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# Potential and utilization of wind and solar energy in Turkey

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**Abstract**
As a developing country, Turkey's prosperity and welfare depends heavily on having access to reliable and secure supplies of energy. As a result, the country's future energy requirements have become a policy priority in recent years. Fossil fuels such as coal, oil, and natural gas are currently the world's primary energy sources. These energy sources have depleted in reserves in recent years and they can also cause irreparably damage to the environment such as global warming and climate change. These environmental concerns can be addressed, to some extent, through more sustainable solutions such as the use of renewable energy resources. In Turkey, the economic and environmental impacts of fossil fuels use have become hard to ignore. In recent years, Turkey has been catching up with global call to shift to renewable energy use and is now putting a focus on renewable energy in its future energy mix. The paper discusses challenges and concerns over the sustainable energy of the country.

*Keywords:* Renewables; sustainable energy; energy policy; bioenergy; energy governance

## 1. Introduction

Wind and solar PV are currently the fastest-growing sources of electricity globally [1]. In 2015, their additional annual generation met more than 90% of incremental demand for electricity. Between 2008 and 2015, the average cost of land-based wind decreased by 35% and that of solar PV by almost 80% [2]. Their deployment is moving on from a phase where the main priorities were technology learning and cost reduction. Today, increasing evidence of a new phase of deployment can be encapsulated by the notion of next-generation wind and solar power; in this phase, wind and solar PV are technologically mature and economically affordable [3]. Technological maturity and lower costs make wind and solar power an increasingly attractive option for policy makers seeking to meet energy policy objectives, such as improving energy security by diversifying supply, reducing local pollution and reducing $CO_2$ emissions [4].

Wind and solar power are expected to make a critical contribution to meeting the ambitions of the Paris Agreement [5]. Their contribution to power systems around the globe is rapidly moving from marginal to mainstream, including developing countries [3]. The success of these sources is driving change in power systems around the globe. Electricity generation from both technologies is constrained by the varying availability of wind and sunshine, which makes their output variable over time [6]. Where variable renewable energy (VRE) is growing beyond a few percentage points as a share of annual electricity generation, power system operation and planning are being upgraded and adapted to accommodate VRE on the grid. These adaptations ensure a reliable balance between electricity supply and consumption at all times, even in the presence of double-digit shares of VRE in annual generation. For example, coal power plants in Denmark have been upgraded to allow for more flexible operation, starting plants quickly and allowing them to change their output across a wide range. In Germany, the four transmission system operators (TSOs) began sharing certain reserve capacities in 2008, which has allowed for a reduction in their combined reserve requirements despite ongoing VRE deployment [1-6].

Turkey is situated at the Southeastern Europe and Eastern Mediterranean region with a population of about 83 million. Turkey has experienced rapid economic growth since 1980s and today Turkey ranks among the fastest growing energy markets in the world. Turkey‟s total national installed capacity

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is about 90 000 MW by the end of 2014 with the average annual growth rate of 4%. Total power generation of the country rose from 194.813 GWh in 2009 to 235 000 GWh in 2014, with an average growth rate of 6,7% [1-3]. Hence, energy-related CO2 emissions have more than doubled since 1990 in Turkey. Turkey has ratified Kyoto Protocol in 2009. There are several efforts to control and mitigate GHG emissions in the country. In this regard, the utilization of renewable energy resources, such as solar, geothermal, and wind energy, appears to be one of the most efficient and effective ways in achieving the Kyoto Protocol's requirements [6-10].
Turkey does not have enough primary energy sources such as petroleum and natural gas. Turkey's second largest energy source after coal and natural gas is hydro. The Turkish government hopes that hydro capacity will expand to 35,000 MW by the year 2020. Furthermore, geothermal energy is the only renewable energy source not originating from solar energy which includes direct use of heat, electricity production and geothermal heat pump. Turkey is the seventh richest country in the world in geothermal potential for its direct use and for electricity generation. It is located on the Alpine–Himalayan organic belt, having one-eighth of the world's geothermal potential [2]. Turkey has 170 geothermal fields over 400 ºC temperature and they are located at Western and Central parts of the country [3]. To realize Turkey's sustainable development, the national energy development strategy includes an energy conservation priority policy, and at the same time is vigorously developing renewable energy and new energy in Turkey [10-16].

