of the EU, United States and Japan (Primary energy divided by GDP (at constant prices, 1995=100) - koe per 1000 euro)

Region	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
EU 27	212	204	200	193	187	188	185	187	185	182	176	169
EU 15	185	179	177	172	168	168	166	167	166	163	158	152
United States	237	229	222	218	217	211	210	205	201	197	190	190
Japan	103	103	103	105	104	102	102	100	100	98	96	93

Among the EU-27, EU-15, United States and Japan, energy intensity is highest in the United States and lowest in Japan (Table 8).

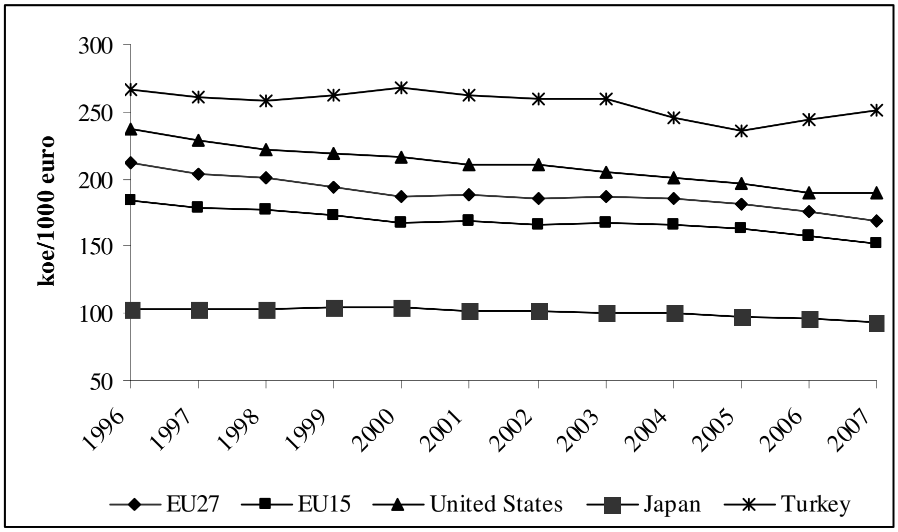

Figure 18. Energy intensity trends of selected economies

To sum up, although energy consumption has increased in most of the regions around the world, there is a decoupling between energy use and economic activity. This decoupling is more evident in the EU. Since 1990, energy consumption has been growing at only one third of the rate of the GDP. In the period 2004-2007 this rate has further slowed down. This fact caused a significant decrease in energy intensities of countries.

Turkey's energy consumption has a much higher increasing trend compared to the EU-27. Economic growth, industrialization and structural changes in the economy had a marginal influence on energy use. But substantial further energy efficiency potentials remain to be opened up by new or enhanced policy measures.

The Role of Energy Trade in Turkey's Economy

In many countries energy trade constitutes an integral part of the total international trade. As a vital commodity with no substitution, energy dependent countries who lack the necessary primary energy resources are obliged to satisfy their inland demand through importing from energy producing countries. Turkey is an energy dependent country whose energy production is far from sufficient to meet domestic demand. As energy production within Turkey has been almost stable in the last fifteen years whereas energy consumption has been continuously increasing as seen earlier in the chapter, Turkey's energy imports have also experienced a significant increase.

Table 9. Turkey's Energy Imports, Energy Exports and Energy Trade Deficit (TMFT, 2009)

Year	in 1000 USD		
	Energy Imports	Energy Exports	Energy Trade Deficit
1989	3,247,338	258,614	-2,988,724
1990	4,622,407	296,347	-4,326,060
1991	3,756,887	290,358	-3,466,529
1992	3,760,095	233,127	-3,526,969
1993	3,964,662	176,507	-3,788,155
1994	3,817,632	243,850	-3,573,783
1995	4,620,801	289,611	-4,331,189
1996	5,777,946	118,467	-5,659,479
1997	5,881,302	72,494	-5,808,808
1998	4,325,202	158,584	-4,166,618
1999	5,004,619	206,250	-4,798,369
2000	9,221,241	292,666	-8,928,575
2001	8,014,661	337,019	-7,677,642
2002	9,126,585	641,436	-8,485,149
2003	11,392,962	765,621	-10,627,342
2004	14,299,533	1,129,399	-13,170,133
2005	21,030,745	2,176,123	-18,854,623
2006	28,610,414	3,358,470	-25,251,944
2007	33,791,135	4,500,741	-29,290,394
2008	48,281,193	7,531,460	-40,749,733

Turkey's energy imports follow a parallel path with energy prices. Throughout the 90s, energy imports increased slightly due to slow increase in energy demand. The first sharp increase was in the year 2000, where imports almost doubled. This increase was mostly the result of the sharp rise in energy prices. After 2004, the rise in imports became even sharper both as a result of increasing energy prices and an accelerated increase in demand due to high economic growth. As of 2008, Turkey's energy bill has reached to the peak value which is an outcome of record high energy prices.

Turkey's energy exports in USD have fluctuated from 1989 to 1999 due to the variations in energy prices and changes in local demand which forwarded energy either to domestic consumption or exports. However, after 2000, in line with the increase in energy imports Turkish energy exports have accelerated continuously and reached to its peak value in 2008. Although this seems a positive sign, it should be noted that since most of the raw materials of exported energy commodities are also imported from external resources, a rise in energy exports also imply a rise in energy imports. In other words, there exists a tight link between the realizations of energy exports with the continuity of imports. (Nenem, 2009)

Since the growth in energy exports was not able to compensate the enormous rise in imports, Turkey's energy trade deficit has continued to deepen and reached almost 40.1 billion USD in 2008. From 1989 to 2008, the energy trade deficit has boomed by 1,263%.

Given such huge deficit scheme that is sourced by excessive energy imports, needless to say, energy trade embodies an integral aspect of Turkey's international trade. Although energy export's share has not been far above 4% of the overall exports from 1989 to 2008. The share of energy imports among Turkey's total imports has historically been from 10% to 25%.

Table 10. Turkey's Total Imports, Total Exports, Trade Deficit and Energy's Percentage Share (TMFT, 2009)

Year	1000 x USD			Energy's share in		
	Total Imports	Total Exports	Trade Deficit	Total Imports	Total Exports	Trade Deficit
1989	15,792,143	11,624,692	-4,167,451	20.6%	2.2%	71.7%
1990	22,302,126	12,959,288	-9,342,838	20.7%	2.3%	46.3%
1991	21,047,014	13,593,462	-7,453,552	17.8%	2.1%	46.5%
1992	22,871,055	14,714,629	-8,156,426	16.4%	1.6%	43.2%
1993	29,428,370	15,345,067	-14,083,303	13.5%	1.2%	26.9%
1994	23,270,019	18,105,872	-5,164,147	16.4%	1.3%	69.2%
1995	35,709,011	21,637,041	-14,071,970	12.9%	1.3%	30.8%
1996	43,626,642	23,224,465	-20,402,178	13.2%	0.5%	27.7%
1997	48,558,721	26,261,072	-22,297,649	12.1%	0.3%	26.1%
1998	45,921,392	26,973,952	-18,947,440	9.4%	0.6%	22.0%
1999	40,671,272	26,587,225	-14,084,047	12.3%	0.8%	34.1%
2000	54,502,821	27,774,906	-26,727,914	16.9%	1.1%	33.4%
2001	41,399,083	31,334,216	-10,064,867	19.4%	1.1%	76.3%
2002	51,553,797	36,059,089	-15,494,708	17.7%	1.8%	54.8%
2003	69,339,692	47,252,836	-22,086,856	16.4%	1.6%	48.1%
2004	97,539,766	63,167,153	-34,372,613	14.7%	1.8%	38.3%
2005	116,774,151	73,476,408	-43,297,743	18.0%	3.0%	43.5%
2006	139,576,174	85,534,676	-54,041,498	20.5%	3.9%	46.7%
2007	170,062,715	107,271,750	-62,790,965	19.9%	4.2%	46.6%
2008	201,960,779	132,001,810	-69,958,969	23.9%	5.7%	58.2%

From this perspective, energy trade composes an important portion of Turkey's overall trade deficit whose contribution rarely fell below 30% of the entire trade deficit since 1989. In 2008 energy trade's participation to overall trade deficit was 58.2%. Consequently, energy trade plays a significant role in Turkey's current account deficit as well, which is considered one of the most weakening aspects of Turkey's economy since 2004 (Table 11). Therefore attempts to control and reduce energy use without compromising growth and production, and hence reducing the dependability on energy imports has become inevitable for Turkey's economic sustainability.

Table11. Turkey's Energy Trade Deficit And Current Account Deficit (TMFT, 2009)

Year	1.000.000 USD	
	Energy Trade Deficit	Current Account Deficit
1996	-5,659	-2,437
1997	-5,809	-2,638
1998	-4,167	1,985
1999	-4,798	-1,341
2000	-8,929	-9,822
2001	-7,678	3,392
2002	-8,485	-1,524
2003	-10,627	-8,036
2004	-13,170	-15,604
2005	-18,855	-23,155
2006	-25,252	-31,316
2007	-29,290	-37,996
2008	-40,750	-41,416

According to a study of The General Directorate of Electrical Power Resources, if Turkey can take determined and successful steps towards improving energy efficiency, the realized level of the predicted consumption level in 2020 can be reduced by 20% corresponding to 45 Mtoe of energy saving. This amount is about 2.5 times Turkey's electrical energy production capacity and is believed to be enough to cover around 30 million households' annual energy need.

CHAPTER 3

ENERGY EFFICIENCY POLICIES

Given all the facts mentioned in the earlier chapter, improving energy efficiency has become an important tool of sustainable energy policy in many countries as well as most multinational entities. Rapidly implementing energy efficiency measures is currently the crucial first step towards addressing energy security, environmental and economic sustainability challenges at the lowest possible cost or even with negative costs. Almost all OECD countries are implementing new instruments adapted to their national circumstances. Many countries have made significant gains in energy efficiency by applying several measures and regulations despite all the barriers to energy efficiency. In this chapter, we will first review the energy efficiency barriers around which the energy efficiency policies and measures are built all around the world by governments and supranational institutions. As the aim of this study is to make a comparative analysis of energy efficiency in Turkey as opposed to the EU, which plays a leading role in promoting energy efficiency, the second and third part of this chapter will be devoted to explaining the historical background and the current situation of policy making on energy efficiency, in the EU and in Turkey respectively.

Barriers to Energy Efficiency and Related Policies

Energy efficiency policies and measures applied everywhere around the world can be categorized either with respect to their target or with respect to what type of barrier it aims to overcome. The policies to lower energy consumption by increasing efficiency, if categorized by their target, are either general framework policy measures that are applicable across sectors, or they target one of the end-use energy consuming sectors such as industry, transportation, households (buildings, lighting, appliances and equipment, utilities). In the second and third part of this chapter, we will make use of this classification time to time while explaining on going policy measures in the EU and in Turkey. In this section of the chapter, we will explain the barriers to energy efficiency and the policy and measures which aim of overcoming these barriers. It is possible and preferred that some policies aim at tackling more than one kind of barrier. It is actually important for governments to coordinate policies in a way to address all of these barriers across all sectors.

Barriers to Energy Efficiency

There is a vast literature on the barriers to energy efficiency and the applied policies. The IEA(2008e) lists some of these barriers as, higher initial capital costs, principal agent problems, uninformed investors with little familiarity with energy-efficient products, risk exposure, discount rate issues and the difficulty of quantifying external benefits. Another report published by the IEA(2008g) titled "Promoting Energy Efficiency Investments – Case Studies in the Residential Sector" has mentioned market barriers such as low priority of energy issues, difficulties in accessing capital, the presence of information asymmetries and principal agent problems and financial barriers such as initial cost, risk exposure and the inadequacy of traditional financing mechanisms for energy efficiency projects to be some important barriers to energy efficiency.

Following from the literature and the study made by Sovacool (2009) on the importance of comprehensiveness of energy efficiency policy, the obstacles standing in front of energy efficiency may be divided into financial and market impediments, political and regulatory obstacles and cultural and behavioral barriers categories.

Financial and market impediments include barriers such as information failure, returns on investment, split incentives / principal agent problem, the invisibility of energy savings and predatory market power. Producers do not distribute accurate information on energy efficient technologies; hence consumers lack readily available information. For example, real-time electricity costs are masked through customer aggregation, average billing and regulated rate plans. There are improper discount rates and unacceptably high rates of return for energy investments, homeowners lack available capital or access to it to purchase energy-efficient technologies; consumers, businesses and utilities are more concerned with “first costs” than “lifetime costs”. There are many forms of split incentives / principal agent problems concerning energy efficiency. Builders make energy decisions for homeowners, landlords make energy decisions for tenants, businesses remain focused on maximizing profit rather than investing in different forms of energy supply, fiscal and regulatory policies discourage energy efficiency and there is limited supply and availability of energy efficient technologies. Predatory market power refers to some predatory practices undertaken by some energy firms and utilities that by means of intellectual property rights, patent blocking and patent suppression prevent entry into the industry.

Political and regulatory obstacles may be of the form variable and inconsistent incentives, under funded research and development and bureaucracy. Inconsistent government standards and fragmented policy making causes some incentives such as subsidies to expire before ever being fully implemented. A bureaucratic approach to energy efficiency projects also discourages energy efficiency improvement.

Another important type of barriers is cultural and behavioral barriers. These barriers arise from public misunderstanding about electricity and energy efficiency, public expectations about cheap and abundant forms of electricity supply and a strong personal desire among consumers to prioritize comfort, control and freedom rather than energy conservation and sustainability. Also energy efficient technologies are believed to be aesthetically unappealing and hence the negative externalities are not assessed properly.

As can be seen, the barriers facing energy efficiency are technical, economic, political and social. They are all interconnected and deeply embedded in the social fabric. Therefore the policies required to overcome these impediments must also be equally rigorous, interrelated and comprehensive in order to be effective.

The first priority for pursuing a successful energy efficiency policy, countries set up institutions and agencies, either at the national level or regional levels or both, dealing specifically with energy efficiency. Such institutions are responsible for the comprehensiveness of the implemented policies as well as their monitoring, tracking and evaluation. According to a World Energy Council (2008) report on energy efficiency policies including a global survey of 76 countries, almost all countries have set up such agencies or institutions.

Considering the technical, economic, political and social barriers, energy efficiency policies can be classified as regulatory measures, financial and fiscal incentives, information / education / training and innovative measures that are currently in the form of introducing a market for energy efficiency which will be explained further in next section.

Regulatory Measures

Increasingly more countries are setting up a proper regulatory framework, with an energy efficiency law or an energy efficiency program with official quantitative targets, to provide long lasting context for energy efficiency policies. The main target of regulations is generally electrical appliances and buildings. Appliance standards and building codes are the most commonly used regulatory instruments. Efficiency standards and labeling are effective methods of transforming the market. Labeling acts as an incentive for manufacturers to differentiate themselves from their competitors and stimulates the introduction of new, more efficient models. Standards remove from the market the less efficient appliances or applications. Hence they work to overcome both market impediments and lack of public awareness.

Financial and Fiscal Incentives

Financial incentives mostly consist of fiscal incentives such as tax credits, tax reductions and accelerated depreciation and direct subsidies. Table 12 shows the major types of energy subsidies, namely financial incentives.

Table 12. Major Types of Energy Subsidies (Sovacool, 2009).

Direct Financial Transfer	Preferential Tax Treatment	Trade Restrictions	Public Funding	Direct Regulation
Grants to producers	Rebates	Quotas	Direct Investment in infrastructure	Mandated deployment rates
Grants to consumers	Exemptions	Technical restrictions	Public R&D expenditures	Price control
Low-interest preferential loans and guaranties	Sales taxes	Trade embargoes	Federal procurement and direct ownership of assets	Market access restrictions
	Producer Levies		Administration of regulatory costs	Federal market planning
	Tariffs			Assumption of legal risk and indemnication
	Accelerated depreciation			
	Reductions in tax rate			
	Altering taxable entity			

Direct subsidies are often considered costly but they are viewed as temporary measures to mobilize consumers and to prepare for new regulations. They allow a cost reduction for the subsidized energy efficient technologies and hence promote them by helping to create a larger market for such technologies. Fiscal incentives are considered cheaper than direct subsidies, and therefore have a more common use. They work well if the tax collection rate is high and hence work poorly in an economy in recession or transition. They obviously help overcome financial and market impediments on energy efficiency.

Although not exactly considered a financial measure, energy pricing is an important tool for energy conservation. Lower energy consumption is an immediate result of higher energy prices. A progressive increase of energy prices even at a low rate, when announced publicly, can in the long term have a large impact on technological innovation. Also as energy efficiency is concerned, changing the way energy is priced instead of lowering or increasing prices, is a different energy efficiency policy. The following section briefly explains energy pricing as a policy tool within the specific case of electricity pricing.

Electricity Pricing

It is a commonly accepted fact that a more accurate pricing of electricity is one of the most effective energy efficiency policies since it improve the efficiency of the industry, provides proper price signals and reduces wasteful energy use (Sovacool, 2009). There are several ways to price electricity more accurately in order to promote energy saving.

Many countries have some type of price cap on residential or industrial electricity. By keeping prices artificially low, price caps cause excessive consumption, undervalue efficiency and make consumers unable to make rational decisions based on the actual cost of electricity and is believed that they should be abolished. Another tradition that causes excessive consumption is the declining block-rate pricing. This means that consumers of small amounts of electricity pay more and larger consumers (often industrial or commercial customers) pay less for electricity. If there were inverse block-rate pricing, where customers are charged higher rates the more they consume, there would be a more rational use of electricity. An example of this kind of pricing is applied in California, where residential customers pay 11.6 cents / kWh for normal electricity use, those consuming 30% more than average pay 13.3 cents / kWh, those consuming twice as much pay 22.8 cents / kWh, and those consuming three times as much pay 24.8 cents / kWh. It has been found that this practice have even reduced rate charges for large customers by as much as 9.5% (Carter, 2001).

One other policy option for accurate pricing is to reflect “time-of-use” in electricity rates and bills. Electricity is usually based on average prices and they combine charges for all appliances, lighting, water heating, and space heating and cooling all into a lump sum which at the end is revealed to customers through monthly bills. But actually electricity production and consumption varies according to the time of day, week, month and year. It is also impossible for the consumers to tell how much of the bill is results from what and how much it could be decreased by using more efficient technologies. Alternative rates to use could be “real/time”, “interval-metering”, “time-of-use” and “seasonal” rates which would reflect meaningful differences between peak and off-peak consumption. Georgia power have experimented time-of-use metering for 1650 large industrial customers and from 1992 to 2002 achieved 17% reduction in peak demand. A pilot program in California used time-of-use rates at the residential level with 2400 customers and found that participants shifted more than 20% of their peak consumption to off-peak hours (Sovacool, 2008).

