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Abstract

Turkey's demand for energy and industrial development, in parallel to urbanization and growing population, are constantly increasing along with electricity demand. In order to meet this demand, there are limited hydrocarbon resources, nonetheless, Turkey has a huge potential for renewable resources that can meet this demand instead of imported coal and natural gas in electricity generation. The use of renewable energy sources, including wind and solar power, has increased rapidly in recent years in Turkey and record growth in renewable power generation has been recorded in a short time where solar power installed capacity reached 5062 MW and wind power reached to 7005 MW by the end of 2018. This trend has the potential to continue and the country's cleaner renewable energy sources can be the main source of electricity generation. This study examines the penetration of renewable energy sources to the grid by analyzing the current grid situation. The results show that the estimated installed capacity for electricity generation capacity of Turkey is about 111.710 MW and 127.754 MW, respectively for the years 2024 and 2029.

Keywords: Electrical energy, Renewable, Hydroelectric, Wind energy, Solar energy

I. Introduction

Turkish economy and industry are growing more rapidly with an increase in population resulting in more demand for energy continuously. For this reason, in order to sustain the development of the country, it needs high quality, continuous, cheap and reliable energy sources to meet the demand. Although Turkey has many sources of energy, it does not have a high potential for hydrocarbon reserves, but renewable energy resources such as solar and wind have great potential due to the geographic location. This benefit brings the potential for renewable energy in electricity production to reduce its dependence on external hydrocarbon sources such as imported natural gas. In addition, environmental awareness is needed to take advantage of these resources to the maximum extent. In addition to wind energy, which started to be used 20 years ago, there has been a very important step to generate electricity from geothermal and solar energy resources as well.

The amount of energy consumed per person is used as a measure of the development and welfare level of the countries. When developed countries are evaluated from this point of view, it is observed that the average energy consumption of OECD is about 6500 kWh/person and the annual energy consumption per person is 10,000 kWh/year in European countries. As shown in Fig. 1, the electricity gross generation per capita in Turkey is 3700 kWh/year and net consumption is about 2855 kWh/year. When electricity consumption per capita is assessed by considering Turkey's process of development, it is evident that the demand will increase continuously in the coming years.

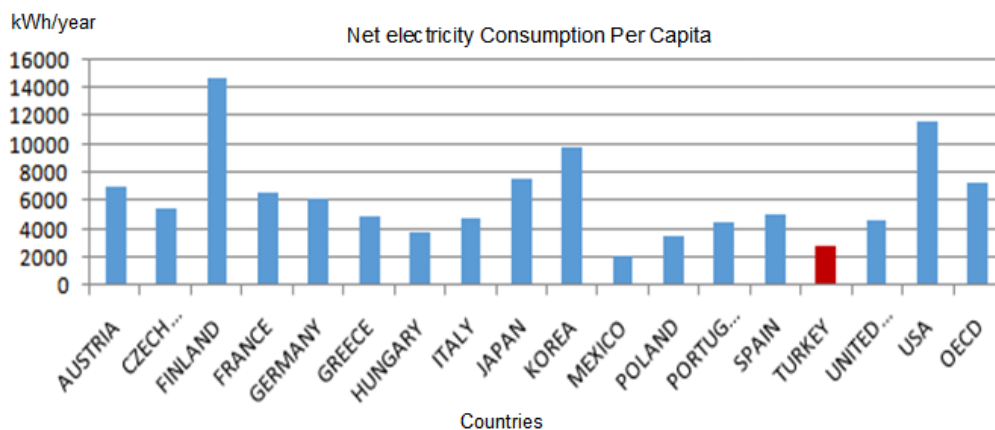


Figure 1. Net electricity consumption per capita of OECD countries in 2017 (Data from TEIAS, 2020)

Each year about 300 TWh of electricity is consumed in Turkey, which is almost a fifth of the amount of primary energy used in Turkey. The gross electricity consumption in Turkey in 2018 was 304,8 billion kWh. Turkey's energy use is expected to increase by 50% over the next decade. The demand for electricity in 2018, with an increase of 3.8% reached 306.7 billion kW has shown in Fig. 2.

