



## Sustainable energy in Turkey: aspiration and endurance

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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

Population and economic growth have over the years increased the demand for energy consumption and consequently put pressure on scarce natural resources such as fossil fuel sources. Estimates from the International Energy Agency (IEA), a 56 % increase in global energy consumption is foreseen by 2040 [1]. Fast-paced economic growth among developing nations drives the increase in demand for fossil fuels as strong growth in income per capita raises demand for personal transportation and freight transport as well as demand for energy in the commercial and industrial sectors. The increase in demand for energy not only puts pressure on the finite natural resources but may also result in geopolitical conflicts when nations lay territorial claims in order to secure access to these resources [1-5].

Energy consumption followed the same structural patterns and evolution. As a result, in 2012, industry and residential sectors accounted for the lion share of total final energy consumption with about 30% each, followed closely by the transport sector (20%), the Turkish economy transformed from one focused mainly on agriculture into one oriented towards the industry and tertiary sectors [6]. In 1923, when the Republic of Turkey was established, the economic structure was completely based on agricultural production and the changes in GDP were dependent

on the harvests. This structure changed in time in favor of the industry sector and the share of agriculture in GDP fell to 8% in 2012 compared to over 30% in the 1960s. Nevertheless, agriculture will continue to remain one of the important components of the Turkish economy in the future. Currently, the industry, agriculture and tertiary sectors dominate the economy, and by 2030 this structure will persist [7-9].

Turkey's energy industry is a critical sector of growth for the entire economy, contributing to one-fifth of the national growth domestic product (GDP) over the past decade and it is one of the twelve critical sectors for growth in the Economic Transformation Program [9]. As Turkey aims to become a developed nation by 2023, the country has increased its focus on securing energy through cost-effective means and diversifying its fuel supply portfolio. Total installed generation capacity at the end of 2014 was 29.1 GW. With projected GDP to grow at 5.5–6.0 % in 2023 [9], the government anticipates an additional 6 GW of new electricity generation will come online between 2015 and 2020 in order to meet the country's electricity demand [6]. Petroleum and other liquids and natural gas continue to be the primary sources of energy, contributing 40 and 36 % respectively towards the total energy

consumption in 2014. About 27 % of the country’s energy consumption is met by coal. Biomass and

waste contribute 8 % while hydropower makes up 12 % to total consumption.

**2. Energy production and consumption in Turkey**

**2.1. General overview**

As a developing country, due to its fast growing economy and population Turkey’s installed capacity has increased rapidly (Figs. 1-3). Turkey is an energy importing country and dependent on the imported energy sources as given in Table 1 [7]. Furthermore this trend seems to be continuing in the future. Energy sources in Turkey are hard coal, lignite, oil, natural gas, hydropower, geothermal, wood and

wastes, solar and wind energy [6-9]. 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 biomass/wastes, solar, coal, natural gas, geothermal electricity and geothermal heat [10-21].

Table 1. Turkey’s energy situation in 2018 (Mtoe)

Energy source	Production	Consumption
Coal and Lignite	15.74	40.98
Oil	3.02	41.91
Natural gas	0.60	41.17
Hydropower	5.16	5.16
Geothermal (electric)	6.88	6.88
Geothermal (heat)	1.47	1.47
Animal & plant wastes	1.60	1.60
Wood	2.70	2.70
Wind	3.06	3.06
Solar	1.25	1.25
<b>Total</b>	<b>39.44</b>	<b>143.67</b>

Mtoe: Million tons of oil equivalent

Source: Ref. [7]

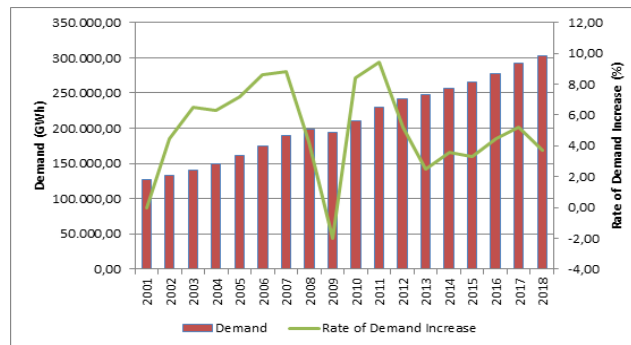


Figure 1. Turkey’s electric Energy Demand and Rate of Increase by Years (GWh-%)

