



Renewables for climate change mitigation and domestic energy utilization in Turkey

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Abstract

As a fast-growing country, energy consumption has increased in Turkey due to economic developments by industrialization and urbanization. To meet the increasing demand, significant investments are required in electricity generation technologies. Turkey has a limited amount of fossil fuel reserve, thus is dependent on foreign energy. Approximately 75% of current energy consumption is met by imports. However, Turkey has a high potential of renewables such as biomass, hydropower, wind, solar, and geothermal energy, but the current utilization rate of these resources is very low. In recent years, in Turkey, hydraulic, solar, geothermal, and wind-based energy production has started to become widespread. The present study discussed the renewable energy sources for climate change mitigation and domestic energy utilization in Turkey.

Keywords: Renewable energy; sustainable development; energy policies; bioenergy; Turkey.

1. Introduction

Large hydroelectric dams use falling water, rather than steam heat, to turn a turbine to make electricity. But all of these kinds of energy lead to toxic pollution, destruction of communities and watersheds, and many serious health problems. None are healthy or sustainable, especially when they are used on a very large scale. On the other hand, fossil fuels are growing scarce and becoming more expensive to find. Fossil fuels are nonrenewable, meaning that once they are used up, systems based on them will literally run out of fuel. At the same time, the danger of global warming and pollution from burning fossil fuels has grown to become a serious environmental health problem for every single person and place in the world [1-9]. Turkey has a limited amount of fossil fuel reserve, thus is dependent on foreign energy. Approximately 75% of

current energy consumption is met by imports. However, Turkey has a high percentage of renewable energy resources including biomass, hydropower, wind, solar, and geothermal energy, but the current utilization rate of these resources is very low [10]. In recent years, in Turkey, hydraulic, solar, geothermal, and wind-based energy production has started to become widespread; producing energy out of biomass is widely used only via direct incineration. At present, due to declining fossil fuels, it is inevitable that energy shortage will occur in the near future [11]. In addition to this, when the environmental problems caused by the animal and vegetable-based wastes are considered, in terms of sustainable development, studies show that finding a solution to these two problems is very important [12-18].

2. Energy utilization, climate change and health problems

2.1. Global energy utilization

The growth of population, increasing deployment of the population in cities and economic growth (GDP) cause more energy demand. Energy use triggers the economic and the social evolution and therefore increases energy consumption [10]. According to

IEA World Energy Outlook [5], worldwide final energy consumption has increased to 12,873 Million tons of oil equivalent (Mtoe) in 2014. Total energy consumption is expected to increase 48% in 2040 mostly based on non-OECD countries [3]. In 2015 as

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can be seen from Figure 1 [4], primary energy consumption was 13,147 Mtoe with 1% increase rate which is below the average of last 10 years 2% [4]. Due to lower GDP growth rates and low population growth rate in OECD countries, energy consumption

of non-OECD countries is expected to be higher compared to the OECD countries, which is already constitutes the 58.1% of global energy consumption in 2015 [4].

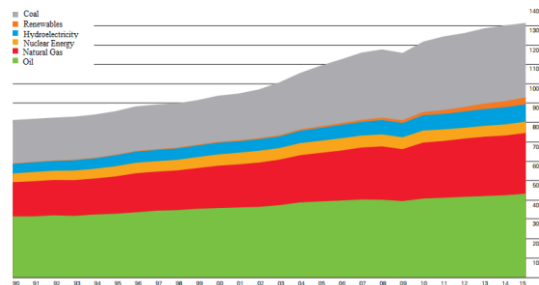


Figure 1. World primary energy consumption by fuel type (M toe) [4]

Global primary oil demand grew by a little more and to reach 87.4 million barrels per day in 2014 [5]. The trajectory that oil use over the coming decades differs considerably, reflecting the different assumptions about government policies to curb rising demand and emissions. According to the Scenarios, oil use increases in absolute terms to 2040, driven mainly by population and economic growth in the emerging economies, in response to strong policy action to curb fossil-energy use. The share of oil in total world energy demand falls and it reaches 27% in 2040 while 32% in 2014 [3-5].

