



Energy Industry in Turkey



General State of the Economy

Turkey, the official name – the Republic of Turkey, is a country located in both South-West Asia and Southern Europe, with its capital in Ankara [1]. The country has borders with Georgia, Armenia, Azerbaijan and Iran (in the east), with Iraq and Syria (in the south), Greece and Bulgaria (in the west). Turkey has access to the Mediterranean, Black, Aegean and Marmara seas.

According to 2022 statistics Turkey, which in terms of size is placed 38th in the world, is home to more than 83 million people. In terms of population density the country is 108th in the world from 247 countries considered [2,3].

The political form of government is a parliamentary republic, the official language is Turkish. The administrative map of the country is divided into 81 provinces [3].



Sources:

1. GDP (purchasing power parity), 2020 est. / The World Factbook/Library/Central Intelligence Agency *228
 2. GDP - per capita (PPP), 2020 / The World Factbook/Library/Central Intelligence Agency *229
 3. Inflation rate (consumer prices), 2019 est. / The World Factbook/Library/Central Intelligence Agency *228
 4. Charges for the use of intellectual property, receipts (BoP, current US\$), 2020 / International Monetary Fund, Balance of Payments Statistics Yearbook, and data files. / License: CC BY-4.0 *88
 5. The Global Competitiveness Index 2019 / Rankings / Reports / World Economic Forum *141
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 7. 2021 Index of Economic Freedom / International Economics / The Heritage Foundation *178
 8. Reserves of foreign exchange and gold, 2017 est. / The World Factbook / Library / Central Intelligence Agency *195
 9. Annual average GDP growth in %, for the last 10 years (2011-2020) / World Bank national accounts data, and OECD National Accounts data files / License: CC BY-4.0 *206
 10. Public debt (% of GDP), 2017 est. / The World Factbook / Library / Central Intelligence Agency(from smallest to largest) *210
- * Total number of countries participating in ranking

Figure 1. Economic indices of Turkey

Turkey has a sufficiently developed market economy, which is reflected in the diagram presented - Fig.1. The country's economy is based on the service sector and the agricultural sector, as well as petrochemical, automotive and electronics industries, which have surpassed the textile industry that was once traditional for the country [3]. For the majority of indices the positioning of the country is higher than the world average, in the top half of the graph, and for 4 indices in the top quarter of the graph (i.e. among the 25% of the best countries in the world included in the rating). Nevertheless, in terms of inflation Turkey is well below the world average.

Between 1990 and 2020 the country experienced sustained GDP growth in purchasing power parity, both in general and per capita [4,5]. GDP at purchasing power parity increased from \$1.985 trillion in 2015 to \$2.173 trillion (14th place in the world) in 2017, and to \$2.393 in 2020 [3]. The country's GDP at purchasing power parity per capita is lower (68th place in the world in 2020), which has also been demonstrating positive dynamics: from \$25,200 in 2015 to \$26,900 in 2017, and to \$28,400 in 2020 [3].

The level of inflation changed from 7.8% in 2016 to 11.1% in 2017 and to 15.4% in 2019, in terms of this indicator the country was 215th in the world (ranked by levels of inflation, smaller to larger) [3].

Energy resources

Turkey has no significant reserves of fossil resources (Table. 1). According to proven reserves of oil and natural gas, the country is ranked 51st and 92nd in the world, respectively [3]. According to data for 2018 in terms of

According to The Global Competitiveness Report 2019, presented by the World Economic Forum, Turkey was 61st (out of an estimated total of 141 countries), behind the large number of EU countries, including neighbouring Bulgaria. This rating reflects the effectiveness of the use of the country's own resources for sustainable development. In addition to a number of economic indicators this index also takes into account such variables as education, health, level of innovation, etc.

In the list of 134 countries that exported high-tech products in 2019-2020, Turkey was 37th, ahead of Kazakhstan and South Africa. According to the Index of Economic Freedom 2022, which is based on freedom of business, freedom from government action, property protection, and freedom from corruption, the country was considered «mostly unfree», 107th, out of 177 countries. In terms of gold reserves and foreign exchange reserves Turkey was 24th in the world, behind Saudi Arabia, Israel and Iran.

According to the indicator for the average GDP growth in % over the last 10 years, the country was 24th out of 206 countries in 2020. In terms of public debt, calculated as a percentage of the country's GDP, Turkey in 2017 was ranked 169th out of 210 countries considered.

For more information on the economy of Turkey see the attached link library by clicking [here](#).

tons of oil equivalent, proved oil reserves amounted to 0.6%, coal - 99.4% (Figure 5). The matrix of unconventional resources looks somewhat different - tight oil accounted for 40.4%, shale gas - 39.2%, kerogen oil - 19.3%, coal mine methane utilization potential - 1.1% (Fig. 5).

Table 1. Fossil energy resources of Turkey

Resource/ explanations	Crude Oil	Natural Gas	Coal	Tight (Shale) Oil*	Coal mine methane	Shale Gas*	Oil Shale
Value	366	3.794	11 525	4.7	8.8-35.7	23.6	1 985
Unit	mmbbl	Bcm	Mt	mmbbl	Bcm	Tcf	mmbbl
Year	2021	2021	2020	2013	2018	2013	2008
Source	[3]	[3]	[7]	[9]	[7,8]	[9]	[10]

*unproved technically recoverable

According to [6] oil reserves in Turkey at the beginning of 2016 were estimated at 312 million barrels, and according to [3], at 366 million barrels in 2021.

Proven natural gas reserves in Turkey are very small. Thus, at the beginning of 2016, it was estimated at 177

Bcf according to [6], and 3.794 billion m³ as of 2021, according to [3].

Total proven coal reserves, according to BP, in 2020 were estimated at 11 525 million tons [7]. According to Advanced Energy Technologies calculations, the poten-

tial for coalmine methane utilization, according to a methodology based on methane emissions from coal mining [8] and its reserves in 2018 from [7], amounted to 8.8-35.7 Bcm.

Turkey also has unconventional hydrocarbon reserves: shale gas - 23.6 Tcf, tight shale oil - 4.7 billion barrels and kerogen oil - 1 985 million barrels [9,10]. However, the share of unconventional resources in oil equivalent

does not exceed 20% of the total traditional fossil resources.

