



## Renewable energy for low carbon economy and sustainable development in Turkey

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### Abstract

Global energy production is growing fastly and renewable energy technologies such as wind, biomass, hydropower, geothermal and solar are finally showing maturity. With respect to global environmental issues, 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 low carbon economy and sustainable energy development in Turkey. Turkey's geographical location has several advantages for extensive use of most of these clean energy sources. In the past decade, Turkey has seen significant growth in renewable energy. In particular, renewable electricity has nearly tripled in the last decade, and its share in total power generation reached 52% in 2020. Turkey aims to continue to promote the expansion of renewable energy resources and will commission 10 gigawatts (GW) each of solar and wind capacity in the period 2017-27. In accordance with forecasts, until 2023 and 2027, the government expects that 76% and 61% of the additional capacity will come from renewable resources, respectively. Turkey has also realised strong potential for growth in geothermal energy, including for power generation, heating and in the agricultural sector. Under the Renewable Energy Support Mechanism (YEKDEM), Turkey offers feed-in tariffs for renewable power plants, including wind, solar, biomass, hydro and geothermal. Additional support is provided if plant components are manufactured in Turkey. The scheme will expire at the end of 2020 and the government is currently deciding on a new mechanism to replace it. This study shows that there is enough renewable energy potential in Turkey for electricity generation. Especially hydropower, biomass, solar and wind are very good.

*Keywords:* Energy issues; renewable energy; sustainable development; YEKDEM; 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 [4-10].

The seventh goal of the Sustainable Development Goals (SDGs) is dedicated to ensuring access to affordable, reliable, sustainable and modern energy for all by 2030 [5-7]. While energy was implicit in the Millennium Development Goals (MDGs), the SDGs explicitly recognise the direct linkage between energy access and consumption and poverty and development [3, 4]. This evolution of the development agenda is closely related to an expanded understanding of poverty, as it moves beyond a monetary definition, to be seen as a more holistic measure of overall quality of life. Energy has thus become recognised as an important aspect of alleviating extreme poverty. However, what remains unclear is the impact that poverty reduction will have on worldwide energy consumption [8]. There is a significant amount of concerning the connection between energy consumption and development,

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ranging from engineering modelling to development policy. Nevertheless, there is a lack of attention given to the direct causal relationship between poverty reduction and energy consumption [8].

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,

## 2. Global renewable energy systems

The types of renewable energy sources (RES) examined include the main and most important, in terms of capacity and technologies such as solar thermal, photovoltaics, hydropower, wind power and biomass energy. The total amount of renewable power capacity by the end of 2019 is 2588 GW whereas the figure if we exclude hydro is down to 1437 GW [2]. From these, solar PV constitute 627 GW, a 122 GW increase from the 2018 figure, wind power is equal to 651 GW, compared to 591 in 2018, and solar thermal is equal to 479 GWth, compared to 482 GWth for 2018 [3]. The estimated renewable energy share for the global electricity production is 72.7% non-renewable electricity and 27.3% renewable electricity [4]. In each type of RES examined in addition to the total installed capacity the status of the technology is given as well as the outlook in terms of prospects and the current research areas [2-8].

A comparison in global renewable energy Levelized Cost of Electricity (LCOE) from 2010 to 2015 shows that almost all renewables have a low and almost equal price in this period whereas there is a substantial decrease in LCOE for solar PV and solar thermal systems; all of them have a lower value compared to conventional fuel electricity production. Another characteristic of renewables is that worldwide more than 10.3 million people are working in jobs related to this industry [2-8].

In the various technologies, solar thermal power includes systems utilizing either the thermal radiation or the light of solar irradiance. The former includes solar thermal systems, which comprise both low temperature systems and high temperature systems, whereas the latter refers to solar photovoltaics. Both have shown a steady increase year-by-year. For solar thermal power the mostly used type of collectors are the glazed water ones. Worldwide the mostly used type is the evacuated tube, whereas in Europe is flat plate collector [3]. Research in this area lead to several new innovations like [2-8]:

Turkish energy policy has concentrated on market liberalization in an effort to stimulate investment in response to increasing internal energy demand. The governments has continued this policy despite lower energy demand induced by the 2001 economic crisis. This paper provides an overview of the clean energy utilization for climate change mitigation and energy sustainability in Turkey.

- Use of polymeric materials for the manufacture of solar thermal absorbers to reduce cost due to lower raw material and manufacturing costs. Also, reduce weight compared to copper or aluminum.
- Improved heat transfer with the use of nanofluids.
- New transparent covers with anti-reflective coatings for high optical transmission, and the use of high vacuum or noble gases.
- Switchable coatings to reduce stagnation temperatures.
- New selective absorber with low emission coatings.
- Temperature-resistant super-insulating materials.

Photovoltaics are breaking every year a new threshold. In 2015 for the first time the installed capacity exceeded the 200 GW limit, in 2016 the 300 GW limit, in 2017 the 400 GW limit, in 2019 the 500 GW and on 2020 the 600 GW. In 2019 an additional of 122 GW were installed, which is equivalent to the installation of more than 50,000 solar panels every hour worldwide. From the 122 GW installed in 2019, 30.1 GW were installed in China; EU, with 16 GW, is second, USA with 13.3 GW is third and India with 9.9 GW is fourth [2-7].

