

The Development of Renewable Energy Sources in Turkey

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Abstract

Especially in last two decades, most of the developed and developing countries around the world have been supporting the researches that investigate more clean and sustainable energy sources. Renewable energy sources play more important role in today's increasingly globalized energy market because of the environmental issues and the sources of fossil fuel are becoming scarce. According to that, as a virtue of the rapidly increase in energy demand, the supply of renewable energy sources are increasingly continue around the world. As a matter of fact, when it is compared to the 2011 rates, the consumption rate of hydro-electricity and other renewable energy sources has increased to 4.3% and % 15.2 respectively in 2012 in the world, is verifying that view.

The aim of this study is to investigate the present potential and sufficiency of the main sources of renewable energy such as solar, wind, hydropower, geothermal and biomass at Turkey. In this regard, even Turkey has a remarkable potential especially in hydro, wind, solar and geothermal energies among Europe, renewable energy sources ratio in Turkey's total energy consumption is not rising at desired level. Furthermore because Turkey hasn't got a rich fossil fuel reserves, it needs to import fossil energy sources to meet its rapidly growing energy needs. In related to this, Turkey's current deficit has been growing due to the increase in fossil fuel sources prices at international energy markets. On the other side Turkey's Green House Gases (GHGs) emission has grown more than two times as a result of its rapidly using of fossil fuel sources due to its growing economy, industrialization and urbanization process since 1990. Within this context, as a foreign dependent country on fossil fuel energy sources (especially on crude oil and natural gas), Turkey should rapidly change its energy policy from fossil fuels to renewable energy sources which are domestic, clean and much more cheaper.

Keywords: Renewable Energy Potential; Turkey; Wind; Solar; Geothermal; Biomass; Hydropower.

1. Introduction

Especially during the last five decades, mostly because of the increasing world population (four times more than the beginning of 20th century), the energy demand of countries all over the world has been increasingly grew. In this sense, it is clear to say that energy sources will play an important role in the future's world economy. The energy resources are separated into three categories: fossil fuels, renewables and nuclear sources (Demirbas, 2006). However, at the present time, the sources that satisfy the

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energy demand is primarily being supplied from fossil fuels such as oil, natural gas and coal. In this regard, world's primary energy consumption was 12.476 million tons of oil equivalents (mtoe) in 2012 and 87% of that was provided from fossil fuels (BP, 2013a). On the other hand it is expected that the energy consumption of the world will reach 14.611,3 mtoe at 2020 and as it is forecasting, the rate of fossil fuels consumption will continue to dominate (80,6% of the world energy consumption) the world energy mix (BP, 2013b). Nevertheless according to the report of IEA (WEO-2013) the demand for all forms of energy will be growing, but the share of fossil fuels usage in the world's energy mix will be fall from 82% to 76% in 2035.

On the other hand the extensive and rapidly increasing use of fossil fuels in the current energy infrastructure is conceived as a main reason of not only climate change and global warming but also environmental concerns such as air pollution, acid precipitation, ozone depletion, forest destruction, and radioactive substance emissions. The reason behind these environmental degradation is induced progressive (GHGs) emissions (especially carbon dioxide (CO₂)) due to an increasingly consumption of fossil fuel sources (Erdem, 2010; Toklu, 2013). From this point of view, it is understood from the report of IEA (WEO-2013), the humanities prosperity will may affect badly from global warming and increasing relapse of the natural environment. Within this scope CO₂ emissions from fossil fuel consumption dramatically increased from near zero to approximately 35.000 million metric tons of CO₂ starting from the industrial revolution and according to expectations it will continue to increase in near future (Kaygusuz, 2009; CDIAC, 2013).

Turkey has a rapidly growing economy when it is compared to OECD average. For instance, between the years of 2009 and 2012, Turkey's average growth rate was 3,5% and in the meantime OECD average was 0,75% (OECD,2013). Associated with its growing economy and increasing population (approximately 74 million of people), as it seems Turkey will play an important role in the consumption of the world energy (World Bank, 2014). Additionally, depending on BP Statistical Review of World Energy 2013, Turkey's primary energy consumption has growth 0.6% in 2012 and also Turkey's share in world's primary energy consumption has increased to 1%. However, to satisfy its energy demands and needs, Turkey is intensively consuming fossil fuels like many other developing countries.