Apart from properly pricing electricity, studies have shown that providing feedback to customers about electricity prices and their electricity consumption frequently, reduces consumption significantly. Kempton and Layne (1994) provided residents with daily electricity prices for a month and found a 10% reduction in electricity use. Another survey informed households daily about how much electricity they were using and found a 20% reduction in consumption (Stern and Aronson, 1984).

Information / Education / Training

Lack of information to consumers is one of the main barriers to energy efficiency. To overcome this issue, there are a large range of tools that countries use such as information campaigns, energy efficiency weeks, labeling of appliances, workshops and training, auditing and local information centers.

Audit schemes are a good way to inform consumers about their possible actions to improve and are mainly developed in industry and non-residential buildings. They are increasingly being made mandatory in many countries and regions although they could be voluntary as well. Energy audits are usually funded by public agencies. In many countries, energy management in industrial companies and in residential buildings is also being made mandatory. Both mandatory audits and energy management require qualified staff, and this is assured by the certification of auditors and by the training of energy managers.

Other attractive mechanisms to capture cost-effective energy efficiency potentials with the involvement of private sector are Energy Service Companies (ESCOs) and Energy Performance Contracting (EPC). The reason for their effectiveness is because they do not involve either public expenditure or market intervention. An energy service company is a professional business providing a broad range of comprehensive energy solutions including designs and implementation of energy savings projects, energy conservation, energy infrastructure outsourcing, power generation and energy supply, and risk management. The ESCO performs an in-depth analysis of the property, designs an energy efficient solution, installs the required elements, and maintains the system to ensure energy savings during the payback period. The concept behind EPC is leveraging money saved on energy and operating costs to pay for building improvements. Customers are able to apply the savings they realize toward facility improvements, within existing budgets and without the need for capital funding.

To sum up and summarize general energy efficiency policies, the conclusions and recommendations of the 2008 report of World Energy Council titled "Energy Efficiency Policies around the World: Review and Evaluation" is a useful source. According to the report, successful energy efficiency programs should involve the following strategies:

- Appropriate fiscal and pricing policies taking into account international competition and the negative impacts of low income households,
- The establishment of a favorable and stable institutional framework including institutions to design, coordinate, implement and evaluate programs and measures and a proper regulatory framework,
- The simultaneous implementation of measures, in other words package of measures,
- Public / private partnership, stable regulatory environment to promote private sector involvement,

- Well planned, regularly strengthened and properly enforced regulations,
- Strengthening the quality of energy services and equipment by certification and testing facilities,
- Promotion of innovative measures in developing countries based on experiences elsewhere,
- Tailoring of measures to its own circumstances for each country,
- Reinforcement of coordination of measures in the international level,
- Integration of other policies with energy efficiency aspects and
- Evaluation of implemented measures and their monitoring using indicators.

Energy Efficiency Policies in the EU

The EU has been playing a leading role in the efforts for an economically and environmentally sustainable energy future. As a part of its commitment to integrate environmental concerns into all relevant policy areas, including energy, it has been setting ambitious targets for increasing energy efficiency and the share of renewable energies in overall energy mix. It is stated in the Energy Efficiency Action Plan (EU,2006) that energy efficiency represents a solution to tackling climate change, improving energy security, reducing costs within the EU and achieving the objectives of Lisbon Strategy (EU Com., 2010). A consultation paper of the EU Commission mentions that "the EU should compete more effectively and increase its productivity by a lower and more efficient consumption of non-renewable energy and resources in a world of high energy and resources prices, and greater competition for energy and resources (EU Com., 2009). This will stimulate growth and help meet our environmental goals. It will benefit all sectors of the economy, from traditional manufacturing to new hi-tech start ups. Upgrading and inter-connecting infrastructure, reducing administrative burden and accelerating the market uptake of innovations will equally contribute to this goal".

In order to meet these goals, the EU has been making policies and measures on energy efficiency since early 1990s. While there were many educational and awareness programmes held on energy efficiency and some regulations on efficiency standards and labeling, the first Energy Efficiency Action Plan was published in 2000. The European Commission presented the communication "Energy Efficiency in the EU - Towards a Strategy for the Rational Use of Energy" (EU Com., 1998) in 1999 which included a target of 1% annual improvement in energy efficiency. In April 2000, the European Commission proposed an energy efficiency plan that included a call for voluntary agreements in a range of sectors such as steel, paper, cement and textile, similar to the one that had recently been agreed to by automobile manufacturers regarding carbon dioxide emissions and cars. Some of the other measures outlined in the proposed energy efficiency action plan were as follows: increased consumer information via labeling and efficiency requirements on household appliances and commercial and other end-use equipment; coordinated EU action plans for long-term agreements with industry; an amendment to directive 93/76/EEC dealing with better energy certification for insulation standards and boiler inspections; establishment of EU-wide energy audits; and improvement in monitoring and evaluation. This action plan was superseded when a new one was published in 2006.

In 2006, the EU published a new Energy Efficiency Action Plan to cut its energy consumption by 20 % by 2020 (EU, 2006). The Action Plan addresses energy efficiency possibilities across all sectors. The plan incorporates 10 energy conservation priorities and more than 70 planned actions, including new appliance efficiency standards, a revision of energy labeling rules and more-stringent energy performance standards for buildings - including new EU minimum standards and the inclusion of more buildings. Twenty of these actions were implemented in 2007. The plan sets forth future binding efficiency requirements for new electricity, heating and cooling installations and a renewed effort to fortify taxation policies encouraging energy efficiency.

The Directive on Energy End-Use Efficiency and Energy Services was adopted in December 2005. The aim of this directive is to remove the barriers on energy efficiency especially in end-use sectors, namely industry, building and transportation, by using defined targets and incentives, as well as preparing an institutional / financial / legal framework and to generalize energy services through energy saving programmes. The Directive requires member states to draw up National Energy Efficiency Action Plans (NEEAPs) to achieve 9% (final) energy savings between 2008 and 2016 including transport fuels. The target is only indicative but the NEEAPs need approval from the Commission and is reviewed every three years.

Table 13 provides a list of European-wide energy efficiency related policy and measures that are initiated by the EU directives or actions. Some of these instruments are mentioned and explained throughout this chapter. Detailed information on the given measures can be found on the IEA web-site.

Table 13. EU Energy Efficiency Policies and Measures (IEA Database)

Name	Type	Target	Year
20 20 by 2020: Europe's Climate Change Opportunity	Policy Processes	Multi-sectoral Framework Policy	2008
Clean Sky Joint Technologies Initiative	R & D	Transport	2008
EU Emissions Trading Scheme 2008-12	Tradable Permits	Framework Policy	2008
Global Energy Efficiency and Renewables Fund	Incentives/ Subsidies		2008
New EU-US Energy Star Agreement	Public Investment	Appliances	2008
Revised State Aid Guidelines for Environmental Protection	Regulatory Instruments	Multi-sectoral	2008
An Energy Policy for Europe	Policy Processes	Multi-sectoral Framework Policy	2007
Competitiveness and Innovation Programme (CIP): 2007-2013	Policy Processes		2007
EU Sustainable Energy Week	Education and Outreach Voluntary Agreement	Multi-sectoral	2007
European Council Action Plan(2007-2009) Energy Policy for Europe	Policy Processes	Framework Policy	2007
Intelligent Energy - Europe Programme (2007 -2013)	Education and Outreach Incentives/ Subsidies R & D	Multi-sectoral	2007
Seventh Framework Programme for Research and Technological Development	Incentives/ Subsidies R & D	Multi-sectoral	2007
Strategic Energy Technology Plan (SET Plan): Towards a low carbon future	Policy Processes	Framework Policy	2007
Directive on Energy End-use Efficiency and Energy Services 2006/32/EC	Policy Processes		2006
European Commission Action Plan on Energy Efficiency	Policy Processes		2006
Green Paper on a European Strategy for Sustainable, Competitive and Secure Energy	Policy Processes		2006
High-level Group on Competitiveness, Energy and the Environment	Education and Outreach Policy Processes		2006
Thematic Strategy on the Urban Environment	Policy Processes Education and Outreach Public Investment Voluntary Agreement	Multi-sectoral Framework Policy	2006
Directive for Setting Eco-Design Requirements for Energy-Using Products		Appliances	2005
Directive on the Taxation of Energy Products and Electricity	Financial	Framework Policy	2004

Directive to Promote Cogeneration of Heat and Power	Regulatory Instruments		2004
Intelligent Energy Europe Programme	Financial Incentives/ Subsidies	Framework Policy	2003
Marco Polo Programme - Intermodal Freight Transport	Incentives/ Subsidies	Transport	2003
Updated Energy Labeling of Household Appliances	Education and Outreach	Appliances	2003
Directive on the Energy Performance of Buildings	Education and Outreach Policy Processes	Buildings	2002
The CIVITAS Initiative - Strategy for Clean Urban Transport		Transport	2001
Co-operation Agreement signed with the USA on Energy Research	Voluntary Agreement	Multi-Sectoral	2001
European Reference Center for International Freight Transport (EURIFT)	Policy Processes	Transport	2001
First Phase of European Climate Change Programme (ECCP)	Education and Outreach Policy Processes Public Investment Regulatory Instruments Tradable Permits	Multi-sectoral Framework Policy	2001
White Paper: European transport policy for 2010: time to decide	Policy Processes	Transport	2001
Energy Efficiency Action Plan		Multi-sectoral Framework Policy	2000
New Criteria for Refrigerators and Washing Machines Eco-Labels	Education and Outreach Regulatory Instruments	Appliances	2000
Directive on Fuel Economy and CO2 Labels for Cars		Transport	1999
Energy Efficiency Label (Energy Star)	Education and Outreach	Appliances	1999
Best Available Techniques Reference Documents (BREFs)	Education and Outreach Voluntary Agreement	Industry	1996
EU Eco-Management and Audit Scheme (EMAS)	Education and Outreach Regulatory Instruments Voluntary Agreement	Multi-Sectoral	1995
EU Energy Efficiency Standards	Regulatory Instruments	Appliances	1992
EU Energy Efficiency Labels	Education and Outreach	Appliances	1992

The next subsections will give brief information on the latest developments in European-wide policy measures in each of the end-use sectors.

Buildings

In the EU, buildings represent a very large proportion of all energy use. In order to address this issue, the EU adopted the Directive for Energy Performance of Buildings (EPBD) in December 2002. (EU, 2002) The directive provided a common methodology for calculating the energy performance of buildings and obliged member states to draw up minimum standards. These should be applied to all new buildings and to existing buildings with a usable floor area above 1,000 m^2 when they undergo a major renovation. However, no EU-wide minimum efficiency standards were imposed. To promote awareness and energy savings in buildings, the directive introduced an energy performance certificate, which has to be made available each time a house is built, sold or rented out. The certificate should help potential buyers or renters to compare the building's energy performance against established national standards and benchmarks, and to consider any cost-effective improvements they could make. In November 2008 the Commission proposed a revision of the EPBD. The key changes that the revised directive which is assumed to be adopted in 2010 will bring are the elimination of the 1,000 m^2 threshold, and some obligations on renewable energy systems for all new buildings. The condition will be that all new constructed buildings as of 2020 would have to be zero-energy.

Appliances

To establish a framework under which manufacturers of energy-using products will be obliged to reduce the energy consumption and other negative environmental impacts occurring throughout the product life cycle, Eco-design directive to set Minimum Efficiency Standards (MEPS) was adopted in 2005 (EU, 2005). It introduces minimum efficiency standards for up to 40 products which cover the industrial sector, the tertiary sector and the building sector. MEPS for nine of these product groups have already been published, many of which in 2009 (e.g. standards on lighting with the more or less implicit phasing-out of incandescent light bulbs, on the stand-by of IT appliances, on electric motors and on pumps etc).

Transport Sector

It is difficult to implement effective policies in transport sector because of the strong lobby of the car industry and transport companies, and the particular relationship of consumers to cars, who see them both as a means of transport as well as a status symbol. Hence, the measures implemented by the EU on the transport sector, for a long time has been limited to the following three areas: voluntary agreements with car manufacturers, the biofuels directive and the mandatory labeling of cars.

The Directive on Fuel Economy and CO2 Labels for Cars requiring passenger cars sold in the European Union to carry a label on fuel economy and carbon dioxide emissions have been in force since 1999. The European Commission adopted in September 2001 a new Transport Policy White Paper (COM, 2001), proposing an action plan aimed at substantial improvements in the quality and efficiency of transport in Europe. The White Paper aims at a shift to an environment-friendly mix of modes of transport. The White Paper proposes a total of about 60 measures, some of which would lead to substantial reductions in energy consumption and CO2 emissions.

In the future it can be expected that the impact of EU policies will be greater with the new Directive on mandatory CO2 standards for cars (Regulation 443/200942 of April 2009 setting emission performance standards for new passenger cars), a higher biofuels target in 2020 (10 %), the integration of air transport in the

European Emission Trading scheme, and the Energy Service Directive that explicitly mentions transport as a field of action.

Industry

Most of the energy efficiency measures for the industry sector are national measures and are not linked to EU Directives or to EU involvement (~82%). However the EU Emission Trading Scheme (ETS), which aims both at the energy industry and large industrial emitters, is by far the most important European-wide instrument to reduce GHG emissions in the industrial sector and, at the same time, to improve energy efficiency. This scheme was recently newly defined for the period 2013-2020 by including large shares of auctioning for the allowances (for the energy sector and the industrial sectors which are not threatened by international competition) and by making use of benchmarks to define the allocation to the other industrial sectors based on the level of the 10% best Europe-wide. Another important EU-wide measure for the industrial sector is the Eco-design Directive which sets minimum standards for a variety of industrial cross-cutting technologies such as electric motors. To sum up all the industrial energy efficiency measures in the EU, they are categorized in five distinguished by the measure type.

Regulations

Regulation for industrial energy efficiency is not the most frequently used instrument, however there are two areas where regulation plays a more or less important role: setting minimum energy performance standards (MEPS) for industrial cross-cutting technologies under the EU Eco-design Directive (legislative-normative instrument) in which some standards have a very large influence in the industrial sector and mandatory energy managers, mandatory energy audits and mandatory reporting of energy consumption (Legislative-informative instrument).

Financial / Fiscal Measures

The second and the most frequently used measure type are financial/fiscal measures (34% of all on-going measures). These cover subsidies given to overcome investment barriers, promotion of energy efficient systems, aids, grants or incentives directed at investments to exceed standards or to accelerate the introduction of standards, aids for environmental studies. Table 14 illustrates the on-going financial incentive programmes since 2000 in the EU.

Table 14. On-going Financial Incentive Programmes Since 2000 in the EU (MURE).

Code	Country	Title	Start	End
BEL5	Belgium	Promotion of Cogeneration	2005	
BG1	Bulgaria	Energy Efficiency Act (EEA) – Mandatory Industrial Audits for Energy Efficiency	2006	
BG2	Bulgaria	Grants for energy audits in SME	2006	
CZ3	Czech Republic	Operational Programme Industry and Enterprise 2004-2006	2004	2006
GER36	Germany	Special fund for energy efficiency in SME´s (Sonderfonds Energieeffizienz in KMU)	2008	
LV15	Latvia	Investments in Clean Fuels	2009	2013
CY3	Cyprus	Governmental grants/subsidies scheme for the promotion and encouragement of RES, energy saving and the creation of a special fund for financing or subsidizing of these investments	2003	
FRA3	France	FIDEME: fund for investment in environment and rational use of energy	2000	
FRA4	France	FOGIME: Guarantee fund for energy conservation	2000	
HUN9	Hungary	HU51 Environment and Energy Operative Programme	2007	
IRL11	Ireland	Combined Heat and Power (CHP) Grants Programme	2006	
ITA15	Italy	Efficient electric motors and inverters	2007	
RO3	Romania	Management of energy demand and development of the energy balance sheets	2001	2010
RO7	Romania	Grant-supported credit line for Romania that has been established by the European Commission and the European Bank for Reconstruction and Development.	2008	2010
RO8	Romania	The promotion of ESCO's	2007	2010
SLO5	Slovenia	Financial incentives for efficient electricity use measures	2008	2016
BEL6	Belgium	Energy audits	2002	
BEL18	Belgium	Financial incentives for investments in energy efficiency	2002	
BG3	Bulgaria	Energy Efficiency and Renewable Energy Credit Line (BEERECL)	2004	
CR1	Croatia	FZOEU energy efficiency programme	2004	
CR2	Croatia	FZOEU and MINGORP energy audit programmes	2004	
CR3	Croatia	FZOEU renewables promotion programme	2004	
CZ2	Czech Republic	Investment subsidies in the framework of the annual Government Programme A	2006	2006
CZ6	Czech Republic	FINESA Programme	2004	

HUN17	Hungary	Third party financing within the frame of Environment and Energy Operative Programme	2007	2013
MAL4	Malta	Support schemes for industry and SME's	2006	2013
NOR15	Norway	Energy Consumption - Industry (Energibruk - industri)	2003	
NOR16	Norway	Grants to local heating plants (Program for lokale energisentraler)	2008	
POR2	Portugal	MAPE/PRIME - Measure for Supporting the Use of Energy Potential and Rational Use of Energy	2001	2006
RO4	Romania	Financial support for investment projects to reduce energy consumption	2001	2008
RO5	Romania	Implementation of investment projects co-financed by Community funds	2008	2010
SK9	Slovakia	Operational Programme "Competitiveness and Economic Growth" priority line Energy	2008	
SLO2	Slovenia	Energy audits and feasibility studies subsidies	2003	
SPA9	Spain	Energy Saving&Efficiency Strategy in Spain (E4) 2004-2012: Technologies in New Processes	2004	2012
UK5	United Kingdom	The Enhanced Capital Allowance Scheme	2001	
UK8	United Kingdom	The Carbon Trust - (Various initiatives)	2001	

The information is gathered from the MURE Measures Database and the first column is the code of each programme in the database. MURE (Mesures d'Utilisation Rationnelle de l'Energie) is a database that provides information on energy efficiency policies and measures that have been carried out in the Member States of the European Union and enables the simulation and comparison at a national level of the potential impact of such measures. It has been designed and developed within the framework of the SAVE and 'Intelligent Energy - Europe' Programmes by a team of European experts, led and co-ordinated by ISIS (Institute of Studies for the Integration of Systems, Rome) and the Fraunhofer Institute for Systems and Innovation Research ISI (Germany). The development of the MURE database was also supported by national funding in each EU Member State.

<u>Cooperative Measures</u>

These are voluntary / negotiated agreements and are considered high impact measures. Roughly half of all EU countries have introduced such types of measures; however, three countries have made particular use of this type of measure: Finland, Sweden and Spain. Table 15 shows the on-going cooperative measures in EU since 2005.

