National Energy Report of Turkey: Energy Situation, Challenges, and Policies for Sustainable Development[1]

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1. Introduction

Although the quality of life depends not only on income, but also on a variety of physical and social conditions, the economic development of countries has traditionally been measured with per capita gross domestic product (GDP). However, measuring human development only by GDP per capita obscures the fact that the primary objective of development is to benefit people (e.g., UNDP, 1990; Şen, 1998; Dowrick et al., 2003). For this, *Human Development Report 1990* proposed the Human Development Index (HDI) to measure "the average achievements of a country in basic dimensions of human development" in addition to economic indicators (UNDP, 1990).

The HDI has later been improved by taking natural resource exploitation and environmental degradation into consideration in calculating the HDI (Desai, 1994; Neumayer, 2001). Finally, Ediger and Tatlıdil (2006) attempted to integrate an energy and environment component to the HDI by using four indicators such as total primary energy consumption per capita, electricity consumption per capita, GDP per unit of energy use, and CO_2 emission per capita.

The main reason for all these efforts is the well-known fact that energy is an essential ingredient of sustainable development. Although it is not one of the basic human needs such as food, water, housing, health, education, and employment, it is central to economic, social,

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and environmental dimensions of sustainable development (Goldemberg and Johansson, 1995; Ediger, 2001; Johansson and Goldemberg, 2002 a, b; Bloom et al, 2004). Ayres et al. (1996) have clearly shown that economic growth is not sustainable because some amount of energy and materials are used to produce goods and services. Therefore, as noted by WEC (2000), one of the most important components of sustainable development should be accepted to achieve accessibility, availability, and acceptability in energy.

However, although it is mostly agreed that a more sustainable energy supply will lead to a more sustainable future, the path toward sustainable energy still remains unclear: developing of sustainable energy and/or technological advances (e.g., Walter 2002; Voorspools, 2004). At present, the second option is usually preferred since most of the developed countries have resource scarcity and environmental degradation problems. The principal energy sources used in many countries are usually imported fossil fuels and their need for such fuels has increased enormously over the past few decades (Ediger et. al., 2006). Only a few countries are self sufficient in terms of fossil fuel production, i.e. their domestic fossil fuel productions are equal to or higher than their fossil fuel consumptions. Also, the share of domestic energy supply in overall energy demand is decreasing steadily in most of these countries.

This situation negatively affects the sustainable development –especially of developing countries. For this, formulating and implementing proper energy policies is vital for the sustainability of import-dependent countries like Turkey. The aim of this paper is, therefore, to discuss within this context the energy situation, challenges, and policies for sustainable development of Turkey in the form of a national energy report of the country. The results achieved in this study may also be important for the sustainable development policies of other similar countries.

The report is organized into six sections. The next section deals with the strategic value of Turkey in European and also in global energy scene. The Sections 3-5 deal with the energy situation of Turkey and major challenges; energy intensity and energy efficiency; and green energy strategies, respectively. The last section includes the results and conclusions, including recommendations for sustainable energy development.

The report is prepared for the AASA (Association of Academies of Sciences in Asia) Beijing Workshop on Sustainable Energy Development in Asia 2008, which was held between November 17-18 in Beijing, China.

2. Strategic Value of Turkey in Global Energy Scene

Turkey is a transcontinental country, stretching across Anatolia in the western Asia and Thrace in the southeastern Europe. With its strong historical, cultural, and economic influence in the neighborhood, it has a multi-dimensional importance in the energy scene of the region including parts of the EU, Russia, Caucasus, Central Asia, the Middle East, and Africa.