Table 1. Comparison of Fuel Mix Rates of Total Energy Consumption among World and Turkey between the years of 2002-2012 (%).

	Oil (%)	Natural Gas (%)	Coal (%)	Nuclear (%)	Renewables (%)
World	35,4	23,5	27,8	5,4	7,3
Turkey	33	29	27	-	10

Source: BP,2013a.

Table 1 (BP, 2013a) shows a comparison of fuel mix rates of total energy consumption among the World and Turkey. As can be seen from the table, between the years of 2002 and 2012, averagely 89% of primary energy was provided from fossil fuels such as crude oil, natural gas and coal in Turkey. When that rate is compared to the

world average (averagely 86% of primary energy consumption were procured from fossil fuels in the World), Turkey's dependency on fossil energy sources can easily be understood. In other words the policy makers in Turkey should reconsider the current energy policy which doesn't support enough the development of sustainable energy. Additionally, exception of hydro-power, other renewable energy sources have a small share at Turkey's energy supply. In this context, a several researches related to renewable potential of Turkey and usage areas of these renewable sources has been published in the literature (Kaygusuz, 2010a; Erdoğan, 2009; Vardar et al, 2013).

The aim of this study is drawing an attention to a large renewable energy potential of Turkey and its importance as an answer that can resolve the country's energy-related challenges. This study is distributed into four main sections. At the following section, an energy related challenges of Turkey will be argued. In section three, the potentials of renewable energy sources such as hyrdo-power, wind, solar, geothermal and biomass in Turkey will be discussed. And finally, some concluding remarks and suggestions has pointed out at the last section.

2. Turkey's Energy-Related Challenges

Turkey is facing with some energy-related challenges such as depletion of fossil fuel sources, increase at budget deficit due to a rise in world fossil energy source prices and environmental pollution.

As it can be understood from the verifies of ADECO Solar, fossil fuels such as coal, oil and natural gas are obtained from limited reserves in World and running out in every passing day. According to the expectations, natural gas (exception of new finds) and oil reserves in the world will be depleted until 2060 (ADECO Solar, 2014). Concordantly like every other country, Turkish state should change its energy policy and canalize their investments from fossil fuels to non consumable (renewable) energy sources.

Table 2. Turkish Potential Energy Reserves (Original Values).

Energy Source	Apparent	Potential	Possible	Total
Hard Coal (Million tonnes)	526	425	368,4	1.319,4
Lignite (Million tonnes)	10.782,3	826,7	143,1	11.752,2
Asphaltite (Million tonnes)	40,7	29,5	7,3	77,5
Bituminous schist (Million tonnes)	1.641,4	-	-	1.641,4
Hydraulics (MW/year)	36,603	-	-	36,603
Petroleum (Million tonnes)	43,13	-	-	43,13
Natural gas (Billion cubic meter)	6,2	-	-	6,2
Uranium (tonnes)	9.129	-	-	9.129
Thorium (tonnes)	380.000	-	-	380.000
Geothermal (MW/year)	32.100	-	-	32.100
Solar (mtoe)	-	-	-	32,6
Wind (MW)	-	-	-	48.000
Biomass (mtoe)	-	-	-	8,6

Source: MENR, 2013.

Turkey's natural energy resources are quite multifarious. For instance, primary energy resources that are producing in Turkey are hard coal, lignite, asphaltite, bituminous schist, hydro-electric energy, petroleum, natural gas, uranium, thorium, geothermal energy, solar energy, wind energy and biomass energy. Besides, secondary energy sources such as coke and briquettes are also producing and consuming in Turkey too (Demirbas, 2002). Concordantly Table 2 shows the potential of these energy reserves in Turkey. As it can be understood from Table 2, though Turkey's oil and natural gas reserves seem limited, coal and lignite reserves are quite abundant. In this regard some natural energy sources of Turkey has notable share at world reserves such as coal (0,3%), geothermal (1%), hydro power (1,6%) and wind power (0,8%). However, petroleum and natural gas reserves are quite limited (BP, 2013a).