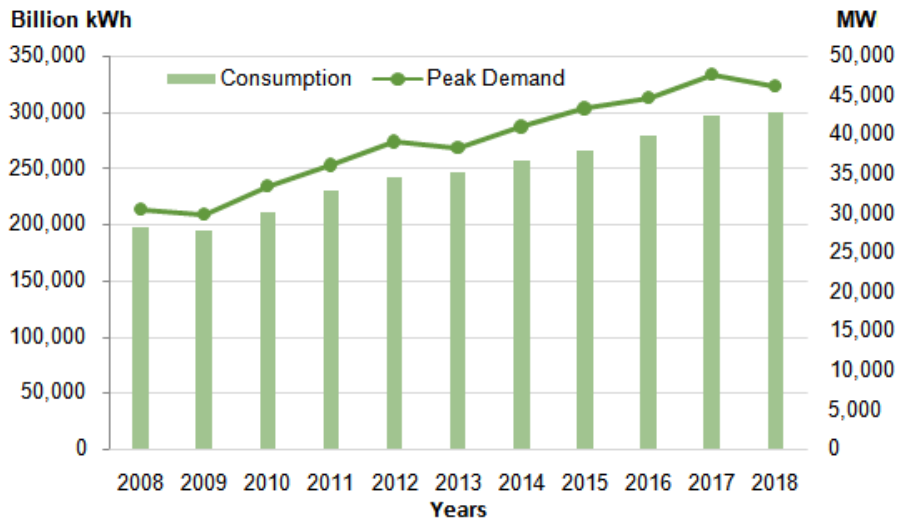


Figure 2. Changes in Turkey's electricity generation and peak demand values

In 2018, 37.3% of Turkey's electricity production was supplied from coal, 29.8% from natural gas, 19.8% from hydraulic energy, 6.6% from wind power, 2.6% from the solar energy, 2.5% from geothermal energy and 1.4% are from other resources. (MENR, 2020)

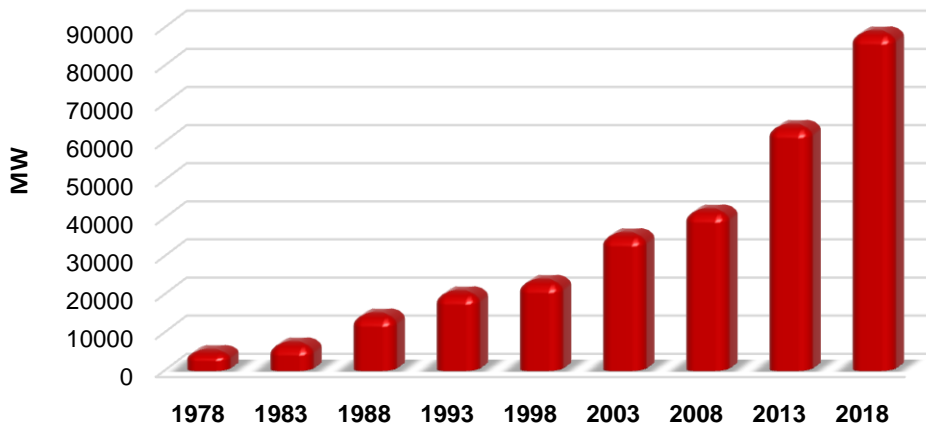


Figure 3. Annual installed power capacity increase of Turkey

As of the end of September 2019, Turkey's installed power reached 90,720 MW, which represents a threefold increase in 15 years. Distribution of Turkey's installed power by resources as of the end of September 2019 are as follows; 31.4% hydraulic energy, 28.6% natural gas, 22.4% coal, 8.1% wind power, 6.2% solar energy, 1.6% geothermal and 1.7% is in the form of other resources. Investigating the installed power capacities per source type, it is seen that the solar power plants increased by 48% to 5,068 MW and the wind power plants increased by 7.5% to 7,005 MW. The share of renewable power plants in installed capacity is 47.8% including hydropower plants, and the solar power plants have the highest increase in installed capacity.