Table 15. On-going Cooperative Measures Since 2005 in the EU (MURE)

Code	Country	Title	Start	End
BG4	Bulgaria	Voluntary long term agreements in industry	2006	
EU11	EU	European Green Light Programme	2007	
EU12	EU	European Green Building Programme	2005	
FIN14	Finland	Energy Efficiency Agreement of Industry 2008-2016	2007	2016
FIN15	Finland	Energy Efficiency Agreement of Energy Production 2008-2016	2007	2016
FIN16	Finland	Energy Efficiency Agreement of Energy Services 2008-2016	2007	2016
GER39	Germany	Contracting in relation to heating, ventilation and air conditioning	2007	
IRL12	Ireland	Energy Agreements	2006	
RO2	Romania	Long Term Agreements with Industry	2008	2010
RO6	Romania	Promoting energy efficiency and RES utilization with final consumers	2008	
SK9	Slovakia	Operational Programme "Competitiveness and Economic Growth" priority line Energy	2008	
SPA14	Spain	Action Plan 2005-2007: Voluntary Agreements	2005	2007
SPA18	Spain	Action Plan 2008-2012: Voluntary Agreements	2008	2012
SWE3	Sweden	The Programme for Energy Efficiency in Industry	2005	
SWE14	Sweden	Energy efficiency in small and medium sized enterprises	2008	

Information / Education / Training

Informational measures for the industrial sector considered as relevant complements to other measures, tend to be implemented by most EU Member States without exception despite their relatively low impact. The information offer may cover a broad range of issues such as energy costs mentoring by energy advisors for smaller companies, information on financial assistance, guidance documents, educational road shows, training of energy managers, energy awareness resources.

New Market Based Instruments

The last type, are the new market based instruments, which have not yet proved their effectiveness but carry great hope. There are essentially three types of new market-based instruments which strive to improve energy efficiency based on market forces. These are; White Certificates, the EU Emission Trading Scheme EU ETS and the use of Clean Development Mechanism and Joint Implementation to improve energy efficiency in countries outside the EU and getting the savings accounted for under the Kyoto Protocol obligations. Below is a brief explanation of these instruments.

A White Certificate is both an accounting tool, which proves that a certain amount of energy has been saved in a specific place and time, and a tradable commodity, which belongs initially to the subject that has induced the savings (implemented a project) or owns the rights to these savings, and then can be traded according to the market rules, always keeping one owner at the time. The White Certificate systems have so far only been implemented in a limited manner in the industrial sector. More countries, e.g. Poland, are experimenting further in the direction of White Certificates, but most likely a few more years will pass before an EU-wide introduction or even harmonization takes place. For the industrial sector, more experiences are required to understand whether the instrument is capable of promoting energy efficiency in this sector.

The European Emission Trading Scheme (EU ETS) is governed by the EU ETS Directive (2003/87/EC and 2009/29/EC) and was launched in January 2005. The EU ETS covers around 11,000 large greenhouse gas emitting installations in the energy and industrial sectors. In total, the EU ETS covers about 50% of Europe's CO2 emissions and 40% of its total greenhouse gas emissions. The EU ETS is made up of consecutive trading periods. The first trading period – often considered to be a "learning phase" – lasted from 2005 to 2007 (phase 1); the second trading period coincides with the Kyoto commitment period from 2008 to 2012 (phase 2). The third trading period (phase 3) will last from 2013 to 2020. In addition to the industrial and energy sector, air transport will be included from 2013 onwards to the scope of the EU ETS.

By the end of a particular period, operators must surrender the number of allowances equivalent to the amount of emissions caused by their installations during that period, otherwise sanctions have to be paid. Companies may emit more emissions than their initial allocation if they purchase extra allowances from others. In general, more stringent ET-budgets will lead to higher prices for European Union Allowances (EUAs) and thus greater incentives to improve carbon efficiency, ceteris paribus. The first trading phase is now finalized but so far little is known about the impacts of the EU ETS on energy efficiency.

The Clean Development Mechanism (CDM) and Joint Implementation (JI) have been set up as flexibility mechanisms under the Kyoto Protocol to save greenhouse gas emissions and energy, outside the EU, in developing countries or other signatory states of the Protocol if the country itself cannot fulfill its target. But so far CDM projects are generally directed towards greenhouse gas reduction, and very little used for energy savings.

Table 16. Number of CDM Projects by Investor Country (UNFCC, 2010)

CDM Investor Country	Number of CDM Projects	% of all CDM projects
Ireland	1	0,04%
Portugal	5	0,20%
Luxembourg	17	0,67%
Belgium	23	0,90%
Norway	33	1,29%
Finland	32	1,25%
Austria	47	1,84%
Denmark	44	1,72%
France	48	1,88%
Italy	47	1,84%
Spain	76	2,98%
Germany	146	5,72%
Sweden	165	6,47%
Netherlands	302	11,83%
United Kingdom	706	27,66%
Total EU	1.692	66,30%
Switzerland	518	20,30%
Total Europe	2.210	86,60%

Brazil	1	0,04%
Canada	46	1,80%
Japan	295	11,56%
Total Other Countries	342	13,40%
Total	2.552	100,00%

As can be seen from Table 16, the EU countries represent two thirds of all CDM projects. If Switzerland is added, Europe's share is close to 90%.

Energy Efficiency Policies in Turkey

While the importance of energy efficiency was realized by the world following the energy crises in 1970s, the demand for energy efficiency in Turkey started in the 1980s. The first planned energy conservation activities in Turkey were implemented in 1981 by the General Directorate of Electrical Power Resources Survey Administration (called EIE in Turkey), which is a foundation under the Ministry of Energy and Natural Resources (MENR). In 1993, the National Energy Conservation Center (NECC) was established within the body of EIE to increase the effectiveness of the activities and extend them across the country. Since 1993, NECC has been conducting various activities and projects promoting energy conservation and energy efficiency nation wide with the support of many foreign sources and international organizations such as United Nations Industrial Development Organization (UNIDO), World Bank, the EU, and Japan International Cooperation Agency (JICA). The MENR has published several strategies, regulations and announcements that aimed to increase energy efficiency especially for the industry and the public sectors, but the Turkish Energy Efficiency Law numbered 5627 was merely put to force in April 18, 2007. Throughout this section, the evolution of the Turkish energy efficiency policy will be illustrated; the administrative structure of energy efficiency in Turkey and the role and functions of related institutions will be analyzed. Information on the Turkish Energy Efficiency Law numbered 5627 and its current implementation will also be given.

Turkish energy policy is mainly concentrated on the assurance of reliable and economical energy supply. In addition to meeting the long term demand for energy, environmental sustainability while reaching the targeted economic growth and social developments are also center to energy policy goals. Hence in order to meet this strategy, energy management, national utilization and energy conservation became a part of national energy policy. Table 17 shows the evolution of Turkish energy efficiency policy and related regulations from 1935 to 2009 and it can be seen that energy conservation end efficiency efforts in Turkey began after 1980s and gained acceleration after 2000s.

Table 17. Evolution of Turkish Energy Efficiency Policy (EIE, 2009)

Type	Date	Scope	Description
Law (No: 2819)	1935		The Electricity Research Administration (EIE) was established.
	1963		Ministry of Energy and Natural Resources (MENR) was created.
	1981		The Energy Efficiency Coordination Committee (EECC) was established by the Prime Ministry, continued its work under the body of MENR after 1984.
	1992		Deliberations about Climate Change Agreement began and became effective in 1994 for the purpose of decreasing ghg emissions and decreasing CO2 emissions levels to 1990 level by the year 2000.
Regulation	1995	Industry	Regulations to increase energy efficiency in the industrial sector aiming large establishments that consume minimum 2000 toe energy annually.
Announcement	1996	Industry	The MENR published guide lines for the instructors who will give Energy Management Course and Training.
Announcement	1997	Buildings and Public sector	The Prime Ministry published a notice on energy efficiency aiming all governmental establishments.
Announcement	1997	End use	The price of off-peak electricity became cheaper in order to make people prefer to use electricity during these times.

Announcement	1998	Industry	MENR published a notice regarding rules of Energy Efficiency Studies Authorization Certificate
Announcement	2000	Buildings	The Ministry of Public Works and Settlement (MPWS) published a notice regarding heat insulation of buildings for increased energy efficiency.
Law (No: 4628)	2001	Electricity Market	Electricity Market Act, which encourages efficient, cheap, environmentally friendly usage of electricity and stable electricity transmission for consumers was put in force.
Announcement	2002		The Ministry of Industry and Trade published notice on energy labeling of home use light bulbs.
Announcement	2002		The Ministry of Industry and Trade published notices on energy labeling of home use washer and dryer machines, dish washing machines and electrical ovens.
Announcement	2004		Energy Efficiency Strategy Paper for Turkey was published by the EIE/NECC in cooperation with Delegation of European Commission in Turkey.
Law (No: 5346)	2005		Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy was put in force.
Regulation	2006		On energy labeling of home type air conditioners.
Regulation	2006		On energy efficiency standards of electrical refrigerators, coolers and combinations and florescent lighting blasts.
Law (no: 5627)	2007		Energy Efficiency Law with the purpose of increase energy efficiency in order to use energy effectively, avoid waste, ease the burden of energy costs on the economy and protect environment
Circular	2008		The Office of the Prime Minister defines measures for the effective and efficient use of energy within public bodies and institutions. This Circular kicked off the "National Energy Efficiency Movement," and announced year 2008 as the "Energy Efficiency Year."
Regulation	2008	Transportation	Regulation on increasing energy efficiency of transportation.
Circular	2008	Lighting	Circular No. 2008/19 dated 13/08/2008 obligated all public bodies and institutions, municipalities and professional chambers of public nature, within a period of one month, to replace incandescent bulbs with energy-efficient bulbs in places under their responsibility
Regulation	2008	Buildings	Regulation on heat insulation of buildings.
Regulation (By-Law on EE)	2008		Regulation on increasing efficiency in the use of energy resources and energy
Regulation	2008	Buildings	Regulation on energy performance of buildings.
Regulation	2009		Regulation on employing an energy manager in the schools those are under the body of Ministry of National Education.

Energy efficiency policy and regulations in Turkey have been mainly concentrated in two sectors; industry and buildings. The studies on transportation, lighting and appliances also gained some weight in the last decade, mostly together with the Turkish Energy Efficiency Law.

As part of industrial energy efficiency studies, a nation wide analysis of the potential for energy conservation was conducted by EIE/NECC in 1993. After the results showed that the industrial sector had an annual energy saving potential of approximately 30%, the MENR instated a regulation on industrial energy efficiency in 1995. According to this regulation, industrial establishments that consume over 2.000 toe energy annually would be required to set up an energy management system in their plants and hire an energy manager. Two announcements related to preparing energy management courses and conducting energy audits were also issued in 1996 and 1998, respectively.

In the scope of energy efficiency studies of buildings, the TS 825 Standard regulated by the Ministry of Public Works and Settlement (MPWS) in 1985 on heat insulation of buildings were revised in cooperation with EIE and put to force in 2000. With the new standard the energy loss of buildings are assumed to be decreased by 50%. At the end of 1997, the Prime Ministry published a notice titled “Precautions for Public Enterprises and Institutions to decrease energy consumptions” and according to this notice public enterprises nation wide report their buildings energy consumption every five years to the MENR. The Ministry of Industry and Trade published notices on household electrical appliances labeling standards, for light bulbs, washer and dryer machines and electrical ovens in 2002, for fluorescent lamps, air conditioners, refrigerators and freezers in 2006. According to these notices, its is made mandatory for all such electrical appliances in the market to have less or equal electricity consumption than allowed and have labels to show their electricity consumption levels.

As a mandatory factor of the National Programme that constitutes the official road map of the Turkish Government in assuming its obligations/ responsibilities within the framework of the Accession Partnership of Turkey to the EU, “Energy Efficiency Strategy for Turkey” was adopted in 2004 by the Ministry of Energy and Natural Resources (MENR) with the aim of improving end use energy efficiency in industry, building and transportation sectors, since Turkey shall have an opportunity to get the energy saving potentials for the related sectors by regulatory arrangements on the basis of the European Union acquis. The strategy was prepared by a cooperation of EIE/NECC and the Delegation of European Commission in Turkey.

The energy efficiency strategy was intended to be a document which is to be agreed by the related governmental institutions and would provide a platform for ensuring development and implementation of targeted/integrated programmes and projects. In this context, the Energy Efficiency Strategy for Turkey consisted of the analysis of the current status of the related legislation, administrative structure and the national energy situation in the energy end use sectors. The strategy proposes an organizational structure and a methodological approach that comprises the related institutions and organizations including international ones, assumptions and risks, implementation programmes on sectoral basis, monitoring and evaluation of the potential impacts of the suggested measures and the time schedule, including short and medium term priorities for the activities to be undertaken by the Turkish Government and to be supported by EU. The strategy concludes with specific recommendations (EIE, 2004).

As a result of the strategy, Turkish Energy Efficiency Law comprising the required legal frameworks for improving energy efficiency was enacted and published in May, 2007.

Turkish Energy Efficiency Law

The main purpose of Turkish Energy Efficiency Law is to increase efficiency in using energy sources and energy in order to use energy effectively, avoid waste, ease the burden of energy costs on the economy and protect environment (ETKB, 2007). The Law has a very broad scope incorporating generation, production, transmission, distribution and consumption of energy at industrial establishments, buildings, power generation plants, transmission and distribution networks and transport as well as raising energy awareness in the general public and utilizing renewable energy sources. The mandatory provisions of the Law are for industrial facilities with annual energy consumptions of 1.000 Toe and for buildings having either 20.000 m^2 total construction area or 500 Toe annual energy consumption.

The Law also covers the supports that will be given to industrial establishments who propose energy efficiency implementation projects, those who make voluntary agreements to reduce their energy intensity and those who consume energy from energy conversion facilities using modern waste burning techniques and hydraulic, wind, geothermal, solar and biomass sources.

The new organizational structure that the Law endorsed can be seen in Figure 19. Energy Efficiency Coordination Board which is on the top of the organization undertakes the responsibilities of not only supervision of all authorizations but also preparation, evaluation, improvement and implementation of plans and programmes regarding energy efficiency strategies.

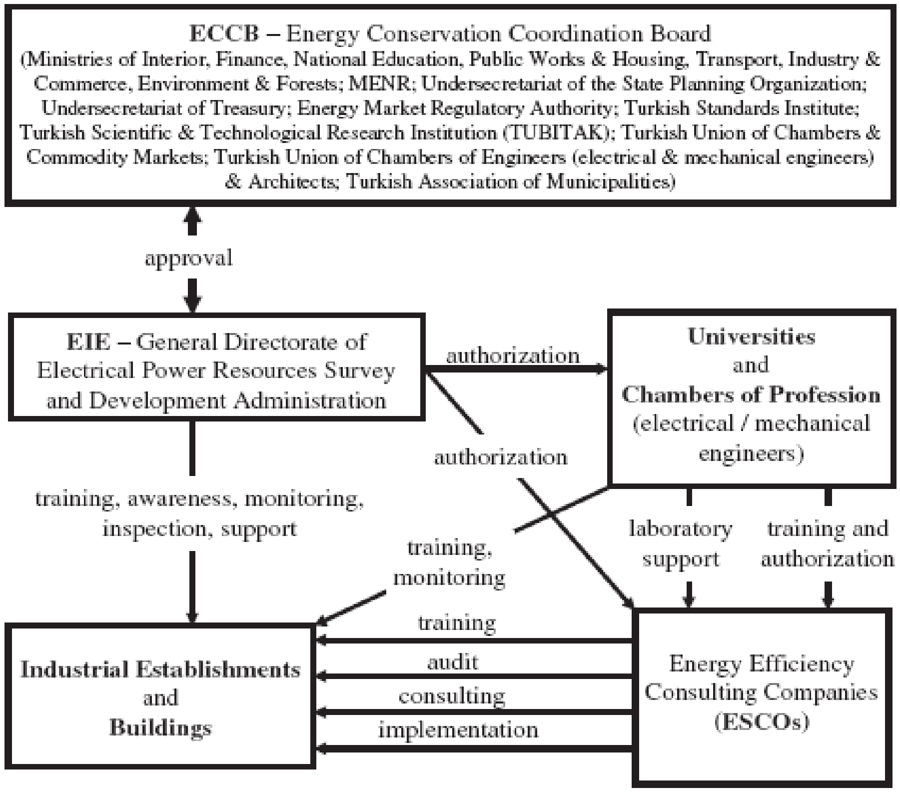

Figure 19.Organizational structure of energy efficiency endorsed by the law (Okay et al., 2008)

In addition, in this new structure, the authorization of organizing energy manager training courses, which were being conducted by EIE, is also given to universities and chambers of profession. EIE and/or authorized universities and chambers can authorize Energy Efficiency Consultancy Companies, known as Energy Service Companies (ESCOs) worldwide, to perform energy efficiency audits for industry and building sectors, to organize energy manager training courses and also to do consulting and implementations of energy efficiency measures developed after the audits. Moreover EIE and/or authorized universities and chambers can be responsible from training of ESCOs as well as supplying laboratory infrastructure for the practical part of the energy manager courses which will be organized by ESCOs.

According to the Law, regulations for proper implementations will be prepared and published by the related institutions. Some of such regulations are as follows:

- Regulation on energy management and energy managers by MENR,
- Regulation on energy performance of buildings by Ministry of Public Works and Settlement (MoPWS) in cooperation with Turkish Standards Institute,
- Regulation on energy certification by MoPWS,
- Regulation about the individual and central heating minimum efficiency standards by Ministry of Industry and Trade (MoIT),
- Regulation about minimum efficiency standards of electrical motors, air conditioners, electrical household appliances and lamps by MoIT,
- Regulation on energy efficiency in the transportation sector by Ministry of Transportation (MoT).

Regulation on transportation, buildings and energy management are already in force as of 2008 and the others are under preparation.

Energy Efficiency Institutions

This subsection will provide brief information on energy efficiency related institutions and their roles and functions in Turkey. Among the mentioned institutions the Energy Efficiency Coordination Board became active with the Turkish Energy Efficiency Law; all the others will be explained in an historical framework.

Energy Efficiency Coordination Board, according to the Law is established to carry out energy efficiency studies within all relevant organizations all over the country, monitor their results and coordinate all efforts. The implementation of decisions made by the board is monitored by EIE. The Board consists of one senior representative from each of the Ministries of Interior, Finance, National Education, Public Works and Settlement, Transport, Industry and Trade, Environment and Forests, the MENR, the Undersecretariat of the State Planning Organization, the Undersecretariat of Treasury, the Energy Market Regulatory Authority, Turkish Standards Institute, Turkish Scientific and Technological Research Institution, Turkish Union of Chambers and Commodity Markets, Turkish Union of Chambers of Engineers and Architects, and Turkish Association of Municipalities. The chair of the Board is the assistant undersecretary in charge of EIE.

