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Comparison of Present Coal and Renewable Energy Sources in Turkey

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Abstract: In parallel with the technological development, industrialization and population increase in today's world, the demands of the countries for electricity has also started to increase considerably. In particular, the issues such as climate change and greenhouse gas emissions that create life-threatening hazards to the environment and human health; Coal and fossil fuels are often compared with renewable energy resources (geothermal, solar, wind, biomass, hydraulics, hydrogen, wave etc.). In this context, it is of paramount importance for Turkey providing approximately 41% of its electricity from coal to commission and to activate efficiently alternative energy sources, which are renewable in sustainable energy corridor of Turkey. In the present work, information about coal potential, which plays a key role in Turkey's electricity production, and given this potential in terms of future energy policies are compared with renewable energy sources.

Keywords: Turkey, coal, climate change, renewable energy sources.

Introduction

The use of energy, which is considered to be one of the most basic inputs of manufacturing and one of the indicative parameters of the level of development for countries, is increasing at a global scale. With increasing demand, fossil fuels, especially those that lead to world energy supply such as coal and oil, the existence of environmental hazards such as climate change and greenhouse gas emissions are becoming increasingly debatable today for reasons such as diminishing and non-recoverable resources. Such that the World Meteorological Organization (WMO) denoted that the year 2016 was warmer than when compared to the pre-industrial period, and entered the record as the hottest year measured with a value of 1,1°C (DeCola & WMO Secretariat, 2017). It also highlights the importance of the Paris Treaty, which has been enacted as the most comprehensive treaty on climate change so far and came into force on 4 December 2016. Along with this treaty signed by 170 countries, it is aimed to keep the global average temperature rise limit below 2°C (www.unfccc.int). The countries involved in the treaty have set out their intention to carry out the commitments of the treaty with the Intended Nationally Determined Contribution (INDC) in the name of achieving this goal. Turkey's energy commitments given in the special context of this document are listed as follows (www4.unfccc.int):

- Solar power generation to reach 10 GW capacity by 2030,
- Electricity generation from wind energy reaches 16 GW by 2030,
- Use of all possible hydroelectric capacities,
- Acquisition of 1 nuclear power plant by 2030,
- Reduction of the rate of losses in electricity generation and distribution to 15 percent by 2030,
- Rehabilitation works in public power generation plants and
- Dissemination of production, cogeneration and micro-cogeneration systems in electricity production

Significant progress is being made in the future towards the use of renewable energy resources, as can be seen from the aforementioned materials. Also showing the variation of total greenhouse gas emissions in 2030 as a result of the commitments given to the UN, Turkey's chart is given in Figure 1. Here, (upper line) based on current energy production without any precautions, estimates 1 billion 175 million tons of greenhouse gas emissions as CO_2 equivalent in 2030. If necessary measures are taken (lower line), this value is reduced by 21% to 929 million tons.

Outside these commitments given by Turkey, using indigenous primary energy sources in energy production rates also support the requirement that the introduction of energy sources which are renewable. Primary energy production between the years 1970-2013 two-fold increase in total primary energy consumption in Turkey has increased six-fold between these years. This deficit was not met with available resources, and in 2013 only 27% of the primary energy consumption was achieved through domestic resources (Turkish Chamber of Mining Engineers, Energy Working Group, 2015). Advanced as a country, Turkey's economy continues to grow and the demand for energy with increasing population density is also escalating day by day. Turkey's overall energy profile of energy production assessment made by this study demonstrated the role of coal as the first place in this profile. In addition, the potential of the country in terms of renewable energy sources has been assessed and information on the current use of these resources

and future projections has been given.

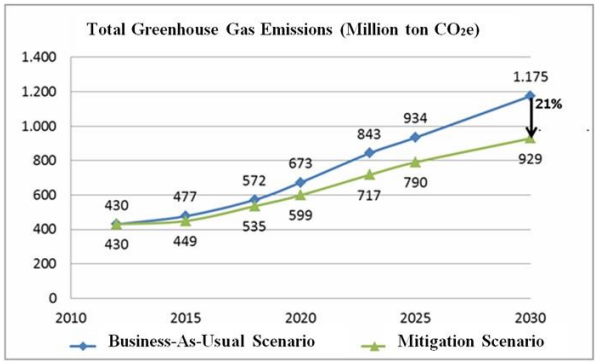

Fig. 1 The total greenhouse gas emissions stated in Turkey's INDC Document (www4.unfccc.int).