Hydro energy comes in a wide variety of sizes starting from the very large units that are greater than 10MW to the pico size of less than 5 kW. The largest application worldwide is the 18GW scheme at the Three Gorges in China. The four top countries are China with 28%, Brazil 9%, Canada and USA both with 7% [2]. Another area of renewables is the wind power that also shows a year-by-year increase. The current installed capacity is 651GW with 60GW installed just in 2019 [5]. Wind has become the least-cost option for new power generating capacity in an increasing number of markets.

The last area of renewables examined is biomass in general, which comprise as main areas in addition to biomass, biogas and biofuels (biodiesel) whereas some people considered waste, like Municipal Solid Waste (MSW), and landfills also as renewables. The big question here is whether to use land for growing energy crops instead of food to satisfy the human needs. The answer to this is to utilize for this purpose land that is not currently used for food production. The biggest challenge here is the transportation sector as more than 90% of transport depends on oil. For example, US consumption with its 200 million cars is 3.5 million barrels of oil per day, which shows the prospects for biofuels. At the end of 2018 the shares of biomass in total final energy consumption and by end-use sector were 88% based on non-biomass and 12% on biomass. The majority of the biofuels produced are ethanol and biodiesel [2-8].

### 3. Energy consumption in Turkey

Turkey is an energy importing country; more than half of the energy requirement has been supplied by imports as shown in Table 1 and 2. Oil, coal and gas have the biggest share in total primary energy consumption [11, 12]. 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 [22]. It is expected that the demand for electric energy in

Other forms of renewables like ocean energy systems, geothermal and hydrogen and fuel cells can also be considered. So, current hot research areas concerning renewables include:

- Increase the efficiency of various renewable energy technologies;
- Design renewable energy components at lower cost;
- Extensive use of RES (many regions, even countries consider transformation into 100% renewables). This will need high shares of renewables, power system transformation and the implementation of storage/integration within a smart energy system; and
- Effective coupling not only for electricity but also for heating, cooling and transportation.

Turkey will be 573 billion kWh by the year 2020 and 760 billion kWh by the year 2030. Turkey's electric energy demand is growing about 4-6% yearly due to fast economic growing [9-16]. Table 3 shows installed electricity capacity in Turkey [11, 12]. Table 4 also shows renewable energy potential, utilization by 2019 and target for 2030 [12]. Turkey has good renewable energy production in 2019 (see Table 5), but it needs 384 millions \$ investment between 2020-2030 [11, 12, 23].

Table 1. Total energy production in Turkey (Mtoe)

Energy Sources	2019
Coal and Lignite	16.36
Oil	3.14
Gas	0.40
Hydropower	7.64
Geothermal	9.66
Wood and Biomass	3.16
Solar/Wind/Other	4.46
<b>Total production</b>	<b>44.82</b>

Table 2. Total energy consumption in Turkey (Mtoe)

Energy Sources	2019
Coal and Lignite	40.57
Oil	35.45
Gas	37.13
Hydropower	7.64
Geothermal	9.66
Wood and Biomass	3.16
Solar/Wind/Other	4.46
<b>Total consumption</b>	<b>144.21</b>

Table 3. Installed electricity capacity in Turkey (MW)

Energy source	2010	2020
<b>Lignite</b>	8 280	10 120
<b>H.coal+Asph.</b>	560	1 210
<b>Imported coal</b>	1 840	8 987
<b>Natural gas</b>	14 840	25 585
<b>Geothermal</b>	90	1 556
<b>Other</b>	2 460	860
<b>Biomass</b>	62	980
<b>Hydropower</b>	16 393	30 510
<b>Wind energy</b>	810	8 318
<b>Total (MW)</b>	45 255	94 750

Table 4. Renewable source potential, utilization by 2019 and target for 2030

Energy sources	Potential (TWh/yr)	Potential (GW)	Utilized (GW)	2030 Target (GW)
<b>Hydropower</b>	180	100	75	180
<b>Wind energy</b>	150	50	20	40
<b>Geothermal</b>	4.2	6.0	3.2	4.2
<b>Solar energy</b>	380	8.1	6.1	10
<b>Biomass</b>	3.6	5.0	1.2	2.2

Table 5. Renewable energy resources in Turkey (1000 TOE/year)

	2010	2019
Total energy demand	101 510	144 295
Total energy production	27 279	44 821
Supply by renewables	9 604	24 155
Biomass and waste	5 023	3 370
Wood/wood waste	4 994	3 136
Biogas	15	108
Biofuels	14	126
Wind energy	31	1 869
Solar energy	420	1 624
Hydropower	3 083	7 640
<b>Geothermal energy</b>	<b>1 048</b>	<b>9 652</b>

Electricity accounted for 24% of total consumption in 2019, the third-largest energy source after oil and gas, with demand increasing across all sectors [11]. Fossil fuels used to dominate electricity generation, but hydropower increased its share to 29% in 2019, while coal and natural gas together amounted to 56%. Coal power, which accounted for over a third

of power generation in 2019, has also rapidly increased in recent years, contributing to about half of the total growth in electricity generation in the last decade. However, other renewable sources, such as wind power, are also increasing, resulting in a sharp reduction in the share of natural gas (see Figures 1-6) [12].