Turkey, due to its geographical position, has a large variety of reserves of renewable energy sources. A selection of basic indicators of this type of resource is presented in Table 2.

Economically exploitable hydropower capability in Turkey amounted to 170 000 GWh/year [11]. According to

Table 2. Renewable energy resources of Turkey

Resource/ explanations	Solar Potential (GHI)*	Wind Potential (50 m)*	Hydro energy Potential**	Bio Potential Agricultural area	Bio Potential Forest Area	Geothermal Potential	Municipal Solid Waste
Value	4.4-4.9	6.0-7.0	170 000	49.1	28.9	1 500	1.10
Unit	kWh/m ² /day	m/s	GWh/year	% of land area	% of land area	MWe	Per capita/kg/day
Year	2018	2018	2013	2020	2020	2013	2016
Source	[13]	[14]	[11]	[15]	[16]	[12]	[17]

*for the majority of the territory of the country

**economically exploitable capability

specialists (Parlaktuna et al., 2013), Turkey's geothermal energy potential was estimated at 1,500 MWe [12]. The level of global horizontal radiation for the majority of the country is 4.4 - 4.9 kWh/m²/day, and in the south, between Gaziantep, Sanliurfa and Mardin provinces, can reach the maximum level of 5.2-5.3 kWh/m²/day [13]. Obviously, these are sufficient resources for the massive development of solar energy in the country. The distribution of wind resources is as follows: for the the majority of the country the wind speed is 6.0 - 7.0 m/s, and in the west of the country, along the coast of Aegean and Marmara seas, it can exceed 7.0 m/s at an altitude of 50 metres [14]. Naturally, this is a good potential for the future development of wind energy in Turkey.

According to data for 2020, 49.1% of the territory of the country is occupied by agricultural land, the area of which has been slightly increasing during the last half-

century [15]; at the same time 28.9% of the territory of the country was forested, also demonstrating a small growth [16].

The level of generation of municipal waste in Turkey is 1.10 kg per capita per day, which is at the world average, slightly lower than in neighbouring Bulgaria (1.17 kg per capita per day) and Greece (1.38 kg per capita per day). An increase of up to 2 kg per capita per day is predicted by 2025 [17]. This resource is a valuable raw material for recycling and energy production.

A detailed list of sites and special reports on Turkey energy resources can be found [here](#).

Energy Balance

According to the BP Statistical Review of World Energy 2022, total primary energy consumption in Turkey in 2021 was 6.83 exajoules, about 27.7% of which was oil, 25.5% – coal, 30.2% – natural gas, 7.6% - hydroenergy, 8.9% – other renewables [7].

Using the data from [3,7] we calculated GDP per unit of primary energy use in Turkey in 2021 – \$15.9 taking into account PPP in 2011 prices per unit of energy expended (the equivalent of energy contained in one kg of oil

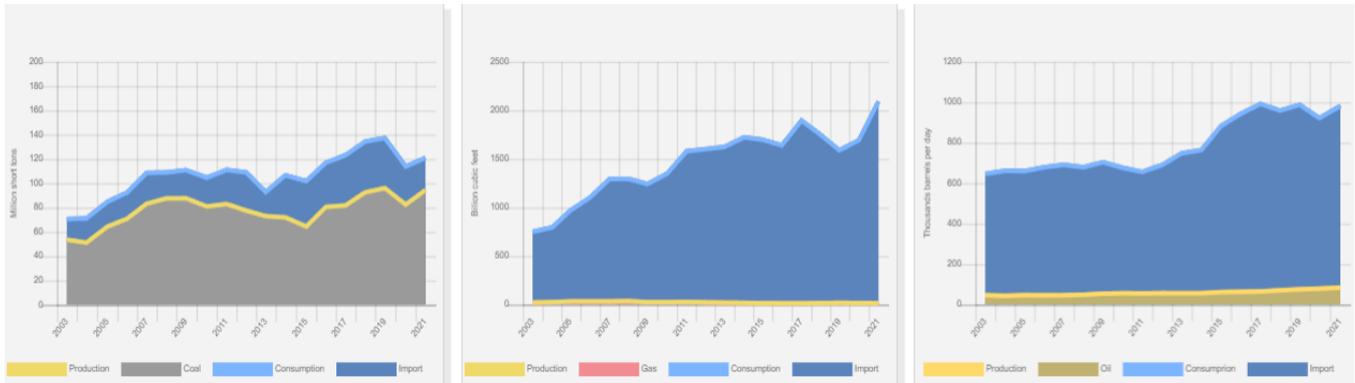
equivalent/\$ PPP per kg of oil equivalent), which corresponds to the world average level of GDP energy efficiency.

Oil consumption between 2001 and 2020 underwent a slight increase (Figure 2), and in 2021 amounted to 981 thousand barrels/day, while production also showed growth – from 47 thousand barrels in 2001 to 84 thousand barrels in 2021 [18]. In 2018, total final oil products consumption in the country amounted to 24 895 ktoe [19].

Oil imports to Turkey in 2018 were estimated at 423,500 barrels / day [3].

Natural gas consumption between 2001 and 2021 grew rapidly and by 2021 amounted to 2092 Bcf, against 563 Bcf in 2001 [18]. At the same time, according to the

International Energy Agency, the total final natural gas consumption in the country amounted to 41 096 ktoe in 2018 [19]. In 2019, Turkey imported about 45.09 Bcm of natural gas [3].