Renewable energy technologies produce marketable energy by converting natural phenomena/resources into useful energy form. In Turkey, such as wind and solar these resources represent a massive energy potential, which greatly exceeds that of fossil fuel resources. The usage of renewable energy resources such as wind and solar in Turkey is a promising prospect for the future as an alternative to conventional energy. This study presents an overview on the potential and production of wind and solar energy in Turkey [3].

## 2. Energy production and consumption in Turkey

Turkey's energy policy target is planned to reach a 20% renewable energy share by the year of 2020, and 30% in 2050, respectively [4]. 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 renewable energy sources. The Ministry of Energy and Natural Resources (MENR) has listed concentrating solar power as an important research issue in the "Long-Term Science and Energy Technology Development Plan‟ [4]. On the other hand, up to now, no commercial solar thermal power plant is in operation in Turkey [3].

Table 1 shows Turkey's renewable energy potential [4]. Table 2 also shows potentials for investment for renewable energies in Turkey. Renewable energy production makes up approximately 14.4% of the total primary energy supply (TPES), i.e. 10.30 Mtoe in 2007, and renewable sources represent the second-largest domestic energy source after coal. Table 3 and 4 shows solar energy potential in Turkey [5-11]. In spite of this high potential, solar energy is not now widely used, except for flat plate solar collectors. They are only used for domestic hot water production, mostly in the sunny coastal regions. In 2014, about 13 million m2 solar collectors were produced and it is predicted that total solar energy production is about 0.968 Mtoe [6-12].

Table 1. Renewable energy potential in Turkey

| Energy source | Potential (MW) | Power plants With licence (MW) |
|---|---|---|
| **Hydropower** | 45 000 | 20 218 |
| **Wind** | 48 000 | 9 244 |
| **Geothermal** | 600 | 636 |
| **Solar** | 33 | - |
| **Biomass** | 9.0 | 54 |
| **Biogas** | 2.0 | 190 |

In recent years, as a result of applied important structural changes and increased investment incentives in renewable energy, investment demands above the potential on wind energy has arisen in Turkey. In the near future there will be an overloaded demand to solar energy like wind energy. In this

context the possible usage areas and rate effects of renewable energies replaced with fossil fuels to the economical benefit of the country can be examined.

Table 2. Potentials for investment for renewable energies in Turkey

| Sectors | Million $ | Remarks |
|---|---|---|
| **Hydroelectric** | 164 | Economical development potential of 28,600 MW, Corresponding 100,000 GWh/a |
| **Wind power** | 67 | Economical development potential of 48,000 MW With wind speed > 7 m/s |
| **Solar thermal** | 175 | Economical development potential of 131,000 GWh/a, Corresponding to approx. 300 million $m^2$ collector area |
| **Biogas** | 8 | Agricultural residual material and dung, when used for electricity generation, 1,000 $MW_e$ and 7,000 GWh/yr |

Table 3. Monthly average solar potential of Turkey

| Months | Monthly total Solar energy (Kcal/$cm^2$.month) | Monthly total Solar energy (kWh/$m^2$.month) | Sunshine Duration (hours/month) |
|---|---|---|---|
| **January** | 4.45 | 51.75 | 103.0 |
| **February** | 5.44 | 63.27 | 115.0 |
| **March** | 8.31 | 96.65 | 165.0 |
| **April** | 10.51 | 122.23 | 197.0 |
| **May** | 13.23 | 153.86 | 273.0 |
| **June** | 14.51 | 168.75 | 325.0 |
| **July** | 15.08 | 175.38 | 365.0 |
| **August** | 13.62 | 158.40 | 343.0 |
| **September** | 10.60 | 123.28 | 280.0 |
| **October** | 7.73 | 89.90 | 214.0 |
| **November** | 5.23 | 60.82 | 157.0 |
| **December** | 4.03 | 46.87 | 103.0 |
| **TOTAL** | 112.74 | 1311 | 2640 |
| **AVERAGE** | 308.0 cal/$cm^2$-day | 3.6 kWh/$m^2$-day | 7.2 hours/day |