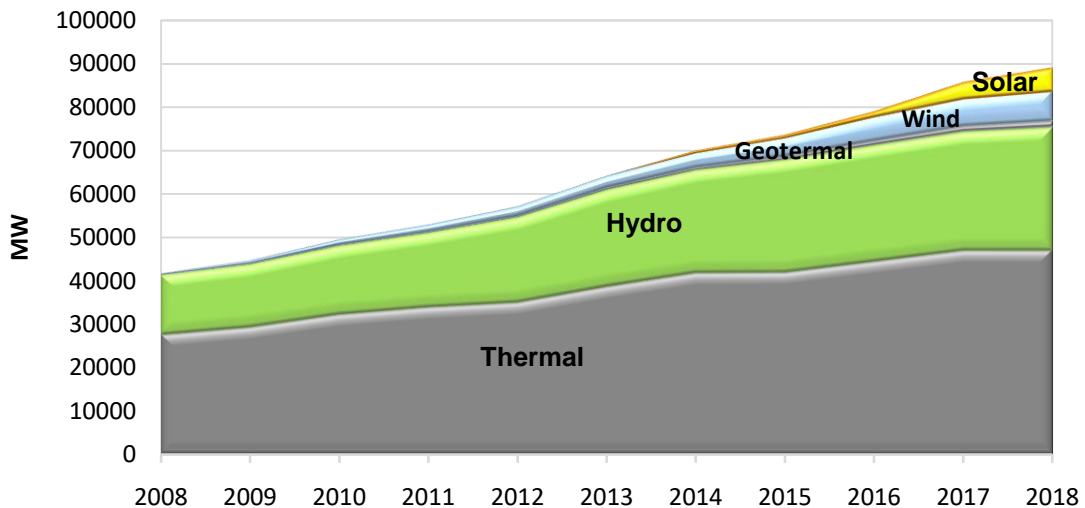


Figure 4. The change of Turkey's electricity installed capacity by years based on resources

II. Renewable Energy Potential in Turkey

Turkey is in fortunate geography in terms of renewable energy sources. It is particularly rich in hydraulic, solar, wind, geotherma land biomass energy potentials.

a) Hydraulic Energy

The average annual precipitation is about 642.6 mm in Turkey, this value corresponds to 501 billion m³ of water per year (DSİ, 2020). However, within the framework of today's technical and economic conditions, the surface water potential that can be consumed for various purposes is an average of 98 billion m³ per year, including 95 billion m³ from domestic rivers and 3 billion m³ from rivers from neighboring countries.

In determining the hydroelectric potential, gross potential, technical potential, and economic potential concepts are important. Turkey's theoretical hydropower potential is about 433 billion kWh whereas the technical potential is about 216 billion kWh and both technically and economically viable potential was calculated to be 130 billion kWh. Turkey's gross potential is 1% of the world total potential (433,000 GWh/year), and 16% of the European total. Figure 5 shows the increase in the installed capacity from hydraulic power plants in Turkey. As can be seen, there is a regular increase in hydraulic energy installed power.

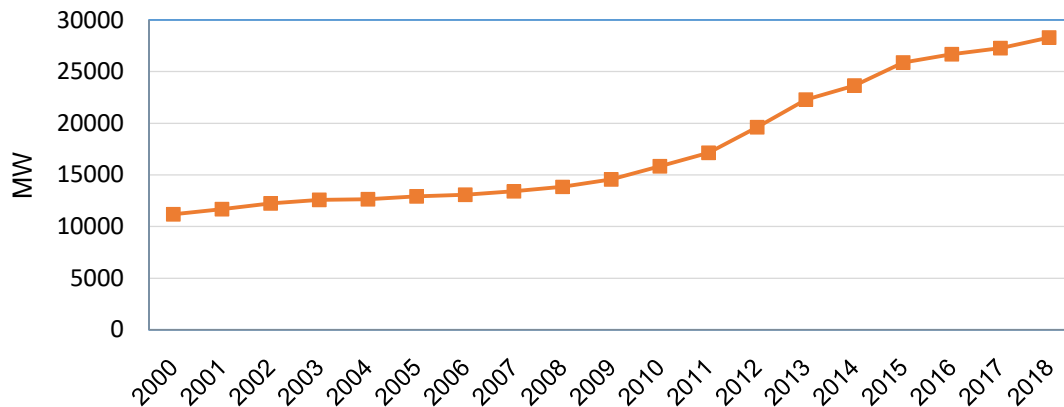


Figure 5. The development of hydraulic power installed capacity in Turkey

b) Solar Energy

Due to the geographical location of Turkey, the average annual sunshine time of 2640 hours and annual average day light duration in Turkey is 7.5 hours and the average annual radiation is 1,527 kWh/m², which is higher than most of the European countries as Fig. 6a shows.