Being one of the biggest countries in Europe, Turkey's expected population growing rate will be 1% (World Bank, 2014) and average GDP growth rate will be 5,2 % per year during the period 2012 and 2017 (OECD, Economic Outlook 2012). In this regard, it is expectable that Turkey's energy demand will going to increase in next decade as a consequence of its rapidly growing population and economy. Turkey has become an attractive option for the energy investors due to its rapidly growing economy and population, however a few challenges are clear from the Turkish state's aspect.

According to the Blue Book which is prepared by Ministry of Energy and Natural Resources (MENR, 2013), Turkey's domestic energy production of primary energy sources couldn't equalised the consumption of energy between the years of 2001 and 2011. More importantly, it is understood that the difference have been rapidly increased between the production and consumption in every passing year. This difference had a direct impact on the consolidated budget. For instance with the increase of oil and natural gas prices in international markets, Turkey's energy imports increased from 4.8% of gross domestic production in 2003 to 7.5% in 2012, accounting for 60% of the widening in the current account deficit (Okumuş, 2013).

On the other hand another energy related problem that Turkey has to come up against is (GHGs) emission which is the main reason of the global warming, climate change and environmental pollution. From this point of view 10 different types of greenhouse gas has reported (National Greenhouse Gas Inventory Report 1990-2011) for Turkey by Turkish Statistical Institute (TurkStat) at 2013. According to this report, a major part of the total (GHGs) emission (averagely 78,5%) was constituted from CO₂ emission during the period 1990 and 2011. In other words, Turkey's (GHGs) emission has grown more than two times as a result of its rapidly economic growth, industrialization and urbanization since 1990 (Erdem,2010).

All because of these challenges Turkey needs to bring a new perspective to its energy policy by radically changing its energy supply to renewable and domestic sources. In this regard renewable energy sources can play an important role in sustainable and independent energy future of Turkey by helping the country to reach its environmental goals and reducing the dependence on imported-fuel supplies of the country.

3. Turkey's Renewable Energy Potential

Being one of the fastest growing economies of OECD, Turkey's energy consumption has increased rapidly between 2002 and 2012. While total primary energy consumption in 2002 was 73,1 mtoe, it raised to 119,2 mtoe in 2012 (BP, 2013b). Unfortunately as it is mentioned before most of this energy consumption of the country depends on fossil fuels (averagely 89% of the total energy consumption during the 2002 and 2012 (BP, 2013b) that Turkey hasn't got rich sources of it. Concordantly, from 2003 to 2012, Turkey's dependency on imports for primary energy has been increasing rapidly. As pointed out in section two, while the share of the energy import on GDP was 4,5 % in 2003, it increased to 7,5% at 2012 (Okumuş, 2013). From this point of view to reduce the country's foreign energy dependency, achieve a sustainable development and avoid from the environmental pollution, Turkey should change its energy policy and giving priority to the renewable energy sources which are more effective and efficient (Simsek, 2013).

Table 3. Investment Potentials for Renewable Energy Sources at Turkey.

Sectors	Million €	Remarks
Hydro-electric	114	-Economical development potential of 28.600 MW. -Corresponding 100.000 GWh/a.
Wind Power	57	-Economical development potential of 48.000MW. -With wind speed >7m/s.
Solar /Thermal	165	-Economical development potential of 131.000 GWh/a. - Corresponding to approx. 300 million m ² collector area.
Biogas	4	-Agricultural residual material and dung. -When used for electricity generation, 1000MW _e and 7000GWh/a.
Total	340	

Source: (Yüksel ve Kaygusuz, 2011).