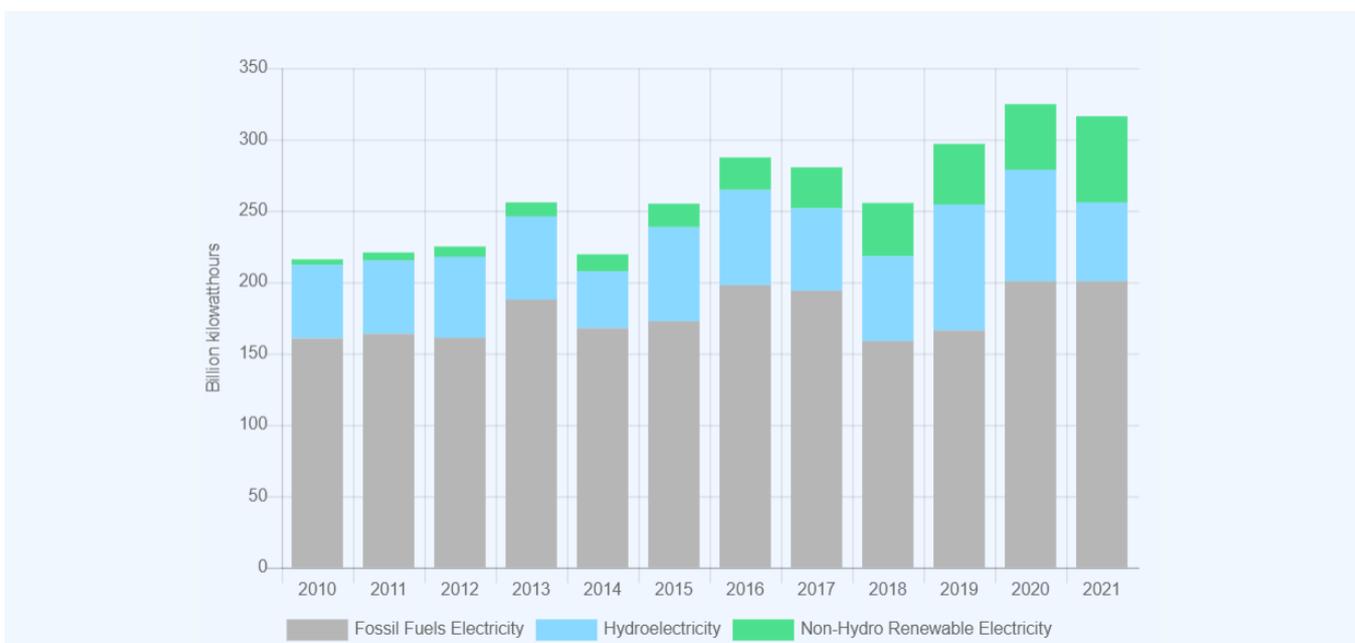
Source: U.S. Energy Information Administration (Dec 2021) / <https://www.eia.gov/>

Figure 2. The production and consumption of fossil fuels in Turkey (left–coal, In the center– gas, right–oil)

Coal consumption in the country since 2001 has gradually increased till 2019, with small annual fluctuations, and in 2019 amounted to 137.176 million short tons, falling to 120.818 million short tons in 2021. Coal production also increased since 2001, but in 2011 it slowed down and amounted to 84.49 million short tons in 2017, rising again to 94.39 million short tons in 2021 [18]. According to BP, in 2021 coal production amounted to 0.75 exajoules, and consumption was twice as high – 1.74 exajoules [7].

The share of imports in TPES of the country according to calculations based on data from [19] in 2018 was more than 74.7%.

Turkey mainly uses fossil fuels for the production of electricity, however, it is worth noting the increase in the share of renewable energy sources, which significantly offset the overall increase in electricity consumption. (Fig. 3).

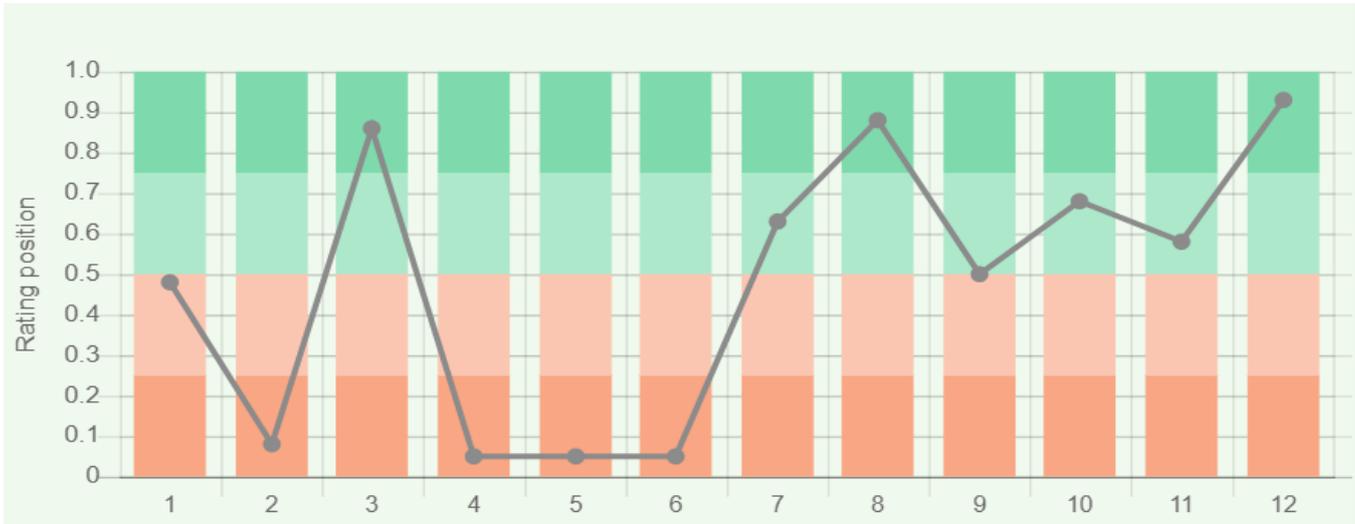


Sources:
Source: U.S. Energy Information Administration (Dec 2021) / <https://www.eia.gov/>

Figure 3. Electricity production in Turkey

In 2021, according to the U.S. Energy Information Administration, the country produced 316.3 TWh, of electricity, where fossil fuels accounted for 63.5%, hydropower – 17.4%, renewables – 19.1% (Fig.6).

Turkey's position in the comparative diagram of energy index is shown in Figure 4.