The General Directorate of Electrical Power Resources Survey and Development Administration (EIE) under the Ministry of Energy and Natural Resources was founded on June 24, 1935 under the law no. 2919. The administration has an economic state enterprise status and is governed by the provisions of private law and is administered in accordance with commercial methods, while enjoying the status of a juridical person. Its income is annually allocated from the budget of the MENR. It was founded with the aim of identifying the power potential of water resources of the country and preparing dam and hydropower plant projects at convenient locations. Energy management, rational utilization and efficient use of energy and increasing the share of solar and wind energies was added to the scope of activities of the administration. With the Energy Efficiency Law put in force in 2007, the functions of the administration are redefined as follows (ETKB, 2007):

a) Make measurements relating to assessing all energy sources with priority for hydraulic, wind, geothermal, solar, biomass and other renewable energy sources, prepare feasibility studies and exemplary implementation projects, develop pilot systems in cooperation with research organizations, local governments and civil society organizations, carry out promotion and consulting activities.

b) Provide awareness raising and training services relating to rational use of energy in industry and buildings, authorize and inspect universities, chambers of profession and legal persons to provide the same services, conduct the secretariat services for the Energy Efficiency Coordination Board.

c) Monitor, evaluate works made by the relevant ministries and bodies, develop measures and/or project proposals for effective and efficient use of energy in transport, electric energy generation plants, transmission and distribution systems.

d) Monitor and inspect the energy efficiency implementation projects and research and development projects approved by the Energy Efficiency Coordination Board.

e) Monitor and evaluate the occurrence of harmful waste and emissions of interest to the environment from the energy consumption points, prepare projections and proposals for measures.

f) Follow and evaluate works and developments on energy in the country and the world, set research and development goals and priorities for the needs and conditions of the country, conduct and procure to conduct research and development studies in this direction, disclose to the public the studies with economic analyses.

g) Ensure that all stakeholders of energy access accurate and updated information, make and update a national energy inventory, establish and operate a national energy information management center to support the planning, projection, monitoring and evaluation works.

h) Develop projections and proposals to utilize domestic and renewable energy sources and increase energy efficiency.

i) Make activities to raise energy awareness and utilize new energy technologies in the general public.

j) Make coordination between public agencies and institutions, universities, private sector and civil society organizations for effective and efficient cooperation on energy efficiency.

k) Make activities to inform and raise awareness of the general public on energy related matters.

l) Cooperate and exchange information with national and international organizations in other countries.

The National Energy Conservation Center (NECC) was established within the body of EIE, by the MENR in December 1992 to increase the effectiveness of energy efficiency activities and extend them nationwide. Since then, the NECC have been working on energy efficiency and management trainings, audits, public awareness as well as developing policies, strategies and regulations on energy efficiency. The main activities pursued by the EIE/NECC are energy management courses, energy efficiency audits and research, energy efficiency training bus program, international projects, data base studies, energy efficiency publications, efficiency of electrical motors studies (EIE, 2009).

EIE/NECC has conducted many international energy efficiency projects with the technical support of foreign sources such as UNIDO, EU, and JICA and the financial support of the World Bank. In the scope of the Energy Conservation Project started in 2000 in cooperation with JICA, an Energy Efficiency Training Center was established in EIE facilities. The center was intended to give training on energy management to engineers from both

Turkish industry and from region countries and to act as an International Training Center for sharing experience with these countries with the financial support of international organizations. EIE has already organized seven International Energy Efficiency Courses in cooperation with UN-ESCAP and JICA in 2002, 2003, 2004, 2005, 2006, 2007 and 2008 for Western and Central Asia, Eastern Europe and Black Sea Region and Middle East countries.

Table 18 summarizes the major internationally supported energy efficiency projects in Turkey.

Table 18. Major Energy Efficiency Projects in Turkey (EIE, 2009)

Donor/ Country	Implementing Agency	Projects and Activities	Types of Assistance	Period
Japan	JICA	Energy Conservation in Industry	- Capacity building at EIE, - Energy managers training, - Performing energy audits, - Establishing of the Energy Conservation Training Center	2000-2005
Germany	GTZ	Support to Energy Efficiency Building in the Erzurum Municipality	- Capacity building at EIE, - Energy managers training, - Demonstration projects	2002-2005
Japan	JICA	Third Country Training	- Organizing energy manager courses for neighborhood countries.	2004-2007
EU	ADEME (France) SenterNovem (Netherlands)	Improvement of Energy Efficiency in Turkey	- Strengthening of the legal and institutional framework, - Assessment of the energy saving potential, - Identification of barriers and support to implementation	2005-2007

Netherlands	SenterNovem	Pilot Project "Voluntary Agreements (VA) with Turkish Industry"	- Develop VA program with selected companies, - Uncover unanticipated bottlenecks in the field, - Increase industry awareness on VA potential, - Capacity building of EIE staff, - Training and authorized Energy Efficiency Consultancy Companies	Feb. 2007-ongoing
EU	Motiva OY (Finland) ENKO, SIT Corp., ILAYDA Consulting Corp. (Turkey)	Increasing Public Awareness in Buildings (enverIBAP)	- Create awareness on energy efficiency in building, - Training EIE staff, students in schools and universities, technical staff in construction sector, housewives, public and other stakeholders (partners for projects, sponsors..)	April 2007-ongoing

The Energy Efficiency Coordination Committee (EECC) was established by the order of the Prime Ministry on April 9, 1981 with order no. 10/01282 with the purpose of awakening public awareness on the importance of energy efficiency. It has been working within the body of the MENR since 1984 and has 53 members from public and private establishments and universities. The Committee has been realizing its facilities under three main topics, namely awareness and training studies, publishing studies and law and written regulations. Under the scope of awareness and training studies, every year in January an Energy Efficiency Week is organized involving various activities, panels and conferences. Several story, picture and project competitions are organized among students from primary and high schools, informative brochures and training films are published and distributed year long.

CHAPTER 4

LITERATURE REVIEW ON ENERGY EFFICIENCY

The literature on energy efficiency can be summarized under two lines of study. Most of the literature consists of either empirical studies made on measuring and monitoring of energy efficiency or qualitative studies on energy efficiency policies which are a part of national or international energy strategy. This chapter will first provide various energy efficiency definitions and then make a thorough review of the empirical studies done on energy efficiency. The second part of the chapter contains a summary analysis of the literature on energy efficiency policies and the research done on energy efficiency in Turkey.

Definition and Measurement

Energy efficiency is a difficult concept to define. It is often confused with energy conservation. Conservation simply means using less energy, whereas efficiency implies meeting a given demand with a lower use of resources (Gunn, 1997). Since an engineer, an economist, an environmentalist each may have different perspectives to efficiency relating to different expectations and goals; there is no single commonly accepted definition.

One of the earliest and most accepted definitions is given by Patterson (1996) as the useful output of a process over energy input into a process.

The definition given in the Directive 2006/32/EC of the European Council and the Parliament on energy end use efficiency and energy services is a general one, such that energy efficiency is ‘‘a ratio between an output of performance, service, goods or energy, and an input of energy’’(EU, 2006a).

The Energy Information Administration (EIA) of US Department of Energy defines energy efficiency as “the relative thrift or extravagance with which energy inputs are used to provide goods or services” and concludes “increases in energy efficiency take place when either energy inputs are reduced for a given level of service or there are increased or enhanced services for a given amount of energy inputs.”(EIA, 1995)

The Turkish Energy Efficiency Law defines energy efficiency as reducing the energy consumption without causing any decline in the living standards and service quality in buildings, and production quality and quantity in industrial establishments.

Following from the most popular use in energy literature, and in the context of this paper, energy efficiency will refer to ‘‘the ratio of energy services to energy input’’ and energy efficiency improvement will mean using less energy to produce the same amount of services or useful output.

What is even more difficult than to define energy efficiency is to measure it. Since the 1973 world oil crisis, national energy efficiency measurement and monitoring became an important component of energy strategy in many countries, especially in the energy deficient ones. In the late 1980’s the concern about global warming greatly caused by fossil fuels, made improvement of energy efficiency in order to reduce greenhouse gas emissions a global target issue. A great amount of research has been made to monitor trends in energy efficiency. Empirical studies on energy efficiency cover measurements of efficiency on plant-level, sectoral, regional and economy wide. Plant level energy efficiency measurements mostly fall under the area of industrial engineering, management and systems design and are not directly related to the context of this paper. As we are ultimately interested in economy-wide energy efficiency we will review the empirical studies both on economy wide efficiency and sectoral and regional energy efficiencies that may serve as a model for evaluating economy wide energy efficiency. We can generalize these studies as those introducing or incorporating various energy efficiency indicators, and thus providing an index for energy efficiency and those that use non-parametric linear modeling.

Indicator Analysis

For measuring energy efficiency changes over time at the economy-wide level, and to be able to make cross-country comparisons and benchmarking, various efficiency - related indicators have been developed. The subject of developing energy efficiency indicators has been on the top interest agenda of many international governmental and non-governmental organizations for years. A number of national energy agencies and international organizations have developed their energy efficiency measurement and monitoring systems such as International Energy Agency(IEA, 1997,a,b, 2004, 2007a,b), Energy Efficiency and Conservation Authority of New Zealand (EECA, 2006), Natural Resources Canada,(NRC, 2006), Office of Energy Efficiency and Renewable Energy of the US, (OEERE,2005) and ODYSSEE (2009). Summary information on some of these systems will be given later in this chapter.

One important study on the definition of energy efficiency indicators is Patterson(1996), who pointed out that at least four types of energy efficiency indicators can be used to measure energy efficiency, namely, the thermodynamic indicator, physical-thermodynamic indicator (energy requirements per unit physical output) and monetary (economic) thermodynamic indicator (energy requirements per dollar output) and economic indicator. Each group of indicators serve a different purpose and the appropriate indicator to use depends on the objective, whether it is concerned with engineering / systems design, economic productivity, the environment, resource depletion, sustainability, national security (Ang, 2006). Most energy economics literature have limited the studies to physical and monetary based indicators because thermodynamic energy efficiency can be measured only at the device level, such as a refrigerator, air-conditioner or lamp and even the most disaggregated energy efficiencies approximated by monetary-based or physical-based indicators may reflect factors beyond pure thermodynamic energy efficiency. [Ang et al. (2003), Ang and Liu (2001), Greening et al. (1997), Howarth et al. (1993), International Energy Agency (1997), Mukherjee (2008), Murtishaw and Schipper (2001), Natural Resource Canada (2006), Ozawa et al. (2002), Bor(2008), The World Bank(2009), Baksi and Green (2007)].

The most widely used classical monetary-based indicator in the 1970s and 1980s is the energy to gross domestic product (GDP) ratio (Ang, 2006). The ratio of total national primary energy consumption to GDP is a measure of energy intensity of the economy at the most aggregate level. The ratio has been widely used for energy efficiency analysis because of its simplicity and the lack of detailed data on energy consumption. In the early 1980s, there were numerous studies evaluating how the ratio would change over time if the country goes through different stages of economic development. For example, in the industrialization of a country, as agriculture is replaced with manufacturing, energy consumption rises faster than GDP; hence the ratio increases, while in the post-industrialization period service sector in the economy replaces manufacturing giving rise to a decrease in the ratio (Dunkerly et al., 1981; Eden at al., 1981). With exchange-rate converted GDP and from mid 1980s, with GDP data given in purchasing power parity (PPP), the ratio can be used to make comparisons across countries. Cross-country variations in the energy–GDP ratio have been studied for industrial countries and for developing countries. Among the major industrialized countries, it has been found that the ratio was the highest for Canada and the United States, while the lowest for Japan. The ratio for European countries tended to fall between these two extremes (Darmstadter et al, 1977; Leach et al, 1986; Ang, 1987). Studies on energy intensities of major developing countries show that there are large differences among them mostly because of economic structures and climate conditions. China having the highest energy intensity also seems to show the most significant decreasing intensity performance, followed by India. An exception among the key developing countries is Korea, which has increased its intensity of energy use mainly due to increased reliance on heavy industry and increasing transportation (Luukkanen and Kaivo-oja, 2002). The ratio is still widely used as an energy efficiency indicator, and in international statistical publications (IEA, 2007b, 2008a; The World Bank, 2009; ODYSSEE, 2009).

The energy coefficient and energy elasticity are two other energy efficiency indicators often found in energy studies in the 1970s and 1980s. Compared to the energy–GDP ratio, these two indicators have the advantage of being an index, which allows comparisons to be made over long time periods and cross countries. Ang (1991) deals with these indicators with the main objective to investigate how energy prices or other macro indicators affect the demand for energy and to quantify their cause-effect relationships. The energy coefficient for a given period is defined as the ratio of the average annual growth rate (AAGR) of primary energy consumption to the AAGR of GDP. When changes in energy consumption and GDP are small, the energy coefficient may be given by the ratio of the proportionate change in E to the proportionate change in Y, or C =dE/E / dY/Y which is called the energy elasticity (Ang, 2006). A study evaluating aggregate energy intensity found that the cross-country energy elasticity has dropped from values well above unity to below or close to unity from 1975 to 1997 (Ang and Liu, 2005) . Most studies dealing with these indicators however fall in the area of econometric studies (Chang et al., 2008; Yamaguchi, 2007; Voss et al., 2007).

One of the major drawbacks of these classical indicators is that they are aggregate indicators, meaning that the denominator, GDP represents many diverse activities. A change in the activity mix in the economy, i.e. structural change which is unrelated to energy efficiency can cause significant variations in these indicators. Rising from this necessity to find more accurate energy-efficiency indicators, to include all sectors of the economy and for energy related environment studies, a line of research called index decomposition analysis (IDA) was adopted by some researchers (Ang and Zhang, 2000; Ang, 2004a; Ang, 2004b; Ang and Liu,2007; Bor,2008). The method incorporates sectoral energy intensity, which was considered a better measure of energy efficiency than the aggregate energy intensity and it is the amount of energy consumption that is required to yield a given level of output at the sectoral level (Ang and Zhang, 2000). Ang and Zhang (2000) listed a total of 124 studies that applied index decomposition analysis techniques to energy demand and gas emissions analysis and two types of indices that are most frequently chosen to decompose the data are the Laspeyres index (Ang 2004a) and the Divisia index (Hulten, 1973).

Energy efficiency indicators may be developed for various sectors, sub-sectors and end-uses, but when national energy strategy is concerned summary measures for a country are needed. It is therefore logical to derive a national composite energy efficiency index by aggregating the energy efficiency indicators derived for individual sectors. This is a bottom-up approach and it has been adopted by a number of countries, including United States (EIA, 1997a,b; OEERE, 2005), and the European SAVE project (ODYSSEE, 2009). Its advantage is that it allows energy efficiency change to be evaluated at various levels to serve different needs and it provides some flexibility in the choice of activity indicators. With appropriate choices, the composite energy efficiency index would better reflect changes in the efficiency at the end-use level. The preferred activity indicators for each energy consuming sector are a topic that has been widely studied and debated (Energy Information Administration, 1995; IEA, 1997a, b; Asia Pacific Energy Research Centre, 2001).

One of the most widely accepted international studies on energy efficiency indicators is the ODYSSEE project, with the objective to set up a permanent structure for monitoring national achievement in energy efficiency and carbon dioxide emissions (ODYSSEE, 2009). The Project started in 1993, through a joint collaboration between ADEME, the SAVE programme of the General Directorate of the European Commission in charge of energy and all energy efficiency agencies in the EU-15 and Norway. Since 1995, it associates the new EU member countries plus Croatia. The database includes about 30 different efficiency indicators for industry, transportation, residential, service and agriculture sectors, and transformation sector. The project has developed a composite energy efficiency index called ODEX, to measure energy efficiency progress by country or by sector and is calculated on the basis of 26 sub sectors (7 modes in transport, 9 end-uses/ equipment for households, 10 branches in industry). Examples to some of the indicators that the project has adopted are: primary energy intensity, final energy intensity, energy intensity of industry to value added, energy intensity of manufacturing, unit consumption of steel, energy intensity of transport to GDP, average consumption of road transport per equivalent car, energy intensity of households, average electricity consumption per household, average electricity consumption of electrified households, energy intensity of service sector to value added, overall efficiency of energy transformations, efficiency of total electricity generation.

Another organization that have been working on energy efficiency measurement and monitoring is the International Energy Agency (IEA). IEA has been working on developing indicators that provide data and analysis of energy use and efficiency trends to support better energy efficiency policy-making and evaluation for more than 13 years (IEA, 1997a, b, 2004). And as of 2005, as part of its contribution to the G8 Gleneagles Plan of Action, it has extended its work to cover 22 IEA member countries, adding Republic of Korea and Switzerland. It has also been showing a significant effort to develop more detailed indicators for the industry sector. The work programme has resulted in a number of publications (IEA, 2007a, b, 2008a). The methodological framework and data developed under the indicators project also provide input to other analytical activities undertaken by the agency, such as the World Energy Outlook (IEA,2008c), and several other energy efficiency and energy technology projects.

Taylor et al. (2009), in his recent article in press, gives detailed overview of the IEA indicator methodology. According to his paper, the IEA indicators approach uses the idea of an indicators pyramid (Figure 20), which portrays a hierarchy of energy indicators from most detailed to least detailed. This illustrates conceptually how the most detailed and disaggregated data and indicators can be combined to give the more aggregated ones higher up on the pyramid.