The potentials and limitations of the renewable energy sources (such as hydro, geothermal, solar, wind and biomass) in Turkey will be argued at this part of the study. Under favour of its geographical location, Turkey has numerous advantages for using many of the renewable energy sources. Turkey is located at the humid and warm climatic belt. In this regard, with its growing economy and proper atmosphere to make an investment for environment friendly technologies, Turkey has remarkable investment opportunities for renewable energy (Kaygusuz and Sarı, 2003). Table 3 shows the investment potentials of the renewable energy sources at Turkey. As it can be seen from that table, especially hydro-power and solar-thermal energy sources have a great potential of investment (82 % of the total investment potential).

Because renewable energy sources are inexhaustible, they are crucial for the future of Turkey's economy and environmental quality (Kaya, 2006). Turkey has substantial reserves of renewable energy resources (Table 2). As stated previously in Table 1, renewable energy production represented about averagely 10 % of total primary energy supply among the years 2002 and 2012. In this regard renewable energy sources are the second-largest domestic energy source after coal in Turkey. Hydro-power, wind,

biomass, geothermal, and solar are the essential renewable energy sources at Turkey (Kaya, 2006). At this section of this study, the potentials of these renewable energy sources in Turkey will be investigated.

Hydro-power

With its cleanliness, hydro-power is an essential energy sources among the other large-scale energy options. On the other hand, by virtue of dams and reservoirs, people can store water during rainy seasons and releasing it during dry ones. In this way, dams and reservoirs can protect human and other living things lifes against to floods and droughts if they are projected as rational. On the other hand, in contrast to the fossil fuel energy sources, hydropower do not induce a bad environmental effects such as acid rain or atmospheric pollution. As a matter of fact, hydropower can help humanity to struggle against the difficulties of global warming and climate change with mitigating the bad effects of them (Yüksel, 2013).

Table 4. Hydropower Potential (GWh/year).

	Gross Potential	Technical Potential	Economic Potential
Turkey	433.000	216.000	140.000
Europe	3.150.000	1.225.000	1.000.000
World	40.150.000	14.060.000	8.905.000

Source: *DSL,2013a.*

During the 1990's, 20% of the world's electricity has been supplied from hydropower (WECTNC, 2012). On the other side, with its rapidly growing population and economy, Turkey's energy and electric demand is increasing rapidly too. At this point, the main renewable energy source to meet this demand is hydropower, which especially efficient in the eastern part of the country (Yüksel,2013).

From this point of view, as it can be seen from the Table 4, Turkey's gross hydro-power potential is approximately 14% of the total hydro-power capacity of Europe. Additionally 32,3% of the gross potential of Turkey is economically utilizable. On the other hand averagely % 60 of the total electricity production of Turkey was provided from hydro-electricity during 1980s. Unfortunately starting from the 1990s, with the frequently use of natural gas to produce electricity, this share was fallen. Nevertheless with the increase in installed capacity of hydro-power plants of Turkey, the hydro-electric production has been raised from approximately 33.270 GWh/year at 2008 to 57.865 GWh/year at 2012. Therefore, the share of hydro-electric production into the total has been also increased to 24,2% from % 16,8 during 2008 and 2012. Concordantly, Turkish state should pay a special attention to the hydro-power because of its remarkable potential (WECTNC, 2012; MENR, 2013).

Wind-power

Known as an environmental friendly and renewable energy source, wind power has many advantages such as cleanliness, endlessness and being cheap when it is compared to fossil fuels. Wind electricity generation systems convert wind energy, with

using the kinetic energy of the mass of moving air, into electricity by means of wind turbines. (İlkiliç, 2012).

Turkey is surrounded on three sides by the sea which are Aegean Sea on the west, Black Sea on the north, Mediterranean on the south of the country and also Marmara as an inner sea. In this regard, especially Aegean, Marmara and East Mediterranean coasts have high wind potential (Kaygusuz, 2010b). According to wind atlas report that is prepared by Turkish State Meteorological Service (MGM,2014), Turkey's technical potential of wind energy is about 48.000 MW (38.000 MW of that procured from terrestrial-based and 10.000 MW of that procured from coastal). In addition to that considering the current electric supply system economic potential of wind energy is 10.000 MW in Turkey. Furthermore it is forecasting that Turkey's installed wind capacity will increase to 20.000 MW at 2023 (WECTNC, 2012).

