

Renewable energy utilization in Turkey: a case of hydropower

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Accepted 01 September 2016

Abstract

Turkey should change its energy policy to simply optimize energy consumption by supporting energy efficiency, give up on supporting environmentally hazardous energy generation such as nuclear, coal, and aim for 100% renewable energy. This will help relieve the economy by reducing energy importation, protect the environment by reducing carbon emissions, and provide energy independence which is a national security matter. Turkey's total gross renewable energy potential is about 650 billion kWh annually while the economical potential was about 340 billion kWh/yr. Turkey has a total gross hydropower potential of 433 GWh/year, but only 125 GWh/year of the total hydroelectric potential of Turkey can be economically used. By the commissioning of new hydropower plants, which are under construction, 36% of the economically usable potential of the country would be tapped. This paper discusses the renewable energy and hydropower situation in Turkey.

Keywords: Renewable energy; energy efficient buildings; climate change mitigation; Turkey

1. Introduction

Turkey, bordering on the Middle East, Russia, and the Caspian states is adjacent to regions which possess over seventy percent of the world's proven oil and natural gas reserves [1]. Turkey also sits on major international waterways. Both factors predispose Turkey to become an important transit state for world energy resources [2]. As part of its drive to serve as a significant energy transit state, Ankara has signed a number of importation agreements in the last decade with neighboring natural gas producers, inaugurated the Baku-Tbilisi-Ceyhan oil pipeline project, launched the Baku-Tbilisi-Erzurum natural gas pipeline, and is exploring additional major energy transport and production projects [3-8]. On the other hand, in 2006, Turkey

announced its decision to build a number of nuclear energy plants [9]. Despite this extensive activity in the energy sphere, it seems, however, that Ankara's energy policy has been undertaken without a strategic plan and with little integration of energy issues into Turkey's overall foreign and security policies [10-18].

This article will analyze Turkey's renewable and sustainable energy policies for energy security and nature conservation. The article discusses the following topics: Turkey's energy situation, renewable energy sources, green buildings, environmental impact due to energy consumption, the climate change mitigation and energy security.

2. Energy situation in Turkey

With a population reaching 77 million, Turkey's energy consumption based on primary energy resources is continuing to increase and this is compounded by the rapidly growing economy [19]. Turkey's increasing energy demand is mostly met by fossil fuels, of which a large portion is imported. The total installed capacity of power is 69,516 MW and the breakdown by resource is 59.7% fossil fuels (natural gas, coal, liquid fuel, etc.), 34% hydro, 5.2%

wind and 1.1% other renewables [20]. Turkey pays millions of dollars for its energy imports every year. In addition to this, the number of buildings has reached 9.3 million and the number of residential and commercial units in these buildings reached to 22 million in 2014, which consume 28.2 million tons of oil equivalent (Mtoe), mainly natural gas, coal and wood for heating and electricity for cooling [17, 18, 19].

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As a developing country and in conjunction with its fast growing economy and population Turkey's energy consumption has increased rapidly. For example, while total primary energy consumption in 2009 was 106 Mtoe in 2013 it raised 120 Mtoe and total energy production in 2009 was 28 and 31 Mtoe in 2013. Turkey is an energy importing country and dependent on the imported energy sources (Table 1 and Figs. 2-4) [17, 18]. Furthermore this trends seems to be continuing in the future. Although it has a wide variety of energy sources, the quality and quantity of most of the sources are not sufficient to produce energy. Some of the energy sources in

Turkey are coal/lignite, asphalt, oil, natural gas, hydropower, geothermal, wood, animal and plant wastes, solar and wind energy [15, 16, 17]. The proven reserves of lignite, the most abundant domestic energy source, is 7300 million ton and found in almost all of the country's regions. Lignite has the largest percentage in total energy production with its 43% share. After lignite, wood has the greatest share in total energy production with its 20% and oil accounts for 13%, 12.4% hydro and the final 15% includes animal wastes, solar, hard coal, natural gas, geothermal electricity and geothermal heat [9, 10, 11, 14, 15, 16, 17, 18].

