DETERMINANTS OF RENEWABLE ENERGY SUPPLY IN EUROPE: A POTENTIAL SOLUTION FOR TURKEY’S ENERGY DEPENDENCY

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DETERMINANTS OF RENEWABLE ENERGY SUPPLY IN EUROPE: A POTENTIAL SOLUTION FOR TURKEY'S ENERGY DEPENDENCY

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Thesis Abstract

Gökmen Sümer, "Determinants of Renewable Energy Supply in Europe: A Potential Solution for Turkey's Energy Dependency"

Energy resources are an essential part of sustainable economic development. Conventionally, industrialized economies use more energy per unit of output and per capita than the developing economies. However, emerging economies have increased their energy demand over the last decade and are expected to dominate world energy growth over the next decades. As an emerging economy, Turkey's energy demand has risen dramatically over the past three decades. High economic growth and improvements in macroeconomic balances over the last decade have been the major driving forces in growing energy demand. Unfortunately, since traditional fossil fuels account for more than 90 percent of the total energy consumption and the country has no large oil and natural gas reserves, Turkey has become heavily dependent on energy. In addition, environmental concerns and the national energy security policy also force the country to seek new energy resources. Therefore, Turkey should utilize her huge alternative energy resources and change her current energy mix.

The aim of this study is to analyze major determinants for energy generation from renewable energy resources, mainly wind, solar and geothermal energy for the EU-15 and the EU-12+2 countries over the period from 1995 to 2008. Major determinants for renewable energy supply are categorized as the domestic country's fundamentals for producing renewable energy and defined as economic capacity, technological infrastructure capacity, foreign investment capacity, environmental effect, nuclear energy capacity, domestic energy capacity, energy trade capacity, renewable energy capacity, domestic oil and gas capacity and oil and gas trade capacity by using Panel Data Models. The empirical evidence of base model reveals that population and FDI have negative impacts on renewable energy supply for the pooled sample. Energy intensity has a negative impact on renewable energy supply for new and candidate countries. These countries should be more sensitive in implementing energy efficiency policies. Surprisingly, results show that the high capacity of nuclear energy is an important determinant for the renewable energy supply, especially for the EU-14 countries. When the components of renewable energy supply are analyzed, empirical results show that production of hydro and solar energy have an important positive contribution in all country groups. However, the striking difference between the EU-15 and the EU-14 is the potential role of geothermal and wind energy. Their contribution on renewable energy supply is positive for the EU-15 while it is negative for the EU-14. So, new member and candidate countries should utilize their wind and geothermal energy capacities fully and efficiently. This will also lower their energy dependency on conventional fossil fuels. This study may also serve as a guideline for potential investors in exploring the opportunities in Turkey's renewable energy market.

Tez Özeti

Gökmen Sümer, “Avrupa’daki Yenilenebilir Enerji Arzının Belirteçleri: Türkiye’nin Enerji Bağımlılığı için Potansiyel Çözüm”

Enerji kaynakları, sürdürülebilir ekonomik gelişimlerin önemli bir bölümünü oluşturur. Endüstrileşmiş ekonomiler, gelişmekte olan ekonomilere oranla birim çıktı ve kişi başına daha fazla enerji kullanırlar. Bununla birlikte yükselen ekonomilerin son on yılda enerji talepleri artmış durumdadır ve önümüzdeki yirmi yılda dünya enerji gelişimini domine edecekleri beklenmektedir. Gelişmekte olan bir ekonomi olarak Türkiye’nin enerji ihtiyacı son otuz yılda önemli ölçüde artmıştır. Son on yıldaki yüksek büyüme oranı ve makroekonomik dengeler, enerji ihtiyacının artmasındaki ana unsurlar olmuşlardır. Maalesef ülkenin enerji tüketiminin %90’ından fazlasının fosil yakıtlar olmasından ve ülkenin büyük oranlarda petrol ve doğalgaz rezervlerinin bulunmamasından ötürü, Türkiye ciddi şekilde enerji bağımlısı haline gelmiştir. Buna ek olarak, çevresel kaygılar ve milli enerji güvenlik politikası da ülkenin yeni enerji kaynakları araştırmasını zorunlu hale getirmiştir. Bu durum, Türkiye’nin alternatif enerji kaynaklarını kullanması ve enerji kaynaklarındaki kullanım oranlarını değiştirmesi gerektiği sonucunu ortaya çıkarmıştır. Bu nedenle, Türkiye yenilenebilir enerji kaynaklarından yararlanmalı ve mevcut enerji karmasını değiştirmelidir.

Bu çalışmanın amacı, başta rüzgar, güneş ve jeotermal enerji olmak üzere, yenilenebilir enerji kaynaklarından enerji üretilmesini belirleyen faktörleri, AB-15 ve AB-12+2 ülkeleri açısından 1995-2008 dönemi için analiz etmektir. Yenilenebilir enerji arzının ana belirleyicileri, yerel ülkenin yenilenebilir enerji üretimindeki temel faktörlerine göre sınıflandırılmıştır. Ekonomik kapasite, teknolojik altyapı kapasitesi, yabancı yatırım kapasitesi, çevresel etki, nükleer enerji kapasitesi, yerel enerji kapasitesi, enerji ticaret kapasitesi, yenilenebilir enerji kapasitesi, yerel petrol ve doğal gaz kapasitesi ile petrol ve doğal gaz ticaret kapasitesi Panel Data Modelleri kullanılarak analiz edilmiştir. Ampirik bulgular, nüfus ve doğrudan yabancı yatırım değişkenlerinin, toplu örneklem için, yenilenebilir enerji arzı üzerinde negatif etkileri olduğunu göstermektedir. Enerji yoğunluğu da yeni üye ve aday ülkeler için yenilenebilir enerji arzında negatif etkiye sahiptir. Bu ülkeler, enerji verimliliği politikalarını uygularken daha fazla duyarlı olmalıdırlar. Şaşırtıcı olarak, bulgular nükleer enerji kapasitesinin yüksek oluşunun, özellikle AB-14 ülkeleri için, yenilenebilir enerji arzı için önemli olduğunu göstermektedir. Yenilenebilir enerji arzının bileşenleri incelendiğinde, deneysel bulgular hidro ve güneş enerjisi üretiminin tüm ülke grupları için pozitif katkı sağladığını göstermektedir. Bununla beraber, AB-15 ile AB-14 ülkeleri arasında dikkat çeken farklılık, jeotermal ve rüzgar enerjisinin potansiyel rolüdür. Bu kaynakların yenilenebilir enerji arzına katkısı, AB-15 için pozitif iken AB-14 için negatiftir. Bu yüzden, yeni üye ve aday ülkeler, rüzgar ve jeotermal kapasitelerini bütünüyle ve verimli şekilde kullanmalılardır. Böylece, AB-14 ülkelerinin geleneksel yakıtlara olan enerji bağımlılıkları azalacaktır. Bu çalışma, potansiyel yatırımcıların Türkiye’deki yenilenebilir enerji pazarındaki fırsatları keşfetmelerine bir kılavuz olarak hizmet edebilir.

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To the people who live according to their beliefs and who care about the future generations …

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CHAPTER 1

INTRODUCTION

Parallel to the technological and economical development, the energy needs of human being have increased significantly in the last century. In addition, economic growth has become highly dependent on energy. This reality brings energy dependency problems for the countries that do not have sufficient energy resources.

In the eighteenth century, right after the industrial revolution, the energy requirements of the world increased sharply and rapidly. As a result, the use and consumption of energy resources increased parallel to the increase in world population. In the 1900s, the population of the world was 1.65 billion people. However, it increased to 6.1 billion in the twentieth century. Today the world population is 6.91 billion people and continues to increase rapidly. According to the World Population to 2300 Report published by United Nations, the population of the world will reach 8.9 billion in 2050. This increase, together with technological developments, will bring a higher energy demand in the next few decades. As of 2010, the total energy consumption in the world is 12.232 mtoe. In addition to upward trend of population and energy consumption of the world, there are drastic debates on the existing reserves of traditional fossil fuels whether there is too much of these or not. Because alternative energy resources are renewable, inexhaustible and have minimum negative impacts on environment, so all those factors encourage a tendency towards alternative energy resources.

Energy, which is important in economic, political, social and environmental aspects, has become one of the most discussed issues globally. The industrialization of the world and technological developments brought a higher energy need for the entire world. However, the amounts of reserves of traditional energy resources differ from one country to another. Thus, this has resulted in major environmental concerns, serious political conflicts, unavoidable economical dependency and important social consequences.

The current traditional fossil fuels have serious negative environmental effects such as the Gulf of Mexico Tragedy (2010), an example of an oil disaster, and the explosions of Chernobyl (1986) and Fukushima (2011) nuclear power plants which are the latest but seem not to be the last environmental tragedies. The explosions of nuclear power plants, even caused by human mistake, an unpreventable national disaster or any technical problem have heavy environmental consequences. The consequences of such calamities are not just results that affect one city or even one country, but also affect many countries and generations.

The environmental consequences of Mexican Gulf Oil Tragedy and the Chernobyl Explosion make us to think twice about how non-renewable energy resources have tremendous and deep environmental impacts on our lives. The explosions in Fukushima in March 2011 forced all the countries which have nuclear plants to think about shutting down their current plants because of the possible negative consequences of any explosion may occur in their countries or even in neighbors' plants. The countries which are planning to have power plants also began to review their investment decision on the nuclear energy.

Because of the political effects of current energy resources, oil and nuclear energy also play the key roles in world political issues. The excess demand for oil brings countries together to form political collaborations. The effects of public movements in North Africa and in Middle East in 2010 and 2011, which have huge oil reserves, determine global oil prices. The countries which have influence and power in this region try to shape the future of these countries. The Iraq and Libya Wars were eventually to get control in the oil market.

The scenario is the same with nuclear energy. Since this energy can be used for producing weapons of mass destruction as was used by the U.S. in 1945 in the Second World War against Japan, nuclear energy is the most debated energy resource. The countries which make research studies or investments on nuclear energy like Iran cause global political crisis. This is because of the existing uncertainty of their final plans whether this will be used in a positive way or it will just be used for producing weapons of mass destruction.

The political effects are highly interrelated with the economic positions of the countries. The countries which consume energy heavily need to spend huge amounts of money in order to survive. On the other hand, the countries which do not have adequate energy resources import energy and this results in economic dependency for those countries. The dependent countries, whether they are developed or developing, need to find cheap, clean and continuous energy resources. Today, the energy expenditures of developed countries began to form a significant part of their total government budgets. This brings additional economic problems to those countries. For example, Turkey has a growing emerging economy together with a yearly $48.5 billion current account deficit. Since Turkey is highly dependent on the energy exporting countries, this current account deficit mainly stems from energy imports. It is very difficult for these countries to achieve sustainable development. For this reason, these countries need to find concrete solutions to decrease their energy dependency.

The consequences of negative environmental effects, the political conflicts and economic dependency in terms of energy have a deep, serious and harmful impact on people's lives. When the situation is considered from a social perspective, it can unfortunately be concluded that environmental disasters make people lose their lives, homes, jobs and catch permanent diseases which affect future generation; the political conflicts cause the deaths of thousands of innocent people, the life standards of people decrease as a result of economic crisis. Today, people are more educated and more aware of the issues that threaten their lives and futures. This makes people establish non-governmental organizations in order to protect and secure themselves and their futures against these menaces.

The existing situation and the future estimations for energy requirements make people find alternative energy resources. Moreover, current and future possible environmental, economical, political and social negative consequences briefly explained above also force the countries to incline towards to renewable energy resources. In this respect, renewable energy has become the answer for this existing and future problem. In fact, the trend to renewable energy is not just about the supply-demand issue. It is obvious that traditional fossil fuels cause environmental, economic, social and political problems and negative effects for the whole world. Those problems have become more and more dangerous for the entire world. Since renewable energy is clean and safe, it is also a solution to prevent or minimize all the problems related to those current energy resources.

Today Germany, Japan, China, the U.K., the U.S., and Spain produce energy from sun, wind, water, even from waste. In the U.S., the laws, codes and regulations in many industries were changed in accordance with this energy use. For example, the USGBC, the United States Green Building Council accreditates construction companies by providing the LEED certificates, Leadership in Energy and Environmental Design. Re-using the rainwater for landscape, using the solar panels to produce electricity of the building or for heating purposes are just a few examples of renewable energy use in construction industry. The BREEAM certificate is the same kind of certificate that is given in the Europe. Germany, when compared to some Mediterranean countries like Turkey, has almost half of the sunny days in a year. In contrast to this fact, Germany benefits from solar energy as 2000 times more than Turkey does in terms of cumulative installed photovoltaic capacity.

Turkey, a highly energy dependent country on imported traditional fossil fuels such as oil and natural gas, has a huge capacity to use its renewable resources. Turkey has experienced significant economic development in the last 10 years. In addition to being defined as a successful country because of being less affected from the 2008 crisis, Turkey also performed better than other European countries during the crisis period. Furthermore, Turkey also has a strong political influence in the Middle East. All those indicators show that Turkey has to solve its energy dependency if she wills to become an important country in the area of international trade.

This study will emphasize the critical role of renewable energy resources in decreasing countries' energy dependency, maintaining their energy security, minimizing the environmental cost of traditional fossil fuels and providing social and politic benefits. In the second chapter, the role of energy trade in Turkey's macroeconomic balances and Turkey's energy dependency will be investigated specifically. A general outlook to global renewable energy production, renewable energy resources' share in total primary energy supply and in electricity generation and the recent developments in the global renewable energy technologies will be presented in the third chapter. The third chapter will also focus on the wind energy, solar energy and geothermal energy not only in a global level but also for the European Union specifically. The fourth chapter provides a general outlook on the renewable energy resources in Turkey. While the historic trend and current situation of wind energy, solar energy and geothermal energy markets in Turkey will be assessed, the recent governmental and private sector based developments in the Turkish renewable energy market will be presented in the fourth chapter. The existing literature on renewable energy and renewable energy resources in Turkey is presented in the fifth chapter. The sixth chapter will implement Panel Data Models to determine the factors affecting renewable energy supply in selected countries. Chapter 6 will also compose the empirical findings and discussion. The last chapter will present conclusion and policy recommendations.

This study aims to bring a different perspective to the Turkish energy market and contribute a long-term solution-based permanent approach to traditional fossil fuel related economic, environmental, politic and social problems of the countries like Turkey. This study may serve as a roadmap not only for the local and foreign investors in deciding to enter Turkey's renewable energy market but also for the government in implementing accurate energy strategies and policies at the appropriate time.

CHAPTER 2

ROLE OF ENERGY TRADE IN TURKEY'S MACROECONOMIC BALANCES AND TURKEY'S ENERGY DEPENDENCY

With the liberalization process in the 1980s and 1990s, Turkey's energy and electricity demand increased rapidly. While Turkey's total final energy consumption accounted for nearly 39 mtoe in 1990, this amounted to 72 mtoe in 2008. On the other hand, total primary energy supply increased from 53 mtoe in 1990 to 100 mtoe in 2008. Parallel to the sharp upward trend the energy sector experienced, electricity consumption and generation skyrocketed. The volume of total final electricity consumption was 44,952 GWh in 1990 and it increased to 159,267 GWh in 2008. In order to meet this demand, the total gross electricity generation also experienced more than a threefold increase and accounted for 198,418 GWh in 2008. Due to the strong and steady economic growth and social welfare increase Turkey has experienced starting from 2002, primary energy consumption and electricity consumption have increased by 36% and 49%, respectively within last 6 years. In addition to these, it is expected that Turkey will experience an average of 4% to 6% of economic growth rates for the next decade. According to the study report on long term electricity demand of Turkey prepared by the Turkish Electricity Transmission Company (2008), Turkey's electricity demand will increase 6.5% annually in low demand forecast and 7,5% in base demand forecast scenarios. Demand for electricity in the country will vary between 362,975 GWh and 390,559 GWh in 2017.

These raising trends both in energy and electricity demand may seem to be natural needs and also the outcomes of the country's intensive economic and social development. Without a doubt, since the use of energy has always been the catalyst of development for countries, there is a solid connection between development and energy needs. However, when it comes to the total production, import and export volumes of traditional fossil fuels, the situation changes in a negative way and makes the country energy dependent.

Traditional fossil fuels have the biggest shares in the country's energy mix. Turkey's primary energy supply was 106 mtoe in 2009. While coal, fuel wood, lignite and animal waste formed more than 35% of TPES, the shares of natural gas and petroleum were 30,8% and 28,7%, respectively. Similar to the trend in energy supply, it is expected that the share of natural gas in total electricity production increased from 17,7% in 1990 to 48% in 2009. Natural gas, which is almost fully imported, creates an additional burden for the Turkish economy. As internal fuels, lignite with 21,4% and hydro with 18,6% have higher shares than petroleum in electricity generation. However, contribution of new renewable energies such as wind, solar and geothermal to the total electricity generation remains insignificant.

Turkey is unlikely to benefit from her internal oil and gas supply due to the weak reserve position in both resources. According to the Turkey Oil & Gas Report (2010), oil reserves, estimated at 265 million barrels in 2009 seem to dwindle to 226 million barrels by 2014. Even though it is expected that gas reserves at 6 billion cubic meters in 2009 will rise to 10 bcm by 2013, Turkey's oil and natural gas productions remain limited.

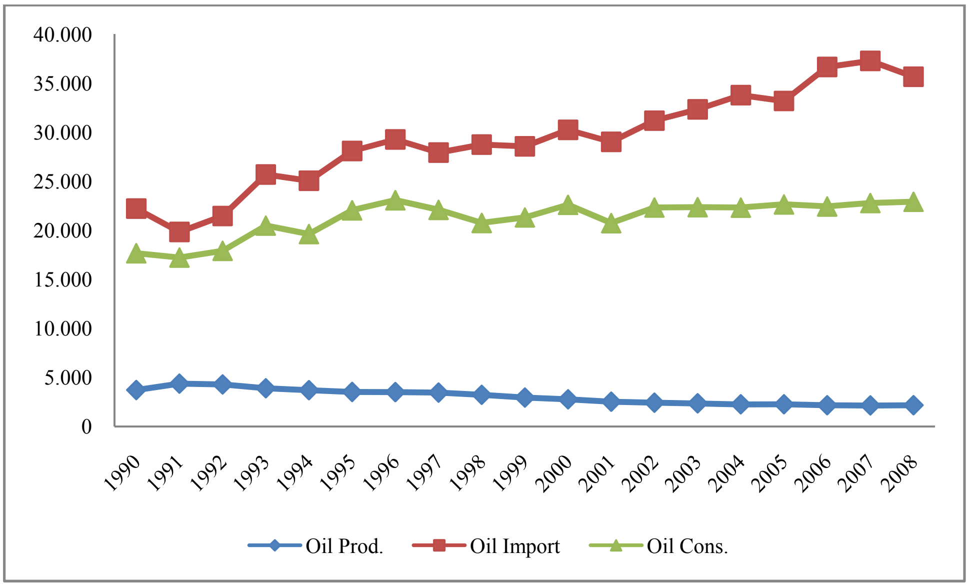


Figure 1. Turkey's oil production, consumption and import volumes in toe (Eurostat, 2010)

Figure above depicts the problematic situation of petroleum trade of the country. During the last two decades, Turkey's oil production remained under 5,000 toe levels. Since Turkey's production could not meet the oil consumption of the country, an upward trend in oil import is apparent especially after 2001. The volume of oil consumption reached 20,000 toe levels and oil import volume was around 35,000 toe by the end of 2008. Turkey's oil dependence ratio for 2008 is around 93%, making Turkey vulnerable to the OPEC region and external oil shocks. The price of crude oil increased gradually especially in the last decade. Therefore, Turkey has to pay more for the same amount of oil, resulting in huge trade and current account deficits.

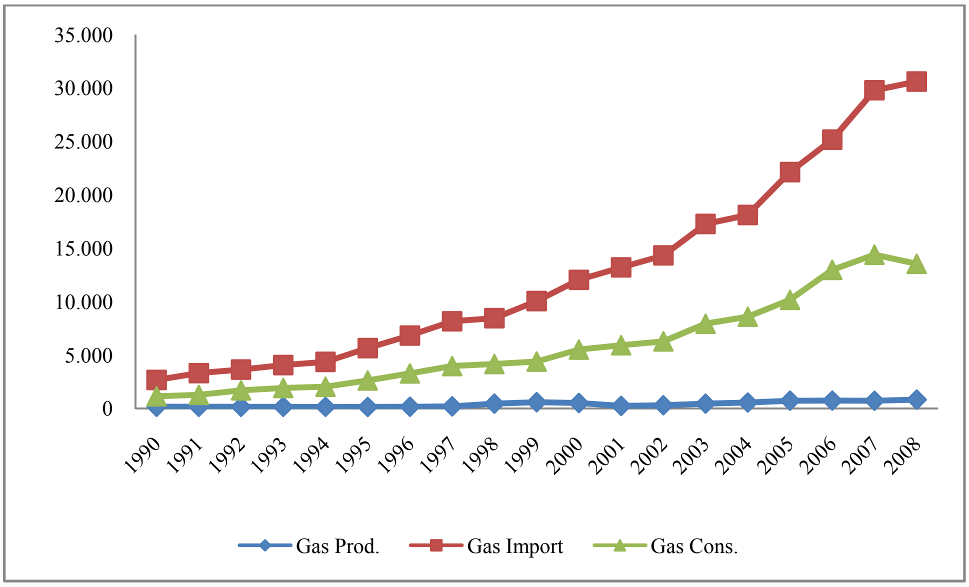


Figure 2. Turkey's natural gas production, consumption and import volumes in toe (Eurostat, 2010)

After 2000, Turkey started to rely on natural gas. Consequently, the share of natural gas in electricity mix increased. Since natural gas is much cleaner and less harmful compared to the other fossil fuels such as oil and coal, it may seem natural to rely on natural gas if the country has adequate reserves. Turkey has increased the amount of imported gas since 1990 whereas its production was not more than 1,000 toe. The price of natural gas also fluctuated a lot.

In addition to the negative impacts of traditional fossil fuels' price fluctuations on the Turkish economy, imbalanced or less diversified natural gas import structure is another problem for Turkey. According to the Ministry of Energy and Natural Resources (MENR), total demand for natural gas is provided by five source countries. Moreover, 2/3 of total natural gas import comes from just one country, the Russian Federation. The import value from Russia accounted for $31.3 billion in 2008, $19.5 billion in 2009 and $13.7 billion in 2010. The cost for natural gas import from Russia started to decrease due to the economic crisis and household's and industry's decreasing energy demand for the last three years. However, the negative impacts of the financial crisis on the Turkish economy began to disappear in 2011. Furthermore, the Turkish economy is expected to grow around 6% in 2011. Thus, the country's gas import based payments will continue to burden Turkey's balance of payments. Apart from Russia, Iran, Azerbaijan, Algeria and Nigeria are the other trade partners in gas. Turkey aims to limit the maximum share of the leading country in gas import with 50% by 2015 in order to diversify the importer countries in its gas portfolio.

The Turkish economy has grown significantly in the last decade. Consequently, energy and electricity demand increased year by year. Due to the inadequate fossil fuel reserves and limited energy production, the Turkish economy is dependent on imported energy resources which add a huge additional cost to the existing trade and current account deficit. Turkey chose export led growth strategy and export volume soared from $12.9 billion in 1990 to $30.8 billion in 2000 and peaked in 2008 with more than $140 billion. Since the European Union is Turkey's primary trade partner, export volume declined to $109 billion due to the global financial crisis and the debt crisis occurred in the EU.

On the other hand, the Turkish import volume which was $22.4 billion in 1990 has more than doubled in 2000 and accounted for $52.8. During the crisis of 2001 of Turkey, import value declined to $38 billion. In 2008, the import value written in Turkey's balance of payment was $193.8 billion which was record high. According to the data obtained from Central Bank of the Republic of Turkey, the balance on goods was always negative throughout the Turkish history. The reasons behind these imbalances of export-import in the structure of balance of payments of the Turkish economy can be explained as follows.

First of all, the Turkish industry and manufacturing trade sectors are strictly related to the imports of intermediate goods and inputs, especially from the

European countries. In other words, in order to produce and export more, Turkey has to import more. Secondly, Turkey's current energy mix creates an additional burden for the entire economy. Natural gas and oil import makes the Turkish economy vulnerable to the external supply and price shocks. Since Turkey does not has adequate energy policies to encourage energy generation from alternative resources, the probability of maintaining the development that Turkey currently experience is a big question. To reach the level of developed countries, Turkey continues to import energy resources. Energy export, import and trade deficit for Turkey are presented in the table below.

Table 1. Turkey's Energy Imports, Energy Exports and Energy Trade Deficit (Nenem, 2009) (TMFT, 2009)

	in 1000 USD		
Years	Energy Imports	Energy Exports	Energy Trade Deficit
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	243,85	-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	206,25	-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
2009	29,888,668	3,752,541	-26,136,127
2010	23,860,206	2,679,503	-21,180,703

It is apparent that Turkey has an unsustainable and imbalanced energy trade structure. The energy trade deficit was $4.3 billion in 1990 but increased by 10 fold and reached $40.7 billion in 2008. It is noteworthy to mention that since total energy demand run low during economic crises of 1994 and 2001, the volume of energy import has declined. The decline in import in 1998 also stemmed from the decline in energy prices. There is no doubt that that amount of imports cause the foreign trade deficit in the country's balance of payments and put a strong pressure on the economy in financing this deficit. For example, Turkey paid almost $30 billion in 2009 and $23.9 billion in 2010 for energy imports which widened the trade and current account deficits. Figure 3 shows the current account balance of Turkey.

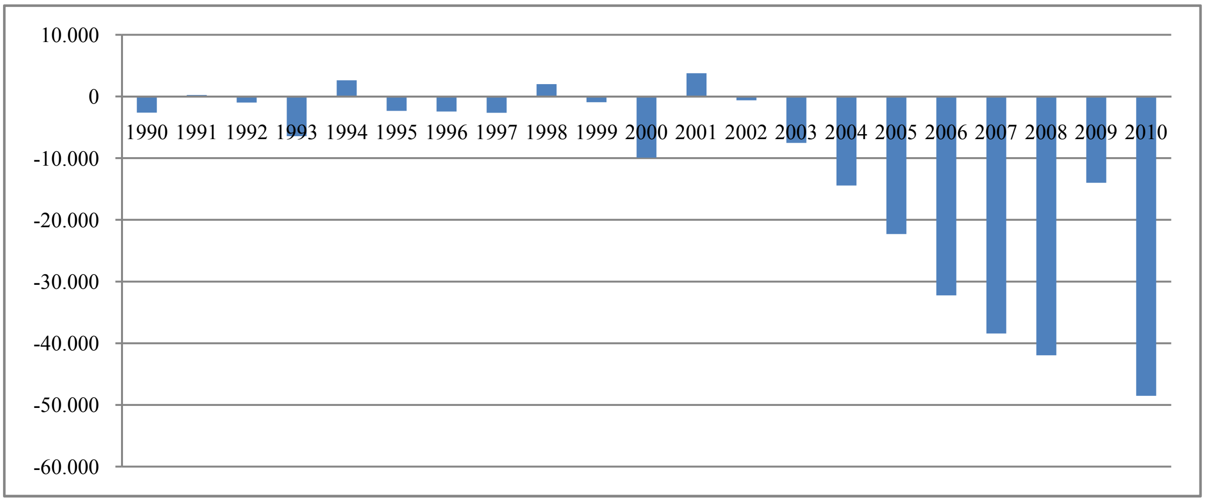


Figure 3. Turkey's current account balance in million USD (Central Bank of the Republic of Turkey, 2011)

The Turkish economy experienced current account surplus 4 times which coincided the crises periods. Current account surplus was $250 million in 1991 due to the Gulf War, $2.63 billion in 1994 and $3.76 billion in 2001 due to the financial and economic crises. Energy import volume, also increased in those years, which indicates a strong correlation between energy import and widening of current account deficit. Even though Turkey's current account deficit declined the levels of

2004 because of global crisis of 2008, it reached the record high level, $48.5 billion by the end of 2010. The share of the current account deficits in the GDP is an important indicator for economic stability. Figure 4 shows the trends of current account over GDP.

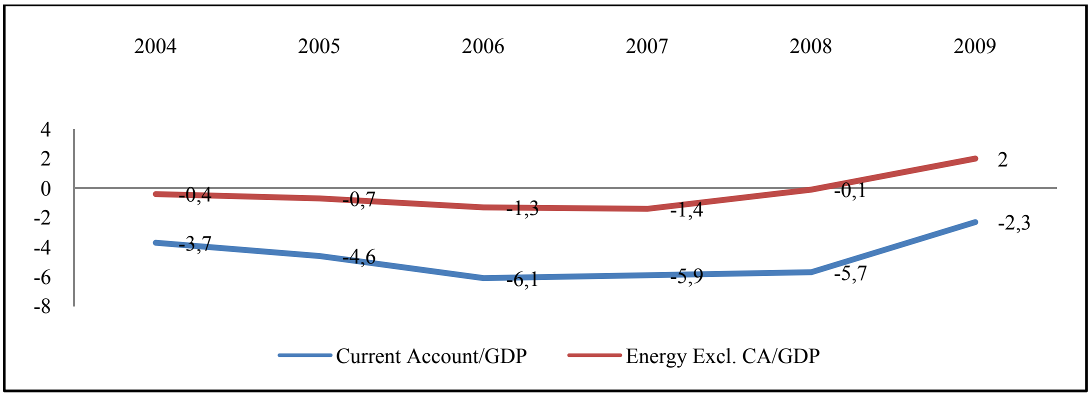


Figure 4. The ratio of current account balance over GDP (%) (Central Bank of the Republic of Turkey & Turkish Statistical Institute, 2010)

The crucial role of energy trade on current account deficit is seen clearly. Since Turkey's energy import has an overwhelming dominance on energy export, current account over GDP is always negative. Over the period of 2004-2009, current account deficit/GDP ratio varies between -3,7% and -2,3%. However, when energy import is excluded, the indicator reaches positive levels. In other words, Turkey's energy dependency burdens the Turkish economy via trade and current account deficit. Turkey is seeking for alternative tools to finance this deficit. It is obvious that Turkey has a lot of things to do in energy field, specifically.

First, Turkey has to change its current account deficit into surplus. Second, Turkey should decrease the pressure on financing of trade deficit and decrease in need for hot money. Third, Turkey should show a strong resistance to the external oil shock and other energy fluctuations. Fourth, she should provide internal energy security and has an opportunity to act more flexibly in political economy. In order to achieve all these goals, the utilization of the country's alternative energy resources is must for Turkey.

When it comes to the issue of sustainability, it is clear that Turkey's current development roadmap does not meet the criterions and requirements of sustainable development ideology. Sustainable development which aims at minimum costs on the environment, human health, animals, etc., during the development process designates the concept of sustainable energy. Renewable energy resources along with energy efficiency form sustainable energy and promise a more humanistic and environment friendly world to the next generations. As known, traditional fossil fuel based and energy related human activities under many sectors changes global climate. They also create global warming through greenhouse gases. Greenhouse gases transfer significant amounts of short wave radiation to the earth and cause the lower parts of the atmosphere to warm up by keeping in the long wave radiation which is reflected from the surface of the earth (Aksoy & Coskun, 2010). Since oil, coal and even the cleanest traditional fossil fuel, natural gas, emit carbon dioxide, carbon monoxide, nitrogen oxide, sulfur oxide and many other particulates, those old but still popular types of energy resource do a great harm to the climate, ozone, public health and world overly.

In order to achieve the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, the United Nations Framework Convention o Climate Change (UNFCCC) entered into force on March 1994. Kyoto Protocol which is an international treaty subsidiary to the UNFCCC was agreed upon in December 1997 in Kyoto, Japan and entered into force on February 2005. Kyoto itself sets quantified emission limitation or reduction targets for 38 industrialized countries and the European Community that ratify the protocol for reducing six main greenhouse gases (GHG) which are carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydro fluorocarbons and perfluorocarbons emissions by an aggregate 5.2% against 1990 levels over the five year period 2008-2012 (Goncu, 2010). Intergovernmental Panel on Climate Change (IPCC) under United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO) is another body for the assessment of climate change and green energy resources.

There are many successful countries in combining renewable energy technologies with the sustainable development process. Spain, for instance, passed Royal Decree law on May 2007 to reduce dependency on foreign imports of fossil fuels and to follow the requirements of the Kyoto Protocol to reduce emissions and develop sustainably. Germany, another successful country in renewable energy, combines the EU’s 20% renewable energy by 2020 of internal target with the external targets set by Kyoto Protocol. The country sees alternative energy technologies as primary tool to achieve both environmental and economic goals. According to a study prepared for the German Parliament in 2002 cited in Lehmann & Niederle (2006), reducing greenhouse gas emissions in the country 80% by 2050 is both technologically and economically realistic.

From the perspective of Turkey’s energy related environmental attitude, it can be seen that Turkey did not rush in signing national and international environmental agreements and setting targets for the future. Since Turkey could not complete its industrialization process and become a developed country, there is perception that the country’s greenhouse gas emissions do not pose critical problems on environment and public health. Nevertheless, since Turkey is an emerging economy, it is expected that total pollutant gas emission will increase gradually unless this traditional fossil fuels are extracted from current energy mix or replaced with renewable energy resources. Figure 5 shows that Turkey's greenhouse gas emissions in overall increase year by year.

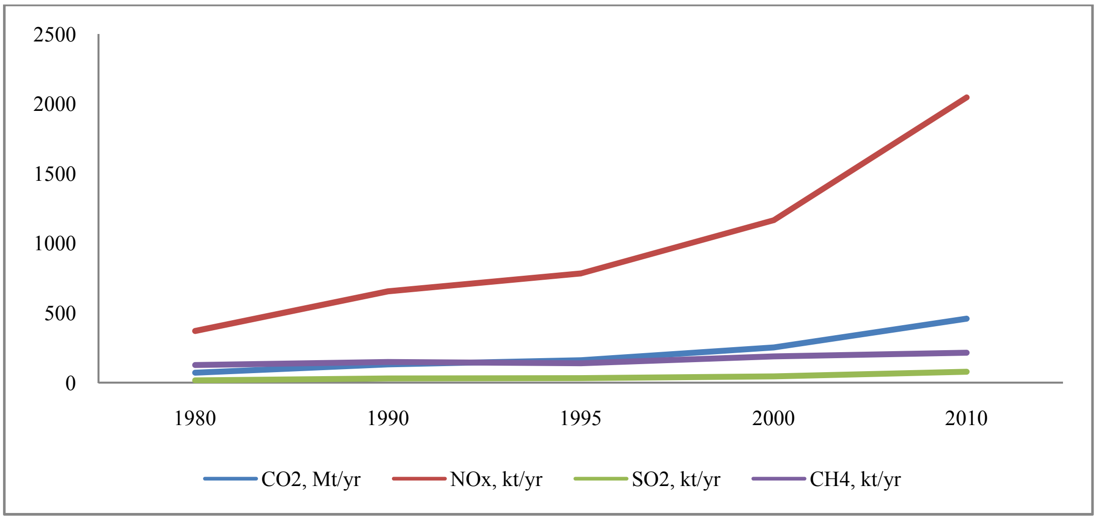


Figure 5. Major greenhouse gas emissions' trends in Turkey (Yuksel, 2009) (Ministry of Environment and Forestry, 2007)

While CO_2 emission was 73.3 million tons in 1980, this reached to 254 million tons for the year 2000 and it is forecasted to be accounted for 460 million tons in 2010. Total nitrous oxide emission which was 372 kilo tons in 1980 and 2046 kilo tons in 2010 has experienced the sharpest increase. Sulfur dioxide and methane emissions are also showing upward trend. In the light of these numbers, Turkey has included a chapter on energy and environment into the Internal 2023 Target Action Plan. Although this plan aims to develop renewable energy technologies which will be able to compete in the global energy market of the future, maintain the nation's water resources sustainably and avoid air pollution and climate change actions, the lack of tangible and specific goals within this chapter make this long term plan questionable.

Renewable energy is the main pillar for the sustainable development. Turkey has tremendous green energy resources including solar, wind and geothermal.

However, Turkey could only add hydro power into her energy mix but with respect to the new alternative energies, she performed poorly.

For environmental and social aspects, FDI may become alternative tool in transferring the leading foreign countries' all environmental and social regulations as well as financing the current account deficit.

The most obvious effect of FDI on the economic growth is being the provision of additional capital. The inflow of foreign funds can be used to deal with investment-saving gap which will provide an opportunity to grow faster without sacrificing current consumption in an emerging country. That kind of long term capital injections into the Turkish economy via FDI may ease the process of financing of current account deficit which was mainly due to the energy import. Financial account under capital account in balance of payments may improve and narrow the gap between current and capital account. Bi-directional positive effect of FDI in renewable energy market on balance of payments may be seen:

First of all, Turkey will start using from its enormous green energy potential which will lead decrease in energy import. Consequently, Turkey will pay less for energy import and this will improve the current account deficit of the country. Secondly, the inflow of foreign fund to the Turkish economy will lower the dependency on portfolio investments. In addition, many job opportunities in renewable energy will be created.

FDI may also help to tackle bottlenecks in the renewable energy industry. High start up costs, difficulties in financing the green energy projects, uncertainties about renewable energy market and inadequate renewable energy policies are the main obstacles.

Until now, Turkish policy makers in energy industry assumed only hydro power as an alternative energy resource. They totally ignored new renewables such as wind, solar and geothermal energy. Therefore, Turkey could not develop technologies in alternative energy sector. FDI may be an appropriate solution for transferring technology and know-how from experienced companies in leading green countries in the short run. Although there are much disagreements between many researchers on whether there is a direct and strong correlation between FDI and economic growth, majority of studies in the literature defends that technology diffusion or technological innovation, human resource development and social progress can be achieved by transferring experienced developed countries' know how to the less developed or emerging countries via FDI. According to Deutsche Bundesbank's FDI report (2003), by supplying new state of the art technology and by training the local employees, the foreign investor can initiate a spillover process where local firms will eventually adapt and implement the superior technology. This situation will raise productivity and boost economic growth additionally. A study presented by Watson et al. (2000) cited in Peterson (2007) concludes that international companies are already engaged in the transfer of cleaner coal technologies and skills to Chinese enterprises through FDI and some joint venture agreements. It can also be concluded that FDI may play a substantial role in the diffusion of energy savings and clean energy technologies to developing countries such as Turkey. If these technological innovations, know how experiences and management techniques that European and developed countries already have can be transferred to the Turkish renewable energy market, then domestic resources would not have to be spent by enterprises on either undertaking their own research and development (R&D) or on importing the required technology.

Turkey introduced the first law on renewable energy resources, Law No.5346 "Concerning the Use of Renewable Energy Resources for the Generation of Electrical Energy" on 18 May 2005. This delayed action shows that Turkey squandered too much time to establish that particular law. Few foreign companies entered the Turkish renewable energy market with Turkish energy companies. Unfortunately, the law of 2005 was very poor and the expected interest in green market could not be observed. In order to attract more investors, Turkey's parliament approved a law on regulating the renewable energy resources market in the country by the end of 2010. It should be understood that there is a reciprocal relation between foreign direct investors and policy makers in host countries. Those foreign companies are coming from the states where the governments are supporting alternative energy market and the companies well enough via sufficient incentives and feed in tariffs. Those governments have built strong and close relationships with the renewable energy firms. Therefore, the foreign firms' investment decision in Turkey is strictly related to the policies, tariffs, supports and tax rates Turkey has. In order to attract not only foreign investors but also local firms into the Turkish renewable energy market, taking the alternative energy policy leader countries as a role model is must.

Many countries in all over the world led by Germany, Spain, the United States, China and Brazil did realize the significance of renewables within their economic, environment and political elbow rooms. Those countries developed not only effective policies but also many innovative renewable energy technologies. By the helping of attractive incentives and government supports, local and global investors increased their attention on those countries' renewable energy resources and heavily invested in those countries. This trend followed by technological improvements resulted in a decrease in the high start up cost of investments made in alternative energy industries. The price of renewable energy based electricity also decreases.

It would be beneficial to present the most important types of policies with their home countries that have promoted renewable energy resources.

After the oil crisis of 1973, president Carter of the United States signed the Public Utility Regulation Policies Act of 1978 (PURPA) which required utilities to purchase power from small renewable generators. PURPA gave birth to the renewable energy industry globally. Germany, the leading country in global renewable energy market, set a fixed price for utility purchases of renewable energy called feed in laws in 1990. Renewable energy producers could sell their power to utilities at 90% of the retail market price during 1990s. The Renewable Energy Sources Act (RESA or EEG) came into force in 2000 and this law focused on grid connection, grid access and power dispatch matters. In fact, feed in tariff is a rate structure pays consumers to produce electricity, rather than charging them to use it. It is very crucial for the investors in renewable energy market because it guarantees a purchase price for that energy for an extended period. The most important feature of feed in tariff is that the payment is pegged to the particular alternative technology used, whether wind, geothermal or solar. For example, the tariff for power generated by offshore windmills is higher than that paid for electricity coming from onshore wind turbines in Germany. Another specification is made for solar power itself. Small rooftop solar installations earn 43,01 Euro cents per kilowatt hour, while large ground solar operations receive only 31,94 Euro cents per kWh in Germany.

On the other hand, the weakness of the Turkish renewable law of 2005 can be assessed because there were not any distinctions for each renewable energy technologies in that law. The market players think that the wholesale price of power is not sufficient for reaching commercial viability even at the windiest and sunniest available sites (Ergun & Ozturk, 2005). When Turkey's relatively higher cost of financing compared to West European countries' financing cost is taken into account, inadequacy of the law 2005 will be felt deeply. Although new renewable law of Turkey aims to specify renewable energy resources and guarantees different prices for each technology, there is much criticism about this. For instance, it is said that the law brings limitations to renewable energy production by limiting the total production of licensed solar energy companies to 600MW annually until the end of 2013 and authorizing the cabinet to determine the limits afterwards. Another concern about the law is about local equipment use incentives. According to law, if the companies use local equipment and technology in renewable energy facilities, then additional support will be provided for a five year term to companies that started producing energy before the end of 2015. However, many researchers note that the support in this law is too low to encourage usage of local equipment. In order to cost saving, some old and unproductive equipment could be imported which will decrease the projects' life and productivity.

Other successful countries are Spain and Denmark. Both countries proved that encouraging the production of renewable energy through feed in tariffs does not always drive up costs. In those countries, feed in tariffs reduced the costs of power from wind because the price is not subject to inflation or to the ups and downs of the global oil and natural gas markets. The total amount of renewable energy resources support has increased more than threefold from €1.740 million in 2004 to

€5.702 million in 2008 in Spain. Along with policies, another impressive tool in renewable energy promotion is setting realistic and ambitious targets. Spain's goal in its Renewable Energy Plan was to cover 12% of the total energy consumption with green energy resources by the year 2010. To achieve this target, Spain has nearly doubled its wind capacity and increased its solar capacity by 70 fold within the years between 2005-2009. Germany, for instance, which has derived only 6,3% of its electricity from renewable energy resources by 2000 and satisfied its 2010 target of 12,5% at the end of 2007, has a national target for 20% of electricity to be generated from renewables by 2020. Moreover, Germany is willing to increase the numbers of job creation in green energy sector from 170,000 in 2005 to 300,000 in 2020.

Apart from feed in tariffs, many countries including the U.K., Sweden, Italy, Belgium and several states of the United States have used tradable green certificates (TGC). TGC or green tags are certificates issued for every MWh of renewable energy resources based electricity, allowing generators to obtain additional revenue to the sale of electricity. The quota, penalty values and the duration of the obligation are the main factors of TGC system. However, this policy has been criticized due to the volatile TGC prices and high risk premium based ineffectiveness. According to the study on the effectiveness of the policies which is defined as the ratio of the change of renewable energy electricity production potential within one year and the remaining technical potential of renewable energy until 2020, (Lehmann & Niederle , 2006) policies based on quotas in general provide a relatively high profit but rather low effectiveness. Feed in tariffs; by contrast, provide lower profits but high effectiveness. The reason behind this outcome is that high risk associated with the prices of green tags in the cap and trade system versus the investment security of a long term guaranteed feed in tariff. However, green certificate trading which provides trading renewable energy production and consumption credits is gaining momentum in the United States, Belgium and Australia. Parallel to this, many emissions reduction policies create allowances for certain gas emissions such as NO_x, SO_x and CO_2.

Tendering/bidding system in which generators compete for either a certain financial budget or a certain capacity of renewable energy resources based electricity generation is another policy tool but it has only been used in France, the U.K. and Ireland for a while. It is noteworthy to conclude that European countries led by Germany and Spain are the most experienced countries in terms of policies, cumulative installations and government supports.

Financing renewable energy projects is another problem. Due to the less developed structure of private equity companies, venture capital firms and investment banks, there are challenging barriers in the Turkish renewable energy market which forces local investors to think twice before taking an investment decision. In addition to these, since incentives, price guarantees and legal framework are immature and insufficient, there are important question marks both in financiers and groups need to be financed. Results of the interviews made with managers of banks and other financial institutions in Turkey reveal that they were suspicious about the future of the projects they finance and the financed firms' ability to repay their credits. However, after World Bank, International Bank for Reconstruction and Development and European Bank for Reconstruction and Development's increasing loan flow to the Turkish renewable energy market starting from 2009, Turkish banks started to finance green energy projects. On the other hand, when the main source of the loans provided by Turkish banks is investigated in detail, it can be seen that European Bank for Reconstruction and Development with European Investment Bank are the real financiers of the Turkish renewable energy projects. In other words, those two European banks have launched the mid-size Sustainable Energy Financing Facility to support Turkey's renewable energy and energy efficiency investments by planning to provide €400 million loans to Turkish banks.

Due to the fact that the European Union is the main financier of Turkish renewable energy projects and the many other elements such as existing strong trade and investment partnership of the EU and Turkey, intensive political interaction and close geopolitical position between the EU and Turkey, if investment decision in the Turkish renewable energy market will be taken by foreign companies, the probability of making an investment by European energy firms from the European Union seem to be higher. This is one of the main reasons why this study includes member and the candidate countries of the European Union. Thus, this study aims to explain the factors affecting the countries' renewable energy supply by comparing Turkey and the European countries. Having said that, presenting how the EU and Turkey are dependent and interconnected to each other will help to understand the main dimensions behind the selection of the EU as probable target foreign direct investor country region.

It is obvious that Turkey has to attract more European investors into her renewable energy market if she has desire to promote her huge green energy potential. According to the data obtained from International Investors Association (YASED), in the beginning, energy industry in Turkey as a whole could not receive the government support that sector requires.

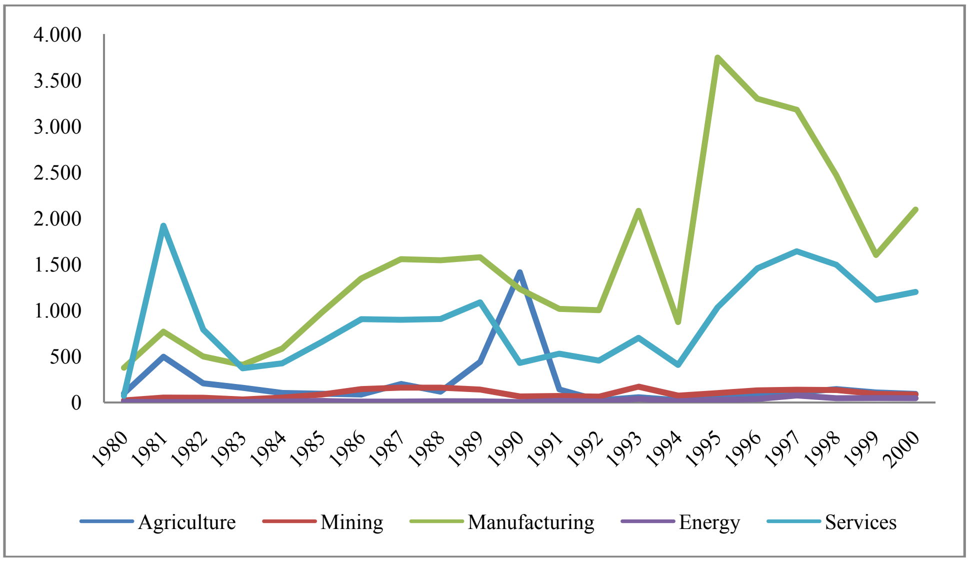


Figure 6. Number of investment incentive certificates by years (YASED, 2011)

Sector Specific Classification of Investment Incentive Certificates Report shows that the number of certificates in energy sector was only 6 in 1980. Although this number had increased to 108 by the end of 2008, it is still relatively low compared to mining, manufacturing and services sectors in Turkey. While manufacturing receives more than 1,100 certificates in 2008, services sector ranks second with almost 500 certificates. Mining with 144 certificates follows services. Agriculture ranks in the last spot right after energy sector.

This trend is the same, even worse for the energy sector, in terms of employment numbers in each sector.

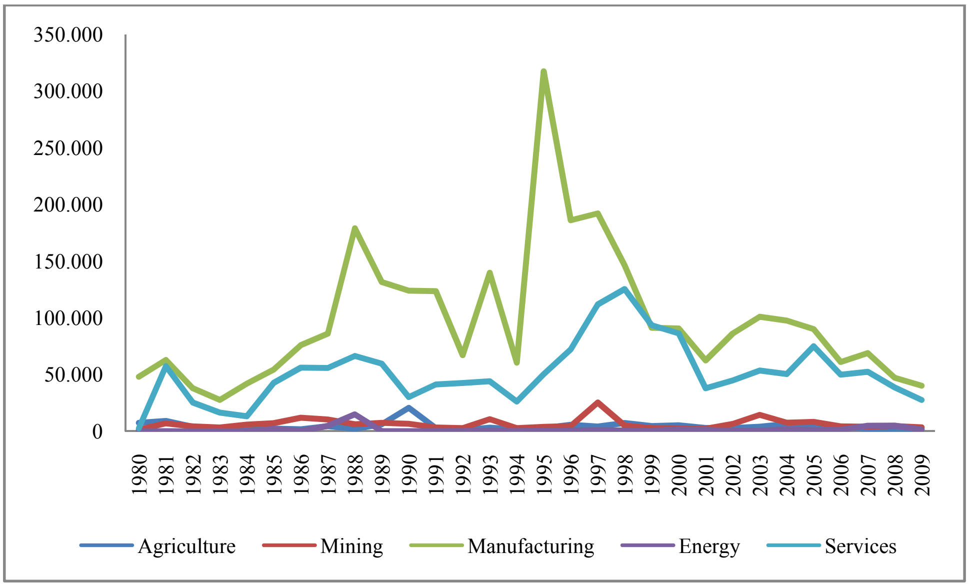


Figure 7. The numbers of employment in specific sectors by years (YASED, 2011)

While the number of energy industry's job creation was only 12 in 1980, this reached 5.000 jobs in 2008. However, energy sector has ranked in the last spot after mining, manufacturing, services and even agriculture. While manufacturing is well ahead with more than 47,000 people, services, mining and agriculture follow manufacturing sector, respectively.

On the other hand, the foreign investment value in energy started to increase in the last decade.

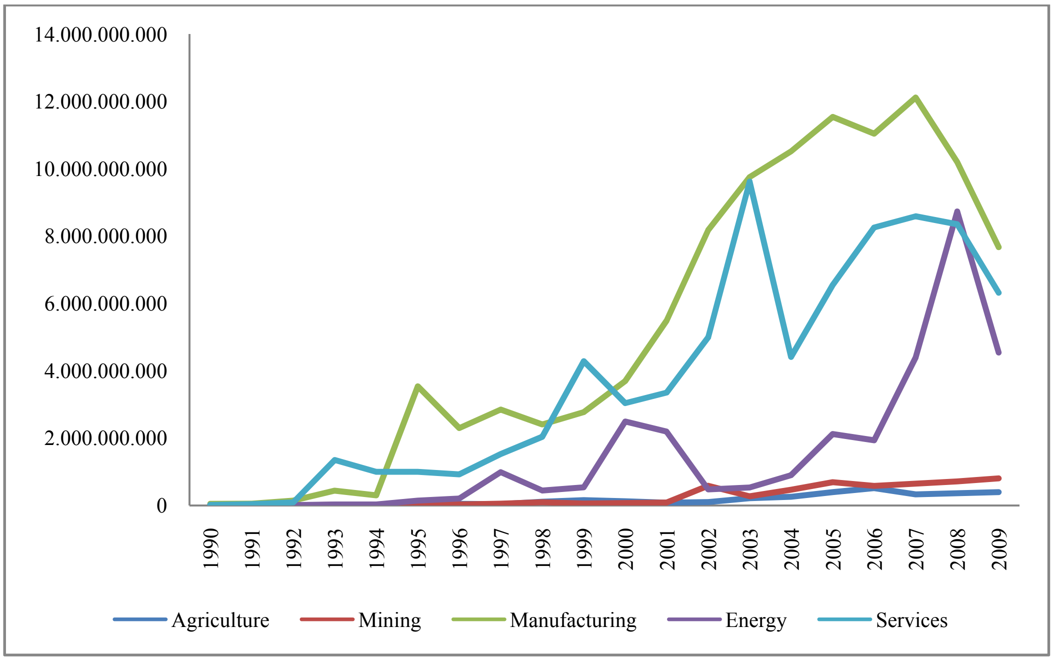


Figure 8. The volume of foreign direct investment inflow to the main sectors in Turkey in Turkish Liras (YASED, 2011)

The total investment volume was only 365 Turkish Liras in 1980. It increased to 2.1 billion Turkish Liras in 2001. Although the value of foreign direct investment in Turkey decreased sharply due to the economic crisis of 2001, it accounted for 2.1 billion Turkish Liras which was the level of the pre-crisis of 2001. This number reached 8.7 billion Turkish Liras corresponding to 31% of total FDI inflow in 2008. Manufacturing and services are the leading sectors in welcoming FDI by the end of 2009. Mining and agriculture follow the energy sector. Since the global financial crisis has occurred in 2008, the impact of this economic trouble is felt in each sector of Turkey. For instance, the value of inward FDI in the energy sector was 8.7 billion Turkish Liras. It decreased to 4.5 billion Turkish Liras in 2009. However, it is expected that the FDI inflow to the energy sector in Turkey will improve in the short and medium run.

In sum, Turkey with its increasing population has a growing economy and the development phase that she already in makes her more energy demanding country. Since energy consumption rate of Turkey is one of the highest rates in the world, the country has to meet this energy demand to maintain her social and industrial development process as much as possible. However, Turkey has inadequate traditional fossil fuels such as oil and natural gas and has no any nuclear power station yet to supply required energy by internal resources; thus, Turkey heavily relies on external energy resources. Increasing share of imported fuels in energy and electricity production and imbalanced energy import structure cause trade deficit in the country's balance of payments and Turkey is being forced to finance this current account deficit. Moreover, this situation makes the country vulnerable to the external energy price and supply shocks and naturally limits the political freedom of the country.

Apart from economic and politic issues, there are also environmental aspects of the problem. Since Turkey has participated in the United Nations Framework Convention on Climate Change by ratifying an agreement to sign the Kyoto Protocol on February 2009, Turkey has to control her greenhouse gas emissions. As cited earlier, concept of sustainable development and environmental agreements such as Kyoto Protocol point out the role of renewable energy and energy efficiency in achieving sustainable energy supply. Undoubtedly, whether economic, environmental or politic, there is no way to reach external targets set by UNFCCC or the EU and internal targets set by Ministry of Energy and Natural Resources (MENR) or State Planning Organization (SPO) through current energy strategy and energy portfolio. Increasing renewable energy production and adding alternative energy resources into the country's energy mix should be defined as primary goals of Turkish governments, peoples, non-governmental organizations (NGOs) and all kind of groups in the short, medium and long run. In order to achieve these goals, assessment of elements that may affect renewable energy supply and the success of utilization of renewable energy resources should be made deeply. Before focusing on Turkey's renewable energy market, in order to form the basis of renewable energy resources, the global renewable energy markets and sub alternative energy resources of the world will be presented in the next chapter.

CHAPTER 3

GLOBAL RENEWABLE ENERGY OUTLOOK

This chapter provides an insight regarding global trends in renewable energy market and demonstrates how global developments in renewable energy industry impacted each renewable energy sources. In this section, the general outlook of each renewable energy resources' production, their shares in TPES and in electricity generation and their trends will be presented for the world, OECD and especially for the EU. While first section will focus on the world wind energy market, the following sections of this chapter will emphasize the importance of solar energy and geothermal energy. The data of this section is obtained from International Energy Agency's IEA Statistics Renewables Information and REN21 Renewables Global Status Report published in 2010.

Global Renewable Energy Outlook

In 2008, global renewable energy sources accounted for 1,567 Mtoe, 12.8% of the world total primary energy supply (TPES) which was 12,026 Mtoe. The share of other energy sources in TPES in 2008 were as follows: 33.1% oil, 27% coal, 21.1% natural gas and 5.8% nuclear energy. Figure 9 shows the shares of the RER in global renewables supply in 2008 as follows:

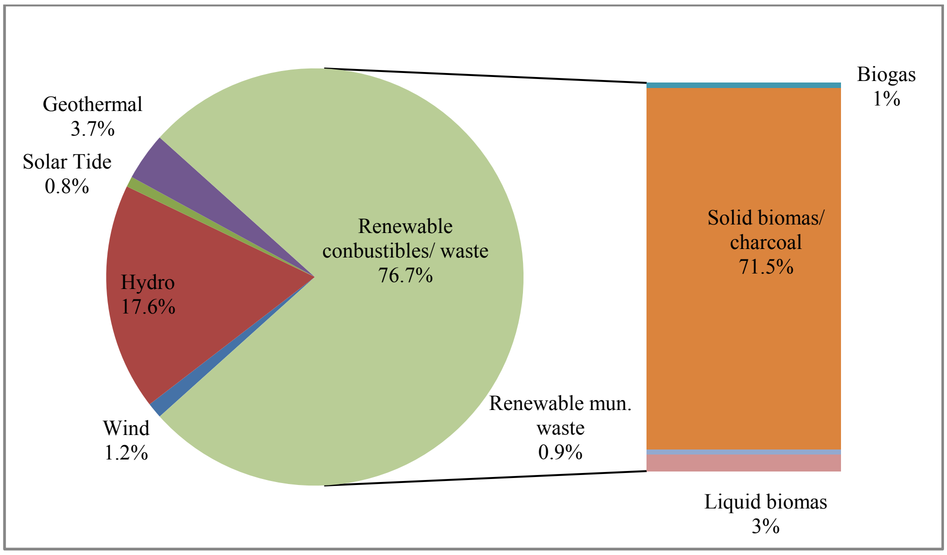


Figure 9. Product shares in world renewable energy supply, 2008 (IEA, 2010)

As shown, solid biomass is the largest renewable energy source, representing 9.1% of world TPES or 71.5% of world renewables supply. While hydro power is the second largest source with 17.6% of renewables, geothermal follows hydro with a share of 3.7% in renewables. When it comes to the share of the newest renewables which are solar, wind and tide, the contribution of these resources remained limited with 2.0% of renewables supply or only 0.3% of world TPES.

When the historical development of RER is observed since 1990, RER has grown at an average annual rate of 1.9 %, which is equal to the world TPES growth rate. In figure 10, annual growth rates of world renewables supply from 1990 to 2008 is presented.

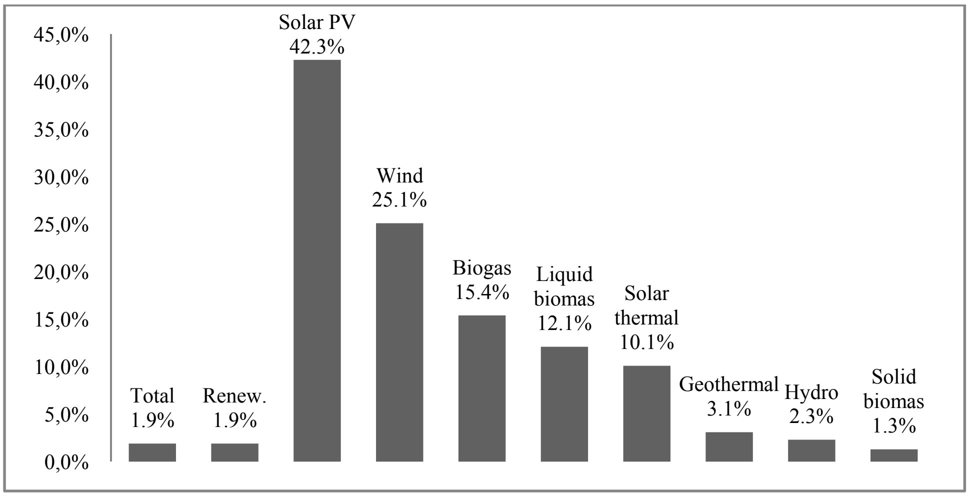


Figure 10. Annual growth rates of world renewables supply from 1990 to 2008 (IEA, 2010)

Solar photovoltaics and wind power experienced the highest growth with annual rates of 42% and 25%, respectively due to their low bases in 1990, as the production still remains. Within narrower focus, global renewable energy capacity grew at rates of 10-60 per cent annually for many technologies during five-year period from the end of 2004 through 2009. Figure 11 shows the average annual growth rates of each renewables capacity from 2004 to 2009.

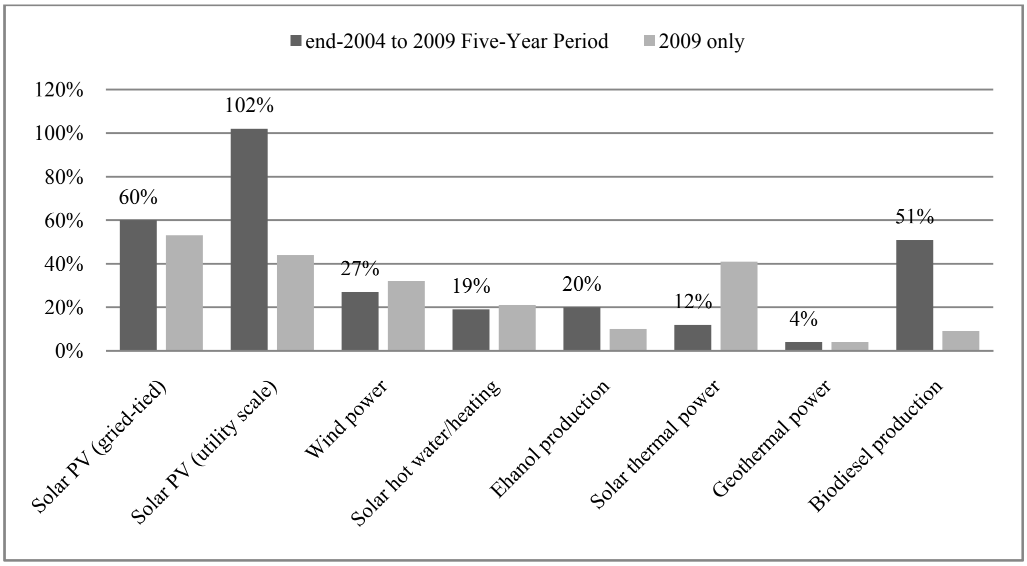


Figure 11. Average annual growth rates of renewable energy capacity, end-2004 to 2009 (REN21, 2010)

By the help of technological developments, for many renewable technologies, growth accelerated in 2009 relative to the previous four years. For example, more wind power capacity was added during 2009 than any other renewable technology. However, grid connected solar PV experienced 60% of annual average growth rate for the five year period, while biofuels grew rapidly, at a 20% growth for ethanol and a 51% for biodiesel. At that point, it should be added that solid biomass, which is the largest contributor to RE in the world, has began to experience slow growth rate because of increasing concerns about its impacts on environment.

Another important point is that there is a strong connection between the development level of the countries and the energy sources they use. Thus, we can group the countries as OECD and non-OECD countries. The largest share of solid biomass, 86.5%, is produced and consumed in non-OECD countries. Because of their non commercial use of biomass, non-OECD countries are the leading renewable energy users, accounting for 76% of world total renewables supply. It is interesting that the hydro electricity generation of non-OECD countries has exceeded that of OCED countries since 2001. In 2008, the share of non-OECD countries reached 59.1%. Per contra, while OECD countries supply only 24% of world renewables, they constitute 44.2% of the world TPES. Table below shows the total primary energy supply and share of renewables in TPES.

Table 2. Shares of Renewables of Regional Total Primary Energy Supply in 2008 (IEA, 2010)

	TPES	Of which: renewables	Share of renewables in TPES	Share of main fuel categories in total renewables%		
	Mtoe	Mtoe	(%)	Hydro	Geothermal, Solar, Wide, Tide	Renewable combustibles/Waste
Africa	655.4	323.6	49.4	2.5	0.4	97.1
Latin America	570.1	175.6	30.8	33.0	1.7	65.3
Asia	1414.2	388.7	27.5	5.5	6.4	88.1
China	2130.6	260.3	12.2	19.3	2.5	78.1
Non-OECD Europe	106.7	11.2	10.5	36.9	1.4	61.7
Fomer Soviet Union	1038.2	29.3	2.8	69.4	1.5	29.1

Middle East	591.8	3.2	0.5	23.8	37.7	38.5
OECD	5422.4	375.3	5.9	30.1	13.8	56.1
World Marine & Aviation Bunkers	334.8	-	-	-	-	-
World	12264.2	1567.2				

In OECD countries, the share of renewables in total energy supply is only 5.9% compared to 49.4% in Africa, 30.8% in Latin America and 27.5% in Asia. China as a region accounts for 12.2% in 2008. The share of renewable energy resources in total primary energy supply in Non-OECD Europe is 10.5%. Due to the abundant traditional fossil fuel reserves they have, this figure was only 0.5% for Middle East region. The breakdown of renewable energy resources is presented below.