Turkey is one of the fortunate countries in Europe and Asia, with its great wind energy potential. In this regard Turkey's energy policy should be canalized to renewable energy sources (which are both cheap and domestic) to reduce its fossil fuel energy dependency and to meet its rapidly growing population and economic needs. Concordantly, to encourage and extend of using renewable energy sources, Turkish Government has adopted "Law on Utilization of Renewable Energy Resources for Electricity Production" (MENR, 2005). From this viewpoint Turkey's policy makers should continue to encourage energy investors to the usage of renewable energy sources such as hydro-power, wind power, solar, geothermal and biomass.

Solar Energy

All of the energy sources around the world are directly or indirectly originating from the Sun. Coal, petroleum and natural gas which are known as fossil fuel are also different states of solar energy (Vardar and Çetin, 2013). Additionally the potential of solar energy that reach to the world's surface has much more potential than the other energy sources (WECTNC, 2012).

In this sense, several technologies have been developed in order to make use of sun rays to produce energy. Boyle (2004) has mentioned that, it is possible to separate these technologies as thermal solar technologies and solar cells. In this sense, in thermal solar technologies the heat which is obtained primarily from solar energy can either be directly used or utilized in electric generation. On the other hand, semi conductive materials transform sun-light directly into electricity in solar cells (photovoltaic cells). In this context solar cells work depending on photovoltaic principle. In other words, there is an electric voltage on the edges when they are illuminated. The source of electric energy given by the cell is in fact the solar energy on its surface. The most important feature of solar cells is the yield value which indicates the rate of transformation of solar radiation on cell surface into electric energy. As indicated by Karamanav (2007), these yield values differ according to the material, but generally it varies between 5% and 20% (Vardar and Çetin, 2013). Even the installation of photovoltaic power systems needs a high technology, after installation the system can produce energy with nearly zero transaction cost in 20-30 years (WECTNC, 2012).

In the sense of solar energy potential, Turkey has advantageous than many other countries due to its geographical location. Turkey's average annual total sunshine

duration is calculated as 2.640 hours (daily total is 7,2 hours), and average total radiation pressure is calculated as 1.311 kWh/m²-year (daily total is 3,6 kWh/m²). Concordantly Turkey's estimated solar energy potential is 32,6 mtoe (MENR,2010a). Despite of all, Turkey has 0,42 mtoe installed heat capacity that obtained from sun collectors. In this regard it can be said that Turkey only uses 4,2% of its technical potential of solar energy (Vardar, A., 2012). However solar energy production has increased from 287 tons of oil equivalent (toe) in 2001 to 630 toe in 2011 and higher production levels are expected in following years (MENR, 2013).

According to the Atlas of Potential Solar Energy in Turkey (YEGM, 2014), South East and Mediterranean region of the country have the highest solar radiation rate when it is compared to others. The South East region of Turkey has annually 1460 kWh/m² solar radiation potential. Furthermore this solar radiation potential has annually estimated 1390 kWh/m² in Mediterranean region.

In the view of such information, Turkish government has adopted the "Law on Utilization of Renewable Energy Resources for Electricity Production" at 2005 to increase the share of solar energy in total energy production of Turkey (MENR, 2005). Besides that it recently announced by Turkish state, the government is planning to install an 3000MW solar power plant (that will be the most powerful solar power plant in the World) at Konya City which is located at the centre of the country (Solarcell, 2014).

Geothermal Energy

Geothermal energy is the energy contained as heat in the Earth's interior that can be used continuously for heating and electricity generation. The origin of this energy is linked with the internal structure of our planet and the physical processes occurring there (Erdoğan, 2009). In this regard geothermal energy is the heat energy obtained from hot water, steam and dry steam and hot dry rocks, which is formed when heat accumulated in deep subterranean rocks is carried by fluids and stored in reservoirs. Geothermal resources mainly form around active fault systems and volcanic and magmatic units (MENR, 2010b).

