GENI Global Energy Network Institute

How is 100% Renewable Energy Possible for Turkey by 2020?

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Organizations

DSI – State Hydraulic Works Company (Devlet Su İşleri)
ENTESO-E – European Network of Transmission System Operators for Electricity
IEA – International Energy Agency
IMF – International Monetary Fund
SPO – State Planning Organization
TEUAS – Turkish Power Generation Company
TEIAS – Turkish Electricity Transmission Corporation
TETTAS – Turkish Electricity Trading and Contracting Company
MEMR – Ministry of Energy and Natural Resources
TEK – Turkey Electricity Authority

Power Terminology

Power is the rate at which energy is generated or consumed. Watts per hour properly refers to the change of power per hour.

GWh – GigaWatt hour: The gigawatt is equal to one billion (109) watts or 1 gigawatt = 1000 megawatts.
kV – kiloVolt
KW – Kilowatt
kWh – kiloWatt hour
kWh/m – Kilowatt hours per meter squared
kWp – Kilowatt peak
Mtoe – Megatons of Oil equivalent: One megaton is a value based on the amount of energy released by burning one ton of crude oil or 6.6 – actual barrels of oil to produce 11.63 MWh of electricity.
MV –MegaVolt: A megavolt is 1 million volts in electronics and physics.
MW – MegaWatt: a megawatt is equal to one million (106) watts
MWe – MegaWatt electrical
MW_t – Megawatt thermal
PV – Photovoltaic
TPES – Total primary energy supply – the total amount of energy to meet the country's basic utility needs
TWh – Terawatt hours: one terawatt is equal to one trillion (10^{12}) watts

Abstract

Located between 36 – 42 north latitude and 26 – 45 east longitude, bordering the Mediterranean, Aegean and Black Seas, Turkey is blessed with renewable resources. Among the European Union, it has the highest hydropower, wind and geothermal energy potentials, which equals 150 TWh, 200 TWh, and 15 TWh respectively[1]. It also has an abundant annual solar energy potential equivalent to 1.3 mega tons of oil equivalent (Mtoe) or 15,120 TWh respectively[2]. The annual biomass potential is projected at around 372 TWh.[1] However, the country has become more dependent on foreign countries in order to cover its day-to-day energy demands. While 77% of the total primary energy consumption in 1970 was met by indigenous energy sources, this percentage decreased to 28% in 2003.

There are various reasons for this development. The main one is the uneven growth of new installed energy capacity in relation to the much faster growth of total energy demand, mostly attributed to Turkey's rapidly growing population and economy. Another major reason is cheap access to fossil fuels, primarily natural gas and oil, as a result of Turkey's role as a transit country for fossil fuels. According to the government's most probable scenarios, Turkey's primary energy supply is expected to double within a decade, reaching 2,442 TWh in 2020.[3]

In order to decrease carbon dioxide (CO_2) emissions, fight climate change, and increase energy security while decreasing its dependences on foreign countries, the Turkish government took actions to exploit its indigenous resources and raise the share of the renewable energies in the electricity production. For this reason, several incentives to foster electricity generation from renewable energy sources have been developed and finally enacted in various laws (namely Law No.5346, which was enacted in 2005 and restructured by Law No.6094 in 2010). The goal of this report is to assess the renewable energy potential of Turkey to better understand realistically a 100% renewable energy scenario by 2020. Starting with the current energy situation and electricity grid infrastructure, the report also serves as a guideline, giving well investigated facts and future predictions of energy and energy potential in Turkey.

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[1] Kemal Baris and Sherhat Kucukali, December 2010
[2] Farkan Dinçer, July 2011
[3] Euracoal, *Key Facts of Turkey*, 2011

1. Key Facts

Turkey is a country with an area of 783.562 km^2 and a population of 74,724,269 people. Located at the border between Europe and Asia it acts as a transit country for fossil fuels. The Turkish economy is defined as a largely developed, emerging market by the IMF, making it one of the world's newly industrialized countries. The country is one of the leading producers of agricultural products, motor vehicles, textiles, ships and other transportation equipment, consumer electronics, construction materials and home appliances. With a gross domestic product (GDP) of $1.116 trillion in 2010, it is the 15th largest economy in the world[4]. With an annual population growth over 10%, Turkey is expected to have 80.2 million people by 2020. At the same time, the IMF[5] predicts an average economic growth of 5.4% per year until 2015.

These developments are expected to continue in the coming years and will inevitably lead to increased energy demand. In order to understand Turkey on a global scale, a comparative visualization of the current general statistics of Turkey and Germany are shown in Figure 1. Despite an area more than twice the size of Germany and a similar number of people, the 2011 GDP was only about one-third that of Germany. Therefore, the energy consumption and the $C0_2$ emission are also one-third those of Germany.

[4] International Monetary Fund, *World Economic Outlook*, 2011
[5] Ibid.

	Turkey		Germany
Population in 2011	74,724,269		
Area	783,562 km2		
Density in 2011	97/km2		
GDP in 2011	1.073 trillion $		
GDP per capita in 2011	14.5 $		
Total energy consumption 2010	1218 TWh		
Total energy consumption per capita 2010	16.3 MWh		
C02 emissions in 2009	253 million tones		
C02 emissions per capita in 2009	3.6 tonnes		

Figure 1: General Statistics of Turkey Compared to Germany
Source: Author with data from the International Monetary Fund, *World Economic Outlook*, 2011

1.1 History, Current Energy Situation and Energy Prediction

In 1970, Turkey's primary energy consumption was 19 Mtoe (221 TWh), whereas in 2010, it reached 105 Mtoe (1221 TWh). For 2020, it is predicted to increase to 222.4 Mtoe (2587 TWh)[6]. However, the share of renewable energy sources in primary energy consumption decreased steadily in the years from 1980 – 2006, as shown in Figure 2. While in 1970, the renewable energies could meet about 35%; in 2010, they only covered around 10%[7]. Biomass and, in recent years, hydro energy produced almost all energy within the renewable energy. At the same time, the primary energy production-consumption coverage decreased constantly from 76.9% to 29%.[8] The energy gap between demand and domestic production is covered by imports of natural gas, oil and hard coal, making Turkey highly dependent on foreign countries. Today's shares of fuels in total energy supply are given in Figure 3.

Overview

In 2010

Primary energy demand:
1,221 TWh.
90% of this mostly imported fossil fuels; the rest provided by renewable energies (mostly biomass).

Electricity demand: 211 TWh
73.5% of this fossil fuels; the rest mainly provided by hydro power.
Installed capacity: 50 GW.

Prediction for 2020:

Primary energy demand:
2587 TWh.
About 91% of this mostly imported fossil fuels, rest

[6] Op cite, note 1
[7] International Energy Agency, *IEA Energy Statistics – Energy Balances for Turkey*, 2010
[8] Op cite, note 2

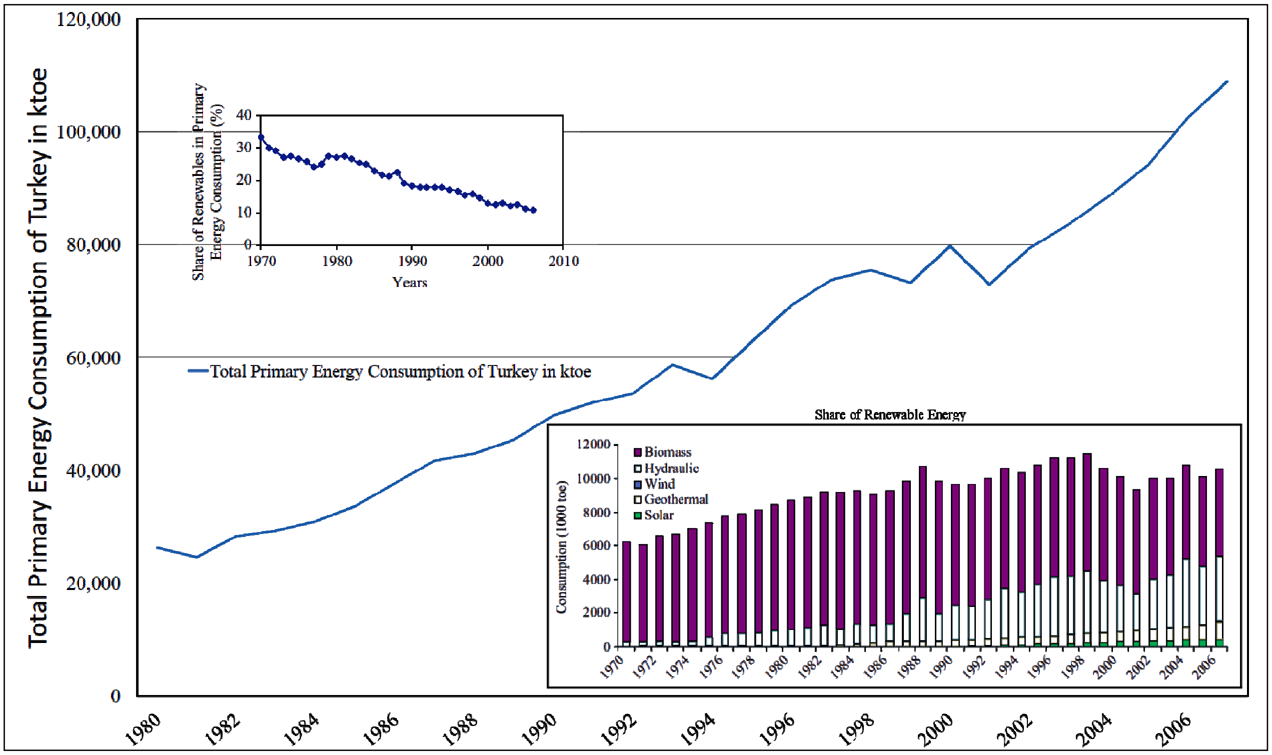

Figure 2: Turkey's Primary Energy Consumption 1970 – 2006 and Share of Renewable Energy.
Source: International Energy Agency, *IEA Energy Statistics – Energy Balances for Turkey,* 2010

1.2 Electricity

Since 1902, when a 2 kW hydropower system started generating electricity in Turkey, the renewable share within the overall energy consumption has been increasing constantly at an annual average growth of 8% to 210 kWh, a total share of 27% within the primary energy consumption. From 1971 to 2009, the electricity consumption per capita rose from 268 kWh to 2296 kWh, about one-third of the consumption of Germany. In 2002, 99.9% of the Turkish people had access to the electricity grid, and the total installed power generation capacity reached 31,845.8MW[9]. According to several studies, the electricity demand is expected to be between 440 and 485 TWh in 2020.[10] To meet the predicted demand, the current installed energy capacity of about 50 GW has to be extended to 80 – 96 GW.

[9] Kemal, Yilanci, and Atalay, " 2007
[10] Op cit., note 1.