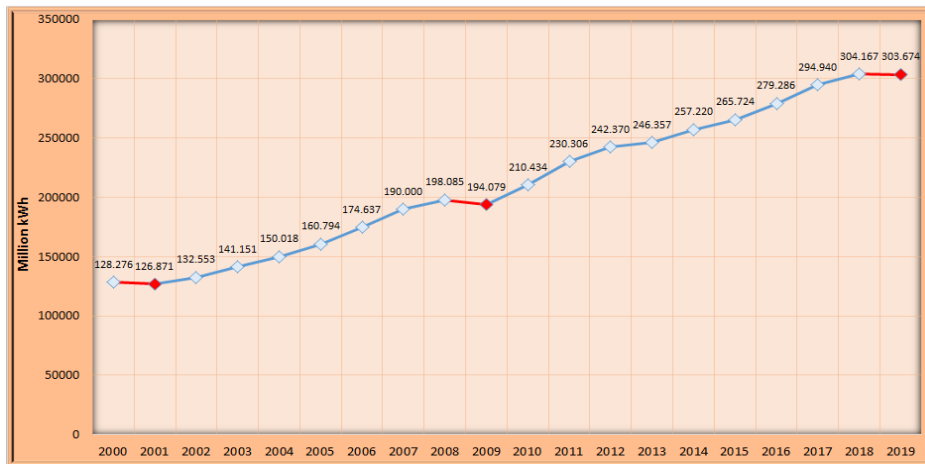


Figure 1. Electricity Consumption in Turkey (GWh)

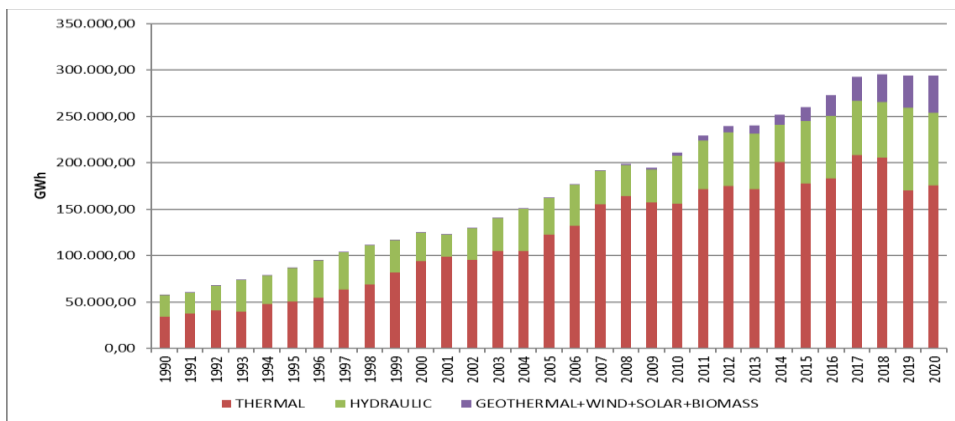


Figure 2. Source-based development of licensed electricity generation in Turkey (GWh)

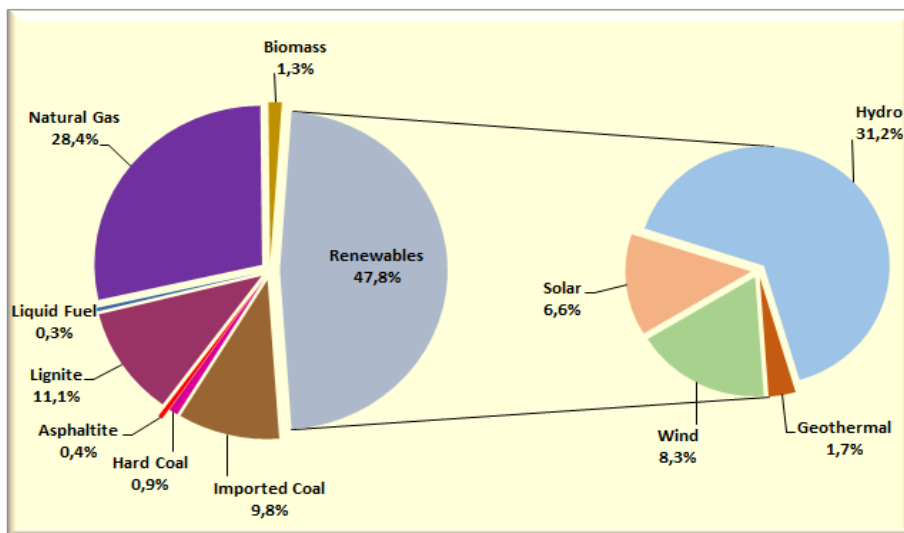


Figure 3. Turkey's installed capacity by primary resources in 2019 (MW, %)