The first of these fundamental trends is that the

2.2. Climate change

The international consensus on climate released in 2007 by the Intergovernmental Panel on Climate Change (IPCC) found that the warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level [8]. There is broad agreement and high confidence that the documented increase in GHG concentrations is changing the earth's climate not only raising average global temperatures but altering regional and local climatic and weather patterns. Observed effects of climate change include: increased atmospheric and ocean temperatures, heat waves, increased evaporation and changes in precipitation patterns, and a greater intensity of storms, floods, and droughts [8, 9]. Thermal expansion of a warmer ocean and the melting of glaciers are contributing to a rise in sea level. These trends are expected to continue for a minimum of several decades even if GHG emissions are reduced [3-9].

world's energy needs are set to rise. With the assumed expansion of the global economy of almost 140% and an increase of 1.7 billion in the world's population, more energy will be needed to satisfy growing demand for energy services, even though new policies and programs are put in place to encourage energy savings [14]. World primary energy demand increases by 35% between 2014 and 2040 in the New Policies Scenario as given in IEA's report [5]. This represents a sharp slowdown in the energy demand growth experienced over the past two decades, testament to the anticipated effect that already implemented and planned policies would have on energy markets [3-7].

Global atmospheric concentrations of carbon dioxide (CO₂), methane, and nitrous oxide have increased markedly as a result of human activities since 1750 [8]. The global increases in CO₂ concentration are primarily due to increased fossil fuel use and land use change, while increases in methane and nitrous oxide are primarily due to agriculture. Carbon dioxide is the most important anthropogenic GHG. Globally, CO₂ concentrations have reached 385 parts per million (ppm). The increasing atmospheric CO₂ and other heat trapping greenhouse gases are causing an increase in the earth's air temperatures. Eleven of the 12 warmest years on record have occurred in the period between 1995 and 2006 [9]. Agriculture, forestry and land use activities accounted for 24% of global GHG emission while industry accounted for 21%. Transportation, other energy (fuel extraction, refining, processing etc.) and buildings accounted for 14%, 10%, and 6% respectively [5]. Since electricity sector is the largest contributor of GHG emissions, electricity generation fuel mix have great importance to decrease GHG emission levels. Increment of

global carbon dioxide amount and growth rate can be found in Figure 2 [4].

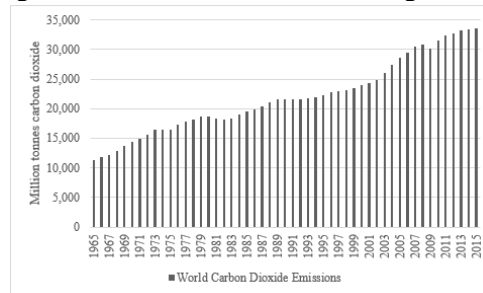


Figure 2. World Carbon Dioxide Emissions (million tons carbon dioxide) [4].

Global warming and climate change are considered as global major problems and raised concern over countries, therefore to combat these effects the first World Climate Conference (WCC) took place in 1979 [9, 10]. In 1991, first meeting of the Intergovernmental Negotiating Committee (INC) was conducted [11]. In 1992, the United Nations Framework Convention Climate Change was formed to fight against climate change to limit average

global temperature change. As the first important agreement, Kyoto Protocol was signed in 1997 and entered into force in 2005. Kyoto Protocol enforced emission reduction targets over 37 industrialized countries and the European community for an overall 5% emission reduction compared to 1990 levels between years 2008 and 2012 [3]. Turkey became a party to the Kyoto Protocol in 2009, yet it did not undertake the commitments [3-10].

2.3. Health problems from fossil fuels

Burning fossil fuels in large power plants is the way most electricity is made. Digging up and burning fossil fuels pollutes air, soil, and water, leading to respiratory and skin problems. It also produces toxic chemicals that cause cancer and birth defects [1]. Our use of fossil fuels leads to global warming, and to wars for control of oil resources. Large hydroelectric dams to make electricity leads to people being forced to leave their homes, go hungry, and lose valuable land, and causes an increase in diseases such as

malaria and schistosomiasis. Small dams have many fewer problems [7]. On the other hands, high voltage wires can cause health problems such as cancer of the blood and other cancers. It is best not to build homes very close to high voltage wires, especially directly beneath them. High voltage wires are just as dangerous when used with clean energy as with fossil fuels. Making energy locally, which is an important part of clean energy, reduces the need for high-voltage wires [6, 7].