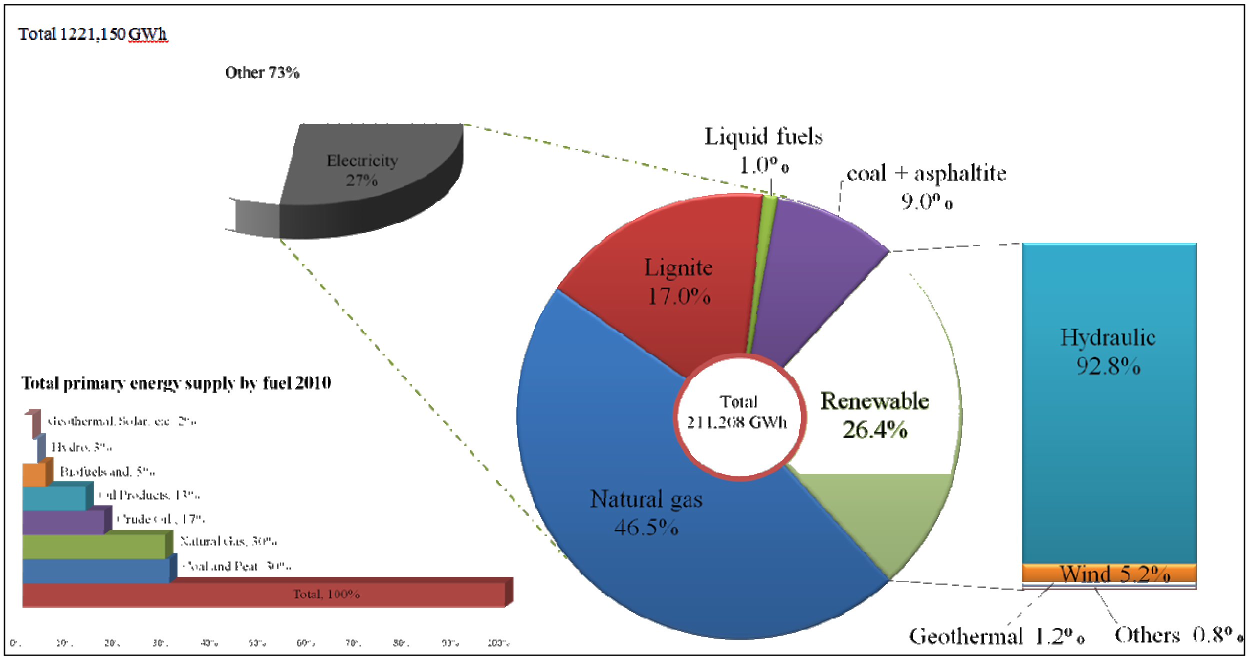

Figure 3: Electricity and Fuel Break Down of the Total Primary Energy Supply in 2010
Source: International Energy Agency, *Key Statistics*, 2011

As shown in Figure 3 for 2010, fossil fuels like natural gas, coal and oil provided almost 90% of Turkey's total primary energy supply. In terms of electricity supply, 73.5% is covered by those CO_2 intensive fuels. The rest is met by renewable energy resources, of which 92.8% is provided by hydro power. Only about 7% of the electricity is provided by wind, geothermal, biomass and solar currently.

The distribution of fuels in Turkey's electricity production has shifted tremendously toward natural gas, making it the main contributor to electricity supply. According to Figure 3, Turkey imported an average of 95.7% of its used natural gas in the years of 1988-2003. The development of the fuel distribution in the years of 1940-2009 is shown in Figure 4. As it can be seen in the chart, coal covered 86% of the energy demand in 1940. The remaining part was met by renewable energies (8% mostly hydroelectric power) and natural gas (6%). Through the years, a constant increase in use of natural gas can be observed. Particularly after 1990, the increased use of imported natural gas altered the shares, leading to a fuel distribution of 19% renewable, 52% natural gas and 29% coal in 2009.

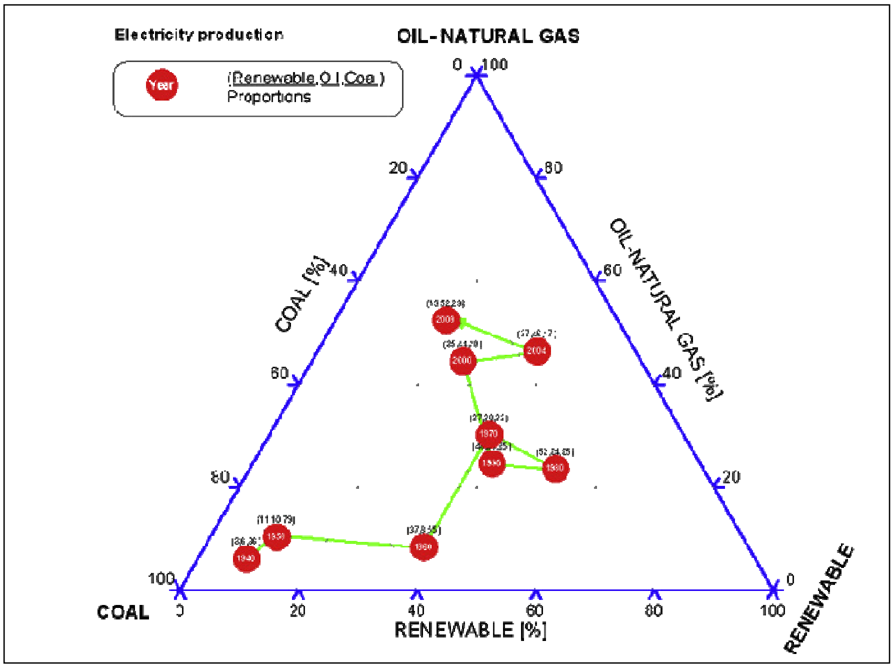

Figure 4: Distribution of Primary Energy Sources in Electricity Production.
Source: Mehmet Çapik, Ali Yılmaz, and Ibrahim Çavuşoğlu, "Present situation and potential role of renewable energy in Turkey," *Renewal Energy*, 2011

1.3 Energy Demand Forecast and Current Government Energy Policies

The majority of well-researched energy surveys for Turkey predict the total primary energy demand is expected double by 2020, reaching 222.4 Mtoe (2586 TWh). Figure 4 above shows the distribution of the energy according to energy reports published by the Ministry of Energy and Natural Resources in 2006 and 2010. This survey assumes a constant dependence on imported fuels for the years to come. According to the report, about 70% of the energy demand will be covered by fossil fuels from foreign countries. The remaining 30% will be met by domestic resources, whereas about 60% will be covered by hard coal and lignite, about 30% by renewable resources and about 10% by other indigenous resources.

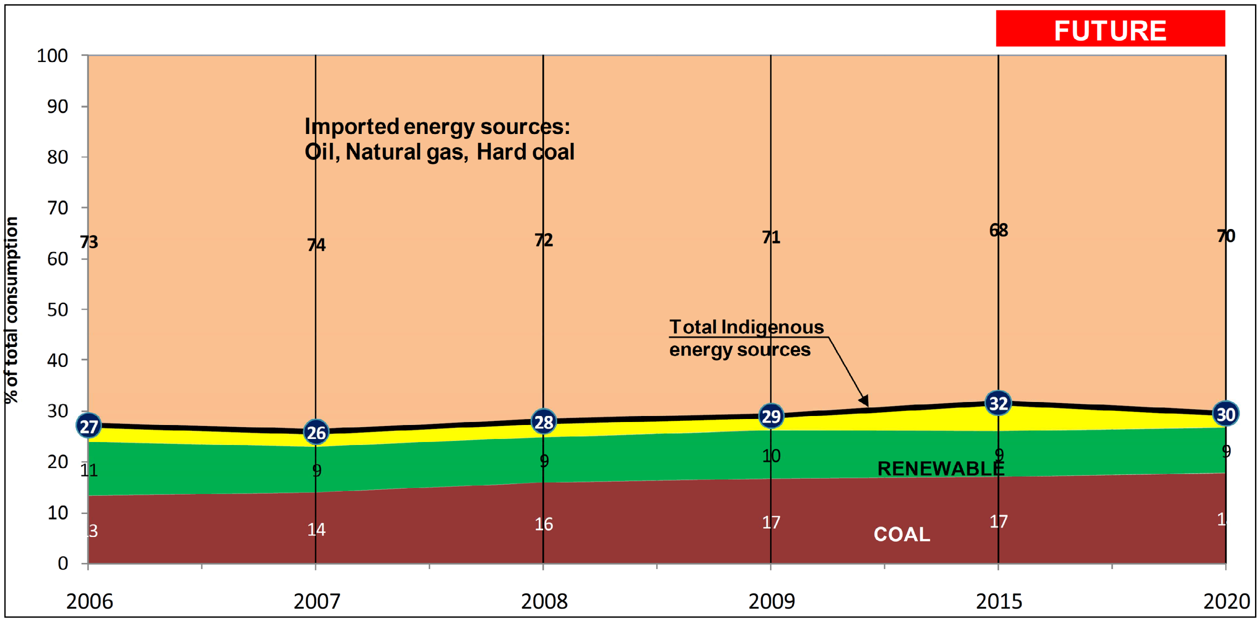

Figure 5: Projection of Distribution Development for Domestic Energy Resources in Total Primary Energy Consumption.
Source: Yılmaz, A. O., *Renewable Energy and Coal Use in Turkey***,** 2010.

Rising energy demand, holding on to the current energy mix, inevitably leads to a rise in the CO_2 emissions of the country. Although Turkey is a party to the United Nations Framework Convention on Climate Change and became a member to the Kyoto Protocol in 2009, it decided not to set any quantitative targets to limit CO_2 emissions. Nevertheless, recently Turkey determined its commitments to reduce green house gases by setting up a unilateral quantitative target for CO_2 emissions in the energy sector.

The development of the CO_2 emissions has been investigated by many scientists around the world. The majority of them, however, predict a strong increase in the CO_2 emissions by 2025. According to the *Turkey Review 200* published by the International Energy Agency, the CO_2 emissions of the country will reach 604 metric tonnes (Mt) in 2020, almost 5 times the emissions of the year 1990. In order to fight the CO_2 emission levels, the Ministry of Environment and Forestry set up a National Climate Change Strategy, which provides an increase in energy efficiency as an increase of the share of renewable energy.

In terms of the electricity, Turkey intends to meet 30% of predicted demand with renewable energies by 2023. Therefore, different laws to foster renewable energies have been enacted. The principle points of these laws are a variety of incentives for individuals and corporate entities producing electricity out of renewable energy, which are explained in detail in Figure 6.

Mechanism	Incentives
Licensing	• Individuals and corporate entities granting an exemption from licensing and setting up a company with a capacity less than 500 kW for building electricity generation facilities out of renewable energy sources.
	• Corporate entities applying for a license only will pay 1% of the licensing cost. Furthermore, they do not pay licensing costs for the first 8 years.
	• Priority is given for system connection.
Land Appropriation	• Real properties, which are either regarded as forest or the private property of Treasury, are leased or right of easement or usage permits are given to such properties.
	• Forest Villagers Development Revenue, Forestation and Erosion Control Revenues are not demanded during the first 10 years: 85% discount is granted for rent, right of easement and usage permits.
Purchase Guarantee	• The Turkish government guarantees, via a feed-in tariff, to buy electricity out of renewable energy plants, built or to be built between 18.05.2005 and 31.12.2015, for 10 years for a fixed price depending on the used renewable energy.
	• The government also promotes domestic manufacturing of the equipment to be used in power plants through additional feed-in tariff.
	• Feed-in-tariff amounts and duration for renewable power plants to be built after 31.12.2015 will be decided by Turkish Council of Ministers

Figure 6: Incentives enacted by the Turkish Government to Foster Electricity Production from Renewable Energy
Source: Author with data from Yılmaz, A. O., *Renewable Energy and Coal Use in Turkey***,** 2010

The predicted development of the Turkish CO_2 emissions seems to be inadequate in terms of the climate change, one the major future global problems.

The pivotal question is: How is it possible for Turkey to mitigate its CO_2 emissions to the smallest feasible level? One answer would be to use the abundant renewable energy potential to produce electricity and, therefore, replace the fossil fuels currently used for its production. Depending on the economic feasibility of generating electricity from renewable energy resources, industrial processes, as well as transportation, could be transformed from fossil fuel intensive sectors into electricity intensive, using power produced from renewable energies with a CO_2 footprint far less then out of fossil fuels. In addition, electricity cross-border connections could function as a buffer to stabilize the grid and provide access to electricity whenever it is needed. Further advantages of this energy transition would be increased energy independence, leading to greater energy security and price stability.