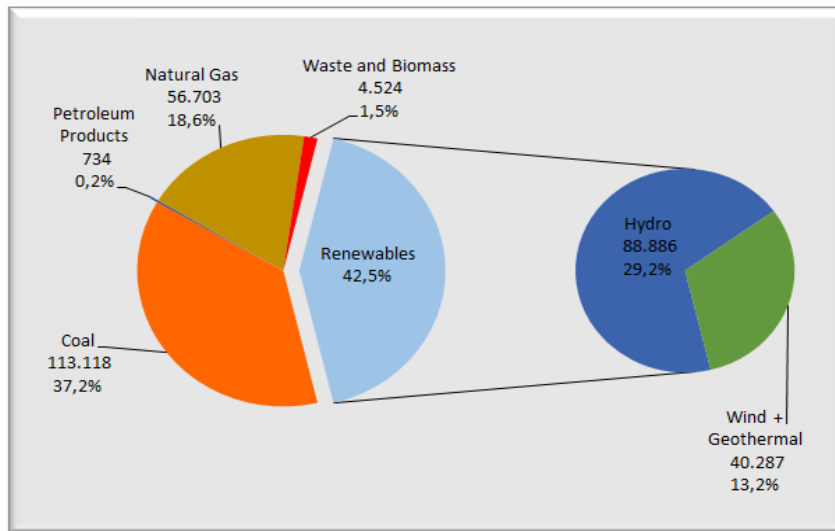


Figure 4. Turkey's electricity generation by primary resources in 2019 (Million kWh, %)

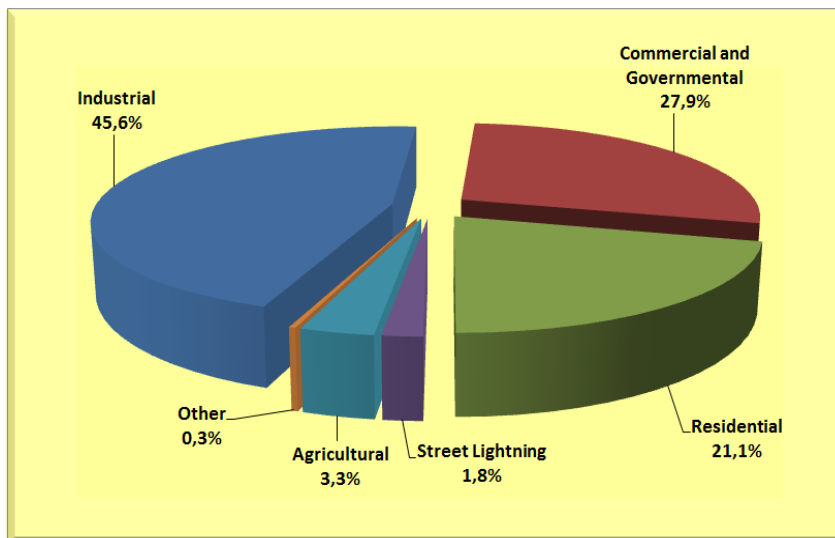


Figure 5. Turkey's electricity consumption by sectors in 2018.

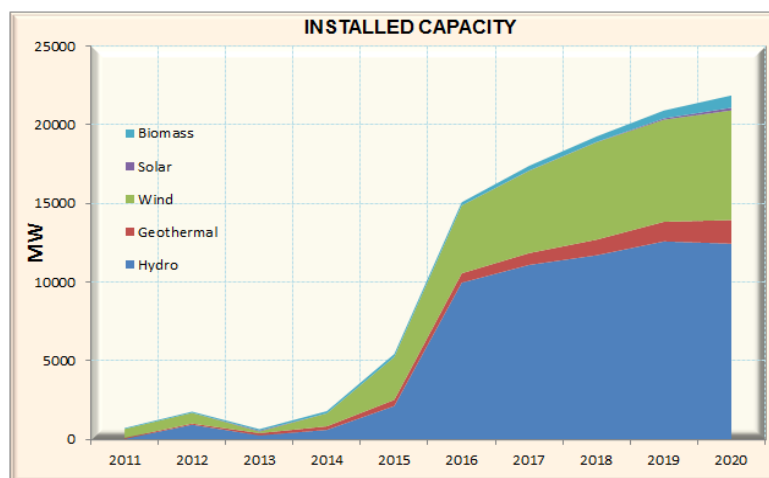


Figure 6. Installed capacity of renewable power plants in Turkey.

Total electricity generation in Turkey reached a near record high of 304.3 terawatt hours (TWh) in 2019 (Figures 1 and 2). While oil does not have a significant contribution in electricity generation and the share of natural gas has been declining in recent years, coal-fired electricity generation has increased [11]. In 2019, coal power generated 113.2 TWh, representing a 103% growth since 2009. Renewable energy sources maintain a notable share in Turkey's power mix, and their contribution is increasing. Hydropower, in particular, has almost tripled its production since 2000. In 2019, hydropower accounted for around 29% of total electricity generation, while wind came in at 7%, solar at 3%, geothermal at 3% and bioenergy at 1%. According to Turkish government data, as of May 2020, hydropower represented the largest source of electricity generation at 34% [12].

Renewable electricity generation has seen noticeable growth, with an almost threefold increase in the last decade, thanks to investments in a variety of resources. Wind power generation grew from 1.5 TWh in 2009 to 21.8 TWh in 2019, while solar power generation increased from 0.8 TWh in 2009 to 10.6 TWh in 2019. The total share of electricity from variable renewables (solar and wind) was 11% in 2019, up from 2% in 2009. Turkey does not yet have any nuclear power generation, but is well advanced in its plans to introduce nuclear, with two reactors currently under construction. This will further diversify Turkey's power generation capacity [13-35].