3. Benefits of renewable energy

Renewable energy is energy that can be made with few negative social, cultural, health, and environmental effects [1, 2]. Renewable energy is also called renewable or sustainable energy, because it is produced from sources that do not run out [3]. By using clean energy, we reduce harm to both human health and the environment caused by finding and using fossil fuels and other forms of polluting, nonrenewable energy. Renewable energy can provide power in rural villages, in big cities, and in factories

without causing harm. Each way of making clean electricity has advantages and disadvantages [6]. And each depends on local conditions such as how much wind, sunshine, or falling water there is in each place. Electricity, even clean electricity, may be too costly for many people to afford. But as more and more people use clean energy, and as the ways to make clean energy are improved, it will likely become easier and less costly to make and use [1-7].

3.1. Paying for renewable energy

Home energy systems that run on solar, wind, or water power cost money to install, but once they are in place they cost little to run and maintain [1]. The income generated by labor-saving electric machines such as grain grinders and water pumps, and the ability to work after nightfall, can often pay for the initial costs [6]. People in many countries are

developing ways to make it possible for everyone to have access to clean energy. Forming village cooperatives to pay for energy collectively is one solution [7]. Another solution is microcredit programs. Microcredit programs allow families to pay small amounts over time, rather than a large amount all at once. By paying into a "revolving

credit fund,” money is made available to help more people install home energy over time [8]. There are no longer any technical reasons why people in poor

3.2. Storing and distribution energy

Any form of energy, in order to be useful when and where it is needed, must be stored. For gas or oil-powered transportation, this means storing fuel in the tank of a car or bus so it can be burned along the journey [1]. For electricity, it means using batteries. Even if energy is made using clean sources such as wind, water, or sunshine, it must be captured in batteries. Batteries can often be among the most costly parts of a clean energy system. They also contain toxic materials and must be replaced after several years. So far, there is no good replacement for batteries as a way to store electrical energy [6, 7]. Large power plants run by private industry and governments generate electricity and distribute it through high-voltage wires to different areas. Then the electricity passes through transformers [1]. Low voltage wires bring the electricity into houses or factories to run lights and machines. The problem with the way most electricity is produced today is not only that it is dirty, but that it is produced on a very large scale and sent over long distances. This is very expensive. Because this distribution system is so

countries or rural areas should not have electricity. The reasons they do not have electricity have to do with a scarcity of social justice [6-9].

expensive, smaller communities may wait years for the national electric system to arrive, if it ever arrives at all [1, 2, 6, 7]. Renewable energy from wind, sun, and water can be made in smaller quantities at a lower cost, so clean energy is easier to use close to where it is produced. Communities that use clean energy can have control over their own energy resources. When electricity is made locally from sunlight, water, or biogas, it reduces dependence on fossil fuels, and on expensive, high-voltage distribution systems [1]. It also avoids having faraway government agencies or large corporations setting prices and controlling where the energy can go. Renewable energy works best if a mix of different sources is used. If one source becomes unavailable, such as sunshine on cloudy days, or falling water in the dry season, the other sources are still able to make power. Fossil fuel energy distributes electricity, dependence, and pollution. So, the renewable energy distributes electricity, independence, self-reliance, and sustainability [1, 2, 6, 7].

4. Energy situation in Turkey

4.1. General overview

Excepting recent headwinds, the Turkish economy has rapidly expanded since 2010 and with it the demand for power (see Figs. 3-5). Energy consumption in Turkey has increased at an average of 5.7% per year in stark contrast to Europe's overall decline. At the same time Turkey is looking to limit its dependence on fossil fuel and energy imports for reasons both political and economic. The inherently 'green' nature of renewables also boosts Turkey's ability to meet environmental standards and thus potentially achieve EU membership [10-19]. The Turkish government has set a target of drawing 30% of its energy from renewable sources by 2023 – the 100th anniversary of the Turkish Republic and its

self-imposed deadline for achieving all EU membership conditions. This target will be achieved by increasing the current hydropower capacity from the current 23 GW to 32 GW and wind capacity from 3.0 GW to 10 GW. The solar capacity target was raised to 5.0 GW in 2016 [10, 18, 19].

Turkey is an energy importing country and dependent on the imported energy sources as given in Table 1 [15, 16]. Furthermore this trend seems to be continuing in the future. Energy sources in Turkey are hard coal, lignite, asphalt, oil, natural gas, hydropower, geothermal, wood, animal and plant wastes, solar and wind energy [16].

4.2. Renewable energy sources

Renewable supply in Turkey is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating [15]. Total renewable energy supply declined from 1990 to 2015, due to a decrease in biomass supply [16]. But, the composition of renewable energy supply has

changed and wind power is beginning to claim market share [17]. In order to use domestic resources and reduce energy dependence Turkey aims to increase share of renewable energy sources in national energy mix and coupled with reduction in greenhouse gas emissions.

