



Renewable electricity for sustainable development in Turkey

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Accepted 02 February 2019

Abstract

In order to reduce dependency on imported expensive fossil fuels, Turkey should be used the renewable energy sources including hydropower, wind, solar, geothermal and biomass energy for electricity generation, because they are domestic and abundant. However considering the total cost of renewable energy production, these sources can be used not to replace the fossil fuels, but to supply energy requirement in the country. Renewable energy is being pointed as a potentially significant new source of jobs and climate change mitigation. The use of renewable energy resources, primarily hydropower, wind and solar, is expected to grow significantly within Turkey's power system. There has been tremendous growth in the installed renewable electricity generation capacity in recent years and Turkey saw a record year in 2017. As deployment of renewable electricity generation technologies is on the eve of acceleration, there is a need to better understand how the rising share of wind and solar will affect Turkey's power system. This paper discusses the status, features, and trends, as well as technical potentials of renewable energy for electricity generation in Turkey. The present study also shows that there is enough renewable potential for meeting the country energy and electricity demand.

Keywords: energy demand; renewable electricity; sustainable development; Turkey.

1. Introduction

The rise of renewable energy is driven by dramatically falling renewable energy costs across the technology spectrum [1-3]. Since 2009, solar *tablr*PV module costs have fallen by more than 80%. The power generated by solar PV declined by 73% between 2010 and 2017. Onshore wind costs have also fallen sharply [4-6]. The global weighted average cost of electricity from onshore wind fell by 22% between 2010 and 2017, making it one of the most competitive sources of electricity available today [8-10]. The cost declines do not end there. By 2020, the average cost of power generation from all commercially available renewable energy technologies will be competitive with fossil fuels [11-14].

Renewable energy needs to be scaled up at least six times faster for the world to meet the decarbonisation and climate mitigation goals set out in the Paris Agreement [5]. The historic 2015 climate accord seeks, at minimum, to limit average global temperature rise to "well below 2°C" in the present century, compared to pre-industrial levels [6, 7]. Renewable energy and energy efficiency can, in combination, provide over 90% of the necessary energy-related CO₂ emission reductions [1]. Furthermore, this can happen using technologies that are safe, reliable, affordable and widely available.

While different paths can mitigate climate change, renewables and energy efficiency provide the optimal pathway to deliver most of the emission cuts needed at the necessary speed [1, 4]. Actual carbon dioxide (CO₂) emission trends are not yet on track. Under current and planned policies, the world would exhaust its energy-related carbon budget in less than 20 years. Even then, fossil fuels such as oil, natural gas and coal would continue to dominate the global energy mix for decades to come [1, 5].

The total share of renewable energy must rise from around 20% of total final energy consumption in 2018 to around two-thirds by 2050 [8]. Over the same period, the share of renewables in the power sector would increase from around one-quarter to 85%, mostly through growth in solar and wind power generation [9]. The energy intensity of the global economy will have to fall by about two-thirds, lowering energy demand in 2050 to slightly less than 2015 levels. This is achievable, despite significant population and economic growth, by substantially improving energy efficiency, the report finds [5-7]. Turkey is a poor fossil energy country; 75% of total energy requirement has been supplied by imported fuels as shown in Table 1. As shown in Table 1, Turkey's energy production is only 35 374 kilotons of

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oil equivalent (ktoe) while energy consumption was 136 230 ktoe in 2016. Petroleum, gas and coal have the biggest share in total energy consumption as shown in Table 1. If we look to the Table 1, we saw that only 25% of the total energy consumption supplied by domestic resources. It means that Turkey is an energy imported country and it should pay a lot of money for buying these fuels. Therefore, the governments and private sector companies should use domestic and clean renewable energy sources as soon as possible [10-14].

In Turkey, energy utilization for industry and heating purposes is increasing very fastly in recent years. Thermal power plants are also use commercial fuels such as hard coal, natural gas and coal/biomass co-firing [12]. Diesel engines are widely used for pumping and irrigation in the rural areas instead of renewable energy. Therefore large capital costs are paid for diesel engines [13]. But, substitution of renewable electricity from solar and wind instead of diesel engines appears to be practically possible. Solar energy and biogas may be an alternative energy source for space heating in rural regions [10-20].

