



## Renewable energy potential, utilization and policies in Turkey for environmental friendly sustainable development

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### Abstract

Renewable energy technologies such as wind, biomass, hydropower, geothermal and solar are finally showing maturity. Turkey's carbon dioxide emissions have grown along with its energy consumption. States have played a leading role in protecting the environment by reducing emissions of greenhouse gases. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for sustainable energy development in Turkey. Turkey's geographical location has several advantages for extensive use of most of these renewable energy sources. This study shows that there is enough renewable energy potential in Turkey for heat and electricity generation. Especially hydropower, biomass, solar and wind are very well.

*Keywords:* Renewable energy; climate change mitigation; sustainable development; Turkey.

### 1. Introduction

Energy is essential to economic and social development and improved quality of life in all countries [1]. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially [2]. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption in the country [3]. Electricity supply infrastructures in many developing countries are being rapidly expanded as policymakers and investors around the world increasingly recognize electricity's pivotal role in improving living standards and sustaining economic growth [4].

The usage of renewable energy resources shows a promising prospect in Turkey in the future as an alternative to the conventional energy. In the past decade, wind energy has become a valuable and dependable source of electricity worldwide. There is a promising potential in Turkey for both wind and

solar energy. In Turkey, several research institutions have initiated research at various stages on the applications of solar energy. The estimated wind and solar energy potentials: 48,000 MW for wind and 80 Million tons of oil equivalent (Mtoe) for solar. Turkey has a considerably high level of renewable energy resources that can be utilized to satisfy a part of the total energy demand in the country. Present applications have shown that renewable energy sources in Turkey are a promising alternative [5-10].

There is a growing concern that sustainable development may be compromised unless measures are taken to achieve balance between economic and environmental outcomes. Since the early 1980s, Turkish energy policy has concentrated on market liberalization in an effort to stimulate investment in response to increasing internal energy demand. The Turkish government has continued this policy despite lower energy demand induced by the 2001 economic crisis. This paper discusses the renewable energy potential, utilization and policies for environmental friendly sustainable development in Turkey.

### 2. Energy consumption in Turkey

Turkey is an energy importing country; more than half of the energy requirement has been supplied by

imports [5, 6]. Oil, coal and gas have the biggest share in total primary energy consumption [7-10].

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Turkey, with its young population and growing energy demand per person, its fast growing urbanization, and its economic development, has been one of the fast growing power markets of the world for the last two decades [11]. It is expected that the demand for electric energy in Turkey will be 573 billion kWh by the year 2020 and 760 billion kWh by the year 2030 [12-16]. Turkey's electric energy demand is growing about 4-6% yearly due to

fast economic growing [17-28].

In 2017, primary energy production and consumption has reached 36 and 145 Mtoe as shown in Table 1 and 2 [12]. The most significant developments in production are observed in hydropower, geothermal, solar energy and coal production. Turkey's use of hydropower, geothermal and solar thermal energy has increased since 1990 [12-14].

Table 1. Total energy production in Turkey (Mtoe).

Energy Sources	2017	2020	2030
Coal and Lignite	14.47	32.36	35.13
Oil	2.68	0.49	0.17
Gas	0.29	0.14	0.10
Nuclear	0.00	0.00	14.60
Hydropower	5.00	10.00	10.00
Geothermal	7.12	1.71	3.64
Wood and Biomass	2.53	4.96	4.64
Solar/Wind/Other	2.75	2.27	4.28
<b>Total production</b>	<b>35.36</b>	<b>51.93</b>	<b>72.56</b>

Table 2. Total energy consumption in Turkey (Mtoe).