Table 1. Turkey's energy production and consumption in 2014 (Mtoe)

| Energy source | Production | Consumption |
|-----------------------|---------------|----------------|
| Hard coal | 990 | 17 692 |
| Lignite | 13 973 | 13 182 |
| Asphaltite | 488 | 416 |
| Oil | 2 485 | 33 896 |
| Natural gas | 443 | 37 628 |
| Hydropower | 5 110 | 5 110 |
| Geothermal (electric) | 1 173 | 1 173 |
| Geothermal (heat) | 1 463 | 1 463 |
| Animal & plant wastes | 1 666 | 1 666 |
| Wood | 2 707 | 2 707 |
| Wind | 650 | 650 |
| Solar | 795 | 795 |
| Total | 31 944 | 120 290 |

Mtoe: Million tons of oil equivalent

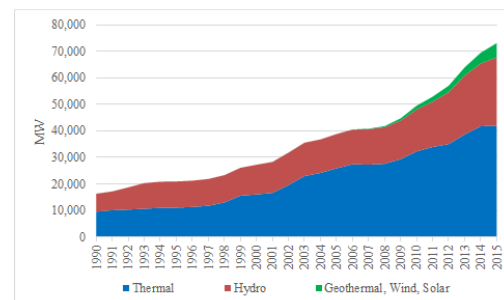
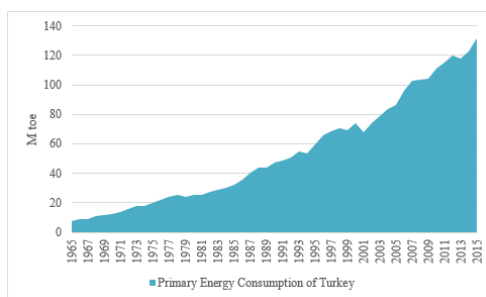


Figure 3. Primary energy consumption of Turkey (Mtoe) [15]

Figure 4. Annual development of installed capacity by sources (MW) [10, 21, 22]

4.2.1. Hydropower

Hydro is one of the most significant and domestic primary energy resource in Turkey with the share of 25.6% of power generation in 2015 and also takes the highest share of renewable resources. Turkey's theoretical hydroelectric potential is 1% of that of the World and 16% of Europe [21]. The gross theoretical viable hydroelectric potential in Turkey is 433 billion kWh and the technically viable potential is 216 billion kWh [10]. The economically viable potential, however, is 140 billion kWh. Annual energy consumption per capita in Turkey has reached 2.900 kWh which is above world average of 2.500 kWh [16]. Currently, Turkey has 178 hydroelectric power plants in operation with total installed capacity of 16 160 MW generating an average of 48.000 GWh/year, which is 35% of the economically viable hydro potential [17]. In 2014, 158 hydroelectric power plants are under construction 8.600 MW of installed capacity to generate average annual 20.000 GWh representing 14% of the economically viable potential [10, 15]. In the future, 1468 more hydroelectric power plants will be constructed in order to make use of additional 26 500 MW installed capacity. As a result of these works, a total of 1746 hydroelectric power plants with 47640 MW will tame rivers to harness the economically viable

hydropower of Turkey [20-22].

4.2.2. Bioenergy

Turkey has a great potential of biomass and bio-energy production [15]. The total annual recoverable bio-energy potential in Turkey was estimated to be around 30 Mtoe, based on the recoverable energy potential from agricultural residues, livestock farming wastes, forestry and wood processing residues and municipal wastes [15-18]. The contribution of energy production share of animal wastes and plant residues to primary energy consumption in Turkey ranged from 6 % in 2000 to 4 % in 2014 [15]. Despite Turkey has a great potential of biomass to produce renewable energy, but the share of renewable energy in energy production is still low. Biogas production potential in Turkey was estimated to be around 1.5 to 2.0 Mtoe. However, since the share of renewable energy in energy production is so low, the possible contribution of biogas to this share can also be ignored [16-19].