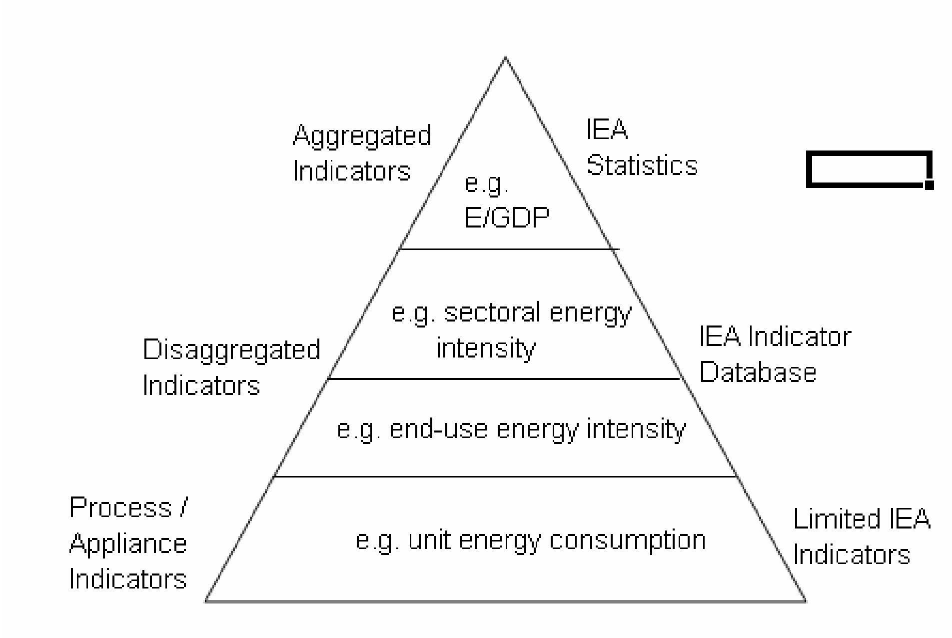

Figure 20.The IEA energy indicators pyramid (IEA, 1997)

In the IEA approach, the top element (the most aggregate indicator) is defined as the ratio of energy use to gross domestic product (GDP). The second row of elements can be defined as the energy intensity of each major sector, as measured by energy use per unit of activity in each sector. Lower rows represent the sub-sectors or end-uses that make up each sector and progressively provide more details. Descending lower down the pyramid requires more data and more complex analysis to re- aggregate back up to a higher level. However, each descent also provides a better measure of ‘‘technical’’ energy efficiency, defined for a specific technology, process, and/or end-use. This hierarchy is important because it shows how detailed changes (which may be the result of policies, technological progress, structural reform, or behavioral change) can be linked to higher order, more aggregate quantities, showing how the former affects the latter.

In its current work, the IEA draws on detailed end-use information about the patterns of energy consumption in more than 20 end-uses covering the manufacturing, household, service and transport sectors of 22 IEA countries over the period from 1990 to 2005 (Figure 21).

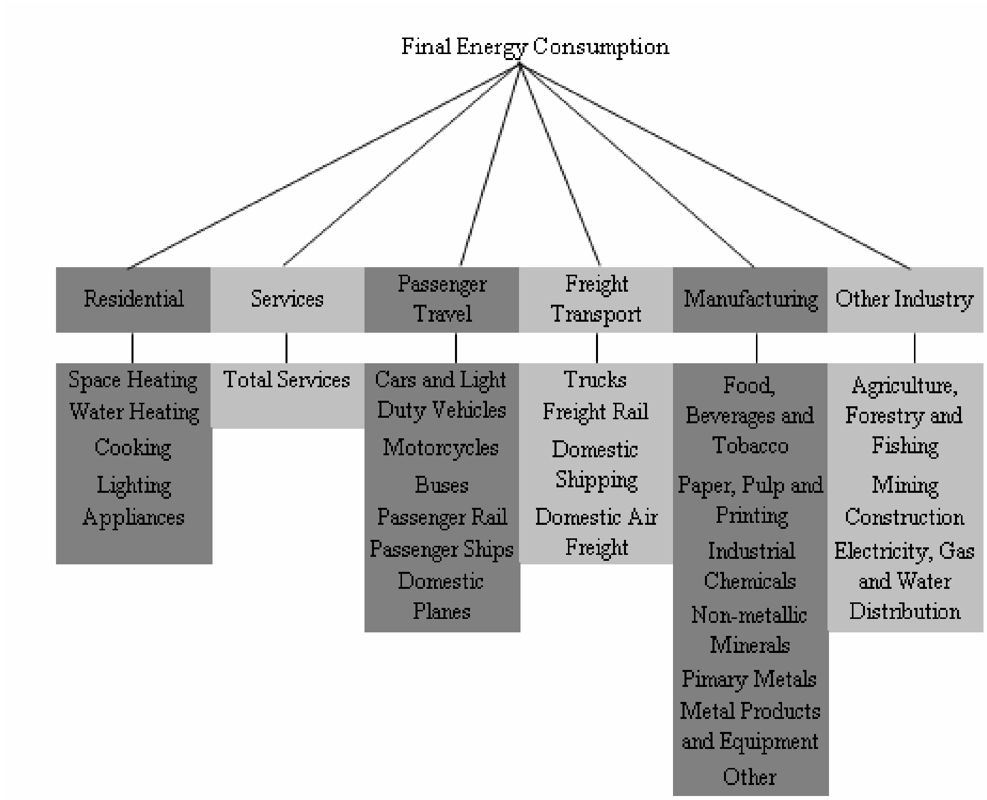

Figure 21. Disaggregation of sectors, sub sectors and end-uses in IEA energy indicators approach (IEA, 2007).

This information, together with economic and demographic data, is used to identify the factors behind increasing energy use and those that restrain it. The IEA energy indicators typically reflect ratios or quantities and can describe the links between energy use and human and economic activities. The indicators include measures of activity (such as manufacturing output or volume of freight haulage), measures of developments in structure (such as changes in manufacturing output mix or modal shares in transport) and measures of energy intensity (defined as energy use per unit of activity) (Taylor et al., 2009).

The following section summarizes the literature on the use of data envelopment analysis (DEA) in energy efficiency studies.

Literature on DEA in Energy Efficiency

IDA-based energy efficiency studies mainly deal with the measurement of energy efficiency changes over time in a specific entity, such as a country or a specific sector. On the other hand, the literature also includes non-parametric models for measuring energy efficiency that deal with the benchmarking of energy efficiency performance across different entities. One of the most widely used methods to evaluate energy efficiency performances of different entities is data envelopment analysis (DEA) (Zhou et al., 2008b).

DEA, proposed by Charnes et al. (1978), is a well-established non-parametric frontier approach to evaluating the relative efficiency of a set of comparable entities featured with multiple inputs and outputs. The recent literature survey by Zhou et al. (2008a) lists a total of 100 studies published from 1983 to 2006 using DEA in the area of energy and environmental analysis. According to the survey, 72 of these publications were made between 1999 and 2006, which shows a rapid increase in the number of studies using DEA methodology. Given its ability of combining multiple factors, the potential of DEA in energy efficiency study has been widely investigated by researchers. It has gained an important role in energy efficiency research and emerged as an alternative to traditional energy efficiency indicators. A review of recent energy efficiency studies using DEA, together with their methodology and major findings are given below.

Hu and Wang (2006) and Hu and Kao (2007) developed a total-factor energy efficiency index by using DEA, which provides a useful alternative to the traditional energy efficiency indicators such as aggregated energy intensity. In their paper, Hu and Wang (2006) analyzed energy efficiencies of 29 administrative regions in China for the period 1995–2002 with a new index called total-factor energy efficiency (TFEE) index which uses DEA to find the target energy input of each region in China at each particular year and then divides the target energy input by the actual energy input. In the DEA model, labor, capital stock, energy consumption, and total sown area of farm are the four inputs and real GDP is the single output. Most significant finding of the study is that there exists a U-shape relation between the TFEE and per capita income in the areas of China, confirming the scenario that energy efficiency eventually improves with economic growth.

Zhou et al.(2008b) presented several DEA-type linear programming methods for measuring economy –wide energy efficiency performance that take labor, capital stock and energy consumption as inputs and GDP as the desirable output. The paper introduces a model that takes into account the effects of the changes in the energy mix, undesirable outputs such as carbon dioxide emissions, and also measures energy saving potential. He applied his proposed methods to measure the energy efficiency performances of 21 OECD countries and found that Canada followed by Japan have the highest energy saving potential and the 21 countries as a whole experienced little change in its overall energy efficiency performance.

DEA analysis has also been widely used in energy efficiency studies at sector, sub-sector or plant level. Boyd and Pang (2000) used DEA to discuss the relationship between productivity and energy efficiency. The study considers plant level data and uses a DEA model that incorporates labor, capital stock and electricity consumption as three inputs and the value of shipments as the only output. After obtaining an index for productivity to estimate efficiency, it uses regression analysis in the second step to estimate how changes in plant level energy intensity are attributable to differences in plant level production efficiency and other economic variables like energy prices and cost of materials. The results show that best practice plants are more energy efficient, holding prices constant, but energy prices carry important information about energy intensities.

Similarly, Ramanathan (2000) used DEA to compare the energy efficiencies of alternative transport modes in the Indian transport sector and found a gradual improvement in energy efficiency of rail transport while a decrease in the efficiency of road transport. Lam and Shiu (2001) applied data envelopment analysis approach to measure the technical efficiency of China's thermal power generation based on cross-sectional data for 1995-1996. Applying regression analysis in the second stage they found that fuel efficiency and capacity factors significantly affect technical efficiency, moreover provinces and autonomous regions that are not under the control of State Power Corporation achieved higher levels of efficiency. The presence of foreign investment did not have a significant effect on efficiency.

More recently, Onut and Soner (2006) applied DEA to assess the energy efficiencies of five-star hotels in Turkey. Their study assessed the energy efficiency of 32 five-star hotels in Turkey and their model incorporated number of employees, annual electricity consumption (kwh/m2), annual water consumption (m3/m2) and annual liquefied petroleum gas consumption (kg/m2) as input factors and occupancy rate, annual total revenue, and total number of guests as the output factors. As a result of their study they found 8 hotels to be energy efficient, they illustrated some good practices observed and proposed measures to reduce resources consumption in the studied hotels.

Onut and Soner (2007) conducted another important study, which evaluates the efficiency of energy use in small and medium size enterprises in the Turkish manufacturing sector. The study conducts data envelopment analysis on the energy use of 20 medium sized companies in the metallic goods industry. In their DEA model, annual electricity consumption (kW h), annual natural gas consumption (m3), annual oil consumption (Ton), and annual LPG consumption (Ton) are taken as inputs and annual total sales ($) and annual total profit ($) are taken as output variables. As more than half of the companies were found to be inefficient, the results indicated that there is great potential to save energy in the industry. The study also proposes new measures and applications to such companies.

Azadeh et al. (2007) proposed an integrated DEA approach to assessing the energy efficiency of energy-intensive manufacturing sectors. Their model, which was also verified and validated in the paper, considers structural indicators in addition to the conventional consumption (input) and output indicators. As both economic and physical energy intensity indicators can be influenced by the structure of the sector, which is defined by being determined by mix of activities or products within a sector, it is logical to consider the structural indicators for a better comparable result. They illustrated their model with a case study considering OECD/IEA countries and Iran. The results indicated that Austria in 1991, 1993, 1995, Canada 1998 and Iran in years 1995-1998 were relatively efficient and Czech Republic was rated to be the least efficient country.

Wei et al. (2007) investigated the energy efficiency change of China's iron and steel sectors by using DEA-based Malmquist Index Decomposition (MPI) approach. The energy efficiency improvement is decomposed into two components: technical change (production frontier shifting effect) and technical efficiency change (catching up effect) over time. Coal, coke, electricity, natural gas and fuel oil were considered inputs while pig iron, crude steel and finished steel were accepted as outputs of the model. The results of the study show a 60% increase in efficiency of China's iron and steel industry but more of the efficiency is induced by technical progress rather than technical efficiency progress. The study also suggests that private firms are more energy efficient than the state owned ones.

Mukherjee (2008) presented several DEA models for measuring the energy efficiency of U.S. manufacturing sectors from a production theoretic perspective. The presented models are five input, single output models and are based on the objectives of energy conservation and cost minimization. One model takes into account the capacity utilization of the sectors as well. To obtain cost minimization some of the proposed models allow substitution of other inputs for energy given input prices. A major finding of the study is that the production processes in manufacturing face difficulty in making rapid adjustments to input proportions in response to energy price shocks, but over time they adjust to price changes.

In a more recent article in press Mukherjee (2010) used a DEA model to measure energy efficiency in the context of an emerging economy. The unit of the study is the "typical firm" in each of the eighteen major manufacturing states in India. The model is based on the joint goal of achieving energy conservation as well as output growth. It is found that India could achieve these targets by increasing its technical efficiency which would require enhancing its manufacturing technology by learning from and adopting the superior technologies from more advanced nations as well as through investing in R&D.

R&D has been considered as an additional input in the DEA model proposed by Conrad (2000) and it was found that an increase in R&D expenditure improves energy efficiency when the technological change is embodied.

Literature on Energy Efficiency Policies

Improvement in energy efficiency reduces fossil fuel dependency, hence increases energy security, fosters economic gains by increasing competitiveness and improving consumer welfare and helps to reduce human-induced carbon dioxide emissions. Worldwide energy consumption would be 56% higher today than it would have otherwise been without the various energy efficiency policies that have been implemented since 1973 (IEA, 2007a). These advantages have made energy efficiency policy a priority in many countries.

A recent report of World Energy Council (2008) titled "Energy Efficiency Policies around the World: Review and Evaluation" presents and evaluates energy efficiency policies in nearly 70 countries, with a specific focus on five policy measures: i) Mandatory energy audits, ii) Energy Service Companies (ESCO), iii) Energy incentives for cars, iv) energy efficiency obligations for utilities and v) packages and measures for solar water heaters. According to the report almost all countries have set up specific institutions dealing with energy efficiency, about half of the surveyed countries have set up quantitative targets with annual monitoring requirement and the main target of regulations are electrical appliances and buildings. ESCOs and EPC (Energy Performance Contracting) are a very attractive mechanism to capture cost effective energy efficiency potentials worldwide because they do not involve either public expenditure or market intervention. EPC can be considered among the most effective mechanisms for promoting energy efficiency in the public sector especially in developing countries. Green taxes dependent on carbon dioxide emissions on cars and road pricing are also some effective ways of enhancing energy efficiency. Energy efficiency obligations for utilities is also an important policy option for developing countries to save electricity as well. The report concludes that, fiscal and pricing policies are the most efficient way of internalizing long-term costs and benefits, there is a need for stable institutional framework, countries should implement a package of measures combining more than one policy in order to be more effective on energy efficiency improvement, the public sector should lead by example.

Another recent report by IEA (2008f), "Promoting Energy Efficiency Investments: Case Studies in the Residential Sector" seeks to offer policies and measures in order to overcome the barriers to energy efficiency. These barriers are either market barriers such as low priority of energy issues, difficulties in accessing capital, the presence of information asymmetries and principal agent problems or financial barriers such as initial cost barrier, risk exposure and inadequacy of traditional financing mechanisms. The study organizes useful energy efficiency policies into four categories: (1.) regulatory measures, (2.) financial and incentive based measures, (3.) voluntary agreements and partnerships, (4.) information and capacity building measures. To overcome the barriers, the study concludes on five lessons: policy packages are needed in order to be successful; no single policy alone can overcome the barriers; public-private partnerships allow more sustainable changes; the goal of market transportation is an important policy and it requires the existence of a market for energy efficiency, strong political will is required to trigger an increase in private participation, and the role of national context and country specific structure should not be missed.

Oliver et al. (2001) who documented specific country experiences in the area of energy efficiency, summarizes energy-efficiency policy applications under four topics: (1.) Demand side management such as fiscal and pricing policies, (2.) Energy conservation centers which have functions such as educating people on public benefits of energy conservation, conducting energy audits or feasibility studies for large businesses, training professionals such as engineers and plant managers whose work has direct impact on energy use, (3.) Standards and labeling where an efficiency standard is a minimum efficiency level that appliance manufacturers must meet in order to sell their products, and labeling stimulates consumer awareness and encourages manufacturers to exceed the standards and use efficiency as a marketing tool, (4.) Commercial building codes which serve the same role as standards to residential and commercial sectors to establish baseline efficiency levels.

Wiel et al.(2006) states in his paper that energy efficiency standards and labels provide a solid foundation for economic growth, climate change mitigation, and regional trade. He mentions that, international cooperation is becoming increasingly advantageous in reducing the resources needed for developing labeling and standards-setting programs and in fostering global trade by avoiding or removing indirect trade barriers. Recognizing this, many countries are participating in regional activities directed at harmonizing energy efficiency standards and labels which are being undertaken by Asia-Pacific Economic Cooperation (APEC), the South Asia Regional Initiative for Energy Cooperation and Development (SARI), the Pan American Standards Commission (COPANT), the Association of South-East Asian Nations (ASEAN), and the North American Energy Working Group (NAEWG), The European Union (EU). In the study, it is expressed that the nations joining in regional harmonization activities have differing reasons for their participation, including the desire to: improve energy efficiency, improve economic efficiency (improve market efficiency), reduce capital investment in energy supply, enhance economic development (enhance quality of life), avert urban/regional air pollution, contribute to mitigating climate change, strengthen competitive markets (reduce trade barriers), reduce water consumption and enhance energy security.

An important debate on energy efficiency is the rebound effect. Gains in the efficiency of energy consumption will result in a reduction in the unit price of energy services. As a result, consumption of energy services should increase, partially offsetting the impact of the efficiency gain in fuel use. (Khazzoom, 1980) This negative effect of energy efficiency improvement is known as the rebound effect. Hence, this phenomenon requires a distinction between potential technological efficiency improvements and realized or actual efficiency improvements. The uncertainty is whether energy efficiency improvements will result in absolutely less energy use or more efficient use of more energy. There has been a wide array of study investigating the size of the rebound effects (Greening and Greene, 1998; Schwartz and Taylor, 1995; Kydes, 1997). Greening et al. (2000) made a survey of over 75 estimates of the rebound in literature and concluded that the rebound effect is very low to moderate, not high enough to mitigate the importance of energy efficiency as a way of reducing carbon emissions. However, climate policies that rely only on energy efficiency technologies may need reinforcement by market instruments such as fuel taxes and other incentive mechanisms. Without such reinforcements, a significant portion of the technologically achievable carbon and energy savings could be lost to the rebound.

Energy prices are an important factor in achieving energy efficiency. Verbruggen (2003) has presented evidence that electricity prices and electricity intensities are inversely related as would be expected by economists. Moreover, Darmstadter (2000) reports that in OECD countries the average rate of change of energy intensity over 1973-90, a period of generally high energy prices was more than twice over 1990-97, a period of relatively low prices.

Ekins (2004) points out in his paper on research needs in the area of energy efficiency, that it is still not clearly understood how to unlock the energy efficiency potential that is technically available, what it would cost, what policy packages are most effective, and what the longer-term scope for energy efficiency improvements might be. There will be a need for greatly increased implementation activity. The role of fiscal incentives requires further understanding; in terms of how effective a potential measure will be, what are its revenue implications, what are its macroeconomic implications for prices and growth, its likely sectoral and distributional impacts, environmental impacts, and administrative and compliance costs. Some important research needs in the area are identified as human behavior, social acceptability, economic costs, network and infrastructure issues, how to stimulate innovation, security and reliability, and markets and governance (Ekins, 2004).