Nevertheless, Turkey's installed solar capacity is only around 5.53 GW. According to estimates, Turkey's potential for electricity generation from solar power is 380 TWh per year and has a potential of about 56,000 MW installed. As seen in Fig. 6b, solar energy capacity is constantly increasing and reached 5062 MW by the end of 2018. This value corresponds to 0.5% of the total power installed capacity. Turkey constitutes a rate of 0.5%, which is quite inadequate. However, in the near future, Turkey is expected to reach higher capacities in terms of renewable generation (Fig. 6).

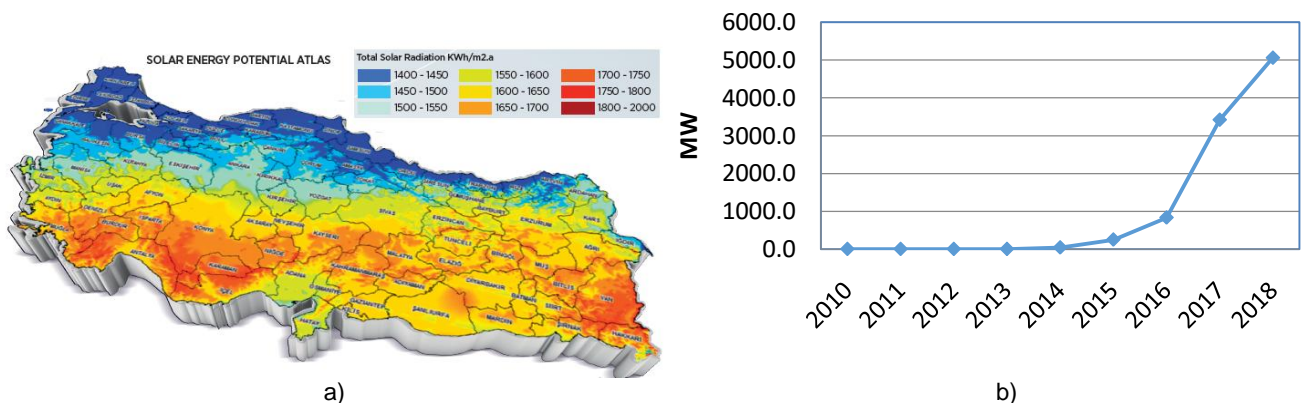


Figure 6. a) Turkey's solar energy potential atlas, b) The changes of solar power installed capacity in Turkey

c) Wind power

Wind energy today is also one of the most important topics in the Turkish energy mix. Turkey's wind energy potential was prepared in 2007 and Turkey has about 5000 MW potential in the zone of 8.5 m/s and has a potential of 48,000 MW in the zone 7.0 m/s speeds. Fig. 7 shows the changes in Turkey's wind power install capacity. As can be seen, Turkey shows a significant increase in wind power installations in recent years.