Situation of Coal in Energy Sector of Turkey

Turkey's primary energy production has doubled in the period between the years 1970 to 2013 and reached from 14.5 Mtoe to 31.9 Mtoe with the average annual growth rate of 1.85%. However, since the total consumption ratio has increased at an annual average rate of 4.4% and the current domestic resources have been limited among these periods causing the production demand not to be met. In 1970, 77% of Turkey's total demand was met from domestic sources while only 26.5% of energy needs was contributed by national sources at the end of 2013 (Turkish Chamber of Mining Engineers, Energy Working Group, 2015).

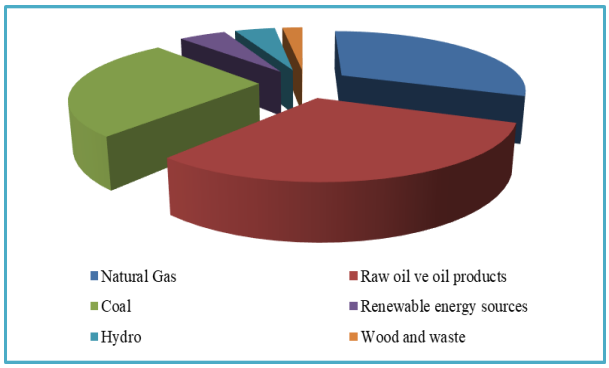

Fig. 2 Distribution of the primary energy supply in Turkey according to sources.

In the following periods, this situation continued to increase and the primary energy supply reached 129 Mtoe levels in 2015, showing a 7% increase over the previous year. When the distribution of this supply according to sources is examined; the first order belongs to natural gas with 39.7 Mtoe. Then, respectively; Crude oil and petroleum products with 39,2 Mtoe, coal with 34,7 Mtoe, renewable resources such as geothermal, wind and sun with 6,7 Mtoe, hydraulic with 5,8 Mtoe and wood, animal and plant residues with 2,9 Mtoe (T.R. Ministry of Energy & Natural Resources, Turkish Hard Coal Board, 2017). The distribution of Turkey's primary energy supply source is illustrated in Figure 2.

By the end of 2015, having studied the distribution of energy production according to sources in Turkey, coal is seen in the first order with 12.8 Mtoe. It was followed by renewable energy resources such as wind, geothermal and solar energy with 6.6 Mtoe, hydraulic with 5.8 Mtoe, wood, animal and plant residues with 2.9 Mtoe, crude oil with 2.6 Mtoe and Natural gas with 0.3 Mtoe (T.R. Ministry of Energy & Natural Resources, Turkish Hard Coal Board, 2017). Distribution of resources of primary energy production in Turkey is shown as a percentage (Fig. 3).

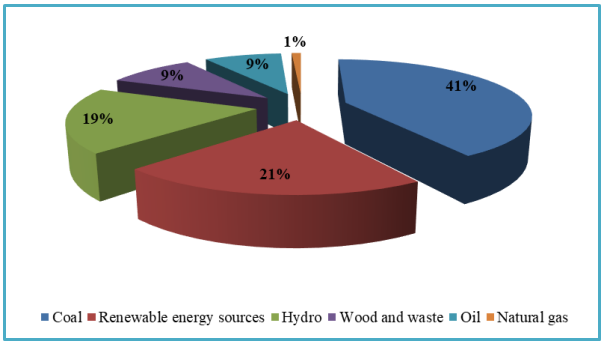

Fig. 3 The distribution of the source of primary energy production in Turkey.