4.2.3. Geothermal energy

Geothermal energy is clean since it is emitting very low CO₂, NO_x and SO_x gases and a renewable energy type [19]. Since Turkey has a large potential for geothermal energy which is indicated as 2000 MW

for electricity generation. It is targeted to have 800 MW installed capacity for power generation by 2030. Among the renewable energy alternatives, geothermal energy in Turkey has become very attractive [17]. The reason for this interest is features of geothermal energy in direct and indirect use. It is unfortunate that geothermal energy in direct use can only be utilized locally. But, firing fossil fuels at 1500 °C, and using the generated heat at only 50-60 °C is obviously a thermodynamic waste. Turkey has a significant potential in geothermal energy and there may exist about 2000 MW_e for electrical power generation. Turkey's total geothermal heating capacity is about 31,500 MW_{th}. At present, heating capacity in the country runs at 1220 MW_{th} equivalent to 147,000 households. These numbers can be heightened some sevenfold to 7,080 MW_{th} equal to 760 000 households through a proven and exhaustible potential in 2016. Turkey must target 1.6 million households equivalent 8,900 MW_{th} in 2030 [17, 18, 19].

4.2.4. Solar energy

Turkey is so lucky about solar energy potentials that it has 4.2 hours insulation time average per day and 1514 kWh/year.m² solar radiation level. Only available rooftop area for PV modules is 611 km² and energy gain from this area will be 90 billion kWh/year. Apart from this area it is determined that the area which has more than 1650 kWh/m² irradiation level is about 4600 m² in Turkey. That means this solar energy potential equals to a natural gas plant with a power of 54,300 MW [10, 16, 17, 19]. Turkey's energy policy target is to reach a 20% renewable energy share by the year of 2020, and 30% in 2050, respectively [15, 16]. The instruments to reach this goal range from the 'Law of the Turkish Policies on Renewable Energies' to the political and financial support of research and development of

5. Conclusions

The use of renewable energy technologies has increased greatly over the past several decades. Technologies once considered quaint or exotic are now commercial realities, providing cost-effective alternatives to conventional, fossil fuel-based systems and their associated problems of greenhouse gas emissions, high operating costs, and local pollution. In order to benefit from these technologies, potential users, decision and policy makers, planners, project financiers, and equipment vendors must be able to quickly and easily assess whether a proposed clean energy technology project makes sense.

In Turkey, final energy consumption was dominated

renewable energy sources [10]. The Ministry of Energy and Natural Resources of the Turkey has listed CSP as an important research issue in the 'Summary of National mid & long-Term Science and Energy Technology Development Plan' (2006–2020) [17]. On the other hand, up to now, no commercial solar thermal power plant is in operation in Turkey [15-20].

4.2.5. Wind power

Surrounded by the Black Sea to the north, the Marmara and the Aegean Sea to the west and the Mediterranean Sea to the south, Turkey has huge potential for wind power generation. Turkey has a theoretical wind energy potential of nearly 90,000 MW [17]. So far only about 1,000 MW capacity wind farms are in operation in Turkey, generating less than 0.5% of total electricity consumed [17]. There are a number of cities in Turkey with relatively high wind speeds. These have been classified into six wind regions, with a low of about 3.5 m/s and a high of 5 m/s at 10 m altitude, corresponding to a theoretical power production between 1000-3000 kWh/(m².yr) . The most attractive sites are the Marmara Sea region, Mediterranean Coast, Aegean Sea Coast, and the Anatolia inland [19]. Capacity is likely to grow rapidly, as plans have been submitted for just under a further 600 MW of independent facilities. At start 2014, total installed wind energy capacity of Turkey is only 1 900 MW [17, 18]. It has estimated that Turkey could meet 20% of its electricity demand from wind power with a target capacity of 20,000 megawatts, even assuming an average 8% annual growth in power consumption. Three sides of Turkey is surrounded by Mediterranean, Black and Aegean sea with the warm and nice weather and good amount of stable wind speeds. However, to use all these advantages, Turkey needs energy [15-22].

by residential, commercial and public services with a share of 35.4%. Industrial consumption accounted for 34.2% and transportation sector accounted for 23.3%. Most of the transportation sector energy consumption related to road haulage. In 2015, coal accounted for 29%, petroleum accounted for 28% and natural gas accounted for 31% of total primary energy consumption. 4% of energy consumption supplied by hydro power and remaining part is supplied by other solid fuels and renewables [10]. Since the essential energy resources of Turkey are fossil fuels, greenhouse gas emission amount is a conspicuous subject. Increase in carbon dioxide emission can be seen in Figure 6.