Energy Sources	2017	2020	2030
Coal and Lignite	38.82	107.57	<b>198.34</b>
Oil	44.53	71.89	<b>102.38</b>
Gas	45.87	74.51	<b>126.25</b>
Nuclear	0.00	0.00	<b>14.60</b>
Hydropower	5.00	10.00	<b>10.00</b>
Geothermal	7.12	1.71	<b>3.64</b>
Wood and Biomass	2.53	4.96	<b>4.64</b>
Solar/Wind/Other	2.75	2.27	<b>4.28</b>
<b>Total consumption</b>	<b>145.30</b>	<b>272.91</b>	<b>464.13</b>

However, the total share of renewable energy sources in total final energy consumption (TFEC) has declined, owing to the declining use of non-commercial biomass and the growing role of natural gas in the system. Turkey has recently announced

that it will reopen its nuclear programme in order to respond to the growing electricity demand while avoiding increasing dependence on energy imports [15-17]. Figure 1 shows the installed power capacity in Turkey by energy source.

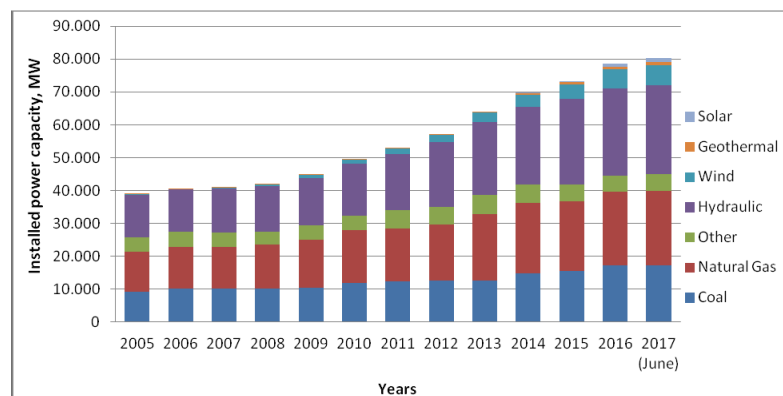


Figure 1. Turkey's Installed capacity (MW).

In Turkey, electricity is mainly produced by thermal power plants, by consuming coal, lignite, natural gas,

fuel-oil and geothermal energy, wind energy (recently) and hydropower plants [20-22]. The electricity requirement was reported as 194 000 GWh in 2008 [21]. The electricity is mainly produced by thermal power plants and accounted for 74,82 % of the total, while hydro power energy was 25,11 % and the wind power energy was 0,07 %. In the thermal electricity production, the lignite part was 18,37 % and natural gas was 44 %. Compared to other energy sources, PV systems don't have sufficient contributions to gross electricity demand. There are no sufficient governmental driving forces to support PV systems in Turkey yet. Turkey's annual solar energy potential is estimated to be 1015 kWh, which

is more than 5 700 times of the present electricity consumption [12-15].

Along with the economic growth and population increase, significant increases were observed both in primary energy and electricity consumption [14]. Consumption of primary energy reached 146 Mtoe as of the end of 2017 with an annual average increase of 3.1% while electricity consumption reached 276 billion kWh with an annual average increase of 5.2% during this period. Figure 2 shows Turkey's electricity power generation (GWh). Table 3 also shows breakdown of installed capacity in Turkey (MW) [12-14].

Table 3. Breakdown of installed capacity in Turkey by energy resources in 2016 and 2017.

Power resources	Installed capacity (MW)(2016)	Installed capacity (MW)(2017)	Added Capacity (MW)(2016-2017)	Increase (%) (2016-2017)
Thermal power plants	44,411.7	46,926.5	2,514.8	5.7
Hydroelectric	26,681.1	27,273.1	592	2.2
Wind	5,751.3	6,516.2	764.9	13.3
Solar PV	832.5	3,420.7	2,588.2	310.9
Geothermal	820.9	1,063.7	242.8	29.6
<b>Total</b>	<b>78,497.5</b>	<b>85,200.2</b>	<b>6,207.7</b>	<b>8.5</b>