As seen from the chart, coal has still indispensable position in Turkey's energy production as in the past.. In recent years, the incentives of the state on energy have increased and especially infrastructure works in renewable and nuclear energy fields have accelerated in order to minimize the negative effects of global climate change and reduce the dependence on external energy. In spite of all these positive developments, it is vital that the existing coal reserves are operated efficiently, the discovery of new reserve fields and the application of technological developments to obtain clean coal energy.

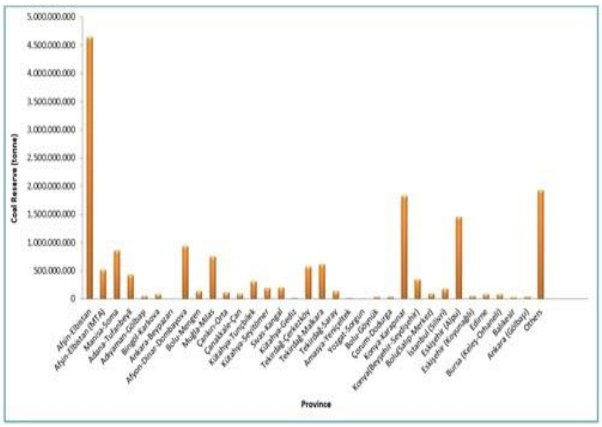

Fig. 4 The amount of lignite reserves by provinces in Turkey.

Coal Reserves and Production in Turkey

Total comprising about 2.1% of world coal reserves, Turkey has an important place in terms of lignite. However, 79% of lignite is used in thermal power plants because it has below 2500 kcal/kg of heat value.

Table 1 Hard coal Reserves in Turkey (tons).

Reserve type	Not-coking hard coal	Semi-coking hard coal	Coking hard coal			Total
	Amasra	Armutcuk	Kozlu	Uzulmez	Karadon	
Ready	384.000	1.739.250	2.845.985	386.049	2.943.021	**8.298.305**
Visible	400.286.853	6.524.821	63.820.075	134.135.139	130.188.611	**734.955.499**
Probable	154.855.599	15.859.636	40.539.000	94.342.000	159.162.000	**464.758.235**
Possible	66.570.778	7.883.164	47.975.000	74.020.000	117.034.000	**313.482.942**
TOTAL	**621.713.230**	**32.006.871**	**155.180.060**	**302.883.188**	**409.327.632**	**1.521.494.981**

About 85% of the approximately 70 Mtons of annual production carried out in recent years is consumed in thermal power plants. The installed power capacity of thermal power plants utilizing lignite is 8.515 MW, which corresponds to 23.6% of total installed power. It is planned to increase the installed power by 20,000 MW by putting the recently evaluated lignite reserves into use quickly (www.mta.gov.tr).

A total of 2,271,826 meters of drilling were carried out by the Mineral Research and Exploration Directorate (MRED) as of November, 2017 as a result of intensive coal exploration studies initiated in 2005. 13 new coalfields were discovered, including 4 large reserves (Karapinar-Ayranci, Eskişehir-Alpu, Afyon-Dinar, Tekirdag-Malkara) as well as extension of 3 existing coalfields and lignite reserves were increased by 9.2 Btons. Thus, the lignite reserves of the country reached 17.5 Btons. The amount of lignite reserves by provinces in Turkey is shown in Figure 4 (www.mta. gov.tr). Hard coal is one of the major coal resources of Turkey with the exception of lignite. The most important hardcoal reserves are located in the Zonguldak basin. In the coal exploration works carried out up to now, the basin has descended to a depth of -1200 m and a reservoir of approximately 1.5 Btons has been located. The reservoirs of these mines and the mines operated in the basin are given in Table 1 (T.R. Ministry of Energy & Natural Resources, Turkish Hard Coal Board, 2017).

Turkey‘s potential of lignite and hard coal are mostly used for electricity generation by thermal power plants. As of the end of 2016, 184,889 GWh of 273,387 GWh electricity generated was supplied from thermal power plants, while 67,268 GWh from hydroelectric power plants and the remaining 21,230 GWh were supplied from renewable energy sources. It is possible to say that after 2009, the role of renewable energy sources in general electricity generation increased. In 2002, wind and geothermal energy production in Turkey increased from 153 GWh to 21,230 GWh with solar energy being included in the system in 2016. In Table 2, the electricity production values of the resource base between 2002 and 2016 are given (T. R. Ministry of Energy & Natural Resources, Head of Strategy Department, 2017).