Table 1. Turkey's energy production and consumption in 2013 (Mtoe)

Energy source	Production	Consumption
Hard coal	990	17 692
Lignite	13 973	13 182
Oil	2 485	33 896
Natural gas	443	37 628
Hydropower	5 110	5 110
Geothermal (heat/electric)	2 636	2 636
Animal & plant wastes	1 666	1 666
Wood	2 707	2 707
Wind	650	650
Solar	795	795
Total	31 944	120 290

3. The role of renewable energy in Turkey

According to the Ministry of Energy and Natural Resources (MENR), the total amount of investments required to meet the energy demand in Turkey by 2030 is estimated to be around USD 120 billion, more than double the total amount invested in the last decade. Turkey's ambitious vision for 2030, envisages especially interesting targets for the renewable part of the energy sector. These targets include [10, 14, 16, 18, 19, 20, 21]:

- 34,000 MW capacity of hydro power plants;
- 20,000 MW capacity of wind power plants;
- Minimum 5000 MW of solar power plants;
- Minimum 1000 MWe geothermal energy; and
- 1000 MWe installed capacity for Biomass energy.

According to MENR studies and various resources Turkey has following minimum technical renewable energy potentials [15, 16, 18, 19, 21];

- 160,000 GWh/year economic hydraulic capacity
- 48,000 MW wind energy capacity
- 1,500 kWh/m²-year average global solar radiation

- 31,500 MWt geothermal capacity
- 8.6 Mtoe biomass potential
- 1.5-2 Mtoe biogas potential

3.1. Hydropower

Hydropower is a renewable form of energy since it uses the power of flowing water, without vested or depleting it in the generation of energy. Because they are clean energy generation plants hydropower can contribute to reducing air pollution and slowing down global warming. Any other air pollutants or toxic wastes are not produced and it promotes energy safety independence and price stability. Hydropower is an electricity sources with long viability and low operation and maintenance cost [14-16]. Figure 1 shows the global historical growth of hydropower since 1980. The blue arrow represents a general historic increase in hydropower in response to growing demand for electricity worldwide.

In 2015, hydropower development continued to grow around the world, with an estimated 33 GW of capacity put into operation, including 2.5 GW of pumped storage – bringing the world's total installed capacity to 1,211 GW. Total hydropower generation for the year is estimated at 3,975 TWh. China

continued to dominate the market for new development and total installed capacity, adding 19.4 GW of new capacity within its borders, including 1.2 GW of pumped storage. Other countries leading in new deployments include Turkey (2.3 GW), Brazil (2 GW), India (1.9 GW), Iran (1 GW) and Vietnam (1 GW). Globally, drivers for hydropower's strong showing include a general increase in demand not just for electricity, but also for particular qualities

such as reliable, clean and affordable power. Looking forward, there remains significant undeveloped potential across all World regions, particularly in Asia, Africa and Latin America. Demand for electricity and other related reservoir services is also high in these areas, forming a strong foundation for continued growth in hydropower.