2. Assessment of the Renewable Energy Potential in Turkey

This section focuses on the assessment of the different renewable energy resources in the country. For most of the renewable energies analyzed, an assessment of the natural, technical and economically feasible potential of the producible energy or installed capacity is made. The natural potential refers to the theoretical natural potential; the technical potential equals the current technical exploitable potential (without attention to the entailed price) whereas the economically feasible potential describes the remaining renewable potential which can be exploited for a price, acceptable to the economy.

2.1 Hydropower

Turkey has an overall natural hydropower potential of 430 terawatt hours (TWh), which is about 1.1% of the worldwide and 13.75% of the European potential.[11] However, only about 30% (130 TWh) of the potential is deemed to be economically feasible.

Overview

Hydropower

Economically feasible potential: ~168 TWh

	In 2010	*Predicted in 2020*
Prod. energy:	48 TWh	155 TWh
Inst. capacity:	14 GW	63 GW

Solar power

Natural potential outweighs electricity demand by 68 (31) times in 2010 (2020). Economically feasible potential depends on the available area. 1.1 (2.5) times the size of Istanbul is enough to cover the electricity demand in 2010 (2020)

Wind power

Economically feasible potential: ~35-70 TWh

	In 2010	*Predicted in 2020*
Prod. energy:	2.9 TWh	n.a.
Inst. capacity:	1.8 GW	n.a.

Geothermal power

Economically feasible potential: ~4.5 GWe

	In 2010	*Predicted in 2020*
Prod. energy:	0.67 TWh	n.a.
Inst. Capacity :	0.1 GW	n.a.

Biomass

Economically feasible potential:

~200 TWh

	In 2010	*Predicted in 2020*
Prod. energy:	0.45 TWh	n.a.
Inst. capacity:	n.a.	n.a.

[11] Dursun and Gokcol, 2011

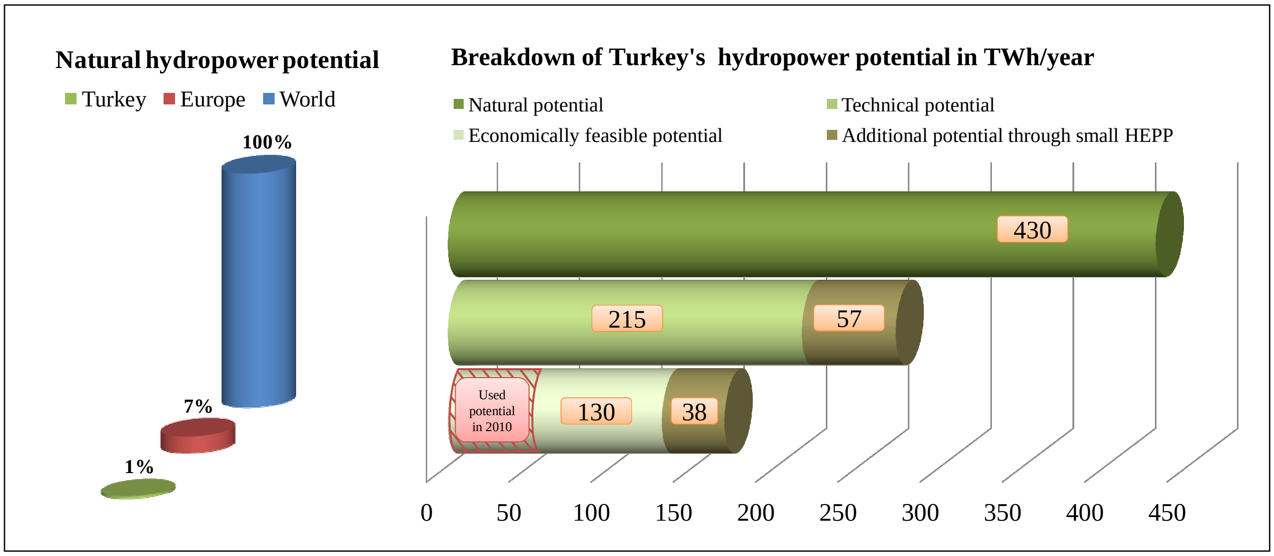

Figure 7: Natural hydropower potential in TWh/Year
Source: Author with data from Dursun and Gokcol, "The Role of Hydroelectric Power and Contribution of Small Hydropower Plants for Sustainable Development in Turkey," *Renewable Energy*, April 2011

Recent investigations of small hydroelectric power plants assume an additional economical energy potential of 38 TWh per year. Ninety-sever percent (97%) of this economic potential is located in 14 of Turkeys 26 river basins. Figure 7 summarizes these facts, allowing a quick and easy understanding. The main rivers in Turkey are shown in Figure 8. Most of them are located in Turkey's eastern regions. Basically, the Euphrates and the Tigris River with their far ranging watershed area and higher elevation contribute to the country's abundant potential, allowing people to build large power plants. In addition, small power plants on rivers with a lower elevation range and drainage area, mostly situated in the western areas, are suitable to produce electricity.

Figure 8: Main Rivers of Turkey
Source: Lynch, Richard, "An Energy Overview of the Republic of Turkey, *Fossil Fuels International*, 2005

With the annual runoff plotted against the economically feasible power potential, Figure 9 gives key facts for the main river basins in Turkey. The numbers in or next to the circles represent the amount of economically feasible energy in GWh per year that can be produced in that particular basin. For example, with a drainage area of about 127,304km^2 and an elevation range of 500 and 5,000 meters, the Euphrates River alone can provide 37,800GWh/year, about 30% of Turkey's economic potential.

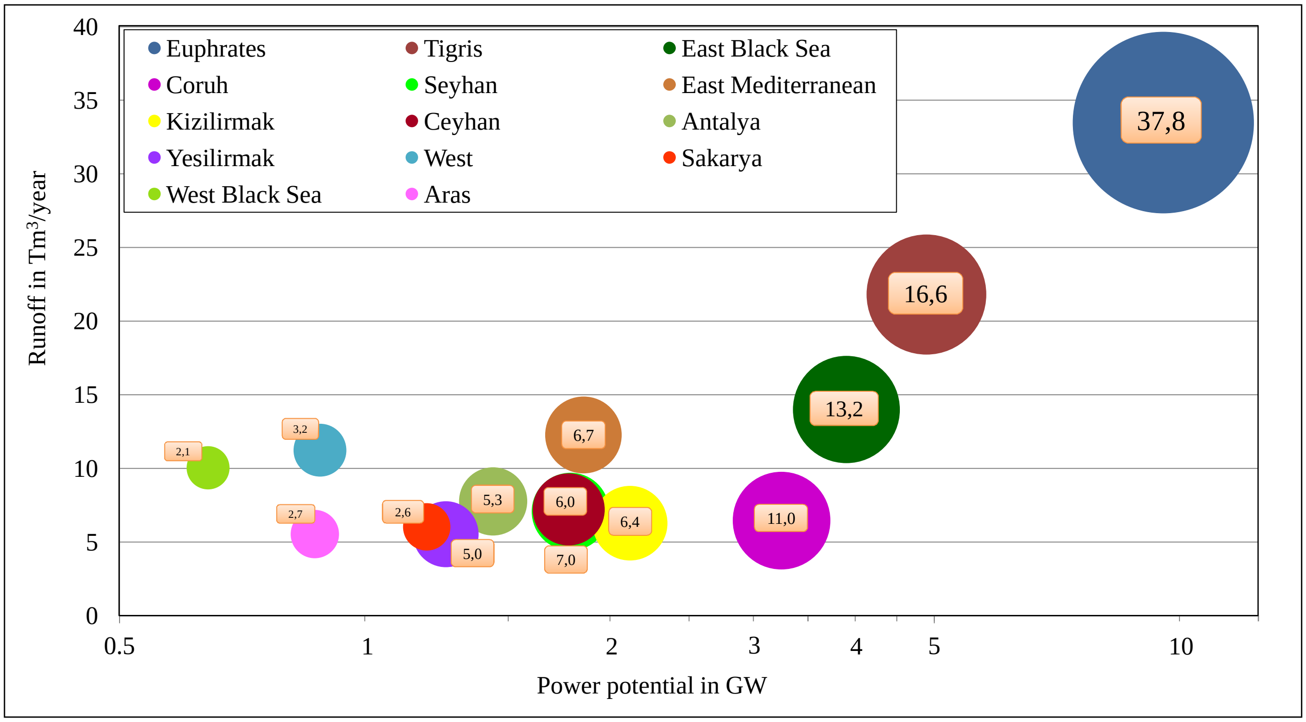

Figure 9: Turkey's Economically Feasible Hydropower Potential Broken Down by Main River Basins
Source: Baris and Kucukali, "Availibility of Renewable Energy Sources in Turkey: Current Situation, Potential, Government Policies and the EU Perspective" *Energy Policy*, December, 2010

The economically feasible power potential (GW) is a function of the runoff (Tm^3/year) of the main river basins in Turkey. The number inside/next to the circle represents the economically feasible energy potential in GWh/year.

2.1.1 Current Situation, Main Projects and Predicted Hydropower Energy by 2020

Since 2009, 172 hydroelectric power plants, with a total installed capacity of 13.7 GW and an annual energy production of 47.8 TWh, are in operation. Another 94 HEPPs, with a total capacity of 5, 2 GW and an annual energy potential of around 17,560 GWh, are under construction. An additional 542 hydroelectric plants will be constructed in the future, reaching a total installed capacity of 63.24 GW and an annual production of about 155 TWh in 2020[12]. Based on a recently released study by the State Hydraulics Company on small hydro power plants, about 5 TWh/year of additional technical energy potential could be gained, whereas 3 TWh of that potential is deemed to be economically feasible. Exploiting all of its economic potential, 32 – 035% of the predicted electricity demand ranging between 440 and 480 TWh can be met by electricity from hydro power plants.

2.1.2 Southeastern Anatolian Project

The Southeastern Anatolian Project (Güneydoğu Anadolu Projesi or GAP), one of the largest power generation, irrigation and development projects of its kind in the world, is being constructed by DSI. This project affects 7.4 million acres of agricultural land and about 7.35 million people in 9 cities. The main advantages for the region will be to expand access to power for residents and the possibility of irrigating about 10% of the cultivable land in Turkey. The undertaking includes 13 projects, seven (7) in the Euphrates and six (6) in the Tigris basin, and includes 22 dams, 19 hydroelectric power plants and irrigation schemes in an area extending over 4.4 million acres. The total cost of the project is estimated to be $32 billion. The total installed capacity of its power plants will be 7490 MW, which implies an annual energy production of 27 TWh.

2.1.3 The Coruh Project

DSI is building the Coruth River Project. It will have a capacity of 8,260 GWh/year. This hydro power project, located in the Coruh River basis will provide 6.4% of Turkey's total electricity generated by hydro power plants.

[12] Ibid

2.2 Solar Energy

2.2.1 Natural and Electricity Potential

Turkey has abundant solar energy resources, as it is located in a sunny belt between 36◦ and 42◦N latitudes. The natural energy potential of the country is estimated to be 1.3 billion tons of oil equivalents (15,120 TWh) and is scattered to different regions which are highlighted in Figure 10. Most of these areas are suitable for developing solar energy power systems.