Table 1. Turkey's energy situation in 2017 (ktoe).

Energy source	Production	Consumption
Coal and Lignite	14 470	38 824
Oil	2 682	44 536
Natural gas	430	45 872
Hydropower	5 112	5 112
Geothermal	7 124	7 124
Bioenergy	2 536	2 536
Solar/Wind/Other	2 754	2 754
Total	35 108	146 758

ktoe: kilo tons of oil equivalent

2. Electricity generation in Turkey

The use of renewable energy resources, primarily hydropower, wind and solar, is expected to grow significantly within Turkey's power system. There has been tremendous growth in the installed renewable electricity generation capacity in recent years and Turkey saw a record year in 2017. As deployment of renewable electricity generation technologies is on the eve of acceleration, there is a need to better understand how the rising share of wind and solar will affect Turkey's power system [11-17].

This evidence-based analysis is designed to highlight priority areas and inform energy planners, system operators, decision-makers and key market players on the consequences of higher shares of renewables and what they would mean for transmission investment and integration strategies in Turkey [18-21]. This study will help inform discussions about Turkey's

transition to a low-carbon electricity system. Being one of the fastest growing economies and in view of the subsequent increase in Turkey's electricity demand, the analysis provides an important contribution to the energy security debate, proposing strategies on how the current transmission system can integrate higher shares of renewables [10-12].

Due to affordable technology costs, the wind and solar (defined together as variable renewable energy) are expected to continue. The analysis shows that Turkey can generate 20% of its total electricity from wind and solar by 2026 without negatively impacting transmission system and planning. Doubling the installed wind and solar capacity to 40 gigawatts (GW) is feasible without any additional investment in the transmission system compared to the Base Case scenario defined in this analysis [11-14].

3. Renewable electricity in Turkey

3.1. Introduction

As the 17th largest economy in the world and 6th largest in Europe, Turkey is experiencing an increase in its energy demand. Turkey has become one of the fastest growing energy markets among the OECD countries in the world, in parallel to its economic growth registered over the last ten years. Also, Turkey has been second largest economy on demand for

electricity and gas after China. Projections performed by Ministry of Energy and Natural Resources confirm that this situation will continue to be valid for medium and long term [12-14].

Turkey's energy policies and strategies are based on energy supply security, alternative energy resources,

diversity of energy resources, utilization of domestic energy resources to create additional value to economy, liberalization of energy markets, and energy efficiency. Due to this perspective, special emphasis has been made to maximum utilization of local and renewable energy resources as highest priority. On the other hand, the rapid pace of urbanization, the positive demographic trends, the economic expansion and rising per capita income are the main drivers of the energy demand. The energy demand is estimated to increase around 4 – 6% per annum until 2023 [11-14].

The Turkish government has made it a priority to increase the share of renewable sources in the country's total installed power to 30 percent by 2023. Renewable energy has been one of the important topics on Turkey's energy agenda. The Turkish government has made the last decade significant energy reforms. The significant progress that has been made in the field of renewable energy started after the enactment of the Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy (Renewable Energy Law, REL) in 2005. After 2005, the Turkish government kept producing, updating and implementing several laws and regulations. Due to this, Turkey's energy sector turned it into one of the most attractive investment destinations in the world. In line with the implementation of investor-friendly regulations and the high increase in demand, the Turkish energy sector is becoming more vibrant and attracts the attention of more investors for each component of the value chain in all the energy sub-sectors [4, 10, 12, 13].

Turkey continues to be one of the fastest growing energy markets in the world; its total energy demand has been increasing rapidly. While imported fossil fuels dominate Turkey's total primary energy consumption with 75%, one of the government's priorities is to increase the ratio of renewable energy resources to 30% of total energy generation by 2023.