Turkey has a high geothermal potential due to its location which is along the Alpine-Himalayan tectonic belt. As it is estimated, Turkey's theoretical geothermal energy potential is 31.500MW. Additionally 77.9% of this total geothermal energy potential of the country is occurred at Western of the Anatolia. However 94% of the geothermal energy is obtained from the low-temperature fields which can be use for direct needs such as thermal tourism and heating. Consequently, with regard to geothermal heat and hydrothermal potential, Turkey is among the first five countries at the world (MENR, 2010b). However Turkey's share of installed capacity of geothermal is only 1% of the world total (BP, 2013a).

Furthermore Turkey has 17 fields which are available for producing an electric from geothermal energy. All of this areas are located in West of the Anatolia. Although installed capacity of this 17 fields estimated as 91,7 MWe at 2010. But after all enhancement operations were done, the potential of producing an electricity from geothermal energy has reached to 706,4 MWe in 2013 and it is expected that rate will increased to 1000 MWe in 2018 (MTA, 2012; MENR, 2010b). As it is mentioned above, despite Turkey has a great geothermal potential, still installed capacity of Turkey's

geothermal energy is not sufficient. Even that, especially after Turkish government has adopted the “Law on Utilization of Renewable Energy Resources for Electricity Production” at 2005, the demand for geothermal energy has increased in Turkey.

Biomass Energy

As one of the oldest energy sources of the human history, biomass energy is using for to meet the energy demand which is related to generating electricity, house heating, fueling vehicles and to procure the heat that industrial facilities need in the production process (Demirbaş, 2008). Biomass energy is an important raw material because of the three significant reasons. One of them is that biomass energy is the only organic fossil fuel that can be sustainable. Additionally when it is compared to other fossil fuels, biomass energy has a positive impact on climate due to reducing (GHGs) emission. Thirdly, biomass energy is creating lots of job opportunities most particularly in rural areas. Unfortunately biomass energy also has some disadvantages too. For instance, even biomass has a positive impact on environmental quality, it can also create some negative effects too. On the other side with its storing, transporting and collecting costs, it can be said that biomass energy is an expensive energy source (Balat, 2005; Demirbaş, 2008).

Turkey has substantial biomass energy potential. As it is estimated from Ministry of Energy and Natural Resources (MENR) at 2013, Turkey has 8,6 mtoe biomass potential. However the share of the biomass production in Turkey’s total primary energy production is decreasing since 2007 (MENR, 2013). As a foreign dependent country on energy sources, Turkey should review its energy policy and place a particular importance to the renewable energy sources such as biomass.

Conclusions

As one of the fastest growing economies in OECD, energy needs of Turkey rapidly increasing every coming year. However Turkey’s current primary energy supply mostly based on fossil fuels. On the other side, as mentioned at the previous sections, Turkey is not a country that has rich fossil fuel reserves. From this point of view, as an energy dependent country, over half of the current account deficit of Turkey arising from energy imports. In this regard, this study is aimed to draw attention to the large renewable energy potential of Turkey and suggest the renewable sources as a solution for Turkey’s energy-related challenges.

Turkey should change its energy policy from fossil fuels to renewable sources as it is possible, not only because of the foreign dependency of country to fossil fuel sources, but also for the reason that fossil fuels have bad effects on atmosphere due to (GHGs) emissions. On the other hand, Turkey also can use other alternative energy sources such as nuclear energy instead of fossil fuels. But it has to be mentioned that, in recent years, mostly developed countries such as Germany, Italy, Switzerland, Belgium, Spain, has abandoned the nuclear projects by virtue of their damaging effects on environment. In spite of that, demand for renewable energy sources is rapidly increasing every passing day. Even Turkey has a great renewable energy potential especially on solar and geothermal, still this renewable sources couldn’t use efficiently. For instance, despite

most of the European countries can benefit from solar energy less than Turkey, yet they are procured an energy from solar more than Turkey. Additionally, Turkey should use geothermal energy more efficient in agricultural production and greenhouse cultivation. Consequently, the policy makers in Turkey should search some ways to canalize the energy investors interest's from fossil fuels to renewable energy sources.

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