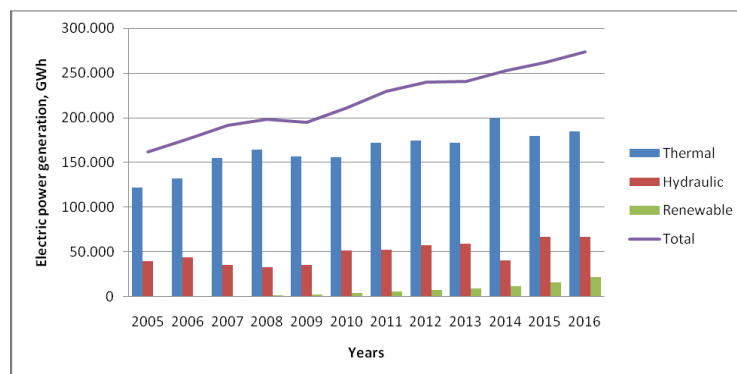


Figure 2. Turkey's electric power generation (GWh).

### 3. Renewable energy in Turkey

Turkey is one of the fastest growing energy markets in the world. Turkey's total energy demand has been increasing rapidly. Imported fossil fuels dominate Turkey's total primary energy consumption by 75%. However, one of the government's priorities is to increase the ratio of renewable energy resources to 30 % of total energy generation by 2023. As seen in Table 3, Turkey had 85.2 GW of installed electricity generation capacity end of 2017. The breakdown by generation sources is as follows: 55.08% fossil fuels (natural gas, coal, liquid fuels etc.), 32.01% hydro, 7.65% wind, 4.01% solar and 1.25% geothermal. Almost all natural gas and around 40% of coal were imported. Therefore, Turkey needs to boost its power

self-sufficiency by handling its rich potential of renewable energy sources.

Renewable energy supply in Turkey is dominated by hydro and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating [5, 19]. Total renewable energy supply declined from 1990 to 2017, due to a decrease in biomass supply [18, 19]. As a result, the composition of renewable energy supply has changed and wind power is beginning to claim market share [12-15]. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease

with the expansion of other renewable energy sources. Table 4 also shows the potentials for investment of the renewable energies in Turkey.

Figure 3 shows expected installed capacity by renewable energies in Turkey.

Table 4. Potentials for investment for renewable energy technologies in Turkey.

Sectors	Million \$	Remarks
<b>Hydroelectric</b>	120	Economical development potential of 28,400 MW, Corresponding 100,000 GWh/a
<b>Wind power</b>	72	Economical development potential of 48,000 MW With wind speed > 7 m/s
<b>Solar thermal</b>	170	Economical development potential of 131,000 GWh/a, Corresponding to approx. 300 million m <sup>2</sup> collector area
<b>Bioenergy</b>	15	Agricultural residual material and dung, when used for electricity generation, 1,000 MWe and 7,000 GWh/a
<b>Total</b>	377	

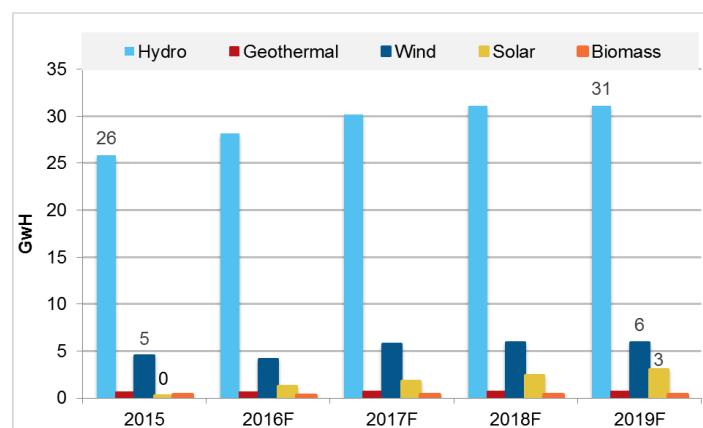


Figure 3. Turkey's expected installed capacity by renewables (GW).