First, Turkey has a strategic position as an oil and gas transit country, providing secure energy transit geography of increasing importance between energy-producing and energy-consuming countries in the region (Figure 1). A number of pipeline projects developed crossing or ending in Turkey have already proven the significance of Turkey's "geo-energy space." The well-known Baku-Tbilisi-Ceyhan crude oil pipeline, which is one of the biggest energy infrastructures of the decade, has been operating since May 2006 as the second oil pipeline of the country after the Kirkuk-Ceyhan. The Russia-Turkey (Western), Novorossisk-Samsun (Blue Stream), Baku-Tbilisi-Erzurum (Shah Deniz) and Turkey-Greece (European) pipelines are the natural gas pipelines extending in north-south and east-west directions. The Samsun-Ceyhan crude oil pipeline and Turkey-Austria (Nabucco), Trans-Caspian, and Iraq-Turkey natural gas pipeline projects are in the planning or implementing stages at present.

Second, Turkey has been very successful in developing energy consumption capacity for last decades (Ediger, 2003). For this, it is often recognized as one of the most important emerging markets in the world's energy sector. Turkey's importance in the world's energy scene thus does not depend on its strategic location only, but also on its economic development performance resulting from the reform efforts of more than two decades. Turkey, which is a founding member of the OECD (Organization for Economic Co-operation and Development) and the G-20 (The Group of Twenty), is also a member of trade organizations such as WTO (World Trade Organization), European Union Customs Union, ECO (Economic Cooperation Organization), BSEC (Organization of the Black Sea Economic Cooperation), and D-8 (Developing Eight).

At present, Turkey has the 17th largest economy in the world with an average GDP growth rate of around 6.6: the GDP growth rate has been 8.4% in 2005, 6.9% in 2006, and 4.5% in 2007. Different sources show that Turkey's GDP at PPP per capita is around 13,000 USD and ranks 48-63 in the world. As a result of such a strong and stable growth coupled

with large privatization and structural changes in economy, Turkey succeeded in attracting a significant amount of FDI and is expected to attract a higher figure in the years to come.