Sources:

1. Crude oil proved reserves, 2021 / International Energy Statistic/Geography / U.S. Energy Information Administration (Nov 2021)*98
 2. Natural gas proved reserves 2021 / International Energy Statistic / Geography / U.S. Energy Information Administration (Nov 2021) *99
 3. Total recoverable coal reserves 2019 / International Energy Statistic / Geography / U.S. Energy Information Administration (Nov 2021) *81
 4. Combination production-consumption for Crude oil 2018 / International Energy Statistic / Geography / U.S. Energy Information Administration (Nov 2021) *219
 5. Combination production-consumption for Natural gas 2019 / International Energy Statistic / Geography / U.S. Energy Information Administration (Nov 2021) *123
 6. Combination production-consumption for Coal 2019 / International Energy Statistic / Geography / U.S. Energy Information Administration (Nov 2021) *128
 7. Electricity – from other renewable sources (% of total installed capacity), 2017 est. / The World Factbook / Library / Central Intelligence Agency *170
 8. GDP per unit of energy use (PPP per unit of oil equivalent), 2020 *66
 - Primary energy consumption - BP Statistical Review of World Energy 2021/BP/GDP (purchasing power parity) - The World Factbook/Library/Central Intelligence Agency
 9. Energy use (primary energy use of oil equivalent per capita) 2020 *127
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 10. The Global Energy Architecture Performance Index Report (EAPI) 2017 / Rankings / Reports / World Economic Forum
 11. Electric power consumption (kWh per capita), 2016 *217
 - Electricity Consumption - The World Factbook / Library / Central Intelligence Agency; Population - United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, custom data acquired via website. Retrieved 15 November 2021
 12. Combination of electricity production-consumption (kWh)/The World Factbook/Library/Central Intelligence Agency *216
- * Total number of countries participating in ranking

Figure 4. Energy indices of Turkey

Turkey is at the bottom of the list of countries in terms of production/consumption of oil and gas, ranging from high to low values. At the same time, in terms of coal reserves the positioning of the country looks quite convincing.

In another rating in 2015, the list of countries for the production of electricity from renewable sources (excluding hydropower), Turkey was 63rd out of 170 countries selected for consideration, ahead of the USA and Canada.

In 2020, Turkey was 13th out of 66 countries ranked by the ratio of GDP per unit of energy use, while in terms of

energy consumption per capita the country is 44th in the world. These are rather convincing indicators of the country's successful striving for energy efficiency. In terms of electricity consumption per capita, the country is 91st in the world, however, for the indicator of combination of electricity production-consumption, Turkey is 15th in the ranked list of 216 countries, ahead of a number of EU countries.

More information about the energy balance of Turkey can be found in the documents from our reference library [here](#).

Energy Infrastructure

A territorial map of the distribution of the largest infrastructure projects of the fossil fuel sector and electricity in Turkey is shown in Figure 5.

In the total potential of fossil energy resources, coal plays the predominant role - 99.4% (Figure 5). The main coal mine in Turkey is Yenikoy, located in the south-west of the country, which can produce 8.5 million tons annually [20].

The largest oil field is Bati Raman, oil production from which, according to [21], was 7,000 barrels per day. The total installed capacity of Turkey's refineries is 560,500 barrels/day (Fig. 5). The main refinery - Izmit Refinery is owned by Tüpraş, with an installed capacity of 226,000 barrels/day [22].

Oil and petroleum products are imported via several oil terminals, including four large ones, and six large oil storage facilities, the largest being Samsun with a capacity of 41,443 m³ [23]. Crude oil is transported via a network of pipelines with a total length of 3,038 km (Fig. 5).