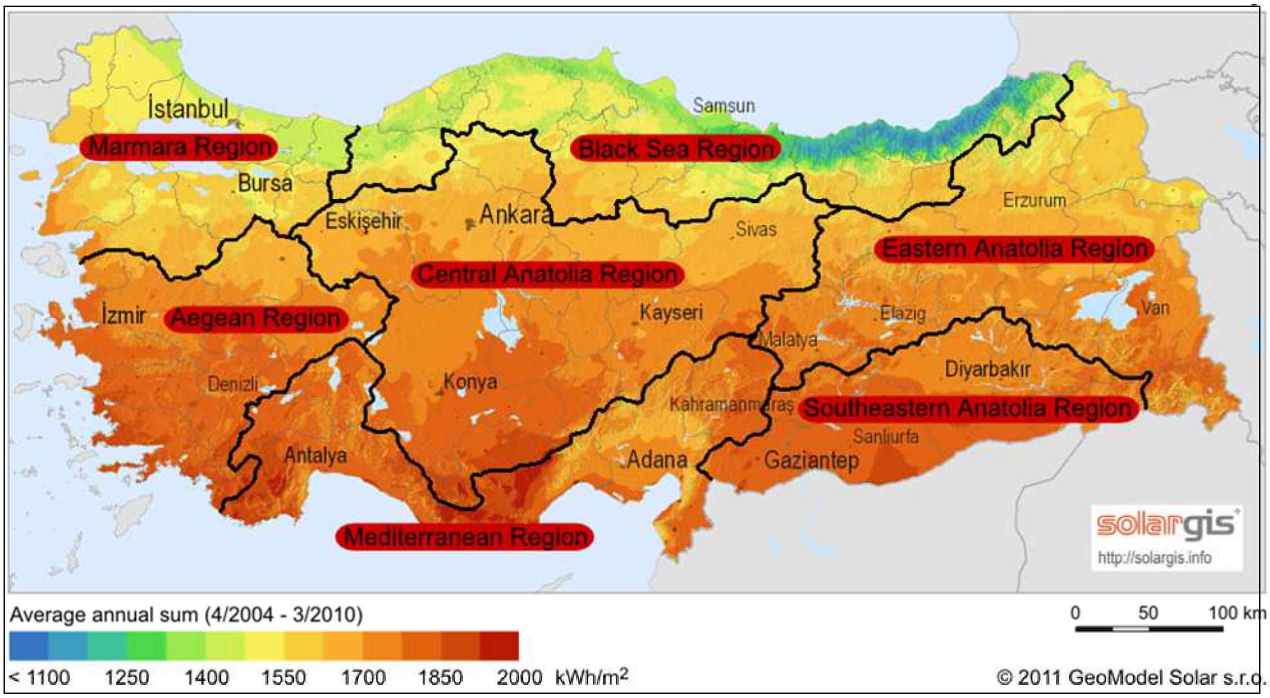

Figure 10: Irradiation Map of Turkey with Average Annual Energy in kWh/m^2 2004 – 2010
Source: Solargis, *Global Horizontal Irradiation 2004 –2010* (modified by author)

Due to Turkey's size and geographic location of each of its regions, the annual mean of the total solar radiation as well as the annual sunshine hours differs for each region as shown in 11. The yearly average total solar radiation varies from a low of 1,120 kWh/m^2 year in the Black Sea Region with 1,971 hours of sunshine a year to a high of 1,460 kWh/m^2 year in South East Anatolia with 2,993 hours of sunshine a year. All other regions range between these two areas. Assuming a standard solar energy plant with a performance ratio (efficiency of a 1 kWp solar system due to reflections, transmissions and conversions losses of the system) of 0.75, the average annual electricity potential varies from 1,118 kWh/kWp in the Eastern Anatolia region to 815 kWh/kWp in the Black Sea region.

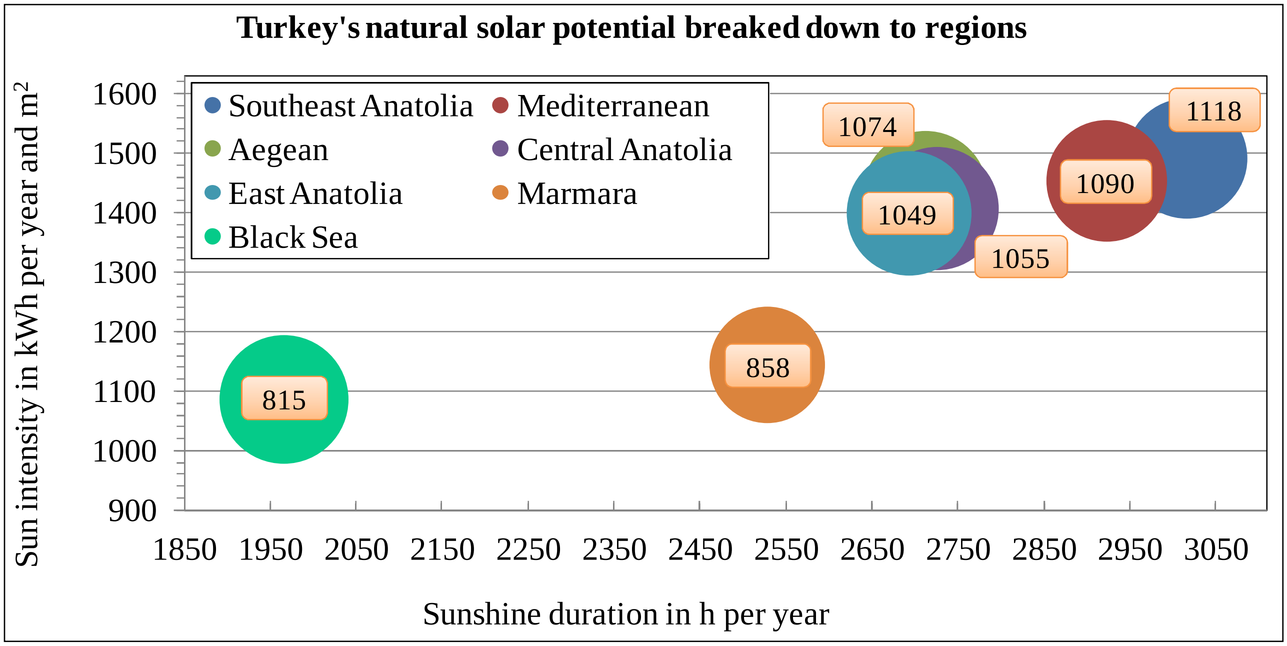

Figure 11: Average Sunshine Per Year and Average Annual Sun Intensity
Source: Baris and Kucukali, "Availibility of Renewable Energy Sources in Turkey: Current Situation, Potential, Government Policies and the EU Perspective" *Energy Policy*, December ,2010

Note: The number inside/next to each circle represents the electricity potential in kWh/kWp of a standard solar system with a performance ratio of 0.75.

Comparing Turkey's natural annual solar potential with the electricity demand of the country in 2010, the solar energy potential exceeds the electricity demand by the factor of 68. The potential also outweighs the predicted doubling of the electricity demand for the year 2020 by a factor of 31. Taking technical, ecological and economic factors into account, the natural solar potential shrinks to an arbitrary amount depending on the system assumptions. One of the main constraints to the natural potential, however, is the area available for the solar systems. The following chapter gives an overview of the space needed to meet the current electricity demand based on previous studies.[13]

[13] Šúri et al., 2007

2.2.2 Area Needed to Cover Current Electricity Demand

Based on studies done by the EIE, Turkey's average annual total sunshine duration is 2,640 hours (a total of 7.2 hours per day); the average total solar radiation is estimated to 1,311kWh/m^2 year (daily total of 3.6 kWh/m^2) which provides an annual energy potential of about 1,512 TWh. With a size of 783,562 km^2 and an electricity demand of 211.2 TWh in 2010, the area necessary to meet the demand is less than 0.26% of the total size of Turkey. This is about 1.1 times the size of Istanbul or 0.8 times the size of Ankara, the capital of Turkey. To cover the predicted electricity demand for 2020, 0.6% of the total area of Turkey, an area with a size of about 2.5 times of Istanbul would be needed.[14] Figure 12 visualizes these facts.

Area needed to cover 100 % of the electricity demand of Turkey

In 2010	1.1 the size of
In 2020	2.5 the size of

Figure 12: Total Area Needed to Meet Electricity Demand in 2010 and 2020.
Source: International Monetary Fund, *World Economic Outlook,* 2011

2.3 Present Situation and Outlook

The total installed capacity of solar panels in 2011 was 7 MWp. It is estimated that 4 to 5 MW will be installed in 2012, 50 to 100 MW in 2013, and as much as 1000 MW in 2014. It is not expected that any large, utility scale projects will be constructed before 2014. Therefore, it is not likely that solar power will play a major role in Turkey's electricity supply in the near future.

[14] General Directorate of Electrical Power Resources Survey 2010

2.4 Wind Energy

Due to its geographic location, Turkey is under the influence of different pressure systems. In winter, the Island High Pressure system expands its impact area to southern latitudes of Turkey, causing strong, gusting winds from the north and especially north eastern directions. Anatolia, especially the western side, is under the influence of western and north western winds. In summer, Turkey is influenced by the Azores High Pressure center, causing constant winds from the north, especially in the western regions of Turkey. The strong gradient of the Azores High Pressure center and the Basra Low Pressure center in the east creates gusting north eastern winds in the eastern region. Southern, as well as eastern regions are generally under the impact of winds from the south and south-eastern direction.

2.4.1 Natural and Electricity Potential

The technical wind energy potential is estimated to be about 114 GW of capacity in regions where the wind speed is higher than 7.0 meters above the ground at 50 meters height.[15] Approximately 20GW of this potential is estimated to be economically feasible in Turkey, as shown in Figure 13. Assuming a capacity factor, which represents the share of actual produced power by a wind power plant compared to the theoretical maximal energy production over the year of the same wind power plant, between 20 and 40% the annual energy production is estimated. Turkey's technically feasible electricity potential from wind power plants ranges between 200 and 400 TWh. However, the economically feasible potential lies between 35 and 70 TWh. As shown in Figure 13, only 1.8GW (about 9%) of the economically feasible potential has been exploited at the end of 2011. The main installed wind power plant capacity in 2009 however, is distributed to only 3 regions – Aegean, Marmara and Mediterranean, which is shown in Figure 14.