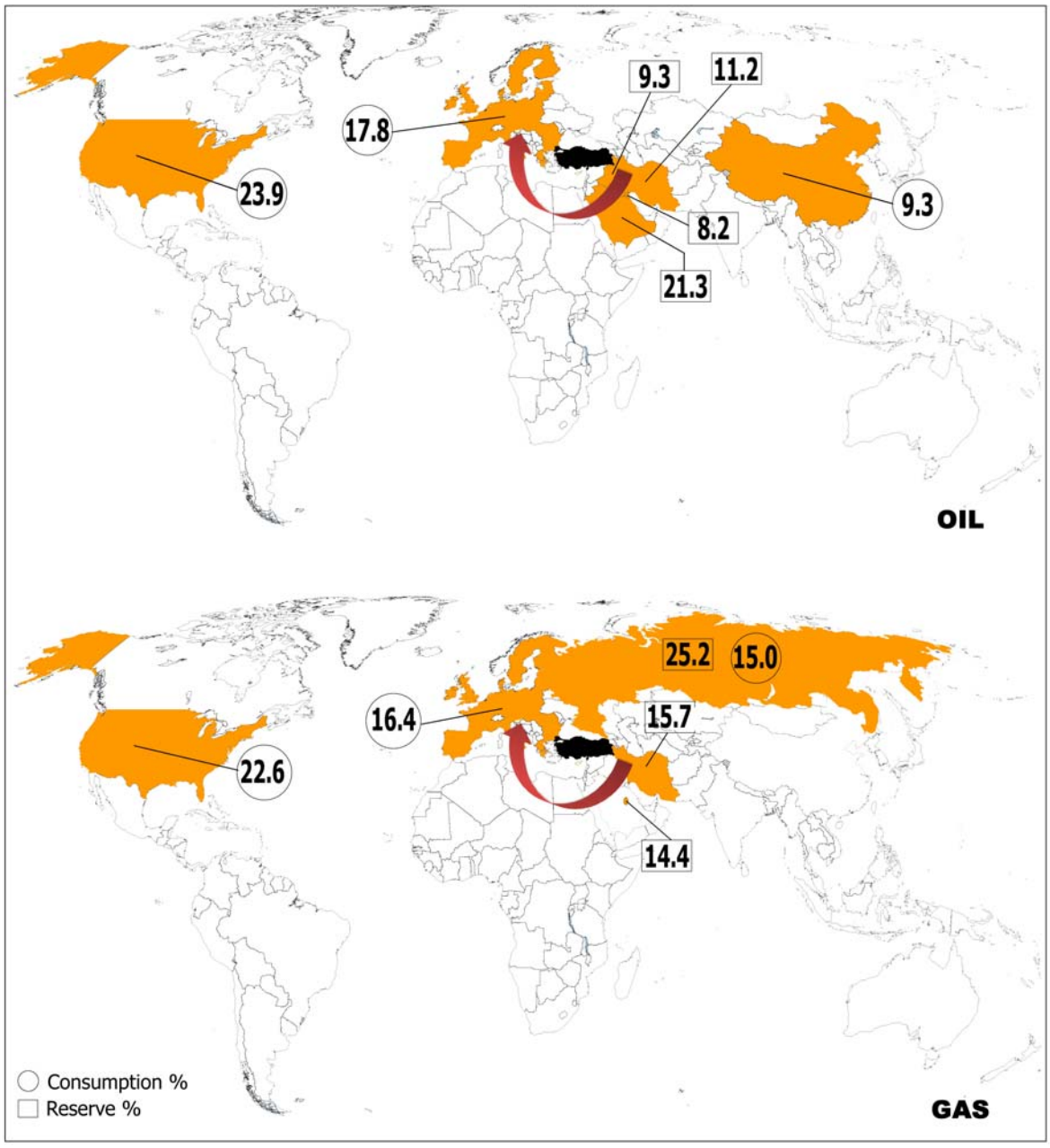

Figure 1. The strategic importance of Turkey's location for Europe's oil and gas security

World Investment Report 2008 summarizes the present situation of FDI in Turkey as follows: "Saudi Arabia was the leading FDI recipient in the region in 2007. Turkey followed, with inflows of $22 billion – an increase of more than 10% compared with 2006 – despite worsening macroeconomic conditions such as slow growth and rising inflation. The increase in FDI reflected mainly large-scale privatizations and private sector cross-border M&A deals. Major EU countries, particularly the Netherlands, Germany, the United Kingdom, France and Italy, together with the United States, Switzerland and Japan, traditionally have been the main sources of FDI in Turkey." (UN, 2008, p. 54).

Finally, Turkey is a candidate for becoming an EU member in the near future and preparation for membership can work as a stabilizer for the Turkish economy (Lise and van Montfort, 2007). A proper investment climate in Turkish energy sector will be important especially for the European Union, which urgently needs to diversify its natural gas routes for reasons including energy security and geopolitics.

Several authors have studied the importance of Turkey as the main transit country to Europe for "EES: European Economic Space" (van der Linde, 2004), for "CEES: Common European Economic Space" (Correlje´ and van der Linde, 2006), and for "Pan-European Geo-Energy Space" (Mañé-Estrada, 2006). They all agree that the potential of Turkey to become an important country for oil and gas transit from Russia, the Caspian Sea region and the Persian Gulf adds to the strategic importance of Turkey for the EU. They also suggest that political and strategic considerations should play an important role in discussions for Turkey's accession to EU and that Turkey should be taken into EU without any delay.

Aurèlia Mañé-Estrada (2006, p. 3785) defines "the pan-European geo-energy space" as "a geographical space where a precise set of energy relationships take place, among different agents —producer states, enterprises and consumer governments— who are active within it, and whose borders are wider than those of the present-day European Union—the current Euro-Mediterranean and the eastern Euro-Asian territories." She also claims that the creation of the pan-European geo-energy space will give Europe "an instrument to establish better relationships and bring about a higher degree of multilateralism in the international energy scene." Because Turkey is also the strategic key of the regional energy industry, she suggests that "Turkey is to become an important supplier of hydrocarbons; geographically, Turkey is the heartland of our pan-European proposition; and finally Turkey is destined to become an intermediary in the relationships to be established amongst the energy agents operating in the region." (p. 3783).