As shown in Table 2, Turkey had 85.2 GW of installed electricity generation capacity at the end of 2017. The breakdown by generation sources in 2018 was as follows: 53% fossil fuels (natural gas, coal, liquid fuels, etc.), 32% hydro, 8% wind, nearly 6% solar and 1.5% geothermal. Almost all natural gas and around 40% of coal were imported. It is obvious that Turkey needs to become more energy independent – and exploiting its rich potential of renewable energy sources is the way to go [11-14].

According to the Ministry of Energy and Natural Resources, the total amount of investments required to meet the energy demand in Turkey by 2023 is estimated to be around USD 110 billion, more than double the total amount invested in the last decade. Turkey's ambitious vision for 2023, envisages especially interesting targets for the renewable part of the energy sector. These targets include [11-14]:

- 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.

Turkey has enough renewable energy such as hydro, biomass, solar, wind and geothermal energy (Tables 1-4 and Figs. 1-4). In recently, electricity generation from renewable sources is increasing steadily, especially solar and wind has more and more attention, after renewable energy law published by the Turkish government. Table 2 shows Turkey's installed capacity and generation development by sources in 2017. As shown in Table 2, the share of renewables about 43% (84 800 GWh) and the part of hydropower is highest (20%). Table 3 also shows Turkey's installed capacity targets for renewable power plant from 2017 to 2023. As shown in Table 3, the amount of installed capacity is increasing steadily from 39 960 MW in 2017 to 66 500 MW in 2023 [11-31].

Table 2. Turkey's installed capacity and generation development in 2017 (GWh).

Resources	Installed Capacity (MW)	Share (%)	Generation (TWh)	Share (%)
Natural gas	26 638	31	108.1	37
Hydropower	27 273	32	58.3	20
Domestic coal	9 872	11	44	15
Import coal	8 794	10	51.1	17
Renewables	11 000	13	26.5	10
Other	1 623	3	7.5	1
Total	85 200	100	295.5	100

Table 3. SHP plants (below 10 MW) by stage of development in 2017.

License type	Stage	Capacity (MW)	Number of power plants
Pre-License	Application stage	1064	240
	Evaluation stage	68.3	18
	Granted	389.6	84
	Granted	2687.8	479
Total		4209.7	821

3.2. Hydropower

In Turkey, potential of hydropower is very high and especially small-scale hydropower plants can be used to produce electricity in rural areas. Hydropower is the second largest source to generate electricity after the coal and provide around 40% of the electric energy in Turkey. The theoretical hydropower potential of the country has been estimated at 433 TWh/year, but economical potential was only 215 TWh/year. In 2017, the total hydropower installed capacity was 27 274 MW and total generated energy was 58 300 GWh in Turkey [20-27].

Small hydropower (SHP) performs a major role in the advance of agricultural modernization and rural electrification in Turkey. It is estimated that, Turkey has 910 GW electricity generation and 4686 MW total installed capacity for SHP. By the end of 2017, the total number of SHP stations in operation throughout the country was 157 with a total installed capacity of 1 360 MW in Turkey. Table 4 shows the small hydropower capacity. In 2017, total hydropower capacity is 29 000 MW and only small hydro power capacity is 4686 MW [20-27].

Table 4. Electricity production by dams in the GAP region since their first operation to 2012.

Hydraulic Power Plant (HPP)	Plant Type	Installed capacity (MW)	Operating Since	Total Electricity Production (kWh)
Atatürk Dam and HPP	Reservoir	2 400	1992	157 642 587 790
Karkamış Dam and HPP	Reservoir	190	2000	5 561 000 275
Şanlıurfa HPP	Canal	50	2006	932 839 611
Karakaya Dam and HPP	Reservoir	1 800	1987	190 909 871 299
Kralkızı Dam and HPP	Reservoir	94	1999	1 672 316 722
Dicle Dam and HPP	Reservoir	110	2000	2 777 925 211
Batman Dam and HPP	Reservoir	200	2003	3 885 089 279
Cağcağ HPP	Canal	15	1968	1 476 129 990
Erkenek HPP	Canal	12	1972	15 410 355
Birecik Dam and HPP	Reservoir	672	2000	27 220 970 225
GAP Total		5 540		392 094 140 757