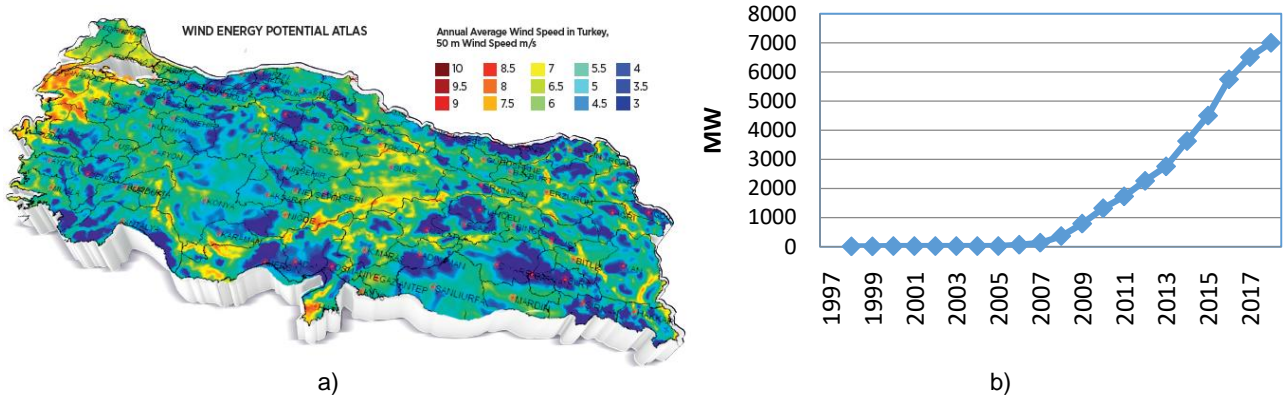


Figure 7. a) Turkey's wind power potential map b) The changes of wind power installed capacity in Turkey

Turkey implemented a unique procedure for areas with solar and wind energy resources called the Regulation for renewable energy resource area (RERA). RERA aims to create large-scale (1000 MW) renewable energy resource sites in the state. Through RERA, it is planned that an additional 20,000 megawatts installation be added to the energy mix in the following 10 years.

Turkey's offshore wind potential is also evident with the possibility of reaching 32 GW. Because of difficulties in application, Turkey's offshore wind energy potential is estimated to be around 11.000 MW. Bozcaada, Bandirma, Gokceada, Inebolu, and Samandag coastlines are the most suitable locations for offshore wind farm development.

III. Utilization of Electricity Production from Renewable Sources in Turkey

It is anticipated that more than 50% of the electricity used in Turkey will be coming from renewable resources, which currently corresponds to 150 billion kWh of electricity. As illustrated in Fig. 8, Turkey's hydroelectric generation differs in some years, consistent with the total electricity production shows that there is a continuous upward trend in installation and generation. Electricity generation from wind and solar energy started in 2008, showing a logarithmic increase over the years. It is predicted that electricity production from wind and solar will reach hydroelectric production capacity in the coming years.

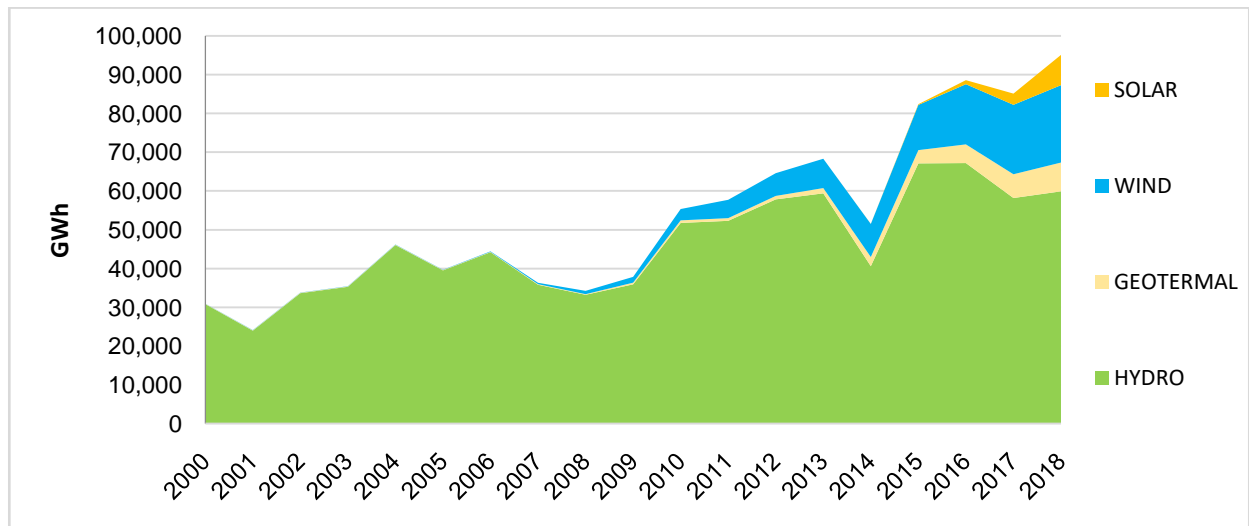


Figure 8. Turkey's electricity generation from various renewables including dam type hydros between 2000-2018 years