The Potential of Renewable Energy Sources in Turkey and Their Role in Energy

Global climate change is presently one of the most important environmental problems. The main cause of this natural phenomenon is the greenhouse gases that

Table 2 The electricity production of the resource base (GWh).

Year	Thermal Power Plant	Hydraulic	Wind + Solar + Geothermal	Total	Increase (%)
2002	95.563	33.684	153	129.400	5,4
2003	105.101	35.330	150	140.581	8,6
2004	104.464	46.084	151	150.698	7,2
2005	122.242	39.561	153	161.956	7,5
2006	131.835	44.244	221	176.300	8,9
2007	155.196	35.851	511	191.558	8,7
2008	164.139	33.270	1.009	198.418	3,6
2009	156.923	35.958	1.931	194.813	-1,8
2010	155.828	51.796	3.585	211.208	8,4
2011	171.638	52.339	5.418	229.395	8,6
2012	174.872	57.865	6.760	239.497	4,4
2013	171.812	59.420	8.921	240.154	0,3
2014	200.417	40.645	10.901	251.963	4,9
2015	179.366	67.146	15.271	261.783	3,9
2016	184.889	67.268	21.230	273.387	4,4

are released uncontrollably to the atmosphere. In particular, CO_2 emitted by fossil fuels burned to generate electricity has the largest share in greenhouse gas emissions. For this reason, both on a global scale and on a country-by-country basis, mechanisms should be looked for to promote clean energy and encourage the use of renewable energy sources. Information about Turkey's potential of renewable energy sources is mentioned in this section together with its place in the overall energy portfolio.

earth's rotation around its axis, surface rubbing, local heat spread, different atmospheric phenomena in front of the wind, and the topographical structure of the land. The features of wind change temporally and locally due to local differences in geography and the non-homogeny warming of the globe (www.eie.gov.tr).

In addition to the disadvantages such as the wind power not having a high income to support wind turbines, the noise problem created by surrounding settlements, and bird dying in case of wind turbines being installed on migration routes (Kaplan, 2015), the

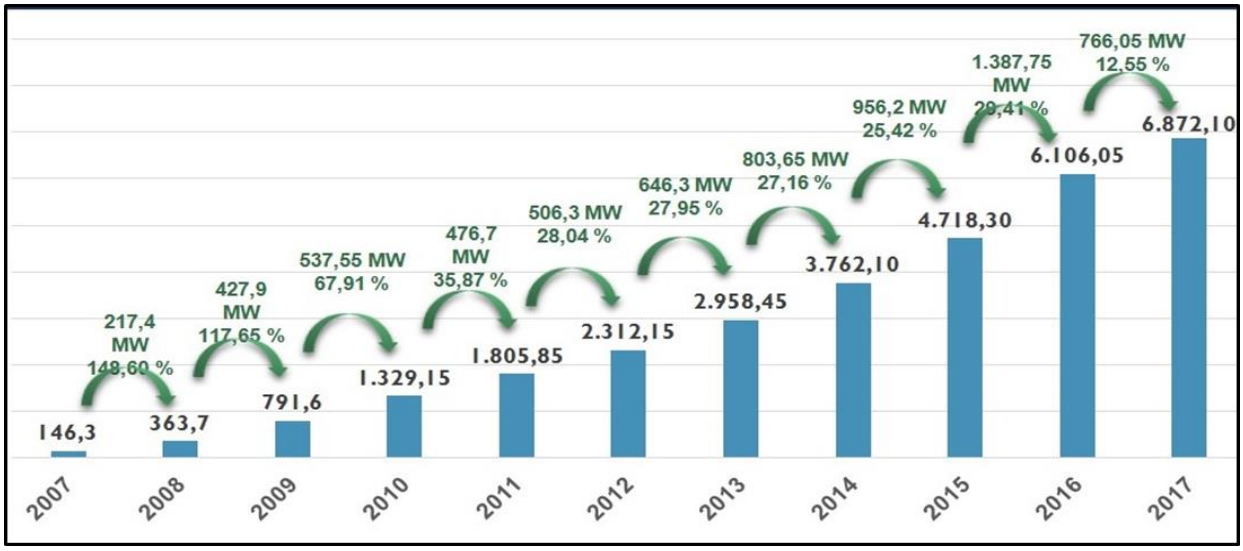

Fig. 5 Installed power distributions of wind power plants on the basis of years.