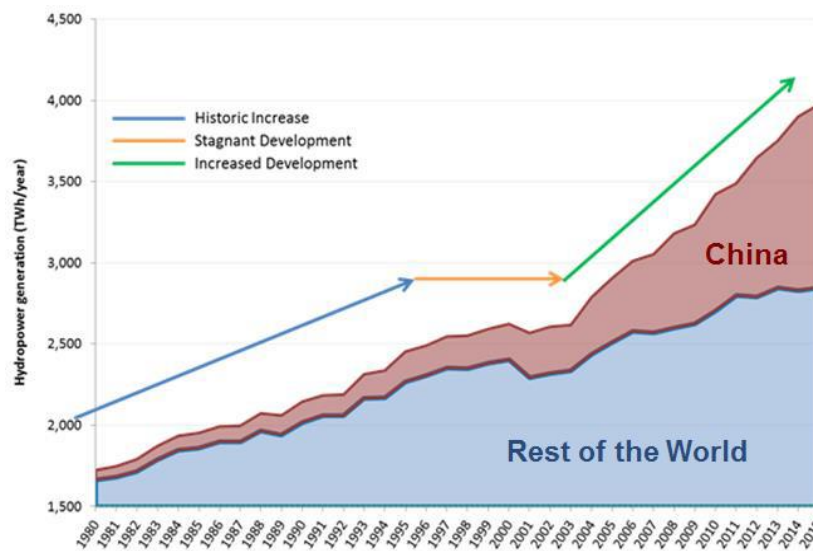


Figure 1. Global total hydropower generation from 1980 to 2015.

Turkey's theoretical hydroelectric potential is 1% of that of the World and 16% of Europe. The gross theoretical viable hydroelectric potential in Turkey is 433 billion kWh and the technically viable potential is 216 billion kWh [9, 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 [18]. As of the end of 2014, 43% of the potential was in operation, and 29% was in the process of being built. Turkey continues to take steps towards developing the investment environment based on competition within the electricity generation sector, which has been opened up to the private sector, 600 licenses had been obtained in 2014 with a total capacity of 13,215 MW for built hydropower plant [15].

As of the end of 2015, there were 486 HES plants, with a total installed capacity of 23, 120 MW. This is the equivalent of 34,8% of the total potential. In 2015, 24,8% of our electricity output came from hydraulics. The base line feed-in tariff for hydroelectricity generation is 7.3 USD cent/kWh. If the equipment is locally manufactured, the facilities can benefit from bonuses provided for locally

manufactured equipment [18]. The maximum feed in tariff price hydroelectricity generation facilities is 9.6 USD cent/kWh. Baseline feed-in tariff is 7.3 USD cent/ kWh. Bonus for locally manufactured component is an extra 2.3 USD cent/ kWh. Namely; bonus for Turbine is 1.3 USD cent/ kWh; bonus for Generator/ Power Electronics is 1 USD cent/ kWh [2, 16, 18, 20].

Approximately 50% of the additional potential of 41 TWh could be realized as small hydroelectric plants (SHP), with installed capacities of less than 10 MW [22]. The share of SHP potential in the total, which is 3% at present, would be 14%. On the other hand, in accordance with the results obtained from the pre-evaluation study, about 15% of the increase in 126 TWh annually exploitable energy potential might be achieved by developing additional SHP potential [2, 18]. However, this study gives only rough results about the additional SHP potential of the country and the potential must be evaluated more precisely, with comprehensive master plan studies for each hydrological basin [5, 10, 13, 15, 16].

3.2. Biomass

Biomass is the major source of energy in rural

Turkey. Biomass is used to meet a variety of energy needs including generating electricity, heating homes, fueling vehicles and providing process heat for industrial facilities [23]. Biomass potential includes wood, animal, and plant wastes [24]. Among the biomass energy sources, fuelwood seems to be the most interesting because its share of the total energy production of Turkey is high at 12%. The total biomass energy potential of Turkey is about 36 Mtoe [25]. The amount of usable biomass potential of Turkey is approximately 14 Mtoe [26]. The electrical production from usable biomass has a net impact of 6.1 billion USD in personal and corporate income and represents more than 350,000 jobs [9, 10, 16, 16, 26, 27, 28].

In Turkey, total amount of waste from forests is 4,800,000 tons (1.5 Mtoe-600 MW); from agriculture 15,000,000 tons [12]. In Turkey, 34 biodiesel facilities received processing license for biodiesel production. Total biodiesel production capacity of all these facilities is 561,217 tons. The biodiesel production is 21,876 tons in 2013. Estimation at least 1.2 million ton/year biodiesel and 0.7 million ton/year bioethanol production capacity based on 2.7 million hectare agricultural land. Also, Turkey has 1.5 - 2 Mtoe biogas potential. Almost 180 million m³/year biogas produced by 20 running biogas plants. Recently landfill gas extraction gained importance (total capacity 162,7 million m³/year) [5, 12, 21, 22, 23].