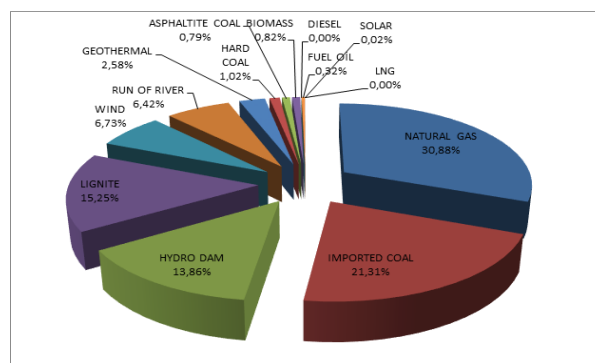


Figure 2. The Distribution of Licensed Electricity Generation by Sources in 2018 (%).

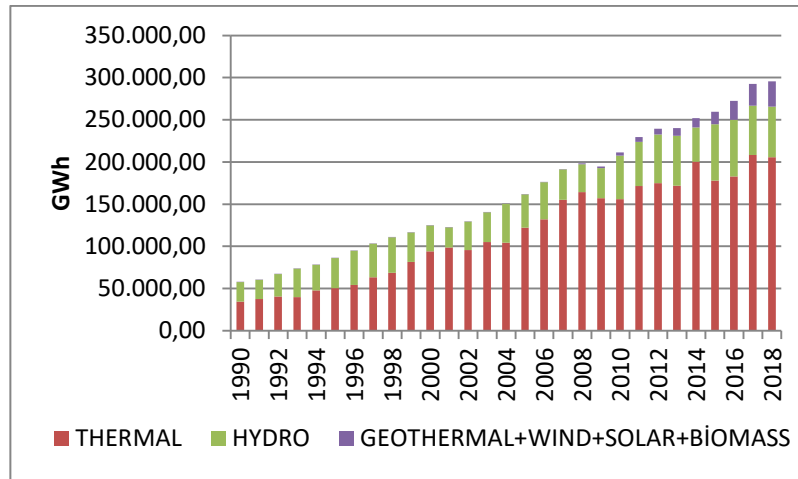


Figure 3. Turkey’s installed capacity by energy sources.

Turkey’s various renewable energy sources represent its second largest energy source after coal. Wood and animal waste account 32 %, hydropower 37 %, geothermal 19 % and wind and solar account for 10.6 % each of total renewable energy production. Table 2 shows Turkey’s total installed power capacity in

2013. In Turkey, 24 % of electricity generation was provided by hydropower in 2013, and will be increased to 36 % in 2023. The largest regional hydropower project in Turkey is the Southeastern Anatolia Project (GAP). Upon competition, GAP will have an installed capacity of 7476 MW [6-9; 15-18].

Table 2. Total installed power capacity in 2018

Energy source	Amount (MW)	Percent (%)
Natural gas	25.74	30.93
Coal	18.53	22.27
Other thermal	2.38	2.86
Hydropower	28.30	34.01
Wind	6.95	8.35
Geothermal	1.29	1.58
<b>Total</b>	<b>83.19</b>	<b>100.00</b>

MW: Mega Watt  
Source: Ref. [7]

**2.2. The role of renewables**

Renewable 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. The composition of renewable energy supply has changed and wind power is beginning to claim market share. The share

of biomass in the renewable share is expected to decrease with the expansion of other renewable sources as shown in Table 3 and 4. These tables show that there is an important renewable energy potential in Turkey [6-9].