Table 3. Primary Energy Supply from Renewable Sources in 2008 (IEA, 2010)

	Hydro	Wind	Solar/tide	Geo-thermal	RCW	Non-RCW	Total
OECD Total	112869.9	16160.1	4942.8	30632.7	210665.3	18793.3	375270.9
OECD North America	58339.0	5141.4	1839.6	15146.9	99391.8	5736.8	179858.8
OECD /IEA Pacific	9763.6	692.9	932.8	5143.5	13431.6	3098.4	29964.3
	Hydro	Wind	Solar/tide	Geo-thermal	RCW	Non-RCW	Total
OECD Europe	44767.3	10325.8	2170.4	10343.4	97841.9	9958.2	165447.8
IEA Total	108431.9	16137.0	4808.7	21284.5	202424.8	18791.5	353086.8
IEA North America	54969.7	5118.3	1705.5	9081.0	91153.5	5736.8	162028.0
IEA Europe	43698.6	10325.8	2170.4	7060.0	97839.7	9956.3	161094.5
Non-OECD Total	163006.6	2631.3	7167.3	27758.3	991334.9	4018.5	1191898.4
World	275876.6	18791.3	12110.1	58391.0	1202000.2	22811.9	1567169.2

In contrast to the non-OECD countries, the share of new renewables including wind, solar and tide of the OECD countries is too high with 68.3% of world renewable energy supply. The OECD counties' wind energy supply in total wind energy generation accounts approximately 86%, while solar and tide's share is 41% in total solar energy production.

In order to analyze the renewable energy based electricity generation, the main markets that renewable energy replaces conventional fuels should be mentioned. These distinct markets are power generation, hot water and space heating, transport fuels, and rural (off grid) energy services. Before presenting the situation of each market detailed, world sector specific consumption of renewables will be discussed.

At a global level, majority of renewables is consumed in the residential, commercial and public services sectors. While about half of the renewable primary energy supply in OECD countries is used in the transformation sector to generate electricity and sold heat, only 26.8% of renewables are used for electricity production and heat production worldwide and 54.1% are used in residential, commercial and public sectors. Transport and industry sectors constitute the rest of the share (IEA, 2010)

When it comes to the global electricity production, as it is shown in figure12, renewables are the third largest contributor to global electricity production.

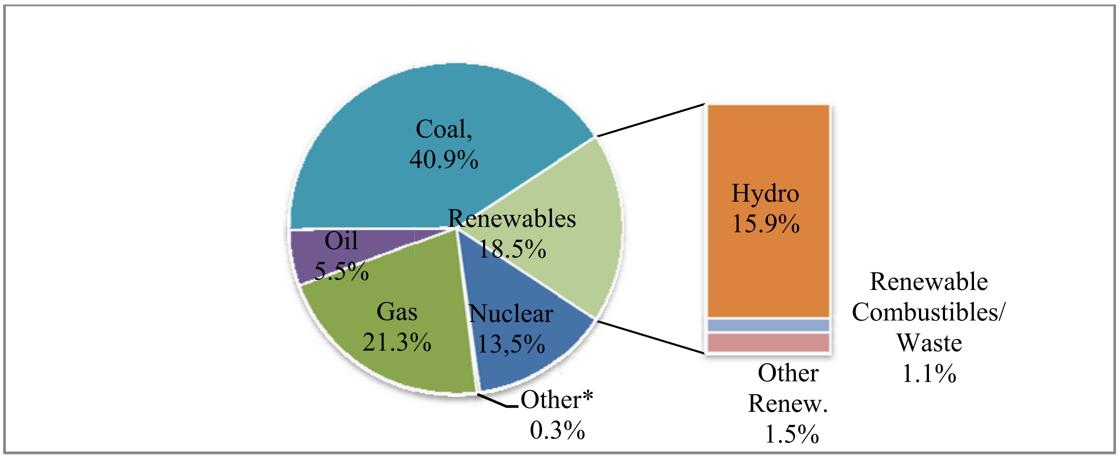


Figure 12. Fuel shares in world electricity production in 2008 (IEA, 2010)

Renewables accounted for 18.5% of world generation in 2008, after coal and slightly behind natural gas. In the transformation sector, hydroelectricity supplies the vast majority of renewable energy, generating 15.9% of world electricity, and 85.9% of total renewable electricity. It is noteworthy that renewable combustibles/waste, including solid biomass, play a minor role in electricity generation, supplying 1.1% of world electricity generation in 2008.

Table 4. Share of Electricity Production from Renewable Sources (%) (IEA, 2010)

	1990	1995	2000	2006	2007	2008	2009e	Average annual percent change 1990-2009
OECD Total	17.3	17.0	15.6	15.5	15.4	16.3	17.2	-0.0
OECD North America	18.4	17.8	15.3	15.6	14.9	15.9	16.6	-0.5
OECD /IEA Pacific	13.1	10.8	9.7	9.2	8.3	8.4	8.6	-2.2
OECD Europe	17.6	18.6	18.9	18.5	19.7	20.9	22.5	1.3
IEA Total	17.2	16.8	15.4	15.4	15.3	16.1	17.1	-0.0
IEA North America	18.2	17.6	15.1	15.6	10.0	15.7	16.7	-0.4
IEA Europe	17.5	18.4	18.7	18.3	19.4	20.6	22.1	1.3
Non-OECD Total	23.3	25.2	23.2	21.3	20.7	20.9	-	-
World	19.5	19.9	18.4	18.1	17.8	18.5	-	-

Renewable electricity generation grew worldwide since 1990 on average by 2.7% per annum but it is less than total electricity generation, which grew at an average rate of 3.0%. Renewable electricity grew at an annual average rate of 1.6 in OECD countries, while it grew by 4.0% in non-OECD countries. Unfortunately, in both regions, renewable electricity grew slower than the total electricity growth.

Another comparison between the OECD and non-OECD countries shows that since 1995, electricity growth has been higher in non-OECD countries, which include developing economies in Asia, and Africa. Population growth which is higher in developing countries than in OECD countries forced the developing and non-OECD countries to demand more energy and electricity. As incomes increased, people switched from fuel wood and coal to liquefied petroleum gases for cooking, and had better access to electricity through improvements in energy technologies.

Consequently, future renewable electricity growth is expected to remain higher in non-OECD countries than in OECD countries. Due to the slow growth of the main renewable source, hydroelectric power, in OECD countries which produces about 32.5% of global renewable electricity, the renewables share in global electricity, which was 19.5% in 1990, fell to 18.5% in 2008. Since hydroelectricity has a critical role in defining the share of electricity production from renewable sources, Table 5 explains the importance of that renewable energy resource on the electricity generation.

Table 5. Share of Electricity Production from Renewable Sources Excluding Hydroelectricity (%) (IEA, 2010)

								Average annual change (%)
	1990	1995	2000	2006	2007	2008	2009e	1990-2009
OECD Total	1.8	1.5	1.9	3.2	3.6	4.0	4.6	4.9
OECD North America	2.8	1.9	1.9	2.4	2.6	3.0	3.3	1.0
OECD /IEA Pacific	1.3	1.3	1.4	1.9	2.0	2.2	2.1	2.6
OECD Europe	0.8	1.1	2.0	4.9	5.8	6.5	7.8	13.0
IEA Total	1.8	1.5	1.8	3.1	3.5	4.0	4.6	5.1
IEA North America	2.7	1.8	1.8	2.3	2.5	2.9	3.3	1.1
IEA Europe	0.7	1.1	2.0	4.9	5.7	6.4	7.7	13.0
Non-OECD Total	0.4	0.5	0.7	0.8	0.9	1.0	-	-
World	1.3	1.2	1.4	2.1	2.3	2.6	-	-

Hydroelectricity forms the basis of the renewable energy based electricity production because when hydroelectricity is excluded, the share of electricity production from renewables dwindles from 19.5% to 1.3% in 1990. Similar to 1990, the share decreases from 18.5% to 2.6% in 2008. Thus, in some cases, it will be beneficial to exclude hydro power from the rest of the RER.

In order to understand the basics of renewable energy technologies, the following section of the chapter will explain the main renewable energy markets and other promising alternative energy resources.

Renewable Energy Markets

This section will focus on the main markets of renewable energy and provide an overview of recent developments in the power generation market, heating and cooling market, transport fuels market, and rural energy services. Since wind, solar and geothermal energy resources will be explained very detailed later, this section will present a general outlook of those markets and also indicate the other renewable energy resources such as biomass power and ocean energy.

According to the Renewable Energy Policy Network for the 21st Century (REN21), existing renewable power capacity worldwide reached an estimated 1,230 gigawatts (GW) in 2009. Table 6 shows the renewable electric power capacities for the developing world, the EU and top six countries as of 2009.

Table 6. Renewable Electric Power Capacity, Existing as of 2009 (REN21, 2010)

Technology	World Total	Developing Countries	EU -27	China	US	Germany	Spain	India	Japan
Wind power	159	40	75	25.8	35.1	25.8	19.2	10.9	2.1
Small hydropower<10MW	60	40	12	33	3	2	2	2	4
Biomass power	54	24	16	3.2	9	4	0.4	1.5	0.1
Solar photovoltaic-grid	21	0.5	16	0.4	1.2	9.8	3.4	-0	2.6
Geothermal power	11	5	0.8	-0	3.2	0	0	0	0.5
Concentrating solar thermal power (CSP)	0.7	0	0.2	0	0.5	0	0.2	0	0
Ocean power	0.3	0	0.3	0	0	0	0	0	0
Total renewable power capacity (including small hydropower)	305	110	120	62	52	42	25	14	9
Total hydropower (all sizes)	980	580	127	197	95	11	18	27	51
Total renewable power capacity (including hydropower of all sizes)	1230	650	246	226	144	51	41	49	56

When large scale hydropower is not included, renewables reached a total of 305 GW, 22% increase over 2008. Among all renewables, global wind power capacity increased the most in 2009, by 38 GW. While hydropower has grown annually by about 30 GW in recent years, solar PV capacity has increased by more than 7 GW in 2009. The leading countries in renewable power capacity in 2009 were China, the

United States, Germany, Spain and India. When all scales of hydro included, top two countries remained same, China and the United States but the followers changed as Canada, Brazil and Japan. The most noteworthy highlights of 2009 were that the renewables accounted for more than 60% of newly installed capacity in the EU and wind power alone was the largest source of new capacity installment in the United States and finally China added an estimated 37 GW of grid connected renewable capacity in 2009, for a total of 226 GW.

Biomass, derived from forestry, agricultural, and municipal residues as well as from a small share of crops grown specifically as fuel, is available is available in solid (e.g., straw or wood chips), liquid (e.g., vegetable oils animal slurries that can be converted to biogas), and gaseous (biogas) forms (REN21 Global Status Report, 2010). Biomass power capacity reached an estimated 54 GW by the end of 2009. As of 2007, the United States was the OECD's largest producer of electricity from biomass with 42 Terawatt-hours (TWh), followed by Japan with 16 TWh and Germany with 10 TWh. Research studies done on the biomass markets show that although Europe's biomass market is more developed than the U.S. market, by late 2009, the United States added 80 biomass projects which provide approximately 8,5 GW of power capacity. This made the U.S. the leading state for total capacity in biomass.

In the EU side, Germany and the United Kingdom also focused on solid biomass electricity production. For instance, Germany increased its generation of electricity with solid biomass 20 fold between 2002 and 2008, to 10 TWh. As of 2010, bioenergy accounted for 5.3% of the country's electricity consumption, making it the Germany's second largest renewable generating source after wind power. Finland, for example, meets 20% of its electricity need with solid biomass.

Thus, Europe's gross electricity production from solid biomass has tripled since 2001 with operating 800 solid biomass power plants.

In developing countries, the situation for biomass is similar to the EU and the U.S. China's capacity rose 14% in 2009 to 3.2 GW, and the country wills to install up to 30 GW by 2020. Brazil has over 4.8 GW of biomass cogeneration plants at sugar mills, which generated more than 14 TWh of electricity in 2009. India also generated 1.9 TWh of electricity with solid biomass in 2008.

Biogas is also a promising energy source for the whole world as an alternative. Its production increased estimated 7% during 2008. Germany surpassed the United States in biogas generated electricity in 2007 and remained the largest producer in 2009. The total domestic production of Germany was estimated 9-12 TWh of electricity, while the U.S. generated 7 TWh with biogas, followed by the UK at 6 TWh and Italy at 2 TWh. Although biogas is used for electricity generation mainly in OECD countries, many developing countries such as Thailand and Malaysia also produce electricity with biogas.

Ocean energy, which is the least mature of renewable energy technologies, includes wave, tidal, and ocean thermal energy conversion (OTEC) systems. Power generation from ocean energy began with the 240 MW La Rance tidal barrage in French coast in 1966 but development for the ocean energy remained limited. An estimated 6 MW is tested in European waters with additional projects off the shores of Canada, India, Japan and more than 20 countries. Portugal installed a 2.5 MW commercial wave plant in 2008 and aims to expand total capacity up to 250 MW by 2020. South Korea completed 1 MW tidal-current plan in 2009 and began construction of a 260 MW tidal plant. The U.K. is currently leading country in ocean energy with 0.5 MW wave capacity, 1.5 MW of tidal stream capacity, and a 1.2 MW tidal-current plant which is the world's first commercial scale tidal turbine.

Heating and cooling markets are one of the main markets that renewable energy sources are used in it. Biomass, solar, and geothermal energy currently supply hot water and space heating for millions of buildings worldwide. While solar hot water technologies becomes widespread, there is also a growing trend to use of solar energy for cooling purposes but since the solar and geothermal energy will be two of the main sections of the research, this section will only mention biomass heating briefly.

Biomass heating applications range from individual residential scale units to large district heating systems, including combined heat and power (CHP) plants. According to Masters and Randolph (2008), there are many ways to capture some of thermal losses and waste heat which stem from electricity generation and transmission through CHP. The use of biomass for district heating and CHP provides about 67% of all biomass heat sold in Europe. The number of CHP increased in Austria, the Czech Republic, France, Germany and Sweden. Denmark generates an estimated 10% of its power and a large share of its heat from biomass in CHP plants. In Sweden, for instance, biomass became the primary energy source for the distinct heat sector and biomass's share of energy production exceeded that of oil. Furthermore, interest in the biomass pellets for electricity generation and heating purposes started to increase. Italy, Germany and France are the leading countries in pellet burning heating sector.

Transport fuel markets mainly include biofuels and biodiesels. Biofuels for transport include ethanol, made primarily from corn and sugar cane and biodiesel, produced from vegetable oils are seen as an important tool to decrease oil use and oil import based energy dependence, to improve urban air quality and to reduce GHG emissions. While corn accounts for more than half of global ethanol production and sugar cane for more than one third, biofuels make small but growing contributions to the fuel usage.

In 2009, production of fuel ethanol reached an estimated 76 billion liters, an increase of 10 percent over 2008. Brazil had been the world leader in ethanol production until 2005 when the U.S. surpassed it. Those two countries accounted for 88% of global ethanol production in 2009. U.S. production rose 16% to about 41 billion liters in 2009. Urbanchuk (2010) estimates that the U.S. ethanol displaced more than 360 million barrels of imported oil for gasoline production. However, debate continues about the net energy of biofuels production, the effect of biofuels from food crops on food prices, the prospects for non food crop biofuels, and the subsidies and import tariffs that affect biofuels markets. Many organizations including the Economist Intelligence Unit (EIU) and the Earth Policy Institute (EPI) think that the use of grain, soybeans, and corns to produce fuel increases food prices and can cause a food crisis in 2011. Service (2010) states "Just a few years ago, the idea of turning farm and forest wastes into cellulosic ethanol, a biofuel to power cars and trucks, seemed a sure winner". He asserts that much of the optimism surrounding cellulosic ethanol has declined due to the economic slowdown, a plentiful supply of ethanol made from corn, and uncertainty among policymakers, even numbers do not support him. He adds that ramp up in cellulosic ethanol production is already well off track.

In biodiesel side, production increased 9% in 2009 and reached 16.6 billion liters globally. Although the European Union represents nearly 50% of total biodiesel production, compare to 65% growth in 2005 and 54% in 2006, production increased less than 6% in 2009. France increased its production by 34% in 2009 and became the world leader in biodiesel production (REN21, 2010). Its production accounted 2.6 billion liters, 16% of global biodiesel.

While some countries such as the U.S., Belgium and Italy experienced negative growth in biodiesel, Argentina, the U.K., Spain, Indonesia, and India expanded their production. It should be explained that although biodiesel and fuel ethanol experienced huge average annual growth rate of 38,6% and 15,1%, respectively between 2000 and 2009, since there are serious conflicts and disagreements on whether biodiesel and biofuel have more benefits than their negative impacts which are mainly on environment, food and agriculture sector, this study will not cover those alternative energy resources.

According to the World Health Organization (WHO) and the United Nations Development Programme (UNDP) (2009), 1.5 billion people worldwide still lack access to electricity, and approximately 2.6 billion are reliant on wood, straw, charcoal, or dung for cooking their daily meals. In many rural areas of developing countries, connections to electric grids may take long time. Thus, renewable energy has an important role in providing modern energy access to the people that continue to depend on more traditional and unsustainable energy sources via acceleration of off-grid systems. From table 7, what kind of energy services that people live in rural areas need and the examples of renewable energy sources that are used to meet energy demand can be seen.

Table 7. Transitions to Renewable Energy in Rural (Off-Grid) Areas (REN21, 2010)

Rural Energy Service	Existing Off-Grid Rural Energy Sources	Examples of New and Renewable Energy Sources
Lighting and other small electric needs (homes, schools, street lighting, telecom, hand tools, vaccine storage)	Candles, kerosene, batteries, central battery recharging by carting batteries to grid	Hydropower (pico-scale, micro-scale, small scale) Biogas from household-scale digester

		Small-scale biomass gasifier with gas engine Village-scale mini-grids and solar/wind hybrid systems Solar home systems
Communications (televisions, radios, cell phones)	Dry cell batteries, central battery recharging by carting batteries to grid	Hydropower (pico-scale, micro-scale, small-scale) Biogas from household-scale digester Small-scale biomass gasifier with gas engine Village-scale mini-grids and solar/wind hybrid systems Solar home systems
Cooking (homes, commercial stoves and ovens)	Burning wood, dung, or straw in open fire at about 15 percent efficiency	Improved cooking stoves (fuel wood, crop wastes) with efficiencies above 25 percent Biogas from household-scale digester Solar cookers
Heating and cooling (crop drying and other agricultural processing, hot water)	Mostly open fire from wood, dung, and straw	Improved heating stoves Biogas from small- and medium-scale digesters Solar crop dryers Solar water heaters Ice making for food preservation Fans from small grid renewable system
Process motive power (small industry)	Diesel engines and generators	Small electricity grid systems from microhydro, gasifiers, direct combustion, and large biodigesters
Water pumping (agriculture and drinking water)	Diesel pumps and generators	Mechanical wind pumps Solar PV pumps Small electricity grid systems from microhydro, gasifiers, direct combustion, and large biodigesters

With solar home systems and lanterns, solar PV systems help to improve household lighting in rural areas. In Bangladesh, close to half a million solar home systems have been installed. India, China and Sri Lanka also invested in solar home systems and solar lanterns. As of 2007, Africa had more than 500,000 systems in use, majority of these in Kenya and South Africa. Cooking and heating is another issue in rural areas of developing countries. Because of inefficient operations of the stoves they use, excessive biomass use and unsustainable forest management caused declining biomass stocks in many countries such as India, South Africa, Uganda, Honduras and Guatemala. Fortunately, the use of factory manufactured improved stoves started to increase the combustion efficiency. In addition to that, the numbers of smaller niche cooking technologies such as biogas systems and solar cookers increase gradually. While China now has 25 million biogas systems, Vietnam has more than 150,000 systems.

To summarize, there is an increasing interest in renewable energy resources relative to conventional energy resources including coal, natural gas, oil and even nuclear power. In overall, renewable energies formed 25% of global power capacity and delivered 18% of global electricity supply in 2009. In addition to the electricity generation from renewables, alternative energy resources in heating and transportation also become popular. While grid connected solar PV increased 100 fold since 2000, wind power capacity grew an average of 27% annually for the last five years. Although the US, Japan and the EU led by Germany and Spain are the leader countries in renewable technologies, developing and emerging countries have more than half of global renewable power capacity. China, India, Brazil and many developing countries in the North Africa, South America and the Middle East started utilize their green energy resources. Furthermore, governments' "Green Stimulus" packages began to support green energy markets and provide more attractive investment environment for the private sector investors.

Since new renewable energy resources are the primary focus of the study, global wind, solar and geothermal energy markets with their sub applications will be presented.

Global Wind Energy Outlook

Wind is becoming an important contributor to the world energy production. Wind power capacity increased by a record 38 GW or 31% in 2009 and reached 160 GW by the end of 2009. The generation of power from wind in 2009 is estimated to be over 260 TWh which is almost equal to the 1.3% of total electricity generation.

Table 8. Cumulative Installed Wind Turbine Capacity as of 2009 (BP, 2010)

Megawatts	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Change 2009 over 2008	2009 Share of total
US	2445	2610	4245	4674	6361	6750	9181	11635	16879	25237	35159	39,3%	22,0%
Canada	126	139	214	270	351	444	683	1459	1845	2371	3321	40,1%	2,1%
Mexico	2	3	3	3	3	3	3	86	86	332	453	36,4%	0,3%
Total North America	2573	2752	4462	4947	6715	7197	9867	13180	18810	27940	38933	39,3%	24,3%
Argentina	15	16	27	28	30	30	31	31	31	33	33	–	#
Brazil	22	22	24	24	31	31	31	231	392	687	935	36,1%	0,6%
Costa Rica	51	51	71	79	79	79	79	79	79	104	129	24,0%	0,1%
Other S. & Cent. America	7	7	9	9	50	54	54	56	79	153	321	109,8%	0,2%
Total S. & Cent. America	95	96	131	140	190	194	195	397	581	977	1418	45,1%	0,9%
Belgium	11	19	34	45	78	106	177	222	297	385	605	57,1%	0,4%
Denmark	1738	2341	2456	2880	3076	3083	3087	3101	3088	3159	3408	7,9%	2,1%
Finland	39	39	40	44	53	83	85	89	113	113	117	3,5%	0,1%
France	25	63	115	183	274	386	775	1585	2471	3671	4775	30,1%	3,0%
Germany	4442	6107	8734	11968	14612	16649	18445	20652	22277	23933	25813	7,9%	16,1%
Greece	158	274	358	462	538	587	705	862	987	1102	1198	8,7%	0,7%
Ireland	74	122	129	167	230	339	498	748	807	1015	1187	16,9%	0,7%
Italy	277	424	700	806	922	1261	1713	2118	2721	3731	4845	29,9%	3,0%
Netherlands	433	473	523	727	938	1081	1221	1557	1745	2222	2226	0,2%	1,4%
Poland	2	3	24	54	55	55	65	170	313	472	849	79,9%	0,5%
Portugal	61	111	153	204	311	585	1087	1716	2150	2829	3474	22,8%	2,2%
Spain	1812	2836	3550	5043	6420	8263	10027	11614	14714	16543	18784	13,5%	11,7%
Sweden	220	265	318	372	428	478	554	571	789	1024	1537	50,1%	1,0%
United Kingdom	362	425	525	570	759	889	1336	1967	2394	3263	4340	33,0%	2,7%
Other Europe & Eurasia	102	148	174	329	631	904	1294	1679	1985	2536	3423	35,0%	2,1%
Total Europe & Eurasia	9756	13650	17833	23854	29325	34749	41068	48651	56851	65998	76581	16,0%	47,8%
Iran	9	9	9	24	63	91	91	91	91	91	91	–	0,1%
Other Middle East	9	9	9	9	9	9	9	9	9	9	9	–	#
Total Middle East	18	18	18	33	72	101	101	101	101	101	101	#	0,1%
Egypt	36	69	69	69	123	146	180	231	310	384	552	43,8%	0,3%

Morocco	14	54	54	54	54	54	64	122	124	206	254	23,3%	0,2%
Other Africa	14	14	14	25	34	34	34	34	34	106	208	96,2%	0,1%
Total Africa	64	137	137	148	211	234	278	386	469	696	1014	45,7%	0,6%
Australia	10	30	71	190	240	421	717	796	972	1587	1886	18,8%	1,2%
China	262	352	406	473	571	769	1264	2588	5875	12121	25853	113,3%	16,1%
India	1035	1220	1456	1702	2125	3000	4388	6228	7845	9655	10827	12,1%	6,8%
Japan	68	142	357	486	761	991	1159	1457	1681	2033	2208	8,6%	1,4%
New Zealand	35	35	35	35	56	167	167	170	321	325	467	43,7%	0,3%
Other Asia Pacific	16	19	24	30	37	90	194	351	498	725	796	9,8%	0,5%
Total Asia Pacific	1426	1798	2349	2916	3790	5438	7889	11591	17193	26446	42037	59,0%	26,3%
Total World	13932	18450	24927	32037	40301	47912	59398	74306	94005	122158	160084	31,0%	100,0%

Although each country in the world has been affected by the global financial crisis more or less, according to the data from BP Statistical Review of World Energy (2010), the performance of wind is a success story. The trend rate of capacity growth over the past 10 years for wind is 28% p.a. China, the United States and Germany are the major players in the wind energy. Until 2007, Germany was the leader of wind industry followed by the U.S. However, the U.S. invested heavily in wind sector and surpassed Germany by reaching more than 25 GW of installed wind power in 2008. It will not be wrong to say that the year of 2009 was Chinese windy year because China more than doubled its installed wind capacity to 25.9 GW and ranked in second place over Germany. From the figure, it can be seen that Europe remains the largest regional wind market in terms of total installed capacity with 48% of the world total. Germany, Spain, Italy, France, the United Kingdom, Portugal and Denmark placed among top 10 countries in added and existing wind power capacity. The fastest growing region over the past five years has been Asia-Pacific, led by China and India. Between 2004 and 2009, developing country investment in sustainable energy has increased from $3.2 billion to $50.7 billion, rising from 18% to 42%, respectively, of global investment led by again China, India and Brazil.

There were several factors that allowed wind power to become even more dominant as an investment inflow sector in 2009 than in the previous year. One of the developments that strengthened wind was the financial go ahead for a number of large offshore wind farms in the North Sea, notably the 1GW London Array, the 317MW Sheringham Shoal project and 165MW phase of Belwind. Apart from an important share of wind industry in governments' green stimulus packages, another factor was that, in uncertain economic and financial circumstances, many investors including venture capitalists and private equity firms have seen wind as a relatively mature, lower risk, sub sector of green energy than other RER. For instance, the biggest initial public offering (IPO) of the year 2009 in clean energy was the $2.6 billion flotation of wind project developer Chinese Longyuan Power.

Global Wind Energy Council (GWEC) estimated that global wind power installed capacity would reach 200GW by the end of 2010. This would represent 26% growth on 2009, the falling in the market due to the global economic circumstances, continued uncertainty and the difficulty to raise capital. According to the ABS Energy Research (2010) the growth in 2009 was primarily related to China, where a record 13.8GW was added more than doubling the capacity to 26GW, and the U.S., where 10GW was added and reached 35GW. Apart from these two countries, the remaining Top Ten countries experienced a wind capacity growth rate of 9%. If the U.S. and China are removed from the wind energy list, the share of the rest 8 countries will drop further from 55% in 2008 to 48% in 2009. Europe, historically the wind power developer leader, contributed just less than one-third of the global growth in 2009. From table 9, the countries that have more than 1GW wind capacity can be seen.

Table 9. The 1 GW Wind Club in 2009 (ABS Energy Research, 2010)

Ranking	Country	2008 capacity (MW)	2009 capacity (MW)	Shift in ranking
1	United States	25237	35086	=
2	China	12104	25806	+2
3	Germany	23903	25777	-1
4	Spain	16754	19149	-1
5	India	9655	10926	=
6	Italy	3736	4850	=
7	France	3404	4492	=
8	United Kingdom	3241	4051	=
9	Portugal	2862	3535	+1
10	Denmark	3180	3465	-1
11	Canada	2369	3319	=
12	Netherlands	2225	2229	=
13	Japan	1880	2056	=
14	Australia	1306	1712	=

15	Sweden	1021	1560	=
16	Ireland	1002	1260	=
17	Greece	985	1087	=

In 2007, there were thirteen countries in the “1 GW club”; this reached sixteen in 2008 and seventeen in 2009. As of 2009, 12 of seventeen countries in this club are the European Union members. South America, North Africa and Eastern Europe are promising regions in wind energy installations for the upcoming years. It is expected to Turkey, Poland, Austria, Norway, South Korea and Brazil will enter this club by the end of 2010. Indeed, many countries began to develop significant wind projects. For instance, 13 countries increased their capacity by more than 50%. The leading countries were Brazil, Canada, Morocco, China, Turkey and Mexico in 2009.

Before presenting the near future of wind energy, it will be beneficial to emphasize the parallel relation between the leading countries in wind energy and the home countries of wind turbine manufacturers. Figure 13 illustrates the origins and the market shares of top wind turbine manufacturers.

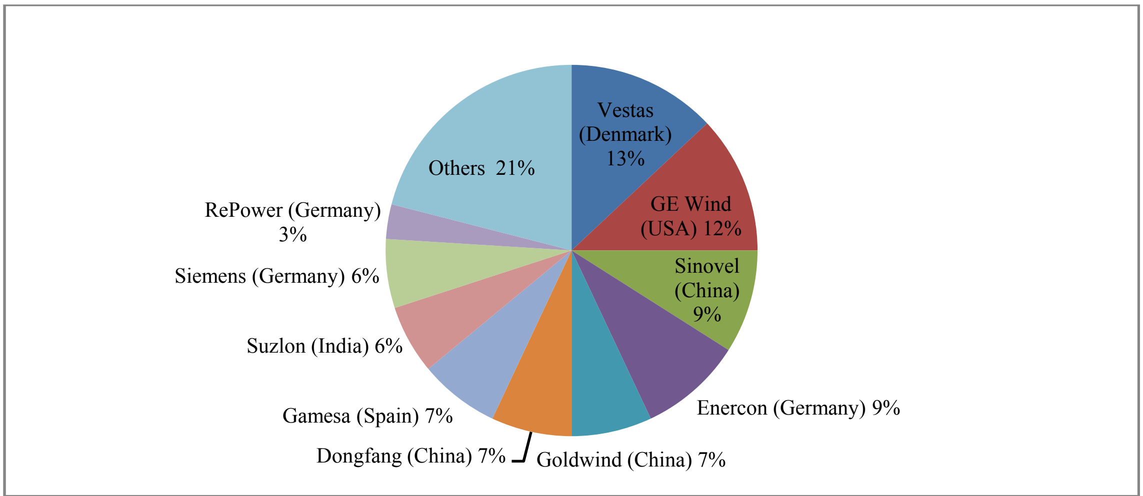


Figure 13. Market shares of top 10 wind turbine manufacturers, 2009 (REN21, 2010)

In 2009, China was the leading country in terms of wind power installations. From the wind turbine manufacture perspective, it can clearly be seen that Chinese firms all together have the biggest share in wind turbine manufacturing sector. The United

States with General Electric Wind is represented with 12% share. As a country which is in third rank in global wind market, Germany has three companies among top ten wind turbine manufacturers with 18% of total share. While Danish firm Vestas maintained its leading position, Spain and India also are the other home countries of the top 10 wind turbine manufacturers.

ABS Research forecasts that the global installed capacity for wind energy will reach 230GW by 2010, with 109GW added from 2008. All regions of the world will show significant growth in three years. 95% of the growth will be in Europe (35%), Asia (31%) and the United States (29%). The summary of National forecasts of wind energy development from 2007 to 2012 can be seen in Table 10.

Table 10. Wind Energy Growth Hot Spots for the period between 2007 - 2012 (ABS Energy Research, 2010)

	Percent growth to 2012 negligible or slow (less than 60% to 2012)	Steady growth to 2012 (60 - 150% to 2012)	High growth to 2012 (>150% to 2012)
Existing large markets (> 2 GW)	Denmark Germany Japan	France Italy Netherlands Portugal United Kingdom United States India	Canada China
Existing medium markets (500 MW - 2GW)		Austria Greece Ireland Sweden Brazil	South Korea Australia Turkey Norway Poland
Existing developing markets (100 - 499 MW)		Czech Republic Finland Ukraine Egypt Hungary Estonia Costa Rica	Taiwan New Zealand Morocco Chile Mexico Bulgaria
Little / no wind power (< 100 MW)	Iceland Malta Slovenia Belarus Pacific Islands Colombia Cuba Curacao Guadeloupe Jamaica	Cyprus Latvia Lithuania Luxembourg Switzerland Iran Tunisia Nicaragua	Albania Croatia Romania Slovak Rep. Russia Philippines Israel Syria South Africa Argentina

Canada and China are the both sparkling countries in existing large wind markets with expected growth of more than 150%. Among existing medium markets, South

Korea, Australia, Turkey, Norway and Poland are expected to experience high growth. While Taiwan, Morocco, Chile, Mexico and New Zealand will experience high growth among existing developing markets, the countries which have little or no wind power such as Albania, Argentina, Romania, Russia and Syria will also see more than 150% increase. Finally, some countries that have large wind industries such as Denmark, Germany and Japan will experience negligible or slow growth to 2012.

European Union Wind Power Outlook

In the history, the close relationship between energy and politics forced European countries to establish European Coal and Steel Community (ECSC). In 1951, Europe's first supranational community was formally established by the Treaty of Paris, signed by France, West Germany, Italy, Belgium, Netherlands and Luxembourg. Many researchers think that the European Coal and Steel Community (ECSC) created the foundation for today's developments of the European Union. By the establishment of this organization, countries aimed to regulate energy resources and to control coal and steel industries. In 1951, 70% of the Community's energy consumption was satisfied from coal, 20% from other energy sources and only 10% was met from oil. This picture of energy mix was only creating concern about environment but since environmental issues were not as critical as today they are, there was not serious energy problem. Unfortunately, this picture changed within 20 years. It is estimated that oil started to represent about 60% of Western Europe's energy consumption of which more than 95% was imported in the beginning of 1970s. It meant that as an economy which is heavily energy dependent, the European economy could be suffered from any fluctuation in the global oil supply. In the meantime, first Six Day War of 1967, then the oil crisis of 1973 and 1978 occurred and the new energy alternative needs was felt strongly.

During the 1970s and 1980s, most of the developed countries were involved in research and development of renewable energy but the European countries and the United States were carrying the banner. Germany was the leading European country in government funding for renewable R&D, especially in wind sector. From 1970s to 1990s, the German government financed more than 40 R&D projects to develop wind turbine designs.

In the beginning, this sector faced with many problems such as due to the insufficient government incentives for promoting wind turbine energy, Germany's renewable actions were decelerated. The U.S. had an opportunity to take more serious steps. However, German government established new wind program for individual energy groups, state owned corporations and private partnerships which accelerated the use of wind in the late 1980s. Germany took the right decisions about renewable energy market but other countries in the Europe could not.

After the ambitious goal of reducing greenhouse gas emissions which was set by along with the United Nations Framework Convention on Climate Change (UNFCCC) , a treaty signed at the Earth Summit in Rio de Janeiro in 1992 and 1997 Kyoto Protocol, European countries began to act more harmonized and coherently. In fact, the European Commission published Green Paper which is the first step of the Europe's renewable energy strategy in 1996. This paper with establishment of White Paper later on, aimed that the share of renewable energy resources in meeting overall energy demand should be 12% by 2010, with a concentration of 22% in the electricity sector, compared to an overall rate of 6% in 1996. However, there were important difficulties encountered in meeting this target. These obstacles were high cost of RE owing to the investment required, inadequate information for supplies, customers and installers and administrative problems. In order to solve these problems, the EU accepted the directive 2001/77/EC that aims to define the general frame of renewable energy politics of the member countries for the next 10 years. In accordance with this legislation, if all member states meet their national goals, 21% of total electricity consumption in the EU will be met by RER by 2010. It should be asserted that the share of wind power in RER for electricity production in the EU was 16.3% in 2002. 6 years later, the European Council set the target of meeting 20% of its energy demand from RER by 2020. With the new directive that adopted in December 2008, around 35% of the EU's total electricity demand will be produced from renewables in 2020. Thus, more new renewable energy capacity was installed in the field of electricity than any conventional electricity source.

Wind energy has the largest share with 39% in installed renewable energy capacity both in 2008 and 2009. The renewable energy sector secured more than 10% of Europe's final energy consumption by the end of 2009 which is good news. However, achieving the target of meeting 20% of its energy demand from RER by 2020 is still questionable.

In 2009, more than 26GW of new capacity was installed in the EU. Renewable power installations accounted for more than 16 GW, 62% of this new energy capacity investment in 2009. Investment in the EU wind farms in 2009 was $13 billion including $11.5 billion of onshore wind power and $1.5 billion of offshore wind power industry. These investments helped the wind power installation in Europe to reach 10,526 MW in 2009. 10,163 MW of that amount has been generated in the EU countries. The wind capacity installed at the end of 2009 will, in a normal wind year, produce 4.8% of the EU's electricity. This amount is expected to reach 181 TWh of electricity, which represents 5.3% of the EU's gross final consumption.

Table 11. Installed Wind Energy Capacity in the EU (EWEA, 2010)

	Installed 2008	End 2008	Installed 2009	End 2008
EU Capacity (MW)				
Austria	14	995	0	995
Belgium	135	415	149	563
Bulgaria	63	120	57	177
Cyprus	0	0	0	0
Czech Republic	34	150	44	192
Denmark	60	3163	334	3465
Estonia	19	78	64	142
Finland	33	143	4	146
France	950	3404	1088	4492
Germany	1665	23903	1917	25777
Greece	114	985	102	1087
Hungary	62	127	74	201
Ireland	232	1027	233	1260
Italy	1010	3736	1114	4850
Latvia	0	27	2	28
Lithuania	3	54	37	91
Luxembourg	0	35	0	35
Malta	0	0	0	0
Netherlands	500	2225	39	2229
Poland	268	544	181	725
Portugal	712	2862	673	3535
Romania	3	11	3	14
Slovakia	0	3	0	3
Slovenia	0	0	0	0
Spain	1558	16689	2459	19149
Sweden	262	1048	512	1560
United Kingdom	569	2974	1077	4051
Total EU -27	8268	64719	10163	74767
Total EU -15	7815	63604	9702	73194
Total EU -12	453	1115	461	1574
Of which offshore and near shore	374	1479	582	2061

Compared to the 2008, more than 10 GW of wind power was installed in the EU. In other words, wind market growth in 2009 was 23%. Of the 10,163 MW, onshore investment amounted 9581 MW and offshore amounted only 582 MW. It can be seen that offshore wind market experienced a 56% growth, while onshore wind power saw

21% increase in 2009. In 2009, for the second year running, wind power was installed than any other energy technology in the EU. As it can be seen from the figure 14, the closest energy source that has been installed in 2009 was natural gas with 6,630 MW, 25% share followed by solar PV with 4,600 MW capacities, 17% share in total power installment in 2009.

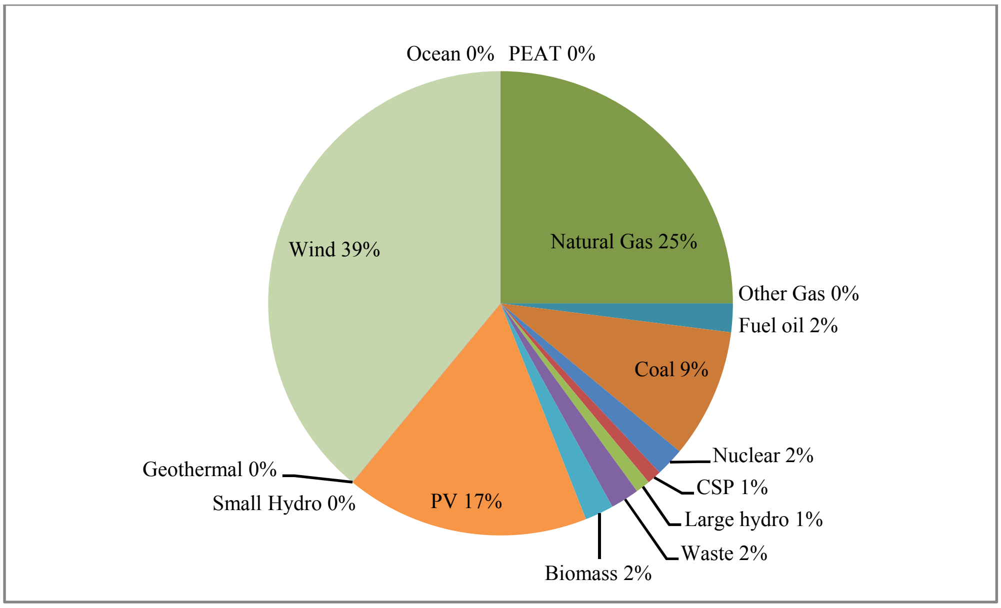


Figure 14. Share of new wind power installations in the EU (EWEA, 2010)

In the EU, 2,406 MW of new coal, 581 MW of biomass, 573 MW of fuel oil, 442 MW of waste, 439 MW of nuclear, 338 MW of large hydro, 120 MW of CSP (concentrated solar power), 55 MW of small hydro, 3.9 MW of geothermal and 405 kW of ocean power were installed in 2009.

For the European country profiles in the wind energy, Germany maintains its leadership in wind energy capacity with total of 25,777 MW followed by Spain with 19,149 MW wind capacity by the end of 2009. However, Spain has installed approximately 2,5 GW wind power which was more than the volume that Germany has installed. Figure 15 shows the shares of the EU countries in new wind capacity installed during 2009.

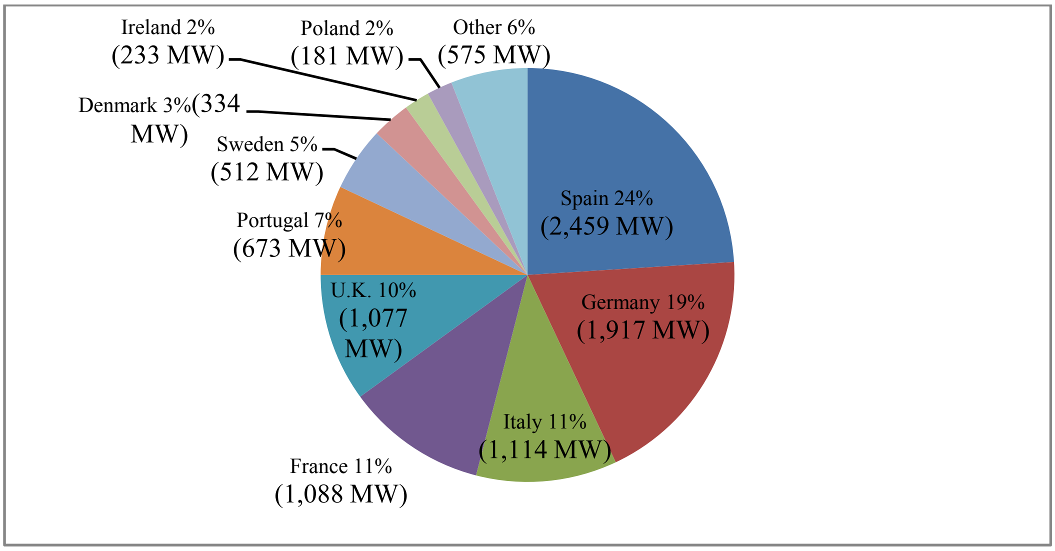


Figure 15. EU member state market shares for new capacity installed during 2009 in MW (EWEA, 2010)

While Italy was third in classification with almost the same share with France, the United Kingdom also installed more than 1GW in 2009. Portugal, Sweden, Denmark, Ireland and Poland followed these countries.

The wind energy capacity of the candidate countries and other major countries in the Europe in 2008 and 2009 can be seen in Table 12.

Table 12. Installed Wind Capacity in the rest of the European Union (EWEA, 2010)

	Installed 2008	End 2008	Installed 2009	End 2008
Candidate Countries (MW)				
Croatia	1	18	10	28
FYROM	0	0	0	0
Turkey	311	458	343	801
Total	312	476	353	829
EFTA (MW)				
Iceland	0	0	0	0
Liechtenstein	0	0	0	0
Norway	103	429	2	431
Switzerland	2	14	4	18
Total	105	443	6	449
Other (MW)				
Faroe Islands	0	4	0	4
Ukraine	1	90	4	94
Russia	0	9	0	9
Total	1	103	4	107
Total Europe	8686	65741	10526	76152

Not only among candidate countries but also among all other European countries, Turkey was the leading country in the wind industry investments both for 2008 and 2009. As a country which has a passion to become a member of the EU, Turkey increased its wind capacity by more than %200 and reached 458 MW in 2008. In addition to this, she continued to expand its wind capacity and accounted 801 MW by the increase of 74% in the end of 2009. As of 2009, Turkey, after Austria, is the thirteenth country in wind power capacity among the EU members. Apart from Turkey, Norway also made investments in wind industry in 2008 but she could not carry its success into 2009. Other countries in the Europe did not experience important success in the wind sector.

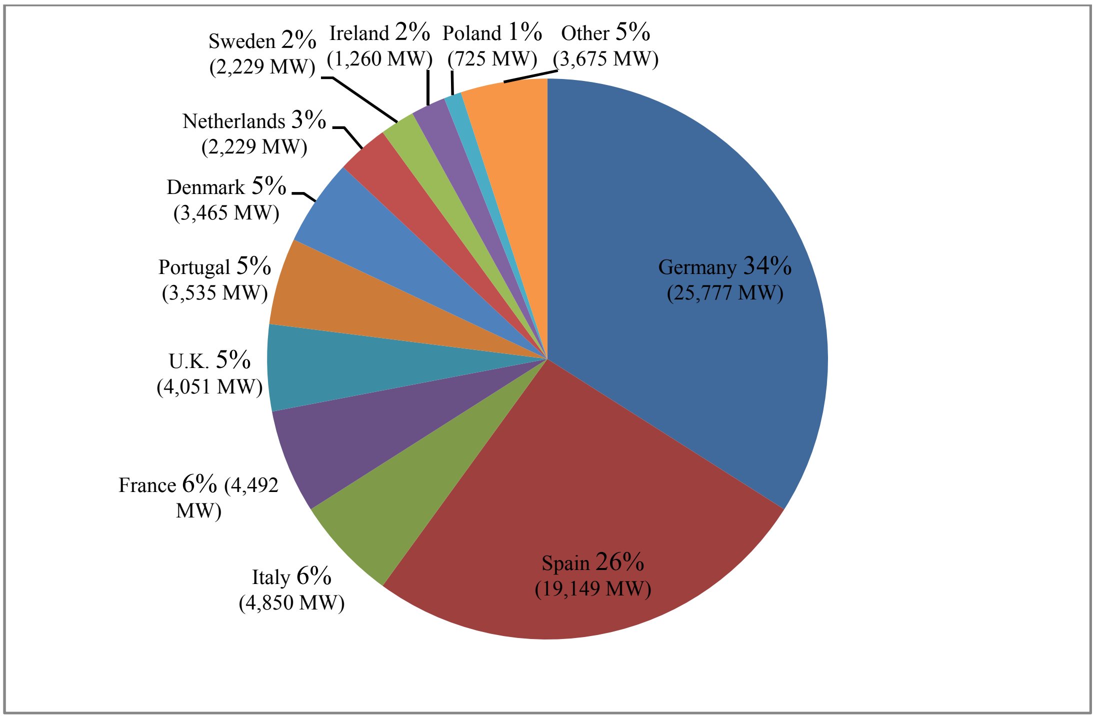


Figure 16. EU member state market shares for total installed capacity in MW (2009) (EWEA, 2010)

A total of 74,767 MW wind power is now installed in the European Union and Germany with Spain are the success examples of the union by 2009. As it can be seen in figure 17, both countries together have almost 60% of total installed wind capacity in the EU.

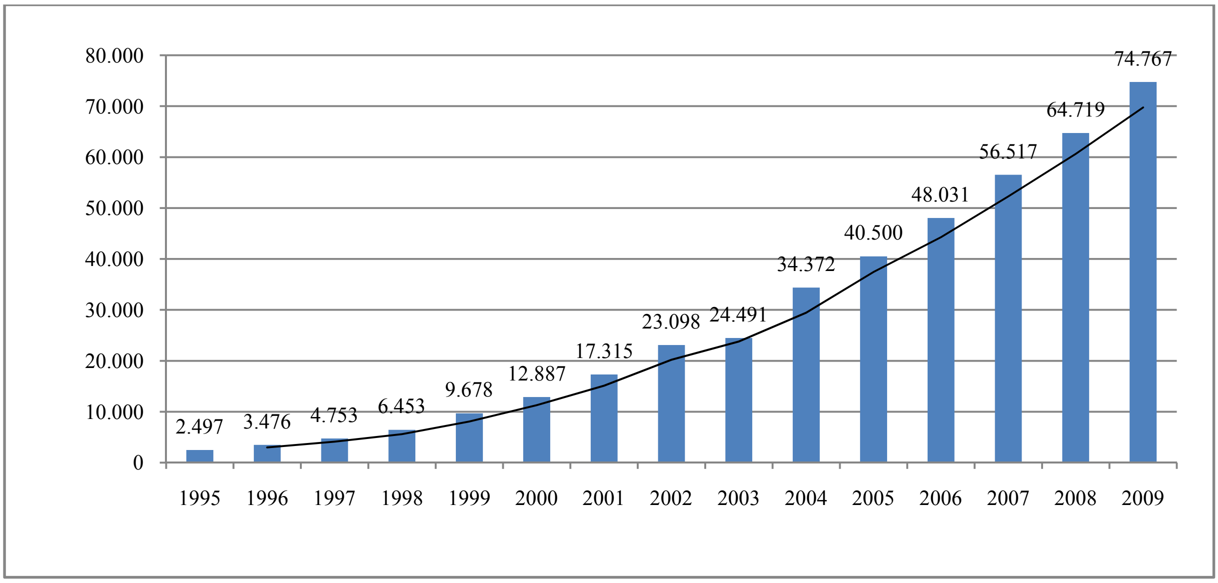


Figure 17. Cumulative wind power installations in the EU in MW (EWEA, 2010)

From the figure above, the importance of wind energy in the EU's energy mix can be understood. In the past 15 years, annual wind power installation in the EU has always been going up. While installed cumulative capacity was only 2,497 MW in 1995, it accounted 24,491 MW in 2003 and reached 74,767 MW in 2009.

The EU is the success story of the world, again, in terms of total installed power capacity. Figure 18 and Figure 19 shows that wind power's share of total installed capacity in the EU has increased from 2% in 2000 to 9% in 2009.

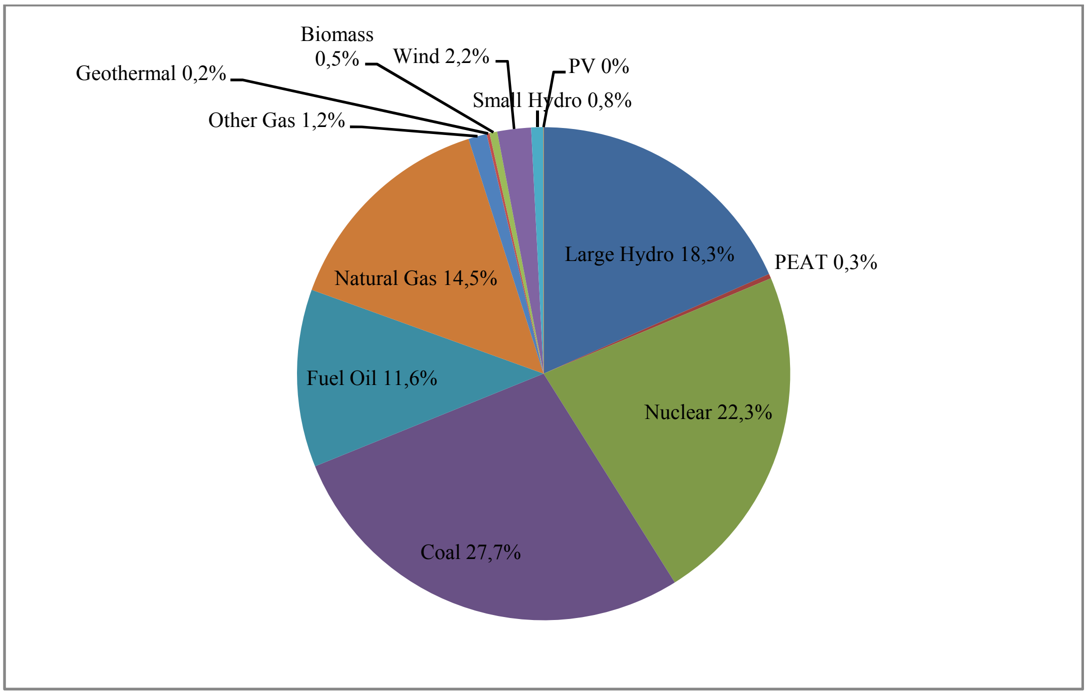


Figure 18. The EU power capacity mix as of 2000 (%) (EWEA, 2010)

In 2000, the share of renewable energy resources in the EU's energy mix was very limited. Although wind power was in the first rank among all renewables, its share was only 2,2% of total power capacity followed by small hydro and geothermal.

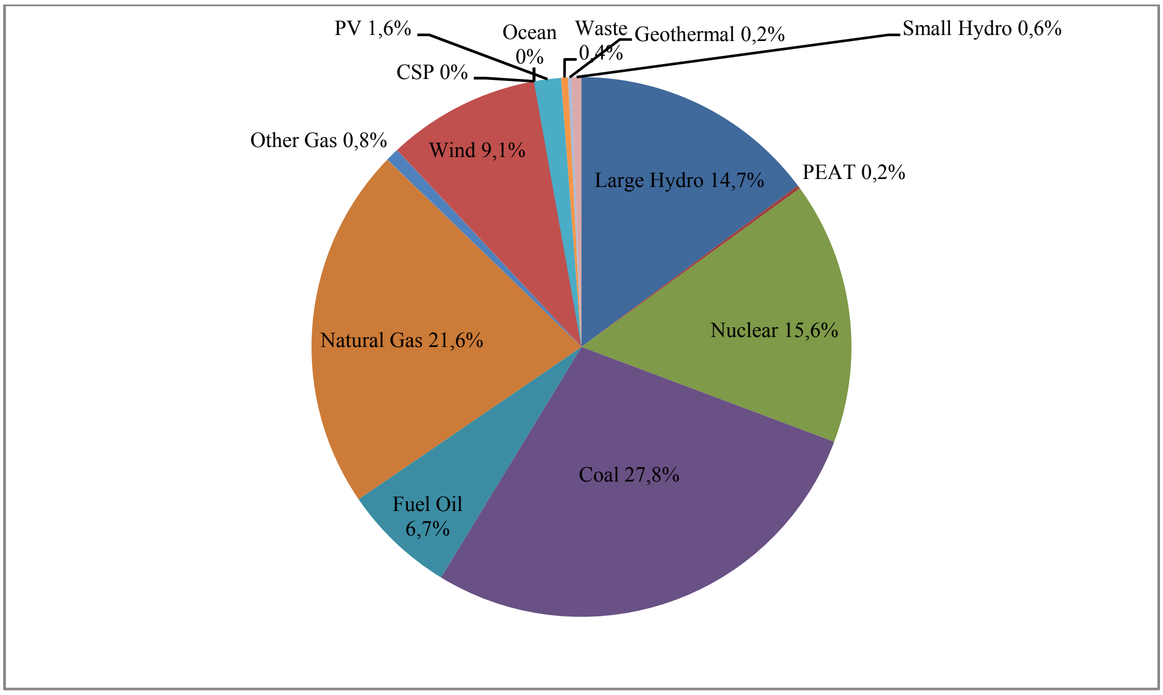


Figure 19. The EU power capacity mix as of 2009 (%) (EWEA, 2010)

In 2009, the wind capacity exceeded 9% of total power capacity and ranked fifth after large hydro. While coal's share almost remained same in 2009 with 27.8%, the shares of nuclear, large hydro and fuel oil declined and accounted 15.6%, 14.7%, and 6.7%, respectively. On the other hand, natural gas increased its share from 14.5% to 21.6%. Undoubtedly, wind with natural gas is the sparkling energy resources of the EU.

To sum up, as a union that aims to has 230 GW installed wind capacity including 190 GW onshore and 40 GW offshore and to meet its 14-17% of total electricity demand from wind energy, the wind power is the primary focus of the EU in the process of achieving its "20% renewable by 2020" target.

When it comes to the latest data on the EU's wind power, it can be observed that renewable power capacity installations accounted 22,682MW in 2010 in the EU. Renewables represented 41% of total new installed capacity in 2010. Due to the huge investment increase in natural gas sector, renewables' share of newly installed capacity decreased in 2010. However, it was the fifth year running that RER have presented more than 40% of total new electricity generating installations.

During 2010, 9,918 MW of wind power was installed across Europe, with the EU countries accounting for 9,295MW of the total. Although this shows a decrease in the EU's annual wind power installations of 10% compared to 2009, wind power accounted for 16.8% of total 2010 power capacity installations. 2010 was the first year since 2007 that wind power did not install more than any other generating technology because natural gas with more than 20GW and PV with 12GW installations surpassed the wind power investment. Of the 9,295MW power installed in the EU, 8,412MW were installed onshore and 883MW offshore. EU wind farm investment was €12.7 billion. While the onshore wind power sector welcomed €10.1 billion during 2010, the offshore wind power industry attracted around €2.6 billion.

In terms of annual installations, Spain, as it was in the previous year, was the largest wind market in 2010, installing 1,516MW followed by again Germany that installed 1,493MW. Surprisingly, there was only one other country, France, installed over 1GW in 2010. The U.K. with 962MW, Italy with 948MW, Sweden with 604MW, Romania with 473MW, Poland with 382MW and Belgium with 350MW followed those three countries in 2010. It is important to highlight that for the first time ever, Belgium and Romania were among the top ten largest annual wind markets.

Overall, 2010 was a record year in the EU with 55.4 GW of new electricity generating capacity installed, more than a 102% increase compare to the 2009 installations. For only the second time since 1998, the EU power sector installed more coal than it decommissioned, emphasizing the urgency of moving a 30% greenhouse gas reduction target for 2020 and introducing an Emission Performance Standard. Parallel to this, the EU power sector continued to move away from nuclear and oil to the natural gas and renewable energy. Thus, renewable power installations accounted for 41% of new installations during 2010, 22,645MW of total of 55.4GW of new power capacity. While solar PV installed 21.7% of total capacity, wind power installation was the second rank with 16.7% share. In addition, 4,056 MW of coal, 573MW of biomass, 405MW of CSP, 208MW of large hydro, 145MW of nuclear, 25MW of geothermal were installed in 2010. In wind power industry, a total of 84,074MW is now installed in the European Union, a growth of 12.2% on the previous year. Germany remains the EU country with the largest installed capacity, followed by Spain, Italy, France and the UK. Portugal, Denmark, the Netherlands, Sweden, Ireland, Greece, Poland Austria are the other 8 countries have over 1GW of installed wind capacity. Finally, as it was projected in 2009, the wind capacity installed at the end of 2010 will, in a normal wind year, produce 181TWh of electricity, meeting 5.3% of the EU's electricity needs.

Cost Analysis of Wind Power

Wind power has been an important success story among alternative energy resources. Its growth and share in energy generation seems to continue worldwide. However, there has been a great debate and criticism on the future and the feasibility of wind energy generation in recent decades. There is no doubt that many factors played critical role in the process of wind energy development. Before explaining the elements affecting wind power, the main physical features and the historical perspective of wind energy will be explained.

Human beings first learnt to harvest natural power of wind in the early civilizations of ancient Iran. In the beginning, wind was used under simple milling devices to rotate the sails. Then, windmills have taken many forms and through the complex mechanical windmills' development, wind was started to use in ultra high tech wind turbines in electricity production. Those wind turbines are characterized by the axis about which the blades rotate, the number of blades, and whether they face into the wind or away from it. Wind energy converters harness the kinetic energy contained in flowing air masses. Today, the most common type of wind turbine is the three bladed, vertical axis turbine, ranging size from a few watts to the largest 5MW turbines.

Winds develop when solar radiation reaches Earth, meeting clouds and uneven surfaces and creating temperature, density and pressure differences. The atmosphere circulates heat from the tropics to the poles, also creating winds. Therefore, generation of electricity with wind energy is achieved by atmospheric wind power rotating a rotor blade propeller on a wind tower rotator shaft that turns a wind turbine (Kruger, 2006).

How much power and energy is available in the wind? To answer that question, the National Renewable Energy Laboratory (NREL) defines the wind power classification scheme which is shown in table 13.

Table 13. Standard Wind Power Classification Scheme (Masters & Rondolph, 2008)

Wind Power Classification	Resource Potential	Wind Power Density (W/m2)	Average Wind Speed (m/s)	Average Wind Speed (mph)
2	Marginal	200-300	5.6–6.4	12.5–14.3
3	Fair	300-400	6.4–7.0	14.3–15.7
4	Good	400-500	7.0–7.5	15.7–16.8
5	Excellent	500-600	7.5–8.0	16.8–17.9
6	Outstanding	600-800	8.0–8.8	17.9–19.7
7	Superb	> 800	> 8.8	> 19.7

For example, Class-5 winds (referred to as “Excellent”) have between 500 and 600 watts of power per square meter of cross sectional area, which correlates to an average wind speed of 16.8 to 17.9 mph and is often thought of as the threshold of economic viability for wind power.

Since land use constraints play a major role in building wind power systems, wind quality varies with geography. For instance Pacific Northwest Laboratory assessed the effect of land use limitations on the U.S. wind energy potential and they indicated that the exploitable wind resource at 50 meters was estimated to be 16,700 billion kWh/yr with no land use restriction, but decreased to 4600 billion kWh/yr under the most severe constraints (Elliott (1991) cited in Masters and Randolph, 2008). From table 14, annual global wind energy resources can be analyzed without land surface restrictions for each region.

Table 14. Annual Global Wind Energy Resources (Assmann et al., 2006) (WEA, 2000)

Region	Land surface with sufficient wind conditions		Wind energy resources without land restrictions	
	%	Thousands km2	TWh	EJ
North America	41	7876	126000	1512
Latin America and Caribbean	18	3310	53000	636
Western Europe	42	1968	31000	372
Eastern Europe and former Soviet Union	29	6783	109000	1308
Middle East and North Africa	32	2566	41000	492
Sub-Saharan Africa	30	2209	35000	420
Pacific Asia	20	4188	67000	804
China	11	1056	17000	204
Central and South Asia	6	243	4000	48
TOTAL	27	30200	483000	5800

North America which has 41% of total land surface with sufficient wind conditions accounted 126,000 TWh equals to 1512 EJ followed by Eastern Europe and former Soviet Union with 109,000 TWh and Pacific Asia with 67,000 Twh of wind energy resources.

From the perspective of the operational concept, wind energy produced in a wind turbine is a function of several parameters such as air density, rotor blade sweep area, wind velocity, time and a conversion efficiency factor. Since all these definitions require technical explanations very deeply, basic factors of wind energy generation will be discussed.

In order to satisfy the fluctuating power demand through wind energy, some criteria should be met. Intermittency or variability exists when a generator cannot control the supply of resources. Those two terms, variability which is a measure of degree and intermittency that the supply alternates or switches on or off are related to wind. Because there are serious concerns about the ability of wind electricity grids to absorb intermittent power due to the fact that wind turbines depend on wind speeds and turbine characteristics. Another important issue is capacity factor. It is the ratio of the electrical energy produced by a generating unit rather than what it would have produced if run continuously at full power. It can vary by month and day. Table 15 shows the capacity factors for each energy resources.

Table 15. Typical Capacity Factors for Different Generating Technologies (ABS Energy Research, 2010)

Energy Technology	Capacity factor
Sewage Gas	90%
Farmyard Waste	90%
Energy Crops	85%
Landfill Gas	70-90%
Combined Cycle Gas Turbine (CCGT)	70-85%
Waste Combustion	60-90%
Coal	65-85%
Nuclear Power	65-85%
Hydro	30-50%
Solar PV	10 -25%
Wind Energy	25-40%
Wave Power	25%

Generators with capacity factors of 70% to 90% such as landfill gas and energy crops are used to deliver base load power which is the minimum load that must be supplied 24 hours a day. On the other hand, energy technologies with low capacity factors are used for peak load power that is the load which arises only for part of the time when demand is highest.