The majority of energy studies conducted in Turkey are either on Turkey's scarce energy resources, policies on energy trade and energy security issues, or they are associated with Turkey's foreign politics (Akkemik, 2009; Okay et al.,2008; Akpınar et al, 2008; Demirbas, 2001; Hepbasli et al., 2001; Kaygusuz, 1999a). The restricted academic studies on energy efficiency on the other hand, are mostly gathered around physical thermodynamic efficiency that fall under the area of engineering and architecture (Bagdatlıoglu, 1996; Kaygusuz, 1999b; Gul, 2007; Kahraman et.al, 2009; Onaygil, 2009). In the survey done by Zhou et al. (2008) on the use of DEA in energy and environmental research, out of the one hundred studies mentioned, only two concentrate on Turkey. Similarly in the survey on the use of index decomposition analysis in energy and environmental studies by Ang and Zhang (2000), out of the 124 studies found in literature, none of them concentrate on Turkey.

Hepbasli and Ozalp (2003) conducted a study to investigate the development of industrial energy efficiency and management studies in Turkey up until 2001. The paper focused on planned governmental activities aiming energy conservation and efficiency of the industrial sector which constituted 38% of Turkey's final energy consumption in 1998. The paper summarized the evolution of Turkey's energy policy during 1853-2001 and illustrated the role of National Energy Conservation Center in increasing the effectiveness of such policies.

A recent study by Onaygil (2009) aims to explain the framework and provisions of Turkish Energy Efficiency Law with a special emphasis on lighting applications. The study gives an overview of all energy efficiency studies and some major projects conducted in Turkey. The crucial role of lighting is also examined under the headings of implementations in the industry, buildings and transportation sectors and studies on efficiency performances of appliances.

Following the survey of literature on energy efficiency studies in Turkey, it is concluded that there are only two papers that fall into the context of this study, both done by Onut and Soner (2006, 2007), where the first one is on measuring energy efficiency of five-star hotels in Antalya Region and the latter is on measuring energy efficiency of the Turkish manufacturing sector as mentioned earlier in this chapter.

CHAPTER 5

DATA ENVELOPMENT ANALYSIS

In this chapter, data envelopment analysis, a non-parametric linear modeling technique, is used to assess energy efficiency of Turkey relative to European countries in order to make benchmarking and draw policy implications. The first section of the chapter provides brief information on data envelopment analysis while the next section introduces the model and the data that will be used. The third section consists of empirical results and discussion.

Data Envelopment Analysis

Data Envelopment Analysis (DEA), proposed by Charnes, Cooper and Rhodes (CCR, 1978), and extended by Banker, Charnes, Cooper(BCC, 1984) to include variable returns to scale, is a well-established non-parametric frontier approach to evaluating the relative efficiency of a set of comparable entities called DMU's, featured with multiple inputs and outputs. Since its introduction, 1000 articles, books and dissertation have been published and DEA measure has been used to evaluate and compare educational departments (schools, colleges and universities), health care (hospitals, clinics), prisons, banks, courts, armed forces, sports, market research, transportation (highway maintenance), courts, agricultural production, benchmarking, index number construction and many other applications (Emrouznejad, 1995). It has also been used to evaluate performance of cities, regions, and countries.

The power of DEA is that it measures relative efficiency, which has the advantage of avoiding the need for assigning a priori measures of relative importance to any input or output. The general definition for the basic kind of efficiency, referred to as "technical efficiency" in economics is:

"Full (100%) efficiency is attained by any DMU if and only if none of its inputs or outputs can be improved without worsening some of its other inputs or outputs."

But in most management or social science applications the theoretically possible levels of efficiency will not be known. Hence it is replaced by the following definition of relative efficiency, by emphasizing its uses with only the information that is empirically available:

"A DMU is to be rated as fully (100%) efficient on the basis of available evidence if and only if the performances of other DMUs does not show that some of its inputs or outputs can be improved without worsening some of its other inputs or outputs."

Notice that this definition avoids the need for recourse to prices or other assumptions of weights which are supposed to reflect the relative importance of the different inputs or outputs. It also avoids the need for explicitly specifying the formal relations that are supposed to exist between inputs and outputs.

The following example illustrates the envelopment mechanism of DEA. Suppose that the points A, B, C, D, E, F, G, H, and I represent input bundles of nine DMUs producing the same output level y using different combinations of two inputs x_1 and x_2.

Table 19. Two Inputs and One Output Case

DMU	A	B	C	D	E	F	G	H	I
Input 1	4	7	8	4	2	5	6	5,50	6
Input 2	3	3	1	2	4	2	4	2,5	2,5
Output	1	1	1	1	1	1	1	1	1

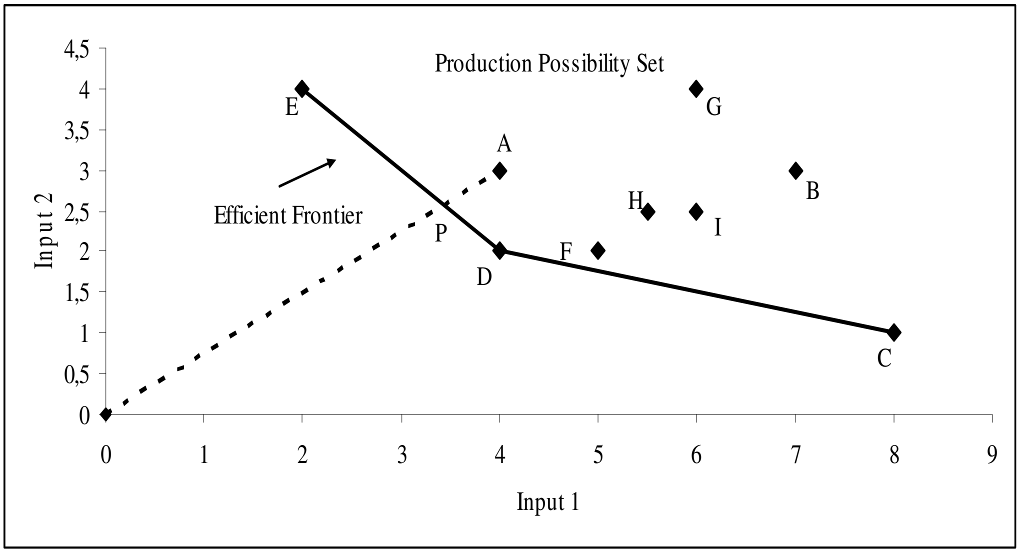

Figure 22. Two inputs and one output case

As far as efficiency is concerned, the DMUs which use less inputs to get one unit output are considered more efficient, hence the line connecting C, D and E is identified as the efficiency frontier. Notice that the frontier touches at least one point and no point on this frontier line can improve one of its input values without worsening the other. All the data points can be enveloped within the region enclosed by the frontier line, the horizontal line passing through C and the vertical line through E. The name Data Envelopment Analysis, as used in DEA, comes from this property because in mathematical parlance, such a frontier is said to "envelop" these points. This region is called the production possibility set. This means that the observed points are assumed to provide (empirical) evidence that production is possible at the rates specified by the coordinates of any point in this region.

The efficiency of DMUs not on the frontier line can be measured by referring to the frontier point as follows. For example, A is inefficient. To measure its inefficiency let OA, the line from zero to A, cross the frontier line at P. Then, the efficiency of A can be evaluated by OP/OA= 0.8571.

Consider an industry producing a single output y from a vector of m inputs $x=(x_1,x_2,\ldots, x_m)$. Let y_j represent output and the vector x_j represent the input bundle of the j-th decision-making unit (DMU). Suppose that input–output data are observed for n DMUs. Then the technology set can be completely characterized by the production possibility set

S={(x, y): y can be produced from x} based on a few regularity assumptions:

1. Feasibility: all observed input–output combinations are feasible. $(x_j, y_j) \in S$; j = 1,2,…n).

2. Free disposability with respect to inputs. $(x_0, y_0) \in S$ and $x_1 \geq x_0 \rightarrow (x_1, y_0) \in S$.

3. Free disposability with respect to outputs. $(x_0, y_0) \in S$ and $y_1 \leq y_0 \rightarrow (x_0, y_1) \in S$.

4. Convexity. $(x_0, y_0) \in S$ and $(x_1, y_1) \in S \rightarrow (\lambda x_0+(1-\lambda)\, x_1, \lambda y_0+(1-\lambda)\, y_1) \in S$; $0 \leq \lambda \leq 1$.

Within the DEA method, input-oriented technical efficiency is defined as the ratio of the optimal (i.e., minimum) input bundle to the actual input bundle of a DMU, for a given level of output, holding input proportions constant. Technical efficiency can also be measured based on output-orientation where efficiency is defined as the ratio of the observed output to the optimal (i.e., maximum) achievable output.

The CCR DEA model for measuring the input-oriented technical efficiency of a DMU with the input–output bundle (x_0, y_0) can be written as:

$\theta^* = \text{Min } \theta$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\lambda_j \leq \theta x_{i0} \quad i = 1, 2, \ldots, m$$
$$\sum_{j=1}^{n} y_j\lambda_j \geq y_0$$
$$\lambda_j \geq 0 \qquad j = 1, 2, \ldots, n \tag{1}$$

An efficient DMU will have θ*=1, implying that no equi-proportionate reduction in inputs is possible, whereas an inefficient DMU will have θ*<1.

Model (1) is the most basic input oriented DEA-model, namely CCR, with constant returns to scale and is an appropriate measure when energy input has strong complementarities with other inputs. But if there is no such assumption and if our primary interest is the efficiency of energy input usage, then we would be interested in knowing what is the possible maximum reduction in energy input, that will allow the same level (observed level) of output without requiring additional amounts of other inputs. In this case we employ a different CCR-type DEA model to measure the energy use efficiency. Instead of the input vector x_0, inputs capital (K), labor (L) and energy (E) are stated explicitly.

$$\beta^* = \min \beta$$

Subject to

$$\sum_{j=1}^{n} K_j\lambda_j \leq K_0$$
$$\sum_{j=1}^{n} L_j\lambda_j \leq L_0$$
$$\sum_{j=1}^{n} E_j\lambda_j \leq \beta E_0$$
$$\sum_{j=1}^{n} y_j\lambda_j \geq y_0$$
$$\lambda_j \geq 0 \qquad j = 1, 2, \ldots, n \tag{2}$$

Both of the previous models assume that inputs are used to produce good or desirable outputs. In accordance with the global environmental conservation awareness, undesirable outputs of productions and social activities such as air pollutants and hazardous wastes are being increasingly recognized as dangerous and undesirable. Energy use also results in the generation of some undesirable outputs such as green house gas emissions as by-products of producing desirable outputs. In economy-wide energy efficiency studies, making comparisons and benchmarking of energy efficiency without taking into account the environmental aspects seem to be insufficient.

Consider a production process in which desirable and undesirable outputs are jointly produced by consuming both energy and non-energy inputs. Assume that x, e, y and u are, respectively, the vectors of non-energy inputs, energy inputs, desirable outputs and undesirable outputs, where energy inputs consist of L different energy sources. Then the production technology can be described as T={(x; e, y u) : (x, e) can produce (y,u)}with the following two conditions in addition to the previous disposability assumptions:

1. Outputs are weakly disposable, i.e., if (x,e,y,u) Є T and $0 \leq \theta \leq 1$, then (x,e, θy, θu) Є T.

2. Desirable outputs and undesirable outputs are null-joint, i.e., if (x,e,y,u) Є T and u = 0, then y = 0.

The first condition implies that the reduction of undesirable outputs is not free but the proportional reduction in both desirable and undesirable outputs is feasible. The second condition implies that the only way to eliminate all the undesirable outputs is to cease the production process.

Assuming there are K entities whose energy efficiency are to be measured, N non-energy inputs, L energy inputs, M desirable outputs and J undesirable outputs, then the related model for computing energy efficiency is stated as:

$\theta^* = \text{Min } \theta$

Subject to

$$
\begin{aligned}
&\sum_{k=1}^{K} z_k x_{nk} \leqslant x_{n0}, \quad n = 1, \ldots, N \\
&\sum_{k=1}^{K} z_k e_{lk} \leqslant \theta e_{l0}, \quad l = 1, \ldots, L \\
&\sum_{k=1}^{K} z_k y_{mk} \geqslant y_{m0}, \quad m = 1, \ldots, M \\
&\sum_{k=1}^{K} z_k u_{jk} = u_{j0}, \quad j = 1, \ldots, J \\
&z_k \geqslant 0, \quad k = 1, 2, \ldots, K
\end{aligned} \tag{3}
$$

Data and Modeling

We apply two different DEA-models in order to analyze energy efficiency in Turkey with respect to the EU countries, one of which takes into account environmental aspects. The first model is a single output model, with GDP in purchasing power parity as the only output. The second model on the other hand is a two-output model which assumes greenhouse gases emissions as the second and undesirable output which is an inevitable product of energy consumption. In our empirical analysis, both our models have eight inputs; capital, labor and R&D expenditure as non-energy inputs and solid fuels, crude oil and petroleum products, gas, nuclear energy and renewables as the five energy inputs. We treat different energy sources as individual inputs in order to make interpretations on the effects of the energy mix on energy efficiency.

For the empirical analysis, we use annual time series data for 32 countries over the period 1995 and 2007. The countries included are the EU-27, Switzerland, Norway, Iceland, Hungary and Turkey. We gathered the energy consumption, green house gases emissions, capital and labor data from Eurostat, and the GDP in purchasing power parity (PPP) from OECD. The unit of GDP is millions of current prices and current PPP in USD**.** Gross capital formation consists of gross fixed capital formation plus changes in inventories plus acquisition less disposal of valuables and it is in millions of purchasing power standard (PPS is the name given by Eurostat to the artificial currency unit in which the PPPs and real final expenditures for the EU 25 are expressed – namely, euros based on the EU 25). Labor is in thousands of workforce and R&D expenditure is again in purchasing power standard. The energy consumption data are all in thousand tones of oil equivalent (Toe) and represent the gross inland consumption of each energy source**.** Gross inland consumption represents the quantity of energy necessary to satisfy inland consumption of the geographical entity under consideration. It is calculated as follows: primary production + recovered products + total imports + variations of stocks - total exports – bunkers. It corresponds to the addition of consumption, distribution losses, transformation losses and statistical differences.

There are three types of frontiers that can be used in DEA: (i) the contemporaneous frontier constructed from only the cross section data from a given period, (ii) the sequential frontier that treats all current and past observations as feasible, and (iii) an intertemporal frontier based on observations from all the periods in the sample (Tulkens and Vanden Eeckaut, 1995). If changing technology has caused performance to improve over time then the later years in the sample would have a higher measured efficiency than the earlier years and this information would be masked from an analysis using contemporaneous frontiers since the benchmark would be changing from year to year (Bhattacharyya et al., 1997). In this study, we use time series data of 32 different DMU's to measure energy efficiency over time and we use an intertemporal frontier where the input-output bundles of each country for each year is considered a distinct DMU.

In both of our applications we use input-oriented DEA-models since we are interested in efficiency of energy as an input and they assume constant returns to scale since it is not meaningful for overall economy to be operating under increasing or decreasing returns to scale.

Empirical Results and Discussion

Table 20 and Table 21 contain the summary efficiency score results from the DEA analysis using the single output model (2) without incorporating the undesirable output and with only one useful output, namely GDP. The overall assessment is that efficiency has improved in all of the countries over the time period 1995-2007 and 17 countries came to be efficient in 2007. While the average energy efficiency score was 0,720 in 1995, it reached 0,909 in 2007. But as we are measuring efficiency based on an intertemporal frontier, this finding reflects the technological progress as well as efficiency improvement. The countries with the highest energy efficiency scores in almost all years are Greece, Turkey, Malta, Iceland, United Kingdom and Luxemburg and the countries with the lowest efficiency scores are Finland, Belgium, Estonia, Slovenia and Romania. Most of the EU-15 countries have continuously increasing efficiency scores such as Austria, Belgium, France, Germany, Spain, Sweden and UK. The most notable increase is seen in the efficiency score of

Slovakia which reached 1 in 2007 from 0,453 in 1995. Norway is another country that improved its energy efficiency drastically from 0,499 to 1 over the years.

Table 20. Efficiency Scores Using the Single Output Model

DMU	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Ave.
AUSTRIA	0,651	0,630	0,647	0,656	0,693	0,754	0,718	0,772	0,750	0,786	0,804	0,859	0,927	0,742
BELGIUM	0,556	0,537	0,562	0,555	0,569	0,621	0,623	0,691	0,650	0,662	0,687	0,730	0,804	0,634
CZECH R.	0,758	0,780	0,750	0,732	0,733	0,801	0,802	0,789	0,763	0,760	0,783	0,841	0,934	0,787
DENMARK	0,672	0,644	0,666	0,680	0,725	0,783	0,799	0,859	0,877	0,925	0,982	0,965	1	0,814
FINLAND	0,489	0,472	0,432	0,411	0,487	0,528	0,579	0,570	0,561	0,574	0,571	0,587	0,615	0,529
FRANCE	0,677	0,706	0,790	0,725	0,736	0,777	0,811	0,906	0,915	0,908	0,953	0,982	1	0,837
GERMANY	0,651	0,644	0,661	0,661	0,698	0,720	0,748	0,811	0,828	0,867	0,914	0,934	1	0,780
GREECE	1	0,990	1	0,907	0,862	0,848	0,912	0,953	0,946	0,986	1	1	1	0,954
HUNGARY	0,696	0,803	0,807	0,879	0,922	0,932	1	0,901	0,933	1	0,955	0,943	1	0,906
ICELAND	0,926	0,928	0,860	0,849	0,888	0,907	0,962	1	0,986	1	1	1	NA	0,942
IRELAND	0,853	0,827	0,795	0,701	0,707	0,782	0,863	0,923	1	0,933	0,962	0,973	1	0,871
ITALY	0,762	0,829	0,831	0,844	0,840	0,863	0,898	0,882	0,883	0,889	0,955	0,941	1	0,878
LUX.	0,880	0,914	0,865	0,896	0,976	0,776	0,988	1	0,855	0,828	0,868	1	1	0,911
NETHER.	0,670	0,662	0,679	0,668	0,687	0,756	0,804	0,901	0,884	0,908	0,931	0,970	0,953	0,806
NORWAY	0,499	0,850	0,552	0,855	0,517	1	0,893	1	1	0,830	0,692	1	0,954	0,819
POLLAND	0,768	0,724	0,733	0,761	0,794	0,802	0,859	0,959	0,983	0,968	1	0,986	1	0,872
PORTUGAL	0,942	1	0,957	0,818	0,705	0,755	0,772	0,771	0,836	0,824	0,860	0,946	0,964	0,858
SLOVAKIA	0,453	0,523	0,532	0,594	0,649	0,719	0,699	0,686	0,824	0,834	0,847	0,947	1	0,716
SPAIN	0,693	0,683	0,679	0,695	0,710	0,718	0,716	0,772	0,729	0,737	0,753	0,809	0,858	0,735
SWEDEN	0,654	0,809	0,776	0,880	0,755	1	0,768	1	0,944	1	1	1	1	0,891
SWITZ.	0,655	0,705	0,797	0,924	0,944	0,776	0,761	0,865	1	0,890	0,915	0,942	1	0,860
TURKEY	0,915	0,915	0,954	0,967	0,895	0,915	0,952	0,887	0,887	0,968	1	1	1	0,943
UK	0,751	0,833	0,857	0,835	0,842	0,889	0,985	0,996	1	1	1	1	1	0,922
CROTIA	0,853	0,731	0,632	0,670	0,682	0,758	0,674	0,655	0,647	0,682	0,768	0,862	0,920	0,733
BULGARIA	0,840	1	1	0,893	0,990	0,525	0,571	0,561	0,539	0,592	0,581	0,624	0,719	0,726
ESTONIA	0,649	0,652	0,762	0,396	0,427	0,543	0,551	0,606	0,646	0,672	0,731	0,840	0,889	0,643
CYPRUS	0,688	0,663	0,708	0,703	1	0,680	0,718	0,724	0,689	0,785	0,827	0,835	0,848	0,759
LATVIA	0,670	0,615	0,733	0,532	0,700	0,839	0,858	0,980	1	1	1	1	1	0,841
LITHUNIA	0,693	0,698	0,754	0,457	0,535	0,717	0,679	0,699	0,787	0,815	0,861	0,911	0,996	0,739
MALTA	0,851	0,935	0,825	0,981	1	1	0,955	1	0,920	0,901	0,899	0,992	1	0,943
ROMANIA	0,728	1	0,851	0,481	0,625	0,582	0,536	0,584	0,636	0,714	0,752	0,758	0,841	0,699
SLOVENIA	0,487	0,443	0,485	0,514	0,528	0,563	0,577	0,640	0,658	0,665	0,721	0,774	0,869	0,610
Average	0,720	0,755	0,748	0,722	0,744	0,770	0,782	0,823	0,830	0,841	0,862	0,905	0,909	

Most of the Eastern Europe countries such as Croatia, Bulgaria, Romania, and Estonia along with Portugal have experienced deterioration in their efficiencies in the years 1998 to 2002. This might be due to declining oil prices in the period 1997-1999 resulting from the Asian crisis and the relatively low prices in the following few years which encourages energy consumption.