The South-eastern Anatolia Project (GAP) is one of the largest power generating, irrigation, and development projects in the world and covering 3 million ha of agricultural land. The GAP project on the Euphrates and Tigris Rivers encompasses 20 dams and 17 hydroelectric plants. Once completed, 55 billion kwh of electricity will be generated annually which is 45% of the total economically exploitable hydroelectric potential [24-27]. The rate of physical realization in GAP energy projects is 74%. The total installed capacity of 10 HPPs now in operation is 5,530 MW and annual electricity production potential is 20.6 billion kWh. The total energy output of HPPs under GAP from their first operation up to the end of 2013 is 392.1 billion kWh which means 23.5 billion \$ in monetary terms. Hydraulic plants in the region

account for half of annual energy production in Turkey and the GAP contributes directly to national economy with its energy projects (Table 4).

3.2. Biomass

Turkey's current installed biomass capacity is 130 MW_e. Turkish biomass market has a good chance of reaching several hundred MW_e installed capacity in the near future [19-23]. Figure 1 shows electricity generation capacity from crop residues in Turkey [29]. Turkey has about 21,7 million hectares of forest area (about 27,2% of country's land area) [19]. A similar share is occupied by pastures and grasslands. The consumption of woody biomass has decreased from 22 to 10% because the consumption of liquefied petroleum gases (LPG) is increasing continuously. It

is easy to transport and ignite, and in addition it is a clean fuel [30]. The annual biomass energy potential

of Turkey has been estimated to be 33 Mtoe and the yearly biomass consumption was 2.54 Mtoe (Table 1).

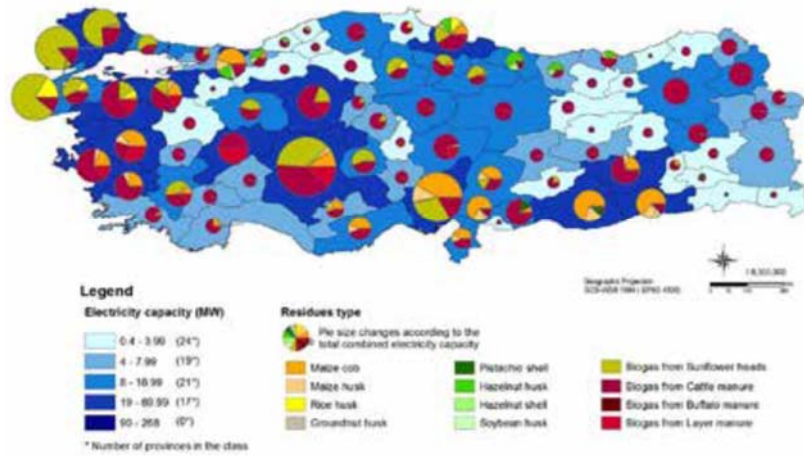


Figure 1. Electricity capacity generation (MW) from crop residues in Turkey.

3.3. Solar energy

Turkey has significant renewable energy (RE) potential, including solar, mainly as a result of its geographic location. Taking advantage of this potential will decrease the country’s dependence on imported fossil fuels as well as reduce greenhouse gas (GHG) emissions. Recognizing this, the government has established a target of at least 30% (or 127.3 TWh) of the total electricity generation from RE by 2023 [2]. In addition, it has set targets of 3 GW of installed solar power by 2019 and 5 GW by 2023. As a result, the solar market in Turkey has grown exponentially over the last few years, with installed solar capacity growing from 40 MW in 2014 to 3,421 MW at the end

of 2017 [10-14, 19-21].