Wind Energy

Wind power is known as a renewable, natural, endless and clean power sourcing from sun. Just a little 1-2% of the energy that the earth gets from the sun can be converted into energy of wind. Air flow occurs because of the temperature and pressure difference occurring as a result of the sun not heating surface of the earth and the atmosphere homogenously. If an air flow is more heated than its original heat, it arises the atmosphere and by the increase in this air mass, the cold air mass of the same volume replaces its place. The displacement of these air masses is called as the winds. While winds move from high pressure areas to low pressure areas, they take different forms due to the

advantages in general can be listed as follows (www.eie.gov.tr);

- Redundant and free in the atmosphere,
- Clean and renewable, environment friendly,
- It never exhausts; there is no risk of increase in price by time,
- The cost is compatible with power plants of today,
- Lower operating and maintenance costs,
- Creates employment,
- It is completely domestic, no external dependency,
- The installation and operation is rather simple and
- It can be operated after installation in a short time.

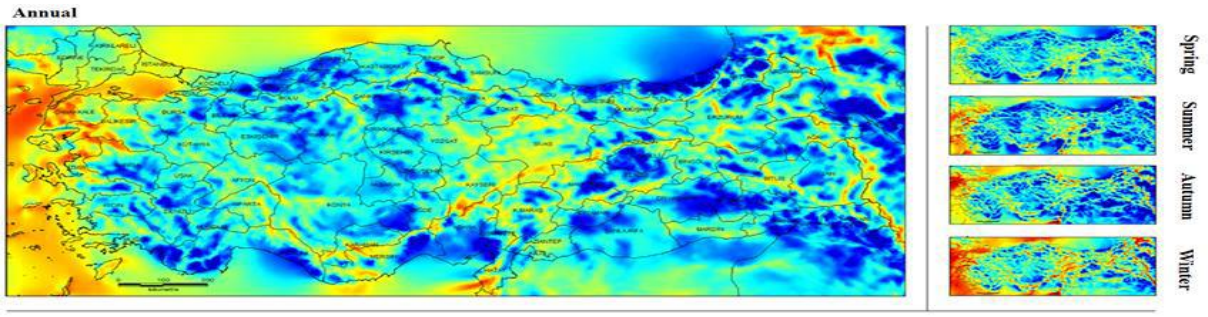

Fig. 6 Wind speed map of Turkey for 50 m height.

In the areas 50 meters over ground level and with the wind velocity of over 7.5 m/s, wind power plant of 5 MW per square kilometer is considered for the establishment in Turkey. In the presence of these assumptions, a Wind Energy Potential Atlas (REPA) is prepared, which gives wind source information produced using a medium-scale digitalized weather forecast model and a micro-scale wind flow model. region, 34% in the Marmara region, 13% in the Mediterranean region and 9% in the Central Anatolia region.

İzmir, Balikesir, Manisa and Hatay are in the forefront in the order of providing the primary wind energy, although there is an increase in installed power in the Black Sea and Southeast Anatolia regions by 2016 (www.enerjienstitusu.com). Turkey to height of 50 m

Fig. 7 The map of solar energy potential in Turkey.