## 4. Renewable energy in Turkey

### 4.1. Overview

Clean 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 [13]. Total renewable energy supply declined from 1990 to 2008, due to a decrease in biomass supply [10-24]. As a result, the composition of renewable energy supply has changed and wind power is beginning to claim market share [13]. 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 5 shows clean (renewable) energy resources in Turkey [13-15]. Table 6 also shows the potentials for investment of the clean energies in Turkey. Figure 6 shows expected installed capacity by clean energies in Turkey.

In 2019, primary energy production and consumption has reached 44 and 144 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 [19-29]. 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 [25-35]. Figure 3 installed capacity by primary resources in 2019 (MW) and Figure 4 also shows the electric generation in Turkey by energy source (GWh).

Along with the economic growth and population increase, significant increases were observed both in primary energy and electricity consumption during the 10<sup>th</sup> Plan period [11]. Consumption of primary energy reached 153 Mtoe as of the end of 2014 with an annual average increase of 3.2% while electricity consumption reached 246 billion kWh with an annual average increase of 4.8% during this period. These increases are more evident in the period following 2014 [12]. Figure 5 shows Turkey's electric consumption by sector. Figure 6 also shows installed capacity of renewable power plants in Turkey [23].

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 [21-23]. At present, only about 35 % of the total hydroelectric power potential is in operation [21]. The national development plan aims to harvest all of the hydroelectric potential by 2020 [16]. The contribution of small hydroelectric plants to total electricity generation is estimated as % 5-10 [23-26]. 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 [21]. This is over 10 % of the cultivable land in Turkey; the land to be irrigated is more than half of the presently irrigated area 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 [21].

Table 6. Investment potential for renewable energies in Turkey

Sectors	Million \$	Remarks
<b>Hydroelectric</b>	128	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>	178	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 MWe and 7,000 GWh/a

Among the renewable energy sources, biomass is important because its share of total energy consumption is still high in Turkey [11, 12, 23]. Since 1990, the contribution of the biomass resources in the total energy consumption dropped from 15 to 4 % in 2014 [22-24]. Biomass in the forms of fuelwood and animal wastes is the main fuel for heating and cooking in many urban and rural areas [12]. The total recoverable bioenergy potential is estimated to be about 36 mtoe in 2008 [23]. On the other hand, using vegetable oils as fuel alternatives has economic, environmental, and energy benefits for Turkey [23]. Animal wastes are mixed with straw to increase the calorific value, and are then dried for use [11, 12].

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 2012. Turkey must target 1.2 million households equivalent 7,700 MW<sub>th</sub> in 2020 [11, 12, 23, 25].

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. 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 [23]. The solar potential unconstrained by technical, economic or environmental requirements of Turkey is estimated at 90 Mtoe per year [11, 12, 23].

Total solar energy production of 5 Mtoe in 1986 increased to 465 Mtoe in 2008 and is projected to rise to 5.5 million toe (Mtoe) (5.5% of primary energy production) by 2025 [11]. 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 2019, Turkey had 16 million m<sup>2</sup> of collector surface area installed with a heat output of 0.84 Mtoe contributing to energy production [23].

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 [13-15]. The electricity requirement was reported as 194 000 GWh in 2008 [15]. 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 [22, 23].

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

#### 4.2. Renewable energy targets

Renewable energy forms a critical component of Turkey's plans to increase the share of power generation from domestic resources. Given the strong renewables growth that Turkey has experienced in the past decade, more recently, under the Eleventh Development Plan (2019-2023), the government increased the target to 38.8% of renewables in power generation by 2023. As part of these efforts, Turkey plans to commission 10 GW each of solar and wind capacity in the period 2017-27. The targets for wind and solar are easily achievable since a significant proportion has already been realised. As such, the expansion targets represent relatively modest volumes compared to the country's potential [11, 12, 23].

In accordance with forecasts, the government expects that 76% of power generation capacity will come from renewables by 2023 and 61% of power capacity will come from renewable resources by 2027. The prime locations for wind power generation are along the Aegean coast, while those for solar power are concentrated in the south of the country. The government estimates the wind energy potential of Turkey to be 48 000 megawatts (MW), while that for solar is 1 527 kWh/m<sup>2</sup>-yr. Turkey has also realised strong growth in geothermal energy, including for power generation, heating and in the agricultural sector. Building upon this success and to achieve its targets for renewables, the government plans to increase installed geothermal and bioenergy capacity to 2 884 MW by 2023, up from 2 678 MW 2019. Turkey's geothermal potential is estimated to be 31 500 MWth [11, 12, 23].