3) Energy Situation of Turkey and Major Challenges

Three major problems of Turkish energy system are often noted as: (1) dependency on imported energy sources, (2) domination of energy consumption by fossil fuels, and (3) low energy efficiencies compared to the other countries (e.g., Ediger, 2001, 2004; Çamdalı and Ediger, 2007). It is obvious that the future accomplishment of Turkey will depend on developing and implementing sound energy policies towards solving these problems.

Turkey is one of the medium-class energy consumers of the world with a total share varying between 0.6% and 1.2% (Ediger, 2003). Its primary energy consumption in 2006 was around 100 mtoe, of which 26.7 mtoe was met from domestic sources and 73.8 mtoe from net-imports (Table 1). The present-day energy mix of Turkey is composed 32.6% of oil, 28.9% of natural gas, 28.0% of coal, 6.7% of renewables (5.2% traditional renewable and 1.5% modern renewable), and 3.9% of hydropower.

Table 1. Energy budget of Turkey in 2006.

x1000 tonnes oil equivalent	Oil	Gas	Coal	Wood	Hydro	Geother.	Solar	Biomass	Wind	Electr.	Total
Primary Energy Supply	32,551	28,867	27,999	5,169	3,886	1,081	403	18	11	-143	99,840
Domestic Production	2,284	839	13,088	5,169	3,886	1,081	403	19	11		26,779
Import	37,356	27,973	15,038							49	80,416
Export	-6,379									-192	-6,572
Bunker	-588										-588
Stock Change, etc.	-121	55	-127					-1			-194
Energy Conversion	-4,392	-14,909	-12,292	-43	-3,886	958			-11	12,374	-22,201
Power Plants	-1,037	-14,770	-10,939	-43	-3,886	958			-11	15,162	-14,565
Others	-3,356	-140	-1,353	0	0	0	0	0	0	-2,789	-7,637
Total Final Energy	28,159	13,958	15,706	5,126	0	2,039	403	18	0	12,231	77,639
Industry	3,976	6,895	13,268	0	0	958	122	0	0	5,777	30,996
Transportation	14,794	131	0	0				18		68	15,010
Housing and Services	1,998	6,932	2,437	5,126		1,081	281			6,004	23,860
Agriculture	3,228		0	0						382	3,610
Non-Energy	4,163		0	0							4,163

The historical development of energy sources in Turkey from 1950 to 2006 show that the share of oil first increased from 7.6% in 1950 to 55.7% in 1977 and then decreased from the 1977 peak to the present value of 32.6% (Figure 2). The traditional renewables such as wood and animal remains decreased gradually from 63.6% in 1950 to 5.2% in 2006. Coal fluctuated around 30%, except for the period between 1967-1984 when it decreased down to

19.8%. Natural gas steadily increased starting from 1976, cutting the coal curve at about 27% in 2005. On the other hand, hydro occurred between 3-4% whereas modern renewables around 1-2%. This situation indicates clearly that natural gas has been replacing oil and traditional renewables in Turkish energy system for last two decades, increasing dependence on natural gas.

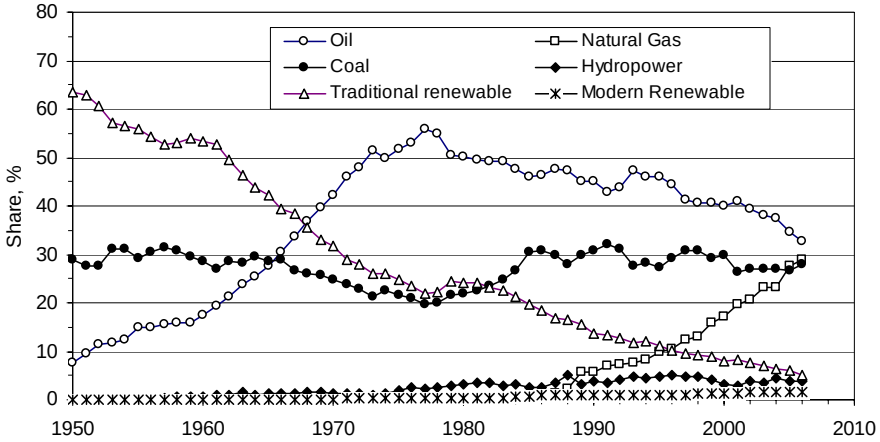

Figure 2. Historical development of shares of energy sources in Turkey, 1950-2006.