Other issues in wind power generation are grid balancing, grid extension, storage technologies including mechanical, chemical and electromagnet, capacity credit, mis-match of supply and demand, load following, dispersion, inadequacy of weather forecasting, spinning reserve and back up and wake effects. Last but not least, three major trends have dominated the grid connected wind turbines' development in recent decade: (1) the turbines have become larger and taller, thus average size of turbines sold at the market place has increased substantially, (2) the efficiency of the turbines' production has gone up rapidly and (3) the investment costs per kW have decreased (EREC, 2010).

The economic viability of expanding the use of large scale wind farms for electricity generating capacity depends on the efficiency of wind turbines, the reduction of wind turbine cost ($/installed kW) and the cost of the electricity compared with the costs of alternative fuels such as solar, fossil and nuclear. According to the European Wind Energy Association's The Economics of Wind Energy Report (2009), 75% of the total cost of energy for a wind turbine is related to upfront costs such as the tribune cost, foundation, electrical equipment and grid connection. Since the main input in wind energy production is free, fluctuating fuels costs do not affect the wind power generation cost. This allows claiming that a wind turbine is a capital intensive technology compared to conventional fossil fuel based technologies such as a natural gas power plant.

Table 16. Cost Structure of a Typical 2 MW Wind Turbine Installed in Europe (€ 2006) (EWEA, 2009)

	INVESTMENT (€1,000/MW)	SHARE OF TOTAL COST %
Turbine (ex works)	928	75.6
Grid connection	109	8.9
Foundation	80	6.5
Land rent	48	3.9
Electric installation	18	1.5
Consultancy	15	1.2
Financial costs	15	1.2
Road construction	11	0.9
Control systems	4	0.3
TOTAL	1227	100

An average installed wind turbine has a total investment cost of €1.23 million per MW. Since the value of project is 2MW, investment costs about €2.5 million. This value includes all foundation, grid connection, electric installation, financial cost, etc.

With 75.6% share, it can be concluded that capital costs of wind energy projects are consisted of the cost of the wind turbine itself. While foundation accounts for 6.5%, grid connection accounts almost 9%. Kaltschmitt et al. (2007) assert that investment costs of wind power include the production costs, transportation and assembly, foundation, grid connection as well as miscellaneous costs including design and infrastructure costs.

Kruger (2006) estimates the cost of wind power by calculations. Construction cost of large scale wind turbines (1500kW with 77-m rotor diameter) is about $1000/kW, compared with natural gas installations at about $600/kW. According to Kruger, a formula for wind power cost estimation was annual energy output based in 2001 and it was as follows:

$$E = 8760\ P.\ (0.087V - P/D^2)$$

Where P = rated power capacity (kW), V = mean annual wind velocity (m/s) at rotor height approximately 50 m, D = rotor diameter (m), 8760 = hours/year.

For a 1500kW turbine with a 77-m rotor and a mean wind speed of 7 to 7.5 m/s, the estimated annual electricity generated would be 4.7 to 5.2 GWh/yr. The electricity cost would be between 3 and 4 cents per kWh.

Operation and maintenance (O&M) costs have large share in total annual costs of wind turbine. For a new turbine, O&M costs might have an average share over the lifetime of the turbine of almost 20-25% of total cost per kWh produced. O&M includes land lease expenses, insurance, repair and technical operation. O&M costs for onshore wind energy are generally estimated to be around 1.2 to 1.5 c€ per kWh of wind power produced over the total lifetime of a turbine. It should be asserted that while cost of wind power is compared with other technologies, operation and maintenance costs with fuel costs, costs of CO2 emissions and capital costs including planning and site work should also be taken into account. It is certain that the rapid development in global wind power capacity had a strong influence on the cost of wind power over the last two decades. Larger turbines and improved cost effectiveness pulled the wind power cost down. For example, in coastal region, the average cost has decreased from 9.2 c€/kWh for the 95 kW turbine which is mainly installed in the 1980s, to around 5.3 c€/kWh for a new 2,000 kW machine with the improvement of more than 40%.

In offshore side, the overall cost is still about 50% more expensive to produce than onshore wind. As it has been explained very detailed in global wind outlook section, the current volume of onshore and offshore wind power installation reflects this situation clearly. Offshore costs are generally dependent on water depth, weather and wave conditions and distance to the coastline. Although higher costs, industrial capacity problems and the availability of installation vessels force countries to think twice before making an investment in offshore wind sector, the U.K., Sweden and Denmark heavily invested in offshore wind farms. Table 17 gives a snapshot on offshore wind farms across Europe.

Table 17. Key Information on Recent Offshore Wind Farms (EREC, 2010) (EWEA, 2009)

Middelgrunden (DK)	In operation	Number of turbines	Turbine size	Capacity MW	Investment cost € million	Investment Cost €/W
	2001	20	2	40	47	1.17
Horns Rev I (DK)	2002	80	2	160	272	1.7
Samsø (DK)	2003	10	2.3	23	30	1.3
North Hoyle (UK)	2003	30	2	60	121	2.01
Nysted (DK)	2004	72	2.3	165	248	1.5
Scroby Sands (UK)	2004	30	2	60	121	2.05
Kentich Flat (UK)	2005	30	3	90	159	1.76
Barrows (UK)	2006	30	3	90	-	-
Burbo Bank (UK)	2007	24	3.6	90	181	2.01
Lillgrunden (S)	2007	48	2.3	110	197	1.79
Robin Rigg (UK)	2008	60	3	180	492	2.73

Within the given time interval, turbine size for offshore wind farms ranges from 2MW to 3.6MW. Turbine farm size also differs from each other due to the capacity of the projects. While Denmark's small Middelgrunden wind farm has 40MW capacity, the U.K.'s planned London Array offshore wind farm will have 1000MW capacity. The capital costs of offshore wind projects are so high because they require complex logistics of installing towers and larger structural preparations. On average, investment costs for a new offshore wind farm are estimated to be between €2.0 to €2.2/W.

In conclusion, the main factors that determine the basic costs of wind energy are upfront investment costs including turbines, wind turbine installation costs, the cost of capital, operation and maintenance costs, planning costs, turbine lifetime, electricity production and energy loses.

Environmental and Economic Impacts of Wind Energy

Wind turbines have many environmental advantages as well as some negative attributes. As it has been explained above, electricity is generated through wind energy without the CO_2, SO_2, NO_x, particulate matter and mercury air pollutants that conventional power plant emit in huge quantities. This is because the "fuel" is free and contains no carbon. The American Wind Energy Association (AWEA) estimates that the development of just 10% of the wind potential in the ten states in the US would provide more than enough energy to replace emission from nation's coal fired power plants and eliminate the nation's major source of acid rain. It would also reduce total CO_2 emissions of the U.S. by almost one third. Again, wind power helped Europe to fight against global warming. For instance, wind power provided 4% of Europe's electricity demand which avoided the emission of 91million tones of

CO_2 in 2008. In the same year, €11.8 billion was invested in the wind energy and this allowed Europe to avoid €2.3 billion of CO_2 equivalent fuel costs of €6.5 billion annually, assuming an average CO_2 price of €25/t. Moreover, wind turbines do not need water for cooling and can be located in arid areas. For instance, whereas a nuclear power plant consumes through evaporation more than 500 gallons of water per MWh, a wind turbine requires about one gallon.

On the other hand, there are potential negative aspects of wind energy. Much of the environmental costs of wind turbines were associated with avian collisions, especially with preservation of bird life. An interesting comparison of bird death caused by wind turbines with other causes of mortality in the United States is provided in Figure20.

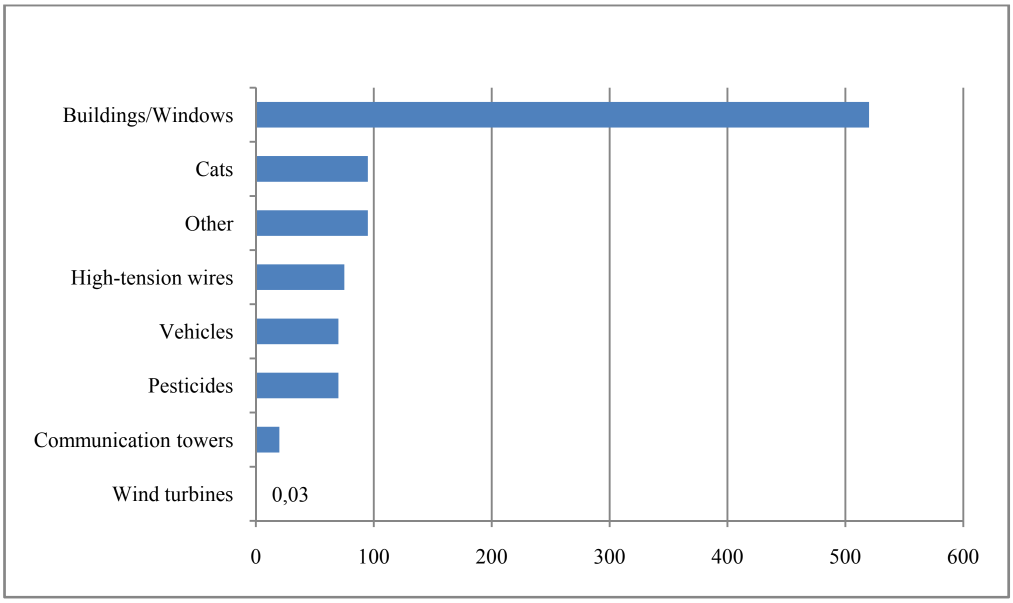


Figure 20. Estimated bird fatalities caused by wind turbines and other lethal encounters (Masters & Randolph, 2008)

Wind turbines are thought to cause on the order of 30,000 bird deaths per year, feral and domestic cats kill 100 million each year and bird collisions with buildings over 500 million. It can be seen that wind farms with more sensitive sitting and taller, slower turbines could reduce bird death rates. Of course, different bird types react very differently to wind turbines.

Another environmental concern about wind energy is noise. Wind turbines mainly emit aerodynamic infrasonic sounds within a frequency range from 0.6 to 1.5 Hz. At these frequencies the human detection limit of 120 to 130 dB is very high. At a distance of 120m from, say a 500 kW wind turbine, infrasonic sounds of 75 to 85 dB were measured which were reduced to 67 to 77 dB at a distance of 300m.

Table 18. Comparative Noise for common activities (EWEA, 2010)

Source/activity	Indicate noise level (dB)
Threshold of hearing	0
Rural night-time background	20-40
Quiet bedroom	35
Wind farm at 350m	35-45
Busy road at 5km	35-45
Car at 65km/h at 100m	55
Busy general office	60
Conversation	60
Truck at 50km/h at 100m	65
City traffic	90
Pneumatic drill at 7m	95
Jet aircraft at 250m	105
Threshold of pain	140

Wind farm at 350m creates almost 35-45 db noise which is less than the noises created by car at 65km/h at 100m or busy general office or even conversation. In the light of these numbers, the studies indicate that there is no serious impact on the population by infrasonic sounds. Newer turbines which avoid the thumping sound caused when downwind blades flex as they pass behind their towers are much better.

Overall, potential negative features of wind energy can be avian interaction with wind turbines, electromagnetic interference, wind turbine noise, visual impact of wind farm turbine density, land use impact of the wind power system and safety considerations from blade throw, ice fall, tower failure and electrical fires.

Before, during and after wind turbine construction, all these concerns and potential environmental costs of wind energy should be assessed and related actions should be taken on time. In Wind Farm Development and Nature Conservation Guide of World Wildlife Fund (WWF, 2001), there are some directives about environmental aspects of wind energy. In habitats directive, it states that where wind farms are proposed, their development should not cause significant disturbance to, or deterioration or destruction of key habitats of species. In the bird directive, to minimize the potential for adverse effects on birds, it is suggested wind farm developers to be aware of known bird migration routes, local flight paths, foraging areas and coastal and inland wetland sites and potential sensitivities of ridges and valleys. For the national statutory sites, WWF says that where wind farms are proposed, their development should not adversely affect the conversation objectives and/or reasons for identification and notification or designation of sites of national wildlife importance.

When it comes to the economic benefits of wind industry, there can be seen many direct and indirect economic advantages of wind energy. The main advantage of wind energy is, of course, reduction of the electricity price. Since wind has a low marginal cost, it pushes out more expensive power generating technologies from the energy market. If a country begins to use its wind energy resources, then it will decrease its fuel import dependence which will strengthen its economy. Instead of paying a lot of money to fuel exporting countries, investment in the country's national wind market will provide significant economic benefits to the citizens of the country.

Job creation is the main benefit of wind in that scope. The Global Wind Energy Council (GWEC) assumes that wind energy creates 15 jobs per MW of annual installation, through turbine manufacturing, wind farm development, installation and indirect employment. Operations and maintenance work also contributes an additional 0.33 jobs per MW of total installed capacity. According to the European Wind Energy Association (EWEA), the EU wind energy sector directly employed 48,363 people in 2002 and this reached 108,600 people in 2007. It means that employment increased by 125%. On average, 12,047 new direct wind energy jobs were created per year in between 2002 and 2007. When indirect employment is included, this number accounted for 154,000 in 2007. Finally, the European wind industry employs 192,000 people by the end of 2009 and it is expected to reach more than 400,000 jobs by 2020. All these numbers show that the wind industry will need more people to fill the future job opportunities not only in Europe but also in other regions. Thus, education and training facilities should be provided.

Another benefit that wind farms bring to local communities is that landowners can provide income by renting out their lands for wind farms. In addition, governments can collect local and regional taxes from wind energy and those taxes can enhance the services that governments provide. Last but not least, wind energy is already helping tackle climate change by replacing polluting fossil fuels. Although environmental benefits of wind energy were explained above, zero carbon wind energy brings external and hidden costs of the fossil fuel based energy prices into sharp relief. If damages of traditional fossil fuels on environment and public health are added on the energy price, then the importance of wind and other renewable energy sources will be understood more clearly. In 2009, wind power in the EU avoided the emissions of 106 million tones of CO_2, equivalent to taking 25% of cars in the EU off the road. Consequently, all these benefits of wind energy provide peoples to live in better environmental conditions with the high quality of lives.

For the countries which have abundant wind power, wind energy may play a critical role in strengthening their energy security, decreasing their energy dependency, avoiding greenhouse gas emissions on a large scale and supporting hundreds of thousands of jobs. Since wind energy technology is developed rapidly, the cost of wind energy farm installation is decreasing. Thus, those countries which have a desire to promote their wind energy have to provide efficient investment environment for the potential investors. Setting realistic and encouraging targets, developing wind energy maps and implementing attractive incentives are the major actions that successful countries in wind energy generation should take.

After wind energy, the global solar energy will be analyzed in the succeeding section.

Global Solar Energy Outlook

The sun provides the energy of life on Earth. It continuously operates as a fusion reactor which radiates energy throughout the solar system. Solar energy reaching the earth appears to have been constant over the human time period and it has huge theoretical potential. Some solar energy is available each day everywhere on earth. According to Kruger (2006) the usable forms of solar energy are direct beam (thermal) radiation which can be focused to a collector, diffuse (thermal) radiation that scattered from clouds and cannot be focused and secondary forms converted to biomass, wind energy and hydropower.

The amount of solar radiation intercepted by the Earth is much higher than annual global energy use worldwide. The availability of solar energy depends on the geographic position of the region, land availability and weather conditions.

Table 19. Annual Global Solar Energy Resources by Regions (Assman et al., 2006) (WEA, 2000)

Region	Minimum EJ	Maximun EJ
North America	181	7410
Latin America and Caribbean	112	3385
Western Europe	25	914
Central and Eastern Europe	4	154
Former Soviet Union	199	8655
Middle East and North Africa	412	11060
Sub-Saharan Africa	371	9528
Pacific Asia	41	994
South Asia	38	1339
Central Asia	115	4135
Pacific OECD	72	2263
Total	1575	49837

Middle East and North Africa are the leading regions in annual global solar energy resources. From both perspectives, minimum and maximum solar energy resources, these regions are the leaders followed by Sub Saharan Africa with minimum and maximum values, 371 EJ and 9528 EJ, respectively.

Energy from the sun can be used in three main ways: (1) Passive heat is the heat received from the sun naturally and can be taken into consideration in the design of buildings to decrease amount of required additional heating, (2) Solar Thermal where the sun's heat is used to provide hot water for homes, swimming pools or heating systems, and (3) photovoltaic energy (PV) that uses energy from the sun, especially daylight, to create electricity to run appliances and lighting. OECD and IEA in their Renewables Information 2010 Report do not include passive solar energy for direct heating, cooling or lighting. They focus on solar photovoltaic which is solar radiation exploited for electricity generation and solar thermal. They also divide that solar thermal into two groups which are hot water production by flat plate collectors and electricity generation by solar thermal electric plants.

Since there are different classification types for solar energy, we grouped solar energy under two sub technologies which are solar thermal and solar photovoltaic systems. This section will also explain the concentrated solar power (CSP) systems briefly. Since PV technologies compose of the great majority of solar power, the focus of this section will be on the photovoltaic systems. Before explaining the details of PVs, solar thermal energy will be presented.

Solar Thermal Energy

The basic principle of solar thermal utilization is the conversion of short wave solar radiation into heat. In other words, the sun heats water contained in a dark vessel, solar radiation is then transformed into useful heat. Solar thermal systems have been started to use more frequently after first oil shock in the 1970s. The development that solar thermal units experienced made solar thermal system more efficient year by year.

Today, the solar thermal technologies replace conventional sources of heat, mainly fossil fuels and electricity because the world's low and medium temperature heat consumption can at least partially be met by using solar collectors. Since hot water and central heating are the most important needs of households, solar thermal power via solar domestic hot water and space heat systems meet those needs. Solar cooling, using absorption or adsorption cooling technologies started to become a feasible alternative as well. Solar thermal can also provide the heat needed in many industries but the difficulties that faced with during the standardization process of solar thermal force investors to increase R&D expenditure on that field.

In the cost side, collectors with approximately 45% of the total costs, account for the largest share of the total investment. While the storage accounts for almost 20%, installation and commissioning are approximately 25% of the overall costs. Solar thermal systems have a large range of total investment costs. Standard domestic hot water systems usually cost between €5,000 and €6,000. In comparison, self installation systems are significantly cheaper between €3,000 and €5,000.

Solar thermal power production experienced huge growth in the 1980s and 1990s reaching 887 GWh in 1998 but the investments in this industry have stopped after that year. From 1998 to 2006, solar thermal market had not experienced any significant growth. After an increase of interest in solar thermal, the U.S. increased its production from 527 GWh in 1999 to 878 GWh in 2009. While Spain followed the U.S. and produced 38 GWh of electricity from solar thermal in 2009, Austria also produced 4 GWh in 2009. These developments accelerated the development of global solar thermal market.

From the economic and environmental benefits perspective, solar thermal systems help to save scarce natural resources by improving diversity of energy supply. They also save CO_2 emissions at very low costs and limit air pollution. Furthermore, almost 40,000 people have full time job in European solar thermal industry by the end of 2008. Since solar thermal power plants are generally located in extremely dry areas that are not used for agriculture, commercial activity within these areas would create many opportunities for local communities. After European countries, China heavily invested in solar thermal power in recent years.

Table 20. Solar Hot Water Installed Capacity, Top 10 Countries/EU and World Total, 2008 (REN21, 2010)

Country/EU	Additions 2008	Existing 2008
	GWth	
China	21.7	105
European Union	3.3	18.3
Turkey	0.7	7.5
Japan	0.2	4.1
Israel	0.2	2.6
Brazil	0.4	2.4
United States	0.2	2.0
India	0.3	1.8

Australia	0.2	1.4
South Korea	00.4	1.0
(other countries)	<0.5	<3
World Total	28	149

As of 2008, China with 105 gigawatts -thermal (GWth) solar hot water capacity is the leading country followed by the EU countries with 18.3 GWth as a whole, Turkey with 7.5GWth and Japan with 4.1GWth. China dominates the world solar hot water and heating market with 70% of the existing total capacity but in overall, European industry is the worldwide technological leader in solar thermal power. Since European countries began to invest in combi systems that provide both water and space heating, this systems now account for half of the annual market. At the end of 2008, the total solar thermal power capacity in operation in the EU27 reached 19.1 GWth (27 million m^2 of collector area). More than 80% of the EU market is concentrated in just six countries which are Germany, Greece, Austria, Spain, France and Italy.

Photovoltaic Systems (PVs)

Photovoltaic power generation is a further alternative to directly utilize solar radiation energy. In contrast to CSP, solar energy is directly converted into electrical energy through photovoltaic system. Photovoltaic is a linkage of two words: “photo” which means light and “voltaic” which is the unit used to measure electrical potential at a given point. PVs use cells to convert solar radiation into electricity. The cell consists of one or two layers of a semi conducting material. The photovoltaic cell operates in accordance with the physics of the photoelectric effect, which is one of the ways ionizing radiation interacts with matter. The most common semi conductor material used in PV cells is silicon which is the second most abundant material in the earth mass. Although the greater intensity of light means the greater the flow of electricity, PV does not need bright sunlight to operate because reflection of sunlight allow it to operate even in cloudy days. PV cells are generally made either from crystalline silicon, sliced from ingots or castings, from grown ribbons or thin film, deposited in thin layers on a low cost backing.

There are several types of PV cells today. Wafer based silicon solar cells is the main technology with approximately 80% market shares in 2009. Polycrystalline solar cells are also important solar cell types. The PV modules' efficiencies differ from solar cell to another. While mono crystalline modules have between 14% to 20% efficiency rates, the efficiency of polycrystalline modules varies from 12% to 17%. In addition to those two solar cells, the emerging systems in solar industry are concentrated PV cells which use concentrating collectors to use minimum expensive semiconducting material while collecting as much sunlight as possible with 20 to 30% efficiency and flexible cells which based on a similar production process to thin film cells, when the active material is deposited in a thin plastic.

The PV technology can be used in many applications. The most popular type of solar PV for residential and commercial needs is grid connected domestic systems. A grid connected system offers the opportunity to sell to the local utility any excess electricity PVs might generate during the day, running the meter in one direction, and then buying electricity back from the grid at night. To feed solar power into the grid an inverter is required to convert the direct current (DC) power generated by PV system into alternating current (AC) power compatible with the mains. Those grid connected inverters are directly connected to the PV system without additional storage capacity. The same system which also produces a large quantity of PV electricity in a single point is called grid connected power plants. This system is used in large industrial buildings such as airport terminals.

Off grid systems are another application for PVs. If the power grid is inaccessible for technical or economic reasons because of the distance to the closest grid connection point, PV energy supply systems are referred to as off grid systems. Where no mains electricity is available, the system is connected to a battery via a charge controller. Typical off grid applications are used to bring access to electricity to rural areas. In addition, off grid systems are also used in industrial application, especially in the telecommunication industry. Since they avoid the high cost of constant investments, these applications are cost effective. Moreover, While PV cells are used in consumer goods such as watches, toys, battery charges, etc., PV systems can also be combined with another energy source such as wind or biomass.

Solar PV which has been seen as the most promising sub sector in alternative energy experienced a huge growth from late 1990s to beginning of 2010s. While global cumulative installed photovoltaic power was approximately 1GW in 1990, it reached almost 23GW in 2009. Parallel to the total power generation, electricity from solar PV increased from 19GWh in 1990 to 18,799GWh in 2009, accounting for 44% annual growth which makes the solar PV the fastest growing renewable electricity technology. The OECD as a whole produced 18.799GWh of PV electricity in 2009, roughly 1% of its total renewable electricity production.

Table 21. Cumulative Installed Photovoltaic (PV) Power as of 2009 (BP, 2010) (IEA Photovoltaic Power Systems Programme, EPIA, EurObserver and SolarBuzz)

Megawatts	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Change 2009 over 2008	2009 Share of total
U.S.	117,3	138,8	167,8	212,2	275,2	376,0	479,0	624,0	830,5	1168,5	1645,5	40,8%	7,2%
Canada	5,8	7,2	8,8	10,0	11,8	13,9	16,7	20,5	25,8	32,7	102,7	214,1%	0,4%
Mexico	12,9	13,9	15,0	16,2	17,1	18,2	18,7	19,7	20,8	21,8	23,0	5,5%	0,1%
Total North America	136,0	159,9	191,6	238,4	304,1	408,1	514,4	664,2	877,1	1223,0	1771,2	44,8%	7,7%
Austria	3,7	4,9	6,1	10,3	16,8	21,1	24,0	25,6	27,7	32,4	37,5	15,7%	0,2%
Belgium	–	–	–	–	–	–	1,0	3,0	21,0	71,0	363,0	411,3%	1,6%
Bulgaria	–	–	–	–	–	–	–	–	–	1,0	8,0	700,0%	–
Czech Republic	–	–	–	–	–	–	–	1,0	4,0	54,0	465,0	761,1%	–
Denmark	1,1	1,5	1,5	1,6	1,9	2,3	2,7	2,9	3,1	3,3	4,6	39,4%	–
Finland	2,4	2,6	2,7	3,1	3,4	3,7	4,0	4,1	4,4	4,9	6,9	40,7%	–
France	9,1	11,3	13,9	17,2	21,1	26,0	33,0	43,9	75,2	179,7	364,7	102,9%	1,6%
Germany	69,4	113,7	194,6	278,0	431,0	1034,0	1926,0	2759,0	3835,5	5877,0	9677,0	64,7%	42,2%
Greece	–	–	–	–	1,0	3,0	5,0	7,0	9,0	20,0	56,0	180,0%	0,2%
Italy	18,5	19,0	20,0	22,0	26,0	30,7	37,5	50,0	120,2	458,3	1188,3	159,3%	5,2%
Netherlands	9,2	12,8	20,5	26,3	45,7	49,2	50,7	52,2	52,8	57,2	63,6	11,2%	0,3%
Norway	5,7	6,0	6,2	6,4	6,6	6,9	7,3	7,7	8,0	8,3	8,6	3,6%	–
Portugal	0,9	1,1	1,3	1,7	2,1	2,7	3,0	3,4	17,9	68,0	100,0	47,1%	0,4%
Spain	2,0	2,0	4,0	7,0	12,0	23,0	48,0	145,0	693,0	3354,0	3423,0	2,1%	14,9%
Sweden	2,6	2,8	3,0	3,3	3,6	3,9	4,2	4,8	6,2	7,9	8,7	10,1%	–
Switzerland	13,4	15,3	17,6	19,5	21,0	23,1	27,1	29,7	36,2	47,9	65,9	37,6%	0,3%
Turkey	0,3	0,4	0,6	0,9	1,3	1,8	2,3	2,8	3,3	4,0	4,8	21,0%	–
United Kingdom	1,1	1,9	2,7	4,1	5,9	8,2	10,9	14,3	18,1	22,5	32,5	44,4%	0,1%
Rest of European Union	4,0	5,0	6,4	19,4	25,0	43,8	59,1	61,4	76,8	157,3	187,7	19,3%	0,8%
Total Europe	143,4	200,3	301,1	420,8	624,4	1283,4	2245,8	3217,8	5012,4	10428,7	16065,8	54,1%	70,1%
Australia	25,3	29,2	33,6	39,1	45,6	52,3	60,6	70,3	82,5	104,5	170,5	63,2%	0,7%
China	10,0	19,0	30,0	45,0	55,0	64,0	68,0	80,0	100,0	145,0	305,0	110,3%	1,3%
Israel	–	–	–	–	–	0,9	1,0	1,3	1,8	3,0	21,0	600,0%	0,1%
India	–	1,0	2,0	3,5	6,0	10,0	18,0	30,0	50,0	90,0	120,0	33,3%	0,5%
Japan	208,6	330,2	452,8	636,8	859,6	1132,0	1421,9	1708,5	1918,9	2144,2	2628,2	22,6%	11,5%
Korea	3,5	4,0	4,8	5,4	6,0	8,5	13,5	35,8	81,2	357,5	525,5	47,0%	2,3%
Malaysia	–	–	–	–	–	–	–	5,5	7,0	8,8	13,3	51,1%	0,1%
Rest of World	486,9	682,3	724,0	786,5	850,6	884,6	923,0	961,4	1041,6	1094,4	1308,4	19,6%	5,7%

Total Others	734,3	1065,7	1247,2	1516,3	1822,8	2152,3	2506,0	2892,8	3283,0	3947,4	5091,9	29,0%	22,2%
Total World	1013,6	1425,9	1739,9	2175,5	2751,3	3843,8	5266,2	6774,8	9172,5	15599,1	22928,9	47,0%	100,0%

The global solar PV market is dominated by Japan, Germany and the United States for a long time period. Their competition in this market is noteworthy. In 1999, Japan was the leading country with 208.6MW followed by the United States and Germany. In 2001, Germany produced more than 190MW of solar PV based power and took the second position. Until 2004, Japan could maintain its leadership but Germany with 1926MW of PV power defeated Japan and became world number one. In the meantime, Spain accelerated its solar PV investments in 2005. Until 2007, the ranking did not change but even Spain was the fourth country in global solar PV market, Spain reached 3354MW of PV power took second rank by surpassing not only the U.S. but also Japan. As of 2009, Germany strengthened its leader position by adding more than 3.8GW solar PV power and reaching 42.2% of total installed PV power. Although Spain could not make any significant contribution its PV volume, she still has the second biggest share with 14.9% of total followed by Japan and the U.S. with 11.5 and 7.2%, respectively.

Apart from these countries, three countries' successes on PV should be highlighted. These states were Italy with more than 710MW, Czech Republic with more than 410MW and Belgium with almost 300MW annual capacity increases in 2009. High feed in tariffs and good national solar resource are the main pillars of this success. Moreover, majority of the countries that experienced high growth rate in 2009, including three countries mentioned above, are European countries. This let us to say that Europe is the leader region in the world solar PV industry. Therefore, the detailed outlook of the EU's solar PV market will be presented later on the study.

South Korea, Canada, China, India and Austria are other promising countries in solar PV.

On the other hand, due to the problems related to PV module prices, debt finance, venture capital and public market investors and Spain, solar PV financial investment volume with $24 billion, has fallen from 25% of the total for all sub clean energy sectors in 2008 to 20%, decreased by 27% in 2009. The reasons for that fall can be explained as follows: No matter what kind of cells and panels were used, PV module average prices fell by almost 50% between third quarter of 2008 and the end of 2009. Each part of PV supply chain has been affected and market shifted from excess demand to excess supply. This development created a controversial situation. While due to the fall in PV prices, the dollar value of financial investment in PV also decreased, more MW of solar PV could be installed for each dollar of investment and this explains the reason of solar PV market growth of 2009. Second, because of financial crisis, investors sometimes faced with difficulties in finding debt finance from banks for projects in Europe and North America. Third, venture capital and public market investors' acquisition activities on young solar companies created caution. Last, Spain, the most dynamic solar market in 2008, saw deep in PV project investment as government lowered tariffs to the pre 2008 level and froze permits for new capacity kept developers at bay. Although financial investment in solar PV decreased in 2009, the quantity of large scale PV plants which are greater than 200 kW and were 2,450 in 2008 reached 3,200 in 2009. These plants that are operated in Spain, Germany and the US, generated 5.8GW of power, more than five times the 2007 capacity. It is very interesting that although majority of PV plants are located in Europe and the North America with the lead of Germany, Spain and the United States along with Japan, 11 of top 15 solar PV manufacturers come from Asia region.

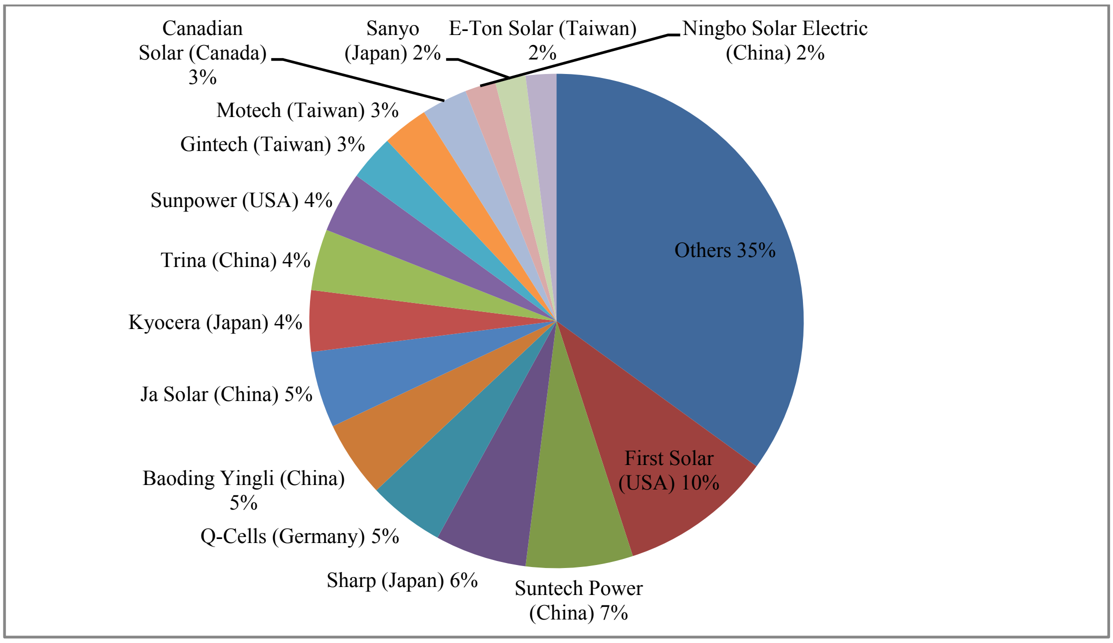


Figure 21. Market shares of top 15 solar PV manufacturers, 2009 (REN21, 2010)

It should be asserted that due to the difficult market circumstance, which was characterized by a declining market environment in the first half of 2009 and an exceptional increase in the second half of 2009, there is a significant uncertainty in data 2009. In addition to this, some companies report shipment figures; whereas others inform sales or production volume which caused different figures of total cell. Nevermore, production data for the global cell production in 2009 vary between 10.5GW and 12.2GW. According to the REN21 these 15 solar PV companies produced 65% of the 10.7GW of cells manufactured in 2009. The home countries of the manufacturers are China, Japan, Taiwan, Germany, the USA and Canada. Among these home countries, Chinese, Taiwanese and Japanese firms produced almost 50% of the global total and amongst the 15 biggest PV manufacturers in 2009; there were only two solar companies which had production facilities in Europe. These firms were First Solar in the U.S., Germany and Malaysia and Q-Cells in Germany and Malaysia. While four solar manufacturing companies were from China (Suntech, BaodingYingli, Ja Solar and Trina), Sharp and Kyocera were Japanese manufacturers. It can be concluded that, since the solar industry is very dynamic and one of the most promising renewable energy resources, the outlook of photovoltaic industry including top manufacturers' country origins and their shares, even within quarter of year, changes dramatically.

European Union Solar PV Outlook

The European Council endorsed a target of a 20% share of renewable energy in overall EU energy consumption by 2020, a 30% reduction in greenhouse gas emissions by 2020 compared to 1990 in the meeting in Brussels on 8-9 March 2007. In order to achieve these targets, the European Council prepared an overall framework for renewables that resulted in the Directive on the "Promotion of the Use of Energy from Renewable Sources". The Directive 2009/28/EC exceeds the targets of White Paper "Energy for the Future: Renewable Sources of Energy" and the Green Paper "Towards a European Strategy for the Security of Energy Supply". The main targets were that renewables should provide 12% of the total and 21% of electricity in the EU by 2010 .

The White Paper also sets goal for the solar PV market of the EU. Installed solar PV systems capacity in the European Union by 2010 should have been 3,000MW, or a 100 fold increase of capacity of 1995. The target was already reached in 2006 and the cumulative installed solar PV capacity at the end of 2009 was 16GW, more than 5 times bigger than the original target. However, only 5 member states have defined specific PV targets. In order to reach 6% of solar electricity by 2020, the EU countries have to reach about 200GW of cumulative installed PV capacity which can be achieved if only the countries set realistic specific targets.

In 2009, the solar PV market in the EU started to slow down in the beginning of the year but the markets began to recover in the second quarter. The real boom happened in the last quarter when in Germany alone 1.46GW of new solar PV capacity were installed. The EU with 16GW of total cumulative installed solar PV capacity is above board leader of the global PV market. Germany with 3.8GW installation, again, placed first rank not only among the EU members but also in the global PV market. As presented earlier, Italy with 730MW, Czech Republic with 411MW and Belgium with 308MW followed Germany.

As mentioned in the preceding subtitles, Germany remains the world's largest PV market with a cumulative installed solar PV of approximately 9.7GW. By the end of 2010, according to the very optimistic approach, this may exceeded 15GW. The success of Germany in PV industry stems from its strong and detailed tariff structure. Germany has more than 20 feed in tariffs for 20 years depending on the system size, new installation date and the type of investment. For instance, for the projects of 1MW that will be invested in between 1 July 2010 to 30 September 2010, the rate of tariff was 0.2555 €/kWh. It increased to 0.3405 €/kWh in the systems smaller than 30kW. These detailed tariff rates build a confidence investment environment in Germany and naturally German solar market seems attractive for foreign investors. While Spain with 3.4GW ranked second, the country also established new feed in tariff with cap of 400MW and additional 100MW for ground based systems in September 2008. Italy followed Spain with almost 1.2GW of solar PV power among the EU countries. Italy also has very strong and proper feed in tariff regulations. Italy offers 2% decrease for new systems each year and also encourage investors to invest in schools and public health areas via offering 5% bonus no matter integrated or non integrated systems used. Italy also changed its 2GW of national PV target for 2015 to 3GW of year 2016. Cumulative installed PV power of Czech Republic accounted for 465MW and allowed the country to rank fourth. Again, the government offers green bonus for particular PV projects and tariff rate is 0.433€/kWh for the systems bigger than 30kWh. Belgium and France with 363MW have almost equal cumulative PV power in the EU but France has relatively deeper and specified solar regulations compared to Belgium.

There are many studies on the future projections, forecasts and targets of the EU. In order to achieve the EU's "20% renewable energy by 2020", European Photovoltaic Industry Association (EPIA) defined ambitious target, called SET for 2020, which is that PV should cover up to 12% of the European electricity demand by 2020. Today this ratio is almost 1%. Moreover, PV can be fully competitive with other electricity sources in as much as 76% of the EU electricity market by 2020 without any form of external price support or subsidy.

For the upcoming years, European Photovoltaic Industry Association (EPIA, 2010) has prepared two scenarios for the future development of the PV industry. The moderate scenario is based on the assumption of a "business as usual" market behavior which does not assume any major enforcement existing support mechanism but takes into consideration a reasonable follow up of the Feed in Tariff aligned on the systems prices.

In policy driven scenario, it is expected that support mechanisms, namely Feed in Tariffs, will be introduced and supported via strong political willingness to consider PV as a major alternative energy resource for the coming years.

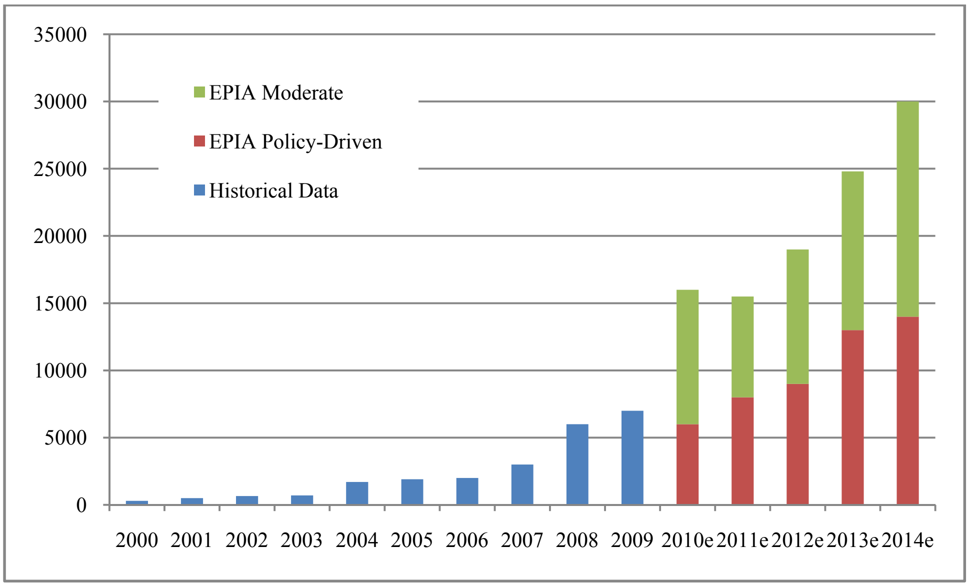


Figure 22. Moderate and policy-driven scenarios for the PV market in the EU (EPIA, 2010)

According to the EPIA, the European solar PV market could increase to 8.2GW in 2010 followed by 6GW in 2011 and 8GW in 2014 in the moderate scenario. In contrast, 11.5GW of solar PV power could be installed in Europe in 2010 and up to 13.5GW in 2014 in policy driven scenario. As shown in figure above, EPIA also expects the world PV market could experience a rise up to 10.1GW by 2010 and 13.7GW by 2014 in moderate scenario while policy driven scenario indicates that the world PV market could account for 15.5 GW in 2010 and 30GW in 2014.

Cost Analysis of Solar PV

The installation costs of PV systems mainly include module and inverter costs, design and mounting expenditures, cost for frames and building permits. Plant size has an important role in defining total costs of solar PV systems because specific costs decrease while plant size increases. For example, while the total specific costs of multi crystalline silicon based PV plant, say for 1 kW, varies between average 4,900 €/kW and 6,800€/kW, this value decreases 4,100- 5,600€/kW range. For a 10 kW system, the overall investment costs of the plant in the same condition are around 4,000 to 5,000 €/kW. The module costs account for the biggest share of the overall expenditures. For multi crystalline modules, the expenditures vary between 1,900 and 3,200€/kW which is contributing 55-65% of the total investment costs followed by inverter costs varying between 300 and 450€/kW. Mounting frames also have a share of roughly 10-15% of overall investment costs. Operation costs which include maintenance and servicing costs such as repairs, insurance, module cleaning are 30€/kW for the 3kW plant, 800€/kW for the 20kW and 108,000€/kW for the 2,000kW solar PV plant.

For the generation costs of PV systems, it can be observed that PV power production costs are decreasing. This trend will accelerate over upcoming years by the technological developments. The primary way to calculate the cost per kWh is to divide the price of the PV system by the number of kWh the system will produce over its lifetime.

Table 22. Expected PV Generation Costs for Roof-top Systems at Different Locations (EREC, 2010) (EPIA/Greenpeace, 2008b)

	Sunshine hours	2007	2010	2020	2030
Berlin	900	€0.44	€0.35	€0.20	€0.13
Paris	1000	€0.39	€0.31	€0.18	€0.12
Washington	1200	€0.33	€0.26	€0.15	€0.10
Hong Kong	1300	€0.30	€0.24	€0.14	€0.09
Sydney/Buenos Aires/ Bombay/Madrid	1400	€0.28	€0.22	€0.13	€0.08
Bangkok	1600	€0.25	€0.20	€0.11	€0.07
Los Angeles/Dubai	1800	€0.22	€0.17	€0.10	€0.07

According to the expected PV system prices under the Advanced Scenario of EPIA and Greenpeace where strong industrial growth is expected to push the prices down, the expected PV generation costs will decrease year by year for each major cities of the world. For example, PV generation cost for roof top systems at Berlin was €0.44 in 2007. It will account for €0.20 in 2020 and €0.13 in 2030. This would increase the competitiveness of the price of electricity generated from PV against typical electricity prices which fluctuates dramatically. Related to the prices of electricity, the term Grid Parity should be mentioned. If PV generation costs and residential electricity prices meet, then Grid Parity will be held. With Grid Parity, every kWh of PV power consumed will be cheaper than the power consumed from conventional electricity technologies. EPIA expects that Grid Parity will be reached first in Italy between 2010 and 2012, and then other countries will benefit from the power generated from PV solar systems.

Environmental and Economic Impacts of Solar Energy

Since PV system is the most cost efficient use of solar energy and becomes more efficient year by year, PV systems' historical improvements and advantages and disadvantages should be explained.

From environmental perspective, solar power, with its all forms, is extraordinarily clean. Although there are some concerns about the toxicity of cadmium (Cd48) used in PV collectors, solar power generators cause no more manufacturing concerns than any other energy related product. As it is obvious, smoke, acid rain, air and water pollution, greenhouse gases such as CO_2 are the main problems that are created by the burning of traditional fossil fuels to generate energy. In contrast to the conventional resources, solar power uses only the power of sun as a fuel. It produces no harmful emissions or polluting gases. From Figure 23, the comparison of the energy sources in terms of the greenhouse gases they create can be seen.

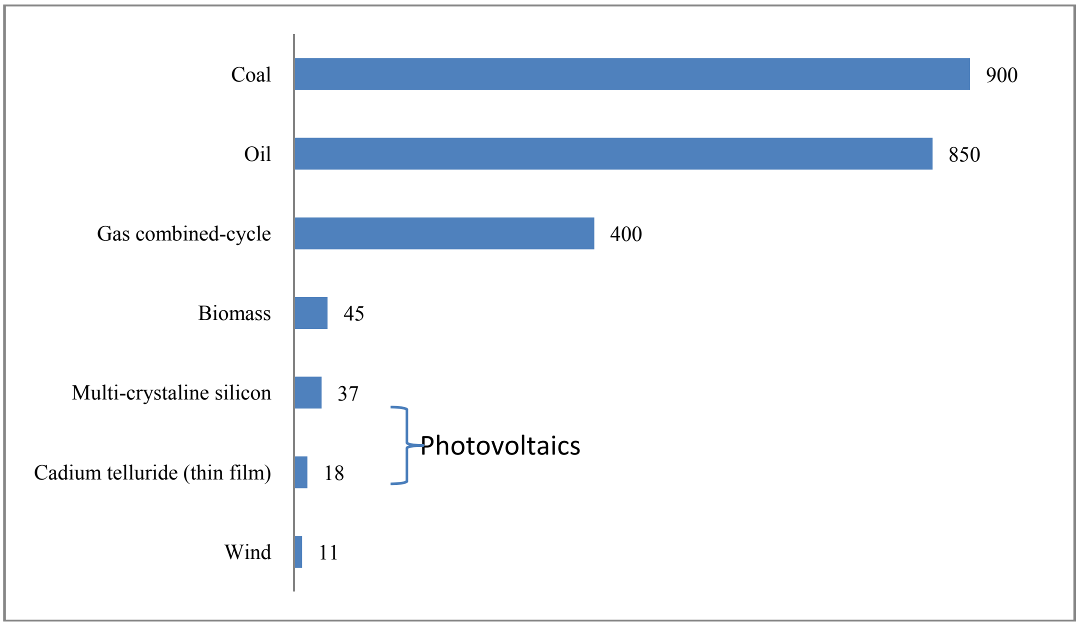


Figure 23. Greenhouse gases pew kilowatt-hour of CO_2 equivalent (EPIA, 2010) (Extern project, 2003; Kim and Dale, 2005; Fthenakis and Kim, 2006; Fthenakis and Kim, 2007; Fthenakis and Alsema, 2006)

While coal creates 900 grams per kWh of CO_2 equivalent greenhouse gases followed by oil with 850 grams per kWh of CO_2 equivalent, photovoltaic systems create only 55 grams per kWh of CO_2 including 37 grams for multi crystalline silicon and 18 grams for cadium telluride thin film. Because of its environmentally friendly feature, it helps reduce the future societal costs of climate change and the increase in the numbers of greenhouse gas related illnesses. Another environmental benefit of the PV system is that modules can be recycled, and naturally the used materials such as silicon, glass and aluminum can be reused. Moreover, PV systems do not produce noise.

According to the EPIA, the estimated life time of a PV module is 30 years and the modules which are almost maintenance free provide over 80% of the initial power after 25 years; therefore, PV systems are very reliable in the long term.

In the financial side of the PV systems, it is clear that the fuel is free since sunlight is free and abundant. However, solar power has a high up-front cost and it requires huge amounts of money to invest in. In addition to this, one of the most controversial issues for PV systems was whether the amount of energy required to manufacture a complete system is smaller or larger than the energy produced over its lifetime. The energy payback time of grid connected PV systems was 2-6 years in 2003 (Assmann et al., 2006). Fortunately, the energy payback time of PV constantly decreases which means that the time required for a PV system to generate as much energy as it requires to be manufactured will be very short. Although solar cells historically have been an expensive way to generate electricity, as mentioned above, this situation started to change rapidly and power generation costs of PV systems began to decrease year by year. Thus, PV solar systems free the countries from foreign oil and natural gas dependence.

The solar PV systems also have many social benefits. For example, it brings electricity to remote rural areas in developing countries in where electricity is not available through house lighting, water pumping, and hospital refrigeration and telecommunication systems. The PV industry increasingly makes contribution to the job creation in worldwide. According to the Solar Generation 6 Report 2011 prepared by EPIA, 30 full time job equivalent jobs are created for each MW of solar power modules produced and installed. Using this assumption, more than 228,000 people are employed in the solar energy sector in 2009 and reach almost 509,000 by 2030.

The forecast and projections of investment and employment potential of solar PV under three scenarios which are reference, accelerated and paradigm shift scenario are shown below.

Table 23. Investment and Employment Potential of Solar PV (Greenpeace/EPIA, 2010)

Reference Scenario	2008	2009	2010	2015	2020	2030	2040	2050
Annual Installation MW	4.940	7.262	7.550	4.117	5.920	18.740	19.928	20.129
Cost €/kW	3.000	2.900	2.800	2.351	2.080	1.703	1.487	1.382
Investment € billion/year	15	21	14	12	13	27	30	28
Employment Job/year	156.965	228.149	237.093	136.329	187.464	508.944	476.114	692.655
Accelerated Scenario								
Annual Installation MW	4.940	7.262	12.091	27.091	59.031	96.171	162.316	174.796
Cost €/kW	3.000	2.900	2.800	1.855	1.340	966	826	758
Investment € billion/year	15	21	34	50	79	93	134	133
Employment Job/year	156.965	228.149	374.319	810.228	1.690.603	2.629.968	4.027.349	43.153.343
Paradigm Shift Scenario								
Annual Installation MW	4.940	7.262	13.625	47.000	135.376	136.833	250.000	250.000
Cost €/kW	3.000	2.900	2.500	1.499	951	744	645	596
Investment € billion/year	15	21	34	70	129	100	161	149
Employment Job/year	156.965	228.149	417.010	1.372.185	3.781.553	3.546.820	5.563.681	5.346.320

In very broad scope, while reference scenario is the most pessimist projection, accelerated and paradigm shift scenarios assume that total of world cumulative PV installed capacity will shoot up. Although the three scenarios indicate that overall costs of PV plants will decrease, the momentum of this decrease will be very different for each option. Similar to the cost issue, annual installation and investment volume will increase in all scenarios but this increase will remain very limited under reference scenario. Parallel to the investment trend, in 2020, PV industry will hire more than 1,690 million people under accelerated scenario, while paradigm shift scenario forecasts that 3,780 million people will be employed in PV sector.

On the other hand, solar PV modules do suffer intermittent problems similar to wind turbines since the sun does not shine always, thus, solar PV panels may not work well on cloudy days. Additional cells and some form of grid energy storage will be needed to provide enough power to meet daytime demand and store energy for cloudy periods. However, since the intermittency is 100% predictable and the clouds only diminish solar cell productivity and cannot eliminate it, these problems in solar PV systems can be handled by focusing on the number of cloudless days per year, latitude, the cost of the solar collectors and the percentage of grid demand supplied by solar modules.

To top things of nicely, the gravity of solar energy is increasing day by day. Solar thermal in heating and cooling, concentrated solar power both in heating & cooling and especially in small and medium electricity generation and solar PVs in large scale of electricity production have significant shares among not only renewables but also whole energy resources.

After explaining the solar energy deeply, the next section will cover the geothermal energy technologies.

Global Geothermal Energy Outlook

Geothermal energy is the heat of the earth. It has been discovered on the earth's surface in the forms of fumaroles, geysers, volcanoes and hot springs. With another words, geothermal energy refers to the energy stored in form of heat beneath the earth's surface.

IEA defines geothermal as energy available as heat emitted from within the earth's crust, generally in the form of hot water or stream. In fact, thermal energy is available everywhere in the upper 10 km of the earth's crust, with a mean temperature gradient of 20 to 30°C/km depth (Kruger, 2006). In addition, geothermal energy has large theoretical potential which is widely dispersed in the world. However, it is expected that the technological ability to use geothermal energy, not its quantity, will determine its future share. From Table 24, global geothermal energy resources potential and the shares of regions will be seen.

Table 24. Annual Global Geothermal Energy Sources by Regions (Assmann et al., 2006) (WEA, 2000)

Region	Millions EJ	%
North America	26	18,6
Latin America and Carribbean	26	18,6
Western Europe	7	5,0
Eastern Europe and Former Soviet Union	23	16,4
Middle East and North Africa	6	4,3
Sub-Saharan Africa	17	12,2
Pacific Asia	11	7,8
China	11	7,8
Central and South Asia	13	9,3
Total	140	100

Total of annual global geothermal energy resources accounts for 140 million EJ. North America with Latin America and Caribbean has the largest share with each 26 million EJ, followed by Eastern Europe and Former Soviet Union with 17 million EJ and Sub Saharan Africa with 17 million EJ. Central and South Asia with 13million EJ geothermal energy resources has 9.3% of total share. It is noteworthy that China, only itself, has roughly 11 million EJ geothermal energy reserves while the share of Western Europe is only 5% of total.

Geothermal springs have been used for bathing, healing and cooking for centuries. In the early 1900s, geothermal fluids were being exploited for their energy content. Several research studies are made to extract boric acid from natural hot water outlets and the low pressure steam was utilized to heat industrial and residential buildings and greenhouses. Along with the heating purpose, the goal of electricity generation from geothermal energy was also achieved in the same time period. Italy, Iceland and followed by Japan, the U.S., New Zealand and Mexico were the important countries in the process of geothermal energy development. By 1942, for example, the installed geothermal capacity had reached 128MWe.

In consequence, geothermal use can mainly be divided into two categories: (1) direct application including space heating and cooling, industrial heating and drying, greenhouses, fish farming and health spas, and (2) electricity production. Many researchers have investigated geothermal potential, both for electricity generation and the direct uses. The International Geothermal Association (IGA) collected all the existing data related to geothermal energy estimations and established confidence interval of the minimum and maximum expected potential for the geothermal exploitation. Table 25 shows the range of world geothermal potential.

Table 25. The Range of Electrical and Direct Uses Potential (IGA, 2003)

	Electricity			
	2003	Extrapolation to year 2020	Minimum	Maximum
TWh/y	50	300	1,000	40,000
GW	8	40	140	6,000
Direct uses				
	2003	Extrapolation to year 2020	Minimum	Maximum
TWh/y	50	140/700	100,000	170,000,000
GWth	15	40/200	30,000	50,000,000

Electrical potential of geothermal energy is 50TWh/y in 2003 which is equal to 8GW. It is expected to reach 300TWh/y, or 40GW, by 2020. While minimum value is 1,000TWh/y and the maximum value is 40,000TWh/y for electricity, the range in terms of GW varies between 140GW and 6,000GW. Direct uses, which are also 50Twh/y, will be amounted to between 140 and 170TWh/y by 2020. Its potential range will be 100,000Twh/y for minimum and 170millionTWh/y for maximum point.

Geothermal Heating and Cooling

The heat from geothermal energy can be obtained in two ways. The first way is that the low temperature in the ground is increased to a useful temperature by using geothermal heat pump (GHP). The second includes direct exploitation of the ground water of the deeper substratum, the temperature of which varies between 25°C and 150°C. Therefore, geothermal heating and cooling can be applied in three areas which are geothermal heat pumps, geothermal energy storage and direct applications including district heating (DH).

While geothermal heat pumps allow transport of heat from a lower level to a higher level, by using external energy that should be as low as possible, the low temperature in the ground can be changed by storage of heat and cold. Two types of geothermal energy storage are borehole thermal energy storage (BTES) which does not need a ground water flow and provides a medium thermal conductivity and aquifer thermal energy storage (ATES) which uses ground water as a heat carrier.

Major areas of direct use of geothermal are central heating and cooling including district heating, agribusiness applications, aquaculture, industrial processes, bathing, swimming and balneology. Figure 24 shows the use of geothermal energy for heating purposes.

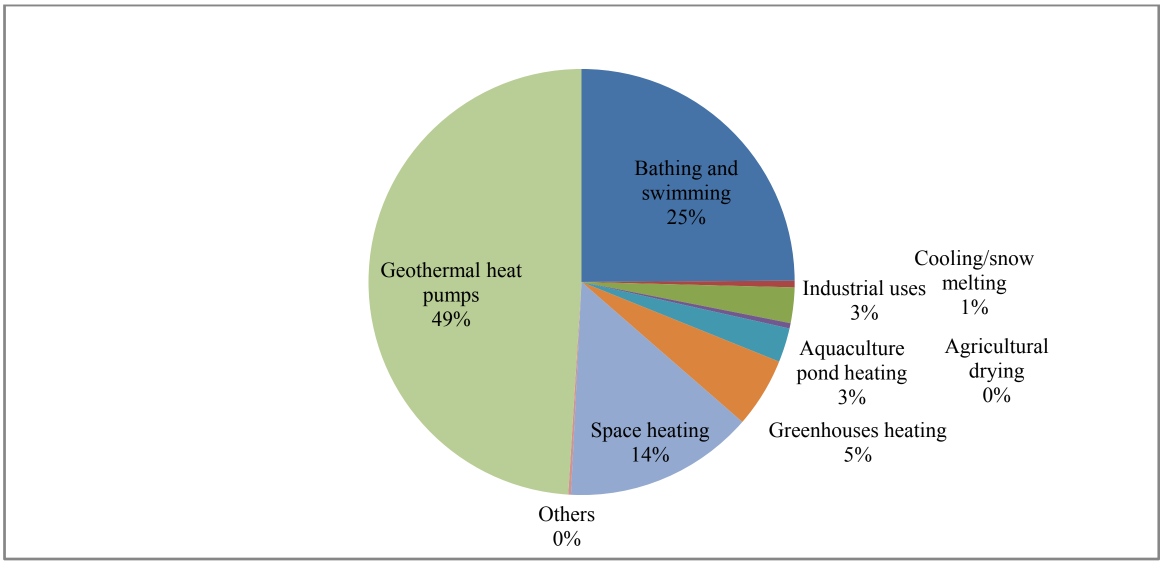


Figure 24. Geothermal direct use applications worldwide in 2010 by percentage of total energy use (IGA, 2010)

In 2010, geothermal heat pumps have the largest share with 49% among direct use applications of geothermal energy. Bathing and swimming has 24.9% share and space heating with geothermal energy which has a wide spread application in residential and industrial buildings took third place with 14.4% of total share in 2010. Greenhouses heating, industrial uses and aquaculture pond heating were the other geothermal heating and cooling applications. It should be mentioned that geothermal energy was used most extensively in agriculture for greenhouse heating during the last 25 years. Since there is often a good correlation between low enthalpy geothermal reservoirs and the sites of greenhouse production areas, interest in that area started to accelerate.

Another application of geothermal is agricultural drying. According to the European Geothermal Energy Council (EGEC, 2007), drying of agricultural products with geothermal energy offers competitiveness and improves quality for different products. There are many successful country examples such as Hungary in drying grains, Greece in drying vegetables, Turkey in drying fruits and Poland in drying wood. Furthermore, geothermal aquaculture which is called fish growing in Greece and France also experienced significant growth.

For the costs of geothermal heating and cooling applications, it can be observed that the regulatory aspects, exploration and investigation for resource classification and exploitation are the most important factors. In other words, the investment, operation and maintenance (O&M) and the development costs compose the overall cost of a geothermal project.

Investment costs of the geothermal projects are mainly influenced by the plant size because specific costs generally decrease with increasing plant size. Plant costs including machinery, design, equipment, engineering, and field costs including drilling, field development, reservoir management and surface exploration are the main sub dimensions of the investment costs. For typical geothermal DH systems which have high investment costs but low operating costs, investment costs are well equipment costs, geothermal plant costs and heat distribution network costs. In contrast to the investment costs, O&M costs are relatively low in geothermal projects. O&M costs consist of costs for personnel, insurance, maintenance and electricity. Consequently, while investment costs vary from €0.2 to €1.2 million per MW, production costs of geothermal heat generation vary from €5 to €45 million per MW (EREC, 2010). While residential geothermal heat pumps with a capacity of 10kW are generally installed for around 1,000-3,000 € per kW, the capital cost of a geothermal district heating system is estimated at approximately over €1 million per MW. Depending on local geothermal settings such as high/low heat flows and shallow/deep seated sources, socio economic conditions and pricing policies, the average MWht selling price to geothermal direct heating subscribers varies between

30 and 60€/MWht (EGEC, 2007). Finally, the cost of electricity generated from geothermal reserves ranges from €0.03 to €0.10c/kWh (Mondaq, 2008).

Between 1995 and 2009, the annual number of newly installed geothermal heat pumps increased by five times. According to the REN21, the use of geothermal direct use heat plants and ground source heat pumps started to grow. There exists some 60GWth of heating capacity from geothermal globally. It is important to note that direct use of geothermal energy is growing faster than geothermal power, with an average annual growth rates exceeding 12% since 2005. Global capacity reached an estimated 51GWth at the end of 2009. Ground source heat pumps, at 35GWth, accounted for 70% of global capacity and almost 50% of direct heat use in 2009. Bathing and swimming has a share of 25% of total geothermal direct heat, followed by district heating with 14% and the others including greenhouses, aquaculture pond heating, agricultural drying, and snow melting, cooling and industrial purposes.

International Geothermal Association (IGA, 2010) emphasizes that lower temperature geothermal resources are found in almost every country in the world. As of 2010, there are 50,583MWth of installed direct use capacity in 78 countries, generating 121,693GWth of geothermal energy per year. The number of countries that use direct geothermal energy was 58 in 2000 and 72 in 2005 which illustrate the growing trend of geothermal heating and cooling clearly.

The United States with almost 13GWth is the leading country in installed direct geothermal energy capacity, followed by China with 9GWth, Sweden with 4.5GWth. Germany has 4.2GWth of capacity including 4.1GWth of heat pumps and 0.1GWth deep geothermal for district heat. Norway also has 3.3GWth installed direct geothermal energy. However, China surpasses the United States in actual energy production at 21TWh, followed by the U.S. with 16TWh, Sweden with 13TWh and

Turkey with 10TWh. Due to the fact that majority of direct use of geothermal energy capacity stems from heat pumps, all these numbers show that installed heat pump capacity has more than doubled since 2005. District heating and direct use geothermal applications are emphasized in many national renewable energy policies since geothermal is an effective way in curbing greenhouse gas emissions. In practice, the importance of geothermal heating and cooling is started to be seen. For instance, China used geothermal heat pumps to heat and cool some of the venues at the 2008 Olympic Games in Beijing.

Although the heating and cooling demand accounts for 49% of the overall final energy demand in the EU, the union has a very modest geothermal heat pump market. Total geothermal heat capacity is almost 12,000MWth in 2008 and ground source heat pump accounts for 9,000MWth of this amount. Almost all of the installations are located in north and central Europe, especially Sweden and Switzerland. Table 26 shows the total quantities and installed capacity of geothermal heat pumps in the EU.

Table 26. Total Quantities and Installed Capacity of Geothermal Heat Pumps in the EU at the end of 2007 and at the end of 2008 (EREC, 2010) (Eurobserv'ER, 2007)

	2007		2008	
	Number	Capacity (MWth)	Number	Capacity (MWth)
Sweden	298049	2682,0	320687	2909,0
Germany	115813	1273,9	150263	1652,9
France	102456	1127,0	121886	1340,7
Finland	38912	827,9	46412	857,9
Austria	40549	454,1	48641	544,8
Netherlands	15230	392,0	19310	508,0
Poland	10000	133,0	11000	180,0
Ireland	7578	124,0	9673	157,0
Italy	7500	150,0	7500	150,0
Czech Republic	6965	112,0	9168	147,0
United Kingdom	5350	69,6	10350	134,6
Denmark	11250	123,8	11250	123,8

Belgium	8200	98,4	9500	114,0
Estonia	3913	50,1	4874	63,0
Hungary	350	15,0	350	15,0
Slovenia	720	6,4	1125	12,2
Lithuania	200	4,3	200	4,3
Romania	40	2,0	40	2,0
Greece	194	1,9	194	1,9
Slovakia	8	1,4	8	1,4
Bulgaria	19	0,3	19	0,3
Latvia	10	0,2	10	0,2
Portugal	1	0,21	1	0,2
Total EU 27	673307	7649,5	782461	8920,2

In 2008, the EU has experienced %16 of annual growth in geothermal heat pumps market and reached 8,920 MWth by the end of year. Sweden with more than two times bigger than Germany, the closest country, had more 320,000 units for a geothermal heat capacity in the region with 2900MWth by the end of 2008. Germany and France are the only countries had more than 100,000 units of thermal heat pumps in the same year.