[15] General Directorate of Electrical Power Resources Survey,*Turkey Energy Efficiency Report*, 2011

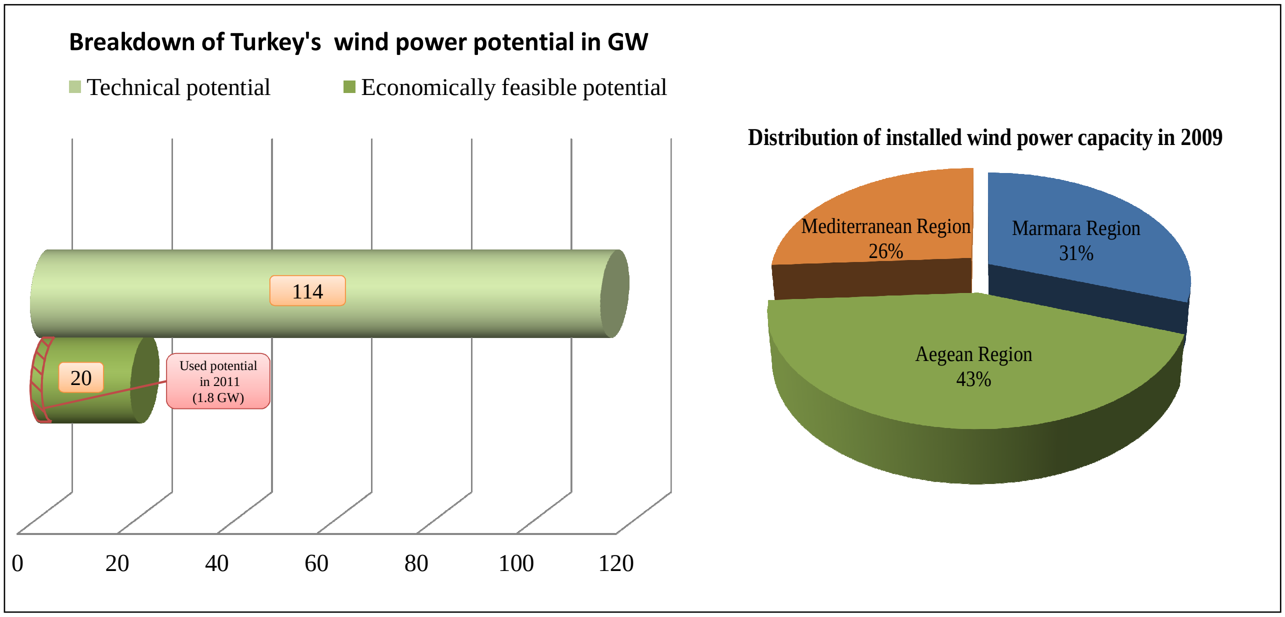

Figure 13: Breakdown of Turkey's Wind Power Potential, Total Installed Capacity and Regional Distribution – 2010
Source: Gencer, et. al, *Wind Energy Potential In Turkey*, 2010

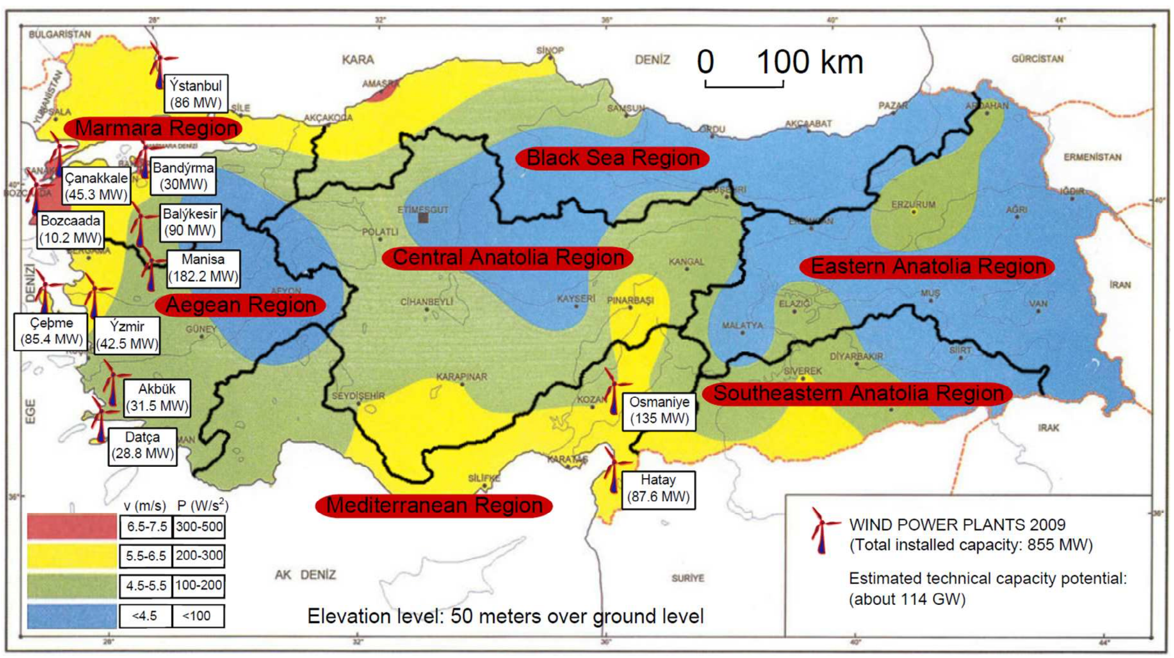

Figure 14: Projection of Development of the Share of Domestic Energy Sources in Overall Primary Energy Consumption.
Source: İsmet Akova, "Development of Wind Energy in Turkey,: *EcoGeo*, 201,

The reason for the distribution can be understood by looking at Figure 14, which shows the wind speed and the associated wind power at 50 m. The main wind potentials are located at the coastlines of the Marmara and Aegean regions, as well the coast of the Black sea region. Just these three (3) regions contain about 74% of the technical potential.

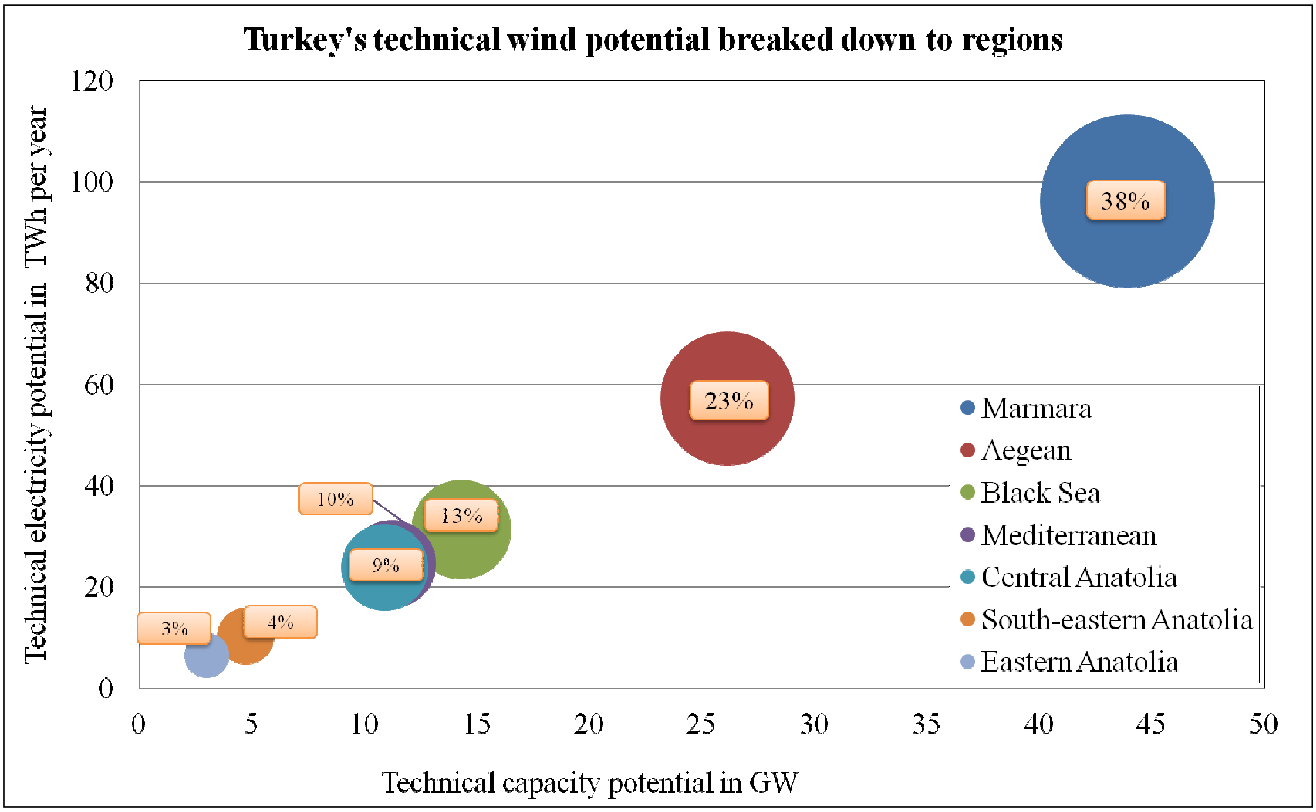

Figure 15: Turkey's Technical Wind Power Potential
Source: Baris, Kemal and Kucukali, Sherhat, "Availibility of Renewable Energy Sources in Turkey: Current Situation, Potential, Government Policies and the EU Perspective" *Energy Policy*, December 2010 (modified by author)

Note: The calculation of the final energy product (y-axis) assumes an average capacity factor of 0.25.

Figure 16 shows the installed capacity of wind power plants after 2005. This is due to the enactment of the Renewable Energy Law 5346. Referring to this graphic, the installed capacity rose from 20.1 MW in 2005 to 1,799 MW in 2011, an increase of about 8,950%. Despite this tremendous increase, the desired level of installed capacity is still not reached and a big share of the economic potential has still not been used.

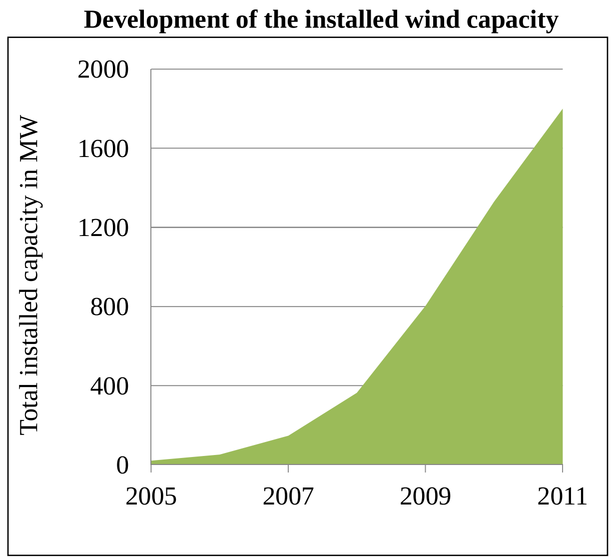

Figure 16: Development of Wind Power Capacity 2005 –2011
Source: Baris and Kucukali, "Availibility of Renewable Energy Sources in Turkey: Current Situation, Potential, Government Policies and the EU Perspective" *Energy Policy*, (modified by author)

2.5 Geothermal Potential

Turkey's geothermal potential is estimated to be 31.5GW_t and 4.5GW_e, with the total installed power generation capacity in 2010 of 795 MW_t (directly thermal used) and 100 MW_e (converted to electricity). Thermal energy is mainly used for district and greenhouse heating.[16, 17]

The reason for the high geothermal potential is the unique location of the country. Located on the active tectonic Alpine-Himalaya Orogen belt, active volcanos, as well as young faults are present. Most of the geothermal energy potential is located in the Aegean and Central Anatolian region. The proven geothermal capacity of the existing wells and springs is about 4,078 MW_t.

The temperature of the fluids in the geothermal fields determines how it is used. Fields with high temperature geothermal fluid can mostly be found in the west of Turkey, seated under grabens, (a depressed land area located between parallel faults) formed as a result of recent tectonic activities. In the Middle- and Eastern-Anatolia regions, low-and moderate-temperature sources along the North Anatolian Zone are present.