One of the most important characteristics of Turkish energy system is its traditionally high rate of demand growth because of the country's high economic performance. This rate varied from a minimum of -6.3% in 2001 to a maximum of 11.59% in 1972, with an average of 4.9% in the period between 1950 and 2006. The rate has been negative only four times: -6.3% in 2001, -5.7% in 1979, -1.9% in 1994, and -0.6% in 1999. The rate of increase of electricity demand is even higher than this, varying from a minimum of -1.8% in 2001 to a maximum of 18.4% in 1976, with an average of 8.8% in the period between 1970 and 2006. The average rate of increase in electricity demand is 8.19% ranking 8th in the 1990's, and 7.35% ranking 11th in the 2000's. These rates are roughly 2 to 3 times higher than the world's average.

As opposed to the high rate of growth in energy demand, the average annual growth of primary energy production has been only 2.7% from 1950 to 2006, making addiction to foreign sources as one of the most significant problems of Turkish economy. This obviously endangers the sustainable development of the country. Turkey's primary energy production from domestic sources meets only 27% of its consumption at present. This ratio is only 3% in natural gas, 7% in oil, and 9% in hard coal. The remaining fractions of fossil fuels were met

by imports, amounting US $33.8 billion in 2007 and the energy bill of Turkey is expected to be US $47 billion in 2008. The largest shares in imports consisted of 37.3 mtoe of oil, 27.9 mtoe of natural gas, and 13.2 mtoe of bituminous coal in 2006. Additionally, 1.8 mtoe of coal products in the form of coke, petrocoke, and briquette were also imported.

Çamdalı and Ediger (2007) have shown that a reduction of US $1.663 billion in fossil fuel cost can be realized by increasing the domestic production of oil, lignite, and hard coal and by decreasing imports in Turkey. But, although the most abundant domestic energy source of the country is lignite with a reserve of about 8 billion tons, they have several geological and geochemical problems for utilization. Their calorific value is low and they contain high amounts of ash, moisture, and sulfur. Nearly 80% of the lignite mined in Turkey is used in 13 large-scale lignite-fired thermal power plants, which are responsible for a considerable amount of air pollution (Say, 2006).

The overdependence on imported fossil fuels is, therefore, a very important problem of the Turkish energy system. From 1950 to 2006, the share of fossil fuels increased from 36.4% to 89.6% in consumption, while it increased from 31.5% to 60.5% in production. While 80.5% of fossil fuel consumption was met from domestic sources in 1950, this rate was only 18.1% in 2006 because of limited resources. In 2006, the consumption of fossil fuels amounted to 89.417 mtoe, but only 16.211 mtoe of this was produced from domestic sources, the rest was imported.

Fossil fuels are also responsible for 75% of electricity generation. The major primary energy source used for electricity generation is natural gas, which consists of 35.3% of installed capacity and 45.7% of electricity generation. Of the installed capacity (40,565 MW), 14,331 MW is natural gas, 13,086 MW is hydraulic, 8,666 MW is lignite, 2.397 MW is oil, 1.986 MW is hard coal, whereas only 59 MW is wind and 41 MW is wood. On the other hand, of the generation (176,300 GWh), 80691 GWh is gas, 44338 GWh is hydro, 32433 GWH is lignite, 14217 GWh is hard coal, 4340 GWh is oil, 154 GWh is wood, and 127 GWh is wind.