Contrary to the heat pumps, the largest geothermal district heating systems within Europe can be observed in Paris in France, Austria, Germany, Hungary, Italy, Poland and Slovakia. In 2008, geothermal heating alone supplied approximately 3Mtoe in the EU and more than 1Mtoe in other European countries. European Renewable Energy Council, in its Rethinking 2050 report, gives attention to the renewable heating and cooling and indicates that geothermal will make up a share of about 10% of total renewable heat contribution by 2030. Table 27 shows the projections on the EU's renewable heating and cooling market

Table 27. Renewable Heating and Cooling Consumption in mtoe (EREC, 2010)

	2007	2020	2030	2050
Biomas	61,2	120	175	214,5
Solar Thermal	0,88	12	48	122
Geothermal	0,9	7	24	136,1

While geothermal energy based heating and cooling placed third rank after biomass and solar thermal in 2007, it is expected that, by 2050 geothermal heat and cooling will experience a huge growth and surpass solar thermal by reaching 136.1Mtoe. Table 28 shows the projection of total heat and cold production in the EU.

Table 28. Heating & Cooling up to 2050 in the EU (EREC, 2010)

Heating & Cooling - EU-27 (Mtoe)	2010	2020	2030	2050
Geothermal Heat Pumps	2,3	6	12	70
Geothermal Direct uses	1,8	2,5	6	20
Heating from CH &P	0,2	2	12	60
Total Heat and Cold Production	4,3	10,5	30	150

This estimation study includes geothermal heat pumps, geothermal direct uses and heating from combined heat power (CHP). By 2020, the EU will try to strengthen the European geothermal industry by increasing the market penetration of geothermal heat pumps and ensuring a wider spread of geothermal district heating and cooling systems. These efforts will provide a pre frame for the huge expansion of geothermal energy use in the Europe. Agricultural applications, new district heating systems for dense urban areas will be established and developed by 2030. These will help geothermal heat pumps and direct use to double in 2030. Finally, geothermal heating and cooling systems will be available and economic for individual buildings and urban areas in 2050. By achieving 70mtoe of geothermal heat pumps, 20mtoe of direct uses and 60mtoes of CHP heating, geothermal will replace conventional power plants such as coal, nuclear and fuel by 2050.

Geothermal Electricity

Geothermal electricity production has not experienced significant growth between 1990 and 2009. From Figure 25, it can be seen that OECD total in gross electricity production from geothermal has experienced an average annual growth rate of 2%, from 28.6TWh to 41TWh.

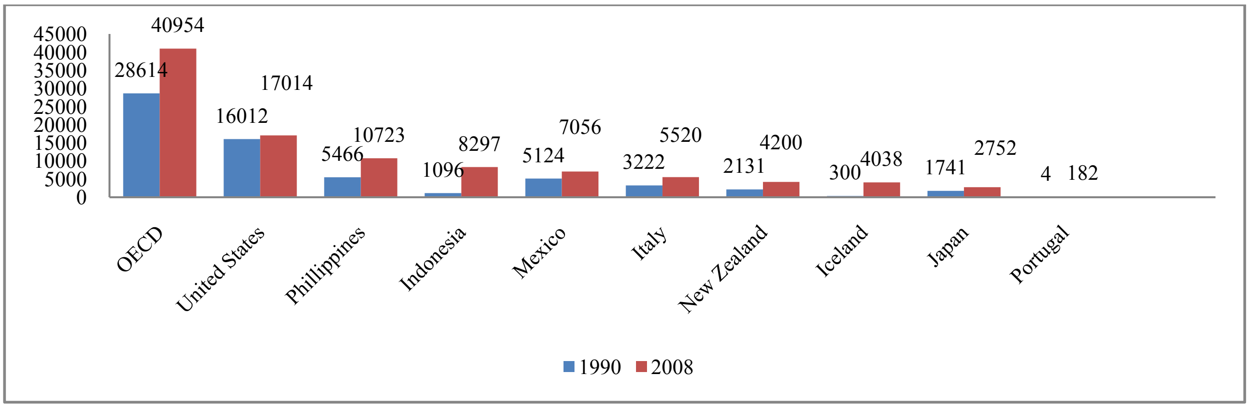


Figure 25. Gross electricity production from renewable and waste sources in GWh (IEA-OECD, 2010)

As depicted figure above, the United States remains the leading geothermal producer of the world with more than 17 TWh of electricity or 39,8% of the OECD total in 2009. However, she could only increase its geothermal electricity generation by 1 TWh in two decades. Two non-OECD countries, the Philippines and Indonesia are the success story of geothermal power utilization. While the Philippines has almost doubled its electricity production from geothermal, Indonesia which had only 1TWh in 1990, has increased the amount of geothermal electricity by more than 7 fold. While Mexico follows those countries, Italy and Iceland are the major representatives of the Europe. Italy with 5.3TWh is the leading country in OECD Europe. New Zealand and Japan followed those countries with the shares of 11.6% and 7%, respectively. Although she is not a critical geothermal electricity producer country, between 1990 and 2009, Portugal experienced a highest growth rate of geothermal electricity generation among OECD countries, %22, by increasing its production from 4GWh to 182 GWh. For the sub region classification, OECD North America remained the largest geothermal electricity producer, with a 56% share in 2009. While OECD Europe generated 10.5TWh of estimated geothermal electricity in 2009, OECD Pacific region could only produce approximately 7.7TWh of electricity from geothermal energy.

Before focusing on the global outlook of total geothermal power capacity including all installed geothermal power plants, it will be beneficial to review geothermal power systems briefly.

Geothermal Power Systems

Geothermal system includes three components which are a heat source, a reservoir and a heat carrier fluid. While the heat source can be either a magmatic intrusion at very high temperature at relatively shallow depths or hot rocks at depth, the reservoir consists of hot permeable rocks from which circulating fluids extract heat (EREC, 2010). The heat carrier fluid in geothermal power systems is water, most often of meteoric origin. In the working principle, hot water and steam are extracted by drilling wells into the reservoir, and once available at production well heads, geothermal fluids can be used for electric power production, direct uses or combined heat and power. Main difference between conventional power plants and geothermal ones is that conventional power plants burn fossil fuels to boil water. Per contra, geothermal power plants use steam produced from geothermal reservoirs which are located at several hundred to a few thousand meters below ground.

There are three types of geothermal power plants: (1) Dry steam, (2) Flash steam and (3) binary cycle.

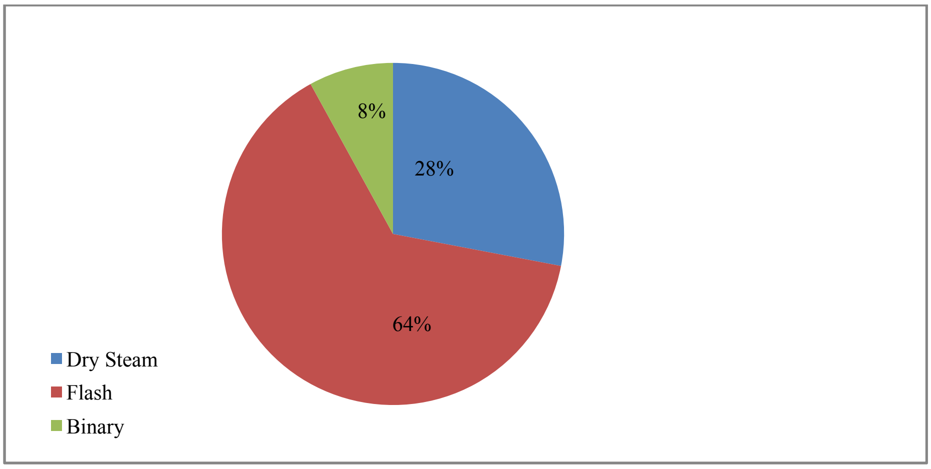


Figure 26. World geothermal power plant distribution, 2009 (EGEC, 2009)

Flash steam plants have the largest share with 64% of total followed by dry steam and binary plants with 28% and 8%, respectively. However, since binary plants offer low cost energy extras at zero mining costs, interest in those units grow gradually. For example, 500 geothermal units were reported online in 2008. According to European Geothermal Energy Council (EGEC), binary plants with the quantity of 250 units and estimated 800 MW installed capacity was the leading geothermal power plant type followed by dry and flash steam plants estimated average 44MW and 31MW, respectively.

Dry steam power plants utilize directly steam, which is piped from production wells to the main plant, then directed towards turbine blades. These turbines require fluids of at least 150°C. Dry steam geothermal plants generally have 55 to 60 MW capacities but 110MW plant installed capacity are recently began to operate. The oldest dry steam power plant is located in the Larderello basin of Italy. Flash steam plants, on the other side, address water dominated reservoirs and temperatures above 180°C. The hot pressured water flows up the well through water stream mixture and a vapor lift process.

Finally, binary cycle power plants which is known organic Rankine cycle (ORC) recover the heat from the geothermal fluid via a heat exchanger for vaporizing a low boiling point organic fluid operate with waters in the 100 to 180°C temperature range. Those binary processes are emerging as a cost effective conversion technology for recovering power from geothermal fields at temperatures below 180°C.

It should be added that Kalina cycle which is a new binary process, has been developed recently. It has attractive conversion efficiencies stem from the use of ammonia water working fluid mixture which allows the system to benefit from the low boiling point of it. Compare to the dry and flash steam power plants, the efficiency of Kalina cycle is estimated at 40%. In addition to all these power plant systems, enhanced geothermal system (EGS) is also very recent mode of geothermal electricity plant. If natural geothermal resources in form of steam and hot water do not exist in the places where the geothermal electricity will be generated in, the heat of the rock can be used by creating artificial permeability for fluids extracting that heat by EGS. After 30 years of R&D actions of the EU on that technology, France could operate the EGS with two production wells and one injection well in 2008.

According to many researchers, concept of EGS will allow geothermal power generation everywhere in the world. However, its overall costs are relatively high compare to the binary and conventional power systems. Current EGS power production costs vary between 0.20-0.30 €/kWh range. EGEC expects that production costs of EGS will be brought down below 0.10€/kwh by 2030 by the helping of technological innovation, learning curve and combined heat power (CHP) optimization.

Last but not least, supercritical fluids and magmatic resources are the promising technologies of future geothermal power plants.

In 2008, geothermal was the third largest renewable source, representing 0.5% of world TPES, or 3.7% of total renewables supply in the world. Annual growth rate of geothermal energy supply from 1990 to 2008 was 3.1%. This rate, according to the Earth Policy Institute (EPI) did not change within the narrower time interval and average annual growth rate of geothermal power between 2000 and 2010 was 3%. Figure 27 shows the proportions of renewable primary energy supply in OECD countries.

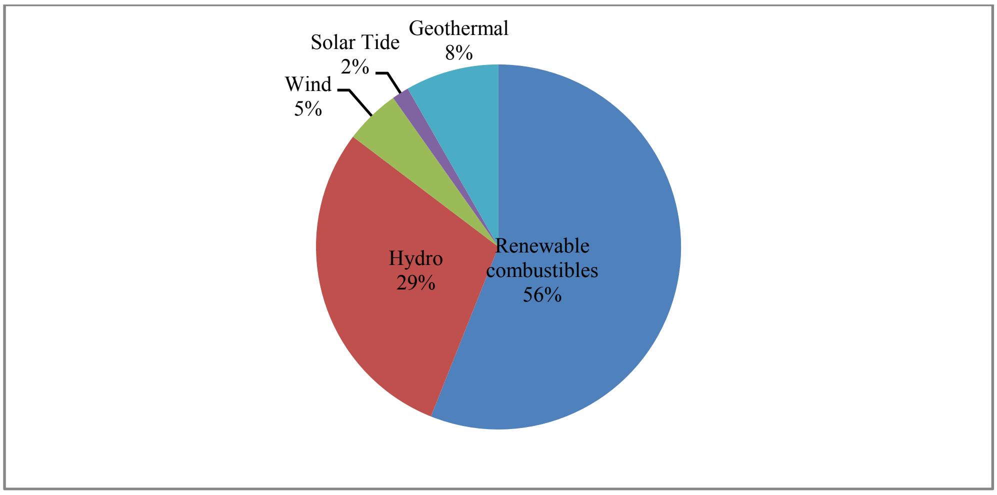


Figure 27. Product shares of renewable energy supply in OECD in 2009 (IEA, 2010)

Renewable combustibles and wastes including solid biomass, biogas, liquid biomass and the renewable portion of municipal waste provided 56.1% of renewable primary energy in OECD countries by 2009. Hydroelectric power is the second largest renewable energy source with 29.3% of total supply. While liquid biomass was the third largest renewable energy source, geothermal with a share of 8.3%, has ranked fourth in total renewable energy supply in 2009.

As of 2009, total cumulative installed geothermal power capacity is 10,702 MW. From Table 29, historical development of geothermal power for each country can be seen.

Table 29. Cumulative Installed Geothermal Power Capacity as of 2009 (BP, 2010)

Megawatts	2003	2004	2005	2006	2007	2008	2009	Change 2009 over 2008	2009 Share of total
Argentina	–	–	–	–	–	–	–	–	-
Austria	1,3	1,2	1,2	1,2	1,2	1,2	1,4	16,7%	-
Australia	0,2	0,2	0,2	0,2	0,2	0,2	1,1	450,0%	-
China	27,8	27,8	27,8	27,8	27,8	24,0	24,0	–	0,2%
Costa Rica	162,5	162,5	162,5	162,5	162,5	162,5	166,0	2,2%	1,5%
El Salvador	161,0	151,0	151,0	195,0	195,0	204,4	204,4	–	1,9%
Ethiopia	7,3	7,3	7,3	7,3	7,3	7,3	7,3	–	0,1%
France (Guadeloupe)	4,2	14,7	14,7	14,7	14,7	16,0	16,0	–	0,1%
Germany	0,2	0,2	0,2	0,2	3,2	6,6	6,6	–	0,1%
Guatemala	33,0	33,0	33,0	33,0	52,0	52,0	52,0	–	0,5%
Iceland	202,1	202,1	202,1	312,1	485,1	575,1	575,1	–	5,4%
Indonesia	807,0	807,0	855,5	921,0	992,0	1060,0	1197,0	12,9%	11,2%
Italy	790,5	790,5	790,5	810,5	810,5	810,5	843,0	4,0%	7,9%
Japan	534,0	534,0	534,0	536,0	536,0	536,0	536,0	–	5,0%
Kenya	121,0	127,0	129,0	129,0	131,0	167,0	167,0	–	1,6%
Mexico	953,0	953,0	953,0	953,0	958,0	958,0	958,0	–	8,9%
New Zealand	399,0	397,0	435,0	488,0	505,0	628,3	628,3	–	5,9%
Nicaragua	77,5	77,5	77,5	77,5	87,5	87,5	87,5	–	0,8%
Papua New Guinea	5,5	5,5	5,5	36,0	56,0	56,0	56,0	–	0,5%
Philippines	1931,0	1931,0	1931,0	1969,7	1908,7	1904,0	1904,0	–	17,8%
Portugal (The Azores)	16,0	16,0	16,0	16,0	29,0	29,0	29,0	–	0,3%
Russia (Kamchatka)	73,0	79,0	79,0	79,0	82,0	82,0	82,0	–	0,8%
Thailand	0,3	0,3	0,3	0,3	0,3	0,3	0,3	–	-
Turkey	20,4	20,4	20,4	27,8	27,8	34,6	81,6	135,8%	0,8%
US	2020,0	2534,0	2653,0	2687,0	2849,6	2910,6	3086,6	6,0%	28,8%
Total World	8347,8	8872,2	9079,7	9484,8	9922,4	10313,1	10710,2	3,9%	100,0%

24 countries excluding Argentina which stopped producing energy from its geothermal resource with their operating geothermal power plants all together generated more than 10.7GW of geothermal power by the end of 2009. In other words, those power plants generate more than 67TWh of electricity annually. The United States with 3,086MW has a 28.8% of world total geothermal power. It is very noteworthy that two non OECD countries, the Philippines and Indonesia are in the second and third rank in global geothermal industry with the share of 17.8% and 11.2% or 1,904MW and 1,197MW, respectively. While Mexico has 958MW of geothermal power, Italy follows Mexico with 843MW of installed geothermal power capacity. New Zealand, Iceland and Japan also have significant capacity in geothermal energy.

Another noteworthy point is that Turkey has experienced 135.8% of annual growth in 2009 and reached 81.6MW of geothermal power capacity. When this volume is compared with the country's huge geothermal potential, it remains very low and limited. An important role of geothermal power can also be seen from some successful countries. For instance, Iceland which is the world leader on a per capita basis with 575MW of geothermal power capacity generates about 90% of its heating energy and 25% of its total electricity from geothermal energy. Similar to Iceland, the Philippines also does meet 18% of its electricity demand from geothermal power. Geothermal power plants provide 26% of the electricity in El Salvador.

In investment side, the greatest increase in installed geothermal power capacity between 2005 and 2010 were (1) the U.S.-530MW, (2) Indonesia-400MW, (3) Iceland-373MW, (4) New Zealand-193MW and (5) Turkey-62MW. Within the same time period, Germany with 2,774%, Papua New Guinea with 833%, Australia with 633%, Turkey with 308% and Iceland with 184% were the leading countries in terms of the percentage increase in geothermal power capacity.

Geothermal energy has fallen by 28% in financial investment in 2009. As all renewable energy resources felt the impacts of global financial crisis, geothermal energy industry also suffered from crisis too. As a renewable requires huge amount of money due to its high start up costs, many investors have not invested in geothermal sector. According to the Bloomberg New Energy Finance, geothermal industry has attracted only $2 billion of financial new investment in 2009. For example, global geothermal sector experienced only two acquisition activities during 2009. Thus, the investments made by venture capital and private equity firms happened only $0.1 billion in 2009. In addition, geothermal with marine industry saw the greatest drop off in R&D funding in 2009, falling by 14% and 13%, respectively.

However, Bloomberg NEF thinks that the fall in geothermal financial investment is temporarily because the level of interest from investors to geothermal remained buoyant everywhere from the hot rocks developments of Australia to Indonesia and the western states of the U.S. This drop probably stemmed from economic influences such as the sharp price decreases in Iceland and the shortage of debt and tax equity finance in the U.S. By the declining of negative impacts of financial crisis on the global economy, the recovery for geothermal industry will be inevitable. As of early 2010, the United States with its 15 states developed nearly 200 geothermal projects which could result 5.2GW to 7.9GW of new capacity.

Although investment volume of geothermal energy dropped in 2009 and its average growth rate is relatively slow compare to the other new renewables such as wind and PV, interest in geothermal energy will increase in the coming years. In company basis, for example, General Electric Energy Financial Services made its first geothermal investment outside the U.S. and announced a $50 million loan for the 220MW Wayang Windu plant in Indonesia developed by Star Energy.

Interest in geothermal has already increased in many countries. Geothermal projects under development grew the most dramatically in Europe and Africa. While ten European countries were working on geothermal projects, this number has more than doubled to twenty four in 2010. Six African countries were trying to develop their geothermal energy resources in 2007, and eleven countries in Africa began to actively consider geothermal power in 2010. For example, it is expected to produce geothermal energy in East Africa’s Rift Valley in Kenya and in Eritrea, Ethiopia, Tanzania and Uganda. Argentina, Canada, Chile, Greece, Hungary, Honduras, Romania, Slovakia, Spain and the Netherlands are the countries which are projected to install initial geothermal capacity by 2015. Many other countries have already set their geothermal goals. Since majority of those countries are European and the EU has very significant and realized targets for the future, the following section will focus on the European geothermal market.

It should be concluded that the geothermal energy will gain strength slowly and its share in total renewable energy resources will develop gradually by the helping of technological advancement, supportive policies and well analysis of its potential benefits. Indeed, the total installed capacity of geothermal power plants is expected to increase from the value of 10.7GW in 2010 to about 160GW by 2050 (IGA, 2010).

European Union Geothermal Energy Outlook

The European Geothermal Energy Council (EGEC) has set targets for installed electric power from geothermal capacity at 5GW total for all of the Europe by 2020, increasing to 15GW by 2030 which means that 5% of total energy production in Europe will be met with geothermal energy resources by 2030. A 3.5% of total heat generation in Europe is also expected to be met by geothermal sector. However, many European countries lack traditional geothermal resources. Unlike solar PV and wind, geothermal sources are concentrated in particular European countries. The vast majority of geothermal energy resources in Continental Europe are located in Italy, Iceland and Turkey. The exploited geothermal potential so far represents 0.3% of the whole renewable energy market.

The most abundant regions in terms of geothermal resources are Larderello-Travale/Radicondoli and Monte Amiata in Italy. These geothermal areas have 810MW installed capacity. While Iceland follows Italy by achieving 575MW of geothermal power, the country with its active volcano also is the leading country in direct uses of geothermal energy, especially in greenhouse and district heating.

Since Turkey is not a member of the EU, Turkish geothermal market will be discussed separately. In the meantime, although Greece has high temperature geothermal resources in the Aegean volcanic island, it could not benefit from those resources because local community forced the geothermal operator to stop its operations. It can be asserted that no matter what kind of energy resource is taken into account, the potential of energy resources only itself, cannot provide sufficient conditions to generate energy or electricity. Creating public awareness, building a strong public communication and assessing a cooperation linkage with nongovernmental organizations are must.

Since the EU has not diversified geothermal resources in its all countries, new technologies and new power system have critical role in achieving the goals set by the EGEC. Therefore, Germany and Austria try to integrate Organic Rankine Cycle (ORC) and Kalina cycle under binary power plants. This will let the countries to produce electricity from cooler geothermal resources. They also try to develop Enhanced Geothermal Systems (EGS) technology to tap into the vast hot rock potential available. The EU looks at the EGS as a hope for the future of its geothermal market.

According to the EGEC, the average growth rate of installed geothermal capacities is slowly decreasing from 4.8% during the 1990-2000 decade to 3.7% for 2000-2010 and 3.3% for 2010-2020. Obviously, these rates do not constitute a reason to be hopeful for geothermal industry in Europe. The geothermal electricity development of the EU stands at the range 1,500 to 2,000MW in 2010. It is estimated to reach 4,000 to 6,000MW in 2020. However, these volumes are defined without the EGS contribution. If EGS begins to generate energy, then, the target of the EGEC will be met and naturally this will help to reach the target of EREC's 20% renewable by 2020.

As explained earlier, Italy is the leader geothermal country among the EU countries. Enel Green Power is the group operates all geothermal areas of the country. In 2009, two additional geothermal power plants were added the country's geothermal power systems and the total installed geothermal capacity became 843MW. The government supports the geothermal industry via feed in tariffs. There is a fixed feed in tariff of €cents20/kWh for 15 years for geothermal plants.

Iceland ranks second place after Italy in Europe. It has seven geothermal plants which of six are currently operating and representing 575MW of an estimated 4,255MW of installable capacity. Iceland meets its power demand fully with the renewable energy resources. Geothermal energy industry supplies 25% of total electricity and 90% of heating. The country plans to install more than 1GW of geothermal power capacity.

France is the third country in Europe with its installed capacity of 16.5MW. The majority of this capacity comes from French West Indies Island of Guadeloupe. As explained above, EGS has a critical role in the EU's geothermal market. France has been dedicated to exploring the potential of EGS technologies in Soultz-sous-Forets area. The country tries to strengthen its market with policies and laws. In 2006, for example, France set targets of 90MW additional geothermal energy capacity by 2010 and 200MW by 2015. It also raised feed in tariffs for geothermal nearly 70% to €0.20/kWh for 15 years in 2010. This amount was €0.12/kWh in 2006.

As a main and dominant player of the EU, Germany has a relatively low investment volume in geothermal market compare to its huge shares in wind and solar industries. The country added its fifth power plant to its geothermal portfolio in

2009 and reached 6.6MW of cumulative installed capacity. However, this volume is insignificant in Germany's energy market. Although it has sufficient geothermal resources, Germany utilizes very little of its geothermal potential. In the light of all these realities, Germany set a target of installation of 280MW geothermal capacity by 2020. The government is willing to achieve this goal via a feed in tariff scheme providing €0.20/kWh for electricity produced from geothermal resources. As of 2010, 150 geothermal power plant projects are being developed which are equal to a €4 billion investment and contributing to the 14% annual growth rate of geothermal energy in Germany.

Greece is an important country in the EU which has more than 500MW geothermal potential. Unfortunately, those geothermal reservoirs have yet to be exploited. In addition, current geothermal projects are criticized and even stopped due to the lack of public awareness, worsening economic conditions and increasing social opposition to renewable energy projects. Another reason why Greece is not a successful in geothermal market is strict feed in tariffs. €cents7.3/kWh in the interconnected electric system and €cents8.46/kWh in the non interconnected island system over 12 years are not sufficient tools to promote geothermal energy in Greece. In order to change the situation, Greek government subsidies are available at 35% of the total investment for developing geothermal resources until 2013.

Spain with its two 20MW projects in Canary Island, the Netherlands with its increasing drilling license applications and Slovakia with a 5MW binary project are the other countries that develop their geothermal energy resources in the EU.

According to the EREC, geothermal power including electricity and heat and cooling will reach 188Mtoe by 2050 in the EU. Table 30 shows the projections of the contribution of each renewable energy resources to energy consumption.

Table 30. Contribution of Renewable Energy to Final Energy Consumption in mtoe (EREC, 2010)

RES Type	2007	2020	2030	2050
Wind	8,9	41	72	133,5
Hydro	27,9	33	34,2	38,5
PV	0,5	15,5	48	116
Bioenergy	77,8	175,5	226	359,1
Geothermal (Electricity and H&C)	1,4	9,7	35,5	188
Solar Thermal	0,9	12	70	122
CSP	0,1	3,7	12,1	33,1
Ocean	-	0,4	1,5	14
TOTAL RES Type	118	290,8	499,3	1004,2

In 2007, total renewable energy resources' contribution to final energy consumption was 118Mtoe and it is expected to increase 290.8Mtoe by 2020, 499.3Mtoe by 2030 and 1004Mtoe by 2050. By 2030, geothermal energy will surpass the hydro (excluding the capacity of pumped storage plants). Geothermal power will experience a huge growth and reach 188Mtoe in 2050. With this volume, it will take the second position after bioenergy and followed by wind, solar thermal, solar PV and hydro. EREC also expects a huge expansion on electricity generated from EGS. By 2010, only estimated 10MW of electricity EGS was produced but this will reach 4,500MW in 2020, 15,000 MW in 2030 and finally 90,000MW by the end of 2050. The expected sparkling development of EGS in the EU will help geothermal power to increase its 8Twh of yearly electricity production volume to 234Twh in 2030 and 780Twh by 2050.

Cost Analysis of Geothermal Power

In order to meet and realize those targets, in January 2009, EGEC published a geothermal research agenda fixing the research priorities for all geothermal technologies. In EGEC Brussels Declaration, in order to decrease costs (1) by 5% for geothermal district heating; reaching 40€/MWh_{th}, (2) by 10% for geothermal heat pumps; reaching 15€/MWh$_{th}$, (3) by 30% for conventional geothermal power including flash and dry steam; reaching 20€/MWh$_{el}$, (4) by 50% for low enthalpy electricity production; reaching 50€/MWh$_{el}$, and (5) by more than 50% for EGS; reaching 50€/MWh$_{el}$ were defined as primarily goals. From Table 31, summary of targeted cost reductions can be seen.

Table 31. Summary of Targeted Geothermal Energy Costs in the EU (EGEC, 2009)

HEATING & COOLING		Costs 2005	Average	Costs reduction by 2030
		Range(€/MWh)	(€/MWh)	(% 2005 costs)
Deep geothermal		2 to 40	7,2	+11
District Heating		40 to 80	50	-5
Shallow	Heat only	10,8 to 320	19	-9
	H&C: heating	7,2 to 270	61	-8
	H&C: cooling	7,2 to 350	16	-8
ELECTRICITY	Costs 2007 Range(€/MWh) (€/MWh)	Average	Costs 2030 Average (€/MWh)	
Conventional Geothermal Power	50 to 90	70	20	
Low Enthalpy Production	80 to 150	115	Target: 50	
EGS	200 to 300	250	Target: 50	
			Projection: 90	

There is no doubt that in order to achieve these sub targets until 2030, some costs related to this strategy should be projected. The EGEC estimates these costs as follows: 30 million €/year for R&D, 750 million €/year for new geothermal power plants, 200 million €/year for new heating and cooling investments, and 20 million €/year for supportive activities like education, training, promotion, public relations and legislation. As seen, these targets require huge amount of money. It seems that the European Investment Bank (EIB) has been and will likely continue to finance the EU’s geothermal projects. Again the EU funded Geothermal Finance and Awareness in European Regions (GEOFAR) under Intelligent Energy Europe (IEE) program will provide financing for geothermal energy investments, particularly for EGS integration.

When it comes to the main costs of geothermal power plants, there are many factors influencing the overall cost of geothermal projects. The investment, operation and maintenance and the development costs are the most important cost items. Two thirds of the geothermal power plants are related to drilling wells. Technological improvements in that area such as micro drilling technology for exploration and laser or fusion drilling for the main borehole drilling began to decline the share of drilling costs within overall geothermal project costs. The economics of electricity generation from geothermal are also affected by resource development. Cost of steel, temperature of the resource, resource depth and permeability and the size of the plant are other factors influencing the cost of a geothermal plant. California Energy Commission (CEC) in 2007 estimated that production costs for a 50MW geothermal binary plant is 92 $/MWh and for a 50MW dual flash geothermal plant is 88$/MWh. To illustrate, 500MW combined cycle natural gas power plant has 101 $/MWh of generation cost while 100MW simple natural gas cycle plant has 586 $/MWh.

Nevertheless, it should not be forgotten that since geothermal power cost is affected by the regional, national and even global competition for commodities such as cement, steel and construction equipment, the overall cost of geothermal projects may increase. Although operation costs for geothermal power plants are too low, high upfront costs and associated risks involved in geothermal development that mentioned above, force the companies to act prudently. For example, Electric Power Research Institute (EPRI) estimated that capital reimbursement and related interest amount for 65% of the total cost of geothermal power. This amount is accounted only 22% for combined cycle natural gas. However, fossil fuel cost for natural gas accounts for 67%. In the short term, investment in geothermal industry does not sound attractive but since geothermal plants have no fuel costs and over a typical 30 year plant life, geothermal energy can become smart investment opportunity in the medium and the long run. Thus, sustained governmental support for encouraging the investors to invest in geothermal industry is very crucial, especially in developing countries.

The Environmental and Economic Impacts of Geothermal Energy

Geothermal energy is considered purely renewable energy because it is generated from natural source of steam and hot water heated by hot rocks underground. As it is clear, earth's heat which is a constant source of unexhausted energy has been radiating from the center of the earth for 4.5 billion years. Thus, geothermal systems do not cover fuel costs. Unlike traditional fossil fuel power plants, geothermal power plants do not emit smoke because there is no burning activity. Although dry steam plants are considered to have the highest levels of air emissions among geothermal power plants, they are much more environment friendly compared with coal or oil. The binary geothermal plants, in contrast, produce zero or almost zero air emissions.

From the global warming perspective, it can be seen that geothermal power plants emit only a small amount of the carbon dioxide and no nitrous oxides or methane. Thus, geothermal energy helps reduce global warming. In addition, geothermal electricity generation avoids the mining, processing and transporting required for electricity generation from fossil fuels. The extraction of minerals from geothermal water can also be used in health centers. Since geothermal energy resource is tapped directly at its source, it does not require large land areas to produce energy.

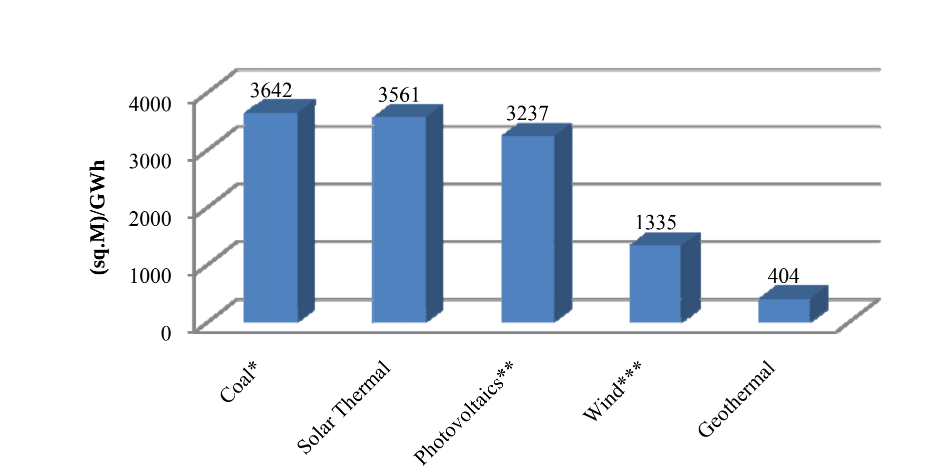


Figure 28. 30 year land use comparison for renewable energy technologies (GEA, 2009)

Geothermal energy uses land less than other energy resources. Over 30 years, a geothermal power facility uses 404m^2 of land per GWh. Coal is the leader in land use with 3642m^2/GWh followed by solar thermal with 3561m^2/GWh and solar PV with 3237m^2/GWh.

During drilling and the basic operation of plants such as cooling tower fans create some noise but it can be controlled by noise absorptive apparatus. Moreover, even some geothermal plants use water for cooling; they usually consume geothermal water, not fresh water.

In terms of economic benefits of geothermal energy, it provides reliable free fuel, helps to develop rural areas, diversifies the fuel portfolio, and creates thousands of jobs. For example, in 2008, the geothermal electricity industry supplied about 2,000 direct jobs in Europe. In the light of the EGEC scenarios, geothermal industry expansion will provide around 50,000 jobs directly in the coming 15 years. GEA also estimates that the geothermal industry directly employed about 25,000 people in 2008. In addition, 12 western states of the U.S. will develop 5,600MW of geothermal potential and it will create almost 100,000 jobs. Not only job creation but also economic output will be generated from this project. Almost $85 billion will be transferred into the American economy within 30 years.

Another contribution of geothermal energy on the countries' economies is tourism activities because most geothermal plants positively affect the geothermal areas. However, majority of people think that it harms the country's tourism capacity and image. At that point, the importance of public awareness and social community is come across. Iceland is a successful example with its largest tourism area, Blue Lagoon which is a geothermal spa and visited by many international tourists every year. Turning geothermal potential into opportunity in not only the energy industry but also in the tourism sector will definitely affect the economy of the country positively.

On the other hand, there are many groups that defends that the geothermal energy disadvantages outweigh its advantages. The main concern about the geothermal energy is drilling issue which is a hard task. In order to drill a well into the earth, the layer of rocks sitting above the hot rocks should be easy to drill through, thus, suitable sites to drill a well should be found. Even found, this geothermal plant, according to the critics, may supply energy only for the local area.

Another concern is that majority of geothermal reservoirs are located in volcanic areas. Since there is always an earthquake risk in those regions and the movements of the layers of the Earth may cause the well to dry up, investors will not accept the risk unless they believe in return on their geothermal investments will be high. Apart from that risk, there could be hazardous gases emissions during the geothermal power plant operations. A small amount of hydrogen sulfide is released into atmosphere in the process of geothermal power generation. Even it is small, hydrogen sulfide may change into sulfur dioxide and sulfuric acid and those poisonous gases may cause serious health and environmental problems.

Unlike solar energy and wind energy, the leading countries in geothermal technologies are more heterogenic. For solar PV and wind energy, the U.S., Germany, Spain, Japan and China are the leader countries. However, the Philippines and Indonesia are the two non-OECD countries follow the United States in power generation from geothermal energy. Although Mexico, New Zealand and Iceland are not listed in the top countries classification of wind and solar energy, they are major players in global geothermal energy market. In addition to these countries, Italy, Japan and Turkey are other important countries in geothermal energy technologies.

It can be concluded that due to the high start up costs, geothermal energy could not grab attention as much as wind and solar energy did. Therefore, total investment volume in geothermal energy markets remained unsatisfactory. Since many countries including Turkey could only benefit from their geothermal energy in heating systems, geothermal electricity and geothermal tourism can be expected to develop for the upcoming years.

CHAPTER 4

TURKEY'S RENEWABLE ENERGY OUTLOOK

This chapter provides an insight regarding current situation of the Turkish renewable energy resources and illustrates the development process of renewables in Turkey. Turkey's wind energy, solar energy and geothermal energy production volumes, their share in TPES and total electricity production and potentials of each renewables will be presented. This chapter will also inform the sector specific recent developments.

Introduction

Renewable energy resources (RER) have received growing attention all over the world. Since RER help in decreasing import based energy dependency, diversifying energy portfolios and contributing sustainable development, many countries began to seek ways to promote their RER and increase the share of renewables in their energy mixes. From the volatility of global oil prices to political instability of petroleum exporter countries, from imbalances of international energy trade to environmental concerns, there are many factors forcing countries to promote RER. Parallel to these trends, Turkey whose energy demand is increasing rapidly because of the huge population, industrialization, technological improvements and development she is experiencing also started to give more emphasis on alternative energy technologies than she ever did.

In fact, Turkey has pretty abundant renewable energy resources in her territory. However, led by lack of political stability and adequate policies, many elements did not allow Turkey to benefit from its national energy resources. Therefore, the country still could not take sufficient steps towards utilizing its RER potentials. Before demonstrating present picture of Turkish renewables, potential of RER in Turkey will be discussed in the light of many academic research studies.

Renewable Energy Potential of Turkey

This part focuses on the potential of the Turkish renewable energy sources. Time to time, forecasts and projections of the volume of RER potential differ not only for overall assessment but also for each energy resources.

In technical feasibility, availability of required technology and resources are taken into account. In economic feasibility, the comparison between expected benefits and the expected costs is made. If the expected benefits equal or outpace the expected costs, then the potential of renewable energy can be seen as an economically feasible. A cost-benefit analysis is crucial in the process of defining the potential whether it is profitable or not. There should be also operational and legal feasibilities for renewable energy resources potential. Since those last two feasibilities are in hand, potential of renewables is grouped under technically and economically feasible titles.

In the literature, there are many studies on Turkey's renewable energy potential. Evrendilek & Ertekin (2003) estimated that Turkey's economically feasible renewable energy potential exceeded 495TWh/year in total. This includes potential 196,7TWh/year of biomass energy, 125TWh/year of hydropower, 102,3TWh/year of solar energy, 50TWh/year of wind energy, and 22.4TWh/year of geothermal energy.

Mondaq (2008) asserts that Turkey's renewable energy sources are plentiful. Turkey's economically feasible potential is estimated at 127,000 MW/year and total hydroelectricity potential is 46,000MW per year. While technical wind energy potential is accounted for 88,000MW, its economic wind energy potential is 10,000MW. In solar side, Turkey's total solar energy potential is assessed at 35mtoe per year with yearly average solar radiation of 3.6kWh/m^2 per day. Geothermal electricity potential of Turkey is estimated about 4,500MW by Mondaq.

Another comprehensive estimation made by Hepbasli & Ozgener (2004) divides hydro potential into three sections. The gross hydro potential, which includes topography and hydrogeology, is assessed to be 432,986 GWh annually. While Turkey's technically feasible hydro potential is 216 GWh, economically feasible capacity is 122,420 GWh by 2000.

From the electricity perspective, Turkey's gross hydroelectricity potential 49,427MW and economically feasible hydroelectricity is 34,736MW. According to SPO (State Planning Organization), Turkey's gross hydro potential amounts to 1% of the world's total hydro potential and economically feasible hydro potential accounts for 15% of Europe's total hydro potential. For wind, the gross potential is more than 400,000kWh. 124,000kWh of gross potential is technically feasible potential. Hepbasli (2004) indicates that Turkey's annual solar energy prospective is 10^{15} kWh. While usable potential is assumed to be 500mtoe annually, total amount of solar energy is 8.8mtoe/year for electricity and 24.6mtoe/year for heat. In geothermal, electrical power potential is between 4,000-5,000MW_e and 31,500MW_t is for geothermal heat and direct use potentials. Hepbasli also estimates visible geothermal electricity potential at 764.81MW_e and visible geothermal heat potential at 3,138MW_e.

Balat (2004) on the other hand, highlights the insufficiency of available data on estimation of wind power potential in Turkey. He asserts that potential wind energy may be as high as 120,000MW. Solar energy potential of Turkey is estimated to be 26.4 million tones as thermal and 8.8 million tones as electricity. Estimated geothermal potential is 38,000MW in Turkey.

Ogulata (2007) estimated total hydropower capacity of Turkey at 433TWh/year but again 125TWh/year of this amount can be economically utilized. The gross wind energy potential of Turkey is more than 400 billion kWh of which 124 billion kWh is technically feasible.

Comakli, Sahin & Kaya (2008) assert that the total gross hydropower potential is nearly 50,000MW and total hydroelectricity production capacity is 112TWh/year. A theoretical wind power production is calculated between 1000 and 3000kWh/m^{2}year.

To sum up, the most encountered assessment for the Turkish renewable energy potential in the literature is made by Evrendilek and Ertekin's Assessing the Potential of Renewable Energy Sources in Turkey (2003). As of 2003, all proven, probable and possible reserves of Turkey's primary energy resources are presented in Table 32.

Table 32. Primary Energy Source Reserves of Turkey (Kaygusuz, 2008) (Evrendilek&Ertekin, 2003)

Energy source	Proven	Probable	Possible	Total
Fossil fuels				
Hard coal (Mt)	428	456	245	1126
Lignite (Mt)	7339	626	110	8075
Asphaltite (Mt)	45	29	8	82
Bituminous shale (Mt)	555	108 6	0	1641
Crude oil (Mt)	41,8			41,8
Natural gas (billion m3)	8,7			8,7
Nuclear sources (t)				
Natural uranium	9129			9129

Thorium	380.000			380.000
Renewables				
Hydro				
TWh/yr	124			124
MW/yr	34.729			34.729
Goethermal (Mtoe/yr)	1,8			
Electricity (MW/yr)	200		4300	4500
Thermal (MW/yr)	2600		28.900	31.500
Wind (TWh/yr)	50	120	230	400
Biomass (Mtoe&yr)	16,9			32
NPP (DW Mt/yr(				86-412
Forest NPP				191-1660
Terrestrial NPP+aquatic NPP				202-1730
Solar energy (Mtoe/yr)	35,2		52,8	88
Electricity	8,8			
Thermal	26,4			

In addition to these alternative sources, biomass and biogas also have importance for Turkey's energy mix. Kaygusuz (2008) estimates the total recoverable bioenergy potential at 16.92mtoe including dry agricultural residue at 4,56mtoe, forestry and wood processing residues at 4,3mtoe, firewood at 4,16mtoe, animal waste at 2,35mtoe, municipality waste and human extra at 1,3mtoe and moist agricultural residue at 0,25mtoe. Biogas which is consisting of dung gas and landfill potential is assessed between 2.2 and 3.9 billion m^3 equal to 1-2mtoe. However, while Balat (2004) estimated the amount of annual biomass potential of Turkey approximately 32mtoe, Comakli, Sahin & Kaya (2008) estimated total recoverable bioenergy potential about 35.4 mtoe by 2003.

Consequently, although many studies estimated various numbers for renewable energy potentials, Turkey has adequate national energy resources to change its energy structure which burdens not only its economy but also its environment.

According to many researchers, Turkey, in terms of renewable energy resources abundance, is one of the richest countries in the world. Erdem (2010) argues that Turkey has the biggest potential in hydro, wind and geothermal energy among European countries. Biomass and solar energy also exist well enough in Turkey to help in its energy dependence reduction process. Excluding biomass, all other renewables can be seen as supportive tools in sustainable development action of Turkey. Since hydro power was utilized relatively efficiently compared to other new renewables in Turkey and the debates on the overall impacts of biomass still exist and could not be concluded, the scope of the Turkish renewable energy sources in this study will be composed of three main RER which are wind, solar and geothermal energy.

Turkey's Renewable Energy Outlook

Turkey has an emerging economy and growing population of over 70 million, is facing a huge growth in energy consumption. According to State Planning Organization (SPO), total primary energy consumption experienced sharp upward trend at an average of 36% between 2002 and 2008. Parallel to energy consumption, total electricity consumption of Turkey has increased 49% in the same time period. Since Turkey's energy demand leaps ahead, Turkey has to meet this energy demand. However, Turkey has poor indigenous conventional energy sources. As explained in the preceding chapter, she is heavily dependent to the imported energy resources. This makes the role of renewables for Turkey much clearer. The snapshot of Turkey's inadequate actions on its renewable market can be seen below.

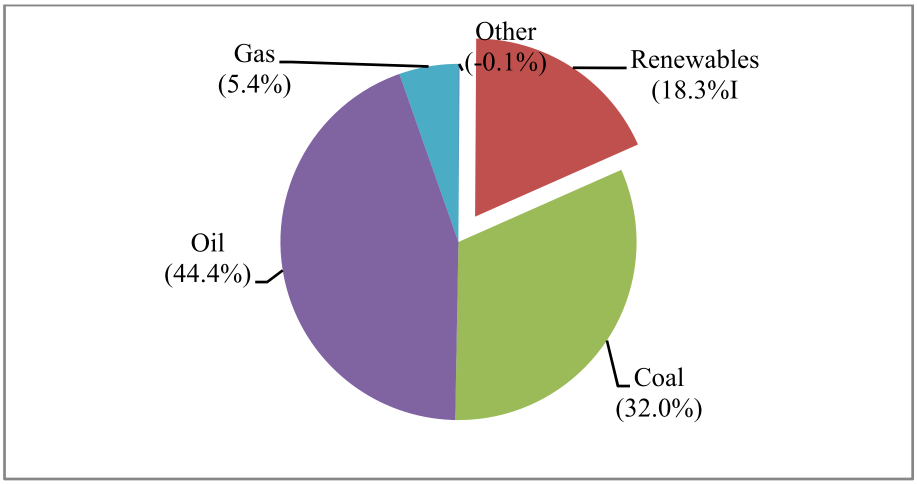


Figure 29. Contribution of renewable energies in Turkey, 1990 (IEA, 2010)

In 1990, total primary energy supply was 53mtoe. Oil and coal had the largest share in TPES. Contribution of renewable energy resources was significant with 18.3% of total. Natural gas followed RER with the share of 5.4%. However, due to the liberalization, economic growth and social development, Turkey's TPES soared and reached estimated value of 92mtoe in 2009.

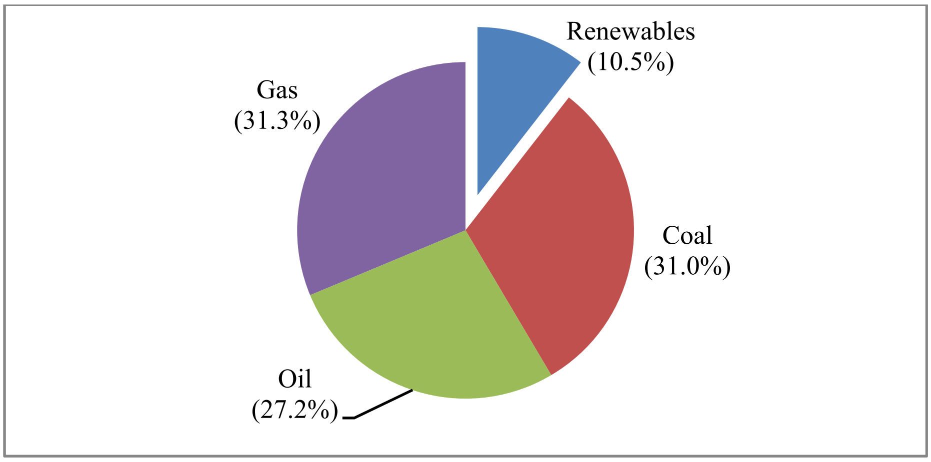


Figure 30. Contribution of renewable energies in Turkey, 2009 estimated (IEA, 2010)

As depicted in figure 34, natural gas which is almost totally imported became the first position with 31.3% followed by coal and oil. The bad news for the Turkish renewable energy market is that the share of renewables in total decreased and accounted for 10.5% of TPES. While total amount of renewables was 9.66mtoe in

1990, this remained almost constant with 9.72mtoe in 2009. During 20 years, while Turkey's energy demand has nearly doubled, renewables could not be utilized as much as enough. However, figure 31 shows the positive part of bad picture of Turkish renewable energy market and allow to be hopeful for the future of renewables.

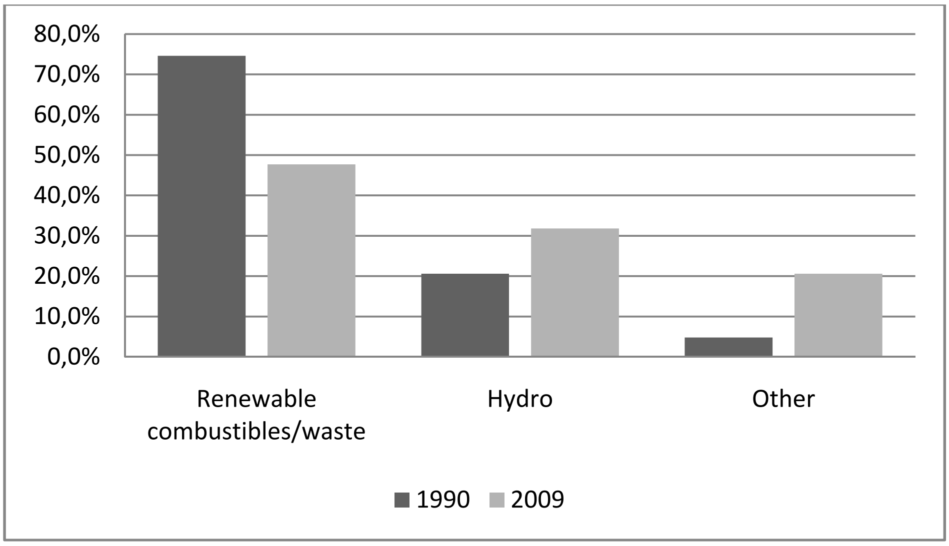


Figure 31. Comparison of renewables' contribution for the year 1990 and 2009 (IEA, 2010)

In my opinion, renewable combustibles and waste should be one of the last tools in promoting the country's renewable energy market due to the negative impacts on the environment. As mentioned earlier, there is an inverse correlation between the usage of renewable combustibles and development level of countries. For example, non OECD countries benefit more from the renewable combustibles including biomass and biogas than OECD countries. While combustibles and waste amounted to 74.6% of total RER in 1990, this has retrogressed and formed 47.7% of total in 2009. While hydropower increased its share more than 10%, the most important improvement was seen in category of other renewables which are geothermal, solar, wind and tide. In 1990, with the share of only 4.8%, the term of "others" was appropriate for renewable energies but during 20 years, geothermal, solar, wind and tide energy technologies have stolen more than 15% share from renewable combustibles and deserved more than the term of “others”. Although the change of total renewables volume does not represent a successful progress in Turkey, an increase in contribution of new RER such as geothermal, solar and wind energies to the total primary energy supply are highly appreciated.

In terms of net generating capacity of renewables, Turkey increased its total capacity from 6,782MW in 1990 to 14,352MW in 2008.

Table 33. Net Generating Capacity of Renewable and Waste Sources in MW (IEA, 2010)

							Average annual percent change
	1990	1995	2000	2006	2007	2008	1990-2008
Total capacity	6782	9895	11307	13258	13679	14352	4,3
Hydro	6764	9863	11175	13063	13395	13829	4,1
Geothermal	18	18	18	23	23	30	2,9
Solar photovoltaic	-	-	-	-	-	-	-
Solar thermal	-	-	-	-	-	-	-
Tide, wave, ocean	-	-	-	-	-	-	-
Wind	-	-	19	59	146	364	-
Industrial waste	-	-	19	27	27	27	-
Municipal waste	-	-	-	-	-	-	-
Solid biomass	-	14	72	72	72	69	-
Biogas	-	-	4	14	16	33	-
Liquid biomass	-	-	-	-	-	-	-

Hydropower and geothermal were the only RER to generate almost 7GW of power in 1990. Solid biomass with the power of 14MW has made contribution in1995. As of 2000, wind energy and industrial waste each added 19MW in net generating capacity portfolio of renewables and waste sources. While solid biomass power generation reached 72MW, biogas contributed 4MW by the end of 2000. For the last 8 years, hydropower maintained its leadership while solid biomass production remained constant, even decreased from 72MW to 69MW. Wind as a sparkling green energy resources, has experienced a significant upward trend and accounted for 364MW in

2008. Meanwhile, total wind capacity reached 800MW by the end of 2009. The development process of Turkish wind energy market will be discussed very detailed in the upcoming section. Geothermal, on the other hand, has only formed 30MW of total 14,352MW in 2008.

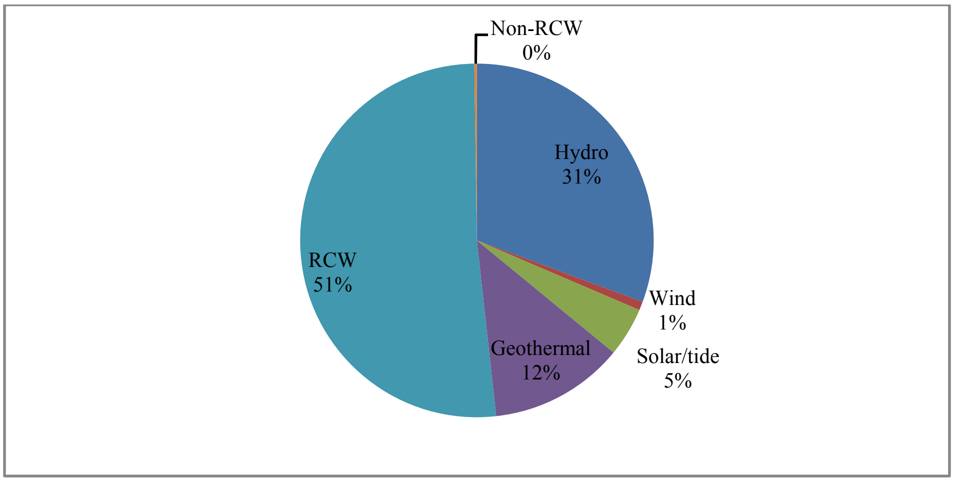


Figure 32. Primary Energy Supply from Renewable Energy Resources in 2008 (ktoe) (IEA, 2010)

When we look at the situation from the perspective of primary energy supply of renewable energy resources, again the mismanagement and inadequate utilization of renewable energy resources in Turkey can be seen. All those installed renewable capacity explained above supplied total of 9310,3 mtoe in 2008. RCW, renewable combustibles and waste including solid biomass, liquid biomass, renewable municipal waste and biogas formed more than 50% of total primary energy supply. As it explained earlier, relying heavily on traditional renewable combustibles and waste is bad signal for the country that dreams to become more developed. Hydro excluding pumped hydro generated 2861,2 mtoe of energy in the same year. Geothermal energy with 1150,5 mtoe of primary energy followed hydro with the share of 12%. While solar and tide along with wind energy formed 6% of total renewable primary energy supply, Non-RCW, non renewable combustibles and wastes including industrial waste and non renewable municipal waste produced only

22,1 mtoe energy in 2008. These numbers definitely show that Turkey could not give sufficient attention to the new renewables including wind, solar, tide and geothermal as much as they require.

When it comes to the electricity generation from renewable energy resources of Turkey, it could be inferred that after the election of 2002 which has resulted the change in government, the first step of the change in the Turkish renewable electricity market has been taken. What is more, enacting of first renewable energy law of 2005, Law No. 5346 Concerning the Use of Renewable Energy Resources for the Generation of Electrical Energy was the biggest pace in Turkey as of 2005. However, this move was not sufficient enough to stimulate the Turkish renewable energy market as a whole. Turkish parliamentary approved a law, Law No. 6994 about making changes on the previous law and regulating the RER market in 2010. All these laws have their positive and negative outcomes but all together aiming an increase of renewables share in total electricity generation. Because while the figures on electricity generation and electricity consumption are strongly correlated to the country's amount of energy needs, renewable energy resources' share in total electricity production is also strictly linked to the intensity of energy dependence and the level of energy security.

For example, according to the International Energy Agency (IEA), aside from 2009, the share of renewable electricity has more or less been in decline since 1990. This decline mainly is a result of total electricity demand surpassing the growth of renewable electricity generation. OECD researchers deem that this situation is seen in economies which have experienced extremely high electricity consumption growth in the past decade whereas electricity production has more than doubled since 1990.

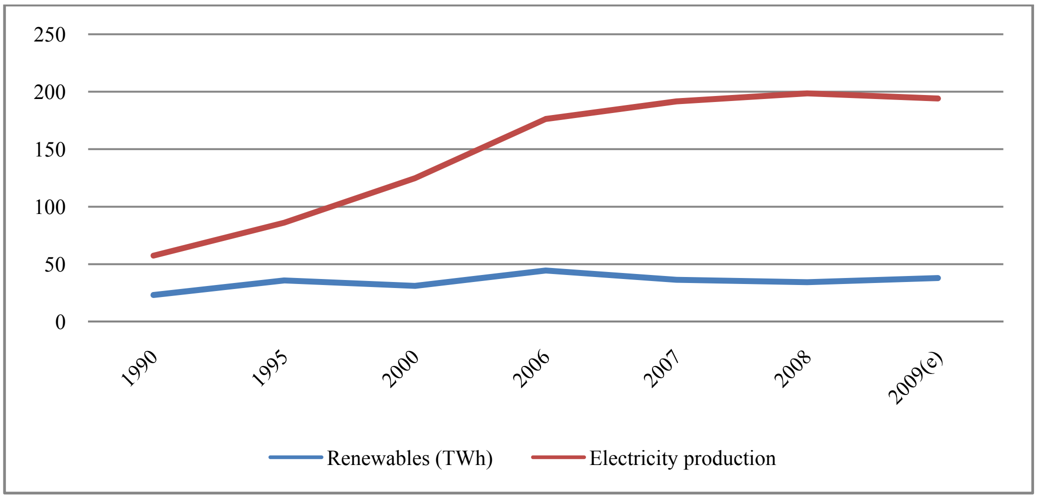


Figure 33. Trends of total electricity production and renewables electricity generation (IEA, 2010 & Eurostat, 2010)

While total electricity production was 57.5TWh in 1990, it accounted for 124.9TWh in 2000 and 194.1TWh in 2009. Even though renewable electricity production rose from 23.2TWh in 1990 to 38TWh in 2009, the share of renewables in total electricity fell from 40.4% to 19.6%. Between 1990 and 1995, renewables electricity has formed more than 40% of total electricity. However, this rate has almost fallen by half and amounted to 24.9% in 2000 and 19% in 2007. In the meantime, it should be asserted that the volumes of electricity generation are calculated by extraction of the amount of electricity produced in pumped storage plants from gross production.

At first glance, the share of renewable electricity in total electricity production may please peoples and governments. Due to the its capacity usage and its share both in total energy and electricity, needless to say, hydropower is the main and dominant renewable energy resource in Turkey. Turkey, indeed, could benefit its hydropower substantially. Nevertheless, this picture including traditional hydropower of the country is a misleading mark for the current situation of the Turkish renewable energy market because there are also many other alternative energy resources such as wind, solar and geothermal called new renewables. If hydropower itself could satisfy the energy need of Turkey and help declining of petroleum and natural gas import, then everything would have been perfect. Just as in the case of not grouping hydropower under alternative energy resources and excluding it from wind, solar and geothermal power in this study, unfortunately, real predicament will be able to come across.

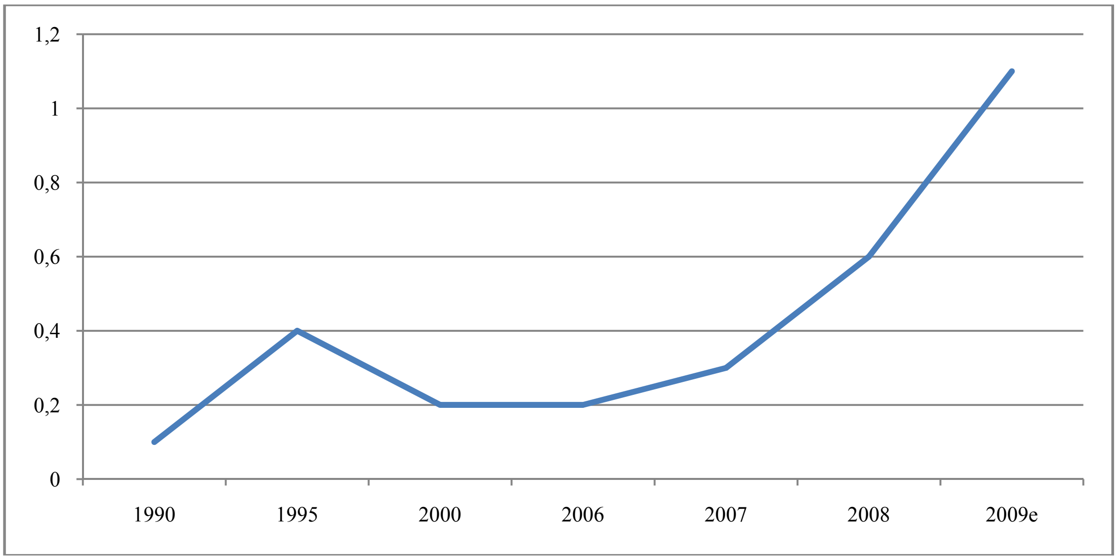


Figure 34. Share of electricity production from renewable sources excluding hydroelectricity(%) (IEA, 2010)

The share of electricity generation from renewables including geothermal, solar thermal, solar PV, tide, wind, renewable municipal waste, solid biomass, liquid biomass and biogas but excluding hydroelectricity was only 0.1% in 1990. Until 2008, this rate could not outpace 0.5%. By the help of new wind and geothermal investments which could be made via the renewable energy law of 2005, the share of renewable electricity reached the level of 1.1% in 2009. Of course, for the country which is the second most populous country and has the one of the highest rates on energy demand among European countries, compared to its rich green energy potential, this compensation rate is very low. The necessity and even the urgency of promotion of national renewable energy resources can also be understood through the mutual comparison with OECD countries that are listed in top 20 economies along with Turkey.

Table 34. Share of Electricity Production from Renewable Sources (%) (IEA, 2010)

	1990	1995	2000	2006	2007	2008	2009e
OECD Total	17,3	17,0	15,6	15,5	15,4	16,3	17,2
OECD Europe	17,6	18,6	18,9	18,5	19,7	20,9	22,5
World	19,5	19,9	18,4	18,1	17,8	18,5	-
United States	11,5	10,8	8,2	9,2	8,4	9,0	10,2
Japan	12,0	10,1	9,9	10,3	9,0	9,5	9,5
Germany	3,5	4,9	6,2	11,2	13,9	14,3	16,1
United Kingdom	1,8	2,1	2,7	4,6	5,0	5,6	6,7
France	13,4	15,3	13,1	10,9	11,8	13,0	12,9
Italy	16,4	17,5	18,8	16,5	15,5	18,6	23,1
Spain	17,2	14,7	16,1	17,6	19,3	19,8	24,8
Canada	62,4	61,0	60,6	59,5	59,5	60,6	60,8
Mexico	24,7	23,0	20,1	15,7	14,3	18,3	13,7
Korea	6,0	1,7	1,4	1,0	1,1	1,0	1,1
Australia	9,7	9,6	8,4	7,9	7,6	7,1	7,1
Netherlands	1,1	1,7	3,3	8,2	7,2	8,9	9,7
Turkey	40,4	41,6	24,9	25,3	19,0	17,3	19,6

The share of renewables in total electricity production for Turkey was much better than many countries and OECD Total and World Average in 1990. This mainly stems from the low electricity production of the country because Turkey had not been classifying under the G-20 countries in that year. As depicted earlier, total electricity generation was only 57.5TWh in 1990. By the time passing, intensive liberalization trend and more open economy based activities led Turkish energy and electricity demand to account to one of the fastest growing rates in the world.

Unfortunately, the Turkish renewable energy market, with the exception of hydropower, could not grow as much as energy demand did. Therefore, Turkey's renewables compensation rate has fallen sharply and accounted for almost 25% in 2006, 19% in 2007 and 17.3% in 2008. Although Turkey has better standing than Australia, the United States, the United Kingdom or Germany, it is still under the average of OECD Europe and World Average by 2008. This figure should not mislead us because even though Turkey is listed among top 20 economies and experiencing striking increase of energy demand, the total energy demand and the energy consumption per capita are still relatively low compared to the other developed countries such as Germany, the U.S. or France. Thus, analyzing a situation by excluding hydroelectricity will make it easier to see the actual picture.