### 3.1. Hydropower

Total gross hydropower potential and total energy production capacity of Turkey are nearly 70 GW and 142 TWh/yr, respectively and about 30% of the total gross potential may be economically exploitable [13, 14]. At present, only about 35 % of the total hydroelectric power potential is in operation [19]. The national development plan aims to harvest all of the hydroelectric potential by 2020 [20]. The contribution of small hydroelectric plants to total electricity generation is estimated to be % 5-10 [22]. On the other hand, the Southeastern Anatolia Project (GAP) is one of the largest power generating, irrigation, and development projects of its kind in the world, covering 3.0 million ha of agricultural land [27]. This is over 10 % of the cultivable land in Turkey; the land to be irrigated is more than half of the presently irrigated are in Turkey. The GAP project on the Euphrates and Tigris Rivers encompasses 22 dams and 19 hydroelectric power plants. Once completed, 27 billion kWh of electricity will be generated and irrigating 1.7 million hectares [13, 14, 19, 20, 22].

### 3.2. Biomass

Biomass is the major source of energy in rural Turkey. Among the biomass energy sources, woody biomass seems to be the most interesting because its share of the total energy production of Turkey is high at 11 %. Turkey's annual biomass potential is about 120 million tons and the total biomass energy potential is about 36 Mtoe [5]. The amount of usable biomass potential of Turkey is approximately 18 Mtoe. Turkey has the potential to produce 4.0 million tons of wood pellet has approximately 780 million dollars of market value by the help of existing woody biomass [12]. Producibile wood pellet could account to 1.4% of total primary energy consumption in 2014 and 1.38% of imported energy. If Turkey utilized existing woody biomass as wood pellet, this would represent a saving of 340 million dollars from energy imported in 2014. The capacity for wood pellet production in Turkey is quite low, due to its high cost [13]. Therefore, relevant institutions should launch more projects to promote the production and consumption of wood pellet. International pellet

standards should be adopted, and private sector should be encouraged by government [14].

Turkey has a great potential, but energy crops sometimes will be required to minimize biomass collection and supply chain risks to bio-based industries. Current cumulative installed biomass capacity in the country of 130 MW<sub>e</sub> is insignificant,

but a number of fully permitted and ready to build projects will promptly increase in 2014 (see Fig. 4). On the other hand, Turkish biomass market has a good chance of reaching several hundred MWe cumulative installed capacity in the next four years. The report provides a complete picture of the market situation, dynamics, current issues and future prospects [12-14].

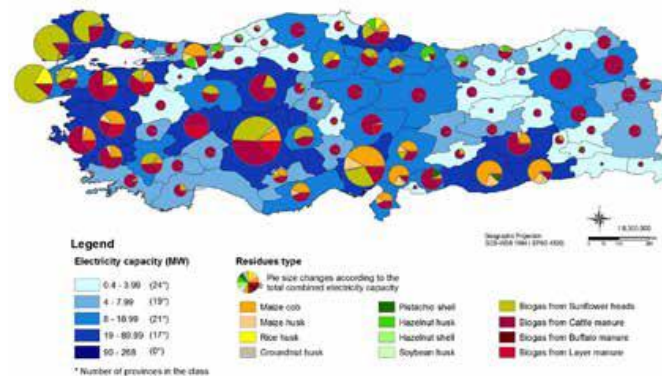


Figure 4. Electricity capacity generation (MW) from crop residues in Turkey.

### 3.3. Wind energy

There are a number of cities in Turkey with relatively high wind speeds [27]. 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/(m<sup>2</sup>.yr) . The most attractive sites are the Marmara Sea region, Mediterranean Coast, Aegean Sea Coast, and the Anatolia inland. 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 1900 MW [12-14].