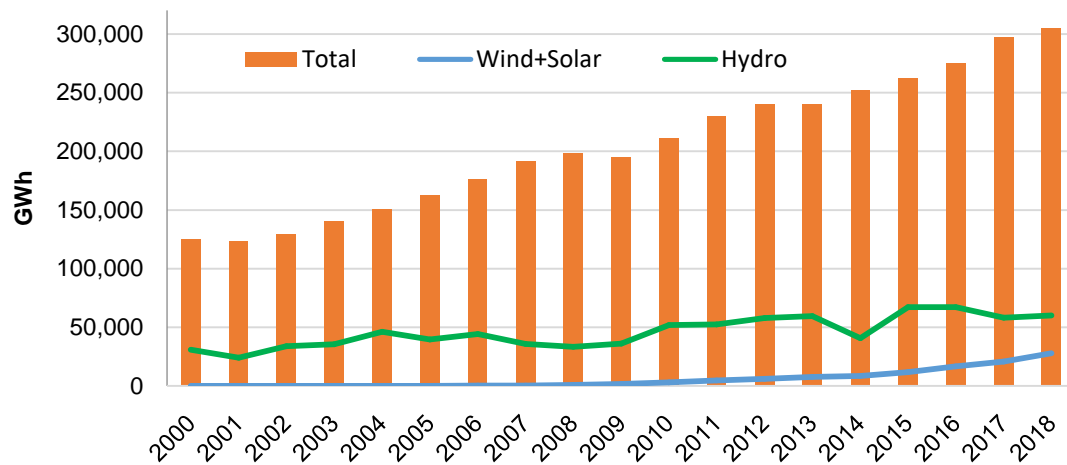


Figure 9. Turkey's total electricity generation comparison with renewable resources between 2000-2018 years

According to the estimation results, in parallel with the development of the gross consumption estimates the capacity of grid in 2028 is expected to be 257 billion kWh with an average increase of 2.4% compared to the low scenario, 284 billion kWh with an average increase of 3.2% according to the base (reference) scenario, and 315 billion kWh an average of 4% according to the high scenario. The estimated installed capacity for the electricity generation in Turkey for the year 2024 is 111.710 MW, while for the year 2029 is 127.754 MW.

IV. Conclusions

Although Turkey shows a continuous increase in electricity demand, electricity production is largely dependent on external sources such as natural gas and imported coal. Therefore, it gives a great opportunity for the implementation of renewable energy sources, especially solar and wind energy in the country.

Turkey's total installed capacity is about 91,341.7 MW by the end of 2019. Among this capacity, 28.36% of the installed power is composed of natural gas power plants, 22.60% hydroelectric power plants with dams, and 11.06% of lignite power plants. While the installed power capacities of renewable energy sources including dam types hydros are about 44,477.8 MW in total where this ratio corresponds to 48.7% of the total installed power. Based on Turkey's electricity demand projections, in order to meet the demand, there is a need of about 37,000 MW power capacity in addition to the existing installed capacity by 2030. This amount corresponds to 40% of the current capacity. Hence, obtaining the expected power from solar and wind energy will contribute greatly to both the evaluation of domestic resources and the reduction of emissions.

References

- MENR, 2020, Ministry of Energy and Natural Resources, www.enerji.gov.tr, Turkey
- TEIAS, 2020, Turkish Transmission Operator Co. www.teias.gov.tr, Turkey
- Guide, 2019, Investor's Guide For Electricity Sector In Turkey, MENR, 2. Edition.
- EPIAS, 2018, Electricity Market Summary Information Report, Energy Markets Operator (Epias)
- European Commission, 2013, Bringing Europe and third countries closer together through renewable energies.
- A. Ilhan, M. Bilgili, 2016, An Overview of Turkey's Offshore Wind Energy Potential Evaluations, J. of Sci. Reviews 9(2): 55-58
- MENR, 2019, Turkey Electricity Demand Projections Report, 2019-2039, www.enerji.gov.tr
- DSİ, 2020, General Directorate of State Hydraulic Works, www.dsi.gov.tr