Table 35. Share of Electricity Production from Renewable Sources Excluding Hydroelectricity (%) (IEA, 2010)

	1990	1995	2000	2006	2007	2008	2009e
OECD Total	1,8	1,5	1,9	3,2	3,6	4,0	4,6
OECD Europe	0,8	1,1	2,0	4,9	5,8	6,5	7,8
World	1,3	1,2	1,4	2,1	2,3	2,6	-
United States	3,0	2,0	1,9	2,4	2,6	3,1	3,6
Japan	1,4	1,5	1,6	2,3	2,4	2,4	2,2
Germany	0,3	0,8	2,4	8,0	10,6	11,0	13,2
United Kingdom	0,2	0,6	1,3	3,4	3,7	4,3	5,2
France	0,5	0,5	0,6	1,1	1,5	1,8	2,3
Italy	1,5	1,5	2,5	4,4	4,8	5,3	6,5
Spain	0,4	0,8	2,8	8,9	10,3	12,2	15,8
Canada	0,8	1,0	1,4	1,8	1,9	1,9	4,5
Mexico	4,4	3,9	3,2	3,7	3,9	3,1	3,1
Korea	0,0	0,1	0,0	0,1	0,2	0,3	0,5
Australia	0,5	0,4	0,6	1,5	1,9	2,5	2,5
Netherlands	1,0	1,6	3,2	8,1	7,1	8,8	9,6
Turkey	0,1	0,4	0,2	0,2	0,3	0,6	1,1

Turkey has always listed at the bottom of the list of renewables share in total electricity production. In fact, this is one of our starting and impulsive points in defining the scope of the study. Imagine a country which has the third highest wind energy potential in Europe, is first in geothermal energy resources in Europe and seventh in the world and second in solar potential among European countries and then look over the table above again.

In 1990, Turkey could only benefit from renewable energy resources with 0.1% in total electricity production places her in the last spot. This rate is far below from OECD Total, OECD Europe and the rest of the states except Korea. Until 2008, the share of renewables accounts for less than 0.5%. On the contrary, there are some countries which could promote their limited renewable energy resources within the same time period. For example, while Italy could only benefit from its renewables with the share of 1.5% in 1990, she has utilized its renewables via efficient policies and feed in tariffs and effective management of these resources. It is estimated that renewables formed 6.5% of total electricity generation in Italy by 2009.

Germany, performed even better than Italy, and its renewables share soared from 0.3% in 1990 to 13.2% in 2009. Spain and the United Kingdom also experienced sharp upward trend with no exceptional year. The United States, on the other hand, could only raise the rate from 3.0% in 1990 to 3.6% in 2009.

There are many other successful European countries which are not listed among top 20 economies such as Iceland with almost 100%, Denmark with 27.5%, Finland with 12.5%, Portugal with 20.4%, Sweden with 10.2% and Austria with 11.8%. It could be concluded that European countries are well ahead in terms of awareness of the role of renewables in countries' energy mixes and economies.

Along with Turkey's strong and intensive international trade relationships with the EU and the process of Turkey's integration to the EU membership, Turkey has to benefit from the European countries' experiences in renewable energy market by providing an optimum investment environment for the European firms.

Table 36. Aggregated Renewable and Waste Statistics in 1990 and 2009 estimations (IEA, 2010)

1990 (TJ)	Geothermal	Solar thermal	Industrial waste	Wood/wood waste/other solid waste	Landfill gas	Sludge gas	Charcoal (kilotonnes)
Production	18137	1172	-	301722	-	-	-
Gross consumption	18137	1172	-	301722	-	-	-
Transformation processes	2880	-	-	-	-	-	
Final energy consumption	15257	1172	-	301722	-	-	-
Industry	-	335	-	-	-	-	-
Other	15257	837	-	301722	-	-	-

2009est (TJ)	Geothermal	Solar thermal	Industrial waste	Wood/wood waste/other solid waste	Landfill gas	Sludge gas	Charcoal (kilotonnes)
Production	60436	17951	1056	192496	49	-	-
Gross consumption	60436	17951	1056	192496	49	-	..
Transformation processes	..	..	..	..	..	..	
Final energy consumption	..	..	..	..	..	..	..
Industry	..	..	..	..	..	..	..
Other	..	..	..	..	..	..	..

While Turkey was able to benefit from its geothermal, solar thermal, wood waste and other biogas in energy generation in 1990, industrial waste, landfill gas, biogasoline and biodiesel were the energy resources that had not been utilized. As a country which was defined as a less developed country and could not industrialized in 1990s, Turkey heavily used its wood, wood waste and other solid waste to produce energy. The amount of wood based energy generation was more than 300,000 TJ in 1990. Geothermal with 18,137TJ and solar thermal with 1,172 TJ were the followers. This composition is mostly changed due to the declining volume of wood waste in Turkey's energy and heating mix. As of 2009, it has accounted for 192,496 TJ. While geothermal has experienced more than 3 fold increase during 20 years, solar thermal could only reach the geothermal energy's 1990s' volume. Although their contributions are too limited and relatively insignificant, Turkey started to use industrial waste, landfill gas, biogasoline and biodiesel in its energy mix. Unfortunately, sludge gas and especially municipal waste related energy generation do not exist in Turkey.

All these figures and numbers above depict that as a country has an increasing energy import based trade deficit, Turkey started to realize its renewable energy resources potential and is willing to promote them. In order to change unsustainable circumstance of current energy portfolio through benefitting from those resources, Turkey set many goals by the centenary of the Turkish Republic, 2023. Even though there are many energy issues in strategic plan of Turkey such as putting all domestic coal and hydro potential into service, meeting 5% of total electricity demand via at least 3 nuclear energy power plants and developing technologies of fuel cells, energy storage techniques, fluidized bed reactors and gasifying coal and biomass, targets on renewable energy, even it is a positive pace, remain on a small scale and limited.

An Energy Market Strategy Plan raised the target for renewable energy resources, including hydro, as a proportion of total production to 30% by 2023. The goal on the wind front is to reach installed capacity of 20GW over the next 12 years. Furthermore, 600MW of geothermal power will be installed by 2023. These targets may sound well enough but the first question comes to mind is that why is not there any goals for other renewables, especially for solar?

Many researchers defend the idea that Turkey is the second richest country in terms of solar after Spain. Unfortunately, building energy strategy plan by ignoring the importance of solar among renewables does not sound logical. Nevermore, possessing tangible renewable targets is better than not having. In the light of these goals, State Planning Organization (SPO) in its ninth Development Plan set priorities and precautions for 2009-2013. According to the roadmap of SPO, in order to increase energy supply security, utilization of national energy resources and prioritizing energy efficiency and energy portfolio diversification are must. Precaution 54 of alternative energy directive indicates that while defining potential of wind power and pumped storage hydro power stations, potential maps of solar energy and biomass energy will be prepared.

Parallel to 2023 Vision Plan, Ministry of Energy and Natural Resources (MENR) in its 2010-2014 Strategic Plan, promises the completion of the licensed renewable energy projects on time. In order to benefit from hydroelectricity potential fully and integrate it to the Turkish economy, MENR will provide the best investment conditions for private sector. Rests of the main strategies for the purpose 2 of Strategic Plan are as follows: electricity power transmission lines will be connected into wind energy station. While regenerations of geothermal energy resources will be fastened and the feature of their renewability will be continued, geothermal electricity fields will be opened to private investors. All these efforts will close Turkish renewable energy up to the 2023 Strategy. Construction of 5000MW of hydroelectricity power stations will be completed by the end of 2013. Installed wind energy capacity which is 802,8MW as per 2009 will be increased 10,000MW by 2015. Finally, while geothermal energy capacity was 77,2MW in 2009, more than 220MW of additional capacity will be installed by the end of 2014.

In this context, many recent developments in the Turkish renewable energy market can be observed. For instance, according to the Energy Market Regulatory Authority cited in Deliotte's Environmental Technologies and Renewable Energy Industry Report (2009), there are plentiful undergoing license approvals basically for hydroelectricity power plants and wind power plants. Hydroelectricity power plant licenses accounted for 253 or 66 of the total new licenses granted to the private sector in 2008. The number of approved license for wind power plants is 105 as of September 2009. These licenses correspond to the capacity of 4,237MW. Moreover, 727 licenses are awaiting review equaling to 31,957MW.

Apart from these, even though Turkey has not defined any specific goals for not only solar PV but also solar hot water markets, the country has ranked third in both additions and existing solar hot water installed capacity among world countries after China and the European Union (REN21, 2010). Renewables deals volume is another development that should grab attention too. According to PricewaterhouseCoopers (2010), Turkey is listed in the fifth place among European countries in the category of renewables deals.

Table 37. Top Ten Europe Renewables Deals by Country, 2009 (PricewaterhouseCoopers, 2009)

	By value (US$m)	% share of total Europe deal value
Spain	5.635	44%
Germany	2.544	20%
Norway	1.537	12%
UK	581	5%
Turkey	500	4%
France	381	3%
Denmark	273	2%
Finland	220	2%
Sweden	216	2%
Portugal	213	2%
Other	646	5%
Total	12.747	100%

As of 2009, deals in the Turkish renewable energy market have formed 4% of the total Europe renewables deals with $500 million. While Spain has experienced $5,635 billion of deals followed by Germany, Norway and UK has taken the shares of 12% and 5%, respectively. France, Denmark, Finland, Sweden and Portugal were the following states in Europe. It can be undoubtedly asserted that renewables deal volume is relatively unsatisfactory compared to Turkey's huge renewable energy potential. Lack of adequate policies and laws to attract foreign investors are the primary elements for that situation. Furthermore, due to the countries experience a time of aftermath of global financial crisis of 2008, investment volume in renewable energy industry remains limited. However, Turkey's green energy market is in the growing position in the market life cycle. This may encourage investors to invest in Turkey's alternative energy sector including environmental technologies, waste and water management sectors. Mergers and acquisitions activity is one of the vital indicators of whether there is an investment tendency to the market or not.

Table 38. M&A Transactions by Foreign Investors in the EGS (Environmental Good and Services) and Renewable Energy Sector (Deloitte, 2010)

Acquirer	Origin	Target	Date	Stake	Deal Value (USD million)
Energo - PRO as	Turkey	RepublicAralık / Hamzalı /Resadiye	April, 2010	100,0 %	407
Not Disclosed	Turkey	TurkeyABK Elektrik Üretim AS	April, 2010	N/D	N/D
Enerco Group	Norway	Essentium Grupo	January,2010	N/D	N/D
Statkraft	Germany	Yesil Enerji	June,2009	95,0%	118,9
EnBW	France	Borusan Enerji	March,2009	50,0%	N/D
EDF Energies Nouvelles	Czech Republic	Polat Enerji	Decmber,2008	50,0%	N/D
CEZ	USA	Akenerji	October,2008	37,4%	302,6
Cogentrix Energy (Goldman Sachs)	Italy	Taşyapı Enerji	July,2008	50,0%	N/D
Italgen	Austria	Bares Enerji	July,2008	100,0 %	50,2
Verbund	USA	Enerjisa	March,2007	50,0%	326,6
Berggruen Holding	Qatar	BND Elektrik	Decmber,2006	66,7%	0,7
United Development Company	Japan	Turk Milenya	June,2006	60,0%	N/D
Sumitomo Corporation		Birecik Dam and HEPP	May,2005	31,0%	40,7

As shown in Table 38, there is an increasing interest in the Turkish renewable energy sector. There is no doubt that renewable energy industries have been one of the most attractive sectors in terms of M&A activity in the last couple of years, especially after an establishment of renewable energy law and the accelerated privatization activities of Turkish government. For example, 52 hydroelectric power plants' tenders were established under 10 groups of which 18 have been finalized with a total deal amount of $439.9 million during 2010. (Deloitte, 2010). Although there are various home countries of acquirer companies such as Japan, Qatar and the US, the majority of foreign investors come from the EU such as Germany, Italy, Czech Republic and Austria. In addition to these, KPMG in its Outlook for Renewable Energy M&A report (2010) listed the acquisition of Turkish wind farm portfolio in the fifth rank among notable M&A transactions in 2009. Renewable Energy Systems Ltd., British renewable energy company acquired wind farm portfolio of 500MW by paying more than $1 billion in the late 2009.

All these sector specific developments in the Turkish renewable energy market can be seen as a hopeful indicator for the future of Turkey's alternative energy markets. Since Turkey has to import most of her energy need, utilization of renewable energy resources should be accelerated. After the renewable law of 2005, Turkey started to benefit from her renewable energy resources. In addition to the country's hydro power, wind energy is also added to her energy mix. However, Turkey could not promote her tremendous geothermal and solar energy. As a country that is willing to become developed and achieve the level of welfare the western countries have, Turkey has to focus on her green energy resources and try to do her best in developing those technologies. Therefore, following sections will present the past, present and the future prospects of wind, solar and geothermal energy technologies in Turkey.

Wind Energy in Turkey

Wind power as an alternative energy resource, in terms of installed capacity, is the most popular and relatively the most developed one among all new renewables including solar, geothermal, tide and wave. After 2005, net generating capacity of wind energy started to increase in Turkey.

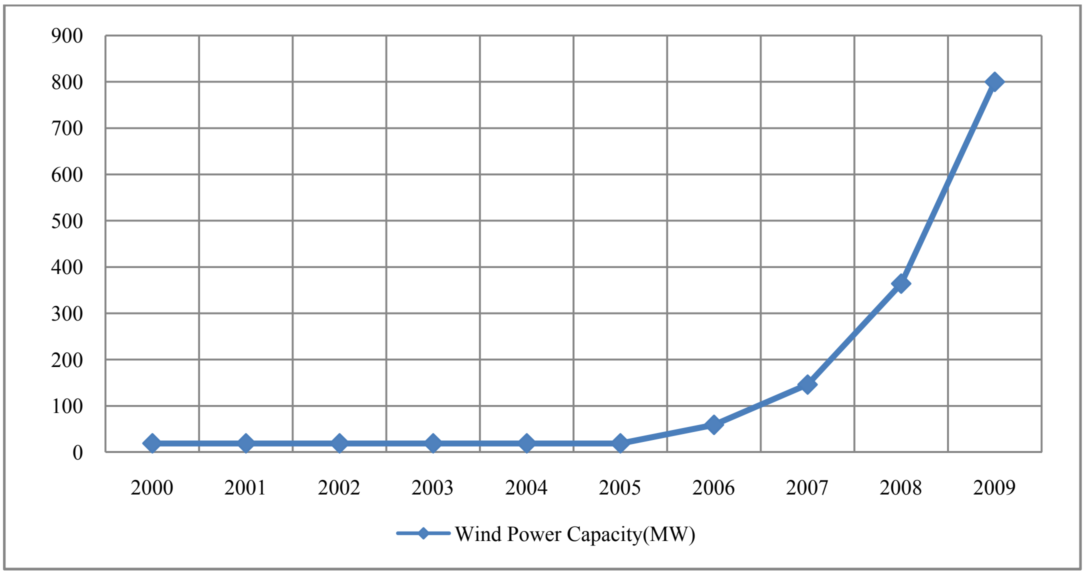


Figure 35. Development of wind energy cumulative capacity in Turkey (MENR, 2010)

As explained under the subtitle of Turkey's energy dependence, liberalization in Turkey mainly started in the beginning of 1980s. Many industrial developments and technological improvements were achieved via market based economy. However, that menace of the country's economy, energy dependence, could not be solved. The main reason of that is illustrated in the figure above. Although we defined wind energy as the most developed new alternative energy of Turkey because of its installed capacity, no wind installation were observed until 1998. In 1998, Demirer Holding Company made a 1,5MW of investment in Alize/Germiyan Region-Çeşme, the Aegean part of Turkey. The annual electricity generated from that wind farm is 4million kWh. As of 2000, total installed wind capacity has accounted for 19MW. By the helping of Renewable Energy Law of 2005, this volume has amounted to 59MW in 2006. For the last five years period, the development of Turkish wind market accelerated and installed wind capacity reached 802,8 MW by the end of 2009. Currently, it is estimated that Turkey has over 980MW of wind power in operation and nearly 500MW are under construction.

Table 39. Wind Farms under Construction in Turkey (ABS, 2010) (GWEC, 2010)

Project	Location	Capacity (MW)	Developer
Bandırma III	Balıkesir	24,0	As Makinsan Temiz Enerji Elektrik Üretim San. ve Tic. A.Ş.
Hisartepe RES	Edirne	15,0	Boreas Enerji Üretim Sistemleri San. Ve Tic. A.Ş.
Mut, Mersin	Icel	34,0	Akdeniz Elektrik Üretim A.Ş.
Osmaniye	Osmaniye	135,0	Rotor Elektrik Üretim A.Ş.
Samandag	Hatay	22,5	EZSE Elektrik Üretim Ltd. Şti.
Sebenoba	Hatay	30,0	Deniz Elektrik Üretim Ltd. Şti.
Seyitali	Izmir	30,0	Doruk Enerji Üretim San. ve Tic. A.Ş.
Soma RES	Manisa	140,8	Soma Enerji Üretim San. ve Tic. A.Ş.
Turbe	Hatay	35,1	EZSE Elektrik Üretim Ltd. Şti.
Turguttepe	Aydın	24,0	Sabas Elektrik Üretim A.Ş.

As 10 major wind projects under construction are depicted in the table, the capacity of each wind farms are expected to be at least 15MW. One of the main remarks of the table is that the home country of the main investor companies seems to be Turkey origin which allows to say that even though many of those companies are in forms of foreign-local Joint Ventures, there is a lack of foreign direct investments in Turkish wind energy market. Although there are several projects in the development stages include a 93MW project in Sahres, 30MW in Edincik and 80MW in Tatlipinar being owned by Relight Energy, Italian company, the numbers of those international wind energy companies may increase and this may be achieved through the FDI and its potentially stimulating impacts on the Turkish economy. In that case, transfer of successful countries' experience via foreign direct investment in the Turkish renewable energy market may be achieved.

On the other hand, many concerns may rise by the groups who may think that FDI in the Turkish renewable energy market can be a threat to Turkey's national security and those parties may oppose a rigorous resistance to the foreign direct investors and the regulatory bodies. In such case, foreign direct investment inflows into Turkey's renewable energy market should be discussed. The potential impacts of FDI should be analyzed. If the research studies and discussions pave the way for opening the country's green energy market to the foreign investors, then public relation will play critical role. By using the correct communication methodology in explaining the reasons behind this strategy clearly and training and educating the people to become more conscious about the benefits of FDI in the country's alternative energy may mollify opposite groups. Major foreign companies operating in the Turkish renewable energy will be discussed towards the late of this section.

The State Planning Organization of Turkey expects that the share of wind energy together with geothermal in total electricity generation will be counted approximately 1%. As presented in the global wind outlook section, ABS Research projects "1GW Club" covering the states that have more than 1GW installed wind power capacity. According to ABS, Turkey along with Poland, Norway, Austria, South Korea and Brazil will join that club very soon. The same institution portrays Turkey as a hot spot of wind energy market of 2009 because it is expected that Turkey which has an existing medium wind market, will experience a high growth of %150 or more to 2012. While Turkey has only 10GW of offshore capacity, Ministry of Energy and Natural Resources estimates the total wind energy potential as a 131,756MW. MENR has also a target of leaping the installed capacity to 10,000MW by 2015. As cited in the previous section, Turkish government's main aim is installing 20,000MW of wind power by 2023. Even Turkey could reach

10,000MW in 2015; debate on whether the country will be able to achieve its 2023 wind target will be slightly questionable. It could be inferred that intensive efforts and tenacity should be continuously perpetuated. For example, EMRA issued 3,000MW of new wind licenses until 2010. This is good news for Turkish wind market but not adequate. Compared to the potential of wind energy in Turkey, initiatives and interests on the country's wind power market should be increased. According to the U.S. Commercial Service (2010), Turkey with total of 48,000MW has the third largest wind energy potential in Europe. ABS Research assesses Turkey's wind potential as twice the current wind output of Spain and the U.S. combined almost 98TWh per annum. However, the country's technical and economical installed capacity potential in wind is 12,000MW with an estimated wind energy production capacity of 400GWh/year. For example, Ogulata (2007) in his paper on Potential of Renewable Energies in Turkey figured out that Europe's wind energy capacity has the biggest share with 72% of global wind energy capacity while Turkey's installed wind capacity has a share of 0.11% in Europe's total installed capacity by 2001. Even though Turkey hopped upwards from 19MW in 2000 to more than 800MW in 2009, when we conduct the Ogulata's observation on the lack of investment in Turkey's wind energy and the U.S. Commercial Service's assessment on the huge wind potential of Turkey, it can be easily said that there is a spate of work to do.

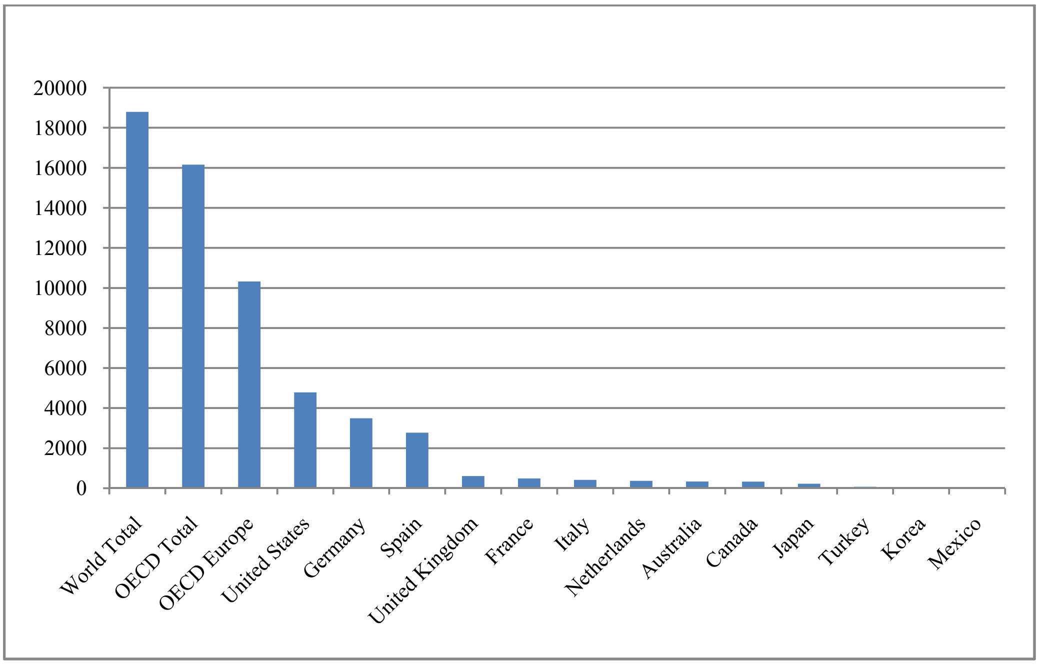


Figure 36. Primary energy supply from wind energy technologies in 2008 in ktoe (IEA, 2010)

Turkey's primary wind energy generation is significantly low compared to not only Europe, but also other G20-OECD countries. As depicted above, Turkey is only in better conditions than Korea and Mexico in. With 72.8ktoe, Turkey is placed within last three countries. While the United States is the leading country with 4,789ktoe wind energy generation, Germany and Spain follows the U.S. with 3,489ktoe and 2,769ktoe, respectively. Turkey's wind energy volume in all categories including OECD Total (16,160ktoe), OECD Europe (10,325ktoe), and World Total (18,791mtoe) remains insignificant.

For the electricity generation from renewable energy resources, the progress that Turkish wind electricity market experienced, especially after 2005, can be seen below.

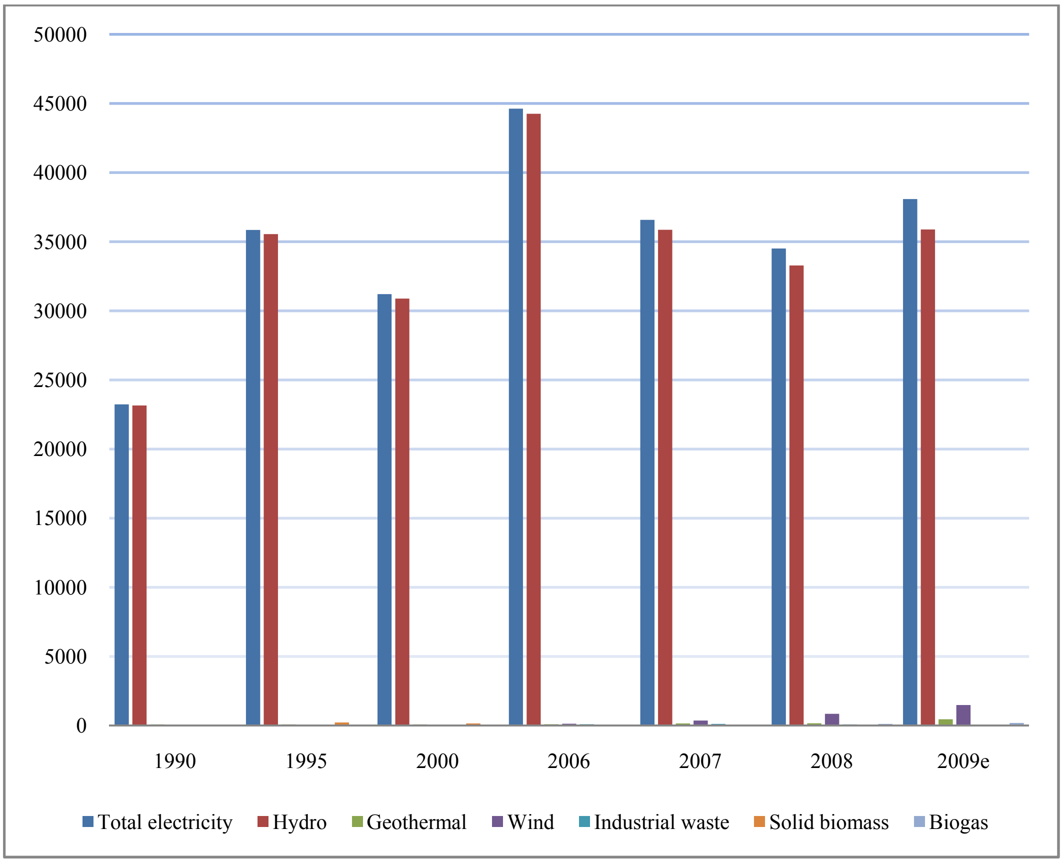


Figure 37. Gross electricity production from renewable and waste sources in GWh (IEA, 2010)

In 2000, wind only made a contribution of 33GWh to the gross electricity production, just over the biogas. Hydroelectricity as in every year was the leader electricity generator in 2000. Geothermal, solid biomass and industrial waste were the other relatively better performing renewables in the same year. However, electricity generated from wind increased and reached 127GWh in 2006 and 355GWh in 2007, placed second after hydro by surpassing all other renewable and waste sources. It is estimated that almost 1,500GWh of electricity was produced from wind in 2009.

Nonetheless, wind energy's successful progress cannot be observed for the wind power's primary energy supply performance.

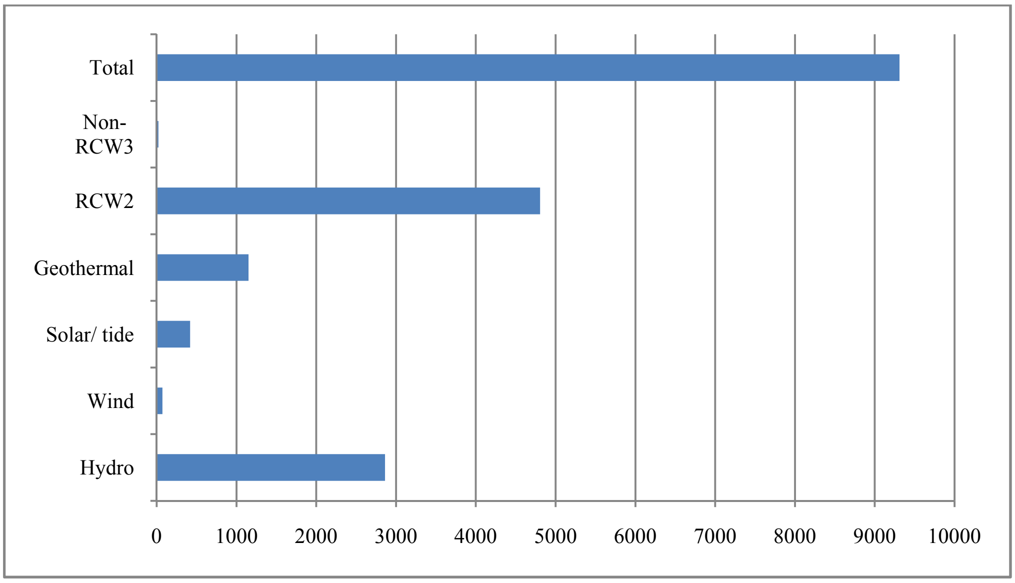


Figure 38. Primary energy supply from renewable sources of Turkey in 2008 in ktoe (IEA, 2010)

Wind energy could only formed 72.8 ktoe of total primary energy supply which was 9310.3 ktoe in 2008. Wind energy generation listed just over the non renewable combustibles and waste includes industrial waste and non renewable municipal waste. The volume of renewable combustibles and waste is remarkable because solid biomass, liquid biomass, renewable municipal waste and biogas with more than 4,800 ktoe exceeded the hydro's energy generation. Geothermal and solar with tide followed hydro with 1150.5ktoe and 419.9ktoe, respectively. The main reason behind the difference between the volume of wind's energy production and electricity production is that other renewables and non renewables can be used in the thermal and heating/cooling applications and systems. However, wind energy is primarily used for electricity production, therefore, its total primary energy supply remains relatively low compared to the other green energy resources.

As mentioned above, the total wind energy potential in Turkey is estimated at 131,756MW by MENR. This huge potential mainly located in the Aegean, Marmara and Eastern Mediterranean regions of Turkey and mountainous regions in Central Anatolia.

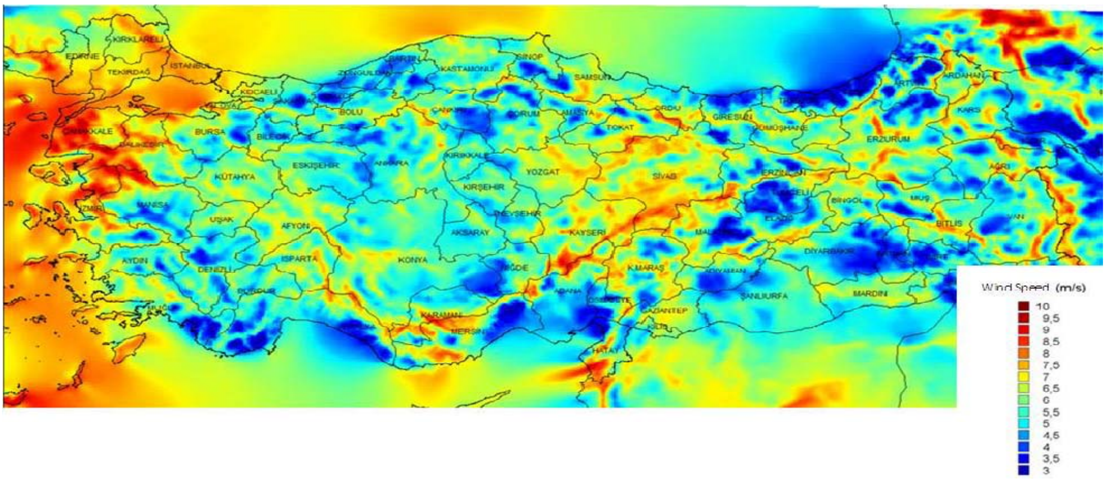


Figure 39. Potential wind energy atlas- above 100m average height in Turkey (Deloitte, 2010)

The majority of Turkish wind farms are built in the Aegean and Marmara regions in which wind speed is more than 8m/s. In addition to these regions, several wind power plants including Deniz with 30MW, Ziyaret with 12,5MW, Belen with 30MW and Bakras with 15MW are located in the Mediterranean region of Turkey. There are many wind farms in Turkey which were built in the light of the wind map above.

Table 40. Operating Major Wind Power Plants in Turkey (WECTNC, 2010)

Location	Company	Capacity (MW)	Start date	Turbine capacity	Number of turbines used in
İzmir-Çeşme	Alize Enerji Elektrik Üretim A.Ş.	1,50	1998	0,5	3
İzmir-Çeşme	Ares Alaçat Rüzgar En. Sant. ve Tic. A.Ş.	7,20	1998	0,6	12
İstanbul-Hadımköy	Sunjüt Sun'i Jüt San. ve Tic. A.Ş.	1,20	2003	0,6	2
Balıkesir-Bandırma	Yapısan Elektrik Üretim A.Ş.	30,00	2006	1,5	20
İzmir-Çeşme	Mare Manastır Rüzgar En. Sant. San. ve Tic. A.Ş.	39,20	2006	0,8	49

İstanbul-Silivri	Teperes Elektrik Üretim A. Ş.	0,85	2007	0,85	1
Çanakkale-İntepe	Anemon Enerji Elektrik Üretim A.Ş.	30,40	2007	0,8	38
Manisa-Akhisar	Deniz Elektrik Üretim Ltd. Şti.	10,80	2007	1,8	6
Çanakkale-Gelibolu	Doğal Enerji Elektrik Üretim A.Ş.	14,90	2007	0,8 and 0,9	13*800 kW 5*900 kW
Manisa-Sayalar	Doğal Enerji Elektrik Üretim A.Ş.	34,20	2008	0,9	38
İstanbul-Çatalca	Ertürk Elektrik Üretim A.Ş.	60,00	2008	3	20
İzmir-Aliağa	Innores Elektrik Üretim A.Ş.	57,50	2008	2,5	23
İstanbul-Gaziosmanpaşa	Lodos Elektrik Üretim A.Ş.	24,00	2008	2	12
Muğla-Datça	Dares Datça Rüzgar En. Sant.Sanayi ve Ticaret A.Ş.	29,60	2008	0,9	37
Hatay-Samandağ	Deniz Elektrik Üretim Ltd. Şti.	30,00	2008	2	15
Aydın-Didim	Ayen Enerji A.Ş.	31,50	2008	2,1	15
Balıkesir-Şamlı	Baki Elektrik Üretim Ltd. Şti.	90,00	2009	3	30
Hatay-Belen	Belen Elektrik Üretim A.Ş.	30,00	2009	3	10
Tekirdağ-Şarköy	Alize Enerji Elektrik Üretim A.Ş.	28,80	2009	2 and 0,9	14*2000 kW 1*800 kW
İzmir-Urla	Kores Kocada Rüzgar Enerji Santral Üretim A.Ş.	15,00	2009	2,5	6
Çanakkale-Ezine	Alize Enerji Elektrik Üretim A.Ş.	20,80	2009	2 and 0,8	10*2000 kW 1*800 kW
Balıkesir-Susurluk	Alize Enerji Elektrik Üretim A.Ş.	20,70	2009	0,9	23
İzmir-Bergama	Ütopya Elektrik Üretim Sanayi ve Ticaret A.Ş.	15,00	2009	2,5	6
İzmir-Çeşme	Mazı -3 Rüzgar Enerjisi Santrali Elektrik Üretim A.Ş.	30,00	2009	2,5	12
Balıkesir-Bandırma	Akenerji Elektrik Üretim A.Ş.	15,00	2009	3	5
Balıkesir-Bandırma	Borasco Enerji ve Kimya Sanayi ve Ticaret A.Ş.	60,00	2009	3	20

Osmaniye-Bahçe	Rotor Elektrik Üretim A.Ş.	95,00	2010	2,5	54
Manisa-Soma	Soma Enerji Elektrik Üretim A.Ş.	49,50	2010	0,9	55
Balıkesir-Bandırma	As Makinsan Temiz Enerji El. Üretim San. ve Tic. A.Ş.	24,00	2010	3	10
Mersin-Mut	Akdeniz Elektrik Üretim A.Ş.	33,00	2010	3	11
Çanakkale-Bozcaada	Bores Bozcaada Rüzgar Enj. Sant. San. ve Tic. A.Ş.	10,20	2000	0,6	17
İzmir-Aliağa	Bergama RES Enerji Üretim A.Ş.	90,00	2010	2,5	36
Edirne-Enez	Boreas Enerji Üretim A.Ş.	15,00	2010	2,5	6
Total Capacity		1044,85			

As of May 2010, more than 1 GW of installed wind power capacity generates energy and electricity in Turkey. Izmir, Balıkesir, Manisa and Canakkale are the leading cities in wind energy production. Although first wind turbine has been installed in 1990s, Turkey could reach its peak wind energy capacity by the end of 2010. After the renewable law of 2005, investment volume in Turkish wind market increased and it is expected this upward trend will continue.

Table 41. Projected Major Wind Power Plants in Turkey (WECTNC, 2010)

Location	Company	Capacity (MW)	Start date	Turbine capacity	Number of turbines used in
Aydın-Çine	Saban Elektrik Üretim A.Ş.	24,00			
Hatay-Merkez	Bakras Enerji Elektrik Üretim ve Ticaret Ltd. Şti.	15,30			
İzmir-Aliağa	Kardemir Haddecilik Sanayi ve Tic.Ltd.Şti. (Otoprodüktör)	12,50		2,50	5
İzmir-Aliağa	Garet Enerji Üretim ve Ticaret A.Ş.	10,00		2,50	4
Çanakkale-Ezine	Garet Enerji Üretim ve Ticaret A.Ş.	22,50		2,50	9
Balıkesir-Bandırma	Galata Wind Enerji Ltd. Şti.	30,00			
Balıkesir-Bandırma	Galata Wind Enerji Ltd. Şti.	93,00		3,00	31

Aydın-Söke	ABK Enerji Elektrik Üretim. A.Ş.	30,00			
İzmir-Foça	Doğal Enerji Elektrik Üretim A.Ş.	30,00		2,00	15
İzmir-Aliağa	Doğal Enerji Elektrik Üretim A.Ş.	30,00		2,00	15
Balıkesir-Kepsut	Poyraz Enerji Elektrik Üretim A.Ş.	54,90		2 and 0,9	27*2000kW, 1*900 kW
Balıkesir-Kepsut	Bares Elektrik Üretim A.Ş.	142,50			
Hatay-Samandağ	Ziyaret RES Elektrik Üretim Sanayi ve Ticaret Anonim Şirketi	22,50		2,5	9
Hatay-Samandağ	Samandağ RES Elektrik Üretim Sanayi ve Ticaret Anonim Şirketi	35,00			
Çanakkale-Ezine	Enerjisa A.Ş.	30,00		2,30	13
Kırşehir-Mucur	Al-Yel Elektrik Üretim Ltd. Şti.	148,28		3,37	44
izmir-Karaburun	Ayen Enerji A.Ş.	30,75		2,10	15
İzmir-Seferihisar	Ayen Enerji A.Ş.	24,00		2,10	12
Total Capacity		785,23			

All these completed, under construction and projected wind power plants indicate that there is an increasing interest in wind based production from the beginning of 2000s. Although the level of wind energy generation and the share of it in total electricity are unsatisfactory, since 2002, 1,118 wind license applications for a total of 86GW capacity which is more than supported limits were applied. According to the state owned Turkish Electricity Transmission Company's (TEIAS) Turkish Electricity Energy 10 Year Forecast, on 1 November 2007 alone, there were 725 license applications accounting for a total capacity of 71.4GW. However, since supported grid capacity is only 7GW, the majority of license applications could not realized.

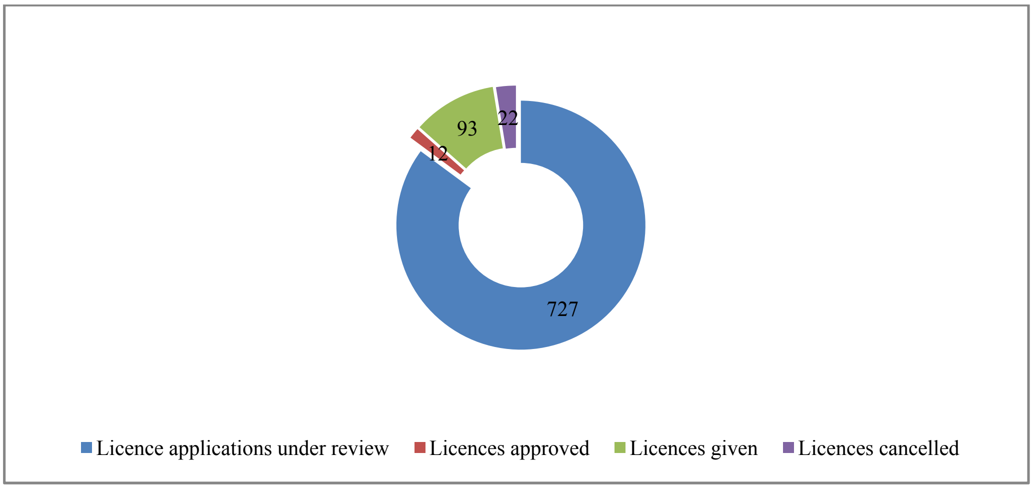


Figure 40. Number of wind power plant licenses in Turkey (Deloitte, 2010) (EMRA, 2010)

There are 93 licenses given and 12 licenses approved for wind power plants by the end of third quarter of 2009. That 105 wind power plant licenses form a capacity of 4,237MW. 727 more license applications which are amounted to 31,957MW are under review. On the contrary, 22 licenses have been cancelled. This picture as a whole illustrates a hopeful view for the future of Turkish wind market. Nevertheless, Turkish policymakers should analyze the weak sides of the current laws and be aware of the problems that wind energy investors face with in Turkey.

For the Turkish wind market, revision and designing of policies as a national support is as critical as for other sectors. According to the ABS Research, a feed in tariff is in operation with a purchase guarantee of the average whole selling electricity price (some 5cent/kWh) for a period of 7 years for electricity generated from renewables. Licenses for 3GW of wind projects have already been granted, with estimates that licenses for 10GW will be issued in the next 5 years, 15GW in the next 10 years and 20GW in the long term. It should be added that there was not any significant support from government until the establishment of Renewable Energy Resources for the Generation of Electrical Energy law of May 2005. In May 2007, a revision of the law increased the tariff to €0.05 to €0.55/kWh until 2017. In fact, this is very low compared to international standards but wind power producers have rights to sell to national power pool freely or provide power directly. The average market price for electricity is €0.07 to €0.08/kWh. In addition to these, at the end of 2010, Turkish parliamentary approved a law on regulating the renewable energy resources market in Turkey. This new law guarantees a price of $7.3 cents per kilowatt hour for wind energy. This price guarantee will cover energy firms that are established between May 13, 2005, and Dec 31, 2015.

At this juncture, barriers to wind market development in Turkey should be mentioned. The authorization process is rather congested due to growing site speculation and remains difficult to navigate (EWEA, 2009). Furthermore, Turkey has a poor grid infrastructure and this limits the development of wind sector. In order to integrate renewable energies into the grid, World Bank approved $100 million of Clean Technology Funds and a loan of $500 million in 2010. Clean Technology Fund will also provide $150 million for smart grid projects. Another loan of $500 million has been provided by International Bank for Reconstruction and Development (IBRD). The role of Turkish banks and other private equity firms in financial aspects of renewable energy projects should be understood. Since renewable technologies including wind energy requires high start up costs, financing the projects is the first and the biggest handicap in the investors' mind. Even though we do not have rather official data to prove that the Turkish renewable energy market is being financed totally by external loans, from the reports that we have and the interviews made with the experts, it can be asserted that the majority of renewable energy projects in Turkey is mainly being funded by World Bank's Clean Energy Funds and International Bank for Reconstruction and Development and European Bank for Reconstruction and Development (EBRD).

For example, EBRD with European Investment Bank (EIB) has launched the new Mid-size Sustainable Energy Financing Facility, MidSEFF, to support Turkey's renewable energy and energy efficiency investments. It is expected that MidSEFF will provide €400 million loans to Turkish banks. These loans will be used by private sector companies to undertake mid-size renewable energy projects. The EBRD will disburse €300 million in loans for up to 12 years to Turkish commercial banks via unsecured senior loans and diversified payment rights securitization programs. The EBRD will also undertake direct risk participation with Turkish banks in selected sub renewable projects up to a total value of €100 million. Garanti Bank is the first local bank to join MidSEFF and €150 million loan with 12 years payback period has received at the end of 2010. Varel Freeman, vice president of EBRD, defines EIB and EBRD as an important component of Turkey's long term energy strategy. Matthias Kollatz-Ahnen, vice chairman of the EIB, indicates that the aim of this loan provided to Garanti Bank is making a contribution to the target of Turkish Republic's "30% renewable energy of the total energy production by 2023".

Along with Garanti Bank, three more banks composed Turkey Sustainable Energy Financing Facility, TurSEFF, under the main organization of the MidSEFF in 2011. Akbank, VakıfBank, DenizBank and Garanti Bank under TurSEFF cooperate with EBRD and provide medium term funding to facilitate investments in small scale energy efficiency and renewable energy projects, primarily by small-medium enterprises (SMEs) and households. However, MidSEFF complements TurSEFF by providing funding with a longer tenor for the larger, more complex renewables and large industrial energy efficiency investments. Again, all these sector specific developments put the case clearly that alternative energy projects in Turkey is being financed externally.

Even though several Turkish banks started to involve in financing of green energy investments, actual source of capital mainly comes from Europe. In addition to these external supports, Turkish government should make substantial investments, provide optimum financing opportunities to the companies which are willing to invest in Turkey and also establish new legislative acts to improve the grid systems which are presently problematic. There are some regulations to increase the ease of doing business in renewable energy sector. For example, small scale projects which are less than 500kW do not need to receive license from Turkish Energy Market Regulatory. However, that kind of specification should be increased and designed to the advantage of private investors.

Last but not least, EBRD estimates that roughly €200 billion is required to realize Turkey's renewable energy sources investment potential. When we compare the current investment volume of renewable energy investments in Turkey, the huge green energy potential and that €200 billion of investment necessity, it can undoubtedly be concluded that the Turkish renewable energy market deserve much more attention and interest not only from foreign investors but also from local companies. Thankfully, expectations about an escalation of interest in Turkish wind energy sector started to emerge and turned into reality. Figure 41 supports the situation through focusing on the market maturity issue.

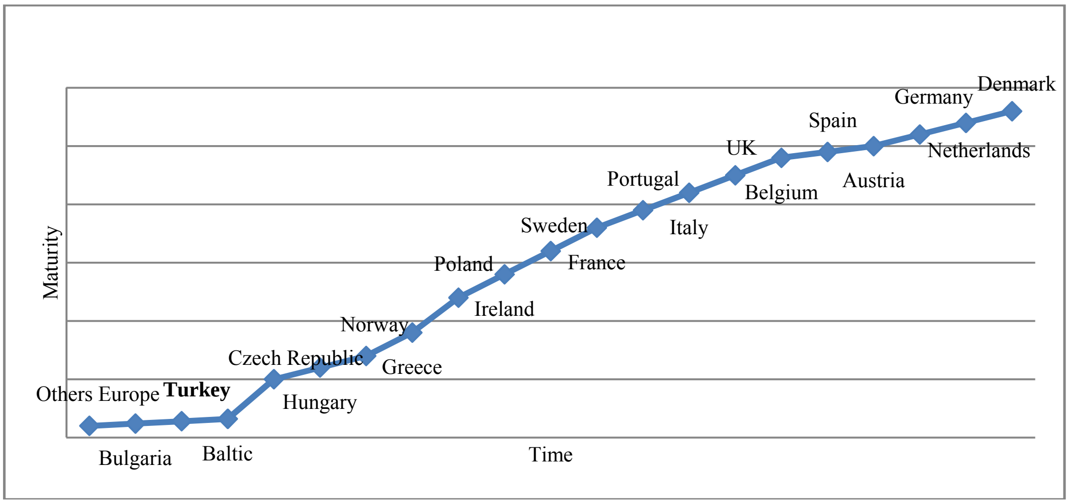


Figure 41. Wind power onshore market maturity in Europe (EWEA, 2009)

European Wind Energy Association sorts European countries under three groups which are growth markets, scaling markets and consolidating markets. The countries from Bulgaria to Norway in the figure represent the growth wind markets. The second country groups including Greece, Poland, and Ireland until Belgium are defined as scaling wind markets and the rightmost countries starting from Spain in the picture are classified as consolidating wind markets. This figure signposts the promising circumstance of Turkish wind industry. Wind energy onshore market maturity for Turkey is in the growth stage. It means that Turkey has a lot of things to do and she is in the beginning of the road. In marketing field, there is a concept of product maturity. According to the theory, a product in growth phase is highly appreciated due to its promising life cycle and potential financial benefits. After the introduction fraction, while sales, net profits and the recognition of product experience sharp upward trend, total costs of production due to the economies of scale go down in the growth and maturity phases. Like a new born child, Turkish wind energy market is willing to develop and reach the strong position that Germany and Spain already have. Needless to say, there will be no way to rely on wind market maturity outcomes and implications unless the country does have adequate wind energy potential to experience all stages of market life cycle.

Luckily, Turkey not only has growing wind market but also has tremendous wind potential. If we go back to the global wind outlook, we will memorize the leaderships of Germany and Spain among European countries along with the U.S. and China in cumulative installed wind capacity. Figure above depicts that Germany and Spain have consolidating wind markets which means that they are much closer to the decline phase of market life cycle than Turkey is. These leading states' proximity to the last phase of wind market may still take few centuries. Moreover, since alternative energies are the resources which can be renewed and not be lasted if only some terrific natural disasters may happen, this market maturity length is pretty much longer. Nevermore, since Turkey is the third richest European country in terms of wind potential, its wind market life cycle will be shoved longer than Spain and Germany. All these points emphasize that in terms of market maturity, potential and realistic targets, Turkey is likely to become one of the most attractive foreign direct investment spot in the world wind market. Preliminary signals of this interest augmentation in Turkish wind market can be perceived as follows.

Joint ventures of foreign companies with Independent Power Producers (IPPs) form the international renewable energy trade relations predominantly in Turkey. For example, Turkish firm Ataseven Energy and German company Epuron formed a JV in 2009 to develop wind power in Turkey. Those two companies are willing to establish 10 plants corresponding to 2,986MW. Sabancı Group, one of the leading holding companies in Turkey, proposed Enerjisa, a JV with Austrian Verbund. Enerjisa has a wind generation portfolio of 185MW. Very recently, the venture's 30MW wind farm including 13 wind turbines has started to produce electricity in Canakkale.

As stated before, Italian wind energy firm Relight Group also actively involved in renewable energy market in Turkey and has opened a Turkish subsidiary under the name of Relight Enerji Üretim. It has received authorization for three wind farms in Balıkesir, in the north of the country totaling 205MW that will require €300 million of total investment value.

In the late 2009 and the beginning of 2010, while French firm EDF Energies Nouvelles acquired a 50% stake in local IPP Polat Enerji, German IPP Evonik together with project developer Germania Windpark Gmbh, Rheine signed an agreement on joint development and subsequent operation of wind farms in Marmara Adasi, Kikagac and Harbiye.

Another German firm EnBW has formed a strategic partnership with Borusan Holding to develop 2GW of renewable capacity over the next 12 years. The company also plans to purchase a 50% stake in Borusan Enerji. Another example of evidence to say that foreign direct investment volume in Turkish wind market is increasing sharply is the JV between Turkish Gama Holding A.S. and American General Electric. In April, 2010, Gama,GE declared their first wind energy projects in Turkey totaling 22MW in Sares and 10MW in Karadag, in the western region of the country. While GE Energy will supply 13 turbines, each featuring 2,5MW, the total cost of projects will be approximately €54million. Industrial Development Bank of Turkey (TSKB) which is also one of the main World Bank loans recipients along with Development Bank of Turkey (TKB) will fund €44 million for these projects. It is estimated that those two wind farms will meet the electricity demand of almost 59,000 average Turkish homes and avoid approximately 80,000 tons a year in greenhouse gas emissions.

To sum up, foreign companies made investments in Turkish wind market are mainly from Germany, France, Austria, Denmark and the United States. Since the majority of the companies' origin is Europe, this strongly confirms that Turkey should increase her international energy trade relation with the companies from the European Union.

For the wind manufacturers operating in Turkey, Danish Vestas, world leader wind turbine producer, is placed in first place with the market share of 36%.

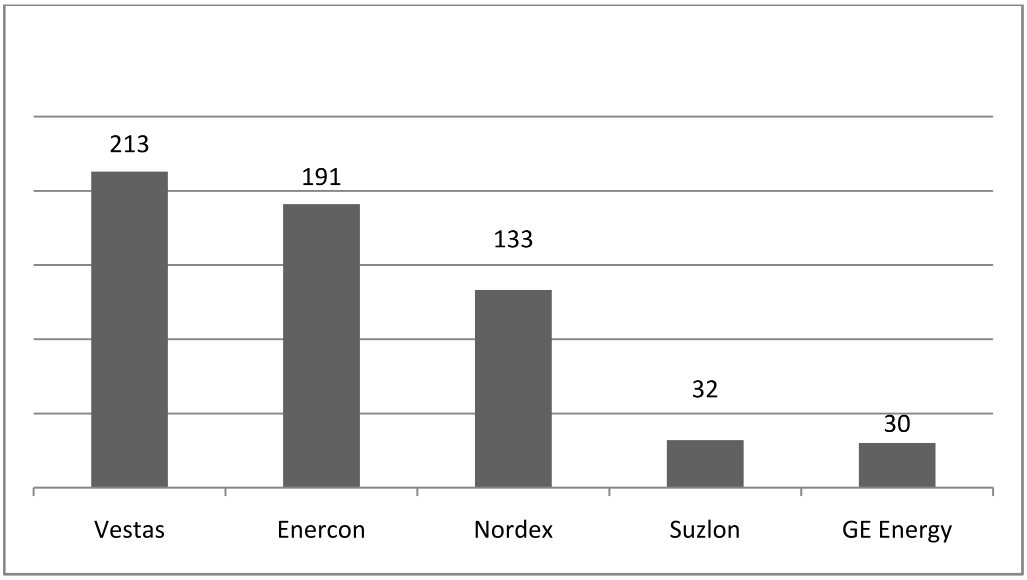


Figure 42. Wind manufacturers' market share in Turkey, 2009 in MW (ABS, 2010) (Turkish Wind Energy Association, 2010)

Enercon and Nordex from Germany are the followers with the share of 32% and 22%, respectively. Suzlon as an Indian wind company and American General Electrics are other important wind manufacturers in Turkey. It can undeniably be asserted that there is a high level of enthusiasm in Turkey's renewable energy market and its increasing very dramatically.

For example, Enercon and Turkish Demirer Holding had a joint venture agreement to produce wind turbine blades in Izmir, Turkey. This JV helps the companies to enjoy exporting those blades to the Balkans and Middle East. Another notion behind this study is that if Turkey could attract foreign investors into its renewable energy market, then the partnerships that countries will create would have exported not only manufacturing parts of renewables but also renewable energy itself. It can be seen that this idea is not too far away from the reality and it sounds feasible both in theory and practice. For example Turkish energy firm Model Enerji signed a contract with American Superconductor Corporation (AMSC) to manufacture, sell, install and operate AMSC's 1,65MW model to manufacture the first locally made MW turbines. This is very significant improvement not only for the Turkish energy market but also the Turkish economy because Turkey imported 96 units of 1,5MW platform from Chinese companies, especially CPC New Unite. This burdens an import cost to the Turkish economy and widens the balance of payments' trade deficit. In addition to these, although Vestas is the market leader in Turkish wind turbine market, it has only sales&services facilities in Istanbul, Turkey. Unfortunately, there are not any blades, towers, nacelles, castings and naturally control systems in Turkey.

As a country which has comparative advantage in terms of human resources and labor abundance compared to the EU average, Turkey should analyze the reasons behind not having production facilities of Vestas or somehow other because while emphasizing the potential importance of foreign direct investment in the Turkish renewable energy market, we are not only talking about foreign investors' fully external investment activities. Although wind power plant construction itself creates thousands of job opportunities, producing intermediate goods in Turkey with even domestic products should be primary aims of Turkish government and private sectors. In such a case, Turkey would produce all required materials during the wind energy production process and maybe build up strong brand equity in global wind industry.

Table 42. Operational Wind Farms in Turkey as of February 2010 (ABS, 2010)

Location	Start date	Capacity (MW)	Turbine manufacturer
Izmir-Çeşme	1998	1,5	Enercon
Izmir-Çeşme	1998	7,2	Vestas
Çanakkale-Bozcaada	2000	10,2	Enercon
Istanbul-Hadimkoy	2003	1,2	Enercon
Balikesir-Bandirma	2006	30,0	GE Energy
Istanbul-Silivri	2006	0,85	Vestas
Izmir-Çeşme	2007	39,2	Enercon
Manisa-Akhisar	2007	10,8	Vestas
Çanakkale-Intepe	2007	30,4	Enercon
Çanakkale-Gelibolu	2007	14,9	Enercon
Hatay-Samandag	2008	30,0	Vestas
Manisa-Sayalar	2008	30,6	Enercon
Izmir-Aliaga	2008	42,5	Nordex
Istanbul-Gaziosmanpaşa	2008	24,0	Enercon
Istanbul-Çatalca	2008	60,0	Vestas
Balikesir-Samli	2008	90,0	Vestas
Mugla-Datca	2008	10,0	Enercon
Didim	2009	31,5	Suzlon
Soma	2009	90,0	Nordex
Bandırma	2010	45,0	Vestas

Table 42 shows the company names of the turbine manufacturers that were used in operating wind power plants of Turkey. Main market players in Turkish wind industry dominate the wind turbine sector. Vestas, Enercon, Nordex, GE Energy and Suzlon, again, are the most important turbine manufacturers in the country. There is not even one Turkish manufacturer among these firms. Since Turkish wind energy market is a developing and promising sector, there is a big question mark on why Turkish companies did not interested in that specific field. The lack of experience and the high start up costs may become two basic answers of this question. By the helping of European investors' experience transfer into Turkish renewable energy market and both internal and external financing of wind projects will make easier to involve Turkish investors in renewable energy industries.

To sum up, wind energy in Turkey is the most developed resource among alternative energy technologies until now. After renewable law of 2005, cumulative installed wind capacity has accelerated and outpaced 800MW. It is expected to increase gradually through the finalization of the projects that under construction.

Another positive remark for Turkish wind energy sector is that Turkish government has started to realize the importance and terrific potential of wind energy and set realistic and concrete targets such as 10,000MW of wind power by 2015 and 20,000MW by 2023. To support wind sector, Turkish policymakers regulated the 2005's law and guaranteed a price of 7.3 cents per kilowatt hour for wind energy. However, many researchers think that law should have been much more encouraging.

Unfortunately, in opposition to the abundance of wind potential, Turkey's investments in wind industry still remain limited. Even though foreign investors' interest in wind market soared for the last two years via composing joint ventures with Turkish companies, the number of partnerships and the volume of investments should be increased. It is certain that Turkey has already lost time because the first wind map of the country was drawn 21 years ago. Nevertheless, Turkey could not benefit its wind power until just before 2005 while its energy demand had gone up. Since there was not any regulation on the Turkish renewable energy market, naturally, foreign investors did not define Turkey as a target market and. Thus, technology and experience transfer from world leader wind states, especially from

European investors could not be achieved. The long and the short of it is, when we consider current foreign direct investment volume in wind industry, economically feasible potential of wind power, designated targets and existing policies, Turkey has finally hit the right road for its wind energy and started to walk on that road rather slowly, so Turkey should speed up through supportive policies, efficient management, synchronous controls and systematic planning.

Solar Energy in Turkey

As a country lies in a sunny belt between to 36° and 42° N latitudes, Turkey has terrific solar energy potential. An area of 4,600km^2 is feasible for investment in solar energy technologies. The southern and western regions of the country contain the highest solar energy potential.

Table 43. Solar Energy Potential for Seven Regions of Turkey (Cicek et al., 2008)

Region	Radiation energy	Sunshine duration period				
	Average (kWh:/m2year)	Maximum (kWh:/m2year)	Minimum (kWh:/m2year)	Average (h/year)	Maximum (h/month)	Minimum (h/month)
Southeast Anatolia	1492	2250	600	3016	408	127
Mediterranean	1453	2112	588	2924	360	102
Central Anatolia	1434	2112	504	2712	381	98
Aegean	1407	2028	492	2726	371	96
East Anatolia	1395	2196	599	2694	374	167
Marmara	1144	1992	396	2528	351	88
Black Sea	1086	1704	408	1966	274	84

As Table 43 depicts, Southeast Anatolia region with 1492kWh/m^{2}year average radiation energy is the most promising part of the country in terms of solar energy generation. Southeast Anatolia is also heading in average sunshine duration period which is 3016 hours per year. Mediterranean, Central Anatolia and Aegean regions are the followers with 2924, 2712 and 2726 hours per year, respectively. To illustrate more clearly, solar energy map of Turkey is shown below.

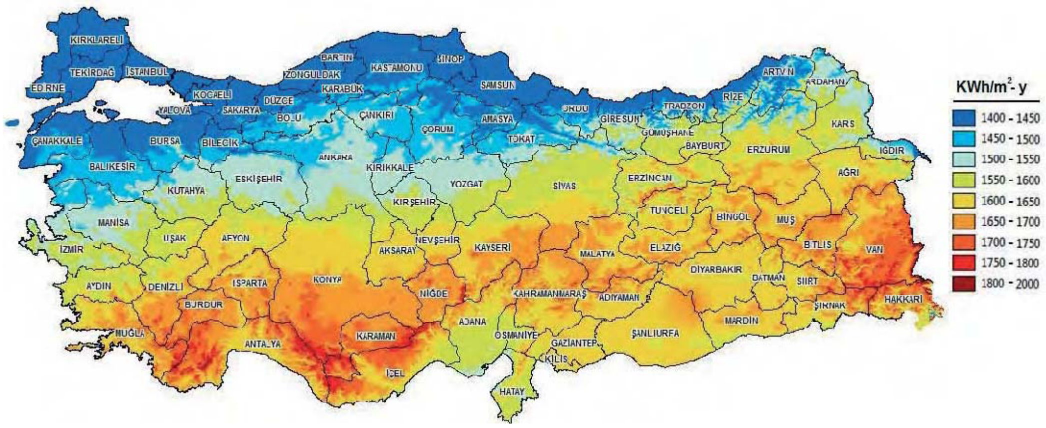


Figure 43. Solar energy atlas of Turkey (Deloitte, 2010) (General Directorate of Electrical Power Resources Survey and Development Administration)

For overall, Turkey's yearly average total sunshine duration is 2,640hours and the yearly average solar radiation is 1311kWh/m^2.yr. Solar energy of Turkey can technically and economically be utilized during 10 months over 63% of the land area, whereas 17% of the land area can be used during the whole year (Kaygusuz & Sari, 2006). While Hepbasli & Ozgener (2004) estimates Turkey's annual solar energy potential as 10^{15} kWh and usable potential as 500 million tons of oil equivalent annually, U.S. Commercial Service computes the country's solar energy potential as 32.6 mtoe corresponding to 500 to 700 MWe. WECTNC estimates total amount of solar energy as 8.8mtoe/yr for electric and 26.4mtoe/yr for heat. Kaygusuz and Sari (2006) asserts that the solar energy that can be reasonably exploited is about 32.6 mtoe per year and 9.8 mtoe of this can be used for thermal applications. In terms of megawatts, Salvarli (2009) approximates that the economic heating and electricity potential of solar energy in Turkey is 116,000MW.

Solar energy applications in Turkey started in 1960s. Solar energy was recognized as an alternative environment friendly resource in the late 1960s. Parallel to the developments occurred in solar energy globally, solar thermal technologies became an interesting and a bit attractive issue for Turkey in 1970s. The solar energy was utilized firstly in water heating in Turkey in 1975. According to Hepbasli, Ulgen

& Eke (2004) the first passive solar system was applied in the building of Middle East Technical University in the same year. After 10 years, residential and industrial solar energy consumption started.

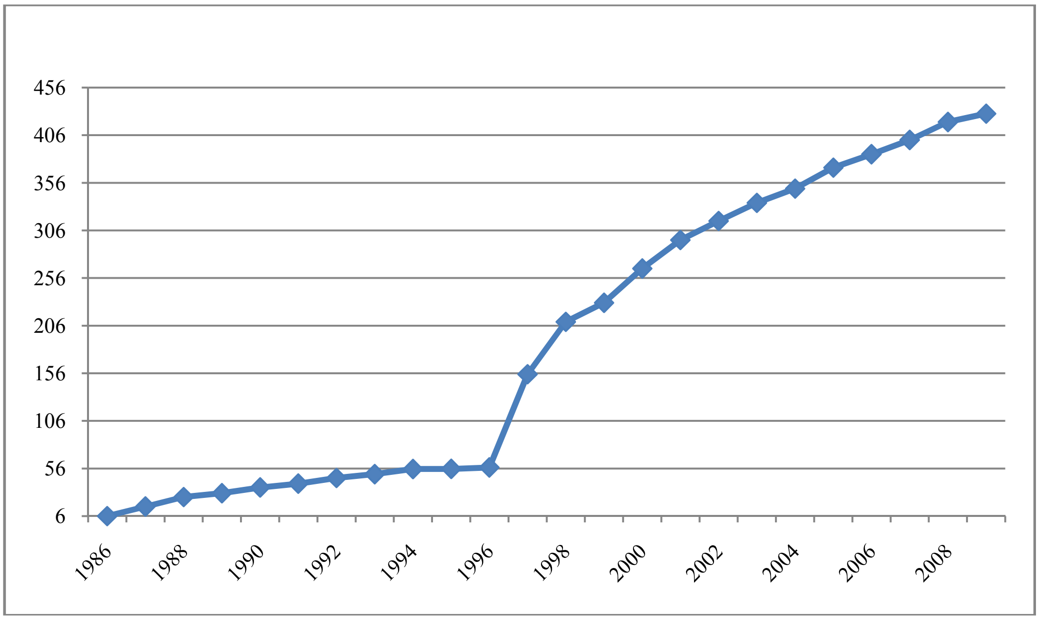


Figure 44. Solar energy production-consumption in Turkey in ktoe (IEA, 2010), (Balat, 2004)

The consumption of solar energy increased from 5ktoe in 1986 to 335ktoe in 2003 and surpassed the level of 400ktoe by 2008. Until 1996, the volume of solar energy remained under around 50ktoe. However, from that year to 2003, it always increased and reached 335ktoe in 2003. Indeed, Turkey generally used solar energy for heating purposes because main solar energy utilization in the country was in the form of domestic hot water systems. By the helping of heavily investment in water heating systems in 1990s, Turkey became one of the leading countries in the world with a total installed capacity of 7.5 million m^2 collector areas in 2001. It can be asserted that typical solar water heaters in Turkey are of the thermosyphon type and consist of two flat plate solar collectors, a hot storage tank and a cold water storage tank (Karagoz and Bakirci, 2010). According to very recent data, it is estimated18 million square meters of flat plate collectors for solar heating have being operated, mainly in southern and western parts in the residential and commercial sectors by the end of 2007. In terms of solar heating and cooling, it can be seen that Turkey is implementing efficient tools and taking right actions on time in its solar thermal roadmap.