Table 4. Regional distribution of solar energy potential in Turkey

| Region | Total solar radiation (kWh/$m^2$-year) | Sunshine Duration (hours/year) |
|---|---|---|
| **Southeastern Anatolia** | 1460 | 2993 |
| **Mediterranean** | 1390 | 2956 |
| **East Anatolia** | 1365 | 2664 |
| **Central Anatolia** | 1314 | 2628 |
| **Aegean** | 1304 | 2738 |
| **Marmara** | 1168 | 2409 |
| **Black Sea** | 1120 | 1971 |

## 3. Wind Energy

Wind energy is the fastest growing energy source and technology in the world and wind power is one of the most widely used alternative sources of energy today. In most of the some countries wind power in share of gross electric consumption is continuously increasing. As an example, in Germany its share has reached to 6.4% in 2010. The west parts of Anatolia have been identified as very favorable locations for wind power generation in Turkey [7]. As for the background in Turkey, wind energy has always played an important role in the historical and economical development of Anatolia [8]. The people

used wind energy for hundreds of years for pumping water and grinding grain in Anatolia. Then, they must have been dominant landmarks already in the 14th century in Anatolia and the wind mills were built mainly in the 19th century. Recently, wind power as a potential renewable energy source has grown in Turkey. Today, it is estimated that Turkey has 160 TWh a year of wind potential, which is about twice as much as the current electricity consumption of Turkey [9].

The Turkish market at present has a large pipeline of projects. The Turkish Wind Power Association estimates that under the current regulatory framework a total installed capacity of about 10 GW will be reached within the next ten years, but it could be as high as 20 GW with the right amendments to the regulatory framework. Turkey has become one of the leading players in the European wind market and globally, and was the 10th largest annual market in 2015 [13].

Turkey's wind resources are estimated at more than 48 GW from areas with >7 m/s wind speeds at 50 meters. As of the end of 2015, the Aegean region (EGE) had the highest installed wind capacity with a total of 1,780 MW, followed by the Marmara region with 1,743 MW and the Mediterranean region (Akdeniz) with 717 MW [6-8]. The Turkish wind market is dominated by local developers: the 685 MW currently under construction is divided between Türkerler (343 MW), Güriş (255 MW) and Bilgin Enerji (87 MW). On the other hand, the leading players in the Turkish wind market are Polat Energy (551 MW), Demirer Holding (368 MW), Borusan EnBW (319 MW) and Bilgin Energy (312 MW), followed by Aksa Energy (269 MW) [13].

According to Ministry of Energy and Natural Resources, the wind potential of Turkey is given as 88,000 GW and the economic potential is estimated as 10,000 MW or higher [8]. Although, wind energy has a significant contribution to the energy system, for effective energy planning in the grid systems, prediction of wind energy production should be accurately up to 48-72 hours. Today, the majority of wind energy projects in Turkey are concentrated in the west with and Mediterranean regions with a total 25 projects. The installed capacity of wind energy is expected to reach 20,000 MW by 2023.

## 4. Solar Energy

Solar radiation arriving on earth surface is the most fundamental renewable energy source. In recent years, solar energy utilization in various applications has increased significantly. Turkey is promising country for solar energy potential. Turkey's geographical location is highly favorable for the utilization of solar energy. Turkey is geographically located (36-42°N latitudes) in a useful position for the solar power in the South Eastern of Europe and the Mediterranean [3]. Solar radiation incident on a horizontal surface and sunshine duration are measured in the meteorological stations by Turkish State Meteorological Service (TSMS) (Figure 1 and 2) in Turkey [6-8]. The country has an average 3.6 kWh/m$^2$-day irradiation and 7.2 hours insolation time per day as shown in Table 3. In the southern parts of Turkey, there are about 3000 sunshine hours per year as shown in Table 4 [6]. The insolation values are higher and conditions for solar power generation are comparable to Spain. Table 3 indicates that the yearly total solar radiation is 1311 kWh/m²-year, and the average total yearly irradiation duration period is 2640 h [9]. Figure 2 shows the solar map of Turkey. The solar resource greatly changes in various areas. Southeastern Anatolia and Mediterranean regions of Turkey are in the highest levels with closing to 1500 kWh/m²-year [6-8].