[16] Dagıstan, Hayrullah , 2009
[17] Kaygusuz Kamil and Kaygusuz, Abdullah, 2009

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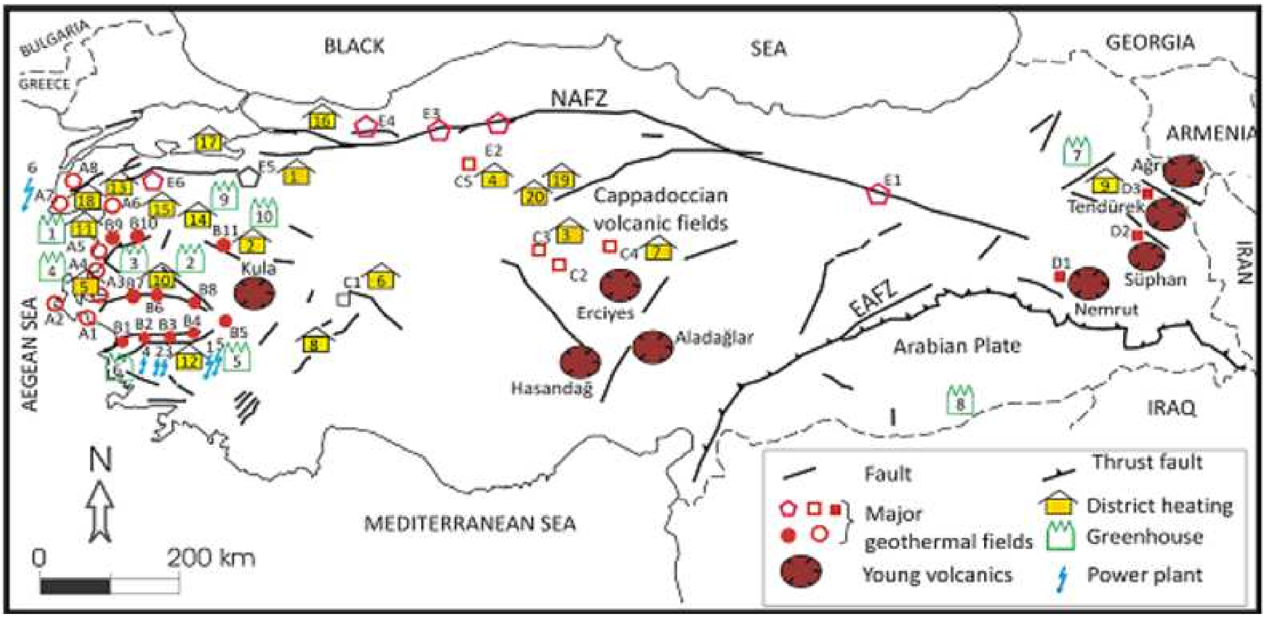


Figure 17: Map of Turkey with Geothermal Felds, Volcanoes, Faults, Main Power and Heating Plants
Source: Umran Serpen, Niyazi Aksoy, Tahir Öngür**,** "Present Status of Geothermal Energy in Turkey," *Proceedings Thirty-Fifth Workshop on Geothermal Reservoir Engineering*,2010

2.5.1 Electricity Potential

Geothermal electricity production started in 1974 at the Kizildere geothermal field in the Aegean region with an installed capacity of about 0.5 MW_e. In 2010, the total installed capacity rose to 100MW_e. Due to the 8th SPO Five-Year Development Plan in 2001, the total installed geothermal electricity capacity was predicted to be 300 MW_e in 2010 which is three (3) times more than the real installed capacity.

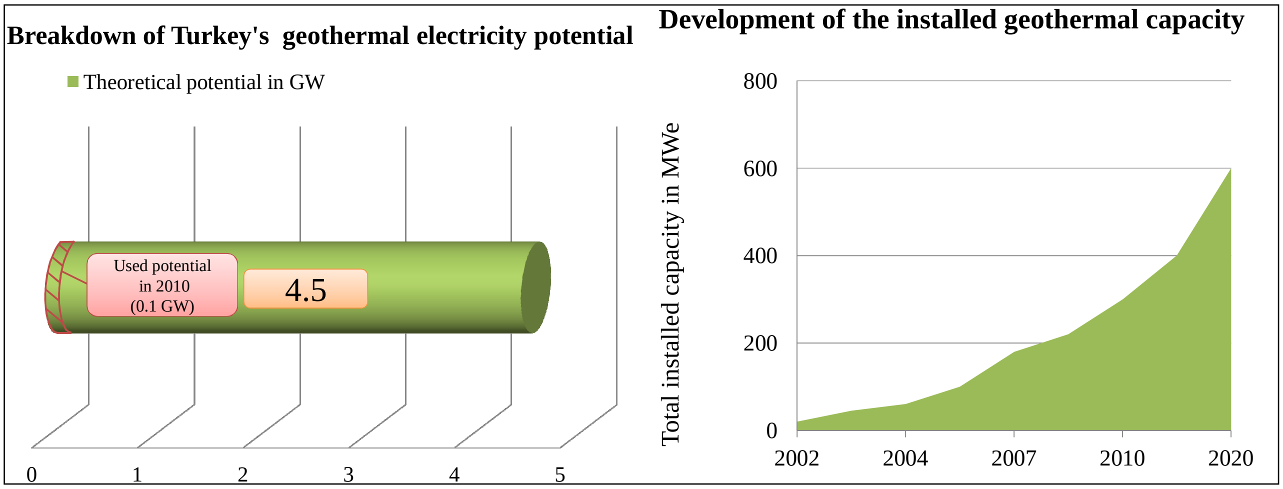


Figure 18: Geothermal Potential – Share of Use and Development of Installed 2001 – 2020
Source: Kaygusuz, K. and Kaygusuz, A., "Geothermal Energy in Turkey: The Sustainable Future," *Renewable and Sustainable Energy Reviews*, August 2004

2.6 Biomass Potential

The natural biomass potential of the country is estimated to be 372 TWh.[18] The energy resource includes various agricultural residues such as grain dust, wheat straw, hazelnut and different wastes. About 53% of the natural potential, about 198 TWh, is suitable for electricity production, whereas only 0.45TWh were used in 2010 as shown in Figure 19.

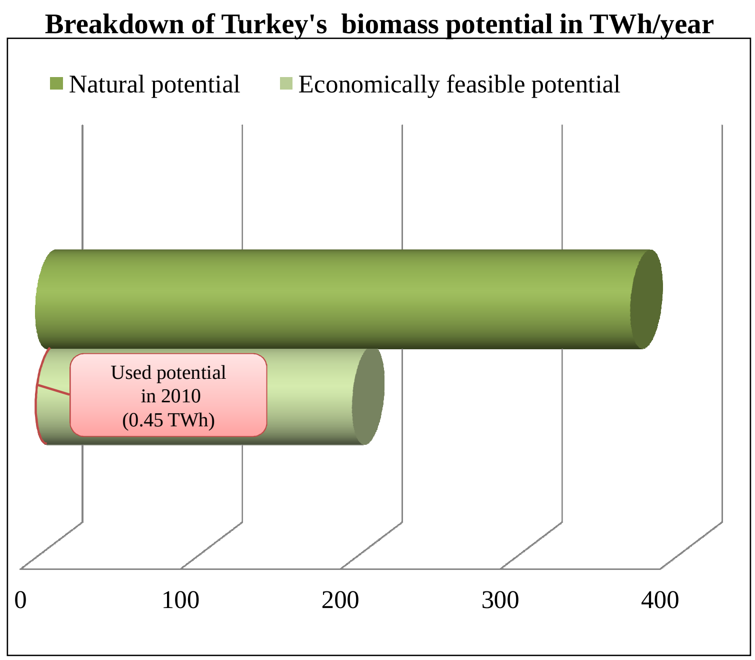
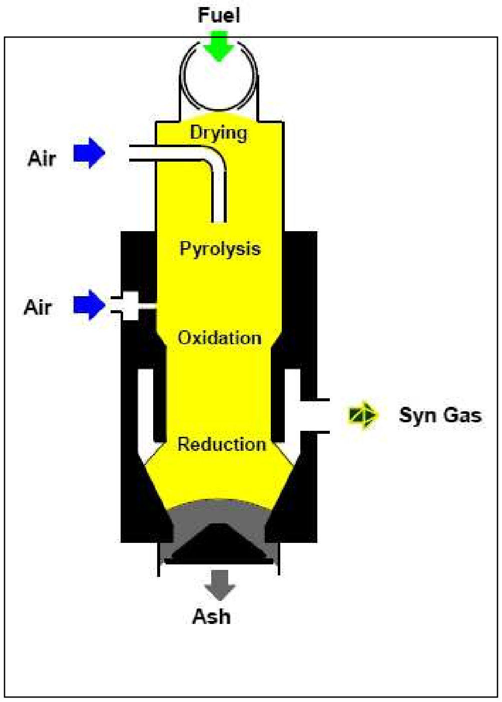


Figure 19: Biomass Electricity Potential and Share of Use
Source: Ayhan Demirbaş, "Production Potential of Electricity from Biomass in Turkey," *Biotechnology* 2006

[18] Çapik, Yılmaz, and Çavuşoğlu, 2011



The method used to convert biomass to electricity is converting biomass to hydrogen and carbon dioxide and the subsequently burning these gases to run a steam turbine. The process of the producing synthetic gas is shown in Figure 20. Due to the complex process and the need for cost intensive purification of the produced gas, commercial use is not readily available. Therefore, very little of this potential is used, and it is not anticipated that it will be used in the near future.

Figure 20: Biomass Gasification Machine for Solid Fuels
Source: Thomas Spaven, *Gasification*, 2011

Due to a low volatility, electricity from biomass and geothermal resources are suitable for base load (the basic level of energy a power plant must produce for its customers), making it a major player in electricity security and stability in a 100% renewable energy scenario.

2.7 Comparison of Electricity Potential for Renewable Energies

The economically feasible electricity potentials of the analyzed renewable energy resources are visualized in Figure 21. The graph also shows the electricity demand in 2010 as well as that predicted for 2020. As can be seen, 0.6% of the total area of the country covered with solar panels will meet the predicted demand. With an expanded area even more electricity could be produced. The economically feasible electricity production from wind energy ranges between 35 – 75TWh. Therefore, at least 8% of the future electricity demand could be covered.

Water energy has been used since 1902; however, only about 3% of the economically feasible potential was exploited in 2010. Even if the geothermal electricity potential is behind the potential of the other renewable energies, almost 15 – 26 TWh could be produced if it were fully exploited. The biomass potential with about 190 TWh per year is about the same amount as the wind potential and is suitable for base load power.

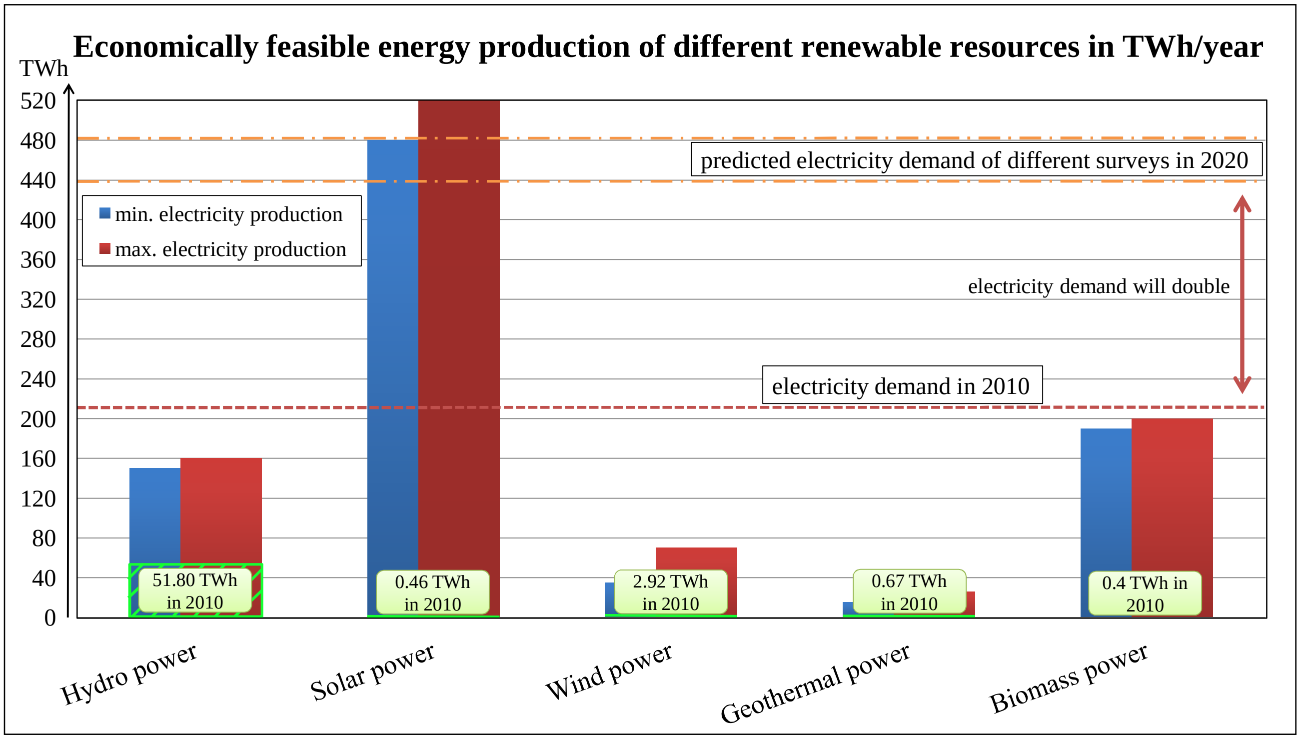


Figure 21: Assessment of Minimum/Maximum Electricity Produced From Renewable Energy Sources 2010
Source: Author

3. Electricity Grid and Cross-border Interconnections

Overview

The electricity grid evolved from the major electricity consumer in 2001 to a well controlled and maintained network.