Table 3. Present renewable energy potential in Turkey

Energysource	Potential (MW)	Power plants with license (MW)
Hydropower	45 000	20 218
Wind	48 000	9 244
Geothermal	600	636
Solar	33	-
Biomass	9.0	54
Biogas	2.0	190

Source: Ref. [7]

Table 4. Potentials for investment for renewable energies in Turkey

Sectors	Million \$	Remarks
<b>Hydroelectric</b>	144	Economical development potential of 28,600 MW, Corresponding 100,000 GWh/a
<b>Wind power</b>	67	Economical development potential of 48,000 MW With wind speed > 7 m/s
<b>Solar thermal</b>	195	Economical development potential of 131,000 GWh/a, Corresponding to approx. 300 million m <sup>2</sup> collector area
<b>Biogas</b>	6	Agricultural residual material and dung, when used for electricity generation, 1,000 MW <sub>e</sub> and 7,000 GWh/yr

Source: Ref. [6-9]

Turkey's theoretical hydroelectric potential is 1% of that of the World and 16% of Europe [6-8]. The gross theoretical viable hydroelectric potential in Turkey is 433 billion kWh and the technically viable potential is 216 billion kWh [7]. The economically viable potential, however, is 140 billion kWh. Currently, Turkey has 178 hydroelectric power plants in operation with total installed capacity of 16 160 MW generating an average of 48.000 GWh/year [6]. In 2015, 166 hydropower plants are under construction 8.600 MW of installed capacity to generate average annual 20.000 GWh representing 14% of the economically viable potential [7]. In the future, 1540 more hydropower plants will be constructed in order to make use of additional 26 860 MW installed capacity. As a result of these works, a total of 1.738 hydroelectric power plants with 45.000 MW will tame rivers to harness the economically viable hydropower of Turkey [8, 9].

Turkey has a great potential of biomass and bio-energy production [10, 11, 19]. The total annual recoverable bio-energy potential in Turkey was estimated to be around 30 Mtoe, based on the recoverable energy potential from agricultural residues, livestock farming wastes, forestry and wood processing residues and municipal wastes. The contribution of energy production share of animal wastes and plant residues to primary energy consumption in Turkey ranged from 6 % in 2000 to 4 % in 2013 [20]. Despite Turkey has a great potential of biomass to produce renewable energy, but the share of renewable energy in energy production is still low. Biogas production potential in Turkey was estimated to be around 1.5 to 2.0 Mtoe. However, since the share of renewable energy in energy production is so low, the possible contribution of biogas to this share can also be ignored [17-21].

Among the renewable energy alternatives, geothermal energy in Turkey has become very

attractive [7]. The reason for this interest is features of geothermal energy in direct and indirect use. It is unfortunate that geothermal energy in direct use can only be utilized locally. But, firing fossil fuels at 1500 °C, and using the generated heat at only 50-60 °C is obviously a thermodynamic waste. Turkey has a significant potential in geothermal energy and there may exist about 2000 MW<sub>e</sub> for electrical power generation. Turkey's total geothermal heating capacity is about 31,500 MW<sub>th</sub>. At present, heating capacity in the country runs at 1220 MW<sub>th</sub> equivalent to 147,000 households. These numbers can be heightened some sevenfold to 7,080 MW<sub>th</sub> equal to 760 000 households through a proven and exhaustible potential in 2016. Turkey must target 1.2 million households equivalent 7,900 MW<sub>th</sub> in 2020 [6-9].

Turkey is so lucky about solar energy potentials that it has 4.2 hours insulation time average per day and 1514 kWh/year.m<sup>2</sup> solar radiation level. Only available rooftop area for PV modules is 611 km<sup>2</sup> and energy gain from this area will be 90 billion kWh/year. Apart from this area it is determined that the area which has more than 1650 kWh/m<sup>2</sup> irradiation level is about 4600 m<sup>2</sup> in Turkey. Except some special applications PV installation is almost none existing in Turkey. However, solar energy is widely used for heating water [15]. The hot water heating system installations cover about 10 million m<sup>2</sup> surface in 2013. 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 economic issues [7]. It is expected that there will be three 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 [6-9].

Turkey has a theoretical wind energy potential of nearly 90,000 MW [7]. So far only about 1,000 MW

capacity wind farms are in operation in Turkey, generating less than 0.5% of total electricity consumed [6]. There are a number of cities in Turkey with relatively high wind speeds. 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 [8, 9]. Capacity is likely to grow rapidly, as plans have been submitted for just under a further 600 MW of independent facilities. At start 2015, total installed wind energy capacity of Turkey is only 2 968 MW [17, 19, 21]. It has estimated that Turkey could meet 20% of its electricity demand from wind power with a target capacity of 20,000 megawatts [17-21].