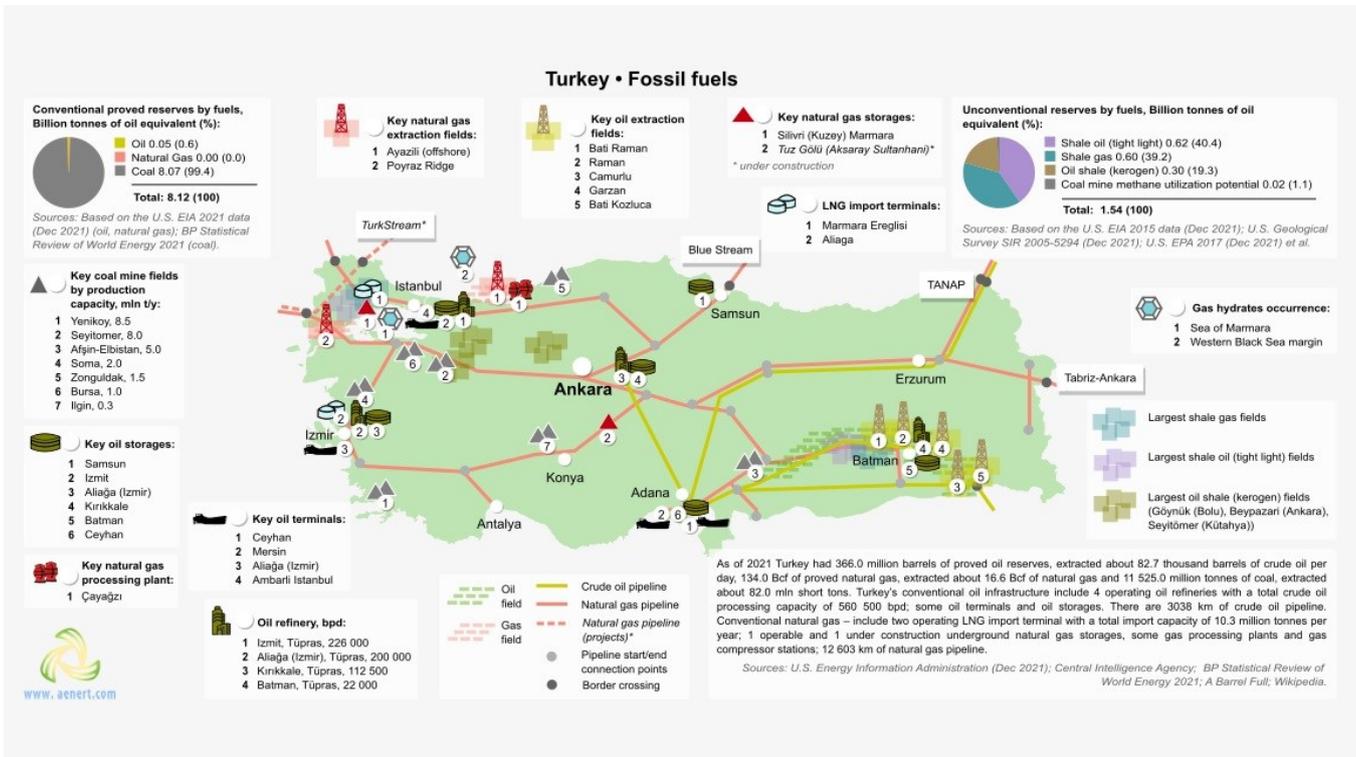


Figure 5. Basic infrastructure facilities of the fossil fuel sector in Turkey

The largest gas field in Turkey is the offshore Ayazılı, the production from which can reach 7.3 mln ft³ / day [24]. The Turkish gas system is represented by one large gas storage facility (another one is under construction), several gas compressor stations, two LNG terminals with a total capacity of 10.3 million tons [25] and a network of pipelines with a total length of 12,603 km. Pipeline gas is imported from Russia via the Blue Stream gas pipeline with a capacity of 16 Bcm/year, as well as the Trans-Anatolian Natural Gas Pipeline launched in 2018 with a capacity of 16 Bcm/year. Gas via this pipeline is delivered from Azerbaijan in transit through Georgia and Turkey to Greece (up to 10 billion m³).

In addition, the “Turkish Stream” gas pipeline is being constructed in conjunction with Russia (Figure 5). The total capacity of this double-stranded gas pipeline will be about 32 billion m³ of gas per year. The gas pipeline is designed in equal proportions to provide gas to Turkey and the countries of South-Eastern Europe. Another important project is the Pars Pipeline from Iran, which

could also ensure gas supplies to Europe by transit through Turkey. Thus, Turkey is gradually becoming one of the most significant transit countries for the delivery of energy resources to the region.

Turkey pays considerable attention to the study of accumulations of gas hydrates, which are also found in the coastal waters of the Black Sea.

The map of the territorial distribution of Turkey's largest infrastructure facilities for electricity generation is presented in Figure 6.

According to the U.S. Energy Information Administration, in 2021 the country produced 316.3 TWh of electricity, where fossil fuels accounted for 63.5%, hydropower - 17.4%, renewables - 19.1% (Fig.6). The country has a significant number of stations for the production of electricity from fossil fuels, including twelve coal and thirteen gas power plants with a capacity of over 600 MW, as well as thirteen hydropower plants with a capacity of more than 510 MW (Fig. 6).

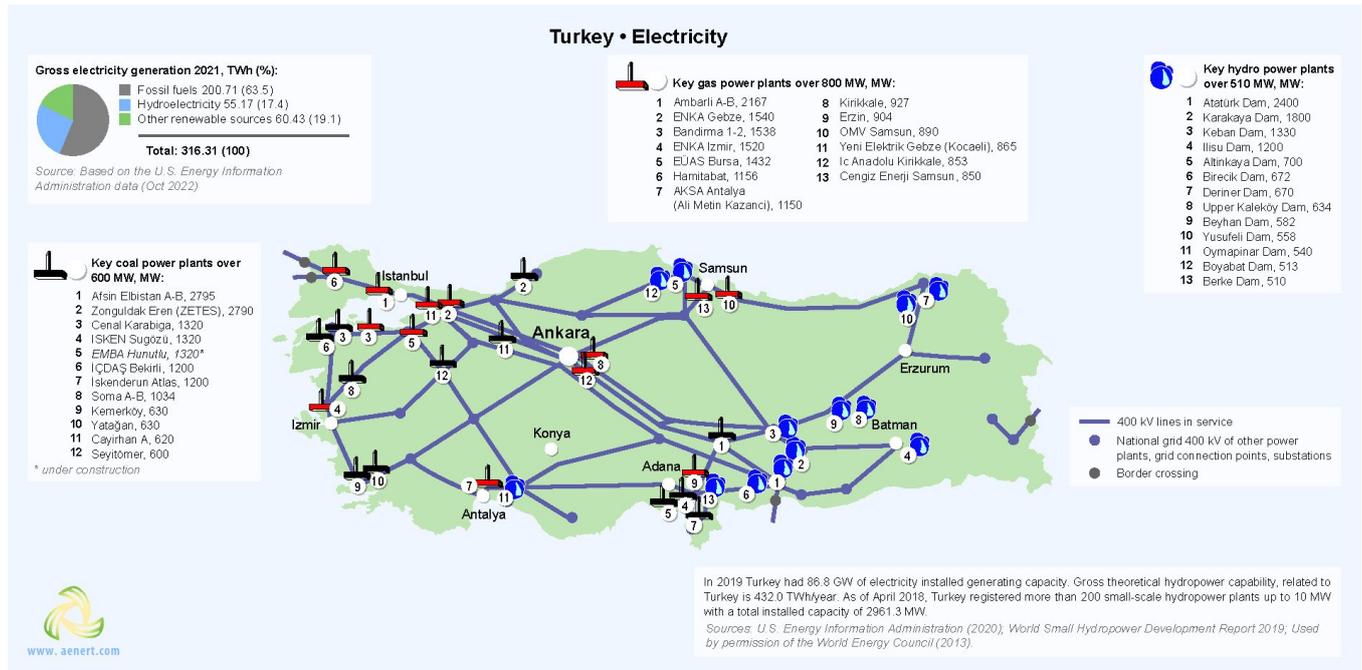


Figure 6. Electricity production in Turkey

The largest power plants in Turkey are: Ambarlı A-B gas power plant with capacity of 2,167 MW [26], Afsin Elbistan A-B coal power plant with installed capacity of 2,795 MW [27], and Atatürk Dam hydropower plant with a capacity of 2,400 MW [28]. The map of the territorial distribution of the largest infrastructure facilities of renewable energy in Turkey is presented in Figure 7. The total electricity production

from renewable sources (excluding hydropower) amounted to 60.43 TWh in 2021 (Figure 6). In the zones of high wind activity there are 12 large wind parks, with a capacity of more than 90 MWt each. In 2016 Turkey registered about 281 wind farms, with a total capacity of 6857 MW [29], and more than 10 GW wind capacity in 2021. The largest is Soma Wind Farm with a capacity of 240.1 MW [30].