3.3. Geothermal energy

Turkey forecasts 6% to 8% yearly growth in energy demand until 2020 and anticipates adding 50,000MW to the grid. Considered to be one of the "hottest" markets in Europe for geothermal, Turkey is the seventh most promising country in the world in terms of geothermal energy potential. Within Europe, Italy is the market leader with over 50% of the European capacity. Turkey and Iceland are currently centers of geothermal exploration and development in Europe and Germany is considered a new, but an important factor in the market [5, 12].

Turkey has drilled around 1200 geothermal wells for geothermal electricity production and direct use applications in these geothermal sites since 1960. About one-third of these well-bores have been drilled since 2009. As of 2014, 64 new geothermal projects have been completed or they are currently under construction in Turkey. On the other hand, tectonically, Turkey is in a very active region. The western part of Turkey is an area of plentiful geothermal activity that undergoing significant

exploration and exploitation, but with relatively little volcanism [5, 9, 11, 26].

With the new additions, there are more than 290 geothermal sites discovered in Turkey and approximately 95% of them are low-to-medium enthalpy sites mostly proper for direct use applications. Even though geothermal energy potential of Turkey was theoretically estimated as 31,500 MWt and recently increased to 60,000 MWt, the proved potential by drilling activities (4209 MWt) and natural discharges (600 MWt) is only 4809 MWt. As of today, 58% of the proved capacity (2705 MWt) is used for geothermal heating, consisting of residence heating (805MWt), greenhouse heating (612 MWt), thermal facilities heating (380MWt), balneological use (870MWt) and heat pump implementations (38MWt) [26].

3.4. 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 BkWh/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 [32]. Except some special applications PV installation is almost non existing in Turkey. However, solar energy is widely used for heating water [6]. The hot water heating system installations cover about 10 Million m² surface. Turkey is the second big country at hot water heating systems all over the world. Apart from this, PV installations are not so much up to now because of the governmental issues [12]. While the existing feed in tariff is about 5.5 ¢cent/kWh, it is foreseen that it will be about 25 ¢cent/kWh for PV and 20 ¢cent/kWh for CSP in January of 2009. Moreover, there will be no licence need for systems up to 500 kW. There are some goals about PV installations in Turkey due to these regulations. It is expected that there will be 3 million installations of private homes which has totally power of 3.000 MW. In addition, the target of installed PV power plant by 2020 is 20.000 MW [32-37].

With an annual solar irradiation of 2,737 hours, which is approx. 7.5 hours a day, Turkey has the highest solar potential in the whole of Europe. Simple solar collectors for hot water generation are pretty common especially in the countryside, but photovoltaics are still rather a rare sight. So far, solar systems with a total capacity of approx. 330 MW have been installed, almost 250 MW of which was

last year. But now the sector expects stronger growth of the Turkish PV market. For this year an expansion of at least 500 MW is expected; in January, 41 MW of new systems joined the grid. Reasons for the upturn are the further sinking costs, increased interest from local banks and investors, the currently due allocation of licenses for the construction of larger systems, as well as rising electricity prices and a growing electricity demand. The required investments in the Turkish energy sector by 2023 have been officially put at US\$ 130 billion [3, 5, 8, 10, 12].

3.5. Wind power

Turkey has the serious wind energy potential. Turkey has 11GW stock of the current Project and the capacity of 20 GW for the national goal in 2023 in terms of wind Energy, therefore, Turkey plays a vital role in the European market. In the future Turkey will probably play an important role in shaping the

investment opportunities. On the other hand, 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 [5, 8, 10, 12, 29].