### 3. Energy investment

Demand for energy and natural resources has been increasing due to the economic and population growth in Turkey. It has posted the fastest growth in the OECD, with an annual growth rate of 5.5 percent since 2002. Since then, Turkey's primary energy supply has increased from 78.4 Mtoe to 155 Mtoe, a two-fold increase within 17 years. Turkey's growing economic performance has also been reflected on the country's electricity generation infrastructure given the dramatic rise in the total installed capacity from 31.8 GW to 88.5 GW, and in the electricity consumption from 132.6 TWh to 305.5 TWh as of end-2018. To satisfy the increasing needs of the country, the current capacity is expected to reach 110 GW by 2023 through further investments to be commissioned by the private sector as underlined in the 11<sup>th</sup> Development Plan for 2019-2023 [7-9].

The success of a privatization and liberalization program going on since 2002 has handed over all of the power distribution assets and 78% of the power generation assets to the private sector, creating revenues of USD 23 billion for the Treasury. In the same period, about USD 100 billion of new public and private investments were completed in power generation, transmission, and distribution assets. The privatization of electricity generation assets and the strategy to clear the way for more private investments has resulted in an increased share of private entities in electricity generation, from 40% in 2002 to 85% in 2018. Under the strategy to increase liberalization and competition in the market, the Energy Exchange Istanbul including power and gas commodities, was established in 2013 [7-9].

Turkey's prominent economic performance, backed by the liberalization efforts, also allowed for attraction of around USD 209 billion of FDI between 2002 and 2018, of which about USD 18 billion flowed into the energy sector. In 2018, investors carried out M&A activities across various sectors with a total deal volume of about USD 12 billion through 256 deals, with the energy industry standing

among the leading sectors in terms of M&A transaction volume with USD 400 million [9].

It is no doubt that Turkey is a net energy importer country, depending on such imports for 72% of its energy requirements and the energy import bill was USD 43 billion in 2018. However, with the exception of fluctuations in certain years, the bills depict a significant downward trend given the considerable decline from USD 60.1 billion in 2012 to USD 37.2 billion in 2017. The import dependence has been the main driving force behind the formulation and implementation of new policies and investment models to commission local and renewable energy resources [7-9].

Turkey has a substantial amount of renewable energy potential, and utilization of this potential has been on the rise over the last decade. As of end-2018, hydro, wind, and solar resources constitute the vast majority of the country's renewable energy resources, accounting respectively for 28.29 GW, 7.01 GW, and 5.07 GW of the total installed capacity. As part of the ongoing efforts to promote localization, the Turkish government has made it a priority to increase the share of renewables to 30 percent, with geothermal installed capacity to be 3 GW by 2023, as well as to have 16 GW of installed capacity in solar and wind each by 2027. In order to create a favorable investment environment to strengthen renewables' position in the market beyond the 2020s, the government has designed various investment models such as unlicensed (small-scale), licensed (medium-scale), and YEKA (large-scale) models, which address different sorts of investors and are encouraged by lucrative incentive instruments [9].

Utilization of local coal reserves in line with the environmental standards for electricity generation has also been prioritized as an instrument to increase localization. The government has adopted a new tender mechanism based on transfer of coal reserves to the private sector with the obligation of building

and operating coal-fired power plants in the vicinity. Turkey has a substantial amount of coal reserves, totaling 17.3 billion tons and composed of mostly lignite. The main coal reserves are located in Kangal, Orhaneli, Tufanbeyli, Soma, Tunçbilek, Seyitömer, Çan, Muğla, Çayırhan, Afşin-Elbistan, Karapınar, Tekirdağ, Alpu, and Afyonkarahisar. Among these reserves, the Afşin-Elbistan field alone has 4.8 billion tons of lignite resources, which constitutes 28% of Turkey's total lignite reserves. The fields to be tendered in reverse-auctions bear 6.4 GW of installed generation capacity potential [9].