The last problem of Turkish energy system is its traditional low efficiency. The final energy consumption of Turkey is 77.639 mtoe, whereas the primary energy consumption is 99.840 mtoe, indicating that 22.2% of the primary energy consumption was spent for energy conversion. The biggest share of secondary energy is electricity, constituting 15.7% (12.231 mtoe) of final energy. In addition to conversion efficiency, the efficiency in other sub sectors such as transportation, distribution, consumption, etc. are also low. For instance the loss in electricity distribution system is considerably high at 15% (Hepbaşlı, 2005).

4) Energy Intensity and Energy Efficiency

The best method to solve the problem of high dependence on imported fossil fuels is to decrease their consumption without harming the country's economic and social development. This can be made possible by decreasing energy intensity, which is the energy consumed per unit of GDP earned. The change in time of energy intensity of a country is, however, not linear but forms an inverted-U shaped curve, typically increasing in the developing stage and decreasing in the developed stage with a peak in between.

In Turkey, energy intensity is twice as high as the OECD average, indicating an inefficient use of energy in the economy compared to the developed countries. Ediger and Huvaz (2006) have shown that energy intensity was improved in some sectors slightly as a result of transformation of the Turkish economy from agricultural to industrial, enhanced by rapid urbanization, especially after 1982. Also, Lise (2006) has shown that the energy intensity dropped somewhat over the period 1980–2003, especially in the services sector. However its overall increasing trend indicates that the economy is still in the developing stage.

The most recent studies have shown that energy intensity can be reduced by improving efficiency in energy use and/or by moving away from energy-intensive activities. The rising per capita income and higher energy prices have also played an important role in lowering energy intensity through changes in energy efficiency. These facts are also true for Turkey since per capita energy use of the country is below the world's average. According to The World Factbook of CIA, although Turkey's electricity consumption ranks 22nd in the world in 2005, per capita electricity consumption is only 1,762 kWh per year, which is 1.5 times lower than the world's average (2,603 kWh per year), 3-4 times lower than the European Union's (6,138 kW), and 7-8 times lower than the USA's (12,796 kWh per year). Therefore, in Turkey, the energy intensity could only be reduced by increasing GDP faster than energy consumption through increase in energy efficiency.

On the other hand, the early analysis investigating co-integration and causality between energy consumption and GDP in Turkey reached contradictory results (e.g., Soytaş and Sarı, 2003; Altınay and Karagöl, 2004). However, Lise and Van Montfort (2007) showed that energy consumption and GDP were co-integrated, i.e., there is a –possibly bi-directional– causality relationship between the two. They establish that there is a unidirectional causality running from GDP to energy consumption indicating that energy saving would not harm economic growth in Turkey. In addition, they find that energy consumption keeps on growing

as long as the economy grows in Turkey. Therefore, Turkey can meet the energy consumption challenges without interrupting its economic growth, by improving energy efficiency.

The studies have shown that energy efficiencies are usually low in Turkey. Utlu and Hepbaşlı (2005) have calculated Turkey's overall energy and exergy utilization efficiencies to be 44.91% and 24.78% in 2000, with the projected values of 55.15% and 30.44% in 2020, respectively. According to Utlu and Hepbaşlı (2006), the energy utilization efficiencies for the Turkish transportation sector range from 23.71% in 2000 to 28.75% in 2020, whereas the exergy utilization efficiencies vary from 23.65% to 28.85% in the same years, respectively. They estimated the exergetic improvement potential for this sector to be 700 PJ in 2020, with an average increase rate of 4.5% annually between 2000 and 2020. According to Utlu and Hepbaşlı (2007), the energy utilization efficiencies for the Turkish overall industrial sector range from 63.45% to 70.11%, while the exergy utilization efficiencies vary from 29.72% to 33.23%. They also determined the exergetic improvement potential for this sector to be 681 PJ in 2003, with an average increase rate of 9.5% annually for the analyzed years. Soytaş and Sarı (2007) have shown that energy saving technologies and increased energy efficiency may increase the growth in manufacturing value added.