When we consider Turkey's position in this frame, it emerges as one of the highest energy efficient countries in almost every year. Although this is an unexpected result considering that Turkey is a highly populated emerging country, some of the reasonable factors behind this could be lower capital stock and lower industrialization rate relative to most of the developed European countries considering the logic of DEA. The efficiency score of Turkey increases from 1995 to 1998 but undergoes a decline in the year 1999 as with many other, mostly Eastern European, countries. The efficiency rises again in years 2000 and 2001, but decreases again in 2002 and 2003. The economic crises of 2001 and 2002 of Turkey, seems to have a negative effect on energy efficiency levels in terms of the deteriorating GDP. According to our results, Turkey's energy efficiency level rises notably after 2004, being efficient in the years 2005, 2006 and 2007. A few developments coincide in the same period; namely, increasingly high energy prices, high economic growth in Turkey as in most emerging countries due to foreign investment and the start of energy efficiency policy and measure implementations in Turkey.

Table 21. Comparison of Efficiency Scores with the Single Output Model

	TURKEY		**EU-15 AVERAGE**	**EU-27 AVERAGE**	**NEW MEMBERS AVERAGE**
Year	**Score**	**Rank**	**Score**	**Score**	**Score**
1995	0,915	130	0,727	0,740	0,690
1996	0,915	134	0,745	0,742	0,736
1997	0,954	102	0,746	0,746	0,745
1998	0,967	89	0,729	0,702	0,660
1999	0,895	151	0,733	0,742	0,742
2000	0,915	132	0,771	0,753	0,725
2001	0,952	105	0,799	0,770	0,734
2002	0,887	160	0,854	0,814	0,761
2003	0,887	159	0,844	0,816	0,781
2004	0,968	87	0,855	0,834	0,809
2005	1	1	0,883	0,858	0,830
2006	1	1	0,913	0,894	0,871
2007	1	1	0,941	0,934	0,925

Table 21 shows a comparison of energy efficiency scores of Turkey with the average scores of EU-15, EU-27 and the new member countries. It is evident that the energy efficiency level of Turkey is higher than the EU average and the new member states have the lowest energy efficiency among the considered groups. All groups experience energy efficiency improvement over time. As we considered each input-output bundle of each year of every country as a distinct DMU, our DEA-model compared 416 DMU's. The rank column shows Turkeys' each year performance rank among the 416, and it shows that Turkey has been in the 100-160 range most of the years.

Tables 22, 23 and 24 summarize the results of the second DEA model which adds an undesirable output, green house gas emissions, to the input-output bundle. The inputs of the model are the same but this time there are two outputs, one desirable, GDP, and the other undesirable, GHG emissions. We make use of three versions of the model, by employing different weights to the good and bad outputs, namely, the ratio of good to bad outputs are (5:1), (1:1) and (1:5). This means that as weight moves from good to bad, the emphasis of the DEA changes from enlargement of the good output to reduction of the bad output. The results given in Table 22 are the results of the (1:1) model, in other words it assumes that reduction of GHG emissions, the environmental target, is of equivalent importance to enlargement of GDP, the economical target.

The first noticeable fact is that the efficiency scores are much lower when environmental factors are involved. This shows that all considered countries are less environmentally efficient even if in terms of productivity they perform well. Although on the average the efficiency scores increase from 0,453 in 1995 to 0,815 in 2007, the upward trend is not as fast and as continuous compared to the previous model. The more developed countries emerge as the countries with the highest efficiency scores, such as Sweden, United Kingdom, Norway, Switzerland and Italy.

Table 22. Efficiency Scores Using Undesirable Outputs Model

DMU	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Ave.
AUSTRIA	0,501	0,489	0,493	0,504	0,546	0,604	0,568	0,614	0,578	0,639	0,657	0,726	0,820	0,595
BELGIUM	0,250	0,234	0,248	0,249	0,264	0,294	0,312	0,458	0,411	0,385	0,376	0,419	0,514	0,340
CZECH R.	0,339	0,346	0,346	0,337	0,349	0,358	0,371	0,383	0,385	0,385	0,380	0,377	0,416	0,367
DENMARK	0,436	0,420	0,431	0,441	0,496	0,521	0,551	0,602	0,594	0,697	0,777	0,678	0,773	0,571
FINLAND	0,271	0,263	0,250	0,252	0,287	0,314	0,331	0,342	0,332	0,351	0,361	0,365	0,383	0,316
FRANCE	0,401	0,423	0,474	0,436	0,431	0,450	0,483	0,635	0,641	0,639	0,681	0,693	0,799	0,553
GERMANY	0,298	0,314	0,322	0,320	0,344	0,352	0,435	0,548	0,580	0,633	0,698	0,704	1	0,504
GREECE	1	0,810	1	0,572	0,541	0,605	0,674	0,761	0,757	0,848	0,846	0,937	1	0,796
HUNGARY	0,336	0,406	0,418	0,459	0,503	0,538	1	0,603	0,649	1	0,663	0,652	1	0,633
ICELAND	0,519	0,564	0,473	0,470	0,475	0,477	0,555	0,593	0,547	1	0,607	0,5	1	0,598
IRELAND	0,433	0,414	0,399	0,401	0,400	0,446	0,469	0,571	0,647	0,580	0,766	0,874	1	0,569
ITALY	0,575	0,641	0,647	0,681	0,693	0,727	0,807	0,762	0,797	0,819	0,885	0,908	1	0,765
LUX.	0,679	0,559	0,554	0,644	0,878	0,411	1,000	1	0,419	0,412	0,430	0,722	1	0,670
NETH.	0,274	0,287	0,296	0,315	0,329	0,367	0,415	0,528	0,527	0,603	0,697	0,776	0,868	0,483
NORWAY	0,431	0,721	0,484	0,705	0,500	1	0,745	1	1	0,767	0,808	1	1	0,782
POLLAND	0,485	0,472	0,488	0,507	0,522	0,558	0,614	0,755	0,842	0,851	1	0,911	1	0,693
PORT.	0,515	0,572	0,433	0,395	0,400	0,445	0,456	0,485	0,614	0,609	0,661	0,768	0,756	0,547
SLOVAKIA	0,251	0,269	0,280	0,313	0,343	0,375	0,340	0,362	0,464	0,483	0,505	0,741	1	0,441
SPAIN	0,351	0,376	0,387	0,374	0,372	0,391	0,412	0,452	0,443	0,464	0,494	0,573	0,630	0,440
SWEDEN	0,460	0,621	0,564	0,720	0,608	1	0,656	1	0,867	1	1	1	1	0,807
SWITZ.	0,593	0,504	0,666	0,994	0,708	0,598	0,703	0,778	1	0,695	0,846	0,883	1	0,767
TURKEY	0,744	0,744	0,790	0,793	0,745	0,775	0,879	0,804	0,810	0,906	1	1	1	0,845
U.K.	0,452	0,509	0,560	0,523	0,559	0,637	0,737	0,866	1	1	1	1	1	0,757
CROTIA	0,401	0,428	0,415	0,420	0,418	0,482	0,486	0,492	0,483	0,530	0,634	0,741	0,775	0,516
BULG.	0,326	1	1	0,364	0,428	0,238	0,268	0,274	0,269	0,297	0,279	0,291	0,366	0,415
ESTONIA	0,401	0,403	0,447	0,262	0,287	0,372	0,391	0,412	0,425	0,444	0,473	0,493	0,504	0,409
CYPRUS	0,579	0,573	0,590	0,482	1	0,384	0,474	0,889	0,432	0,411	0,424	0,431	1	0,590
LATVIA	0,450	0,364	0,428	0,345	0,473	0,606	0,628	0,735	1	1	1	0,893	1	0,686
LITHUNIA	0,248	0,255	0,255	0,155	0,209	0,299	0,288	0,302	0,338	0,357	0,401	0,448	0,466	0,309
MALTA	0,868	0,907	0,935	0,984	1	1	1,000	1	0,799	0,857	0,862	0,961	1	0,936
ROMANIA	0,352	0,349	0,317	0,230	0,297	0,327	0,331	0,356	0,392	0,454	0,499	0,509	0,533	0,381
SLOVENIA	0,285	0,232	0,251	0,273	0,279	0,311	0,324	0,348	0,375	0,372	0,398	0,416	0,471	0,333
Average	0,453	0,483	0,489	0,466	0,490	0,508	0,553	0,616	0,607	0,640	0,660	0,700	0,815	

Turkey and Greece are again among the most efficient countries. Malta appears as the most efficient country with average efficiency score of 0,936, but this result is predictable considering its very low energy consumption levels being a very small country. One of the most industrialized countries, Germany, while among the least efficient in 1995 with an efficiency score 0,298, improved its energy efficiency very effectively throughout the years to reach an efficiency score of 1 by 2007. Although some of this improvement can be accounted for technological progress, this situation is not as valid in all countries. Hence it can be considered as a policy success. The new member Eastern European countries such as Romania, Lithuania, Slovenia, Czech Republic and Bulgaria have been among the least energy efficient countries almost in all years, and moreover have experienced little improvement over the years.

When we compare the efficiency scores over the years of Turkey and EU-15, EU-27, and the new members, the same results from the previous model holds for Turkey. The results show that Turkey's energy efficiency is higher then that of EU's in all years and its efficiency has relatively deteriorated in the years 1999 and 2002-2003 again. Energy efficiency performance of the EU has continuously risen over the years, but this time efficiency performance of EU15 is the highest and has experienced the highest improvement (Table 4).

Table 23. Comparison of Efficiency Scores with Undesirable Outputs Model

	TURKEY(1-3)		EU-15 AVERAGE	EU-27 AVERAGE	NEW MEMBERS AVERAGE
	Score	Rank	Score	Score	Score
1995	0,744	120	0,460	0,438	0,410
1996	0,744	119	0,462	0,463	0,465
1997	0,790	103	0,471	0,475	0,480
1998	0,793	102	0,455	0,427	0,392
1999	0,745	117	0,476	0,475	0,474
2000	0,775	108	0,504	0,479	0,447
2001	0,879	77	0,554	0,531	0,502
2002	0,804	98	0,642	0,594	0,535
2003	0,810	95	0,614	0,577	0,531
2004	0,906	71	0,645	0,614	0,576
2005	1	1	0,689	0,637	0,574
2006	1	1	0,743	0,677	0,594
2007	1	1	0,836	0,789	0,730

The previous results were from the model that attained equal weights to good and bad outputs. Table 5 shows the differences in efficiency scores when we employ different weights to the undesirable output GHG emissions and the desirable output GDP. We can see that as the weight to the undesirable output increases, giving more emphasis on environmental performance, the efficiency scores decrease for Turkey. This implies that although energy consumption performance in terms of generating GDP is increasing, not only Turkey but almost all other countries are falling back on environmentally stable energy usage.

Table 24. Efficiency Score Results for Turkey with Different Weights

Weights to Good and Bad Outputs						
Turkey	1 : 5		1 : 1		5 : 1	
Year	Score	Rank	Score	Rank	Score	Rank
1995	0,730	116	0,744	120	0,744	129
1996	0,721	119	0,744	119	0,751	126
1997	0,769	108	0,790	103	0,802	105
1998	0,774	105	0,793	102	0,807	104
1999	0,703	123	0,745	117	0,769	119
2000	0,735	114	0,775	108	0,802	106
2001	0,873	77	0,879	77	0,879	84
2002	0,773	107	0,804	98	0,820	98
2003	0,780	101	0,810	95	0,834	95
2004	0,892	73	0,906	71	0,917	72
2005	1	1	1	1	1	1
2006	1	1	1	1	1	1
2007	1	1	1	1	1	1

Sensitivity Analysis

In order to check and verify the efficiency score results obtained, especially for Turkey, different DEA models with different input and DMU variations are applied. Some of these models consider Turkey together with only the EU-15 countries over the same period, some of them consider energy inputs as the only inputs in the system in order to eliminate the effect of capital stock and labor efficiency in the overall efficiency. Some models on the other hand use all the inputs and all 32 countries as in the original models but apply different DEA-types. Summary information on the models and data used and the relative results obtained are given below.

Table 25. Summary results for six different DEA-models and scores for Turkey

		Model 1		Model 2		Model 3	
		Bad output-energy inputs		CCR-energy inputs		Non-separable bad output	
	Year	Score	Rank	Score	Rank	Score	Rank
Results	1995	0,584	140	0,806	148	0,744	114
	1996	0,584	141	0,798	154	0,744	113
	1997	0,611	118	0,827	125	0,790	98
	1998	0,646	102	0,859	97	0,792	97
	1999	0,589	133	0,804	149	0,742	115
	2000	0,611	117	0,840	114	0,773	105
	2001	0,610	119	0,825	127	0,878	72
	2002	0,586	136	0,784	166	0,795	96
	2003	0,572	149	0,778	169	0,797	93
	2004	0,664	95	0,887	79	0,902	68
	2005	0,855	42	0,958	39	1	1
	2006	0,961	24	0,990	26	1	1
	2007	1	1	1	1	1	1
Number of DMUs			416		416		416
Average of scores			0,508		0,727		0,580
No. of efficient DMUs			22		20		59
No. of inefficient DMUs			394		396		357

		Model 4		Model 5		Model 6	
		Non-controllable variables		Weighted SBM		Bad output-EU15	
	Year	Score	Rank	Score	Rank	Score	Rank
Results	1995	1	1	1	1	1	1
	1996	0,993	206	0,967	79	0,972	77
	1997	1	1	1	1	1	1
	1998	1	1	1	1	1	1
	1999	1	1	0,814	111	0,854	100
	2000	1	1	0,837	106	0,867	98
	2001	1	1	1	1	1	1
	2002	0,963	249	0,878	92	0,906	90
	2003	0,995	201	1	1	1	1
	2004	1	1	1	1	1	1
	2005	1	1	1	1	1	1
	2006	1	1	1	1	1	1
	2007	1	1	1	1	1	1
Number of DMUs			416		416		208
Average of scores			0,934		0,644		0,797
No. of efficient DMUs			192		72		73
No. of inefficient DMUs			222		344		135

The efficiency score results are given only for Turkey and for comparison purposes, Turkey’s rank, total number of DMUs, number of efficient and inefficient DMUs and the average efficiency score for all DMUs is also given.

Models 1 and 2 are the same models (the undesirable output model and the single output model respectively) used previously in the chapter but contain only the five energy inputs, namely solid fuels, crude oil and petroleum products, gas, nuclear energy and renewables as the inputs of the system. It is found that Turkey’s efficiency scores are slightly lower without the capital and labor effects. Turkey reaches full efficiency only in the year 2007 whereas earlier it was found to be efficient in the last three years, 2005, 2006 and 2007. This implies that lower capital formation as opposed to a large GDP has some effects on Turkey’s energy efficiency. But similar to our previous results, among the 416 DMUs considered, Turkey’s efficiency rank is still in the range 1-170 in both models. In addition to this fact, again in concordance to previous results, Model 1 which takes environmental concerns into account with the objective to minimize the undesirable output , ghg emissions, produces lower efficiency scores compared to Model 2 which only aims to maximize the desirable output.

Model 3 is a different model called unseparable bad output model. It is often observed that certain 'bad' outputs are not separable from the corresponding 'good' outputs. In each case, reducing bad outputs is inevitably accompanied by reduction in good outputs. Furthermore, it often occurs that a certain bad output is closely related (non-separable) with a certain input. In our case the bad output ghg emissions is unseperable from the good output GDP. Furthermore, emissions of green house gases are proportional to some fuel consumptions such as solid fuels, crude oil and petroleum products and gas. Hence in this model the outputs and the mentioned inputs are defined to be unseperable and nuclear energy, renewables, capital, labor and R&D expenditure are defined to be separable inputs. But although the methodology is different the results this model yields are very similar to the previous results with the undesirable output. Turkey is again efficient in the years 2005, 2006 and 2007, its average efficiency score is 0,84 which is again high above the EU average. Turkey's efficiency rank in all years stays in the range 1 and 115 among the 416 DMUs.

Models 4 and 5 do not consider undesirable outputs; hence they are single output models. Model 4 defines the non-energy inputs to be uncontrollable, and Model 5 assigns weights (1: 2) to the non-energy and energy inputs. In both cases Turkey results as efficient in most of the years considered. Also considering the very high number of efficient DMUs (192 and 72 respectively) and Turkeys rank among the 416 with very high efficiency scores (in a range 1-250), it is concluded that these models do not carry enough valuable information, and the results are not very significant.