It is also worth mentioning that Turkey's natural gas sector has been steadily improving. In order to increase security of supply and seasonal gas send-out capacity, Turkey has commissioned two Floating Storage Regasification Unit (FSRU) terminals in 2018 and opened up the first phase of the Tuz Golu (Salt Lake) Natural Gas Storage Facility. Another goal of these investments is to expand Turkey's gas storage capacity to 11 billion cubic meter by 2023,

#### 4. Conclusions

Turkey is a developing country and has formulated a number of energy-related policies. In recent years, the country has also committed to reducing climate change and promoting sustainable development. This is evidenced from a wide-range of initiatives and policy implementation from a policy of heavy reliance on fossil fuels to those promoting renewable energy in energy generation mix. Key institutions, policy drivers, and legislative frameworks have also been put in place to facilitate the implementation of these policies. Although these policies and initiatives provide significant motivation and interest for the development and utilization of renewable energy and energy-saving technologies, the policy frameworks and the institutions governing these policies are at best constrained with lack of capabilities and abilities to deliver the intended objectives of these policies and action plans. The government and its agencies should look across these policies so that they can maximize positive synergies where possible to avoid redundancies and fragmented authoritarianism when they formulate future energy policies.

Demand for energy and natural resources has been increasing due to economic and population growth in Turkey. Over recent years, the country has experienced the fastest surge in energy demand among OECD countries, and is set to double its energy use over the next decade. The projections of the Ministry of Energy and Natural Resources

up from its current capacity of 4 billion cubic meter [9]. As a crossroads between major energy consumers and suppliers, Turkey occupies a strategic location that serves as a regional energy hub. The existing and planned oil/gas pipelines, the critical Turkish straits, and promising finds of hydrocarbon reserves around Turkey allow for increased leverage over regional projects and reinforce the country's gateway status. Last but not least, Turkey has taken important steps in energy efficiency. In the National Energy Efficiency Action Plan, which was adopted in 2018, Turkey aims to achieve savings of USD 30 billion in total by 2030. In this regard, approximately USD 11 billion of investments will be made by 2023, resulting in energy savings equivalent to 23.9 Mtoe. This saving is equal to decreasing the primary energy consumption of Turkey by 14% in 2023 compared to the base usage scenario. As part of Turkey's efficiency efforts, Turkey will eliminate the need for USD 4.2 billion worth of power plant investments [9].

confirm that this trend will continue for the medium and long term. Recent energy data indicate that Turkey is a net energy importer country, depending on such imports for 73% of its energy needs. This high rate of energy dependence has been the main driving force behind the formulation and implementation of new policies to commission local and renewable energy resources. In this respect, Turkey announced the National Energy and Mining Strategy in 2017 which identified security of supply, localization, and predictable market conditions as the main pillars to follow in energy sector. Under the Strategy, ensuring localization and reducing import dependence through utilization of domestic resources stands as a top priority for Turkey which is ambitious to generate 2/3 of its electricity from local and renewable resources by 2023.

Turkey has a substantial amount of renewable energy potential, and utilization of this potential has been on the rise over the last decade. As of the end of 2018, hydro, wind and solar resources constitute the vast majority of the country's renewable energy resources, accounting respectively for 28,291 MW, 7,005 MW and 5,068 MW of the total installed capacity of more than 88,526 MW. However; biomass/biogas and geothermal energy resources are also expected to comprise a considerable portion with the rapid growth in utilization of these resources. As a result, Turkey's 2023 vision can be

given as:

- Raising Total Installed Power Capacity to 120 GW
- Increasing Share of Renewables to 30 Percent
- Maximizing Use of Hydropower and Reaching 34 GW
- Increasing Wind Installed Capacity to 20 GW
- Increasing Solar Installed Capacity to 10 GW
- Installing 1.0 GW Geothermal Capacity
- Raising Natural Gas Storage Capacity to More than 11 BCM
- Commissioning Nuclear Power Plants (Two Operational Nuclear Power Plants, with a Third Under Construction)
- Increasing Coal-fired Installed Capacity to 30 GW

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