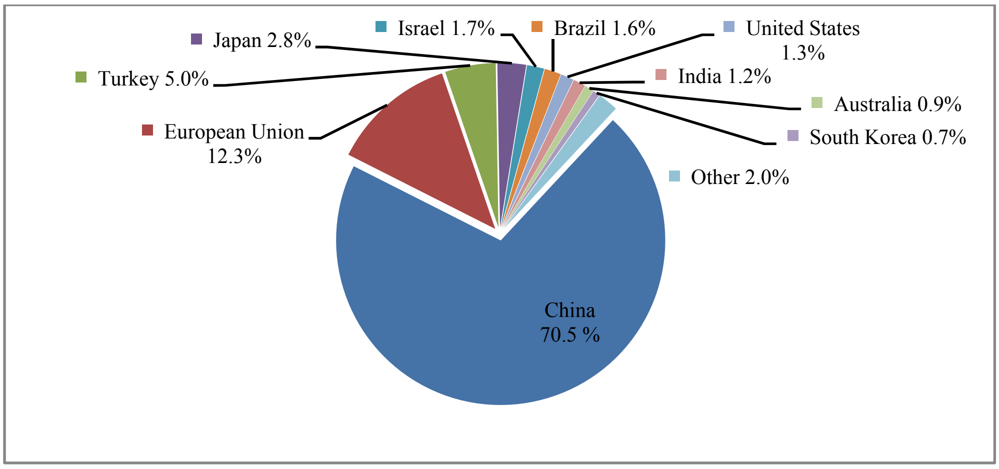


Figure 45. Solar hot water/heating existing capacity, top 10 countries/regions as of 2008 (REN21, 2010)

Turkey is currently the third largest producer of solar thermal power with the capacity of 7.5GWth, after China and the EU. While China and the European countries formed more than 80% of total solar hot water capacity, Turkey itself took 5% of total share. Germany, Brazil and India were other countries that led the market. In other words, while Turkey ranked in third place in solar hot water/heat annual amounts for 2009 after China and Germany, she took the second place after China in terms of existing solar hot water/heat capacity by the end of 2009. REN21 also conducts the country's success with the zero interest government loans because use of solar thermal in remote villages in Turkey is increasing rapidly due to those loans provided by government.

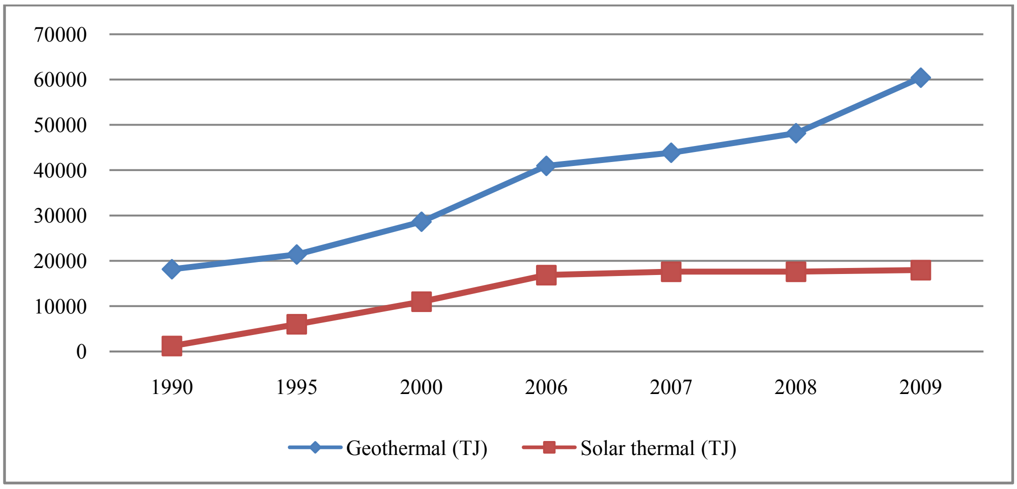


Figure 46. Comparison of solar thermal and geothermal power production (IEA, 2010)

In 1990, Turkey's solar thermal production was only 1172TJ. At the end of 1990s, Turkey could pull its solar thermal generation up to the 10967TJ. Although country experienced more than 16% of increase in between 1990 and 2008 and generated almost 18000TJ of solar thermal power, the volume of solar thermal production is relatively low compared to the other renewables such as geothermal power. For example, while geothermal production was 18137TJ in 1990, this volume soared and outpaced 60000TJ in 2009.

It can be observed that the production and consumption volume of solar thermal power could only accounted for the volume of geothermal production of 1990's. This situation tells that even though solar thermal energy of Turkey increased year by year, cumulative power generation is not satisfactory when it is compared to the marvelous potential of the country.

When it comes to the photovoltaic systems, main PV application areas in Turkey can be grouped as telecom stations, fire observation stations, lighthouses, and highway emergency systems for the early development phase of the country.

Historically, PV power system technologies just began to be developed in Turkey in 1980s. The first PV powered water pumping system was applied in Solar

Energy Institute (SEI) in 1988. First grid connected PV system; a 4.8kWp PV system was installed in Didim Solar and Wind Energy Training Center of Turkey General Directorate of Electrical Power Resources Survey and Development Administration in 1998. Another 1.2 kWp grid connected system was installed in Ankara. The interest in PV technologies increased in the 1990s and four PV power plants with total power of 50kWp were installed in Afyonkarahisar, Göcek, Usak and Kahramanmaras (Sayar (2002) cited in Hepbasli et al., 2004). In order to use solar energy in small scale agricultural irrigation, a PV pumping system was installed in Didim Training Center in 1998. As of 2010, the total installed PV technology in Turkey is estimated about 5MW.

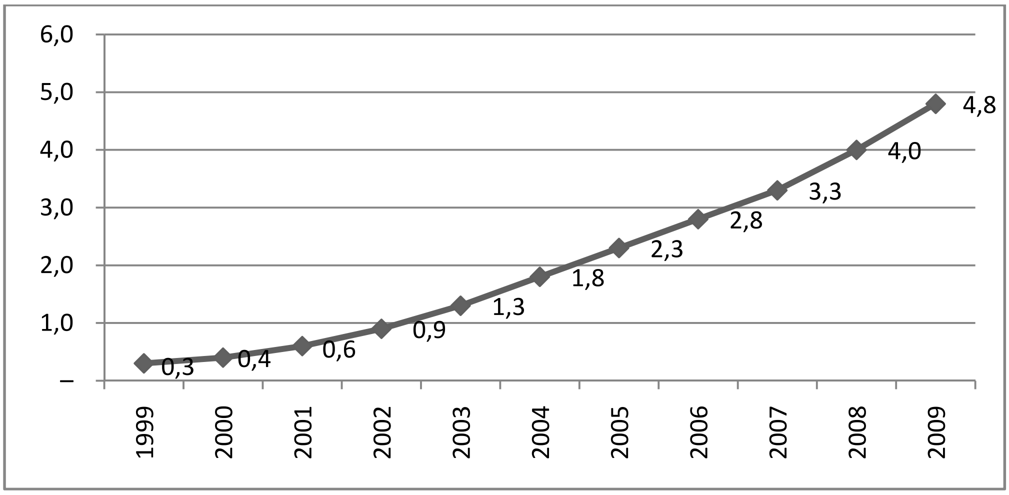


Figure 47. Cumulative installed photovoltaic (PV) power of Turkey in MW (BP, 2010)

From 1999 to 2003, the cumulative installed PV system in Turkey varied between the ranges from 0.3 MW to 0.9MW. In 2003, the volume has surpassed 1MW of capacity for the first time ever. Although the new law on renewables in 2005 was not specifically adequate for the promotion of Turkish solar power, cumulative installed PV power, in terms of change over previous year, accelerated and reached 3.3MW in 2007, 4.0MW in 2008 and 4.8MW in 2009. Unfortunately, this volume of installation compared to its abundant solar power remains insignificant in the global PV market.

It should also be asserted that there is not any grid connected PV systems in Turkey which means that majority of PV technologies are off grid inverters and often used for smaller jobs and home. In Turkey, for example, off grid PV systems are used for signaling purposes and lighting of highways.

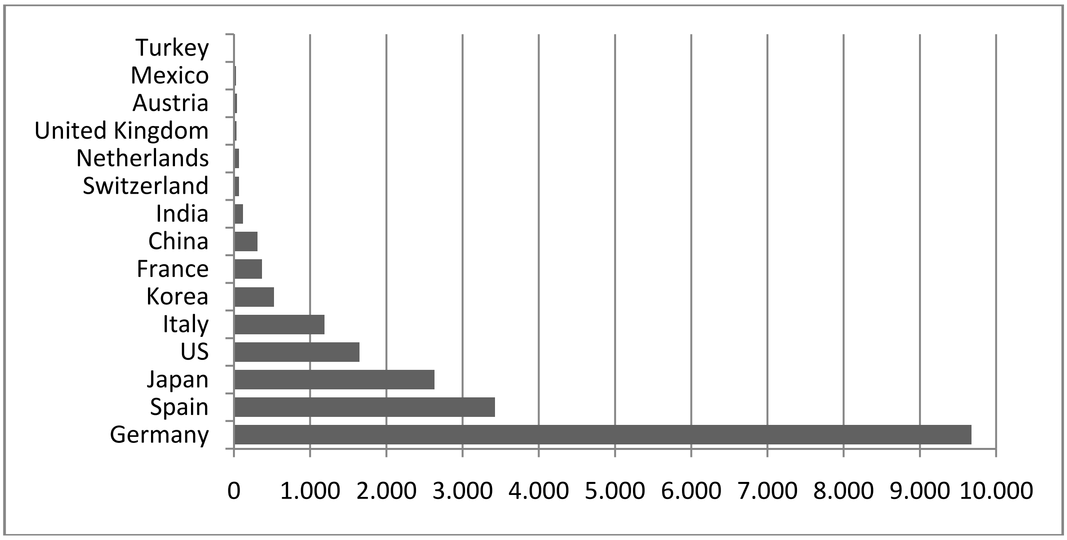


Figure 48. Cumulative installed photovoltaic (PV) power of the leading G-20 economies in 2009 (BP, 2010)

In contrast to the interests that rival countries of Turkey in G20 have shown, Turkey has performed terribly in PV system utilization. While Germany, Spain, Japan and the United States are the dominant player of the market with 42,2%, 14,9%, 11,5%, and 7.2% respectively, the share of Turkey in global PV system market is less than 0,05%. As a country has second best solar potential in Europe after Spain, this picture explains the reasons why the country has to rely on external energy resources via import.

Imagine you almost have all the required main inputs for the generation of energy in your national borders but there is something missing. You need a recipe to follow, then you should follow the rules that the successful countries followed. You need a policy to regulate all actions, then you should implement the laws that the top countries established. You need a technology to combine all inputs and start to produce energy, then you should welcome know how transfer through FDI. As depicted figure above, Turkey, on the contrary, delayed in taking all the steps she had to and thus, she became extremely dependent on import based energy injections into its energy mix.

From the policies, tariffs and economics perspective, it can be said that Turkey is totally experiencing a lack of specific law on its solar energy. The Renewable Law of 2005 contains all the principles which were set for the other renewables including wind and geothermal energy. For the price of purchased energy that is generated within the scope of this law will be equal to the price that Energy Market Regulatory Authority (EMRA) set for the previous year. In addition to this, this price may not be less than the Turkish Lira equivalent of 5 Euro Cent per kWh and may not exceed the Turkish Lira equivalent of 5,5 Euro Cent per kWh. As seen, there is no specification for Turkish solar power.

In order to attract investors to the Turkish solar market and force the policy makers to focus more on the PV technologies, TUBITAK (The Scientific& Research Council of Turkey) provided project support to Ege University Solar Energy Institute to form a national PV technology platform in 2008. The organization called National PV Technology Platform includes universities, research institutes and the industrial firms. The year of 2008 was also critical for the R&D activities on Turkish PV technologies.

In addition to TUBITAK and SPO, the Solar Energy Institute of Ege University (SEI) which was established in 1978 is one of the most key research institutes in Turkey. This institution aims to develop organic dye-sensitized solar cells and the lamination of silicon solar cells. In 2008, SEI has increased its PV power capacity outpacing 24kWp by producing its own PV modules which is good and hopeful news for the PV future of the country. Along with SEI, Mechanical and Energy Engineering Department (MESAB) of the Marmara Scientific and Industrial Research Institute (MRI) and the Building Research Institute (YAE) made research on low temperature applications of solar energy until the late 1980's.

There are many other universities seeking for producing electricity from solar power. Mugla University, for example, has installed a 40kWp grid connected power system in 2008 and a 15,6kWp dual axis solar tracker in 2009 which helped total installed PV capacity of the campus to be accounted for 110kWp. The Middle East Technical University and Bilkent University with its Institute of Materials Science and Nanotechnology also continue their R&D studies on PV systems.

For the economics of PV technologies in Turkey, many researchers argued that there was no way to see profitable investments in the Turkish solar market with the incentives and purchase guarantees that the Renewable Law of 2005 set. Ozturk et al. (2009) calculated installation costs of typical small PV systems (<5kWh) in Turkey as around 9€/Wh installed. Life cycle cost analysis, based on a 10% Net Discounted Factor and a 20 year lifetime, could be around €52 cents per kWh. The researchers indicated that small PV systems would have no payback period within this life time and there will not be logical to invest in Turkey's PV market.

In order to change the situation in favor of not only local but also foreign investors, Turkey's Parliament has tried to specify the renewable law of 2005 in the late 2010. According to the new law, 13.3 U.S. cents of price guarantee for solar energy is the highest rate among all renewables. Even though this is a promising step for the PV market of Turkey, this rate is not enough to add solar energy into Turkish energy portfolio. According to the very recent data obtained from Solarbuzz, Solar Market Research and Analysis Company (2011), industrial solar electricity average price is 16,27 U.S. cents per kWh as of March, 2011. While commercial solar electricity price is 20,87 U.S. cents per kWh, residential solar electricity average price is 30,53 U.S. cents per kWh by the end of first quarter of 2011. In the light of these numbers, insufficiency of incentives and policies can be understood very easily.

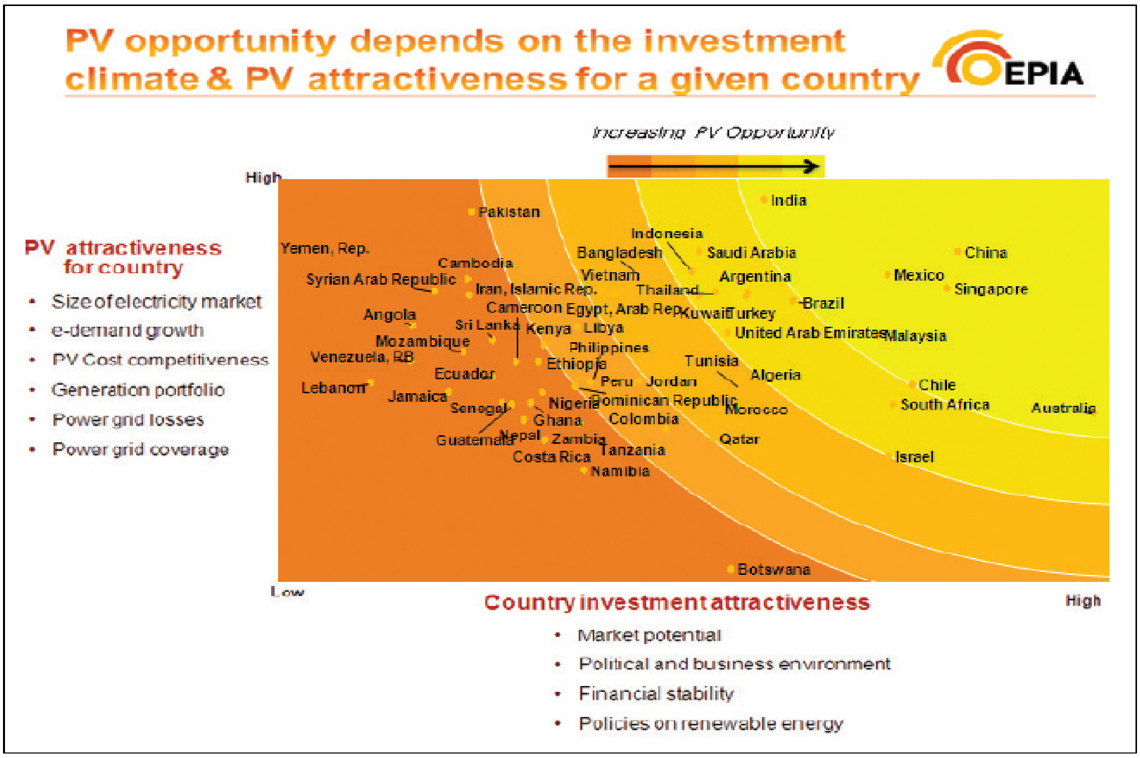
GENSED (Turkish Solar Energy Industrialists Association) suggests that in the conditions cover 1600kWh/m^2/yr radiation, 2,8€/Wp investment cost, 1% performance loss, 30% equity-70% loan, 2% operating cost, solar feed in tariff should be around 20€c/kWh. GENSED asserts that PV module prices decreased more than 40% within last 2 years and the countries which have been successful in solar market provided incentives in the level of 55€c/kWh in the very beginning of market development phase. Thus, Turkey should increase its solar incentives and deregulate its renewable energy policies. Furthermore, since this new law limits the total production of licensed solar energy companies to 600MW annually until the end of year 2013 and defines the Cabinet to be responsible in determining the limits afterwards, a question mark on the installation capacity also raised.

Under these circumstances which can be summarized as huge solar potential, lack of policy support, inadequate technology and newly increasing consciousness about the importance of solar PV, although investment decisions in Turkish solar PV market started to increase for the last 2-3 years, the PV sector in Turkey is still fairly small. The major business types in Turkish solar industry are importers, system integrators, retail sales and wholesale suppliers. There are only a few domestic battery manufacturers such as Aneltech Corporation and Girasolar Ltd in off-grid PV market. Those firms began to produce crystalline based solar modules from the unit cells. In addition to these Turkish firms, three domestic PV module manufacturers exist in Turkey; Aneles Cooperation, DATATSP Co., and Terasolar Co. According to the Energy Focus (ENF), global PV research and advisory group, 14 solar system installers operates in Turkey such as Alditi, TWI Turkey, SUNENSYS, GO Enerji, DPE Solar, CleanGlobe.

Apart from domestic companies, Turkey attracted many international firms' attention into its solar PV market. In December 2009, Solar Turkey conference, Outlook on the Turkish solar projects, expansion and innovation programs, arranged by Green Power took place in Istanbul, Turkey. Many representatives from international solar business era attended this organization and many green energy companies began to think about an investment decision in solar market of Turkey. Turkey's solar energy potential continues to arouse investor interest not only in firm level but also in governmental level. In the first quarter of 2011, for instance, Dutch Minister for Foreign Trade, Henk Bleker, with many investors including Dutch alternative energy company Joceka, had visited Turkey to explore direct business opportunities via matchmaking meetings with Turkish companies in Ankara, Izmir and Istanbul. Sharp-Solar which has more than 50 years of experience in solar development also defines Turkey as a primarily emerging solar market in the world. Company's vice president of Europe region, Peter Thiele, highlights not only the enormous solar potential of Turkey but also the counterproductive impact of policies. According to the Thiele, if Turkey establish all related laws and find the attractive feed in tariff rates in solar energy, a huge amount of investment will be flown into the Turkish solar PV market. Although Sharp-Solar considered building up a PV panel production facility in Turkey but due to the inefficient policy environment, the firm formed an agreement with Enel Green Power and STMicroelectronics to build major PV factory in Italy, not in Turkey. The project of 160MW will require a total investment of €320 million. In addition to this, Enel Green Power and Sharp also formed a JV to develop solar farms. This JV aims to install cumulative capacity at a level of 500MW by the end of 2016.

All these sector specific developments show that Turkey has missed very big opportunity and she is still out of the game in the global solar PV market. In order to convince foreign companies to invest in the Turkish solar industry, Solarex2011, Solar and Photovoltaic Technologies Exhibition, was organized in between March 10-13 in Istanbul. 61 foreign companies from 15 countries specialized in solar energy explored investment opportunities in Turkey. Indeed, Turkey has to be considered one of the main solar PV market by the foreign investors from all around the world.

The map below explains the reasons behind the concept that there should be a sanguine about the PV system not only in enjoying an investment decision in Turkey but also in solving the Turkey's energy related economic and environmental problems. Both for the firms and the country itself, this can be illustrated as a win-win game, for sure.



Climate and PV attractiveness for Sunbelt regions (Source: EPIA)

Figure 49. The matrix of PV attractiveness and country investment attractiveness (EPIA & A.T. Kearney, 2010)

The European Photovoltaic Industry Association (EPIA) with the collaboration of the Strategy Consulting firm A.T. Kearney (2010) defined 66 states as Sunbelt countries and made some projections for the future of PV under different scenarios. For example, while an Accelerated scenario presents 66 Sunbelt countries would reach an installed PV capacity of around 405 GW by 2030, ambitious Paradigm Shift scenario emphasizes that number could even reach about 1,100 GW by 2030. In the Figure 49, EPIA classifies the countries in terms of PV and investment attractiveness. For the country investment attractiveness, overall market potential measured by the size of GDP, political and business environment, financial stability and renewable energy policies are taken as indicators while size of electricity market, electricity consumption growth, irradiation and cost of existing energy sources, power transmission losses, power grid coverage and flexibility of current generation mix to accommodate increasing penetration of intermittent electricity sources such as PV are selected for the figuring out the attractiveness of PV specifically.

Finally, although Turkey has tremendous pure solar potential, because of those indicators, she listed under the second tiers group including middle sized countries with dynamically growing economies together with Argentina, South Africa, Saudi Arabia, Egypt and Thailand. Nevertheless, it is expected Turkey to become the most promising country in terms of PV system in Europe if only she could take the right actions on time and the follow the route that Germany and Spain already did as European countries. EPIA in that report defines Turkey as the most PV attractive country along with Egypt Arab Republic and Syrian Arab Republic in North Africa and Mediterranean regions. All precarious circumstances and the tragedy in the Middle East and North Africa considered, those countries leave Turkey alone in this classification. Since the regime has collapsed in Egypt and revolution is not too far away for the Middle East countries including Syria, Turkey remains the most attractive country in solar energy market.

In addition to this attractiveness in Turkish PV market, PV systems are ready to make significant contribution both economically and environmentally. As a country accepted the law draft on the Kyoto Protocol participation in February, 2009, Turkey has to consider the negative outputs of traditional fossil fuels on environment.

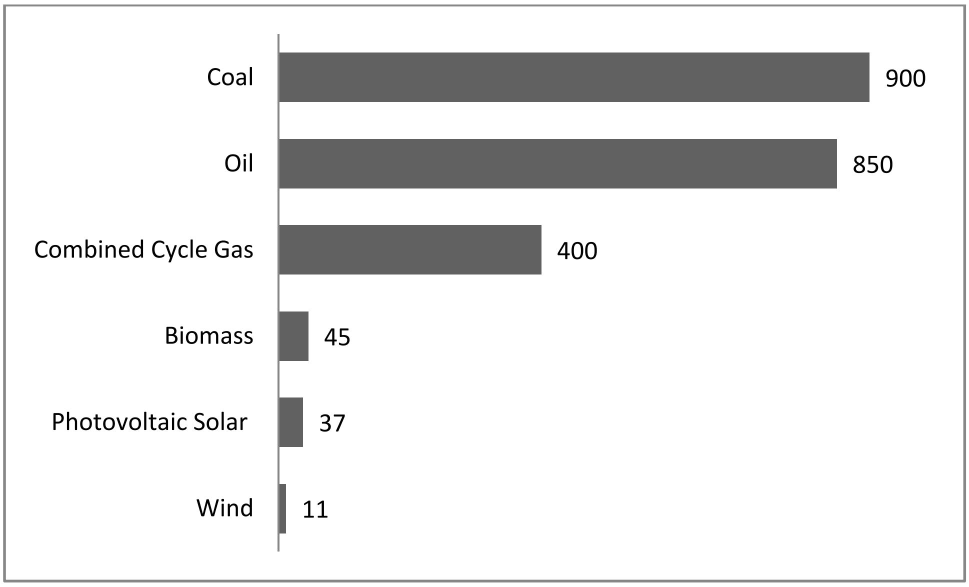


Figure 50. Greenhouse gas emission by each energy technologies (grams/kWh of CO_2 equivalent) (Turkish Photovoltaic Industry Association, 2010)

As explained in the global solar energy outlook section, Photovoltaic modules only use sunbeams as a fuel source. Therefore, PV technologies do not give any damage to the environment. The greenhouse gas emission by PV system is only 37grams per kWh of CO_2 equivalent. In the Figure 50, only wind energy creates less harmful gasses than solar PV. Compared to the coal, oil, CHP and even biomass energy, solar PV with its recyclable modules is totally environment friendly alternative energy resource.

From the economics perspective, it can undeniably be indicated that the startup cost of solar PV systems are relatively high compared to the other energy resources. However, solar PV panel has average 30 years lifetime and it continues to produce electricity with only 20% loss of its first power. Since the technology is being developed rapidly, while the lifetime of solar PVs increases, the loss ratios decrease gradually. Moreover, Turkey's solar map shows that solar PV companies have opportunity to invest in many solar regions in the country which means that Turkey will be able to meet the energy demand of all its regions and export solar PV based energy by development of grid connection systems. Since the EU has serious concerns on the energy supply security issues, instead of importing natural gas from Russia and petroleum from Middle East countries, relying on more its internal solar energy will strengthen the relationship between Turkey and the EU.

For the job creation, solar PV industry will provide thousands of job opportunity. Just for an illustration, it is expected that 200,000 employees will be hired under solar electricity sector by 2020 in Europe. Related to this, solar PV sector will affect the supplier industries in the value chain and the harmony created by all these sub industries will allow the country to focus on more research and development activities.

To sum up, Turkey started to use solar energy application in 1960s. She performed pretty well in solar thermal application in terms of cooling and heating. Turkey is currently the third largest producer of solar thermal power with the capacity of 7.5GWth, after China and the EU. However, this situation is totally different for the electricity generation from solar PV. During 50 years, Turkey could only install 4.8 MW of solar PV capacity. As a country which is placed in the second rank after Spain in terms of solar energy potential, Turkey’s inadequate movement can be assessed just comparing her with Spain. As of 2010, Spain forms almost 15% of world cumulative installed photovoltaic power whereas Turkey has 0.02% of world total. Lack of specific law on solar energy, insufficient government support to the private sector and high start up costs due to the lack of latest technology are the primary obstacles that Turkey should overcome.

Turkey has a tremendous geothermal power potential because she lies on the active Alpine-Himalayan Orogenic Belt. Similar to the Western Great Basin of the U.S., the western parts of Turkey, especially Aegean and Marmara and Central Anatolia have abundant geothermal activity currently undergoing important exploration and exploitation (Basel, Serpen & Satman, 2010). Figure 51 shows the proportion of geothermal energy potential by regions.

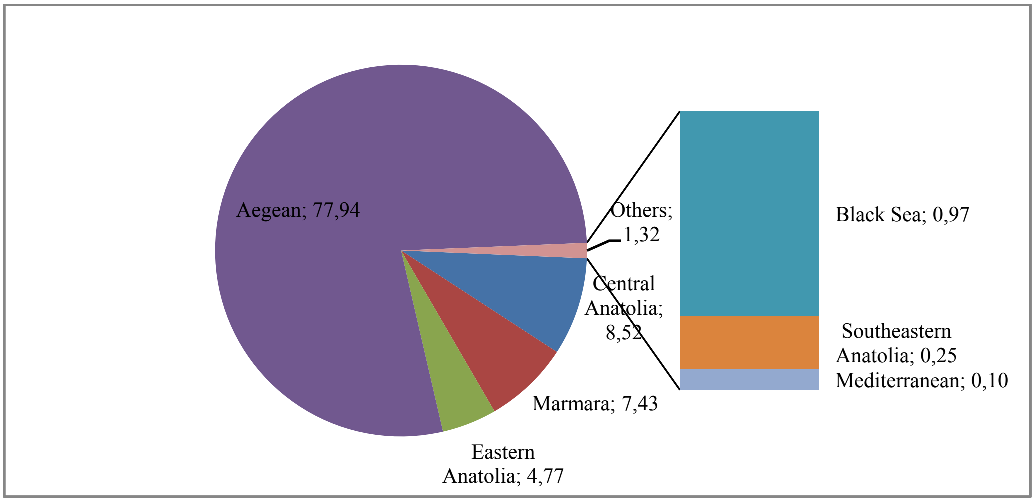


Figure 51. Regional distribution of geothermal potential fields in Turkey (WECTNC, 2010) (General Directorate of Electrical Power Resources Survey and Development Administration)

Three fourths of the country's geothermal potential is located in the Aegean region followed by Central Anatolia and Marmara regions. While Eastern Anatolia forms nearly 5% of total geothermal energy potential of the country, the shares of the rest of the regions including Black Sea, Southeastern Anatolia and Mediterranean remain insignificant.

Table 44. Major Geothermal Fields of Turkey (Basel, Satman &Serpen, 2010) (General Directorate of Mineral Research and Exploration, 1996, 2005)

Locality	Flow Rate (l/s)	Ave. Tem. (°C)	Max Temp. (°C)
Germencik/Aydin	1515	220	232
Sultanhisar-Salavatli/ Aydin	731	163	171
Imamkoy/Aydin	40	142	
Omer-Gecek /Afyon	817,5	94	
Kizildere/Denizli	250	217	242
Simav/Kutahya	476	184	
Balcova/Izmir	536	81	
Seferihisar/Izmir	264	144	153
Diyadin /Agri	561	72	
Sandikli/Afyon	496	68	
Dikili/Izmir	250	120	
Terme/Kirsehir	688	102	
Kozakli/Nevsehir	247	91	
Golemezli/Denizli	340	70	
Kuzuluk/Sakarya	271	81	
Tuzla/Canakkale	120	160	174
Kula/Manisa	140	135	
Salihli/Manisa	150	104	
Caferbeyli/Manisa	6,5	155	
Kavaklıdere/Manisa	6,5	215	

Even though geothermal energy is classified under the new renewable energy resources, its historical progress is not rather new in Turkey. The first geothermal well was drilled in İzmir-Balcova geothermal field in 1963 and followed by Denizli-Kizildere geothermal field exploration. The first space heating application by geothermal energy was in a hotel in Gonen-Balikesir in 1964. In 1970s and 1980s, the examinations of geothermal energy in Turkey gained momentum. Denizli Kizildere was the field in which a pilot power plant with a capacity of 0.5MW was installed in 1974. The first downhole heat exchanger system was installed in Izmir-Balcova in 1983. The Denizli-Kizildere geothermal power plant has been put into operation by the Turkish Electricity Establishment which is renamed as Turkish Electricity Generation and Transmission Corporation in 1984. This conventional steam cycle power plant with $17.4MW_e$ capacity has been generating an average gross power of $10MW_e$ since that year. The first geothermal energy based greenhouse heating system of 0.45 started to operate in Denizli Kizildere geothermal field in 1985. Since greenhouse heating is an important field of geothermal heating, Table 45 shows the major greenhouse heating areas in Turkey.

Table 45. Major Greenhouse Heating Areas in Turkey (Aksoy, Ongur& Serpen, 2010)

Location	Greenhouse Area, (decare)	Estimated Power, (MW_t)
Dikili-Izmir	775	83,7
Salihli-Manisa	350	22,6
Turgulu-Manisa	110	15,4
Balcova-Izmir	100	10,5
Kızıldere-Denizli	357	40
Gumuskoy-Aydin	50	2,5
Diyadin-Agri	2,4	3,1
Karacaali-Urfa	170	25
Sindirgi-Balikesir	200	3
Simav-Kutahya	100	17
Total	2104,4	207,4

As of 2009, a total of 2.104.000 m^2 of greenhouses are heated by geothermal fluids corresponding to 207,4MWt of energy. The states located in Aegean region form the majority of greenhouse heating technologies in Turkey. Direct application of geothermal energy can involve a wide variety of end uses, such as space heating and cooling, industry, greenhouses, fish farming, and health spas (Demirbas et al., 2004). For Turkey, most of the development in the geothermal direct use is observed in geothermal district heating fields. Geothermal district heating applications in Turkey started in Balikesir Gonen in 1987. As of 2010, district heating systems of Turkey can be seen from Table 46.

Table 46. Turkey's District Heating Systems (Aksoy, Ongur& Serpen, 2010)

Place	Date	Installed Power, (MW_t)
Gönen-Balıkesir	1987	18,4
Simav-Kütahya	1991	36,6
Kırşehir	1994	5,6
Kuzuluk-Sakarya	1994	11,2
Kızılcahamam-Ankara	1995	17,6
Balçova-İzmir	1996	77,7
Afyon	1996	33,9
Kozaklı-Nevşehir	1996	19,2
Sandıklı-Afyon	1998	29,3
Diyadin-Ağrı	1998	8,4
Armutlu-Yalova	2000	4,8
Salihli-Manisa	2002	25,1
Sarayköy-Denizli	2002	27,2
Edremit-Canakkale	2004	16,9
Bigadic-Balikesir	2006	10
Bergama-Izmir	2006	10
Güre-Balikesir	2006	8,5
Sorgun-Yozgat	2007	20,9
Yerköy-Yozgat	2007	3,3
Dikili-Izmir	2008	10
Total		394,6

Between 1990 and 1995, geothermal direct use application experienced a significant growth of 185% and 12 district heating systems were constructed during the period of 1991 and 2004. Direct use capacity of district heating systems reached total capacity of approximately 400MW_t and it is estimated that the district heating systems have served 35,000 households by the end of 2004. (Serpen et al., 2010). International Geothermal Association (2010) quotes Balcova-Izmir as an instance in its "Geothermal-Natural Choice" report. Geothermal district heating project was started in 1995 in Balcova. As of year 2006, the Balcova district heating system enjoyed a 90MWth installed capacity, sustaining a 250GWh generation of geothermal heat. It is estimated that the system avoids the emissions of 18,000 tonnes CO_2 per year.

The first residential geothermal heat pump system was installed in the late 1990s. However, heat pumps are not used at present, because of high cost of electricity. In addition to these, technologically superior an air cooled binary cycle power plant with gross capacity of 7.3MW_e was completed in Aydin-Salavatli-Sultanhisar. The largest flashed steam power plant, rated 45MW_e, is presently in advanced construction stage at Germencek (EGEC,2007).

Another use of geothermal energy is heating and geothermal heated pools used for bathing, swimming and balneology account for a capacity of 402MW_t and utilize 12,677.4TJ/yr (Akpınar et al., 2006). Thermal tourism activities and balneology applications are performed in Balcova, Yalova, Sandıklı-Gönen, Haymana, Bolu and Havza in Turkey. Turkey also uses geothermal energy in drying fruits in Kızılcahamam-Ankara. General Directorate of Mineral Research and Exploration (MTA) wills to build a geothermal power plant in Karakurt-Kayalar-Kırsehir to dry fruits.

The detailed geothermal energy developments in Turkey presented above gives an idea that Turkey started to take a rigid line in geothermal power industry. For the last figures in an officially level, Taner Yildiz, the minister of Energy and Natural Resources, implies that while geothermal electricity generation which was 15MW in 2002 has reached 95MW, residential heating which was 30,000 residences equivalent accounted for 81,000 residences equivalent by the end of 2010. 50 hectares of greenhouse heating increased to 200 hectares and the number of geothermal tourism and geothermal based health applications increased from 215 to 306. However, when these activities are compared to the country's huge geothermal potential, they are not satisfactory for the concept of sustainable energy and the energy security of Turkey.

In terms of stored thermal energy, the total geothermal resource base for Turkey is estimated to be an average value of $3*10^{23}$ J with a deviation of +/- $1*10^{23}$ J. This potential is located in 276 geothermal occurrences including 110 fields. These fields' temperature ranges from 22.5 °C to 220 °C.

Table 47. Turkey's Geothermal Resource Base (in 10^{23} J) between 3 to 10 km Depth for Different Temperature Classes (Basel, Satman & Serpen, 2010)

Depth, km	Temperature, °C				Total
	T<100	100<T<150	150<T<250	T>250	
	Stored Heat, x 1023 J				
3	1,72	1,30	0,65	0,30	3,97
4	1,77	2,31	1,97	1,01	7,06
5	1,77	2,61	4,22	2,41	11,01
6	1,77	2,70	6,55	4,85	15,87
7	1,77	2,70	7,94	9,19	21,60
8	1,77	2,70	8,54	15,2	28,21
9	1,77	2,70	8,86	22,4	35,73
10	1,77	2,70	9,01	30,6	44,08

According to the U.S. Commercial Service, Turkey ranks first in Europe and seventh in the world for the utilization of its geothermal energy resources and fifth for the potential of geothermal resources. As cited in Ogulata's paper on Potentail of Renewable Energies in Turkey, World Energy Council and World Energy Council Turkish Natural Committee (WECTNC) assessed Turkey's considerable geothermal potential at 4,500MW for electricity production and 31,100MW for thermal applications.

According to the General Directorate of Electrical Power Resources Survey and Development Administration, in the case of utilization of geothermal energy potential wholly, Turkey will thank a lot to its geothermal resources because she will be able to produce 8 billion kWh/ year electricity corresponding to $800 million of net income. This amount of electricity can meet roughly 3 billion residences' electricity demand. For the geothermal heating, 1 billion m^3 of natural gas import will be avoided equaling to $400 million exchange disposition. By the helping of greenhouse heating, 30,000 employees will be hired only in that sector and $600 million of net revenue will be originated. By achieving nearly 400 thermal facilities, 250,000 of job opportunities will be created. In overall, Turkey will generate $6,8 billion of net gains per year.

In contrast to the genial picture that illustrated above, Turkey could benefit from its geothermal resources only in a little scope.

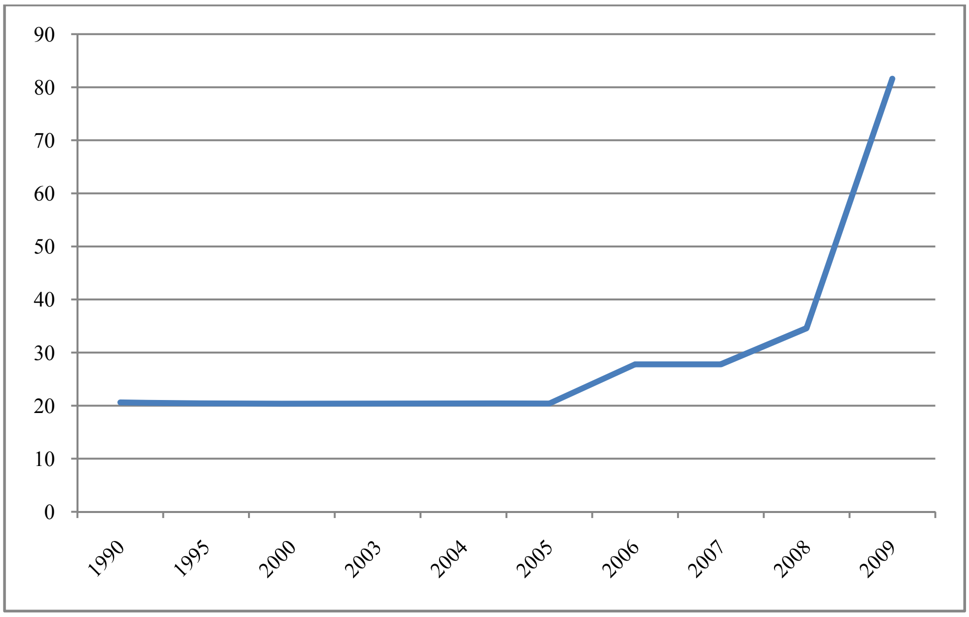


Figure 52. Turkey's cumulative installed geothermal power capacity in MW (BP, 2010)

As depicted above, the cumulative installed geothermal power capacity remained steady at the level of 20MW from 1990 to 2005. After an establishment of the new law on Turkish Renewable Energy Resources, interest and investments in geothermal energy fields in Turkey started to increase. It should be said that the impetus of this increase is not as strong as of wind sector. Turkey could add only 7MW to its geothermal portfolio in the years of 2006 and 2007. This supplementation value was accounted for 6.8MW in 2008. The main expansion was experienced in 2009 because the volume of total installed geothermal power capacity amounted to 80MW. Turkish Ministry of Energy and Natural Resources (MENR) aims to hike 80MW to 300MW by the end of 2014. State Planning Organization (SPO) expects that the share of geothermal energy together with wind energy within the total electricity production will become 1% in the near term.

Comparison between Turkey's and the rest of the world's primary energy supply from geothermal energy can render an opinion about the level of utilization of the country's geothermal energy resources.

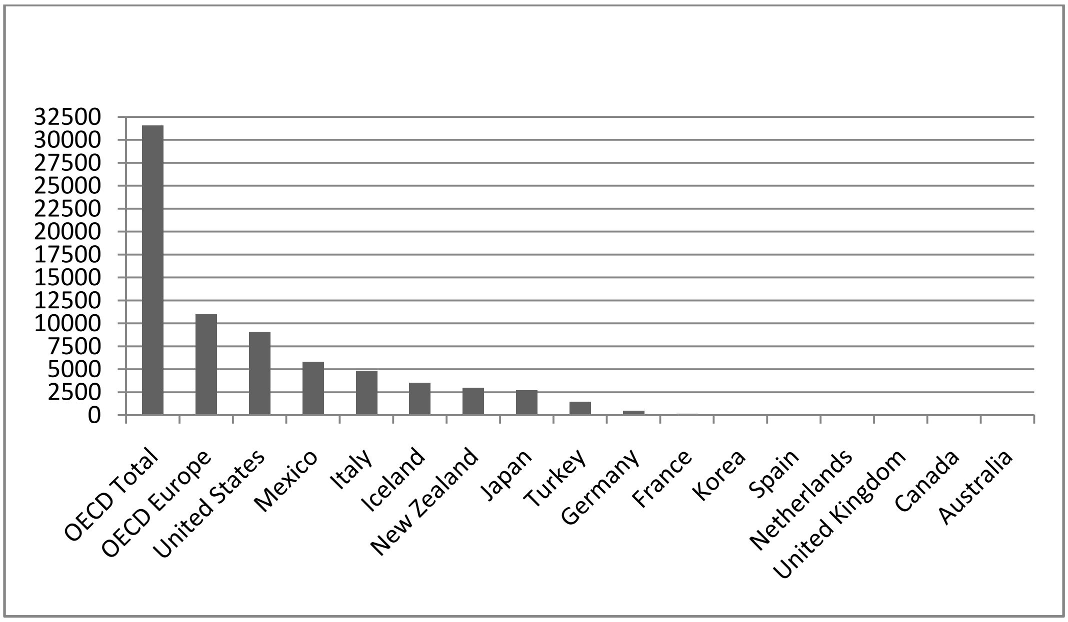


Figure 53. Estimated primary energy supply from geothermal energy in 2009 in ktoe (IEA, 2010)

It could be inferred that Turkey has a better ranking in global geothermal market than she has in the global wind market. Among OECD and G20 countries, Turkey with almost 1,500ktoe geothermal energy generation performs better than Germany, France, Netherlands, the United Kingdom and Korea. However, the United States with more than 9,000ktoe is the leading country in terms of total primary geothermal energy supply. Mexico and Italy are the other G20 and OECD countries that surpass Turkey. It is noteworthy to mention the success of Iceland and New Zealand in geothermal energy. Although their GDPs are lower than Turkey, they produce much more geothermal energy than Turkey with 3,547 and 2,993ktoe, respectively. Furthermore, if Turkey's leading position among European countries in geothermal potential is memorized, Iceland and Italy's predominance on Turkey is a bad signal for the potentially leader country.

In more general perspective, while Iceland, with 373MW, ranked third in the list of the countries with the greatest increase in installed geothermal capacity between 2005 and 2010, Turkey is named as the fifth country with 62MW installation. Luckily, Turkey has added 47MW its geothermal capacity, more than Italy's 40MW in 2009.

For the electricity generated from geothermal energy in Turkey, there can be seen a parallel trend along with primary energy supply from geothermal power.

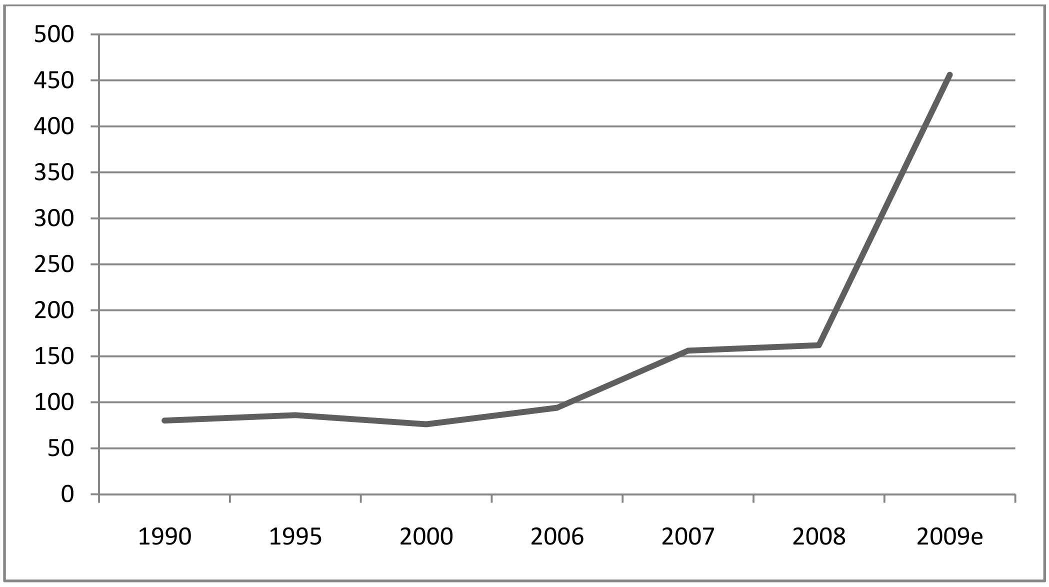


Figure 54. Gross electricity production from geothermal energy in Turkey (IEA, 2010)

As depicted in the Figure 54, the country's geothermal electricity generation remained constant until 2006. For example, gross electricity production from geothermal energy in Turkey accounted for 80GWh in 1990. While this volume increased by a short head and amounted to 86GWh in 1995, 76GWh was the volume of geothermal electricity in 2000.

As on every new renewable energies, the impacts of new renewable law of 2005 are felt on geothermal electricity generation positively. Sharp upward trend started from 2005 to up until now. While electricity from geothermal energy was accounted to 156GWh in 2007, geothermal energy contributed more than 160GWh to electricity generation in 2008. The greatest increase was observed in 2009. It is expected that more than 450GWh of gross electricity is produced from geothermal energy in that year. Figure 55 compares the production of geothermal electricity of the major geothermal countries.

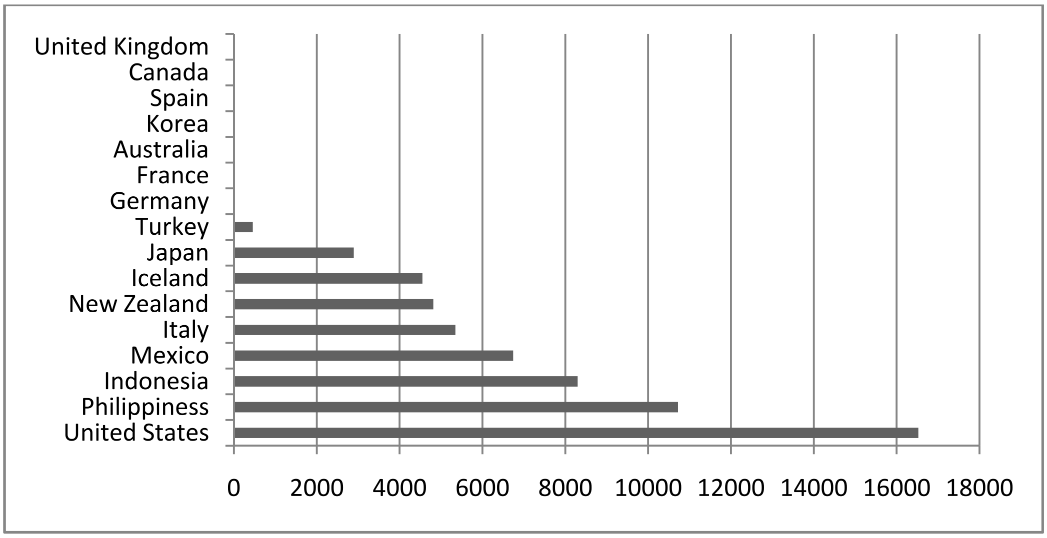


Figure 55. Electricity generation from geothermal energy in GWh (IEA, 2010)

Similar to the primary energy production from geothermal power, Turkey produced more electricity from geothermal than the United Kingdom, Spain, France, Canada, Korea and Australia. However, Turkey's this position should not mislead people to think that Turkey is a successful country in geothermal electricity generation. Those countries beaten by Turkey do not have significant geothermal potentials in their national borders. Germany, in addition to these countries, aims to use its geothermal potential but again Turkey perform better than Germany which has only 19GWh of geothermal electricity production in 2009.

Apart from these countries, Turkey is one of the worst performing countries when compared to its huge geothermal potential. While the United States is the leader with 16,525GWh of geothermal electricity generation, the Philippines and Indonesia are the following non-OECD countries with 10,723GWh and 8,297GWh, respectively. Mexico, New Zealand and Japan are other important countries in utilization of geothermal potential. Although Turkey has the richest geothermal power resources among European countries, Italy with 5,247GWh and Iceland with 4,553GWh of geothermal electricity generation are the leading countries in Europe. When all these numbers are conducted, Turkey ranks ninth position among these countries. If Turkey has a near volume of geothermal electricity production to the leading countries, then there will not be a problem. Since Turkey produces almost 6 times lesser geothermal electricity than Japan, the closest country in the classification, this is not a hopeful picture for Turkey when it is linked to its seventh position in global geothermal power potential. No matter which overall volume is taken into account, OECD Europe or OECD Total, Turkey's contribution to the world's overall geothermal output is insignificant.

When it comes to the policies, tariffs and the economics of geothermal energy in Turkey, some distinctions within the laws can be observed. While the Geothermal Resources and Mineral Waters Law No. 5686, enacted in 2007, sets the rules and principles for effective searching, exploring, developing, producing and protecting the geothermal resources, licensing and feed in tariff issues are covered by the Electricity Market Law and Renewables Law (Deloitte, 2010). The Electricity Market Law No. 4628 indicates that renewable energy facilities including geothermal energy are required only to pay 1% of the total license fee or the license for construction, and they are exempt from license fees for the first eight years following the completion date.

In addition to these laws, Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy, as explained before, is the primary policy for not only geothermal energy but also new renewables. This law did not specify each renewable energy resources. Instead of separated provisions, it presents several suggestions. For example, the law emphasizes the importance of geothermal energy especially for the heating needs. According to the law, geothermal sources together with solar thermal resources should provide heating energy for the housing units within the borders of administrative districts and municipalities located in regions where geothermal resources are sufficient to meet heating needs. For the price of purchased energy that is generated within the scope of this law will be equal to the price that Energy Market Regulatory Authority (EMRA) set for the previous year. In addition to this, this price may not be less than the Turkish Lira equivalent of 5 Euro Cent per kWh and may not exceed the Turkish Lira equivalent of 5,5 Euro Cent per kWh. Those two main provisions allow to say that the main aim for geothermal energy is to benefit from it for the heating applications. Since there is not any distinction defined only for the geothermal energy in the law, geothermal electricity was not primary focus.

EMRA asserts that only 1 geothermal energy license is issued in 2008. In order to regulate the law of 2005, promote geothermal energy and achieve the geothermal energy targets of 2013 projections which will be presented a little later, Turkey's parliament set new price guarantees. That law guarantees a price of 10.5 U.S. cents per kilowatt hour for geothermal energy.

For the economics of geothermal energy resources in Turkey, a stochastic study was conducted by Serpen, 2005 cited in Serpen et al. 2010. This study indicates that geothermal utilization looks profitable with the electricity selling prices of around 6 cents/kWh. The payout time for that kind of investments is estimated to vary between 7 and 8 years. For district heating, the outcomes of the study are much more interesting. The study indicates that district heating system projects do not seem to be profitable with 2005's low fixed rate heat tariffs. For instance, Balcova's district heating system along with Seferihisar-Cumali and Gediz geothermal resources have always resulted in negative Net Present Value (NPV) with low tariff rates and deposit costs imposed on people. From that point, it can undoubtedly be inferred that feed in tariff rates, incentive packages and strengths of policies are the major factors on the profitability of projects. Naturally, if the project has a negative present value, then for both local and foreign investors, there will be no reason to invest in Turkish geothermal energy market. On the contrary to the district heating projects, greenhouse heating looks very profitable. Based on the same study, to build a 100 decare greenhouse, only $5 million is required and the project finances itself within 2 years. If the investor chooses to construct a power plant which consumes roughly the same amount of heat, the project will cost around $12 million and pay out in 8 years. Thus, greenhouse seems to be more profitable than power generation.

As for each renewable energy resource, there are many problems and potential barriers for geothermal energy market in Turkey. These could be grouped under three categories which are technical, economical and legislative. In the report of Turkish

Environmental Technologies and Renewable Energy Report prepared by Deloitte (2010), the main reason for the low exploitation of geothermal resources in Turkey is defined as a lack of technical expertise. This picture is such a big shame for the country which has tremendous potential and more than 50 years of research experience in geothermal energy field and it clearly supports the idea of transferring know how of the experienced foreign geothermal investors into Turkish geothermal market via FDIs. This claim is also valid for the perspective of economic problems. Turkey could not create an economically feasible environment for the entrepreneurs who wished to invest in the country's geothermal resources. The projects with high start up costs could not be financed by the internal capitals of Turkey. Thus, while global investors did not prefer taking risk and invest in such a market that is financed hardly, local investors made their investment decisions on different energy fields such as involving in the privatization process of Turkey's electricity transmission companies and the mergers and acquisitions of other renewables like wind and solar.

Legislation as a third obstacle for Turkish geothermal resources will have negative impact on the market unless it does not cover adequate policies and is not managed correctly. Progress of Turkish renewable energy laws including geothermal energy resources does not make investors hopeful. To some extent, new improvement on price guarantee of geothermal energy is good news for the future of the country's geothermal market.

Lastly, tragicomic actions of the local governors and municipality presidents should be asserted. Local government official of Sandikli connected a coal fired boiler to existing geothermal district heating system. The decision of integrating geothermal as a new renewable energy technology into the coal as a conventional energy cannot be explained in a logical manner. There are several examples on dismantling the existing district heating facilities through connecting natural gas to the houses for heating purpose.

In contrast to the mismanagement of geothermal resources and despite those problems that Turkish geothermal market comprises, there are many rosy developments in the sector.

Before presenting the recent developments in Turkish geothermal market, it should be asserted that Turkey tried to promote its geothermal resources through public sector investments. Before and after privatization process of Turkey which was experienced during 1980s, private sector did not show interest in geothermal market. This trend continued until mid 2000s. Renewable law of 2005 is the sign that Turkish government changes its mind and realizes the critical role of private investors in open and liberalized Turkish economy. From that year to now, privatization activities not only for geothermal but also for other energy sectors soared.

Taner Yildiz, the minister of Energy and Natural Resources, notes that after the completion of 13 geothermal fields' tender, the total value of geothermal liberalization amounted to $208 million including 34 geothermal fields, 9 of that for electricity generation. The minister argues that efficient investments in those areas will generate over 1 billion kWh/year electricity through 150MW of total installed electricity capacity. All these liberalization efforts will provide $1 billion of investment opportunity for both local and foreign investors. Construction, engineering, greenhousing, and the other sectors related to heat pumps, tribunes and pipes will feel the positive impacts of those investments in geothermal market directly or indirectly. It is expected to these investments will raise welfare level by fostering economy with roughly $370 million contribution and more than 10,000 jobs creation within 2-3 years. Finally, one of the most important news for the foreign investors, who plan to invest in Turkish geothermal energy market, is that General Directorate of Mineral Research and Exploration's geothermal field tenders will be continued and 29 geothermal fields will be privatized in the near future. In consequent, privatization is the hottest issue for geothermal market in Turkey. Thus, the numbers of joint ventures and the involvement level of private companies in geothermal resources are increasing dramatically.

In 2009, Akenerji, the largest private energy production company in Turkey, obtained permits for three years to search for geothermal energy resources in Izmir and Bursa. The company continues its feasibility studies in those regions to generate electricity from the collection of absorbed heat from underground.

In March 2010, the Dora-2 geothermal power plant came on line. The project has installed capacity of 9.5MW and will produce around 75,000Gwh. Dora-2 which is the second geothermal project in the region owned by the same Turkish company, MEGE Elektrik Uretim A.S. was completed within 27 months. This geothermal plant is a binary cycle system and is expected to replace 20,000 tons of oil products and save 150,000 tonnes of CO_2 emissions.

Italian leading company Enel Green Power which has 32 geothermal plants in Italy generating 730MW, formed a joint venture called Meteor with Turkish company Uzun. This JV will hold 142 licenses to explore geothermal resources in the west of the country. Italian partner will finance the initial surface exploration. The CEO of Enel Green Power foresees the total value of investment chains which may produce 100MW of energy as approximately €350 million. One of the main reasons behind the decision of Enel Green Power's entrance to Turkish geothermal energy market is the new renewable law. Since the law offers extra bonuses if the equipment used is made in Turkey, the company hopes to benefit from that scheme.

Turkish Zorlu Energy Group announced that one of its affiliates has signed a facility agreement of $410 million with Turkish banks Akbank and Garanti Bank in the second half of 2010. The company will finance its renewable energy based projects with that loan because the firm discovered a new 60MW field in its feasibility studies. After becoming preferred bidder for the Denizli-Kizildere power plant under the privatization of ADUAS (Ankara Dogal Elektrik Uretim ve Ticaret A.S.), Zorlu Group aims to ensure that Kizildere Geothermal Power Plant will reach to a high capacity via modern technology, local employment and natural agriculture development.

Dutch Investment Company Transmark Renewables and German Geothermeon AG which is an expert in Hot Fractured Rock (HFR) and Enhanced Geothermal Systems (EGS) have formed a new JV company, Sonsuz Enerji B.V in November, 2010. Sonsuz Enerji will focus on the exploration of 8 licenses which are mainly located in Western Turkey. First exploratory drilling activity is scheduled for the second half of 2011. This JV, in our opinion, is very critical because the trend in geothermal energy industry is leaning to Enhanced Geothermal Systems globally. By the entrance of Geothermeon AG into Turkish geothermal market, Turkey will also welcome the knowhow of this technology.

In order to maintain all these hopeful developments in geothermal sector and reach the 2023 Vision Plan’s energy related desire by implicating geothermal resources into the energy portfolio of the country, Turkey set specific geothermal goals. Turkey’s Geothermal Energy 2013 Projections on electricity and heating prepared by State Planning Organization’s are presented below.

Table 48. Projection of the Year 2013 on Geothermal Electricity and Direct Use Applications in Turkey (Turkish Geothermal Association, 2005).

Geothermal Evaluation	February, 2005	Capacity	2013 Projections	Capacity (MW)	Total Annual Energy
Electricity Production		20MWe/94GWh		550MWe/2475GWh	4 billion kWh/yr
Residential Heating	103,000 resid.	635MWt	500,000 resid.equiv.	4000MWt	
Thermal Tourism	215 Spas	402MWt	400 spa equiv.	1100MWt	
Greenhousing	635000 m2	192MWt	5,000,000m2	1700MWt	
Cooling	-	-	50,000 resid. equiv.	300MWt	
Drying	-	-	500,000tonnes/yr	500MWt	
Fishing&Others	-	-	-	400MWt	
Total Direct Use	-	-	-	8000MWt	35,040,000MWth/year

According to the Turkish Geothermal Association (TGA), Turkey's geothermal electricity production amounted to 20MWe corresponding to 94GWh in 2005. This is expected to reach 550MWe or 2,475GWh by the end of 2013. TGA projects the total annual energy need as a 4 billion kWh/year. For residential heating, 635MWt of geothermal heating power in 2005 will hike up to 4,000MWt in 2013. In other words, from 103,000 residences equivalent energy to 500,000 residences equivalent energy is projected by 2013. The number of thermal spring and spa facilities will be increased from 215 to 400. Greenhousing will experience almost 10 fold growths and reach 1,700MWt by 2013. The activities on geothermal cooling, fruit drying and fishing which have insignificant share in geothermal energy mix will be promoted and those three sub sectors all together will generate 1,200MWt of energy.

To sum up, total geothermal direct use will accounted to 8,000MWt in 2013. This usage along with geothermal electricity projections will substitute 3,88 million tones/ year of fuel oil equal to $4,24 billion/year. From the environmental perspective, if Turkey generates 550MWe of electricity and 8,000MWt of direct use, then she will baffle 10 million tones/year. In addition to these, it is expected that Turkey will be able to export greenhouse applications to the neighbor countries.

While Turkey's greenhouse export was $15 million in 2005, Turkey will enjoy $250 millions of export volume in 2013.

Table 49. Required Additional Investment Costs for the 2013 Geothermal Projections (TGA, 2005)

Geothermal fields	Target 2013	Additional Investment Differential($)
Electricity generation	550MWe	1,000,000,000
Heating(residence, thermal)	4000MWt	800,000,000
Greenhouse heating	1700MWt	350,000,000
Drying	500,000tonnes/yr	100,000,000
Thermal Tourism	400 spas equiv.	800,000,000
Cooling	50,000 resid. Equiv.	200,000,000
Total Investment Value		3,250,000,000
Expected Welfare Creation		16,000,000,000

As depicted table above, required total investment value is $3,250 billion until 2013. $1 billion, the highest additional investment differential, will be needed in achieving geothermal electricity generation targets. Geothermal residential heating with $800 million and greenhouse heating with $350 million will follow geothermal electricity capacity increase. Geothermal drying, thermal tourism and geothermal cooling markets will require more than $1 billion until 2013. All these numbers clearly shows that Turkish geothermal energy market will expand but there is a huge financing and investment gap in that sector. Needless to say, local and foreign investors should consider this opportunity to become major geothermal energy players in Turkey.

When we conduct SPO's 2013 Projections with Turkey's 2023 Vision Plan and the role of geothermal within that package and Turkey's growing energy and electricity demand, then it will not be wrong if Turkish geothermal market defined as in the process of development stage. For sure, geothermal investment volume in

Turkey will gather speed. Parallel to these expectations, TGA estimates that geothermal industry will create nearly 200,000 job opportunity in 2013. When it is compared with the number of 2005 which is 40,000, the significance of these projections will be understood deeply. Last but not least, if all these projects are hold and $3,250 billion of investment are made, then $16 billions of economic contribution will be generated.

All sector specific developments and the projections mentioned above designate that the Turkish geothermal market started to develop in the last 5 years. The increase of foreign direct investors' interests in geothermal market of Turkey can be observed by checking out the ascending trend of joint ventures. It should be noted that the main collaborations of foreign investors generally appear in the form of Europe-Turkey joint ventures. However, the EU firms do not only cooperate with Turkish firms but also form a partnership with other European countries which evaluate an investment decision in Turkish geothermal market. Together with foreign companies, Turkish firms' affinity in geothermal resources is increasing day by day. Turkish government also started to support these improvements by setting realistic goals and establishing more sufficient policies about geothermal energy resources. Even though there are still many barriers slowing the sector's development impetus down and Turkey could not take adequate actions on time, Turkish geothermal energy may become one of the main pillars of the country's energy dependence. It may also enlist local and global investors' interests in the high probability of exporting Turkey's geothermal energy to the neighboring states.