In 2010

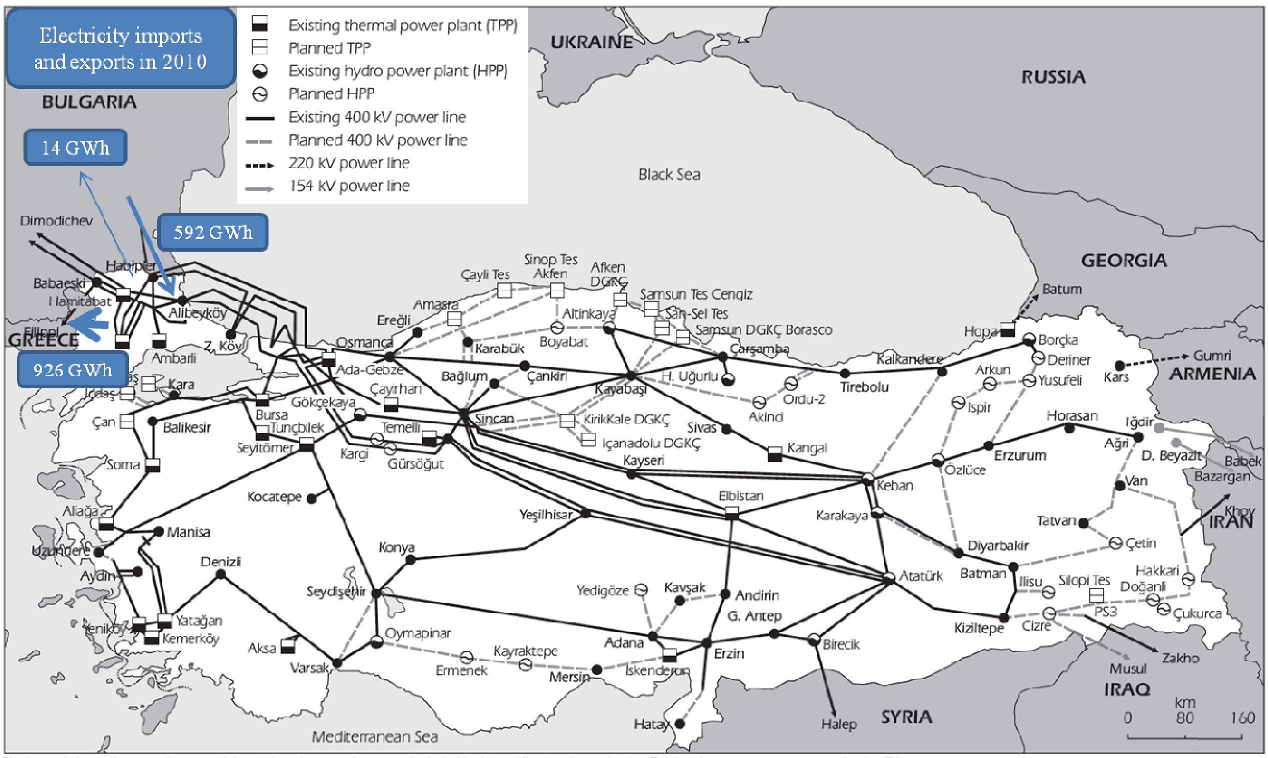
The three (3) state owned public enterprises responsible for electricity production, transmission and trading, namely TEUAS, TEIAS and TETTAS. In October they joined in the European Network of Transmission System Operators for Electricity. Grid adaption and upgrades may be necessary to ensure minimal losses in a 100 % renewable energy

In 1926, the first electricity company, the Kayseri ve Civarı Elektrik Turk Elektrik Inc. was founded. In 1935, several government institutions with authority relating to electricity production were established. In addition to electricity production and distribution, these companies were given the task of identifying the renewable energy potential, mainly focused on the hydro potential for the country. In December 1963, the Ministry of Energy and Natural Resources of Turkey was founded to control the energy policy. All generation assets were passed to TEK, except those belonging to Cukurova Elektrik T.A.S. and Kepez ve Antalya Havalisi Elektrik Santralleri T.A.S. The transmission and distribution operations were handed to the local governments.

Due to the increasing electricity demand, growing power consumption and the government's electrification plans required more coherent organization of the power industry. For that reason, TEK was founded in 1970, and is a fully state-owned and state run entity. Since 1971, it has been responsible for the generation and distribution of electricity throughout the country. In November 1984, with enactment of the Law 3096 –"Respecting Authorization to Institutions other than the TEK for Generation, Transmission, Distribution and Trade of Electricity," private sector firms were allowed to build and operate the electricity generation, transmission and distribution systems. In addition, the country put effort into expanding the grid in a sustainable and reasonable way to meet the rapid and steady electricity demand in Turkey to support its rapid and steady economic growth. This led to a fast and uncontrolled expansion of the electricity grid in the year between 1985 and 2001. Therefore, the transmission and distribution losses increased from 15.9% to 19.3% (about 23 TWh in 2001), becoming the biggest share of consumption.

In 2001, the Electricity Market Law, which paved the way for a free market in power generation and distribution, was enacted. As a result, TEAS was restructured to form three state-owned public enterprises, namely Turkish Electricity Transmission Co. (TEIAS), Turkish

Electricity Generation Co. (TEUAS) and Turkish Electricity Trading and Contracting Co. (TETTAS). In order to be accepted in the European Energy Grid, Turkey improved frequency control, operation and maintenance performance in recent years[19]. Finally, since September 2010, Turkey has been included in the European Network of Transmission System Operators for Electricity (ENTSO-E). The actual physical connection consists of 2 lines with Bulgaria and one with Greece. The net transfer capacity for export ranges from 1.0 to 1.1 GW, whereas the imports vary from 0.8 to 1.3 GW. Figure 22 shows the actual electricity transfer of Turkey due to data provided by ENTSO-E in 2010.



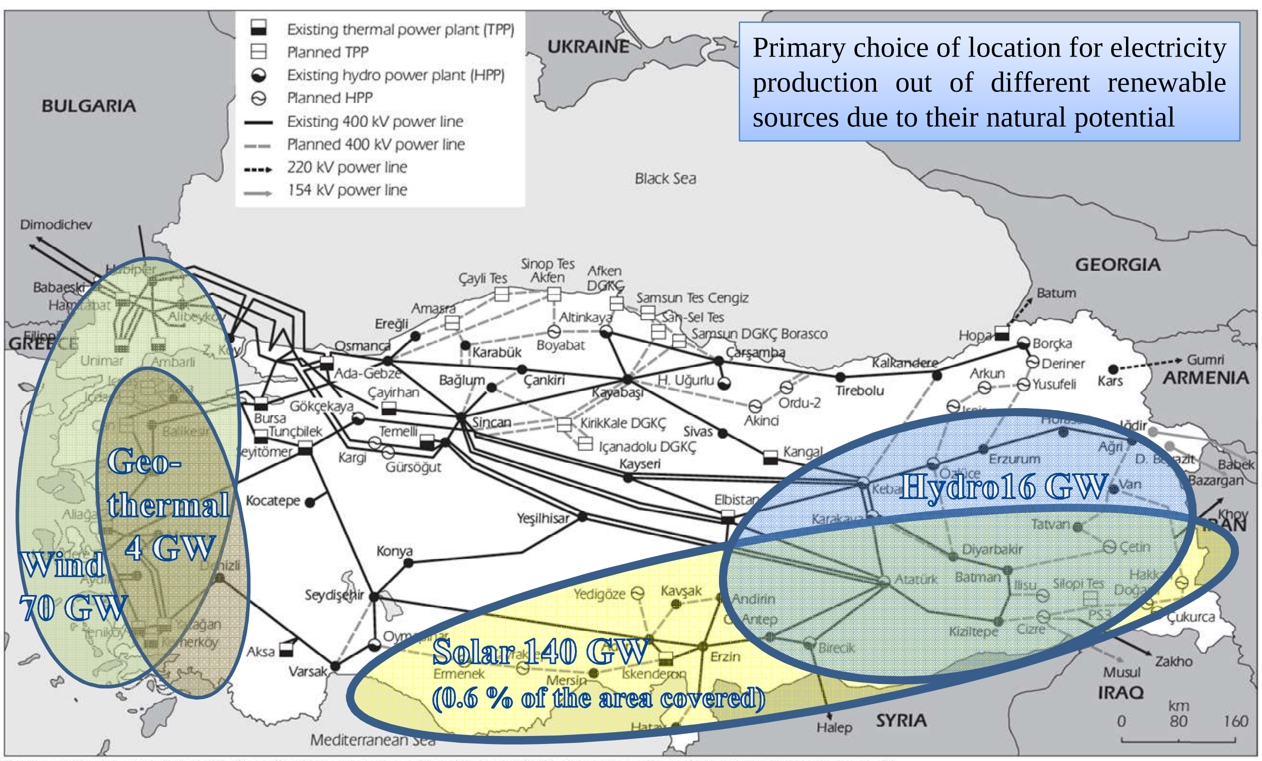
The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Figure 22: Turkey's 2010 Electricity Grid in 2010 and Existing/Planned Thermal and Hydro Power Plants y.
Source: International Energy Agency, *Turkey 2009 Review* (modified by author)

Only 14GWh has been exported to Bulgaria, whereas 592 GWh has been imported. Also, 926GWh were delivered to Greece. Joining the European Network and opening Turkey's internal electricity market creates a convenient position for all parties granting each of them to trade power at every moment. The near-term synchronization with unsynchronized eastern and south-eastern neighbors is unlikely due to the ENTESO-E's technical requirements. However,

[19] Kemal, Yilanci, and Atalay, 2007

power transmission between Turkey and these countries is possible and practiced in the following two ways depending on the signing date of the contract. Contracts signed before the introduction of the 2001 Electricity Market Law must be completed as “island” operations. This means that the importing areas have to be isolated from the Turkish electricity grid and run synchronously with the grid of the exporting country. For contracts signed after the enactment of 2001 the method of “unit direction” can also be used. This offers the possibility of operating a power generating facility or a unit of a generating facility in the electricity system of another country in parallel with the national electricity system. According to the 2009 Electricity Market and Security of Supply Strategy, direct current (DC) lines will be the main option for interconnections with non-ENTSO-E countries. In order to extend the exploitation as well as the electricity production of renewable energy resources in Turkey, the electrical grid will have to be upgraded in specific areas to provide the capacity needed for power delivery. The primary choice for the location of electricity production from the main renewable energy resources based on their natural potential is shown in Figure 23. The numbers in the graph represent an assessment of the economically feasible total installed capacity in the marked area and can be used to estimate the needed electricity grid in that area.