Turkey added 804 MW of new wind power in 2014 for a total installed capacity of 3,763 MW. Turkey's installed capacity has grown at over 500 MW per year since 2010 and Turkey's National Transmission Company expects annual installations to reach 1,000 MW per year from 2015 onwards. On the other hand, Turkey's best wind resources are located in the provinces of Çanakkale, Izmir, Balıkesir, Hatay and Istanbul. As of the end of 2014, the Aegean region had the highest installed wind capacity with a total of 1,486 MW, followed by Marmara region with 1,359 MW and the Mediterranean region with 543 MW [34-36].

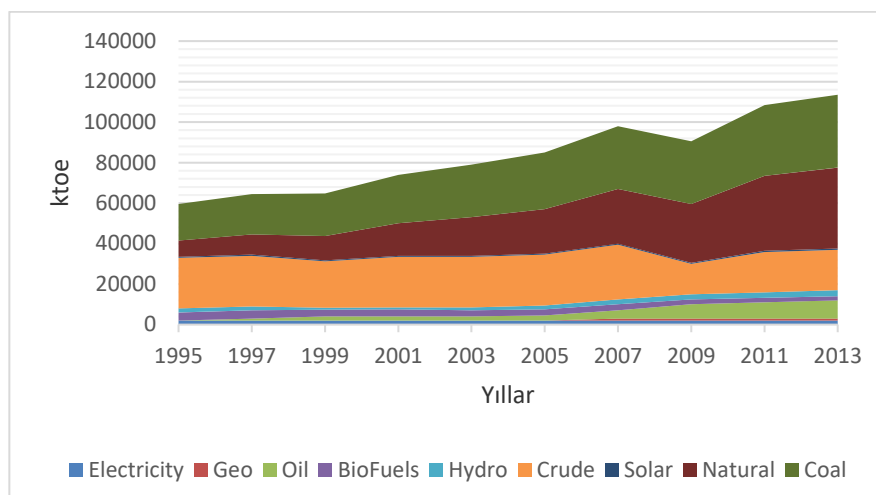


Figure 2. Total primary energy supply in Turkey

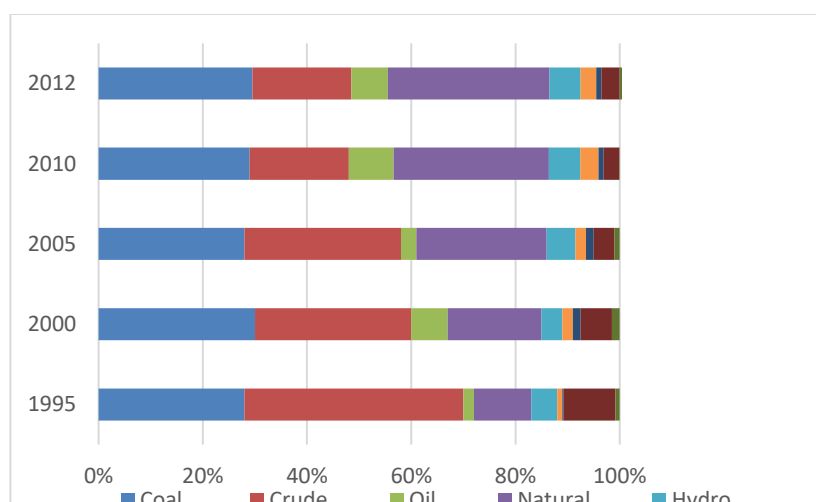


Figure 3. Turkey's distribution of sources in total primary energy supply between 1995- 2012