CHAPTER 5

LITERATURE REVIEW

Literature on Sustainable Development

Sustainable development is a huge concept and it includes various fields such as climate change, promotion of new and renewable sources of energy, agriculture development and food security, disaster reduction solutions, agricultural technology for development, harmony with nature, promotion of human rights, and maintenance of international peace and security (Morgera, 2010). In the past, sustainable economic development was defined as development that could be sustained without periodic cycles of prosperity and recession. However, today, the definition of sustainable development also includes the proviso that it not has an impact on peoples' environmental and social awareness or even imposes a burden on future generations (Kruger, 2006).

The assertion that energy is the primary input of economic growth and social welfare is accepted at the global level. A generation ago, the linkage between sustainable development and energy has been researched by focusing on the security conditions of energy supply to the consumers. However, since fossil fuels such as coal, oil, even natural gas which are the most important energy resources are declining rapidly and since these fuels caused serious environmental problems, the part of energy in sustainable development has shifted from the concept of pure energy to the concept of sustainable energy. In this context, interaction between energy production and consumption with sustainable development stands out with two remarkable points: (1) person's basic needs can be met only by benefitting from the energy which is the source of welfare and economic progress, (2) the quality of life should not be jeopardized for the current and next generations and the maximum payload of eco system should not be exceeded (Ataman, 2007). Therefore, it can be seen that sustainable energy contains policies, technologies and applications that have minimum financial, environmental and social costs. Consequently, the main components of the sustainable energy consist of energy efficiency and renewable energy.

According to the European Renewable Energy Council (EREC, 2010), the countries will to achieve sustainable development should move into a sustainable energy future, based on cost effective, clean and stable supplies. The key principles that can help counties to achieve sustainable energy are phasing out fossil fuels as soon as possible, increasing energy efficiency, implementing clean, renewable solutions, and discarding dirty, unsustainable energy resources. British Petroleum (BP) in its Sustainability Report 2006 defines sustainability as the capacity to endure as a group, by renewing assets, creating and delivering better products and services that meet the evolving needs of society and contributing sustainable environment. All these elements guide renewable energy as a primary tool in sustainable energy. A sustainable world energy outlook report prepared by European Renewable Energy Council also highlights the significant role of renewable energy by supporting that renewable energy can contribute to sustainable economic growth, high quality jobs, technology developments, global competitiveness and industrial and research leadership. Hernandez, Miguel, and Rio (2010) also give emphasis on the role of the alternative energy in sustainable development and assert that the deployment of the renewable energy sources contributes to sustainable development through the promotion of socioeconomic cobenefits including diversification of energy supply, creation of a local industry with international projection in a rapidly expanding sector, generation of employment and business opportunities in less industrialized rural areas. While explaining the gravity of renewable energy, Tony Hayward, BP Group Chief Executive, indicates three distinct challenges arising from the world's growing demand for energy which are security, sustainability and affordability. Energy security issue is related to how to provide energy reliable in a world where there is a mismatch between production and consumption places. Each country, more or less, has renewable energy resources such as water, wind and solar energy. Although some countries have not adequate policies, technologies and background to promote renewable energy to ensure their energy security, renewable energy with energy efficiency can play important role in energy security problem.

Sustainability which is related to how to meet that demand in a way that is environmentally sustainable and avoids damaging climate change can be solved by benefitting from renewable energy resources' environment friendly features. Finally, since economic development and an improved quality of life rely on energy that should be accessible and affordable to those who need it, renewable energy with its long term benefits can make contribution to have affordable energy, even its start up cost is too high. Ghosh et al. (2002) heed environmental benefits of renewable energy resources in sustainable development and support that renewable energy resources contribute to global sustainability through green house gas (GHG) mitigation which is one of the conditions that denoted under the Kyoto Protocol of United Nations Framework Convention on Climate Change (UNFCCC).

Apart from environmental issues, International Energy Agency (IEA) stresses economic and social factors in explaining the relationship between sustainable development and renewable energy. In World Energy Outlook 2008, renewable energy has been illustrated as a key to sustainable development via bringing major benefits to public health, social welfare and economic productivity. It can be observed that while the contribution of renewable energy to the mitigation of climate change and the reliability of the energy supply are generally accepted and analyzed for a long time, the researchers began to study the socio economic aspects linked to the use of renewable energy very recently. Majority of the studies has focused on the socio economic impact of establishing renewable energy on the creation of jobs (Bribian, Sastresa, Scarpellini, & Uson, 2009).

Literature on Renewable Energy

Since the concept of sustainable development is strictly related to energy and especially renewable energy, literature review on energy and renewable energy will be presented.

In the literature, energy has been classified by many researchers. For example, Twidell and Weir (2005) assort energy supplies into renewable and non renewable energy and say that there are five ultimate primary sources of energy. These are the sun, the motion and the gravitational potential of the sun, moon and earth, geothermal energy from cooling, chemical reactions and radioactive decay in the earth, human induced nuclear reactions and chemical reactions from mineral sources. In contrast this classification made, Kruger (2006) classifies primary energy resources into three major types:

- Primordial: These are the heat sources that originated with the formation of the earth such as boiled water and geothermal resources including hydrothermal and petro thermal

- Fossil: This is decayed organic (carbon containing) matter fossilized over millions of years that can be extracted by the mineral extraction industries.
- Renewable: This consists of the energy fluxes available on a daily basis from incoming solar and lunar sources.

Kruger also categorizes energy available for the human quest by origin as solar including thermal, hydropower, kinetic, biomass, lunar including tidal and terrestrial including geothermal heat. In parallel to Kruger (2006), Demirbas (2009) assorts energy sources under three sections but instead of primordial energy, the author uses the fissile energy sources that are uranium and thorium. In addition to these classifications, Kaltschmitt et al. (2007) divide energy resources into two sub headings by focusing on time period of the energy resources. Fossil energy resources which are stocks of energy that have formed during ancient geologic ages by biological processes are divided into biogenous and mineral energy resources. Hard coal, natural gas and crude oil are located under fossil energy resources. However, recent energy resources are currently generated and include the energy contents of biomass and the potential energy of a natural reservoir.

Renewable energy has had many definitions over the last five decades. Many researchers have focused on different technical aspects and social dimensions. According to Kruger (2006), a broad definition of renewable energy from the environmental movement since the 1960s includes any energy source that is alternative to conventional fossil fuels. While alternative energy is being explained, Kruger (2006) defines renewable energy as the energy derived from natural processes that are replenished frequently. Twidell and Weir (2005) also identify renewable energy as an energy obtained from natural and persistent flows of energy occurring in the immediate environment. The authors assert that renewable energy may also be called Green Energy, Sustainable Energy or Alternative Energy. In detailed definitions, Assmann et al. (2006) argue that the term “renewable energy sources” refers to hydro energy, biomass energy, solar energy, wind energy, geothermal energy and ocean energy. Assmann et al. (2006) also mention the term “new” renewables that suggests a greater focus on modern and sustainable forms of renewable energy. According to the authors, these are modern biomass energy, geothermal heat and electricity, small scale hydro power, low temperature solar heat, wind electricity, solar photovoltaic and thermal electricity, and ocean energy including tidal, wave, current, ocean thermal, osmotic and marine biomass energy. In the literature, there can be find many research studies about the classification of renewables. For instance, Twidell (1992) classifies renewables under four headings:

- Accepted renewables with long experience: large hydro, biomass combustion, geothermal.
- New renewables with new beginnings: wind, passive and active solar heat, agro industrial biofuels, small scale hydro, wave and tidal, heat pumps and photovoltaic
- Clean up renewable with technologies linked to wastes from the utilization of resources: Municipal waste combustion, landfill gas, biogas
- Integrated renewables: techniques of renewable energy incorporated in whole, integrated processes; combining renewable energy forms with each other.

Akkaya (2007) classifies renewables depending on familiarity of the methodology of producing energy from renewable energy resources and divides into two sections. While traditional renewable energy resources include biomass and large scale hydro energy, new renewables contains solar, wind, geothermal, biodiesel and wave energy. According to the classification made by Ozdamar (2001), in the light of the main source of the energy, alternative resources can be analyzed under three sections such as sun based, earth based and moon based. While the sun is the main source of the hydro power, wind energy, biomass energy and solar heat, the earth provides energy for the geothermal energy and the moon does it for the tidal too. Goldemberg (2006) cited in Kaltschmitt (2007) also classifies the renewable energy like Ozdamar. All renewable energy used by humankind originates from one of the following sources: radiant energy emitted by the sun including solar energy and its derivatives, geothermal energy from the interior of earth, tidal energy originating from the gravitational pull of the moon.

Literature on Renewable Energy in Turkey

In the literature, many studies regarding renewable energy of Turkey has been conducted. In the study that seeks to foresight of Turkey's renewable energy, Celiktas and Kocar (2009) state that the renewables will bring economic and environmental benefits and help to achieve improved living standards. Indeed, the majority of Turkey's renewable energy relates studies focuses on energy dependence as an economic factor, climate change and poisonous gases as the environmental factors and social welfare as a social indicator.

Kirtay (2009), in the study of the Role of RER (Renewable Energy Resources) in Meeting Turkey's Electrical Energy Demand, calls attention to the Turkey's energy import ratio. As of 2009, 97 % of natural gas demand, 93 % of oil demand and 50 % of coal demand in Turkey is met by imports. Kirtay (2009) indicates that this energy imbalances increase the cost of energy. In order to decrease energy cost which damages the Turkish economy, energy structure of the country should be changed through RER. While Uslu (2008) agrees with the idea that Turkey's RER can be seen as an important tool to reduce foreign dependence on energy, she stresses that RER, alone itself, cannot solve this problem. According to her, Turkey should also explore new coal and petroleum reserves, modernize existing coal and lignite production facilities, build biomass power plants and nuclear stations. It can be seen that while offering new alternatives and suggestions for decreasing energy import, Uslu does not mention about the environmental issues and she totally ignores the potential negative impacts of the coal, petroleum, nuclear and biomass on environment.

Very recent study made by Erdem (2010) tries to figure out the contribution of RER in meeting Turkey's energy related challenges and gives priority to the heavy dependency on energy imports too. Since Turkey has an increasing energy demand but finite reserves of fossil fuels, the rapid rise in global energy prices affects the Turkish economy in a negative way. To lower the energy price pressure and meet its growing energy needs, Turkey should encourage the adoption of renewable energy through benefitting from free wind, hydro, solar, and geothermal energy. Apart from economic benefit of RER and unlike Uslu, Erdem also explains the reason why her study does not touch upon environmental side of the issue. From greenhouse gas (GHG) emissions point of view, Erdem does not see Turkey in a trouble since CO_2 emissions per capita are only 3 quarters of world average, as of 2010.

In contrast to the opinion that Turkey's environmental problems are caused by fossil fuels are not important as much as economic problems are, it can be seen that from economists to the geographers, from environmentalists to the engineers, many researchers opposed that idea and made contribution to the literature on environmental benefits of RER. Due to the economic and social development that Turkey experiences, Turkey's energy demand and consumption increases day by day. Although she does not face a problem about poison gas emissions, it does not mean that this situation will continue similarly. Moreover, the world faces with the problem which is called global warming. According to Yaylalı (2008) in order to control the greenhouse gas, CO_2 and other similar gases, Turkey has to begin to generate energy from its RER which have the potential to provide energy with zero or almost zero emissions. Otherwise, Turkey will reach and even exceed its gas limitations defined under Kyoto Protocol.

Demirbaş and Pehlivan (2008) explain the advantages of RER over fossil fuels by pointing out the intimate connection between RER and sustainable development. According to the authors, the most efficient way to decrease or even avoid environmental problems that stem from the intensive use of fossil fuels is utilization of RER very passionately. They also conclude that December 1997 of Kyoto Protocol to the UNFCC is starting and important turning point of RER promotion worldwide.

Demirbas in his separate paper, Global Renewable Energy Projections (2009) approaches RER as a promising alternative solution to the environmental problems, since alternative energy is clean, environmentally safe and inexhaustible. Demirbas strongly supports that renewable energy is an essential characteristic of sustainable development.

Another study on relationship between environment and RER made by Yuksel (2008) aims to discover the fundamental role of the RER on climate change mitigation. While doing this, author also discusses the importance of building up a long term comprehensive strategy which should assess environmental impacts of developing RER. Balat (2008) focuses on the both environmental and economic aspects of RER. The author gives equal importance to both issues but the attribution that helps her research sounds different stem from prevision about investment opportunities in Turkish renewable energy market. According to the author, over the next three decades, it is expected many foreign investors and financiers will be interested in the Turkish hydropower market. At this juncture, it can be said that Balat (2008) tries to explain something different from the literature. Instead of only presenting the potential benefits of RER on the Turkish economy and environment, comparison between RER and fossil fuels of Turkey, the author insinuates Foreign Direct Investment (FDI) in Turkish hydropower market. After this substantial and distinct foreseeing, the main question that comes to mind is that "why has the author limited her FDI proposal only with hydropower market of Turkey?"

Assessments on Turkish RER show that Turkey has abundant solar, wind and geothermal resources that can become attractive to foreign investors if investment conditions become mature enough. Thus, the attractiveness of Turkish renewable energy market, especially for those resources, should be assessed.

On the contrary, Yuksel (2009) approaches the need of investment in renewable energy market of Turkey from different perspective. The main points that he wants to connect each other are financing, policies and investment sides of RER. According to International Energy Agency (IEA, 2005) Turkey is to be the receipt of a US $ 202 million renewable energy loan provided by the World Bank. The investors who are interested in Turkish renewable energy market can use these loans that are expected to finance 30-40 % of associated capital costs. The author designates that since there are some external financing opportunities in Turkish renewable energy market, Turkey should increase privately owned and operated power generation from RER. It should be beneficial to indicate Turkey's main energy policy principle which is to meet our energy needs at desired levels of quality in a reliable and inexpensive way, and to upgrade existing facilities to meet the demands and conditions of current time. Since that principle requires huge investments in Turkish energy sector and public does not has economic power to spend huge amount of money, mobilizing private sector capital, capabilities and dynamics to renewable energy sector is must.

According to Kaygusuz (2000) implementation of build - operate – transfer (BOT) and transfer of operation right (TOR) models in energy projects during 1980s and 1990s made substantial contribution to development process of Turkish energy sector and economy. In order to ensure reliable and affordable energy supplies for Turkey which has growing population and developing economy, the Turkish renewable energy market should be strengthened by adapting of that kind of models into the current economic conditions. It is clear that this goal can be achieved if only Turkish government could promote independent power production under BOT and TOR models and seek ways of increasing attractiveness of Turkish renewable energy market for the international investors (Salvarli, 2009). There is no doubt that Turkish policy makers should not only establish new and sufficient renewable energy laws but also provide reliable investment environment to encourage private sector to involve in renewable energy market.

After the economic and environmental connections, the third point that is met in the literature of renewable energy resources in Turkey is social benefits of RER. Kaygusuz (2004) aims to explain the linkages between RER and its social benefits via referring poverty alleviation. According to the author, Turkey, like many developing countries, has lack of access to convenient and efficient energy services which can be seen as a major barrier against achieving long lasting solutions to poverty. In order to remove that barrier to poverty reduction, the share of renewable energy resources based electricity and energy production should be increased and finally renewable energy technologies can provide energy services for sustainable development as a social tool.

Ataman (2007) explains the social benefits of RER by comparing it with fossil fuels and emphasizing the term “social cost”. Ataman defends that although negative impacts of fossil fuels on environment and human health are well known by majority of communities, peoples do not calculate the social costs which include deforestation, greenhouse effect, climate change based flood and drought in the selection process of which energy resources is going to be used. Since suppliers and demanders do not care about these environmental and extrinsic costs enough, market price of fossil fuels does not reflect the real price. Thus, tendency to use more RER in energy generation will minimize that social cost.

Another research made by Ogutcu (2010) seeks to find relationship between renewable energy and social welfare escalation. Ogutcu denotes that building RER based clean energy industry in Turkey means not only more environment friendly electricity generation but also more high paying jobs in every region of the country. He supports that if Turkey booms its renewable energy market and begins to benefit from RER, then the job creation will happen which helps Turkey to decrease its unemployment rate.

In addition to economic, environmental and social aspects of RER, politics and policy aspects of RER in Turkey were studied in the literature. Ogulata (2007) in his research compares the potential of Turkey’s RER with world’s RER. The researcher finds that Europe’s wind energy capacity has the biggest share 72 % in global wind energy capacity, while Turkey’s installed wind capacity has a share of 0.11 % in Europe’s installed capacity in 2001. Although Turkey has a huge potential not only in wind but also in solar and geothermal power, there is a lack of investments in renewable energy market of the country. It is certain that the European REM is much more developed than Turkey. Therefore, Turkey should analyze the successful regions in REM very deeply. Supportive research made by Akkaya (2007) emphasizes the critical role of policies and experiences in becoming a successful player in renewable energy market. As a country wills to stimulate its renewable energy market and encourage private sector players to invest in its RER, Turkey has to take some countries as a role model. Akkaya shows the EU countries as success story and suggests Turkey to follow the renewable energy targets, policies, incentives and financing strategies of the EU.

Another similar but more political approach comes from Hisarciklioglu, the president of the Union of Chambers and Commodity Exchanges of Turkey (TOBB). In his paper, The Global Energy Challenges and Turkey (2010), he strongly supports that if Turkey wants to become a member of the EU, being well prepared for a low carbon age through utilizing share of RER in its energy mix according to the EU regulations and standards is must. From that point of view, it can be seen many research stduies on the investigation of the EU and Turkey relationship in the light of the REM policies. Similar to the ideas that have been presented by Hisarciklioglu, Bakis and Demirbas (2004) have also tried to figure out the EU and Turkey's relationship via RER in the beginning of 2000s. The authors advocate that the only way to meet the criteria that EU has set for the sustainable development is following the renewable energy promotion steps that EU has already taken it. In parallel with these needs, Turkish parliament approved a renewable energy law which will provide feed in tariffs and purchase obligation for electricity from RER in 2005. According to Tanay Sidki Uyar, World Wind Energy Association (WWEA) vice president, Turkey made first but important step to strengthen the country's decentralized renewable energy sector. Balat (2009) also describes that law as a significant step in harmonization process of Turkey's REM to the EU.

On the contrary, while explaining the New Energy Paradigm, Saygın and Cetin (2010) explains the problem that the researchers believe Turkey faces with. According to the study, although Turkey tries to enlarge its REM by adopting the EU's renewable energy related regulations, the country still could not internalize the new laws specifically enough. The reason behind this problem stems from the fact that policies and measures adopted in Turkey aiming to enhance the use of RER are mainly driven by the requirements of the EU accession process. In other words, the EU forces Turkey to change something. Even though it works in theory and parliamentary, since Turkey can not walk on the renewable energy road voluntarily, this situation does not work in practice. While Saygın criticizes the performance of Turkish side in practice, Bilgin (2009) puts forward a proposal by questing connections between RER, the EU accession and Turkey's geographic position. First, the author focuses on the energy related challenges of the EU and Turkey and shows the similar weaknesses and strengths of the counter parties. Then, he suggests that Turkey should definitely use its significant geographic position against the EU during the accession process. From geopolitical perspective, Turkey should have an opportunity to export its RER to the neighbor countries including the EU27 countries. Bilgin (2009) finally concludes that these actions will develop bilateral trade relation between Turkey and the EU.

Bezir et al. (2009) want to evaluate the barriers of renewable energy use in Turkey. The authors merge all problems of renewable energy utilization on four main barriers. These are (1) Economic barriers, (2) Cost of Technologies, (3) Financing Problems and (4) Scientific/Technical barriers. The researchers indicate that since

RER have low energy intensity per unit and the utility can not accurately forecast the exact time of electricity generation expectation from RER, connecting intermittent renewable with an existing electricity grid can cause serious supply problems.

Comakli et al. (2008) accept the barriers of renewable energy use in Turkey and also add that RER are widely dispersed compared to fossil fuels. Because of these cons of RER, they defend that renewable energy must be either used in a distributed manner or concentrated to supply the higher energy demands of the regions and industries.

In opposition to these studies, Kaygusuz and Sari (2006) approaches the renewables' discrete feature from positive perspective and try to conduct it with sustainable development. According to the authors, RER in Turkey can offer the possibility to actively involve the people in participating in sustainable development through their diversity and distributed development.

Apart from the barriers of RER in Turkey, the works related to public awareness on renewable energy for Turkey is quite limited. Hepbasli and Ozgener (2004) link the progress of the renewable energy investments with the public recognition. The authors think that public awareness on the importance of renewable energy within the concept of sustainable development increases gradually. Another research which aims to explore the level of awareness of Canadian, Romanian and Turkish university students on renewable energy made by Akbulut et al. (2008) found that majority of students think that alternative energy sources should be top priority for the governments. Although the scope of this study is limited, it gives an idea that people from not only Turkey but also whole world become conscious about green energy and its necessity for humanity.

CHAPTER 6

DETERMINING FACTORS AFFECTING THE RENEWABLE ENERGY SUPPLY

In this study, panel data models are employed to empirically assess the determinants of renewable energy supply for the EU-27 countries and the candidate countries for the period between 1995 and 2008. The first section of the chapter provides brief information on the methodology of panel data analysis while the following section introduces the model and the data that will be used in this study. The third section consists of empirical results and discussions.

Panel Data Analysis

Panel data procedures are described as the simultaneous investigation of a system of equations that consider both country specific characteristics and change over time (Ozkan-Gunay, 2011). Estimation process has two step procedures; the variance components are first estimated by using the residuals from Ordinary Least Square (OLS) regressions, and then feasible GLS, generalized least square, estimates are computed using the estimated variances (Greene, 2007). The effects of many independent variables which will be presented succeeding section on renewable energy supply in Turkey, EU member countries and candidate countries are analyzed by testing different econometrics models such as OLS and Fixed Effects Model (FEM). FEM assumes that the effects of the numerous omitted individual time varying variables are individually unimportant but are collectively significant where ε_{it} is a classical disturbance with E $[\varepsilon_{it}|X_i] = 0$, Var $[\varepsilon_{it}| X_i] = \sigma_\varepsilon^2$ and $Cov[\varepsilon_{it}\varepsilon_{js} |X_i, X_j] = 0$ for all i,j (Greene, 2007).

$Y_{it} = \alpha_i + \beta^{/} X_{it} + \varepsilon_{it}$

The individual effects can be absorbed into the intercept term of a regression model as a means to explicitly allow for the individual or time heterogeneity contained in the temporal cross-sectional data. Therefore, α is a separate constant term for each unit that varies both cross-sectionally across countries and over time. The problem of multicollinearity is avoided by imposing the following restriction.

$\sum_i\alpha_i=\sum_i Y_i$

Data and Modeling

In this study, the determinants of primary renewable energy supply are analyzed according to the classification of determinants in the study of Ozkan-Gunay (2011). Major determinants for renewable energy supply are categorized as domestic country's fundamentals for producing renewable energy and defined as economic capacity (EC), technological infrastructure capacity (TIC), foreign investment capacity (FIC), environmental effect (EE), nuclear energy capacity (NEC), domestic energy capacity (DEC), energy trade capacity (ETC), renewable energy capacity (REC), domestic oil and gas capacity (DOGC) and oil and gas trade capacity (OGTC).

$REN_{it} = f$ (EC, TIC, FIC, EE, NEC, DEC, ETC, REC, DOGC, OGTC)

Three versions of model are utilized in the context of Panel Data Models. In the first model, energy parameters are defined in terms of total production, consumption, import and export besides other parameters.

Model 1

$$REN_{it} = \beta_0 + \beta_1 GDP_{it-1} + \beta_2 GDPPC_{it-1} + \beta_3 POP_{it-1} + \beta_4 EI_{it-1} + \beta_5 RDE_{it-1} + \beta_6 FDI_{it-1} + \beta_7 GHG_{it-1} + \beta_8 PNUC_{it-1} + \beta_9 TEP_{it-1} + \beta_{10} TEC_{it-1} + \beta_{11} TEM_{it-1} + \beta_{12} TEX_{it-1} + \square_{it}$$

where subscript *i* denotes countries and *t* represents time period.

The second model considers energy parameters in terms of supply volume and excludes countries' energy consumption and energy trade indicators.

Model 2

$$REN_{it} = \beta_0 + \beta_1 GDP_{it-1} + \beta_2 GDPPC_{it-1} + \beta_3 POP_{it-1} + \beta_4 EI_{it-1} + \beta_5 RDE_{it-1} + \beta_6 FDI_{it-1} + \beta_7 GHG_{it-1} + \beta_8 PNUC_{it-1} + \beta_9 SUPOIL_{it-1} + \beta_{10} SUPGAS_{it-1} + \beta_{11} PSOL_{it-1} + \beta_{12} PGEO_{it-1} + \beta_{13} PHYD_{it-1} + \beta_{14} PWIND_{it-1} + \square_{it}$$

where subscript *i* denotes countries and *t* represents time period.

The third model covers energy indicators more specifically by including all production, consumption, and export and import volume of different type of energy sources.

Model 3

$$REN_{it} = \beta_0 + \beta_1 GDP_{it-1} + \beta_2 GDPPC_{it-1} + \beta_3 POP_{it-1} + \beta_4 EI_{it-1} + \beta_5 RDE_{it-1} + \beta_6 FDI_{it-1} + \beta_7 GHG_{it-1} + \beta_8 PNUC_{it-1} + \beta_9 PSOL_{it-1} + \beta_{10} PGEO_{it-1} + \beta_{11} PHYD_{it-1} + \beta_{12} PWIND_{it-1} + \beta_{13} POIL_{it-1} + \beta_{14} COIL_{it-1} + \beta_{15} PGAS_{it-1} + \beta_{16} CGAS_{it-1} + \beta_{17} MOIL_{it-1} + \beta_{18} XOIL_{it-1} + \beta_{19} MGAS_{it-1} + \beta_{20} XGAS_{it-1} + \square_{it}$$

where subscript *i* denotes countries and *t* represents time period.

The annual time series data covers 27 European Union member countries and three candidate countries. Due to the lack of available country specific data, Malta and Former Yugoslav Republic of Macedonia cannot be included in the sample. Therefore, sample includes 15 old members, 11 new members as well as 3 candidate countries. Since the existing sample displays large discrepancies in terms of economic, technological development levels as well as the utilization of renewable energy resources, sample is disaggregated as EU-15 for initial members and EU-14 for the new members and candidate countries.

The data used in the models are retrieved from different sources for each variable. The data on total primary renewable energy supply as the dependent variable are taken from Eurostat Energy Statistics and are crosschecked with the statistics of OECD- International Energy Agency. Main determinants for Renewable Energy Supply are presented in Table 50.

Table 50. Determinants of Renewable Energy Supply

Determinant	Proxy Variable	Definition	Source	Effect
Economic Capacity (EC)	Market Size(GDP)	Gross Domestic Product	Eurostat	+
	GDPPC	National Output divided by the population or value of goods produced per person	Eurostat	+
	Population(POP)	All those persons who are usually resident in the country (millions)	UNCTAD	+ / -
	Energy Intensity (EI)	The amount of energy required to produce a unit of economic output(GDP)(kilogram of oil equivalent per 1000Euro)	Eurostat	+ / -
Technological Infrastructure Capacity(TIC)	R&D Expenditure(RDE)	All expenditures for R&D performed within a statistical unit or sector of the economy (millions of €)	Eurostat	+
Foreign Investment Capacity(FIC)	Inward Foreign Direct Investment (FDI)	Sum of capital provided from a foreign direct investor (millions of €)	OECD	+
Environmental Effect (EE)	Total Greenhouse Gas emission (GHG)	Sum of primary greenhouse gases emitted in the country (CO2 equivalent)	Eurostat	+ / -
Nuclear Energy Capacity(NEC)	Total Nuclear Energy Production(Pnuc)	Sum of generated energy in nuclear power plants as a result of fission of the nuclear fuel inside of the	Eurostat	-

		reactor (toe)		
Domestic Energy Capacity(DEC)	Total Primary Energy Production (TEP)	Sum of first stage of production of various forms of energy (thousand tonnes of oil equivalent)	Eurostat	-
	Total Final Energy Consumption(TEC)	The amount of final energy consumed in the country (toe)	Eurostat	+
Energy Trade Capacity(ETC)	Total Energy Import(TEM)	The amount of energy bought from foreign countries (toe)	Eurostat	+
	Total Energy Export(TEX)	The amount of energy sold to foreign countries (toe)	Eurostat	-
Traditional Fossil Fuel Capacity(TFFC)	Total Primary Oil supply(Supoil)	Sum of oil production and oil import minus oil export(toe)	Eurostat	+ / -
	Total Natural Gas Supply(Supgas)	Sum of gas production and gas import minus gas export(toe)	Eurostat	+ / -
Renewable Energy Capacity(REC)	Total Solar Energy Production (Psol)	The amount of solar radiation exploited for hot water and electricity production (toe)	Eurostat	+
	Total Geothermal Energy Production (Pgeo)	The amount of produced energy available as heat emitted from within the earth's crust, usually in the form of hot water or steam (toe)	Eurostat	+
	Total Hydro Energy Production(Phyd)	The amount of energy generated from hydro(toe)	Eurostat	+ / -
	Total Wind Energy Production (Pwind)	The amount of energy produced from wind (toe)	Eurostat	+
Domestic Oil & Gas Capacity (DOGC)	Total Oil Production(Poil)	The sum of energy produced from all petroleum products (toe)	Eurostat	-
	Total Oil Consumption(Coil)	The sum of energy consumed from oil in the country (toe)	Eurostat	+
	Total Natural Gas Production(Pgas)	The sum of energy generated from natural gas within the country (toe)	Eurostat	-
	Total Natural Gas Consumption(Cgas)	The sum of energy consumed from natural gas in the country (toe)	Eurostat	+
Oil & Gas Trade Capacity(OGTC)	Total Oil Import(Moil)	The amount of imported petroleum products (toe)	Eurostat	+
	Total Oil Export(Xoil)	The amount of exported petroleum products (toe)	Eurostat	-
	Total Natural Gas Import(Mgas)	The amount of imported natural gas (toe)		+
	Total Natural Gas Export(Xgas)	The amount of exported natural gas (toe)	Eurostat	-

GDP, GDP per capita, population and energy intensity are taken as the economic capacity (EC) indicators. GDP is an important indicator for the size of the economy. The larger the economy, the higher is energy demand. Therefore, the sign for the GDP coefficient is expected to be positive. GDPPC is a widely accepted indicator for welfare of citizens in a country. Higher GDP and GDP per capita allow the countries to give much more attention on utilization of renewable energy resources as well as available funding sources. As a result, expected sign of the GDP per capita is expected as positive. As a demographic parameter, population is included in the model because market size also depends on the population size. However, the sign of this parameter is ambiguous. The country with high population may have higher demand for energy and this may force them to produce energy from alternative energy sources. On the other hand, these countries may prefer to use traditional energy resources for the sake of high economic growth in the short run due to lack of available funding for investment in renewable energy supply. The effect of energy intensity on renewable energy supply, which is derived from gross inland consumption of energy divided by GDP, is also ambiguous. While the countries with high ratio for energy intensity are willing to decrease their energy dependency on traditional energy resources, they may ignore energy intensity issue and rely on conventional energy resources.

Total greenhouse gas (GHG) is also taken into account as an environmental determinant in the model. It has an ambiguous effect on renewable energy supply. Many developed countries (DCs) that emit too much greenhouse gases seek for new alternative energy resources along with energy efficiency to decrease the volume of poisonous gases. But some DCs prefer not to change their current energy portfolios.

Expenditure on R&D is an important indicator for a country's preference on technology development. Renewable energy sector also requires high investment in technology. Therefore, the impact of R&D expenditure on renewable supply is expected to be positive.

As a foreign investment capacity indicator (FIC), inward FDI is included in the model. Since inward foreign direct investment provides technology and knowhow transfer opportunity from developed countries to developing ones and helps countries to finance not only their energy projects with high start up cost but also their current account deficit, FDI is expected to affect the renewable energy supply of host country positively.

While production and consumption indicators are grouped under domestic capacity main heading, import and export variables are classified under trade capacity. Therefore, total energy production (TEP) and total energy consumption (TEC) are classified as domestic energy capacity (DEC). If TEP of the country is too much, then the country may not need to produce energy from her renewable energy resources. On the contrary, the higher rate of consumption may force country to utilize her renewable energy resources. Thus, the expected sign of TEP is negative and TEC is positive.

The function of energy trade capacity (ETC) includes total energy import (TEM) and total energy export (TEX). If a country is dependent on imported energy resources, then she will try to find solution to decrease her dependency and may decide to increase the share of renewable energy supply. Thus, the coefficient of TEM is expected to be positive. However, the country's total energy production may exceed the total energy consumption. In that case, she may export energy which may decrease the need for the promotion of renewable energy resources. The impact of TEX on renewable energy supply is expected to be negative.

Since oil and natural gas are the most important conventional fossil fuels, their production and consumption volumes are included as domestic oil and gas capacity (DOGC) in the second version of the model. While the production of oil and natural gas is expected to affect the renewable energy supply negatively, the consumption of oil and natural gas may affect the dependent variable positively.

Oil and gas trade capacity (OGTC) includes export and import figures in oil and gas. Similar to the energy trade capacity, import volume of oil and natural gas may affect the dependent variable positively because the countries may decrease their energy dependence through increasing renewable energy supply. On the other hand, oil and natural gas export may allow countries to continue to rely on traditional fossil fuels. In that case, the expected sign of Xoil and Xgas may become negative.

In order to determine the relation between renewable energy supply and supply volume of energy resources, total primary oil supply (Supoil) and total primary natural gas supply (Supgas) are defined as traditional fossil fuel capacity (TFFC) in the third version of the model. Since supply figures include all domestic capacity (production and consumption) and trade capacity (import and export) parameters, Supoil and Supgas have an ambiguous effect on renewable energy supply.

Hydro, wind, solar and geothermal energies are taken as the major indicators of renewable energy capacity of the country (REC). Since these resources are purely renewable, the expected sign of production volumes of wind, solar and geothermal is expected to be positive. On the contrary, hydro energy may have an ambiguous impact. Many countries accept hydro as an alternative energy source over the periods, so this tendency may slow down the development process of other renewable resources.

Finally, nuclear energy production is defined as an indicator of nuclear energy capacity (NEC). A country that generates energy from nuclear power plants may not consider renewable energy supply necessary. Therefore, NEC is expected to have negative impact on renewable energy supply.

In the light of these assumptions, the following hypothesis will be tested in this study.

H_1 : If the economic capacity of the country is high, then renewable energy supply will be high.

H_2 : If a country has a high share of expenditure in R&D, then the supply of renewable energy will be high.

H_3: If the foreign investment capacity of the country is high, then renewable energy supply will be high.

H_4: If a country has a high nuclear energy capacity, then renewable energy supply will be low.

H_5: There is a negative relation between total energy production (TEP) and renewable energy supply.

H_6: There is a positive relation between total energy import (TEM) and renewable energy supply.

H_7: If a country has a high renewable energy capacity, then renewable energy supply will be high.

H_8: If a country has a low total oil production, then renewable energy supply will be high.

H_9: There is positive relation between total natural gas consumption and renewable energy supply.

H_{10}: If a country is dependent on imported energy resources (oil and natural gas), then renewable energy supply will be high.

H_{11}: If a country has high levels of GHG emission, then renewable energy supply will be high

Empirical Findings and Discussion

Before presenting the empirical findings for the major determinants of renewable energy supply in Turkey as well as European countries, the correlation between the independent variables are analysed. Table DM2 shows the correlation between independent parameters in Model 1.

Table 51. Pearson Correlations among Variables of Model 1

Variables	GDP	GDPPC	POP	EI	RDE	TEP	TEC	TEM	TEX	FDI	GHG	Pnuc
GDP	1											
GDPPC	0,285**	1										
POP	0,870**	,024	1									
EI	-0,375**	-0,632**	-0,250**	1								
RDE	0,958**	0,338**	0,761**	-0,336**	1							
TEP	0,777**	0,190**	0,723**	-0,218**	0,762**	1						
TEC	0,972**	0,210**	0,918**	-0,324**	0,927**	0,815**	1					
TEM	0,919**	0,244**	0,824**	-0,358**	0,859**	0,624**	0,922**	1				
TEX	0,542**	0,279**	0,418**	-0,269**	0,493**	0,753**	0,535**	0,565**	1			
FDI	0,472**	0,457**	0,327**	-0,279**	0,460**	0,437**	0,433**	0,423**	0,414**	1		
GHG	0,929**	0,130**	0,933**	-0,266**	0,874**	0,811**	0,982**	0,886**	0,517**	0,392**	1	
Pnuc	0,666**	0,183**	0,542**	-0,180**	0,716**	0,587**	0,659**	0,589**	0,245**	0,342**	0,561**	1

** significant at the 0.01 level (2-tailed)

* significant at the 0.05 level (2-tailed)

The variables with r>0.7 are accepted as highly correlated variables. GDP and population are used for economic capacity determinants but the coefficient between GDP and population (0.87) is high. Moreover, GDP and population variables are correlated with the same independent variables. GDP is correlated with R&D (0.95), TEC (0.97), TEM (0.91) and GHG (0.92). Similarly, population is correlated with R&D (0.76), TEC (0.91), TEM (0.82) and GHG (0.93). Therefore, population is eliminated from the model. R&D is correlated with TEP (0.76), TEC (0.92), TEM (0.85), GHG (0.87) and PNuc (0.71). This outcome is highly relevant from a policy point of view; however an econometric problem of the relevance of all the variables appears when all are used simultaneously.

Similar steps are followed for Model 2 and 3. The correlation matrix for the independent variables defined in terms of energy types as well as the source of energy type (domestic or international trade).

Table 52. Pearson Correlations among Variables of Model 2 and Model 3

Variable	GDP	GDPPC	POP	EI	RDE	Poil	Coil	Moil	Xoil	Supoil	Pgas	Cgas	Mgas	Xgas	Supgas	Pnuc	Psol	Pgeo	Phyd	Pwind	GHG	FDI
GDP	1																					
GDPPC	0,293**	1																				
POP	0,846**	,024	1																			
EI	-0,359**	-0,641**	-0,244**	1																		
RDE	0,958**	0,316**	0,764**	-0,325**	1																	
Poil	0,400**	0,172**	0,341**	-0,157**	0,340**	1																
Coil	0,962**	0,231**	0,898**	-0,360**	0,909**	0,361**	1															
Moil	0,886**	0,265**	0,791**	-0,376**	0,828**	0,193**	0,901**	1														
Xoil	0,579**	0,302**	0,438**	-0,286**	0,516**	0,789**	0,511**	0,594**	1													
Supoil	0,948**	0,242**	0,887**	-0,375**	0,881**	0,334**	0,987**	0,950**	0,556**	1												
Pgas	0,470**	0,220**	0,366**	-0,193**	0,413**	0,795**	0,399**	0,466**	0,944**	0,441**	1											
Cgas	0,852**	0,188**	0,736**	-0,298**	0,809**	0,475**	0,824**	0,771**	0,618**	0,828**	0,569**	1										
Mgas	0,866**	0,135**	0,801**	-0,241**	0,823**	-,006	0,860**	0,857**	0,263**	0,869**	0,143**	0,728**	1									
Xgas	0,240**	0,219**	0,120*	-0,177**	0,248**	0,169**	0,158**	0,479**	0,660**	0,258**	0,696**	0,300**	0,157**	1								
Supgas	0,919**	0,208**	0,825**	-0,273**	0,840**	0,587**	0,882**	0,839**	0,751**	0,893**	0,700**	0,884**	0,774**	0,375**	1							
Pnuc	0,692**	0,397**	0,689**	-0,358**	0,698**	,064	0,723**	0,623**	0,155*	0,682**	-,014	0,537**	0,615**	-,079	0,433**	1						
Psol	0,394**	-,010	0,552**	-0,220**	0,416**	-,022	0,379**	0,337**	,038	0,372**	-,002	0,319**	0,498**	,064	0,331**	0,226**	1					
Pgeo	0,271**	0,106*	0,324**	-0,152**	0,100*	-,022	0,271**	0,300**	,061	0,312**	,011	0,266**	0,440**	-,071	0,341**	0,659**	0,098*	1				
Phyd	0,431**	0,173**	0,495**	-0,278**	0,394**	-,073	0,489**	0,437**	,027	0,469**	-0,100*	0,222**	0,423**	-0,124*	0,254**	0,674**	0,256**	0,284**	1			
Pwind	0,564**	0,173**	0,427**	-0,206**	0,601**	,037	0,504**	0,484**	0,157**	0,510**	,094	0,418**	0,590**	0,156**	0,446**	0,182**	0,620**	,001	0,117*	1		
GHG	0,924**	0,130**	0,933**	-0,260**	0,875**	0,400**	0,958**	0,858**	0,527**	0,947**	0,460**	0,834**	0,843**	0,198**	0,907**	0,596**	0,424**	0,250**	0,366**	0,503**	1	
FDI	0,472**	0,445**	0,326**	-0,267**	0,457**	0,313**	0,428**	0,427**	0,441**	0,425**	0,359**	0,392**	0,312**	0,204**	0,450**	0,324**	,064	-,051	,100	0,201**	0,390**	1

** significant at the 0.01 level (2-tailed)

* significant at the 0.05 level (2-tailed)

The variables with r>0.7 are accepted as highly correlated variables. GDP and population are used for economic capacity determinants but the coefficient between GDP and population (0.84) is high. Furthermore, GDP and population variables are correlated with the same independent variables. GDP is correlated with R&D (0.95), Coil (0.96), Moil (0.88), Supoil(0.94), Cgas(0.85), Mgas(0.86), Supgas(0.91) and GHG (0.92). Similarly, population is correlated with R&D (0.76), Coil (0.89), Moil (0.79), Supoil(0.88), Cgas(0.73), Mgas(0.80), Supgas(0.82), and GHG (0.93). Therefore, population is eliminated from the model (C). R&D is correlated with Coil (0.90), Moil (0.82), Supoil(0.88), Cgas(0.80), Mgas(0.82), Supgas(0.84) and GHG (0.87). This outcome is highly relevant from a policy point of view; however an econometric problem of the relevance of all the variables appears when all are used simultaneously. Thus, research and development expenditure (R&D) with population is eliminated from the model (D).

In the light of correlation analysis, four sets (A, B, C and D) of Ordinary Least Squares (OLS) and Fixed Effects Model (FEM) are run separately for country groups: (1) Pooled Sample referring the EU-27 member countries excluding Malta and candidate countries excluding Former Yugoslav Republic of Macedonia, (2) the EU-15 which are early members of the EU and (3) the EU-14 referring the new members and the candidate countries. For the period of 1995-2008, the three versions of the model are classified as: Model I, where total energy variables are included as determinants of renewable energy supply; Model II, where each energy supply variable is included as well as all other explanatory variables, and Model III, where indicators of sub-energy resources are considered.

Table DM4 presents OLS and FEM estimates for the potential determinants of renewable energy supply for pooled sample.

Table 53. OLS and FEM of Model 1 for the Pooled Sample

	OLS				FEM			
Independent Variable	A	B	C	D	A	B	C	D
Constant	2440.47 (8.567)	804.18 (1.532)	2214.57 (3.865)	1952.92 (3.633)				
GDP	-0.014*** (-9.712)	-	-0.011*** (-6.857)	-0.010*** (-7.366)	-0.005*** (-3.808)	-	-0.005*** (-3.873)	0.0008 (0.604)
GDPPC	-	0.081*** (4.730)	0.012 (0.658)	0.020 (1.201)	-	-0.010 (-0.357)	-0.006 (-0.230)	0.047 (1.511)
POP	0.0002*** (11.919)	0.0002*** (12.289)	-	-	-0.149 (-0.001)	-0.799 (-1.002)	-	-
EI	-1.755*** (-3.356)	0.165 (0.247)	-1.299* (-1.744)	-1.134 (-1.614)	-1.645** (-2.171)	-1.422* (-1.805)	-1.698** (-2.174)	-0.639 (-0.854)
RDE	0.286*** (6.850)	0.054 (1.432)	0.063 (1.367)	-	0.419*** (9.174)	0.341*** (8.236)	0.421*** (9.065)	-
FDI	-0.019*** (-4.139)	-0.034*** (-6.393)	-0.023*** (-3.893)	-0.024*** (-4.094)	-0.005** (-2.140)	-0.005** (-2.163)	-0.005** (-2.122)	-0.004 (-1.471)
GHG	-0.102*** (-14.075)	-0.074*** (-10.355)	-0.082*** (-9.770)	-0.084*** (-10.139)	-0.067*** (-8.522)	-0.055*** (-7.483)	-0.067*** (-8.614)	-0.093*** (-11.679)
Pnuc	-0.202*** (-6.324)	-0.144*** (-4.315)	-0.148*** (-3.965)	-0.015*** (-4.274)	-0.472*** (-9.257)	-0.494*** (-9.667)	-0.473*** (-9.349)	-0.537*** (-9.711)
TEP	0.271*** (5.152)	0.260*** (4.647)	0.210 (3.395)	0.235*** (4.002)	0.125*** (3.093)	0.157*** (3.934)	0.126*** (3.103)	0.205*** (4.683)
TEC	0.177*** (3.426)	-0.030 (-0.577)	0.273*** (4.477)	0.249*** (4.300)	0.185*** (3.453)	0.097* (2.018)	0.184*** (3.439)	0.190*** (3.214)
TEM	0.246*** (5.331)	0.235*** (4.770)	0.193*** (3.539)	0.214*** (4.128)	0.077** (2.289)	0.080** (2.354)	0.078** (2.302)	0.128*** (3.453)
TEX	-0.346*** (-5.882)	-0.335*** (-5.349)	-0.292*** (-4.200)	-0.320*** (-4.853)	-0.074* (-1.608)	-0.095** -2.061)	-0.074 (-1.618)	-0.139** (-2.754)
R^2	0.810	0.778	0.735	0.735	0.968	0.967	0.968	0.960
Adj. R^2	0.804	0.772	0.727	0.728	0.964	0.963	0.964	0.956
Est.Autocor. of e(i,t)					0.520	0.617	0.518	0.671
F[.,.]	[11, 355] 138.31	[11, 367] 117.36	[11,355] 89.71	[10,362] 100.82	[39, 327] 256.37	[39, 339] 258.05	[39,327] 256.41	[38,344] 214.47
Log-likelihood	-3347.04	-3485.18	-3408.58	-3462.61	-3019.06	-3122.12	-3019.03	-3107.57

The explanatory power of the OLS model ranges between 0.73 and 0.81. However, the R^2 do not improve when some of the independent are excluded in the model. On the other hand, FEM assumes that the intercept changes across countries and for each country there is a constant term. This term captures the country specific characteristics, such as differences in economic and political environment as well as energy resources and abundancy. Therefore, the FEM captures all these specific characteristics and performs better than OLS Model, as it is presented with higher R^2 (0.96).

When individual explanatory variables are analyzed, it is seen that most of the variables are significant. In the OLS Model, GDPPC, RDE, PNUC, TEM and TEX have the expected signs. The coefficient of GDP is negative in all versions of OLS Model and statistically significant at 1% confidence level. This result indicates that the size of the economy has a negative impact on renewable energy supply. On the other hand, GDP per capita is found to be positive in all versions of OLS Model, indicating that the welfare of the country has a positive impact on the renewable energy supply. The coefficient of the population is positive and statistically significant at 1% confidence level. This result shows that highly populated countries may have a tendency towards renewable energy supply. Empirical finding supports the argument that countries with high population may have higher demand for energy and this may force them to produce energy from alternative energy sources. The level of energy intensity shows inconsistent results in terms of sign of the coefficient and the significance level.

The coefficient of RDE is positive. Thus, empirical results present that there is clear impact of RDE on renewable energy supply, supporting the hypothesis that if a country has a high share of expenditure in R&D, then the supply of renewable energy will be high.

In contrary to the expectations, the impact of FDI on renewable energy supply is found to be negative and statistically significant at 1% confidence level. This finding indicates that FDI does not provide technology diffusion and capacity utilization in renewable energy resources of the host country.

The coefficient of GHG is negative and significant at 1% confidence level. Unfortunately, this indicates that the countries in the pooled sample prefer not to change their traditional energy resources while they are achieving higher economic growth rates. The external cost of high economic activity is apparent in the current sample.

It is assumed that if a country has high capacity of nuclear power, then she may not consider renewable energy supply as an alternative energy source and does not invest in these. The empirical finding on nuclear energy confirms this argument at 1% significance level. TEP of a country also determines the pattern in utilization of renewable energy resources. If a country is abundant in energy resources, then she may not have a tendency toward renewable energy resources. However, the empirical results show that there is a positive relation between TEP and renewable energy supply mostly significant at 1% confidence level. The expected sign of TEC is positive due to the assumption of higher rate of consumption may force country to utilize her renewable energy resources. However, it is found to be inconsistent in the current sample.

The impact of international trade in energy on renewable energy supply is found to be parallel to the expectations and moreover, they are highly significant. It is assumed that if a country is dependent on energy import, she may have preference in utilization of renewable energy resources to lower import dependency in energy. Similarly, if there is an excess supply of energy, the country may prefer to export excess part. The empirical findings confirm these hypotheses for the current sample over the period 1995 and 2008.

When the FEM results are analyzed, the striking finding is the improvement in R^2. R^2 increases to 0.96, stating that the explanatory variables explain 96% of the change in renewable energy supply. In addition, F values are very high, supporting the power of the model. In FEM, most of the explanatory variables reveal similar results with the OLS results, except GDPPC and POP variables. GDPPC has a negative impact on renewable energy supply in versions of Model B and C while population has a negative impact in versions of A and B. However, the coefficients are not statistically significant.

The empirical findings show that FEM overperforms than OLS Model because it takes into account country specific effects. Secondly, the Model D can be expected as the base model. Because, population and RDE are eliminated due to their correlation with other explanatory variables.

In order to see the sensitivity of the empirical findings to the selected sample, the sample set is disaggregated as EU-15 and EU-14 . The results of OLS and FEM estimation for the former member countries of the European Union are presented in table 54.

Table 54. OLS and FEM of Model 1 for the EU15

	OLS				FEM			
Independent Variable	A	B	C	D	A.	B	C	D
Constant	3827.13 (4.399)	2668.40 (1.605)	9055.42 (6.797)	5990.86 (4.309)				
GDP	-0.017*** (-9.677)	-	-0.013*** (-7.519)	-0.007*** (-4.412)	-0.007*** (-3.843)	-	-0.006*** (-3.394)	-0.0006 (-0.365)
GDPPC	-	-0.006 (-0.237)	-0.082*** (-3.338)	-0.009 (-0.393)	-	0.042 (0.519)	0.023 (0.304)	0.077 (0.876)
POP	0.0003*** (6.544)	0.840 (1.272)	-	-	0.0003 (1.656)	0.337 (0.144)	-	-
EI	-5.565 (-1.135)	5.539 (0.854)	-23.870*** (-4.394)	-17.047*** (-2.874)	12.615 (1.659)	19.957 (1.369)	15.482 (1.091)	12.119 (0.757)
RDE	0.521*** (8.959)	0.169*** (3.118)	0.271*** (6.679)	-	0.409*** (6.832)	0.323*** (5.570)	0.416*** (6.888)	-
FDI	-0.023*** (-5.411)	-0.033*** (6.004)	-0.019*** (-3.708)	-0.026*** (-4.721)	-0.004 (-1.373)	-0.005 (-1.471)	-0.004 (-1.446)	-0.003 (-0.978)
GHG	-0.130*** (-17.877)	-0.105*** (-12.800)	-0.135*** (-16.982)	-0.137*** (-15.403)	-0.087*** (-7.791)	-0.068*** (-6.531)	-0.082*** (-7.577)	-0.113*** (-10.143)
Pnuc	-0.200*** (-6.429)	-0.165*** (-4.454)	-0.238*** (-7.225)	-0.273*** (-7.570)	-0.600*** (-8.601)	-0.607*** (-8.471)	-0.579*** (-8.379)	-0.652*** (-8.475)
TEP	0.158*** (2.870)	0.197*** (2.991)	0.263*** (4.714)	0.380*** (6.454)	0.157*** (2.809)	0.208*** (3.722)	0.167*** (2.974)	0.255*** (4.119)
TEC	0.368*** (7.257)	0.220*** (3.757)	0.411*** (7.187)	0.266*** (4.528)	0.220***	0.082 (1.236)	0.204** (2.728)	0.219** (2.600)

					(2.999)			
TEM	0.150***	0.179***	0.245	0.345***	0.099**	0.115**	0.112**	0.169***
	(3.102)	(3.075)	(4.979)	(6.611)	(2.128)	(2.402)	(2.392)	(3.260)
TEX	-0.225***	-0.277***	-0.355***	-0.486***	-0.103	-0.143**	-0.117*	-0.197**
	(-3.622)	(-3.709)	(-5.685)	(-7.364)	(-1.617)	(-2.219)	(-1.831)	(-2.781)
R^2	0.895	0.845	0.878	0.848	0.963	0.961	0.963	0.953
Adj. R^2	0.889	0.836	0.871	0.840	0.958	0.955	0.958	0.946
Est.Autocor. of e(i,t)					0.434	0.587	0.442	0.618
F[.,.]	[11, 184] 143.08	[11, 191] 95.08	[11, 184] 120.76	[10, 185] 103.89	[25, 170] 181.95	[25, 177] 175.36	[25,170] 179.05	[24,171] 145.12
Log-likelihood	-1756.23	-1857.19	-1770.97	-1792.24	-1651.70	-1717.01	-1653.22	-1677.34

R^2 of the OLS model ranges between 0.84 and 0.89. It means that the explanatory power of the EU-15 model improves compared to the pooled sample. On the other hand, since FEM assumes that the intercept changes across countries and for each country there is a constant term, variables in FEM estimation explain the dependent variable by around 96%.

Similar to the pooled sample model, most of the variables are significant. However, the variables which have expected signs differ. In the OLS Model, in addition to the RDE, PNUC, TEM and TEX, TEC also has expected sign. The coefficient of GDP is negative in all versions of OLS Model and statistically significant at 1% confidence level. Related to this, the striking finding indicates that the size of the economy has a negative impact on renewable energy supply in the EU-15 sample. Although it has positive impact on dependent variable in the pooled sample, the coefficient of GDPPC is negative in this version of the model. The coefficient of the population is positive but unlike in the pooled sample, it is not statistically significant. This result shows that highly populated countries may have a tendency towards renewable energy supply. The level of energy intensity, like in the pooled sample, shows inconsistent results in terms of sign of the coefficient and the significance level.

It is assumed that if a country has a high share of expenditure in R&D, then the supply of renewable energy will be high. The coefficient of RDE is positive and statistically significant at 1% confidence level. Therefore, this hypothesis is hold for the EU-15 sample too.

Another noteworthy finding is that the impact of FDI on renewable energy supply is found to be negative and statistically significant at 1% confidence level. It means that FDI does not transfer know how in renewable energy resources of the EU-15 countries.

As it is in pooled sample, GHG has negative impact on dependent variable and it is significant at 1% confidence level. This indicates that the countries in the EU-15 sample prefer not to change their traditional energy resources while they are achieving higher economic growth rates. The external cost of high economic activity is apparent in the EU-15 sample.

The countries which can produce energy from nuclear power plants are assumed to not utilize their renewable energy resources. Thus, if a country has a high nuclear energy capacity, then renewable energy supply will be low. The empirical finding on nuclear energy shows that this hypothesis is hold at 1% significance level. On the other hand, domestic energy capacity of the country which includes TEP and TEC of a country also determines the pattern in utilization of renewable energy resources. If a country is able to produce enough energy with her abundant energy resources, then she may not have a tendency toward renewable energy resources. However, the empirical results show that there is a positive relation between TEP and renewable energy supply significant at 1% confidence level in all versions of OLS. The impact of TEC on renewable energy is inconsistent in the pooled sample. However, as expected, the coefficient of TEC is positive in the EU-15 sample. It confirms the hypothesis which is higher rate of consumption may force country to utilize her renewable energy resources.

TEM and TEX as energy trade capacity indicators have the expected signs in the EU-15 sample. However, they are less significant compared to the pooled sample. As expected, a country which is dependent to the imported energy is willing to increase the share of renewable energy supply. On the other hand, a country which has abundant energy resources to export does not have tendency to generate renewable energy. The empirical findings confirm these hypotheses for the EU-15 countries over the period 1995 and 2008.

When the FEM results in current sample are analyzed, it can be seen that F values are very high, supporting the power of the model. In FEM, most of the explanatory variables reveal similar results with the OLS results, except GDPPC and EI variables. GDPPC has a positive impact on renewable energy supply in all versions of FEM whereas it has negative effect in OLS versions. In addition, while it has inconsistent impact on renewable energy supply in OLS Model, the coefficient of EI is positive in FEM estimations.

The empirical findings show that FEM outperforms than OLS Model because it takes into account country specific effects. Secondly, the Model D can be expected as the base model because, population and RDE are eliminated due to their correlation with other explanatory variables in the EU-15 sample, too.

Since economic size, renewable energy production capacity and technological infrastructure of the EU-14 countries differ from the early members; following model covers the new member and candidate countries.

The results of OLS and FEM estimation for the new member and the candidate countries of the European Union are presented in table 54.

Table 55. OLS and FEM of Model 1 for the EU14

	OLS				FEM			
Independent Variable	A	B	C	D	A	B	C	D
Constant	342.49 (1.998)	-313.11 (-1.643)	-785.32 (-2.420)	-373.84 (-1.191)				
GDP	0.003 (0.702)	-	0.030*** (4.877)	0.011** (2.473)	-0.002 (-0.856)	-	0.0005 (0.219)	0.002 (1.213)
GDPPC	-	0.045*** (6.701)	0.060*** (5.719)	0.048*** (4.664)	-	0.110*** (7.114)	0.109*** (6.971)	0.111*** (7.641)
POP	0.0002*** (15.019)	0.0003*** (18.815)	-	-	-0.0001* (-1.961)	-0.0001*** (-4.784)	-	-
EI	1.102*** (3.176)	1.162*** (4.054)	2.105*** (4.051)	1.447*** (3.064)	-0.587 (-1.675)	-0.229 (-0.777)	-0.375 (-1.259)	-0.028 (-0.121)
RDE	1.197*** (3.899)	0.894*** (4.359)	-1.523*** (-3.776)	-	0.510** (2.493)	0.054 (0.357)	0.147 (0.788)	-
FDI	0.092*** (3.485)	0.093*** (4.094)	-0.056 (-1.612)	-0.060 (-1.671)	0.032* (2.038)	0.007 (0.548)	0.008 (0.585)	0.009 (0.712)
GHG	-0.066*** (-7.591)	-0.617*** (-7.847)	-0.013 (-1.175)	0.001 (0.136)	-0.034*** (-4.258)	-0.018** (-2.595)	-0.020** (-2.764)	-0.019*** (-2.884)
Pnuc	-0.157** (-2.440)	-0.090* (-1.757)	0.106 (1.133)	-0.038 (-0.442)	0.285*** (5.063)	0.318*** (6.358)	0.300*** (6.164)	0.313*** (6.878)
TEP	0.178*** (3.185)	0.164*** (3.437)	-0.221*** (-2.899)	-0.173** (-2.208)	-0.004 (-0.120)	-0.028 (-0.901)	-0.020 (-0.661)	-0.022 (-0.746)
TEC	0.054 (0.686)	0.045 (0.730)	0.540*** (4.843)	0.368*** (3.395)	0.187*** (2.927)	0.142*** (2.842)	0.128** (2.504)	0.128** (2.512)
TEM	-0.029 (-0.439)	-0.018 (-0.365)	-0.315*** (-3.318)	-0.192* (-2.041)	-0.032 (-0.784)	-0.026 (-0.856)	-0.038 (-1.097)	-0.042 (-1.225)
TEX	-0.044 (-0.677)	-0.034 (-0.610)	0.115 (1.174)	0.013 (0.132)	-0.014 (-0.313)	-0.013 (-0.360)	-0.022 (-0.619)	-0.007 (-0.216)
R^2	0.939	0.960	0.878	0.864	0.987	0.991	0.990	0.989
Adj. R^2	0.935	0.957	0.870	0.856	0.985	0.990	0.988	0.988
Est.Autocor. of e(i,t)					0.506	0.461	0.497	0.518
F[.,.]	[11, 159] 224.03	[11, 164] 360.96	[11, 159] 104.43	[10, 166] 105.86	[24, 146] 468.27	[24, 151] 775.42	[24, 146] 609.94	[23, 153] 812.47
Log-likelihood	-1336.22	-1360.24	-1395.74	-1452.19	-1203.43	-1219.88	-1181.09	-1222.82

For the new member and candidate countries, the adjusted R^2 ranges between 0.935 and 0.990 in all sets for OLS Model and FEM estimations, indicating the relative strength of variables in explaining the variations in renewable energy generation. Among the first model variations which focus on the total energy indicators, the model which covers the new member and the candidate countries has the biggest explanatory power. A peak level of R^2 can be observed version A of FEM estimation.

Empirical findings indicate that the sample for the EU-14 countries show different characteristics from the pooled and the EU-15 samples. When both FEM and OLM Models are considered, the coefficients of GDP, GDPPC, EI, RDE, FDI, Pnuc, TEP, TEM in the EU-14 are different from the other samples. The only variable that shows similar impact is GHG for three samples. Although its significance decreases in current sample, the effect of GHG is negative. While the coefficient of population is same with pooled sample, TEC's coefficient is also same with the EU-15 sample.

For the OLS Model, R^2 improves and ranges between 0.86 and 0.96 in current sample. Parallel to this, F value of the version B has the highest rate with 360.96, indicating power of the model. EC (economic capacity) indicators including GDP, GDPPC, POP and EI and TEC as a DEC (domestic energy capacity) variable have positive impact on renewable energy. While the coefficient of GHG and TEM is negative, the impact of RDE, FDI, Pnuc, TEP and TEX is inconsistent. Only GDP, GDPPC and TEC are the variables which have the expected signs. For each OLS Model of three samples, POP is found to be the common variables in terms of showing the same characteristic which is positive. GDPPC has positive impact on dependent variable as it has in the pooled sample. Finally, one of the most important outcomes of this model is that foreign direct investment inflow has a positive and statistically very significant effect on renewable energy resource utilization in the new member and candidate countries (Version A and B). For example, a 1% increase in FDI inflows results in a 9.3% increase in the volume of renewable energy supply in OLS Model. Although the significance and the magnitude of FDI's coefficient decrease in FEM estimation, the effect of FDI is still positive.

When it comes to the FEM results in current sample, it can be observed that R^2 has the highest value with 0.99 among all FEM estimations of Model 1. F value of the EU-14 sample is also powerful (812.47). In FEM, only GDPPC and TEC reveal similar results with the OLS results. As expected, GDPPC and TEC have positive impact on renewable energy supply in all versions of FEM and they are significant at 1% confidence level.

Since the explanatory power of the versions is similar in each versions of FEM, the Model D can be expected as the base model because; population and RDE are eliminated due to their correlation with other explanatory variables in the EU-14 sample.

The variables which have negative impact on renewable energy in the EU-14 sample are GDP, POP, EI, GHG, TEP, TEM and TEX. However, the majority of these variables are statistically insignificant. On the other hand, the coefficient of GDP, Pnuc and TEC is positive and they are significant at mostly 1% confidence level. These empirical results confirm the hypotheses that if the economic capacity of the country is high, then renewable energy supply will be high and there is a positive relation between renewable energy supply and total energy consumption. However, the hypothesis on a country which has a high capacity of nuclear power may prefer not to produce energy from renewable energy resources is rejected at 1% confidence level in all versions of FEM. One of the most striking finding in this sample is that FDI as a foreign investment capacity indicator, has positive impact on renewable energy in all versions of

FEM. This output confirms that FDI does provide technology diffusion and capacity utilization in renewable energy resources of the host country.

When each FEM versions are compared with each other in three samples, it can be seen that TEC, TEX, GHG and RDE show similar pattern. While GDP and GDPPC are the common variables for the EU-15 and the EU-14 sample, EI is the only common variable for the common sample and the pooled sample.

Table 56 presents OLS and FEM estimates for the potential determinants of renewable energy supply for the pooled sample.

The table below illustrates the model covering energy supply variables for all countries.