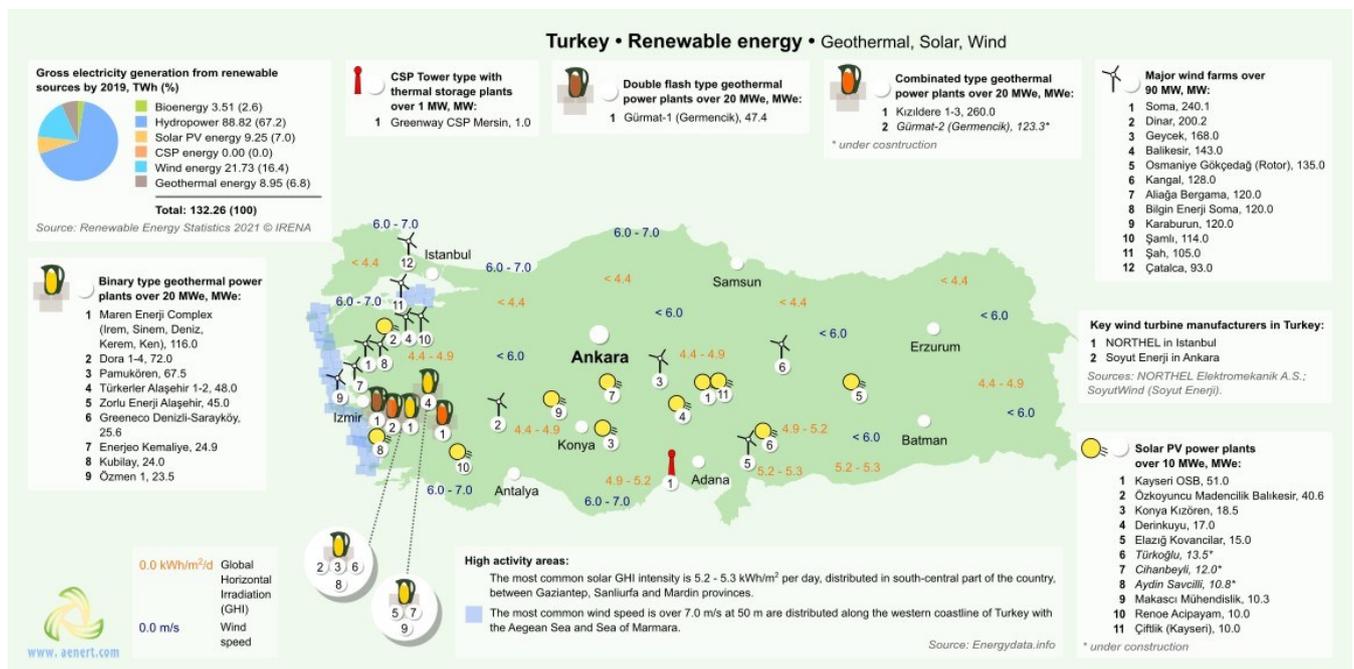


Figure 7. Renewable energy in Turkey: solar, wind and geothermal resources

Turkey has a number of large wind turbine manufacturers, such as NORTHEL, Soyut Enerji (Figure 7).

As noted above, the level of global horizontal solar irradiation in some areas of the country can reach 5.3 kWh/m²/day [13]. As a result, there are a number of PV power plants on this territory. In Mersin there is the Greenway CSP Mersin tower type power plant (1 MW) [31]. About 7% of electricity from renewable sources in Turkey is generated via PV stations. The largest station of this type is Kayseri OSB (51 MW) [32].

In the western provinces of Turkey, rich in geothermal resources, there are a number of facilities, including binary-type power plants, double flash and combined-type

power plants that use geothermal energy to produce electricity and heat. One of the largest is Maren Enerji Complex binary-type power plant, with a capacity of 116 MW [33], the leading combined-type power plant is Kizildere 1-3, with a capacity of 260 MW [34], Gürmat-2 (Germencik) Double Flash Geothermal Power Plant has an installed capacity of 123.3 MW [35]. Turkey is one of the world leaders in terms of installed capacity of geothermal energy; the country is ahead of such giants as New Zealand, Mexico, Italy and Iceland.

Figure 8 shows the main bioenergy objects of the country for energy production.