Turkey added 766 MW in 2017, bringing the country's total wind power capacity to 6,857MW. 2017 marked a turning point for Turkey's wind industry: in December, 2.11 GW were issued preliminary licences for 67 wind projects by Turkey's electricity transmission operator Teias. This completed a round which had started in June 2017 with the assignment of 710 MW of so called pre-licences, issued to projects meeting specific criteria

and participating in grid capacity auctions. In addition, the country's first wind tender was held in August, where 2.0 GW of onshore wind capacity was allocated under Turkey's YEKA renewable energy programme. Recently Turkey's energy and natural resources ministry also announced its plans to start offshore wind development to boost the country's renewable energy capacity. The ministry has identified potential zones for the country's first offshore wind tender [12-14].

After finalizing the tenders and YEKA project, Turkey's wind capacity is expected to grow by around 4 GW in the next three to four years. However, the country needs private investment to meet its growing demand; there will be an investment and capacity gap between 2018 and 2019. In 2018, there will be a second YEKA tender. There are currently more than 30 projects amounting to 800 MW under construction. Turkey's national target for wind power is set at 20 GW by 2023. Figure 5 shows Turkey's wind energy potential atlas [13].

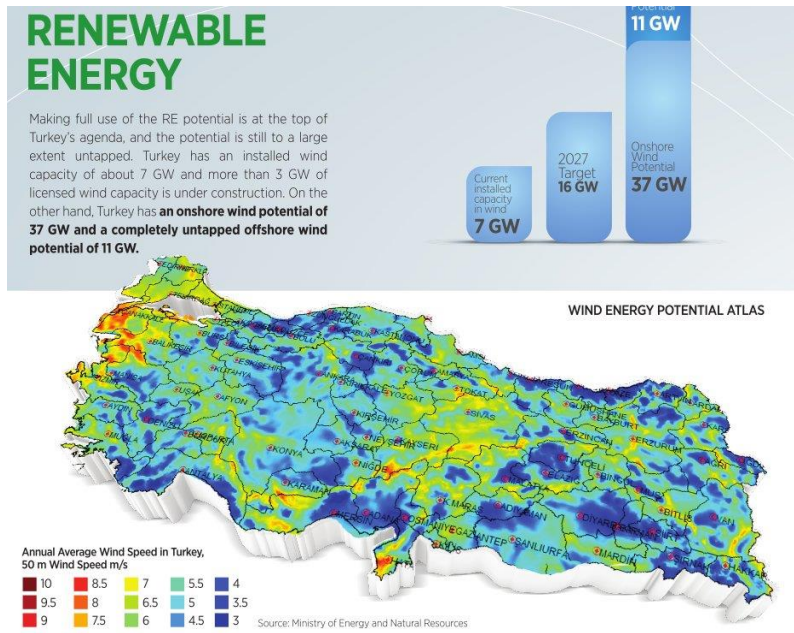


Figure 5. Turkey wind energy potential atlas.

**3.4. Solar energy**

Turkey receives a high level of solar radiation throughout the year with mean daily sunshine duration of about 7.2 h and solar energy intensity of 12.96 MJ/m<sup>2</sup>.day [26]. The highest and lowest solar energy potential of Turkey is in the Southeast Anatolian region with an average solar radiation of 14.37 MJ/m<sup>2</sup>.day and sunshine duration of 8.2 h/day

and in the Black Sea region with an average solar radiation of 11.02 MJ/m<sup>2</sup>.day and sunshine duration of 5.4 hour per day, respectively [12]. The solar potential unconstrained by technical, economic or environmental requirements of Turkey is estimated at 90 Mtoe per year [12-14]. Figure 6 shows solar energy potential in Turkey [13].