Table 56. OLS and FEM of Model 2 for the Pooled Sample

	OLS				FEM			
Independent Variable	A	B	C	D	A	B	C	D
Constant	2475.52 (7.506)	-2379.10 (-5.099)	-1274.71 (-2.613)	-1428.54 (-3.240)				
GDP	-0.003*** (-2.798)	-	-0.0002 (-0.224)	0.0002 (0.399)	0.003*** (4.435)	-	0.001* (1.972)	0.001** (2.245)
GDPPC	-	0.266*** (12.275)	0.172*** (8.369)	0.181*** (10.376)	-	0.214*** (6.127)	0.233*** (7.039)	0.233*** (7.944)
POP	0.587 1.705)	0.0002*** (7.146)	-	-	-0.001*** (-6.133)	-0.0006*** (-4.377)	-	-
EI	-1.988*** (-4.094)	1.362*** (3.048)	1.063** (2.185)	1.146** (2.424)	-0.672 (-1.114)	0.061 (0.102)	0.631 (1.127)	0.628 (1.150)
RDE	0.253*** (4.572)	0.003 (0.113)	0.029 (0.740)	-	0.126*** (3.854)	0.085** (2.594)	-0.0008 (-0.024)	-
FDI	-0.004 (-1.305)	-0.009*** (-3.348)	-0.007** (-2.355)	-0.007** (-2.373)	-0.002 (-1.457)	-0.001 (-0.857)	-0.001 (-0.794)	-0.001 (-0.803)
GHG	-0.005* (-1.829)	0.190 (0.001)	0.008*** (3.754)	0.009*** (5.014)	0.011** (2.106)	0.009* (1.941)	0.005 (1.389)	0.005 (1.427)
Pnuc	0.032** (2.257)	0.038*** (3.528)	0.040*** (4.095)	0.041*** (4.281)	0.067** (2.552)	0.040 (1.690)	0.017 (0.820)	0.017 (0.843)
Supoil	-0.032** (-2.114)	-0.107*** (-8.368)	-0.060*** (-4.548)	-0.065*** (-5.457)	-0.026 (-1.190)	-0.059** (-2.619)	-0.076*** (-3.548)	-0.076*** (-3.588)
Supgas	0.003 (0.208)	-0.083*** (-6.353)	-0.040*** (-3.065)	-0.044*** (-3.526)	-0.161*** (-6.208)	-0.104*** (-4.691)	-0.121*** (-5.147)	-0.121*** (-5.167)
Psol	29.189** (2.637)	35.139*** 4.236)	17.223*** (5.388)	18.033*** (6.012)	44.790*** (4.059)	51.244*** (4.921)	16.937*** (8.588)	16.936*** (8.612)
Pgeo	-2.769 (-0.570)	10.715*** (2.904)	13.070*** (3.507)	13.904*** (3.919)	-14.650** (-2.273)	-11.051* (-1.785)	14.749*** (3.746)	14.736*** (3.790)
Phyd	1.963*** (20.332)	1.333*** (14.664)	1.775*** (23.124)	1.764*** (23.478)	0.775*** (4.739)	0.817*** (5.257)	0.944*** (6.451)	0.944*** (6.498)
Pwind	1.863*** (3.002)	1.569*** (3.484)	1.757*** (4.007)	1.687*** (3.944)	2.818*** (4.245)	2.120*** (3.481)	1.694*** (5.136)	1.693*** (5.223)
R^2	0.950	0.971	0.966	0.966	0.991	0.991	0.992	0.992
Adj. R^2	0.947	0.969	0.964	0.964	0.989	0.990	0.991	0.991

Est.Autocor. of e(i,t)					0.407	0.491	0.360	0.360
F[.,.]	[13, 190] 282.75	[13, 190] 497.45	[13, 190] 424.83	[12, 191] 461.28	[27, 176] 718.93	[27, 176] 785.21	[27, 176] 875.88	[26, 177] 914.73
Log-likelihood	-1756.84	-1701.40	-1717.08	-1717.30	-1583.52	-1574.60	-1563.54	-1563.54

In this model, each sub energy resource' supply volume is taken into account whereas total energy variables are excluded. The explanatory power improves significantly when each sub energy resource supply employed, which was not observed for the Model I. The adjusted R^2 ranges from 0.947 to 0.991.

In the OLS Model, GDPPC, RDE, Psol, Pgeo, Pwind, EI and GHG have the expected signs. Unlike expectations, GDP has ambiguous impact on renewable energy in current sample. GHG and EI are other variables that show both positive and negative effect in OLS versions. GDPPC as an economic capacity indicator has positive impact on dependent variable and is significant at 1% confidence level. It supports the hypothesis that the welfare of the country has a positive impact on the renewable energy supply. Another EC indicator, population has positive impact on renewable energy supply. As it is in the pooled sample of Model 1, the argument on "countries with high population may have higher demand for energy and this may force them to produce energy from alternative energy sources" is hold in this model, too.

Research and Development expenditure has positive effect on dependent variable. Although its significance in this model is less than compared to the first model, technological infrastructure capacity of the country is positively related to the renewable energy supply.

The coefficient of FDI is negative in current sample. It indicates that foreign direct investment does not impact renewable energy supply positively. Therefore, the hypothesis that FDI may provide technology diffusion and capacity utilization in renewable energy resources of the host country is rejected.

As expected, the capacity of country's nuclear energy has negative impact on renewable energy supply in the pooled sample of Model 1. However, the coefficient of Pnuc is found to be negative and statistically significant at 1% confidence level. This outcome is also used to reject the argument that if a country has high capacity of nuclear power, then she may not consider renewable energy supply as an alternative energy source.

Although supply of oil and natural gas is expected to have an ambiguous impact on renewable energy supply, the coefficient of Supoil and Supgas is negative and statistically significant at 1% confidence level. This empirical finding indicates that countries in this sample can supply enough traditional fossil fuels and do not require producing energy from renewable resources.

Renewable energy capacity of the country has positive and statistically significant impact on dependent variable. As expected, the coefficient of Psol, Pgeo and Pwind is positive. Furthermore, they are statistically significant at 1% confidence level. In addition to these renewable energies, Phyd also has positive impact on renewable energy. This result supports that if a country has a high renewable energy capacity, then renewable energy supply will be high.

For FEM estimations, R^2 of the versions is around 0.991 which is the higher than the pooled sample of Model 1. However, it can be seen that only GDP, GDPPC, EI, RDE, Psol and Pwind have expected signs. Unlike OLS results, four variables show different characteristics. GDP and GHG which have inconsistent impact in OLS Model, their coefficient is positive in FEM results. While the coefficient of POP is positive in OLS Model, the impact of POP is negative and statistically significant at 1% confidence level in FEM versions. Finally, as a renewable energy capacity indicator, Pgeo has inconsistent effect on dependent variable.

Since version D of FEM has the highest F value (914.73) and excludes POP and RDE variables due to their correlations with other explanatory variables, the Model D can be expected as the base model.

Similar to the Model 1, the sample set is disaggregated as EU-15 and EU-14 countries to see the sensitivity of the empirical findings to the selected sample. The results of OLS and FEM estimation for the early members of the European Union are presented in table 54.

Table 57. OLS and FEM of Model 2 for the EU15

	OLS				FEM			
Independent Variable	A	B	C	D	A	B	C	D
Constant	6798.98 (2.736)	-12600.81 (-2.092)	4557.66 (1.228)	2278.38 (0.681)				
GDP	-0.0007 (-0.518)	-	0.0009 (0.835)	0.002** (2.179)	0.004*** (4.039)	-	0.0007 (0.886)	0.0005 (0.767)
GDPPC	-	0.372*** (3.528)	0.066 (1.007)	0.128** (2.650)	-	0.365*** (3.512)	0.457*** (4.853)	0.446*** (4.933)
POP	0.870* (1.862)	0.0002*** (4.004)	-	-	-0.001*** (-5.336)	-0.0006*** (-3.065)	-	-
EI	-7.463 (-0.802)	31.488** (2.216)	-6.773 (-0.710)	-3.933 (-0.420)	-25.994*** (-4.045)	19.337 (1.387)	31.865** (2.528)	31.591** (2.520)
RDE	0.195*** (3.203)	0.041 (0.727)	0.080 (1.391)	-	0.046 (1.048)	0.057 (1.274)	-0.019 (-0.454)	-
FDI	-0.008** (-2.501)	-0.009** (-2.696)	-0.009** (2.659)	-0.008** (-2.532)	-0.002 (-0.919)	-0.002 (-1.012)	-0.002 (-1.036)	-0.002 (-1.088)
GHG	0.003 (0.628)	-0.008 (-1.436)	0.008** (2.623)	0.010*** (3.509)	0.015** (2.090)	0.004 (0.575)	-0.001 (-0.253)	-0.0009 (-0.178)
Pnuc	0.011 (0.429)	-0.018 (-0.730)	0.036** (2.361)	0.036** (2.325)	0.088** (2.494)	0.030 (0.928)	0.001 (0.040)	-0.002 (-0.081)
Supoil	-0.115*** (-5.176)	-0.056** (-2.090)	-0.095*** (-3.849)	-0.094*** (-3.803)	-0.064** (-2.167)	-0.071** (-2.323)	-0.079*** (-2.898)	-0.077*** (-2.875)
Supgas	-0.069*** (-2.862)	-0.065*** (-3.155)	-0.071*** (-3.282)	-0.078*** (-3.662)	-0.162*** (-4.958)	-0.108*** (-3.657)	-0.111*** (-3.683)	-0.111*** (3.723)
Psol	2.800 (0.179)	10.218 (0.686)	12.760*** (3.086)	13.966*** (3.438)	39.571** (2.630)	45.894*** (3.017)	16.375*** (6.673)	16.354*** (6.695)
Pgeo	25.994** (2.168)	31.347*** (2.844)	18.036** (2.188)	22.298*** (2.900)	-12.034 (-1.304)	-11.630 (-1.237)	11.660** (2.148)	11.390** (2.120)
Phyd	1.475*** (9.725)	1.545*** (10.704)	1.510*** (10.289)	1.506*** (10.214)	0.584*** (2.873)	0.788*** (3.820)	0.931*** (5.035)	0.938*** (5.113)
Pwind	2.609*** (4.056)	2.165*** (3.555)	1.839*** (3.728)	1.742*** (3.550)	3.277*** (3.832)	2.489*** (2.969)	1.900*** (4.576)	1.868*** (4.584)
R^2	0.964	0.968	0.966	0.966	0.989	0.988	0.990	0.990
Adj. R^2	0.960	0.964	0.962	0.962	0.986	0.986	0.988	0.989

Est.Autocor. of e(i,t)					0.365	0.518	0.324	0.324
F[.,.]	[13, 98] 207.24	[13, 98] 233.86	[13, 98] 220.35	[12, 99] 236.31	[20, 91] 419.75	[20, 91] 404.04	[20, 91] 497.13	[19, 92] 527.84
Log-likelihood	-953.71	-947.16	-950.39	-951.48	-887.30	-889.42	-877.92	-878.05

The adjusted R^2 remains almost same with the pooled sample; around 0.96 in OLS Model and 0.99 in FEM. In OLS Model, most of the explanatory variables reveal similar results with the pooled sample of Model 2 results, except Pnuc. Although it is assumed that high capacity of nuclear power has negative impact on renewable energy supply, production of nuclear energy has positive effect on dependent variable in the pooled sample. However, the impact of Pnuc is inconsistent in current sample. GDPPC, RDE, EI, GHG, Psol, Pgeo and Pwind have expected characteristics in the EU-15 countries. The coefficient of GDPPC, POP, RDE, Psol, Pgeo, Phyd and Pwind is positive whereas FDI, Suopil and Supgas has negative impact on renewable energy supply. In addition to the ambiguous effect of Pnuc, GHG, EI and GDP also have inconsistent impact on dependent variable. Therefore, all excepted and rejected hypotheses of OLS versions of Model 2 for pooled sample are also applicable for the EU-15 countries. Only exception is for the hypothesis of Pnuc.

When FEM results are analyzed, there can be seen an improvement in R^2 values compared to OLS versions (0.99). The variables which show expected sign are GDP, GDPPC, Psol, Pwind, EI and GHG. In FEM, four variables change their characteristics as they do in the pooled sample. Two of these variables are same with the pooled sample. GDP which has inconsistent impact on renewable energy in OLS Model has positive coefficient in FEM results. While the coefficient of POP is positive in OLS Model, it has negative effect on dependent variable in FEM versions. Other two variables are RDE and Pgeo. These variables change their effect from positive to inconsistent in FEM versions.

When FEM results of this sample compared with the estimations in pooled sample, it can be observed that R^2 does not change. Although F value of the FEM versions decreases, Model D has still the highest F value (527.84). It makes it to be selected as a base model. The comparison between FEM results of the EU-15 and pooled sample indicates that RDE, GHG and Pnuc change their signs from positive to inconsistent. Although their significance change at different confidence levels, rest of the variables have same characteristics.

Due to the different conditions they have in terms of social, economic and technological aspects, both OLS and FEM versions are run for new member and the candidate countries. Empirical findings for the EU-14 countries are shown in Table 58.

Table 58. OLS and FEM of Model 2 for the EU14

	OLS				FEM			
Independent Variable	A	B	C	D	A	B	C	D
Constant	-93.90	269.78	621.17	719.06				
	(-0.701)	(0.958)	(1.935)	(2.384)				
GDP	0.008**	-	0.014***	0.013***	0.006***	-	0.006***	0.006***
	(2.701)		(4.453)	(4.684)	(3.018)		(3.111)	(3.785)
GDPPC	-	-0.027	-0.097***	-0.111***	-	-0.004	-0.012	-0.012
		(-1.074)	(-3.702)	(-5.304)		(-0.189)	(-0.514)	(-0.558)
POP	0.0002***	0.0002***	-	-	-0.299	-0.0001	-	-
	(7.574)	(7.483)			(-0.137)	(-0.545)		
EI	-0.786***	-1.016***	-0.633**	-0.596**	-0.642**	- 0.886***	-0.714**	-0.714**
	(-3.935)	(-4.898)	(-2.527)	(-2.414)	(-2.552)	(-2.949)	(-2.641)	(-2.683)
RDE	-0.384	0.267	-0.376	-	-0.049	0.422*	-0.004	-
	(-1.275)	(0.869)	(-0.899)		(-0.206)	(1.832)	(-0.017)	
FDI	0.029*	0.035*	-0.008	-0.013	-0.001	-0.0002	-0.003	-0.003
	(1.778)	(1.965)	(-0.403)	(-0.638)	(-0.128)	(-0.017)	(-0.239)	(-0.265)
GHG	-0.016***	-0.015***	-0.010***	-0.010***	0.008*	0.008*	0.008*	0.008*
	(-6.512)	(-5.662)	(-3.342)	(-3.531)	(1.961)	(1.947)	(1.956)	(1.980)
Pnuc	0.105***	0.111***	-0.003	-0.015	0.131***	0.136***	0.130***	0.130***
	-3.150	(2.994)	(-0.077)	(-0.394)	(4.461)	(4.358)	(4.487)	(4.773)
Supoil	0.162***	0.110**	0.301***	0.288***	0.092**	0.069*	0.092***	0.092***
	(3.732)	(2.749)	(6.631)	(6.708)	(2.714)	(1.982)	(2.920)	(2.967)
Supgas	-0.085***	-0.087***	-0.086***	-0.084***	0.027	0.04	0.031	0.031
	(-4.328)	(-4.062)	(-3.395)	(-3.332)	(0.913)	(1.234)	(1.022)	(1.064)
Psol	232.177***	191.686**	181.196*	117.95*	143.343**	118.076*	133.54**	132.86***
	(3.122)	(2.371)	(1.912)	(1.859)	(2.786)	(2.027)	(2.427)	(3.475)
Pgeo	-10.296***	-8.643***	-2.871	-1.970	-2.401	-2.125	-2.385	-2.368
	(-5.264)	(-3.654)	(-1.151)	(-0.864)	(-0.619)	(-0.516)	(-0.663)	(-0.689)

Phyd	1.251***	1.371***	2.299***	2.354***	1.656***	1.626***	1.657***	1.657***
	(7.243)	(6.355)	(13.146)	(14.400)	(6.681)	(6.188)	(6.714)	(6.762)
Pwind	2.841	3.634	2.553	3.930	-2.620	-3.971	-2.352	-2.357
	(0.290)	(0.357)	(0.214)	(0.332)	(-0.352)	(-0.503)	(-0.318)	(-0.321)
R^2	0.976	0.974	0.964	0.964	0.990	0.988	0.990	0.990
Adj. R^2	0.972	0.970	0.959	0.959	0.987	0.986	0.987	0.987
Est.Autocor. of e(i,t)					0.135	0.251	0.137	0.138
F[.,.]	[13, 78]	[13, 78]	[13, 78]	[12, 79]	[19, 72]	[19, 72]	[19, 72]	[18, 73]
	246.87	228.65	165.31	179.46	382.39	339.20	383.71	410.65
Log-likelihood	-618.07	-621.51	-635.98	-636.45	-577.45	-582.91	-577.29	-577.29

Even though the explanatory power of the model in this sample does not change and range between 0.97 and 0.99, the empirical results for the new member and candidate countries demonstrate important differences from the pooled sample and the EU-15 countries.

First of all, it can be said that this model has the most striking findings among Model 1 and Model 2 versions. In the OLS Model, only GDP, Psol and Pwind have the expected signs in current sample. The number of variables which have expected sign accounts for two in FEM results which are GDP and Psol.

In OLS Model, the coefficient of GDP, POP, Supoil, Psol, Phyd and Pwind is positive. GDPPC, EI, GHG, Supgas and Pgeo, on the contrary, have negative impact on dependent variable. RDE, FDI and Pnuc have inconsistent effect on renewable energy supply.

When versions of OLS Model are compared with each other, it can be observed that POP, Psol, Phyd and Pwind as the positive variables and Supgas as the negative variable show common characteristics in all samples including pooled, EU-15 and EU-14. In addition to these, Pnuc has inconsistent impact in the EU-15 and current sample.

When FEM results are analyzed, it can be seen that the explanatory power of the model increases (0.99). Even though R^2 remains almost constant and F value decreases (410.65) when they compared to the FEM results of the pooled sample and the EU-15, Model D is still the base model.

Unlike other samples, there are many variables showing different characteristics from OLS versions in current sample. GHG, Pnuc, Supoil, Supgas which have positive coefficients in FEM results have negative or inconsistent impacts on renewable energy supply in the versions of OLS Model. Furthermore, the coefficient of POP, FDI and Pwind is negative in FEM. However, their effect on renewable energy supply is positive or inconsistent in OLS models.

When FEM results in current sample are compared with the findings of pooled sample and EU-14, it can be observed that GDP, Psol and Phyd are the variables which have positive impact on dependent variable in all samples. POP and FDI are the common variables that affect renewable energy supply negatively in all samples. While Pnuc is a common variable both for pooled and current sample, the impact of RDE is inconsistent both for Eu-15 and EU-14 countries.

Consequently, Model 2, which includes each sub energy resources' supply figures as well as other explanatory variables, indicates that empirical evidences in this sample are very different from other samples.

First, supply of oil and supply of gas as Traditional Fossil Fuel Capacity (TFFC) indicators have positive impact on renewable energy supply. It is assumed that their coefficient may be positive or negative.

Second, GDPPC which is expected to have positive impact has negative impact on dependent variable. It means that the welfare of the new member or candidate country has a negative impact on the renewable energy supply.

Third, energy intensity (EI), unlike in other samples, has negative effect on renewable energy supply. It is statistically significant at 1% confidence level. This empirical finding shows that new member and candidate countries with high ratio for energy intensity are willing to decrease their energy dependency on traditional energy resources via renewable energy supply.

Fourth and last, the coefficient of geothermal and wind energy production is found to be negative in all versions of EU-14 sample. Although they are statistically insignificant, the impact of those Renewable Energy Capacity (REC) indicators on dependent variable is striking.

In addition to the four versions of the model I and model II which are grouped as a GDP included (A), GDPPC included (B), population excluded (C) and population and R&D excluded, model III have another version. This version (E) excludes consumption variables of the model.
Consumption and production parameters are used for domestic oil and gas capacity. However, the coefficient between total oil consumption (Coil) and total natural gas consumption (Cgas) (0.82) is high. The correlation between Coil and GDP (0.96) and the correlation between Cgas and GDP (0.85) are also high. Moreover, Coil and Cgas are correlated with the same independent variables. Coil is correlated with Moil (0.90), Supoil (0.98), Mgas (0.86), Supgas (0.88), Pnuc(0.72), and GHG (0.95). Similarly, Cgas is correlated with Moil (0.77), Supoil (0.82), Mgas (0.72), Supgas (0.88) and GHG (0.83). Therefore, total oil consumption and total natural gas consumption are also excluded from the model (E).

Five sets (A, B, C, D and E) of Ordinary Least Squares (OLS) and Fixed Effects Model (FEM) are run separately for country groups: (1) Pooled Sample referring the EU-27 member countries excluding Malta and candidate countries excluding Former Yugoslav Republic of Macedonia, (2) the EU-15 which are early members of the EU and (3) the EU-14 referring the new members and the candidate countries. For the period of 1995-2008, the three versions of the model are classified as: Model I, where the variables of EC, TIC, EE, NEC, FIC, DEC and ETC are included as the main determinants of renewable energy supply; Model II, where TFFC and REC are included and DEC and ETC are excluded and Model III, where DOGC and OGTC are considered.

Table 59. OLS and FEM of Model 3 for the Pooled Sample

	OLS					FEM				
Independent Variable	A	B	C	D	E	A	B	C	D	E
Constant	2064.01	-2218.98	-1205.46	-1455.67	-1441.18					
	(6.968)	(-5.685)	(-3.001)	(-3.944)	(-3.385)					
GDP	0.001	-	0.001*	0.002***	0.0007	0.004***	-	0.002***	0.002***	0.001**
	(1.201)		(1.733)	(3.047)	(0.922)	(4.703)		(3.040)	(3.300)	(2.528)
GDPPC	-	0.276***	0.198***	0.212***	0.215***	-	0.202***	0.202***	0.205***	0.227***
		(13.103)	(10.113)	(12.155)	(10.627)		(5.882)	(5.937)	(6.848)	(7.795)
POP	-0.224	0.0002***	-	-	-	-0.0008**	-0.0004**	-	-	-
	(-0.574)	(6.852)				(-4.399)	(-2.469)			
EI	-2.729***	0.421	-0.026	0.100	1.279**	-0.784*	0.119	0.004	0.026	0.737
	(-6.318)	(1.068)	(-0.061)	(0.236)	(2.753)	(-1.373)	(0.201)	(0.007)	(0.047)	(1.339)
RDE	0.221***	0.043	0.056	-	-	0.106***	0.058*	0.005	-	-
	(5.320)	(1.543)	(1.548)			(3.625)	(1.858)	(0.170)		
FDI	-0.004	-0.004*	-0.003	-0.003	-0.002	-0.001	-0.001	-0.0003	-0.0003	-0.0008
	(-1.350)	(-1.961)	(-1.393)	(-1.335)	(-0.890)	(-1.180)	(-0.669)	(-0.227)	(-0.213)	(-0.539)
GHG	0.037***	0.017***	0.033***	0.034***	0.012***	0.018***	0.009	0.008	0.008	0.007
	(6.778)	(4.286)	(8.645)	(8.993)	(4.255)	(3.001)	(1.567)	(1.330)	(1.326)	(1.568)
Pnuc	0.085***	0.076***	0.108***	0.110***	0.064***	0.045	0.044	-0.024	-0.023	0.001
	(5.805)	(7.209)	(10.280)	(10.583)	(6.329)	(1.220)	(1.230)	(-0.759)	(-0.743)	(0.071)
Psol	15.843***	14.729***	17.911***	19.098***	16.952***	15.071***	16.412***	17.024***	17.017***	15.963***
	(4.559)	(5.867)	(6.542)	(7.239)	(5.644)	(7.414)	(8.433)	(9.005)	(9.029)	(8.114)
Pgeo	12.740***	10.405***	17.362***	17.826***	15.253***	-3.962	0.052	7.129*	7.233*	14.427***
	(2.891)	(3.374)	(5.205)	(5.346)	(3.699)	(-0.833)	(0.011)	(1.727)	(1.777)	(3.663)
Phyd	1.798***	1.194***	1.490***	1.489***	1.529***	1.007***	0.964***	0.914***	0.911***	0.899***
	(19.451)	(14.771)	(19.806)	(19.714)	(17.710)	(6.506)	(6.404)	(6.078)	(6.117)	(6.178)
Pwind	1.245**	1.957***	1.314***	1.239***	2.295***	2.323***	2.409***	1.605***	1.612***	1.994***
	(2.391)	(5.229)	(3.223)	(3.049)	(5.137)	(4.788)	(5.116)	(4.064)	(4.245)	(5.134)
Poil	0.057	-0.058	0.107**	0.094*	-0.051	0.014	-0.080**	-0.038	-0.039	-0.086**
	(0.857)	(-1.217)	(2.274)	(2.022)	(-1.522)	(0.352)	(-2,068)	(-0.976)	(-1.002)	(-2.342)
Coil	-0.380***	-0.155***	-0.345***	-0.338***	-	-0.245***	-0.100	-0.114*	-0.113*	-
	(-4.968)	(-3.030)	(-6.221)	(-6.091)		(-4.316)	(-1.686)	(-1.934)	(-1.932)	
Pgas	0.151**	-0.029	0.142***	0.130***	-0.041	-0.103***	-0.112***	-0.166***	-0.166***	-0.129***
	(2.749)	(-0.700)	(3.881)	(3.625)	(-1.408)	(-2.827)	(-3.177)	(-4.764)	(-4.779)	(-5.376)
Cgas	-0.558***	-0.194**	-0.450***	-0.429***	-	0.0177	0.111	0.167**	0.167**	-
	(-6.249)	(-2.761)	(-6.923)	(-6.723)		(0.260)	(1.653)	(2.638)	(2.647)	
Moil	0.081	-0.078**	0.070**	0.056*	-0.067***	0.050	-0.023	-0.024	-0.025	-0.074***
	(1.642)	(-2.195)	(2.104)	(1.745)	(-4.060)	(1.644)	(-0.749)	(-0.771)	(-0.796)	(-2.863)
Xoil	-0.062	0.022	-0.162***	-0.151***	-0.004	-0.022	0.056	0.039	0.039	0.099**
	(-0.821)	(0.415)	(-3.092)	(-2.893)	(-0.131)	(-0.472)	(1.194)	(0.837)	(0.855)	(2.488)
Mgas	0.051	-0.072	0.055	0.049	-0.139***	-0.105**	-0.136***	-0.201***	-0.202	-0.177***
	(0.847)	(-1.656)	(1.219)	(1.077)	(-3.435)	(-2.459)	(-3.228)	(-4.992)	(-5.042)	(-5.329)

Xgas	-0.181** (-2.573)	0.156** (2.746)	-0.043 (-0.806)	-0.023 (-0.446)	0.175*** (3.476)	0.064 (1.138)	0.138** (2.483)	0.195*** (3.783)	0.195*** (3.798)	0.152*** (3.107)
R^2	0.968	0.983	0.979	0.979	0.972	0.993	0.993	0.993	0.993	0.993
Adj. R^2	0.965	0.982	0.977	0.977	0.970	0.991	0.992	0.992	0.992	0.991
Est.Autocor. of e(i,t)						0.323	0.386	0.421	0.421	0.379
F[.,.]	[19, 184] 301.12	[19, 184] 586.44	[19, 184] 473.00	[18, 185] 495.41	[16, 187] 411.46	[33, 170] 763.48	[33, 170] 813.40	[33, 170] 828.03	[32, 171] 858.79	[30, 173] 826.85
Log-likelihood	-1710.35	-1643.92	-1665.45	-1666.774	-1698.06	-1553.61	-1547.19	-1545.39	-1545.40	-1556.96

The explanatory power of the Model 3 ranges between 0.968 and 0.992. This is the highest R^2 value among all versions of OLS model in three samples.

In OLS Model, GDP, GDPPC, RDE, GHG, Pnuc and REC indicators have positive impact on renewable energy supply. FDI, Coil and Cgas are the only three variables affect dependent variable negatively. However, POP, EI, Poil, Pgas, OGTC indicators have inconsistent impact on renewable energy supply. The coefficients of the variables are generally statistically significant at 1% confidence level.

It is found that GDP, GDPPC, RDE, Psol, Pgeo and Pwind have the expected signs which are positive. This finding supports that the country's economic growth, welfare, technological infrastructure capacity and renewable energy capacity affects renewable energy supply positively.

In FEM results, the explanatory power of the model is around 0.993. F value is also high in Model D (858.79). Thus, Model D is the base model. POP, Pnuc, Pgeo, Pgas, Cgas, Mgas and Xgas in FEM show different characteristics from OLS results. However, the variables which have expected signs are same with the OLS Model, except Pgeo. While the impact of Pgeo is expected to be positive, the coefficient of geothermal production is inconsistent. In addition to these variables, Pgas and Cgas also reveal expected signs in current sample.

Table 60 shows the results of Model 3 for the early member countries.

Table 60. OLS and FEM of Model 3 for the EU15.

	OLS					FEM				
Independent Variable	A	B	C	D	E	A	B	C	D	E
Constant	10844.78 (4.620)	-22208.90 (-4.497)	2587.88 (0.761)	2475.54 (0.733)	2934.12 (0.879)					
GDP	0.003*** (3.115)	-	0.004*** (3.565)	0.004*** (4.312)	0.003*** (3.990)	0.004*** (3.578)	-	0.002** (2.731)	0.002*** (2.857)	0.002** (2.093)
GDPPC	-	0.595*** (7.398)	0.178*** (3.151)	0.188*** (3.564)	0.211 (4.112)	-	0.430*** (4.455)	(0.427)*** (4.766)	0.424*** (4.933)	0.449*** (4.851)
POP	0.491 (0.096)	0.0004*** (6.660)	-	-	-	-0.0007** (-2.733)	-0.731 (-0.299)	-	-	-
EI	-18.285** (-2.240)	50.333*** (4.302)	-4.255 (-0.493)	-4.617 (-0.539)	-7.532 (-0.887)	-18.829*** (-2.905)	31.900** (2.404)	32.986** (2.683)	32.966** (2.697)	34.891** (2.630)
RDE	0.071 (1.615)	-0.028 (-0.720)	0.021 (0.476)	-	-	0.049 (1.227)	0.032 (0.809)	-0.004 (-0.115)	-	-
FDI	-0.002 (-0.855)	-0.003 (-1.403)	-0.001 (-0.750)	-0.001 (-0.691)	-0.001 (-0.787)	-0.0008 (-0.429)	-0.001 (-0.691)	-0.001 (-0.723)	-0.001 (-0.739)	-0.001 (-0.974)
GHG	0.029*** (4.388)	0.0003 (0.053)	0.026*** (4.247)	0.027*** (4.670)	0.019*** (5.192)	0.010 (1.154)	-0.005 (-0.645)	-0.006 (-0.801)	-0.006 (-0.798)	-0.002 (-0.375)
Pnuc	0.115*** (6.621)	0.048*** (2.970)	0.105*** (6.372)	0.107*** (6.738)	0.089*** (6.558)	-0.007 (-0.139)	-0.071 (-1.324)	-0.108** (-2.492)	-0.109** (-2.566)	-0.056 (-1.449)
Psol	13.021*** (4.240)	15.153*** (5.893)	14.612*** (4.974)	14.878*** (5.180)	14.855*** (5.107)	14.163*** (5.589)	16.719*** (6.899)	16.350*** (7.175)	16.356*** (7.222)	15.161*** (6.217)
Pgeo	5.926 (0.818)	2.964 (0.494)	11.246 (1.678)	11.826* (1.802)	11.360* (1.970)	0.234 (0.036)	1.364 (0.218)	4.207 (0.774)	4.121 (0.770)	12.937** (2.416)
Phyd	1.146*** (7.820)	1.268*** (10.298)	1.089*** (8.012)	1.083*** (8.037)	0.941*** (7.971)	0.718*** (3.526)	0.870*** (4.487)	0.799*** (4.251)	0.801*** (4.323)	0.866*** (4.736)
Pwind	2.005*** (4.270)	2.410*** (6.130)	2.198*** (4.893)	2.185*** (4.893)	2.589*** (6.351)	2.481*** (3.782)	1.837*** (2.906)	1.558*** (3.141)	1.544*** (3.238)	1.940*** (3.870)
Poil	0.046 (0.735)	0.004 (0.094)	0.072 (1.225)	0.069 (1.184)	-0.006 (-0.160)	-0.037 (-0.665)	-0.075 (-1.401)	-0.036 (-0.708)	-0.035 (-0.703)	-0.072 (-1.484)
Coil	-0.241** (-2.547)	-0.161** (-2.145)	-0.182* (-2.012)	-0.185* (-2.057)	-	-0.115 (-1.424)	-0.054 (-0.692)	-0.069 (-0.911)	-0.070 (-0.943)	-
Pgas	-0.107 (-1.719)	-0.115** (-2.250)	-0.114* (-1.926)	-0.115* (-1.951)	-0.203*** (-6.203)	-0.162*** (-3.377)	-0.146 (-3.188)	-0.182*** (-4.124)	-0.182*** (-4.146)	-0.115*** (-3.739)
Cgas	-0.147 (-1.468)	-0.006 (-0.075)	-0.141 (-1.489)	-0.140 (-1.488)	-	0.156 (1.680)	0.229** (2.535)	0.246*** (2.988)	0.246*** (3.004)	-
Moil	-0.066 (-1.337)	-0.030 (-0.737)	-0.031 (-0.670)	-0.035 (-0.749)	-0.105*** (-3.472)	-0.005 (-0.135)	-0.038 (-0.890)	-0.032 (-0.786)	-0.031 (-0.782)	-0.067* (-1.971)
Xoil	-0.084 (-1.178)	-0.053 (-0.913)	-0.116* (-1.741)	-0.115* (-1.725)	-0.029 (-0.689)	0.046 (0.692)	0.086 (1.344)	0.069 (1.121)	0.068 (1.122)	0.108* (2.006)
Mgas	-0.123* (-1.757)	-0.187*** (-3.215)	-0.176** (-2.605)	-0.176** (-2.617)	-0.266*** (-5.682)	-0.177*** (-3.120)	-0.165*** (-3.027)	-0.204*** (-3.973)	-0.203*** (-4.006)	-0.155*** (-3.506)

Xgas	0.372*** (4.115)	0.299*** (4.014)	0.382*** (4.480)	0.386*** (4.553)	0.499*** (9.606)	0.130* (1.742)	0.116 (1.607)	0.133* (1.967)	0.132* (1.976)	0.068 (1.021)
R^2	0.983	0.988	0.985	0.985	0.984	0.992	0.992	0.993	0.993	0.991
Adj. R^2	0.980	0.986	0.982	0.982	0.981	0.989	0.990	0.991	0.991	0.989
Est.Autocor. of e(i,t)						0.300	0.377	0.366	0.369	0.348
F[.,.]	[19, 92] 290.67	[19, 92] 421.49	[19, 92] 322.53	[18, 93] 343.29	[16, 95] 376.27	[26, 85] 409.82	[26, 85] 439.58	[26, 85] 477.92	[25, 86] 502.81	[23, 88] 461.83
Log-likelihood	-911.05	-890.52	-905.31	-905.45	-908.06	-870.29	-866.40	-861.75	-861.76	-872.39

Adjusted R^2 for the EU-15 countries improves in OLS Model versions but stay constant in FEM. It ranges between 0.980 and 0.991 in current sample.

The variables with positive coefficient are GDP, GDPPC, POP, GHG, Pnuc, REC variables and Xgas. On the other hand, FDI, Coil, Pgas, Cgas, Moil, Xoil and Mgas have negative impact on renewable energy. Inconsistent impact for EI, RDE and Poil can be observed. It should be added that majority of variables which have positive coefficient is statistically significant at 1% confidence level. For the expected signs, only GDP, GDPPC, REC factors excluding Phyd, Pgas and Xoil have the expected signs.

Comparison between OLS versions in this sample and in pooled sample shows that many variables reveal similar characteristics on dependent variable. However, POP, RDE, Pgas, Moil, Xoil, Mgas and Xgas differ from other sample in terms of impact they have.

When FEM estimations are analyzed, it can be seen that Model D has the highest F value (502.81) which makes it the base model. Compared to the OLS Model, many differences can be observed.

First, the variables with positive sign change. In addition to GDP, GDPPC, Xgas and REC variables, Cgas and Xoil also have positive sign. For the negative coefficients, POP, FDI, Pnuc, Poil, Coil, Pgas, Moil and Mgas have negative impact on renewable energy supply. EI, RDE and GHG have inconsistent effect on dependent variable.

Second, instead of Xoil, new variables which are Pnuc, REC, Poil and Pgas have expected signs along with GDP and GDPPC. Empirical findings support those early member countries which can produce energy from nuclear power, oil and natural gas will not prefer to produce energy from renewable energy resources.

Third, GDP and GDPPC as Economic Capacity indicators and Psol, Pwind, Pgeo as Renewable Energy Capacity indicators have positive and statistically significant impact at 1% confidence level.

Fourth, among 20 independent variables, 7 variables change their characteristics in current sample. While RDE and GHG have positive impact on dependent variable in FEM estimation of pooled sample, they have inconsistent effect in EU-15 sample. Vice versa, Pgeo and Xoil change their signs from inconsistent to positive. Finally, Pnuc, Poil and Moil which are inconsistent in the pooled sample become negative in current sample.

Final version of the Model 3 is run for the new member and candidate countries. The output of Model 3 which includes all sub energy resources' specific domestic and trade capacity indicators are shown in Table 61.

Table 61. OLS and FEM of Model 3 for the EU14.

	OLS					FEM				
Independent Variable	A	B	C	D	E	A	B	C	D	E
Constant	-65.74 (-0.462)	422.47 (1.539)	245.30 (1.011)	175.79 (0.738)	-30.02 (-0.116)					
GDP	0.011*** (3.895)	-	0.007*** (2.946)	0.008*** (4.752)	0.011*** (5.779)	0.007** (2.243)	-	0.007** (2.359)	0.008*** (2.903)	0.011*** (5.779)
GDPPC	-	-0.052** (-2.364)	-0.034* (-1.751)	-0.022 (-1.297)	-0.008 (-0.455)	-	-0.007 (-0.310)	-0.018 (-0.744)	-0.014 (-0.638)	-0.008 (-0.455)
POP	-0.955* (-1.916)	-0.293 (-0.620)	-	-	-	-0.231 (-0.090)	0.591 (0.218)	-	-	-
EI	-0.118 (-0.533)	-0.7060*** (-3.281)	-0.580*** (-2.869)	-0.579*** (-2.850)	-0.093 (-0.502)	-0.628* (-1.807)	-1.029*** (-2.948)	-0.701** (-2.174)	-0.689** (-2.158)	-0.093 (-0.502)
RDE	0.041 (0.166)	0.9090*** (3.755)	0.361 (1.323)	-	-	0.050 (0.203)	0.396 (1.652)	0.113 (0.438)	-	-
FDI	-0.450 (-0.003)	-0.011 (-0.770)	-0.007 (-0.517)	-0.0009 (-0.073)	0.006 (0.427)	-0.007 (-0.569)	-0.010 -0.742	-0.009 (-0.723)	-0.007 (-0.611)	0.006 (0.427)
GHG	0.008** (2.093)	0.005 (1.241)	0.002 (0.775)	0.002 (0.709)	-0.0007 (-0.344)	0.013** (2.483)	0.012** (2.220)	0.014** (2.589)	0.014** (2.598)	-0.0007 (-0.344)
Pnuc	0.088*** (3.023)	0.089*** (2.837)	0.089*** (3.058)	0.099*** (3.498)	0.074** (2.406)	0.123*** (3.531)	0.144*** (4.152)	0.120*** (3.445)	0.124*** (3.726)	0.074** (2.406)
Psol	170.580*** (3.028)	94.337 (1.477)	134.577** (2.238)	189.39*** (4.322)	194.51*** (4.197)	151.003*** (2.899)	129.976** (2.290)	138.16** (2.534)	154.28*** (3.860)	194.51*** (4.197)
Pgeo	-3.136 (-1.506)	-2.784 (-1.240)	-4.384** (-2.249)	-5.283*** (-2.877)	-3.957** (-2.162)	-2.889 (-0.756)	-1.680 (-0.410)	-3.106 (-0.875)	-3.522 (-1.036)	-3.957** (-2.162)
Phyd	1.184*** (6.160)	1.394*** (6.679)	1.289*** (6.487)	1.238*** (6.319)	1.225*** (5.665)	1.670*** (6.851)	1.593*** (6.364)	1.672*** (6.915)	1.681*** (7.017)	1.225*** (5.665)
Pwind	-15.690* (1.804)	-19.150** (-2.086)	-14.502 (-1.663)	-13.514 (-1.548)	-3.823 (-0.418)	-10.236 (-1.239)	-10.432 (-1.218)	-10.063 (-1.228)	-9.535 (-1.183)	-3.823 (-0.418)
Poil	-0.144 (-0.789)	-0.473** (-2.602)	-0.234 (-1.270)	-0.169 (-0.947)	0.108 (0.574)	-0.360* (-1.869)	-0.413** (-2.082)	-0.359* (-1.928)	-0.352* (-1.909)	0.108 (0.574)
Coil	0.029 (0.434)	0.108 (1.465)	0.060 (0.868)	0.059 (0.841)	-	0.070 (0.909)	0.057 (0.715)	0.068 (0.880)	0.068 (0.899)	-
Pgas	0.464*** (3.548)	0.583*** (4.138)	0.409*** (3.249)	0.368*** (3.003)	0.121 (0.994)	0.419** (2.699)	0.322** (2.082)	0.436*** (2.801)	0.432*** (2.798)	0.121 (0.994)
Cgas	-0.262*** (-4.195)	-0.334*** (-4.983)	-0.264*** (-4.192)	-0.238*** (-3.958)	-	-0.180** (-2.076)	-0.180* (-2.001)	-0.186** (-2.272)	-0.176** (-2.247)	-
Moil	0.030 (0.776)	-0.006 (-0.152)	0.038 (0.988)	0.051 (1.349)	0.077* (2.022)	0.013 (0.275)	0.045 (0.893)	0.012 (0.244)	0.013 (0.266)	0.077* (2.022)
Xoil	0.033 (0.746)	0.062 (1.345)	0.005 (0.136)	-0.009 (-0.232)	0.004 (0.113)	-0.041 (-0.723)	-0.079 (-1.396)	-0.035 (-0.620)	-0.037 (-0.667)	0.004 (0.113)
Mgas	0.087* (1.836)	0.157*** (3.141)	0.093* (1.934)	0.072 (1.582)	-0.120*** (-6.902)	0.093* (2.047)	0.125** (2.714)	0.098** (2.224)	0.092** (2.216)	-0.120*** (-6.902)
Xgas	-0.441* (-1.917)	-0.402 (-1.652)	-0.402* (-1.749)	-0.399* (-1.724)	-0.404 (-1.609)	-0.387 (-1.680)	-0.355 (-1.475)	-0.414* (-1.846)	-0.410* (-1.840)	-0.404 (-1.609)
R^2	0.988	0.987	0.988	0.988	0.985	0.991	0.991	0.991	0.991	0.991

Adj. R^2	0.985	0.984	0.985	0.985	0.981	0.988	0.987	0.988	0.988	0.988
Est.Autocor. of e(i,t)						0.003	0.052	0.004	-0.009	0.071
F[.,.]	[19, 72] 333.99	[19, 72] 296.85	[19, 72] 331.29	[18, 73] 346.04	[16, 75] 308.61	[25, 66] 317.65	[25, 66] 295.39	[25, 66] 320.29	[24, 67] 337.70	[22, 69] 348.09
Log-likelihood	-583.61	-588.97	-583.98	-585.08	-596.85	-569.43	-572.74	-569.05	-569.19	-573.11

The explanatory power of this model which ranges between 0.985 and 0.991 remains almost same with the previous version of model.

The coefficient of GDP, RDE, Pnuc, Psol, Phyd, Coil and Pgas is positive and mostly significant at 1% confidence level. Among these variables, GDP, RDE, Psol and Coil have also expected signs. In contrary to the expectations, GDPPC, Pgeo, Pwind, Cgas have negative impact on renewable energy supply. As expected, the coefficient of Xgas is negative. Moreover, the coefficient of POP and EI which is assumed to be ambiguous is also negative.

When OLS Models are compared with each other, it can be seen that GDP, Pnuc, Psol, Phyd, Poil and Cgas have the common impacts on renewable energy resources. It means that all empirical findings related to these variables are applicable for three samples which are pooled, EU-15 and EU-14. Furthermore, as a technological infrastructure capacity indicator, RDE in current sample has same characteristic with pooled sample.

In FEM results, explanatory power of the model is around 0.991. Model E has the highest F value in current sample (348.09)

As expected, GDP, RDE, Psol, Coil, Moil have positive impact on renewable energy in emerging European countries. In addition to these variables, Pnuc, Phyd and Pgas also have positive effect on dependent variable and they are statistically significant at 1% confidence level.

In contrary to the expectations, GDPPC, EI, Pgeo, Pwind and Cgas have negative impact on dependent variable in new and candidate countries. Moreover, the coefficient of Xgas, as expected, is negative for the current sample over the period 1995 and 2008.

In FEM, all explanatory variables excluding POP and Moil reveal similar results with OLS Model. The coefficient of POP which is negative in OLS Model becomes inconsistent. Furthermore, the impact of Moil is found to be positive in FEM results whereas it is inconsistent in OLS Model.

Finally, when FEM results are compared with each other, it can be observed that GDP, POP, Psol and Phyd have similar characteristic in three samples. It means that all empirical evidences related to these variables are applicable for each sample. While RDE, Poil and Xoil are the common variables both for the pooled and EU-14 sample, GHG is the only common variable for the EU-15 and current sample.

CHAPTER 7

POLICY RECOMMENDATIONS AND CONCLUSION

Today, the world is experiencing a shift to renewable, energy efficient and low carbon technologies driven by energy security and climate change concerns. Due to the inadequate fossil fuel reserves and mismatch between the produced and consumed energy, many developed countries become dependent to the external injection of energy via import. This problem has also been experienced in developing countries like Turkey. Therefore, energy shapes and steers the countries' economic, social, political and environmental thinking in a global level. Since countries are willing to decrease their energy dependence, secure their energy supply and decrease the environmental cost of conventional fossil fuels, transition to a sustainable energy system is occurring both in developed and developing countries. In the light of concept of sustainable energy, renewable energy resources, along with energy efficiency technologies, started to emerge as an obligatory path to follow.

As an emerging economy, Turkey's energy demand has increased rapidly, especially for the last two decades. Turkey's total final energy consumption accounted for nearly 39 mtoe in 1990 and this amounted to 72 mtoe in 2008. Turkey experienced strong and steady economic growth and social welfare starting from 2002. Therefore, primary energy consumption and electricity consumption increased by 36% and 49%, respectively within last 6 years. However, this upward trend in energy needs is being met by traditional fossil fuels led by oil, coal, lignite and natural gas. Since the amount of those energy resources is very limited in the country and since there is not any significant renewable energy production, Turkey is totally dependent to the imported energy resources. This devitalizes the country's economic and social power and also weakens the political influence of Turkey in the region.

On the other hand, Turkey has tremendous renewable energy resources. It is estimated that Turkey's economically feasible potential is 127,000 MW/year. While Turkey's gross hydro potential amounts to 1 % of the world's total hydro potential, Turkey also has huge amount of solar, wind and geothermal energy. It is assessed that Turkey has the third highest wind energy potential in Europe, first in geothermal energy resources in Europe and seventh in the world. Turkey also has second highest solar energy potential among European countries. In this context, utilization of renewable energy resources rises as one of the best solution to fight against all energy related problems and achieve sustainable development for Turkey.

After analyzing Turkey's energy dependency, related problems and energy potential renewable energy supply is selected as a recipe to follow. In order to determine the fundamental factors affecting renewable energy supply, different econometric models such as Ordinary Least Square (OLS) and Fixed Effects Model (FEM) were employed. The study is based on country level data in the EU region. In order to see the differences between developed and developing countries in Europe, the fundamental determinants of renewable energy supply were analyzed for the different groupings of countries; the pooled sample (including all member and candidate countries), the EU-15 (early members of the EU) and the EU-14 (new members & candidate countries). As an emerging candidate country, Turkey was grouped under the EU-14 sample. Due to the lack of available country specific data, Malta and Former Yugoslav Republic of Macedonia could not be included in the sample. Therefore, pooled sample includes 15 old members, 11 new members as well as 3 candidate countries. Three sets of OLS and FEM were run separately for the period of 1995-2008: Model I, where total energy variables are included as determinants of renewable energy supply; Model II, where each energy supply variable is included as well as all other explanatory variables, and Model III, where indicators of sub-energy resources are considered.

Empirical results for three models reveal that FEM outperform OLS for all sample sets. For the pooled sample, POP (population) and FDI (foreign direct investment) have negative impact on renewable energy in all three models whereas RDE (research and development expenditure) has positive impact in all models.

Potential fundamental factors in affecting renewable energy supply are not similar for the EU-15 and the EU-14 countries. The common characteristics for the two groups of countries are determined as the positive effects of TEC (total energy consumption), Psol (solar energy production) and Phyd (hydro energy production), and the negative impact of TEX (total energy export) on renewable energy supply. The hypotheses and the common results for both the EU-15 and the EU-14 that support the hypotheses are shown below:

(1) There is a positive relation between the renewable energy supply and total energy consumption. It indicates that if a country’s energy consumption volume increases, then she will prefer to utilize her renewable energy resources.

(2) As a REC (renewable energy capacity) indicator, Psol (production of solar energy) has positive impact on renewable energy supply. If a country produces energy from solar systems, then she will increase her renewable energy supply.

(3) If a country has excess energy to export it, then she will not need to produce energy from renewable energy resources. She will continue to rely on traditional fossil fuels.

(4) It was assumed that Phyd (production of hydro energy) may have ambiguous impact on renewable energy supply because many countries which could utilize their hydro energy could not benefit from their new renewable energy resources. However, empirical finding shows that there is a positive relation between renewable energy and hydro energy production.

When it comes to the dissimilarities observed between the EU-15 and the EU-14, it can be seen that GDPPC as an Economic Capacity indicator, has positive impact on renewable energy supply in the EU-15 countries. Thus, the hypothesis that

(5) "If the economic capacity of the country is high, then renewable energy supply will be high" is accepted for the EU-15 countries.

However, GDP and GDPPC have inconsistent impact on renewable energy in the EU-14 countries.

The empirical evidence supports that FDI has negative impact on dependent variable in the EU-15 countries. Thus, the hypothesis that

(6) "If the foreign investment capacity of the country is high, then renewable energy supply will be high" is rejected for the EU-15 countries.

On the other hand, FDI showed different characteristics for the EU-14 countries. While FDI has positive impact in Model 1, it has negative impact in Model 2. Furthermore, FDI has inconsistent effect on renewable energy in Model 3. In addition, its statistical significance is low in these models. This outcome can be conducted with the lack of available renewable energy related FDI data. Therefore, promoting renewable energy resources through FDI in the emerging economies of Europe should be analyzed in further research studies.

It was expected that the impact of Supoil (supply of oil) and Supgas (supply of natural gas) is ambiguous. Empirical evidence reveals that these variables have negative impact in the EU-15 countries; whereas they have positive impact in the EU-14 countries. It can be inferred that the emerging economies in Europe do not consider the way of providing energy whether through import or production and just focus on the volume of energy supply. Thus, they do not try to promote their renewable energy resources.

EI (energy intensity) has a negative impact in all models in the EU-14 countries. It is assumed that the effect of energy intensity on renewable energy supply, which is derived from gross inland consumption of energy divided by GDP, is ambiguous. While the countries with high ratio for energy intensity are willing to decrease their energy dependency on traditional energy resources, they may ignore energy intensity issue and rely on conventional energy resources. For the new and candidate countries, energy intensity is found to be an obstacle to renewable energy supply. Thus, emerging economies including Turkey have to decrease their energy intensity levels.

Finally, in contrary to the expectations, Pnuc (nuclear energy production) has a positive impact on renewable energy supply and is statistically significant at 1% confidence level in three models of the EU-14 countries. Since many developing countries in Europe including Turkey are lag behind in installation of nuclear power plants, they should invest in nuclear energy and execute promotion of renewable energy resources synchronously.

In conclusion, the EU-15 and the EU-14 countries have different characteristics in terms of economic, social, technological and even cultural development. Therefore, discrepancies in the samples of three models can be observed. For example, while supply of oil and supply of natural gas have negative impact on renewable energy supply in the EU-15 countries, these variables have positive impact on renewable energy supply in the new and candidate countries. It can be said that developed countries in the EU consider oil and natural gas supply whether they are provided by import or production. Since many developed countries in the EU such as Germany, France, Spain and the U.K. do not have adequate traditional fossil fuels, the consciousness on the drawbacks of oil and natural gas trade is much clearer for those countries.

Parallel to the empirical finding on supply of oil and gas, consumption of oil has similar impact on renewable energy supply. While consumption of oil has positive impact on renewable energy supply in the emerging economies of Europe, it has negative effect in the EU-15 countries.

Foreign direct investment, as mentioned earlier, is also another variable that shows dissimilarities between the EU-15 and the EU-14 countries. While the impact of FDI is negative in the early members of the EU, it has both positive and negative impacts in the new and the candidate countries. This can be explained as follows: While developed countries in Europe such as Germany and France have latest technology and sufficient know-how to promote their alternative energy resources by themselves, developing countries in the EU need to have the know-how and the technology of the developed countries to utilize their green energy resources. At this juncture, potential impacts of FDI on renewable energy supply should be assessed for the new and candidate countries.

When it comes to the EU-15 and pooled sample, it can be concluded that they have more common characteristics than they have with the EU-14. In addition to the common negative impacts of FDI and supply of oil and natural gas, production of gas and natural gas import also have negative impact on renewable energy supply both in the EU-15 and pooled sample. In contrary to the expectations, the countries which import natural gas do not prefer to utilize their renewable energy resources in the pooled sample and the EU-15 countries. However, as expected, the countries which can produce natural gas will continue to rely on the conventional fossil fuels such as natural gas.

Another similar finding is observed for the production of wind energy. The impact of wind energy production is positive and statistically significant at 1% confidence level both in the pooled and the EU-15 countries. This indicates that the possibility of utilization of renewable energy resources is much higher for the countries which could start to generate energy from wind power. However, this outcome was not being observed for the geothermal energy production in these samples.

For the total energy variables, while having different impacts separately, total energy consumption, total energy production, total energy import and total energy export have the same impacts both in the pooled sample and the EU-15 countries. While total energy production, total energy consumption and total energy import have positive impact on renewable energy, total energy export has negative impact in the EU-15 and the pooled sample. All these variables are statistically significant at least at 5% confidence level. This empirical evidence shows that the countries in the pooled sample consider the total energy figures to define their roadmap for the renewable energy supply.

The assessment of Turkey’s current energy dependency together with her renewable energy potential, global renewable energy market and determinants of renewable energy supply, following policy implications could be drawn not only for Turkish energy actors but also for the new member and the candidate countries.

- Turkey should utilize her renewable energy resources.

Since Turkey has inadequate conventional fossil fuel reserves and she is heavily dependent on external energy supply, Turkey should promote her huge renewable energy resources such as wind, solar and geothermal energy by investing in green energy market. Increase in the share of renewable energy in total primary energy supply will decrease the value of current account deficit and energy dependence of Turkey. In addition, while negative impacts of conventional fossil fuels on environment and human health will be reduced, many job opportunities will be created.

- Turkish policymakers should establish sufficient and concrete policies in order to promote renewable energy resources. Throughout the process the successful countries in renewable energy supply can be considered as role model.

Like many countries did, Turkish government should set ambitious but realistic targets and timetables in combination with effective policies. In addition to $500 billion of target export volume by 2023, energy and renewable energy specific goals should be set. Furthermore, realistic targets on decrease in energy import should also be projected.

Many tools affecting renewable energy supply positively such as Renewable Energy Portfolio Standard (RPS) and green certificates should be enacted. In addition to this, renewable energy law in practice should be developed in favor of private investors. Although empirical findings reveal that the impact of FDI on renewable energy supply is inconsistent in the new and candidate countries, it is expected that this may stem from the lack of available renewable energy specific FDI data of the countries. Since the incentives and the Feed-in-Tariffs that Turkey offers are not sufficient enough to attract private investors into Turkey's renewable energy market, many local and foreign investors postponed their investment decisions. Although the number of joint ventures in wind, solar and geothermal markets of Turkey is increasing rapidly, Turkish government has to regulate all policies and improve the weaknesses of the current renewable energy law. However, it should not be forgotten that each policy and regulation should meet the specific needs of the Turkish renewable energy market. Thus, policies should be appropriate, flexible, credible, clear, result oriented and simple in favor of both investors and Turkey.

- Enactment of stable frameworks for independent energy producers is a must for Turkey.

If Turkey is willing to promote her renewable energy resources, then she should create private markets for renewable energy. Establishment of a transparent and stable framework and rules, governing competition on prices and access to customers are significant tools in utilization of green energy resources. Utility regulatory frameworks that allow fair competition for electricity production by independent renewable energy producers are essential for grid connected renewables in Turkey. In this context, the electricity sector including transmission and distribution utilities should be carefully liberalized. Continuous privatization which is required for the free market economy is also essential for more efficient energy markets. However, the valuation of the channels and utilities that are privatized should be evaluated very deeply.

- Turkey should support local investors by increasing R&D expenditure on renewable energy.

First, Turkey should understand local renewable energy flows and their potential use. Then, continued research and development is required on local renewable energy technologies. Although many developed countries like Germany, the U.S., the U.K. and Spain have the latest available high technology in this specific market, many emerging economies such as China, India, Brazil and South Korea started to develop renewable energy technologies. Thus, Turkey should focus on the sector specific developments and share an important amount of capital from the government budget for the development of renewable energy technologies. Even though it can be seen as a costly process in the short term, the benefits of this spending will be felt in the medium and in the long run. Therefore, supporting innovative ideas through allocating a larger share of public sector funding, forming a public- private cooperation and offering satisfactory purchasing prices for the electricity generated from renewable energy resources are essential for the promotion of renewable energy resources in Turkey.

- Public awareness on renewable energy should be created.

Turkey should educate and disseminate information regarding energy resource availability, the potential and benefits of renewable energy, government incentives for each energy resources and the negative impacts of conventional fossil fuels have on environment, human health and the Turkish economy. Turkish energy authorities should establish national training programs in high schools, universities and other public related institutions. Using appropriate communication techniques such as social media, holding seminars and conferences about the benefits of renewable energy resources and arranging competitions on the innovative ideas for the utilization of renewable energy resources are the major tools in creating public awareness on renewable energy.

- Public institutions and the universities should be encouraged to produce their own energy from renewable energy resources

In order to develop consciousness about the renewable energy resources, universities and public institutions such as schools, hospitals and other governmental organizations should generate energy from alternative energy resources. This can be a good example to show citizens that everybody can make a contribution to the national energy plan by realizing the importance of renewable energy resources and adding them to their energy mix. It is expected that Bogaziçi University will be the first "green university" of Turkey because Bogaziçi is willing to install three wind power stations, each of which has 2MW of capacity. The university will also sell the excess electricity and generate additional income to fund its other energy related projects. The number of that kind of green entrepreneurship should increase.

- Turkey should use her tremendous renewable energy potential as an effective tool in the negotiation of the accession to the EU.

Turkey is willing to become a member of the European Union. In order to achieve this goal, Turkish parliament passed many reforms and laws for the last 10 years. However, the decision making bodies of the EU think that there are still lots of things Turkey has to do. Apart from political issues, energy can be one of the strongest sides of Turkey against the EU. Although Turkey and the EU share the common destiny which is energy dependency, Turkey, by producing her own energy from renewable resources, can show the EU that she will not bring extra load for the EU energy market. This will be positive criteria for the EU enlargement decision makers to accept an energy sufficient country, Turkey, to the EU.

- Turkey, with her huge potential in renewable energy, her geopolitical position and cultural diversification should bring the EU know-how and the Middle Eastern capital to improve Turkish renewable energy market and decrease its energy dependency.

Turkey, with her geopolitical position is considered as energy hub in the region. From renewable energy perspective, Turkey should transfer the know-how of the leading EU countries. In addition to this, Turkish geopolitical position and cultural proximity to both the EU and the Middle Eastern countries can bring the Middle Eastern capital and the EU know-how together, the tools that are needed to improve Turkish renewable energy market.

- Energy efficient technologies should be integrated into Turkey's electricity market.

Energy efficiency which means getting the same benefit while using less energy is very critical issue for the countries whose energy consumption is increasing very rapidly. As a country experiencing a higher growth rate of energy consumption compared to the European Union average, Turkey has relatively high rate of energy intensity. As the empirical evidence supports, energy intensity has negative impact on renewable energy supply in the new member and candidate countries. Since energy efficiency including energy intensity is the main tool of sustainable energy along with renewable energy, energy actors in Turkish electricity market should accelerate and implement energy efficiency policies for 4 main sectors which are industrial, building, household and transportation to decrease energy intensity.

- Turkey should build a sustainable energy system which must put environmental concerns on the top of the priority list.

As a country has participated in the United Nations Framework Convention on Climate Change by ratifying an agreement to sign the Kyoto Protocol on February 2009, Turkey has to consider her greenhouse gas emissions. Undoubtedly, increasing renewable energy production and adding alternative energy resources into the country's energy mix should be defined as primary goals of Turkish governments, people, non-governmental organizations (NGOs) and all kind of groups in the short, medium and the long run. Since renewables offer the potential for carbon free energy, Turkey should promote her renewable energy resources and make comparisons "before and after" utilization of renewables annually. Even though GHG (greenhouse gas) emission level of Turkey does not cause serious problem for now, Turkey's high rate of energy consumption will increase the volume of emitted poisonous gases. Therefore, sustainable energy system should set ambitious targets on limiting different kinds of greenhouse gases.

- Turkey should consider producing energy by nuclear power together with investing in solar, wind and geothermal energy.

In order to decrease their energy dependency, many developed countries have installed nuclear power facilities for a long time period. Since it is alternative to oil, natural gas and coal, nuclear energy was expected to become the main energy source of the future. However, the explosions of Chernobyl and Fukushima nuclear power plants and the global political crisis caused by the countries like Iran which attend to have research studies and investment on nuclear energy, made nuclear energy one of the most debated issues globally. Although there are some risks related to nuclear power, many developed countries are enjoying the advantages of nuclear power and this trend seems to continue in the emerging economies. Empirical findings also support that a country which has a high capacity of nuclear power strongly considers renewable energy supply in her energy mix. Thus, nuclear energy could be added the country's energy portfolio along with renewable energy resources only in case the potential environmental and social hazards are captured.

- The future of natural gas in Turkey's energy portfolio should be open to discussion.

Undoubtedly, natural gas is the most popular energy resources of 2000s. Since its start up cost is relatively low and the return of investment is faster compared to the other alternative energy resources, energy firms primarily prefer to invest in natural gas plants. Thus, the share of natural gas in Turkey's electricity mix increased dramatically. Unfortunately, the foreign dependence ratio of Turkey for natural gas is around 97%. It indicates that natural gas makes Turkey vulnerable to the external price and supply shocks. In order to ensure the energy security and decrease the burden that natural gas creates on the Turkish economy, electricity generation from natural gas should get decreased gradually.

In addition to this, an imbalanced natural gas import structure is another problem that Turkey has to solve. Total demand for natural gas is provided by five source countries and 2/3 of total natural gas import is come from just one country, Russian Federation. Furthermore, since the majority of agreements on natural gas import are based on "buy or pay" long term contracts, in the case of any decrease in domestic gas demand due to the price increment or any economic crisis, those kinds of contracts will limit the positive change opportunity for domestic selling prices even there is price decline in international market. Thus, Turkey should change the maturity and the specifications of the contracts already in force and natural gas suppliers of Turkey should be diversified.

This study contributes to the literature by: (1) covering all EU members and the candidate countries where there exists a large discrepancy between economic and technological development levels in potential determinants affecting renewable energy supply; (2) including the candidate countries in the sample, Croatia and especially Turkey due to her strategic economic and geopolitical importance in the region as well as her adoption of market-oriented policies which has started long before the new members of the EU.

In addition, to our knowledge, this is one of the first academic studies analyzing potential determinants of renewable energy supply in the emerging economies of Europe by employing Panel Data Analyses for the period of 1995-2008. This study shows that the policymakers and energy authorities should take into consideration the specific characteristics of the new member and candidate countries of the EU in renewable energy utilization. While this research can pave the way for the governments of the emerging economies in Europe to decrease their energy dependency by establishing legal, political and environmental framework on renewable energy, it may also help private investors to select what kind of factors they should take into account before they invest in those emerging renewable energy markets.

For future studies, each of the determinants of renewable energy supply might compose a basis for further studies. In addition, gross capital formation, patent applications for each renewable energy resources and prices of electricity and other energy resources can be added into the model. Integration of qualitative variables such as political stability, ease of doing business, government effectiveness and accountability of the countries may increase the reliability of similar studies. Since renewable energy supply is a very dynamic industry, especially in emerging countries, more recent data can be used. The study can also be extended by adding other emerging countries such as Brazil, Russia, India and China to analyze whether there are distinct differences among emerging economies from different regions.

Finally, in order to combine determinants of renewable energy supply with finance issues, each country or country group can be compared in terms of renewable energy related FDI attractiveness. In such case, cross comparison between the fundamental factors affecting renewable energy supply and the investment attractiveness in this specific sector can be made.

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