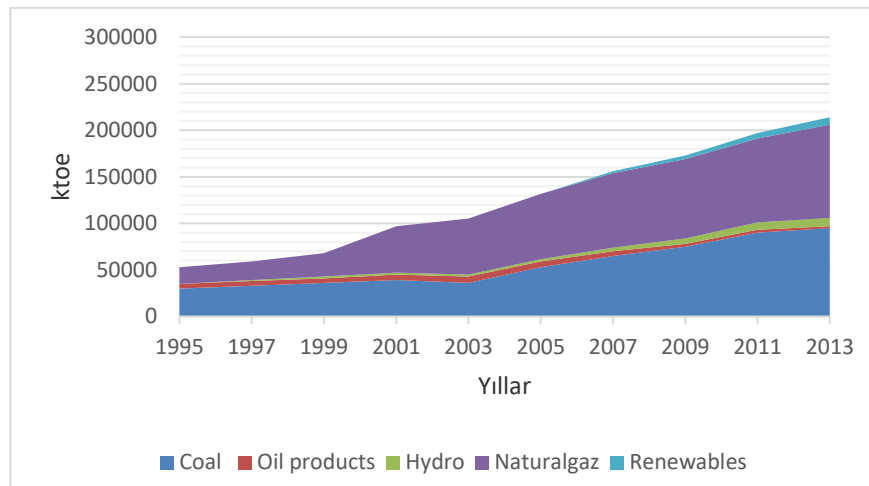


Figure 4. Turkey's electricity generation by fuel (ktoe = kilo tons of oil equivalent)

4. Conclusions

Turkey's energy demand is increasing consistently. The country's energy policy focuses on increasing the supply of energy to fuel its economic growth. In a sun-rich country like Turkey, whether via centralized systems such as solar power plants or via decentralized systems for houses, hotels, shopping malls, hospitals, factories etc., solar energy can meet most of the energy demand. The country's other renewable energy resources, i.e. the wind, geothermal, biofuels, hydro, wave, hydrogen, also have huge potential. Contrary to the arguments claiming that renewable energy cannot provide baseload power; one can rely 100% on renewable energy sources to generate power 24 hours a day by simply installing storage technologies such as heat storage or power storage systems, or by utilizing geothermal systems and biofuels to back up your solar or wind systems. Turkey is developing many hydropower plants, many of which are associated with the US\$32 billion Southeastern Anatolia Project (GAP) along the basin of the Tigris and Euphrates Rivers. Under the GAP project, which is considered one of the most ambitious water development projects ever undertaken, Turkey will erect 22 dams, 19 hydroelectric power stations (with some 7.5 GW in generating capacity), and an expansive network of tunnels and irrigation canals covering 1.7 million ha. The GAP project is overseen by the Southeastern Anatolia Project Regional Development Administration. By the end of 2007, some three-quarters of the energy projects planned under the GAP scheme had been completed. The entire GAP project is scheduled to be fully completed by 2013. Turkey is using about 30% of its hydro potential, and its unused potential consists of small hydro projects.

At the end of 2007, the installed capacity of hydroelectric plants in Turkey stood at 13 393 MW. Small hydro projects have been one of the most attractive options for private investors in Turkey. The capacity of the small hydroelectric plants to be put in service over the next five years is expected to be about 44 000 GW, which corresponds to some 22 % of the current electricity generation capacity in Turkey. The following concluding remarks may be drawn from this study:

- Hydropower is an important energy source for Turkey because it is renewable, clean, and less impactful on the environment. Plus it is a cheap and domestic energy source.
- Turkey's hydropower potential can meet 40-60% of its electric energy demand in 2030 (about 800-900 TWh). By evaluating small hydropower plants, Turkey will provide an important part of its total electric energy demand from its own hydropower resources.
- Only 5% of economically feasible small hydroelectric potential has been developed. If all the remaining small hydro energy potential of Turkey was completely exploited, it would bring about an amount of about 20 TWh/yr of electricity generation, which means almost 10 percent of the annual total electricity demand of the country.
- In Turkey, only 30 percent of economical hydropower potential is currently utilizable. If Turkey could efficiently exploit its remaining hydro potential having an amount of 100 TWh/yr hydropower capacity.

Acknowledgment

The author acknowledged to Prof. Dr. Kamil Kaygusuz for his valuable suggestions for accomplished to this study.

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