Solar energy potential of Turkey is well since it located geographically in a region called the “solar band”. The government’s general directorate of renewable energy (YEKA) estimates that Turkey receives, on average, 1.02 million TWh/year of solar radiation each year. Turkey’s average annual total sunshine duration is calculated as 2640 h (daily total is 7.2 h), and average total irradiation as 1311 kWh/m².year (daily total is 3.6 kWh/m²) as shown in Figure 2. As shown in Figure 2, Mediterranean and Southeastern regions have the highest solar energy potentials with 1460 kWh/m².year and sunshine duration of 2993 hours per year.

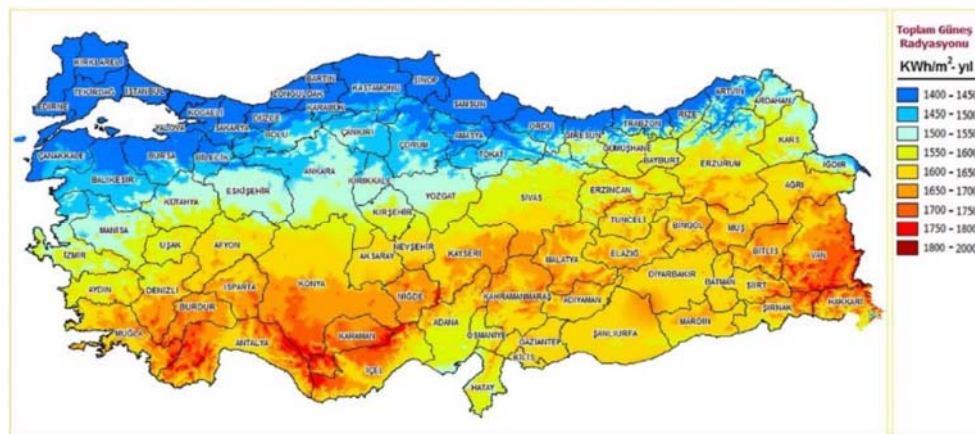


Figure 2. Solar energy potential in Turkey.

According to a study by the Ministry of Energy and Natural Resources (ETKB), in its high demand scenario, Turkey’s energy demand will increase by

approximately 7.5% per year by 2023 and will reach 538 TWh. The low demand scenario expects the energy demand to reach 480 TWh by 2023, with an

annual increase rate of 6.7%. Similarly, for the year of 2030, Turkey's energy demand will reach 757 TWh in the high demand scenario and 610 TWh in the low demand scenario [11-14].

Solar energy is one of the most valuable renewable energy sources, which is still untapped in Turkey, with an expected potential of at least 500 GW. Turkey's renewable energy investment totalled 2.2 billion USD in 2018, down 5% from 2017. At the end of 2018, the cumulative installed PV power in Turkey reached about 5,062.9 MW – a 48% growth compared to the previous year, when a total of 3,420.7 MW was installed. Photovoltaic installations started to take off in 2014 with 40 MW installed capacity. In 2018, about 1,642 MW of new PV power capacity was added (see Table 2) [2, 3].

3.4. Wind energy

In 2017, Turkey added 766 MW and bringing the country's total wind power capacity to 6,857 MW. Addition to this situation, marked a turning point for Turkey's wind industry: 2.11 GW were issued preliminary licences for 67 wind projects by Turkish electricity transmission operator TEIAS [16]. This completed a round which had started in June 2017 with the assignment of 710 MW of so called pre-licences projects. In addition, the country's first wind tender was held in August, where 1 GW of onshore wind capacity was allocated under Turkey's Renewable Energy Sources Department (YEKA) renewable program. 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. Figure 3 shows Turkey wind energy potential atlas [10-14].