The government also has a target to maximise the potential of hydropower by 2023. To this end, the government estimates Turkey's hydroelectric

#### 4.3. Renewable support mechanisms

Turkey has offered various support mechanisms to promote an expansion of renewables capacity, including FiTs, competitive auctions and rooftop solar compensation. For onshore wind, the IEA expects that competitive auctions will drive capacity expansions, along with projects that received feed-in tariff licences but are awaiting final permitting and transmission capacity to be auctioned. The forecast

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 [29, 33, 34, 35].

potential to be 433 TWh, while the technically usable potential to be 216 TWh and the economic potential to be 160 TWh/year. Given that hydro generation was nearly 89 TWh in 2019, a sizeable share of Turkey's economic potential for hydro has already been realised. In fact, it is envisaged that based on projects already under construction, hydropower capacity will reach 32 000 MW by 2023, indicating that a sizeable amount of the economic potential will have been realised by then. As such, additional hydro will play a limited role after 2023 [11, 12, 23].

The government considers Turkey's biomass potential to be about 100 TWh, and the amount of biogas that can be produced from biomass ranges from 17.4 TWh to 23.3 TWh. Turkey is also placing an increased focus on pumped hydro energy storage as a means to facilitate the integration of larger shares of variable renewables into the grid. Studies have been undertaken by the MENR since 2005. Based on these studies, the conceptual design of the Gökçekaya Pumped-Storage Hydroelectric Plant (1 400 MW) and the Altınkaya Pumped-Storage Hydroelectric Plant (1 800 MW) were drawn up. Similarly, a feasibility report entitled "Yahyalı Hybrid Project" was prepared in Turkey for a wind farm project that would be integrated into a pumped storage system to optimise wind power potential and connect it to the transmission and distribution system smoothly. Investment in Turkey's first pumped-storage hydroelectric plant will be undertaken by EÜAŞ for the Eskisehir project whose lower reservoirs will be drawn from the Gökçekaya Dam (1 400 MW capacity). Additionally, a 1 000 MW pumped storage hydroelectric plant designed by private sector in Eğirdir Lake (Isparta) is also being planned [11, 12, 23].

expects limited hydropower growth after 2020 in the absence of planned development beyond the commissioning of large-scale projects currently under construction which will already likely allow Turkey to realise its 160 TWh of economic potential. Overall, affordable financing remains a key challenge in Turkey, especially due to depreciation of the Turkish lira and high nominal interest rates on

loans. The MENR projects that Turkey's renewable capacity expansion could occur over 30% faster if macroeconomic conditions were to improve, new distributed solar PV regulation were implemented smoothly and more capacity were allocated under competitive tenders. Under YEKDEM, Turkey has offered FiTs for renewable power plants since 2011. The feed-in tariffs are

## 5. Energy and climate change in Turkey

Turkey is a rapidly growing country whose income level is moving towards that of the rest of the OECD area [11]. This catch-up process has been associated with a rapid growth of greenhouse gas emissions. Nonetheless, carbon emissions from any country

### 5.1. Emissions reduction strategy

In accordance with the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties framework, Turkey pledged to reduce greenhouse gas (GHG) emissions by up to 21% from a business-as-usual level by 2030 (including land use, land-use change and forestry). Turkey's growing economy and level of development limits its ability to lower emissions levels from current levels, prompting the country to opt for a business-as-usual baseline, allowing some emissions growth from current levels. An expansion of renewables, including solar and wind, is a critical component to meeting the targets [11].

Nonetheless, Turkey has not yet ratified the Paris Agreement, and it may update its Intended Nationally Determined Contribution (INDC) in accordance with changing circumstances. Turkey does not currently plan a peak in its emissions. The Ministry of Environment and Urbanization is carrying out the "Capacity Building and Monitoring Project for Achieving the Greenhouse Gas National Contribution Target", which will inform efforts to update Turkey's INDC, including to reflect policies put in place after 2015 [12].

The country's domestic CO<sub>2</sub> reduction strategy is outlined in the 2010 National Climate Change Strategy 2010-2023 and its implementing plan, the 2011 National Climate Change Action Plan (NCCAP) 2011-2023. Central tenets of the NCCAP include an improvement in energy efficiency as well as an expansion of renewable power. Turkey will need to update its NCCAP and National Climate Change Strategy by the end of 2023 at the latest. Studies to update the NCCAP will begin in 2020, with a goal to complete them within three years.

currently set at USD 0.130 per kWh for solar and biomass, USD 0.104 for geothermal, USD 0.070 for wind and hydro plants; they are valid for ten years. Additional support is provided if plant components are manufactured in Turkey, although the local content premiums are valid for a shorter period of five years [11, 12, 23].

contribute equally to the pressure on the global climate [12]. Consequently, the major issue facing policy makers is how to contribute to reducing the burden on global resources at a low cost and without jeopardizing the rapid growth of the economy [23].

Long-term (2030-50) policy and strategy options will also be considered.

Total greenhouse gas (GHG) emissions in Turkey were 526 million tonnes carbon dioxide equivalent (Mt CO<sub>2</sub>-eq) in 2019 of which energy-related emissions accounted for 72%. The rest came from industry process emissions at 16%, agriculture at 14% and waste management at 3%. Turkey proposed to reduce GHG emissions by up to 21% from a business-as-usual level by 2030. In line with population growth and economic development, Turkey's economy is expected to continue to expand, resulting in higher energy demand and consequently rising emissions. However, Turkey has an opportunity to consider ways to expand its economy without a commensurate surge in GHG emissions. So far, Turkey plans to increase renewable energy capacity and decrease energy intensity through energy efficiency measures [11, 12, 23].