For the residential–commercial sector, the energy efficiency is found to be 55.60% in 2000, and is expected to be 65.53% in 2020, whereas the exergy efficiency was 8.02% in 2000, with a projected value of 10.07% in 2020 (Utlu and Hepbaşlı, 2005). On the other hand, the improvement of energy efficiencies in textile and agriculture sectors is specifically important because of their contribution in Turkish exports and the economy in general (Öztürk, 2005; Sayın et al., 2005).

Therefore, increasing energy efficiency should be one of the key policies to deal with the supply security problem in addition to diversification of supply and resources and developing alternative energy resources. It is known that the governments can facilitate economic growth by organizing their energy sector effectively and efficiently (e.g., van der Linde and van Geuns, 2005).

5) Green Energy Strategies

Renewable energy resources are usually accepted to be one of the most effective solutions to the problems of import-dependency, resource scarcity, and environmental

degradation. Green energy strategies allow not only sustainable development but also reduce poverty by making an important contribution to the economies of countries. Goldemberg and Coelho (2004, p. 711) summarize the advantages of modern renewable energy sources as "they enhance diversity in energy supply markets; secure long-term sustainable energy supplies; reduce local and global atmospheric emissions; create new employment opportunities offering possibilities for local manufacturing and enhance security of supply since they do not require imports that characterize the supply of fossil fuels."

In Turkey, Ediger and Kentel, examining the renewable energy potential of the country in 1999, have concluded that the country has substantial reserves of renewable energy resources and a step-wise shift (i.e. combined use) from fossil fuels to renewable ones seems to be a serious and the sole alternative for Turkey. Although much has been accomplished since then, the actual utilization of these resources are quite low at present because of several reasons (Kaya, 2006; Demirbaş and Bakış, 2005; Demirbaş, 2006; Dumanlı et aş., 2007).

In 2006, only 10.2% of the primary energy demand was met from renewable sources, of which 5.0% is combustible biomass and waste, 3.6% is hydro, 1.1% is geothermal, 0.4% is solar, and 0.1% is wind. On the other hand, the share of electricity generation from renewable sources (RES-E) has been around 25% including hydropower; whereas, the total share of renewables including waste, wind, and geothermal was only 0.21% (Table 2). In 2006, the electricity generated from waste, wind, and geothermal amounted to 153.9 million kWh, 126.5 kWh, and 94.0 kWh, respectively.

Table 2. Electricity generation by renewable sources in Turkey in 2006. Data from TEİAŞ (2007).

	Million kWh	%
Geothermal	94.0	0.053
Wind	126.5	0.072
Biomass including waste	153.9	0.087
Hydropower	44,244.2	25.09
Fossil Fuel	131,681.0	74.69
Total	176,299.8	99.99

However, the investments in green energy supply are encouraged by governments and other authoritative bodies. A number of incentives were provided to the RES-E by the

Electricity Market Law of 2001 and Energy Efficiency Law of 2007. The incentives were later made more effective by the Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electricity of 2005, in which RES-E was defined for the first time. The law also requires Energy Market Regulation Authority to grant RES Certificate for electricity generation and to provide a purchase guarantee for a price that will not be below 5 euro cent/kWh for 10 years.

The Energy Ministry of Turkey (MENR) is determined to increase the use of renewable energy resources to solve energy supply security problem of the country and for environmental concerns. The increase in use of renewable sources will also provide Turkey economic benefits in the accession stage to EU through some mechanisms such as the Emission Trading System. According to the draft strategy paper for electricity generation, the MENR is planning to increase the share of renewables in electricity generation to 25% in 2020. This means that all of the technical and economical potential of hydropower (around 30,000 MW) will be used by 2023. The installed capacity of wind power is planned to be 11,000 MW in 2013, 15,000 MW in 2015, and 20,000 MW in 2020. Also, all of the 600 MWe of geothermal potential is planned to be in operation by 2020. Solar energy use will also be increased. The strategy paper also foresees a decrease in the share of natural gas in electricity generation to 30% by 2020.