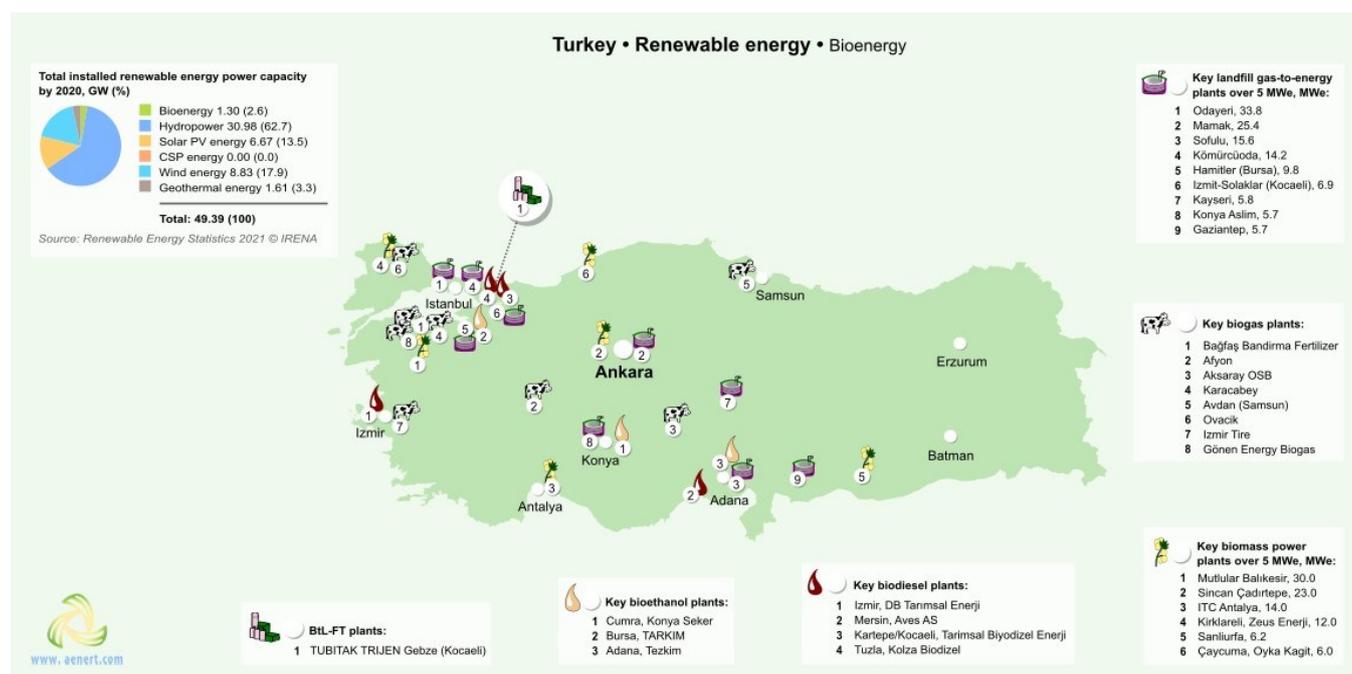


Figure 8. Renewable energy in Turkey: Bioenergy

The share of bioenergy in electricity production is 2.6% (Fig.7). There are biogas enterprises in the country as well as enterprises for processing municipal waste, production of biodiesel, bioethanol, pellets, etc. (Fig.8).

Turkey's largest enterprises for the production of second-generation biogas and bioethanol: Izmir, DB Tarımsal Enerji with an installed capacity of 80,000 t/year and Konya Seker, located near Çumra, with a capacity of 84 million litres per year [36,37]. The largest biogas plant in the country is BağfaşBandırma Fertilizer Biogas plant with an installed capacity of 9.9 MW [38].

Among other bioenergy companies, TUBITAK TRIJEN Gebze BTL-FT Plant is capable of producing 250 t/year of liquid hydrocarbons [39]. The main enterprise using biomass for energy production is the Mutlular Balıkesir, with

an installed capacity of 30 MW [40]. Odayeri generates about 33.8 MWe of electricity from landfill gas [41].

For current information on the development of energy in the country see [here](#). More information about Turkish energy infrastructure is also available [here](#).

Education and Innovation

The set of indices reflecting the position of Turkey among other countries in the field of education and innovation can be seen in Figure 9.

Turkey is 41st out of 132 countries considered in the ranking of countries of the Global Innovation Index 2021 (see diagram), having lost seven ranking positions. According to the number of patents granted to Turkish residents, both inside the country and abroad, the country ranks 27th in the world, behind a number of European countries, but nonetheless shows a figure higher than the world average. Similarly, by the number of patents in force, the country is above the world average – 24th place, which largely characterizes the country's patent attractiveness.

In terms of government expenditure on education as a percentage of the country's GDP, the country is not performing very well - 88th out of 177 countries selected for consideration, which has enabled 21 Turkish universities to enter the QS University Rating.

Turkey is very well positioned when considering the number of publications of specialists in scientific and technological journal and patent activities. The country is

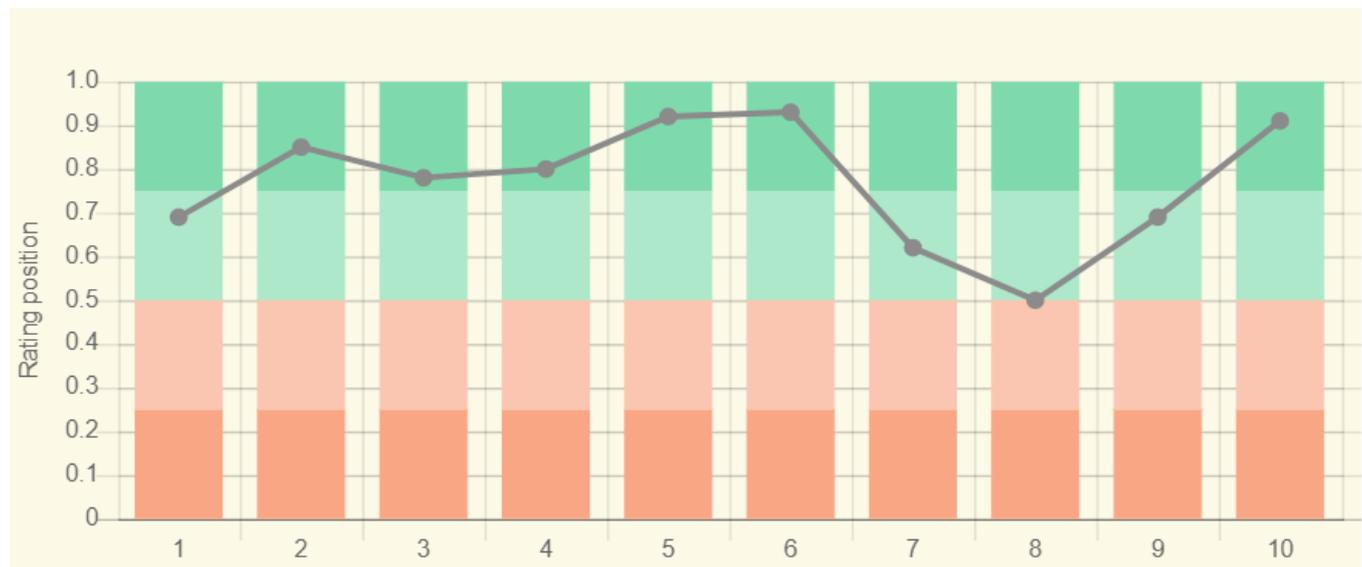
20th out of 240 participating countries in the Scimago ranking, and in Scientific and Technical Journal Activities it is ranked 17th out of 197 countries. The country is also among the leaders in the region in terms of the number of Internet users and is 37th in terms of government expenditure of research and development.

Turkish universities, such as the Middle East Technical University, Hacettepe University, and Istanbul Technical University train specialists in various fields of energy, including Mining Engineering, Civil Engineering, Geological Engineering, Renewable Energy, Energy Engineering, etc.

In the field of synthetic fuel production the main research institutes are Gazi University, Bogazici University, and Istanbul Technical University.