Model 6 on the other hand is the undesirable output model explained and applied in the previous section but considers Turkey together with only the EU-15 countries. The model considers 16 countries in the years 1995-2007, hence considers 208 DMUs. The average efficiency score of all DMUs is 0.797, which is significantly higher than the previous result. The reason behind this may be the result of the lack of some very efficient countries such as Malta, Norway and Switzerland. Turkey still results in higher efficiency scores than the average. It is again concluded that this analysis also does not contain any more information than the applied methods.

In conclusion; it is found that energy efficiency has improved over the years, efficiency is lower when environmental factors are incorporated and it is even lower as more emphasis is given to environmental performance, Turkey emerges as one of the more energy efficient countries among the considered 32 countries, and the new member countries are falling back in energy efficiency performance.

The next chapter investigates the factors effecting efficiency with a panel data analysis of the obtained efficiency score results and some factors such as activity mix, energy mix, energy intensity and energy prices.

CHAPTER 6

FACTORS EFFECTING ENERGY EFFICIENCY

In the previous chapter, relative energy efficiency scores were obtained and analyzed using data envelopment analysis for 32 European countries, including Turkey, for the years 1995-2007. Energy efficiency is found to have increased over the years in all countries and the efficiency scores resulted significantly lower when considering the environmental aspects of energy use. In this chapter, the energy efficiency score results of the undesirable output DEA model will be used to examine the effects of structural factors such as energy mix and the activity mix on energy efficiency. The relationship between energy efficiency and energy price changes, the capital formation of the economy and energy intensity are some other factors that are analyzed in this chapter. The first section of the chapter introduces and explains the data and methodology, where the second section contains the empirical results and discussion.

Data and Methodology

The data included in the study cover the 32 European countries listed in the previous chapter over the period 1995-2007, and energy efficiency scores obtained from the undesirable output model are used as their efficiency scores (ES) throughout these years. The factors whose effects on energy efficiency that will be investigated are the energy source mix of the total consumption, activity mix of the economy, the level of capital formation, energy intensity and energy prices.

The independent variables and their expected signs are explained as follows:

GAS, OIL, SLD, NUC and REN are respectively the percentage of gas, oil and petroleum products, solid fuels, nuclear energy and renewable energy consumption in the total energy consumption in year t. The related data is gathered from Eurostat. As efficiency scores are calculated taking green house gas emissions into account as an undesirable factor and by aiming to minimize them as an output, it is expected that as the percentage of nuclear energy and renewable energy sources increase in the energy mix, energy efficiency should also increase. On the contrary, gas, oil and solid fuel intensity should have a negative effect on energy efficiency. But considering that energy mix of a country can depend on numerous factors, such as infrastructure, proximity to exporters, production potential, cost of energy imports; and these factors may affect the consumer price of each energy source in the country, the consumption and the efficiency levels may differ. Therefore, the expected sign of these variables may be both negative and positive.

INDGDP, AGRGDP and SERVGDP are respectively the percentage of industry, agriculture and services in the GDP of an economy in the year t. They are all retrieved from Eurostat and given in gross value added in basic prices. AGRGDP contains agriculture, hunting, forestry and fishing whereas SERVGDP contains wholesale and retail trade, repair of motor vehicles, motorcycles and personal and household goods; hotels and restaurants; transport, storage and communication.

In the industrialization of a country, as agriculture is replaced with manufacturing, energy consumption rises faster than GDP; while in the post-industrialization period service sector in the economy replaces manufacturing meaning a higher GDP development without requiring more energy. (Dunkerly et al., 1981; Eden at al., 1981). Hence, as the percentage of industry in economy rises, energy efficiency is more likely to fall and as the percentage of service sector in the economy rises, the country is likely to become more energy efficient. Hence the expected sign for INDGDP variable is negative, while the expected sign of SERVGDP is positive. On the other hand, a rise in the level of agriculture may increase or decrease the level of energy consumption depending on the direction of the shift in the activity mix, and also depending on the mechanization level of agriculture in the country. Therefore the expected sign of AGRGDP is ambiguous.

CAPGDP is the ratio of fixed capital formation of a country to its GDP in year t. Higher capital formation in a country implies more investment in production and industry. Therefore it may have a similar effect on energy efficiency as INDGDP. Meanwhile, this capital may not be forwarded directly to industry but to services, so the sign of this variable actually depends on country specific factors and is ambiguous. However, as the fixed capital formation in PPP was used as an input in the DEA analysis, although defined as non-discretionary input, higher values affect the efficiency scores obtained negatively. Hence the expected sign for this variable is negative.

EI is the energy intensity of the economy in year t, namely the ratio of total national primary energy consumption to GDP. Energy intensity is the most widely used monetary-based energy efficiency indicator and it is a measure of efficiency at the most aggregate level (Ang, 2006). Its expected sign is negative by definition.

Energy prices are an important factor in achieving energy efficiency. Verbruggen (2003) has presented evidence that electricity prices and electricity intensities are inversely related as would be expected by economists. Moreover, Darmstadter (2000) reports that in OECD countries the average rate of change of energy intensity over 1973-90, a period of generally high energy prices was more than twice over 1990-97, a period of relatively low prices.

The variables reflecting energy prices in this study are ELP, OP and EPI.

ELP denotes the electricity prices for industrial consumers (with annual consumption: 2000 MWh; maximum demand: 500 kW; annual load: 4 000 hours) obtained from Eurostat. Its unit is Euro (from 1.1.1999)/ECU (up to 31.12.1998) per Kilowatt-hour. Electricity constitutes an important portion of energy consumption in a country and electricity prices are influential on the consumption level.

OP denotes the annual Europe Brent oil spot FOB price in dollars per barrel. It is assumed same for all countries in each year and is expected to only measure the impact of international oil prices effect on energy consumption throughout the years.

EPI is the energy price index of OECD with 2005=100 for all countries in year t. In most of the model versions in this study, oil prices and electricity prices are used as an indicator of energy prices; energy price index is used only in one version.

When energy prices are high, consumers not only consume less energy, but they also prefer more energy efficient technologies in order to make cost reductions. Therefore the expected sign of ELP, OP and EPI is positive.

The effect of given variables on the energy efficiency performance of the 32 European countries is analyzed by Panel Data Models. Ordinary Least Squares Regression, Fixed Effects Model and Random Effects Model are used in the study and the selected results are given in the next section.

NLOGIT has been used in computing the regression analyses.

Empirical Results and Discussion

The effect of structural factors such as energy mix and activity mix as well as energy prices and energy intensity on the energy efficiency performance is analyzed using panel data models. Three types of panel data models, namely ordinary least squares

(OLS), fixed effects (FEM) and random effects (REM) are run with many versions involving different sets of explanatory variables to determine the best specification. Lagrange Multiplier test and Hausman test is applied to determine the performance of the different types of panel data models. Except for version eight, both Hausman and Lagrange Multiplier statistics favored FEM over the other models. The eighth version had more explanatory power with OLS. The results of all versions under FEM and the eighth version with OLS are presented in Table 26.

The different versions are designed in three groups. The first group considers various sets from all the explanatory variables together, meaning that it includes variables indicating energy mix, activity mix, energy prices and energy intensity. The second group models aim to explain the effects of energy mix on energy efficiency, and the third group aims to explain the effects of economic activity mix on energy efficiency. In all of the versions, the calculated F values are higher than F-table values within the 0.01 significance level except for the version 8' (OLS) where it remains in the 0.05 significance level.

The explanatory power of the fixed effects model including all variables except for CAPGDP, because it is out of category, and EPI, because its substitutes OP and ELP are included, version 1, is 79%. This indicates that the given independent variables are capable of explaining 79% of the variations in energy efficiency. Versions 2, 3 and 4 include only nuclear and renewable energy from energy mix, only industry from activity mix, and also the capital intensity of the economy as well as energy price indicators. All three versions also have an explanatory power ranging between 77% and 79%.

Table 26. Panel Data Estimates of the Effects of Structural Factors and Energy Prices on Energy Efficiency Performance: Fixed Effects Model

	All Variable Types				Energy Mix			Economy Mix	
Version No	1	2	3	4	5	6	7	8	8' (OLS)
OIL	-0.009**				-0.022***				
	(-2.080)				(-6.606)				
SLD	-0.007				-0.026***	-0.018***			
	(-1.629)				(-7.177)	(-4.941)			
NUC	-0.005	-0.001		-0.023***	-0.017***	-0.009	-0.002		
	(-0.730)	(-0.250)		(-3.647)	(-3.007)	(-1.648)	(-0.484)		
REN	0.003	0.009*	0.009*	-0.001	0.003	0.016***	0.024***		
	(0.550)	(1.985)	(2.012)	(-1.096)	(0.659)	(3.377)	(5.066)		
INDGDP	-0.004	-0.010**	-0.010**	-0.012***				-0.028***	-0.008***
	(-0.795)	(-2.394)	(-2.402)	(-2.995)				(-6.427)	(-3.642)
AGRGDP	-0.008							-0.022***	-0.011***
	(-0.579)							(-3.799)	(-3.397)
SERVGDP	0.009							-0.020***	0.005*
	(0.961)							(-3.074)	1.928
CAPGDP		-0.009***	-0.009***	-0.084**					
		(-2.800)	(-2.800)	(-2.771)					
EI	-0.000**	-0.001***	-0.001***	-0.000***					
	(-2.151)	(-3.180)	(-3.284)	(-3.315)					
ELP	1.689*	1.386	1.366						
	(1.746)	(1.469)	(1.456)						
OP	0.002***	0.003***	0.003***						
	(3.583)	(4.864)	(4.869)						
EPI				0.004***					
				(9.639)					
Constant									0.675***
									(7.117)
R^2	0.79	0.79	0.79	0.77	0.63	0.59	0.56	0.61	0.88
Adj. R^2	0.76	0.76	0.76	0.74	0.60	0.55	0.53	0.57	0.81
F [,]	[39,237]	[36,240]	[35,241]	[30,284]	[35,379]	[34,380]	[33,381]	[34,373]	[3,404]
F value	23.40	25.66	26.50	31.74	18.79	16,24	15.07	17.37	13.01

Dependent variable is energy efficiency score obtained from DEA undesirable output model.
Figure in parentheses are the t-statistics.
*** Significant at the 1% level
** Significant at the 5% level
* Significant at the 10% level

In the first and the most comprehensive version, only oil percentage (OIL), energy intensity (EI), electricity prices (ELP) and oil prices (OP) are statistically significant, and the rest of the variables are statistically insignificant. In versions 2, 3 and 4 industry intensity, and capital intensity of the economy are also statistically significant in addition to energy intensity and energy prices.

The coefficient of oil percentage and solid fuel percentage is negative as expected, with oil being significant at the 5% level. The renewable energy percentage in the energy mix has a positive effect on energy efficiency in almost all versions, and it is significant at the 10% level in the second and third versions.

The coefficient of nuclear energy capacity has in all versions a negative sign. It implies that the existence of nuclear energy in the energy consumption mix has a decreasing effect on energy efficiency. The reason behind this result may be that among the countries considered, many countries do not use nuclear energy, hence too many data for this variable was zero. Although in most cases this effect is statistically insignificant, there are some versions (Version 4) that it is significant at the 1% level.

CAPGDP has a significant negative effect on the energy efficiency score as expected since capital is considered one of the inputs in the DEA model calculating energy efficiency.

Energy intensity by definition is a good indicator of energy efficiency. The results also confirm this fact, where EI shows a negative relationship with energy intensity and with a significance level of 1% in all the versions it has been included.

All energy price indicator variables, in all the versions they have been included resulted in a positive sign as expected. While electricity price effects are not statistically significant, oil prices have a significance level of 1%. This can be interpreted as the overall economy wide energy efficiency is highly dependent on international oil prices. Energy price index also shows a significance positive relationship in the only version it was included, version 4.

In the second group, three versions of estimates of energy mix effects are run. One dependent variable is eliminated in each version. The first version that contains all four variables namely, OIL, SLD, NUC and REN, which is version 5, has the highest explanatory power among all with 63%. This implies that only energy source mix is capable of explaining 63% of all variations in economy wide energy efficiency. The results are compatible with the previous versions in a sense that oil, solid fuel and nuclear energy percentage are significantly negatively related to energy efficiency whereas renewable energy percentage is significantly positively related to energy efficiency. The significance levels are mostly 1%.

In the third group, the effect of economical activity mix is assessed. The FEM incorporating all three variables, namely the industry, agriculture and services percentage, has an explanatory power of 61%. Ordinary least squares regression, on the other hand, assigns the same variables an 88% explanatory power. When considered in a group with only like variables, all three variables have statistically significant effects on energy efficiency. The percentage of industry and agriculture result in a negative sign and the intensity of service sector have a positive sign as expected.

As a result, the effect of structural factors as well as energy prices on the overall economy wide energy efficiency was assessed in this chapter using the energy efficiency results obtained in chapter 5. It is concluded that the energy mix of the total energy consumption in the economy, the economic activity mix of the country and energy prices have significant effects on energy efficiency. Also, the finding that the fixed capital formation level in a country is inversely related to energy efficiency, and very high progression of energy prices in the last few years helps explain Turkey's high energy efficiency level partly.

CHAPTER 7

CONCLUSION

The constraints on energy supply and the more recent elevation of climate change has increased the attention given to energy efficiency around the world. According to a World Energy Council report (2008), almost all OECD countries have set up specific institutions dealing with energy efficiency, such as energy efficiency agencies, either at the national level or at regional levels and they are implementing new instruments adapted to their national circumstances. Energy productivity improvements in most world regions since 1990 resulted in 4.4 Gtoe energy savings in 2006 and avoided 10 Gt of carbon dioxide. Hence, energy efficiency is seen as the most effective way to a sustainable energy future. Improvements in energy efficiency can reduce the need for investment in energy infrastructure, cut fuel costs, increase competitiveness, increase energy security by decreasing the reliance on imported fossil fuels and reduce negative environmental impacts.

The EU plays a leading role in energy efficiency improvement being more than 50% dependent on imported energy. Their policies carry an integrated approach to climate and energy policy that aims to combat climate change and increase the EU's energy security while strengthening its competitiveness.

Turkey is also an energy deficient country, whose import dependence reached almost 75% in 2008. Turkey's energy trade deficit has boomed by 1,263% from 1989 to 2008 and reached 40.1 billion USD in 2008. Energy trade composes an important portion of Turkey's overall trade deficit; its contribution was 58.2% in 2008. Therefore, Turkey is in great need of an accurate energy efficiency strategy.

This study summarized the developments of energy efficiency policies in the EU and in Turkey and made an assessment of economy wide energy efficiency levels and improvements of 32 European countries throughout the period 1995-2007. The 32 countries consist of the non-EU countries Norway, Switzerland, Iceland, candidate countries Turkey and Croatia in addition to the EU-27. For the measurement of relative energy efficiency, a non-parametric linear modeling technique, data envelopment analysis was used. The model assumes capital, labor and total R&D expenditure as non-energy inputs, solid fuels, oil, gas, nuclear energy and renewables as energy inputs while accepting GDP in purchasing power parity as the desirable and green houses gases emissions as the undesirable output. Two versions of the model, one with a single output and the other with undesirable outputs incorporating environmental factors and few sensitivity models are run. Furthermore, energy efficiency changes over time are analyzed as a second step by evaluating the contributing factors such as activity mix of the economy, sources of primary energy resources, especially the share of renewables, and changes in energy prices.

The empirical results indicate that although energy efficiency has improved over the years, efficiency is lower when environmental factors are involved and it is even lower as more emphasis is given to environmental performance in all of the countries considered. The more noticeable improvement in energy efficiency takes place in the last five years which coincides with accelerated energy efficiency measures and policies both in Turkey and in the EU. Turkey emerges as one of the more energy efficient countries among the considered 32 countries, and the new member countries are falling back in energy efficiency performance. The second step regression analysis results imply that energy mix in the total consumption, the economic activity mix of the country and energy prices have significant effects on energy efficiency.

According to the results, the following direct and indirect policy implications could be drawn for Turkey.

- Turkey should accelerate energy efficiency policies and measures

Although according to our data, Turkey emerged as one of the energy efficient countries in the last few years; these years coincide with the start of effective energy efficiency policy, regulations and monitoring. Turkey's energy consumption growth rate is one of the highest in Europe, hence she will always need an accurate energy efficiency policy and should complete the regulatory framework initiated with the Energy Efficiency Law in 2007 as soon as possible in order to coordinate all sectors and areas with energy saving potential. Turkey's other policies should also integrate energy efficiency aspects.

- Turkey should implement accurate energy efficiency policies

Implementing the right energy efficiency policies is one of the major decision points in Turkey. As the empirical evidence also supports, incentive pricing is a must condition for successful energy efficiency policy. Fiscal and pricing policies are the most efficient way of internalizing long-term costs and benefits. The government should initialize careful design of new taxation schemes, taking into account international competition and the negative impacts on low-income households or small and medium sized enterprises. Energy prices will also have a large impact on technological innovation. To be efficient, regulations should be well planned, regularly strengthened and properly enforced. The public sector should lead by example. Innovative methods should be promoted based on experiences of other developing countries. Innovative energy efficient technologies should not only be promoted but also subsidized in the industry sector which is the main driver in energy productivity improvements.

- Turkey should increase investment in renewable energy

Renewable energy is not only a cleaner energy source which will increase environmentally sustainable energy efficiency but also serves the purpose of reducing reliance on external energy supply. Turkey should encourage through attractive incentives, the investments in geothermal, wind and solar energy. In general, energy mix of the country should be addressed in accordance with efficiency aspects.

- Evaluation and monitoring should become a priority

Since it is known for a fact that there is high level of informal data especially in the energy sector, as a first step, accurate and comprehensive data collection needs to be developed in Turkey in order to improve energy efficiency assessments. Additionally, quantitative targets should be set and regularly and seriously measured in order to monitor and evaluate the progress achieved.

The major contribution of this thesis is to provide economy-wide energy efficiency performance analysis for Turkey by taking into account environmental concerns. The second contribution of the study is to compare Turkey's energy efficiency performance across the EU countries and derive crucial policy implications by incorporating environmental factors and policies. A new application from an emerging market, Turkey, will contribute to the portfolio of emerging economies literature.

For future studies, another factor could produce useful results if incorporated in the data envelopment analysis, that is, the cost effect. Given data availability, using the prices of each energy input, for each country and for each year may yield more realistic results on the efficient use of energy. Also GDP per capita could be used as an output to compare the energy efficiency levels of countries according to their income levels. The effects of implemented energy efficiency policies and measures may be assessed empirically and in detail in the future years when enough time has passed over the Turkish Energy Efficiency Law for its reflections. There are also many other factors whose effects on energy efficiency could be analyzed such as foreign investment level, privatization level and market economy conditions in the energy market, climate conditions, proximity to energy producer countries, technological advancement and education level.

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