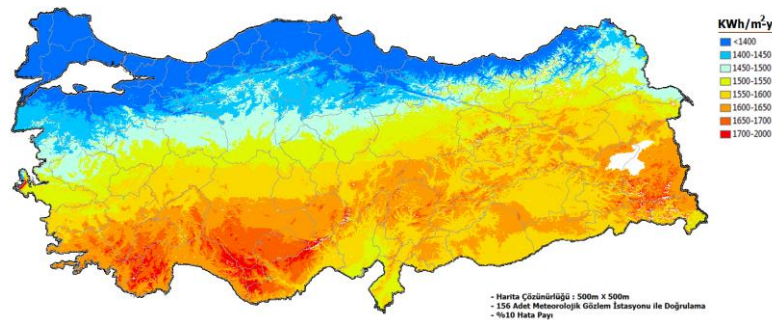


Figure 6. Solar energy potential in Turkey.

Total solar energy production of 0.465 million tons of oil equivalent (Mtoe) in 2008 increased to 0.827 Mtoe in 2016 and is projected to rise to 5.5 Mtoe (5.5% of primary energy production) by 2025 [14]. Flat plate solar collectors are the most widespread solar thermal application in Turkey, which are generally used for the production of commercial and domestic hot water, especially throughout the coastal regions. In 2017, Turkey had 14 million m<sup>2</sup> of collector surface area installed with a heat output of 0.4 Mtoe contributing to energy production [13].

**3.5. Geothermal energy**

Turkey is one of the countries with significant potential in geothermal energy and there may exist about 2000 MW<sub>e</sub> of geothermal energy usable for electrical power generation in high enthalpy zones. Turkey's total geothermal heating capacity is about 31,500 MW<sub>th</sub>. At present, heating capacity in the country runs at 1240 MW<sub>th</sub> equivalent to 150,000 households. These numbers can be heightened some seven-fold to 7,180 MW<sub>th</sub> equal to 800, 000

households through a proven and exhaustible potential in 2014. Turkey must target 1.2 million

house holds equivalent 7,700 MW<sub>th</sub> in 2020 [12, 13, 25].

#### 4. Conclusions

Renewable energies have the important potential of allowing development and environmental challenges to be dealt with jointly. In recent years there has been a significant development of alternative energy technologies, both in terms of performance and cost reduction. Moreover, many developing countries are particularly well positioned when it comes to developing a new generation of energy technologies. For example, simple technologies like solar water heaters, solar pasteurisers, wind pumps, improved cooking stoves, biomass briquettes, and biogas, have the potential to make a huge difference in securing modern energy services for the poor and to be an important step towards achieving the Millennium Development Goals. On a broader level, grid-connected large-scale hydro plants and wind power have great potential to enable growth and development in developing countries, while not countering ongoing efforts to mitigate climate change and reduce greenhouse gas emissions.

Energy production from renewables should be improved in Turkey to reduce the dependency and environmental pollution and increase the development level of the country by increasing the economic level of the country. The author believes that Turkey does not use its clean energy sources efficiently and should promote new technologies and use all its renewable energy potential. According to the government policies, new capacity investments, supply diversity and maximizing energy efficiency are critical points for Turkey in conjunction with the

increasing primary energy demand. In order to avoid the risks linked to both energy dependence and developing a sustainable energy model, the government is committed to promoting alternative solutions based mainly on local and renewable energy sources. Therefore, Turkey has initiated a forward looking and innovative energy policy in which renewable energy plays a significant role.

After examining and analyzing renewable energy potential and its current utilization of Turkey, it can be briefly concluded that renewable energy has been more popular. In Turkey, the share of renewable energy in the total electricity generation was 9% while it was over 10% for installed power capacity in 2017. Added to them, essentially wind energy from the available renewables in Turkey has showed significant increase. Wind energy occupies about 82% of the total renewable based installed power capacity of Turkey as of July 2018. Solar and geothermal based installed power capacities take the remaining 30% with the shares of about 18% and 12%, respectively. Turkish governments should be give more and more attention to develop the renewable energy utilization for achieving the 2023 renewable targets. Turkish governments must give more importance to the utilization of its renewable energy resources with the assistance of useful laws and amendments as well as major incentives which can all remove the available barriers to renewable energy investments.

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