In 2019, estimated CO<sub>2</sub> emissions in energy-related sectors were 378 Mt CO<sub>2</sub>-eq, growing by 86% since 2000. Electricity and heat generation is the largest emitting sector, accounting for 42% of total emissions in 2019. The rest was emitted in transport (20% of total emissions), industry (19%), residential (9%), services (7%) and other energy (4%). Emissions have increased across all sectors in the last few decades, with particularly rapid growth from 2013 to 2019. In those four years, total CO<sub>2</sub> emissions (excluding LULUCF) grew by 33%, driven by rapid increases in power generation, transport and industry.

A breakdown by fuel gives another perspective on energy-related CO<sub>2</sub> emissions, which have increased

from all fossil fuels over the past decades. Coal combustion is the largest source of CO<sub>2</sub> emissions, accounting for 43% of total emissions in 2018, most of which came from coal use in electricity generation. The steady growth in electricity generation emissions corresponds to the increase in coal-related emissions. In addition, natural gas emissions increased with growing gas electricity generation from 2000 to 2019, though they have fallen more recently. Oil-related emissions are closely correlated with transport emissions, which accounted for nearly 66% of total oil emissions in 2019 [11].

## 5.2. Promoting renewable energy

In Turkey, there is a much more potential for renewables, but represent about 37% of total energy production and 10% of total energy consumption. This share is not enough for the country and the governments should be increase to this situation. More than half of the renewables used in Turkey are combustible fuels and waste, the rest being mainly hydro, solar and geothermal. Turkey is richly endowed with hydropower, wind and geothermal resources. Sectoral studies have indicated that small-scale hydropower is under developed, and a total potential production of 33 TWh of electricity per year [21]. It is estimated that Turkey has the potential for up to 48 000 MW of wind power capacity, capable of generating about 25 TWh of electricity per year [10-35].

## 6. Conclusions

Turkey is an energy-dependent country; almost 77% of its energy resources are imported. Since Turkey is not energy independent, there should be a sharp shift from imported fossil fuels to renewables. Turkey's renewable energy potential, moreover, is good enough to change the direction of its energy policies. Renewable energy resources offer an optimum solution for Turkey's energy challenges. Renewable energy costs are decreasing sharply, while efficiency is improving due to technological improvements. Turkey's 2023 energy goals also aim to use domestic energy resources efficiently and effectively.

Turkey uses the energy sources inefficiently and consumes more energy to produce a product. So, the production costs in this country are higher than the world's average. Energy policies of Turkish government should support the domestic energy sources and use the installed power plants efficiently in Turkey. Coal is the most reliable domestic energy source in Turkey should be consumed more in the

The government further reformed the regulatory framework to reduce pollution from energy production. In 2006, the new Regulation on Control of Air Pollution from Industrial Plants set standards for emissions of NO<sub>x</sub>, SO<sub>2</sub>, CO and PM from combustion plants. PM and CO standards were lowered for both solid and liquid fuel-fired power plants. PM standards were tightened from 150 to 100 mg/m<sup>3</sup> for solid fuel-fired power plants and CO standards were lowered from 250 to 200 mg/m<sup>3</sup> (for solid fuel-fired plants) and from 175 to 150 mg/m<sup>3</sup>.

There is also large potential for geothermal and solar thermal applications in Turkey. Solar collectors are already a significant, market-driven business. The government expects the use of geothermal and solar energy to double between 2014 and 2030. The organic component of waste incineration is also considered a renewable option in the future, using appropriate technology to meet high health and environmental standards. On the other hand, commercial use of renewable energy has not developed rapidly. Financial assistance is being provided for the development of renewable energy projects. In 2014, USD 800 million was made available; by 2020, about half had already been committed to finance 66 projects with several other projects under preparation [15-25].

industry and electricity production in order to reduce the energy production costs of Turkey and the dependency on other countries. Natural gas is an expensive energy source and the consumption is high in Turkey. Moreover, the share of natural gas in electricity generation is 46% in Turkey. Because of dramatically high dependency on natural gas, Turkey will be one of the most affected countries in a possible natural gas crisis in the world. In other words, consuming natural gas is a disadvantage for Turkey in terms of development.

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. Therefore, Turkey has initiated a forward looking and

innovative energy policy in which renewable energy plays a significant role.