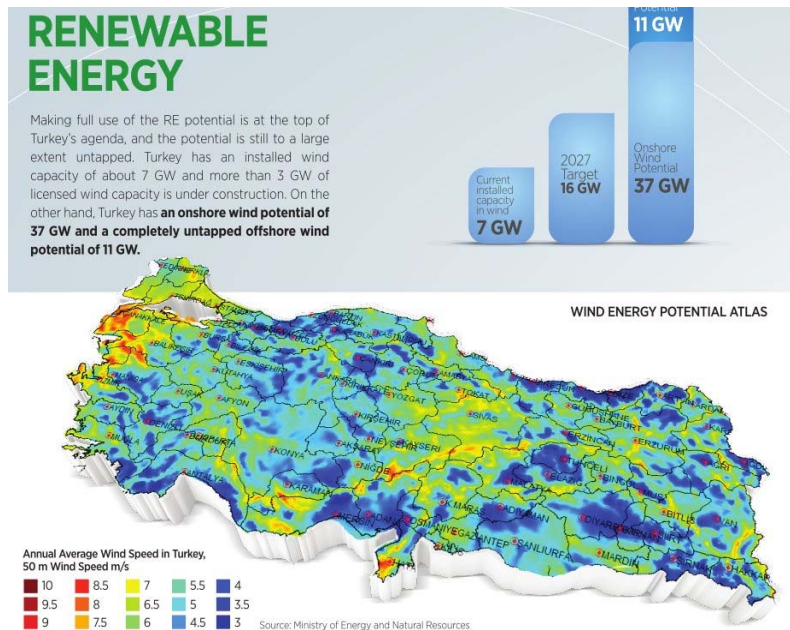


Figure 3. Turkey wind energy potential atlas.

3.5. Geothermal energy

Turkey's geothermal energy potential is well and a significant development was achieved geothermal electricity production and direct uses during last ten years. Geothermal Law published by the government and its regulations accelerated the geothermal activities. So, direct-use applications have reached 2886.3 MW_t, and including district heating (805 MW_t), 3 million m² greenhouse heating (612 MW_t),

thermal facilities, hotels heating 420 MW_t, balneological use (1,005 MW_t) and heat pump applications (42,8 MW_t). Geothermal electricity production has reached to 400 MW_e with 17 power plants. The geothermal power plants install capacity under construction is 165 MW_e. Figure 4 shows geothermal resources in Turkey [13-15].



Figure 4. Geothermal resources in Turkey.

4. Conclusions

With a rapidly growing economy Turkey has become one of the fastest growing energy markets in the world. Turkey has been experiencing rapid demand growth in all segments of the energy sector for decades. Recent forecasts indicate that the growth trend of 6-8 % per year will prevail in the energy sector in the following years. The primary energy consumption, which reached around 126 million tons of oil equivalent (toe) in 2010 will rise to 146 million toe in 2017 and 222 million toe in 2020. The limits of Turkey's domestic energy sources in light of its growing energy demand have resulted in dependency on energy imports, primarily of oil and gas. At present, around 30 % of the total energy demand is being met by domestic resources, while the rest is being satisfied from a diversified portfolio of imports.

Turkey has the challenge to decrease its energy dependency, fulfill the huge growth in the energy demand but at the same time reduce the GHG emissions as mentioned in the Paris Agreement. The current plans for generation are mainly based on the addition of coal and gas power plants and would lead as we can see in the baseline scenarios to a huge increase in the GHG emissions as well as the imports of crude oil and coal.

Acknowledgement: The author greatly acknowledge to Professor K. Kaygusuz and Professor M.S. Güney

A shift toward renewable energy technologies is expected with the GHG mitigation scenario. This scenario is quite ambitious in term of added capacity but the investment costs are actually lower than the nuclear scenario. The addition of capacity stops after 2023 since the government plan is only for the period 2013-2023 explain why this scenario has higher GHG emissions than the nuclear scenario but the government should keep on the same pace for additional renewables for the period 2023–2040 since the plans are currently not enough.

Renewable energy sources derive their energy from existing flows of energy from ongoing natural processes, such as sunshine, wind, flowing water, biological processes, and geothermal heat flows. A general definition of renewable energy sources is that renewable energy is captured from an energy resource that is replaced rapidly by a natural process such as power generated from the sun. Currently, the most promising alternative energy sources include wind power, solar power, and hydroelectric power. Other renewable sources include geothermal and ocean energies, as well as biomass and ethanol as renewable fuels.

to valuable suggestions for preparation of this manuscript.

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