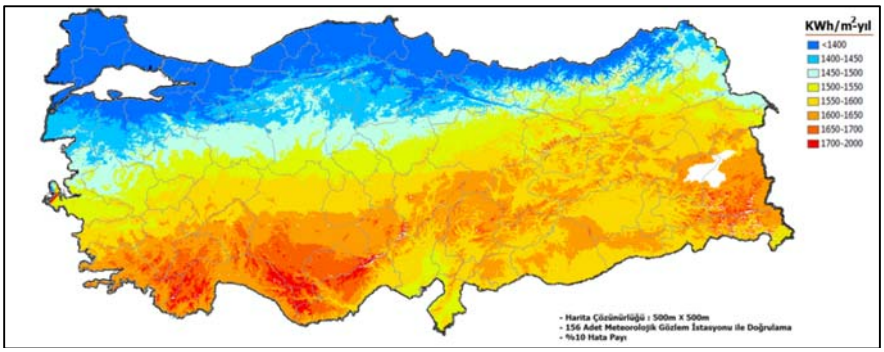

Figure 1. Turkey's solar energy potential.

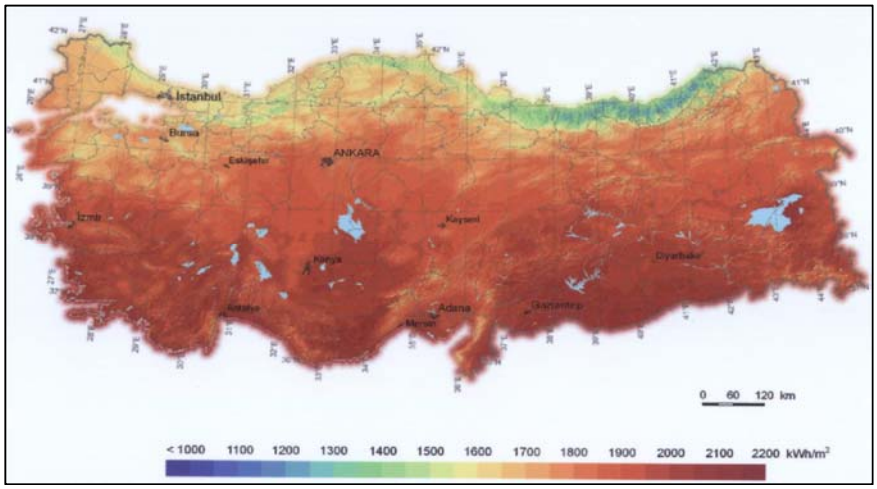

Figure 2. Turkey's solar energy atlas

Solar energy is widely used in Turkey [3]. The main solar energy utilizations in Turkey are the flat-plate collectors in domestic hot water systems [7]. The hot water heating system installations exceeds 10 million m2 area having with a total installed capacity of 7.8 GWth in 2008. Turkey is in the 2nd rank of the top countries using solar thermal power in worldwide following China. In China, this figure exceeds 100 GWth [3-5].

Furthermore, utilization of photovoltaic systems is very limited with the usage of some governmental organizations in remote service areas such as telecom stations, forest fire observation towers and highway emergency only. However, it is hoping that the photovoltaic system will play an important role in the future energy planning in Turkey. The installed capacity of solar energy in Turkey is very small. Short-term forecasts are important tasks with potential, leading to improved energy forecasts and helping to increase the efficiency of the renewable energy productions for photovoltaic solutions as well contributing to improve the management and presumably the design of the energy grids in the future. Short-term forecasts are important tasks with potential, leading to improved energy forecasts and helping to increase the efficiency of the renewable energy productions as well contributing to improve the management and presumably the design of the energy grids in the future [10-16].

## 5. Conclusions

Due to the current development in the renewable energy sector and the investor-friendly possibilities such as the feed-in tariffs in the different sub-sectors of the renewable energy, might be interesting for the Dutch companies, industries and other interested that deal with renewable energy. 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. 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. 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 6-8% per annum until 2030. The Turkish government has made it a priority to increase the share of renewable sources in the country's total installed power to 30% by 2030.

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 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.

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