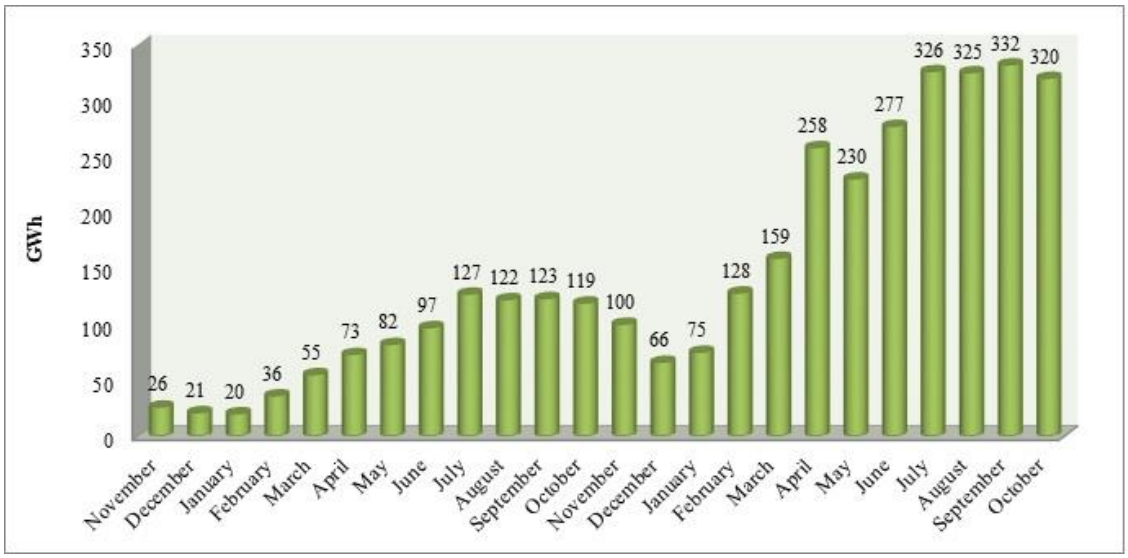

Fig. 8 Electricity production realized by licensed and unlicensed SPP in Turkey (2015 Nov. – 2017 Oct.).

Turkey wind energy potential of 48,000 MW has been identified. This sum corresponds to the potential area correlating to 1.30% of Turkey's surface. The installed capacity of licensed wind power plants working by the end of 2016 was 5,751.3 MW and its share in total installed power was 7% (www.enerji.gov.tr; www. polatenerji.com). Figure 5 shows the installed power distribution of wind power plants depending on years (www.enerjienstitusu.com). When the regional distribution of wind energy plants in use is examined, in terms of installed power, 39% is in the Aegean wind speed map is depicted in Figure 6. (www.eie.gov.tr).

Solar Energy

Another source of renewable energy resources is solar energy. Looking at the world as a whole, the average energy production from solar energy is 1%. When the countries are examined on some occasions, Italy accounts for 8% of its electricity production, Greece 7.5% and Germany 6 to 7% from solar energy. In

Turkey, this rate is only 0.5%. Despite having a considerable potential in terms of solar income, this potential cannot be assessed as necessary because of the lack of a scientific and permanent solar energy policy and the fact that roof applications do not reach desired levels (Turkish Chamber of Mechanical Engineers, Report of Energy Working Group and METU Energy Commission, 2017).

The total installed capacity of 1644 Solar Power Plants (SPP) in Turkey was determined as 1362.60 MW. In 2016, 1,020,000,000 kWh of electricity was produced by the SSP. SPP mainly work with two different structures. These are photovoltaic and thermal systems. In the photovoltaic system, solar radiation is converted into electricity by means of panels, and the energy generated is used by making it suitable for use with the converter device. In thermal systems, the sun's rays are conveyed to a certain point by special mirrors. The liquid (water, oil etc.) located at this certain point is heated to some degree, therefore the mechanical energy is converted into kinetic energy by vapor pressure as it is in the thermal systems with this heated liquid. Figure 7 shows the map of solar energy potential in Turkey (www.enerjiatlasi.com). When the map is examined the energy density shows itself especially in the south and southeastern part of the country. In addition, the electricity generation values realized by licensed and unlicensed solar power plants (SPP) in October and before October of the year 2017 are given in Figure 8 (www.enerjiatlasi.com).