The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Figure 23: Map of Turkey with Primary Areas for Renewable Energy Resource.
Source: International Energy Agency, “Turkey 2009 Review” (modified by author)

4. Conclusion and Outlook

> **Overview**
>
> Current and even future electricity demand for 2020 could easily be met with renewable energies for an economically feasible situation.
>
> Even the primary energy demand could be covered by renewable energies, if sufficiently exploited!
>
> The transition from a fossil fuel based energy system to a renewable energy system is possible, if more commitment is shown.

Turkey has abundant renewable energy potential. If sufficiently exploited and efficiently distributed, this potential would easily be enough to meet the current electricity demand and even the predicted demand for 2020, as can be seen in Figure 23. Solar energy has the highest potential among the renewable energy resources. Furthermore, regions like South Anatolia and the Mediterranean Regions have high solar radiation and are predicted to produce electricity from solar energy. The estimated potential is about 125 times greater than the electricity demand in 2010 and only limited by the area provided. In fact, 1.1 times the area of Istanbul (about 0.3% of Turkey's total area) would be enough to meet the current electricity demand and only 2.5 times the area of Istanbul to cover it in 2020.

The wind potential, which is over 50%, located in the Marmara and Aegean Regions, can cover at least 17% of the today's electricity demand. The actual electricity production varies depending on the use of the right turbines on the right place. Therefore, the economically feasible electricity potential varies on a larger scale between 35 and 75 TWh per year. Approximately 150 to 160 TWh, (74%) of the current electricity demand can be provided through hydro power, the initial technology in Turkey used to produce electricity, starting in 1902. Only about 30% of this potential, which is up to 50% provided through the Euphrates and the Tigris River, is used. The geothermal electricity potential, mostly located at the Alpine-Himalaya Orogen belt in Turkey's west regions is estimated to about 15 to 25TWh per year. This potential may appear low; however, geothermal electricity potential out of other renewable energy resources, like biomass generated electricity, is less volatile than electricity and can be used to cover the base load in a 100% renewable energy scenario. Biomass electricity potential is about 200 TWh per year. However, this potential has not been exploited in a significant way due to the high cost and technologically difficult process of converting biomass to the gases needed for the actual electricity production. The total amount of renewable energy potential will generate a minimum annual electricity potential of 870 TWh per year. This is 4.1 times more than the electricity demand in 2010 and about 1.8 times more than the maximum predicted in

2020. If it comes to the primary energy demand, the *minimum* estimated renewable energy potential cannot cover the total demand, as shown in Figure 24.

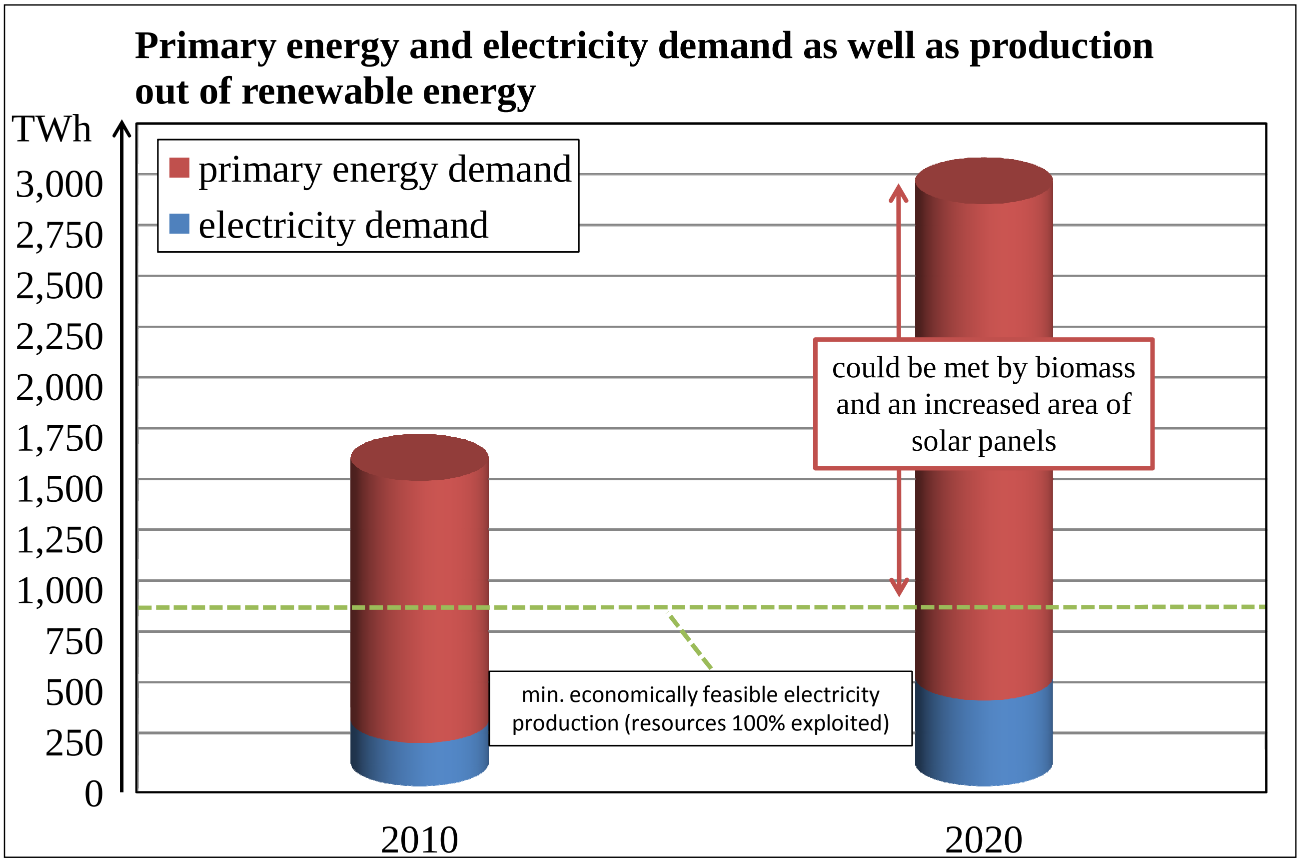


Figure 24: Primary Energy and Electricity Demand for 2010 and 2020 (Predicted)

Source: **Author** Note: The dashed green line represents the minimum economically feasible electricity potential.

The national electricity grid was improved in recent years, transitioning from the major consumer (due to high losses) in 2001 to a frequency controlled, loss reduced and well maintained grid, which in September 2010 became part of in the European Network of Transmission System Operators for Electricity.

Taking all facts into account, the question, "Is possible to be 100% renewable in 2020 in terms of electricity," can be easily answered with ***yes,*** as there is no lack of the renewable energy resources. When it comes to the question, "***how*** is 100% renewable possible for Turkey by 2020," the answer is more complicated as different issues in the means of transition of the energy system have to be discussed.

To the question: How is it possible to be 100% renewable by 2020 in terms of the electricity demand in a country which has an abundant renewable energy resources, enough to over produce for today's and the future's total energy demand, depending on the exploitation level of the resources? As a matter of fact, the will of the Turkish government, its people, companies and investors must pave the way for implementing renewable energy strategies. Compared to subsidies of other European countries, those offered by Turkey (listed on *page 8*) are lower, and, therefore, less attractive to investors. Furthermore, there is the common belief that electricity from renewable energies is still more expensive then from fossil energy fuels. This does not apply in every case, as shown in Figure 25.

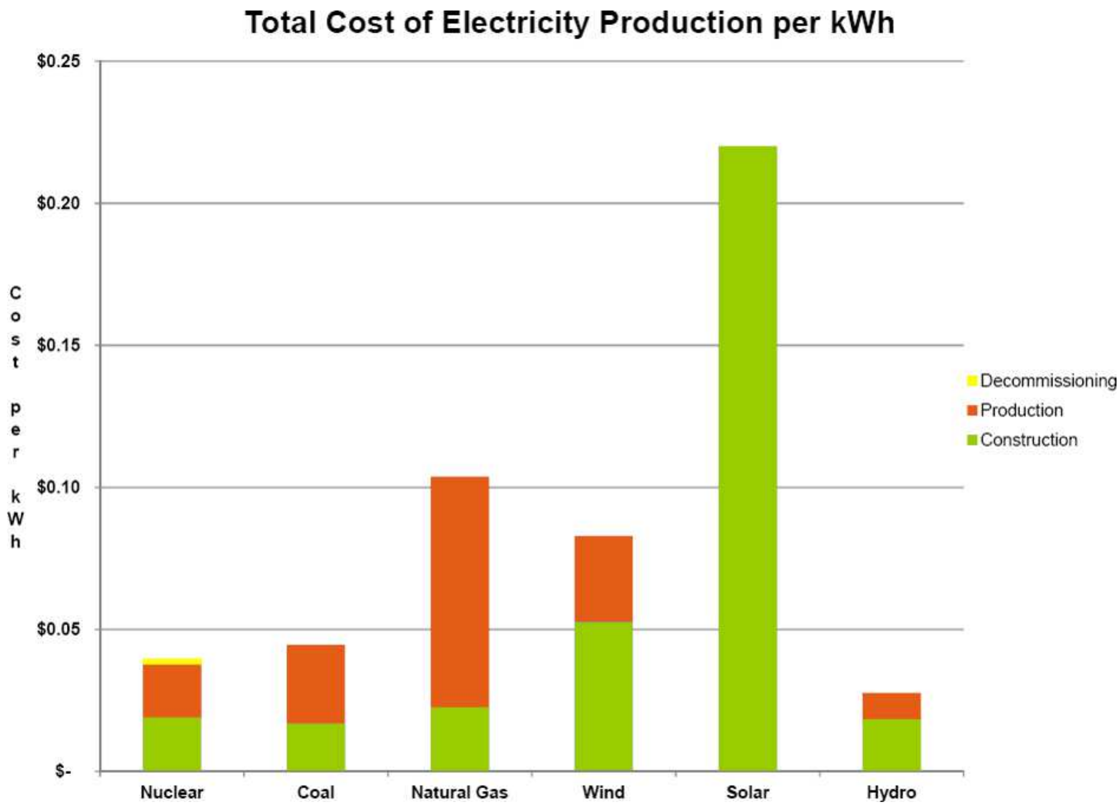


Figure 25: Total Electricity Cost Including Construction, Production and Decommissioning for Renewal Energy
Source: Jason Morgan, **"Comparing Energy Costs of Nuclear, Coal, Gas, Wind and Solar,"** *Nuclear Fissionary*, 2010

Published in April 2010, the chart shows that electricity from hydro power is already more cost effective than electricity from other fuels. Even the price for electricity from wind power is becoming competitive in some cases with that of natural gas and almost with that of coal generated energy. The price of power from solar panels is still higher; but the cost differences decrease day-by-day due to more efficient panels, mass production and rising fossil fuel costs and will finally reach a lower level. Many studies indicate that the transition cost of the energy system will be far less than the long term cost for continuing to use fossil fuels. The main reasons for this are higher adaptation costs due to climate change impacts attributed to high carbon dioxide emissions as well as energy and economic security due to high dependence on foreign countries for fuel imports.

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