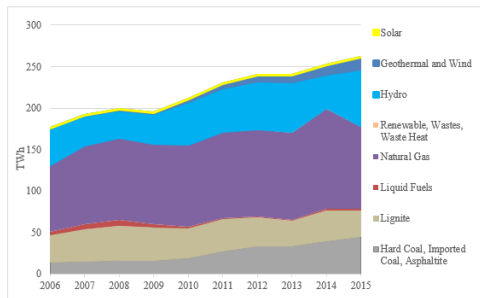


Figure 5. Electricity generation by primary energy resources (TWh) [10, 21, 22]

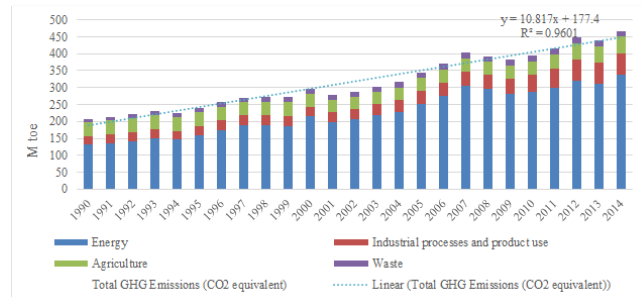


Figure 6. Greenhouse Gas Emissions of Turkey (million tons carbon dioxide equivalent) [17]

References

- [1] A community guide to environmental health, Chapter 23: clean energy, Available from www.hesperian.org/ (accessed 10 January 2018).
- [2] Kaygusuz K. Energy for sustainable development: a case of developing countries. *Renewable and Sustainable Energy Reviews* 2012; 16: 1116-1126.
- [3] IEA, International Energy Agency. Redrawing the climate-energy map: world energy outlook special report, OECD/IEA, Paris, 2013.
- [4] BP, British Petroleum. Statistical review of world energy, BP, June, 2016.
- [5] IEA, International Energy Agency. World energy outlook 2015. IEA, Paris, 2015.
- [6] REN21. Renewables 2015 Global Status Report. Paris, France: REN21 Secretariat.
- [7] WEC, World Energy Council. World Energy Survey 2016, WEC, London, 2016.
- [8] Fourth Assessment Report, Intergovernmental Panel on Climate Change, (IPCC, 2007.)
- [9] Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)], IPCC (Intergovernmental Panel on Climate Change), 2007. Cambridge University Press, Cambridge, UK, and New York, 996 pp.
- [10] Tetik, E. Turkish electricity sector: a bottom-up approach. Ms Thesis In Industrial Engineering, Işık University, İstanbul, Turkey, 2017.
- [11] Kaygusuz K. Clean energy policies for sustainable development in Turkey. *Journal of Engineering Research and Applied Science* 2012; 1(2): 1-10.
- [12] Kaygusuz K and Toklu E. Energy issues and sustainable development in Turkey. *Journal of Engineering Research and Applied Science* 2012; 1(1): 1-25.
- [13] Kaygusuz, K. Hydropower as clean and renewable energy source for electricity generation. *Journal of Engineering Research and Applied Science* 2016; 5(1): 359-369.
- [14] Kaygusuz, K., Toklu, E., Avcı, AC. Energy security in a developing world: a case of Turkey. *Journal of Engineering Research and Applied Science* 2015; 4(1): 265-277.
- [15] MENR, Ministry of Energy and Natural Resources. Blue Book. Available from <http://www.enerji.gov.tr> (accessed date 16 July 2014).
- [16] MENR, Ministry of Energy and Natural Resources. Energy Statistics in Turkey. Available from <http://www.enerji.gov.tr> (accessed date 16 Jan 2014).
- [17] WECTNC, World Energy Council Turkish National Committee. Energy report of Turkey for 2013, WECTNC, Ankara, Turkey, 2014.
- [18] IEA, International Energy Agency. Energy Policies of IEA Countries: Turkey 2016 Review, OECD/IEA, Paris, 2016.
- [19] ECS, Energy Charter Secretariat. In-depth energy efficiency policy review of the republic of Turkey. Brussels, Belgium, 2014, available from www.encharter.org.
- [20] TURKSTAT, Greenhouse gas emissions, 2014. Available: <http://www.tuik.gov.tr/>
- [21] TEIAS, Electricity sector report for Year 2015, Available: <http://www.teias.gov.tr/>
- [22] TEIAS, Turkish electricity generation-transmission statistics. Available: <http://www.teias.gov.tr/>