In the field of unconventional oil, leaders in patenting are Altaca Insaat Ve Dis Ticaret A.S.. Research in this field is being conducted by the Middle East Technical University, Ankara University, and Hacettepe University.

The Middle East Technical University and Dokuz Eylül University conduct research in the field of gas hydrates. Another important area is coalbed methane, here leaders in the number of publications are the Middle East Technical University and Istanbul Technical University.



Sources:

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 9. Research and development expenditure (% of GDP), 2018 / UNESCO Institute for Statistics. License: CCBY-4.0 / Data *119
 10. Scientific and technical journal articles, 2018 / National Science Foundation, Science and Engineering Indicators. License: CCBY-4.0 / Data *197
- * Total number of countries participating in ranking

Figure 9. The indices of education and innovation in Turkey

In the field of hydrocarbon production from reservoirs with low permeability, leading research institutions are the Middle East Technical University and the Turkish Petroleum Corporation. The leading patent holders in the field of bioenergy are Episome Biyoteknolojik Urunler Sanayi Ve Ticaret Anonim Sirketi, Altaca Insaat Ve Dis Ticaret A.S. Research is conducted by Ege University and Yuzuncu Yil University.

A large number of companies patent technical solutions in the field of energy production from renewable sources. In the field of solar energy - Hse Hitit Solar Enerji

Anonim Sirketi, Bimed Teknik A.S. Leading research organizations in this field are Gazi University, Ege University, and the Karadeniz Technical University.

Uztek Endustri Tesisleri Insaat Imalat Ve Montaj Sanayi Ve Ticaret Limited Sirketi are all ahead in the number of patents in the field of wind power, and the Middle East Technical University, Istanbul Technical University, and Gazi University conduct research in the field.

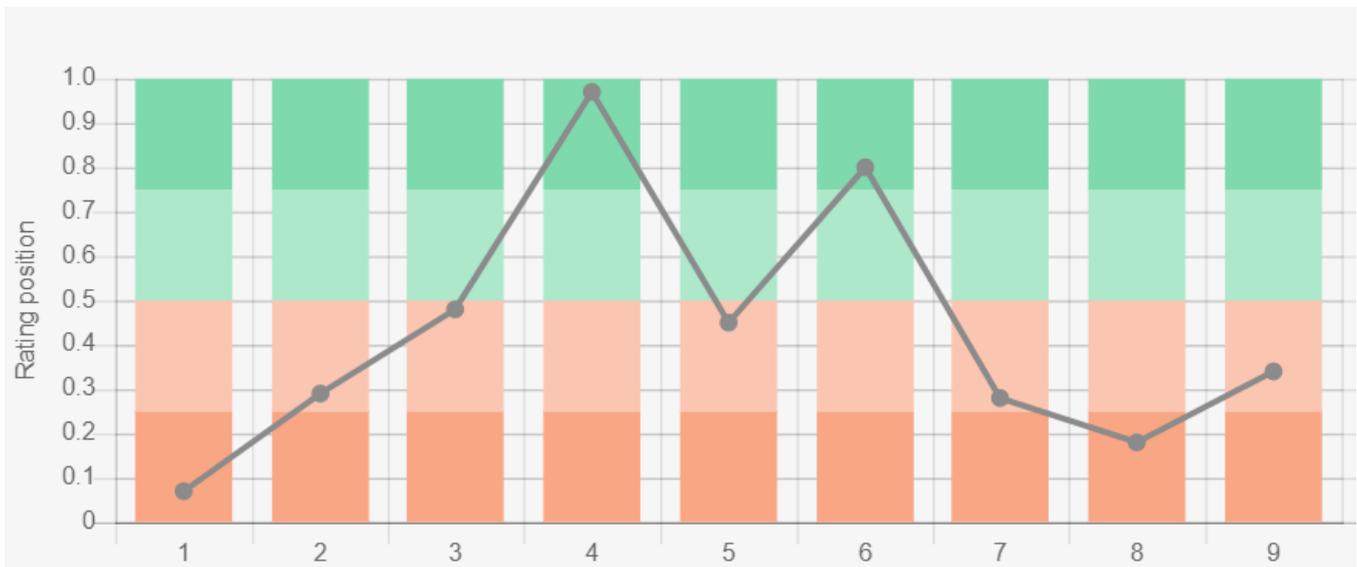
Additional information about education in the country can be obtained [here](#), and the list of research institutes [here](#).

Ecology and Environment Protection

The diagram of environmental indices presented in Figure 10, to some extent reflects the ecological situation in the country, which in the case of Turkey is quite negative. First of all, the country demonstrates a relatively high level of CO₂ emissions in general, and per capita. It is also necessary to note the high level of methane emissions in the country. Turkey is at 39th place in the Climate Change Performance Index (CCPI) 2022, which consists of 60 positions and includes 61 countries

responsible for more than 90% of global energy-related CO₂ emissions.

In terms of forest area as a percentage of the country, Turkey was 121st in 2020 out of 234 countries. However, the trend associated with its change from 2010-2020 looks very positive, and according to this indicator the country is 6th in the world. Also, the country is very well positioned in the Environmental Performance Index (EPI) 2020, which focuses primarily on the environmental activities of national governments, aimed at reducing



Sources:

1. CO₂ total emission by countries 2020 / European Commission / Joint Research Centre (JRC) / Emission Database for Global Atmospheric Research (EDGAR)*208
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* Total number of countries participating in ranking

Figure 10. Environmental indices of Turkey

negative impact on the environment, and rational use of natural resources. In this ranking, the country is 108th out of 180 participating countries, behind many countries in the region, including, for example, Iran, Saudi Arabia and Azerbaijan.

However, according to the Environmental Vulnerability Index, which is based on years of observations and 50 indicators that include, for example, changing climatic characteristics or the quality of water resources, waste

volumes, oil spills and other hazardous substances, etc. Turkey is 185th out of 234 countries, and is characterized as «vulnerable». Finally, it is worth mentioning that according to the Ecological Footprint Atlas rating Turkey is among a number of ecological debtors.

For more information on the energy complex of Turkey see the attached link library by clicking [here](#).

References

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The sources of charts and curves are specified under the images.