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## References

- [1] Kaygusuz, K. Energy services and energy poverty for sustainable rural development. *Renewable and Sustainable Energy Reviews* 2011; 15: 936-947
- [2] REN21, Renewable Energy Network. Global renewable energy report for 2020. Available from [www.ren21.net/](http://www.ren21.net/) (accessed date 11.06.2021).
- [3] Weiss, W., Spörk-Dür, M. Solar Heat Worldwide, Global Market Development and Trends in 2019. IEA Solar Heating and Cooling Program, 2020.
- [4] Snapshot of Global PV markets 2020. IEA-PVPS—Annual report 2020, Report IEA-PVPS T1-37: 2020
- [5] IEA, International Energy Agency. Global energy review 2021. IEA, Paris 2021.
- [6] IEA, International Energy Agency. World energy outlook 2020. IEA, Paris 2020.
- [7] IEA, International Energy Agency. Net zero by 2050: a roadmap for the global energy sector. IEA, Paris,
- [8] Kalogirou, SA. Renewable energy systems: current status and prospects. in “Solar Energy Conversion in Communities”. Springer Nature, Switzerland, 2020.
- [9] Bilgen, S, Keles, S, Kaygusuz A, Sari A, Kaygusuz K. Global warming and renewable energy sources for sustainable development: a case study in Turkey. *Renewable and Sustainable Energy Reviews* 2008; 12: 372-396.
- [10] Kaygusuz, K. Energy and environmental issues relating to greenhouse gas emissions for sustainable development in Turkey. *Renewable and Sustainable Energy Reviews* 2009; 13: 253-270.
- [11] International Energy Agency (IEA). Energy Policies of IEA Countries: Turkey 2021 Review, OECD/IEA, Paris, 2021.
- [12] Ministry of Energy and Natural Resources (MENR). Energy Statistics of Turkey in 2020. <http://www.enerji.gov.tr> (accessed date 06 May 2021).
- [13] Kaygusuz, K. Clean energy policies for sustainable development in Turkey. *Journal of Engineering Research and Applied Science* 2012; 1(2): 1-10.
- [14] Kaygusuz, K., Toklu, E. The increase of exploitability of renewable energy sources in Turkey. *Journal of Engineering Research and Applied Science* 2016; 5(1): 352-358.
- [15] Yüksel, I., Kaygusuz, K. Renewable energy sources for clean and sustainable energy policies in Turkey. *Renewable Sustainable Energy Reviews* 2011; 15: 4132-4144.
- [16] Toklu, E., Kaygusuz, K. Present situation and future prospect of energy utilization in Turkey. *Journal of Engineering Research and Applied Science* 2012; 1(2): 11-24.
- [17] DSI, State Water Works. Hydropower potential in Turkey, Ankara, Turkey, 2019.
- [18] Kaygusuz, K. Hydropower as clean and renewable energy source for electricity generation. *Journal of Engineering Research and Applied Science* 2016; 5(1): 359-369.
- [19] TEIAS, Turkish Electricity Transmission Corporation. Electricity production statistics in Turkey, TEIAS, Ankara,, [www.teias.gov.tr](http://www.teias.gov.tr) (accessed date 04.02.2021).
- [20] Kaygusuz, K., Kaygusuz, A. Energy and sustainable development in Turkey, Part I:Energy utilization and sustainability. *Energy Sources* 2002; 24: 483–498.
- [21] GAP, Southeastern Anatolia Project. Energy production in GAP region, 2019. <http://www.gap.gov.tr/>.
- [22] Bilgen, S., Keleş, S., Sarıkaya, I., Kaygusuz, K. A perspective for potential and technology of bioenergy in Turkey: present case and future view. *Renewable and Sustainable Energy Reviews* 2015; 48: 228-239.
- [23] TCMEEC, Turkish Chamber of Mechanical Engineers Energy Commission. Turkey Energy Outlook 2020. May 2020, Ankara, Turkey. <https://enerji.mmo.org.tr/>
- [24] Bahadır, A., Keleş, S., Kaygusuz, K., Türker, MF., Yeğin, M. Bioenergy potential, utilization and policies in Turkey. *J. of Eng Res App Sci* 2013; 2(2): 167-183.
- [25] Geothermal energy in Turkey, [www.jeotermaldernegi.org.tr](http://www.jeotermaldernegi.org.tr) (access date 14 Jun 2019).
- [26] Kaygusuz, K., Toklu, E. Energy issues and sustainable development in Turkey. *Journal of*

- Engineering Research and Applied Science 2012; 1(1): 1-25.
- [27] Kaygusuz, K., Güney, M.S., Kaygusuz, O. Renewable energy for rural development in Turkey. *Journal of Engineering Research and Applied Science* 2018; 7(2): 886-895
- [28] Kaygusuz, K. Prospect of concentrating solar power in Turkey: the sustainable future *Renewable and Sustainable Energy Reviews* 2011; 15: 808-814.
- [29] Alboyaci B, Dursun B. Electricity restructuring in Turkey and the share of wind energy production. *Renew Energy* 2008; 33: 2499–505.
- [30] Cicek BN, Ozturk M, Ozek N. Renewable energy market conditions and barriers in Turkey. *Renew Sustain Energy Rev* 2009; 13: 1428–36.
- [31] EMRA, 2020, Electricity Market Development Report, viewed 10 March 2021, <https://www.epdk.org.tr/Detay/Icerik/1-1271/electricityreports>.
- [32] Melikoğlu, M. Geothermal energy in Turkey and around the World: A review of the literature and analysis based on Turkey's Vision 2023 energy targets. *Renewable and Sustainable Energy Reviews* 2017; 76: 485-492.
- [33] Vardar A, Cetin B. Economic assessment of the possibility of using different types of wind turbine in Turkey. *Energy Source Part B* 2009; 4: 190–8.
- [34] Ilkilic C, Nursoy M. The potential of wind energy as an alternative source in Turkey. *Energy Source Part A* 2010; 32: 450–9.
- [35] Guler, O. Wind energy status in electrical energy production of Turkey. *Renew Sustain Energy Rev* 2009; 13: 473–8.
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