Hydraulic Energy

Hydraulic energy is a sort of energy realized by converting the existing potential energy of water into kinetic energy. The kinetic energy generated by lowering the water from the upper levels to the lower levels provides rotation of the turbines and electrical energy is obtained. Hydraulic energy potential depends on the precipitation regime. In addition to these functions, hydropower plants with storage facility built for electricity production serve many purposes (flood prevention, irrigation, development of aquatic products, tourism development, facilitating transportation, etc.). In addition, hydropower plants with storages provide energy storage facilities and have an important role in meeting the needs of the most peak hours of energy. In addition, hydroelectric power which is domestic and renewable is a strategic energy source that will not be exhausted as long as the world's water cycle continues (Bozkurt & Tur, 2015).

An average altitude of Turkey is 1131 meters and the areas higher than 1000 meters cover about 55.5% of

Table 3 Electricity generation and future projects in GAP context.

Condition	Annual av. generation (GWh/year)	Ratio (%)	Total installed cap. (MW)	State (MW)	Private sector (MW)	HEPP (number)
Active	22790	61,7	6175	5527	648	34
Under construction	6907	18,7	2370	1399	971	7
Planning & projection	7246	19,6	2192	270	1922	65
Total	36943	100	10737	7196	3541	106

Table 4 Coruh Basin Master Plan Projects.

Dams and HEPPs	Installed capacity (MW)	Annual energy generation (GWh/year)	Current situation
Laleli Dam & HEPP	102	251	Planning
İspir Dam & HEPP	132	359	Planning
Aksu Dam & HEPP	120	344	Planning
Yusufeli Dam & HEPP	558	1888	Under construction
Artvin Dam & HEPP	332	1026	Active
Arkun Dam & HEPP	245	842	Active
Gullubag Dam & HEPP	96	314	Active
Deriner Dam & HEPP	670	2118	Active
Borcka Dam & HEPP	301	1039	Active
Muratli Dam & HEPP	115	444	Active
Total	**2671**	**8625**	

the total surface area. 64% of the country's land inclination is above 12%. This makes Turkey advantageous in terms of topography and hydrological conditions for hydroelectric power generation. Hydroelectric power plants have advantages in terms of operation, environment and strategy as well as the advantage of using domestic resources (www.tesisat.org).

Turkey's theoretical hydropower potential of 433 billion kWh and 216 billion kWh is technically considered hydropower; the potential developed by existing investments is 158 billion kWh/year. It is estimated that this value will reach 180 billion kWh/year along with the new projects that can be developed together with the completion of the basin master plans. 596 hydroelectric plants' total installed capacity which is in operation by the end of the year 2016 in Turkey is 26.819 MW. The average annual output of these power plants is 93.653 billion kWh. This value corresponds to approximately 52% of the total developed potential. Hydroelectric power plants (HPP) were constructed and built by the State Hydraulic Works (SHW) with 12.380 MW (46.2%) of the 26,819 MW installed capacity in the process of converting the hydroelectric potential into energy. With the hydropower potential starting with Seyhan I HEPP in 1956, Alpaslan I, Akkopru, Kilavuzlu and Ermenek HEPPs in 2012, Deriner Dam and HEPP in 2013, Cine Dam and HEPP in 2014, Topas Dam and HEPP in 2016, the total installed capacity reached 12.380 MW with an average annual capacity of 43,992 billion kWh together with 6 small HEPPs (Anamur, Ercis, Kernek, Silifke-I, Uludere, Durucasu with less than 2 Mw installed capacity) making in total of 66 HEPPs. In addition, the total installed capacity of the three hydroelectric power plants under construction in the State Hydraulic Works' investment program is 1.920 MW and the annual average energy production is 6.313 billion kWh. When these HEPPs are completed, they will reach a hydroelectric potential of 14,300 MW, which will be built and operated by SHW generating 50,305 billion kWh of energy annually (T.R. Ministry of Forestry and Water Works, General Directorate of State Water Works, 2016).