The MENR has planned to add until 2013 an installed capacity of about 12,110 MW RES-E, which consists of 8216 MW hydro (mostly SHP), of 3,770 MW wind, of 124 MW geothermal, and of 20 W solar. Turkey's hydroelectricity potential of 130 TWh is the second after Norway in Europe, but only one-third of it is in use at present (Şalvarlı, 2006). However, a total 334 hydroelectric power plant projects with 8,478 MW installed capacity have already been granted licenses. For wind, the total license application has already exceeded 85,000 MW of which 2,126 MW have been granted license. For geothermal, out of 500 MWe potential, 31 MWe are in use and 52 MWe is under construction.

Experts are in agreement that the renewable energy development of Turkey in the future will be driven by stipulations set by the EU during the accession period. The European Union directive on the promotion of RES-E gives the new EU-members targets for their RES development until 2010. Reiche (2006, p. 374) stated that the further evolution of RES in the European Union and its Accession States will most likely depend on a combination of prices and political support: "Putting an end to price distortion by removing subsidies for conventional fossil and nuclear energies and internalizing external costs would be a decisive step for a better competitiveness of RES. Ratification and progressive tightening of climate

change agreements in later commitment periods (after 2012) will also help." Turkey is in the way of transposing the *acquis communautaire* into their national law and has already complied to a significant extent and continues moving towards this direction (Patlitzianas et al., 2006).

In addition to renewables, the Turkish Government has also decided to ratify the Kyoto Protocol (Ediger, 2008). The Government sent the draft law to the Parliament for ratification in May 2008 and the Parliament is expected to pass the law by the end of the year. Finally, the year 2008 has been declared by the Prime Ministry as the Energy Efficiency Year by a decree in August 2008. These efforts will certainly increase the sustainability of the economic and social development of Turkey because as noted by Lise (2006) in the absence of carbon policies, no significant reduction in CO2 emissions can be observed in the Turkish economy.

6. Conclusions

The scarcity of fossil fuels in most countries requires giving more emphasis on domestic resources in the countries' energy mix. Ediger et al. (2007) have recently developed the Fossil Fuel Sustainability Index (FFSI) for efficient management of fossil fuel resources for the sustainability of energy systems. The study, which is conducted in the presence of independence, lifetime and environmental constraints, concluded that "A truly sustainable development may be achieved with the diversification and use of local energy sources considering the impact of each energy system on the environment is small and well within the tolerance limit." (p. 2974).

However, Turkey is placed in the low FFSI countries, ranking 55 in 62 countries. In addition, the domestic fossil fuel resources are limited only to lignite, which is known to have several geological, geochemical, and environmental disadvantages. Therefore, the only solution appears to be to decrease energy demand by increasing energy efficiency with the help of technological change for a sustainable development. It is possible to achieve large improvements in living standards without increasing energy use (Goldemberg and Johansson, 2002 a). As also clearly stated by Masera et al. (2000, p. 2084), *"…as families gain socioeconomic status, they abandon technologies that are inefficient, less costly, and more polluting."*

However, whether the efficiency improvement and sustainable conversion technologies are effective and efficient enough to act as a remedy for resource scarcity in the long run is also debated (e.g., Voorspools, 2004; Bretschger, 2005; Deutch, 2005). Alcott (2005) discussed whether the technological efficiency gains actually increased the overall consumption of energy together with material and other resources. Pasche (2002) also showed that a growing part of income has to be spent for continuing technical progress in order to compensate the pollution effects of growth.

Finally, it should be reminded that the developed countries should act in partnership with developing countries not to repeat the environmental and social legacy of unsustainability of the industrial era. As Byrne et al. (1998) have appropriately argued that the industrial countries have the wealth, technology, and responsibility to solve the problems of climate and social inequity by avoiding globalization of fossil fuel economy.

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