Significant improvements have been made in the hydropower development of the GAP project. As of the end of 2016, the proportion of projects in the GAP region, which were established by the State and private sectors, reached a level up to 87%. 13% of the remaining planning and projects in the project stage to bring the country's economy to work quickly continues. Table 3 gives detailed information on GAP (T.R. Ministry of Forestry and Water Works, General Directorate of State Water Works, 2016).

Another important project for hydroelectric power generation is planned to be realized on to the Coruh Basin. Coruh River main branch located within the master plan projects (8564 billion kWh/year) is the technical potential of Turkey corresponding to about 5%, project information is given in Table 4 (T. R. Ministry of Forestry and Water Works, General Directorate of State Water Works, 2016).

Nuclear Energy

Globally, 11% of electricity production is provided by nuclear energy. The US, which has 99 nuclear power plants with the world's largest nuclear power plant, obtained 19.5% of its electricity production in 2015 from nuclear energy. 18, 6% of Russia's electricity production is realized by the present 36 nuclear power and 7 power plants are in the construction phase. 31, 7% of South Korea's electricity is provided with 25 power plants while 58, 3 of France's nuclear power plants are producing its 76.3% electricity need. China, with 36 nuclear plants, has begun building 21 new nuclear power plants to meet the demand for electricity in the coming years (T.R. Ministry of Energy & Natural Resources, Head of Strategy Department, 2017).

Turkey became a member of the International Atomic Energy Agency at the same year of its establishment in 1956 and began to build the first nuclear power plant in 1965. In 1976, a field license was obtained for the first nuclear power plant in Akkuyu. Following the receipt of the field license, four nuclear power plant tenders were opened between 1977 and 2009, but these tenders were not finalized. On 12 May 2010 an intergovernmental agreement was signed with the Russian Federation for the establishment of the first nuclear power plant. The agreement for the establishment of the second nuclear power plant was signed with Japan on May 3, 2013 (T.R. Ministry of Energy & Natural Resources, Head of Strategy Department, 2017).

The nuclear power plant to be established in accordance with the agreement signed with Russia will have a total installed capacity of 4800 MWe with 4 reactors of 4 units VVER-1200 type (AES-2006). On 13 December 2010, Akkuyu NGS Electricity Generation Inc. was established to carry out the project within the scope of the agreement. Akkuyu nuclear power plant is expected to start construction until the end of 2018. It is planned that the first unit will be operated in 2023 and the other units will be operated until the end of 2026 by a year's span. According to the international agreement signed with Japan on May 3, 2013, the total installed capacity of the nuclear power plant planned to be built within the Sinop province borders will be 4480 MW. It is aimed to start construction of the power plant until the end of 2019. According to the agreement, the first two units of the plant are planned to be operated in 2023 and 2024, while the other units are to be operated in 2027 and 2028. Feasibility studies are continuing to confirm the suitability of the site for the Sinop Nuclear Power Plant (T.R. Ministry of Energy & Natural Resources, Head of Strategy Department, 2017).

Geothermal Energy

As is known, geothermal energy is a domestic, renewable, clean, cheap and environmentally friendly underground source. Because of being located on an active tectonic belt with geological and geographical position, Turkey can be counted as rich among the countries of the world in terms of geothermal. There are many geothermal resources at different temperatures in the form of around 1000 natural outcrops spread over the country. Turkey's theoretical geothermal potential is 31,500 MW. 78% of the potential areas are located in western Anatolia, 9% in central Anatolia, 7% in Marmara region, 5% in eastern Anatolia and 1% in other regions. 90% of the geothermal resources are low and medium temperature and suitable for direct applications (domestic heating, thermal tourism, mineral waters etc.) and 10% for indirect applications (electric power generation) (www.mta.gov.tr).

The geothermal energy capacity of the world is 12.8 MWe according to the year 2016 data. The first 5 countries in electricity generation from geothermal energy are USA, Philippines, Indonesia, Mexico and New Zealand. The use of except electricity is 70 329 MWt, while the top 5 countries in the world for direct use applications in China, the US, Sweden, Turkey and Iceland (www.mta.gov.tr) Geothermal potential of Turkey shown in Figure 9 (Korkmaz et al., 2014).

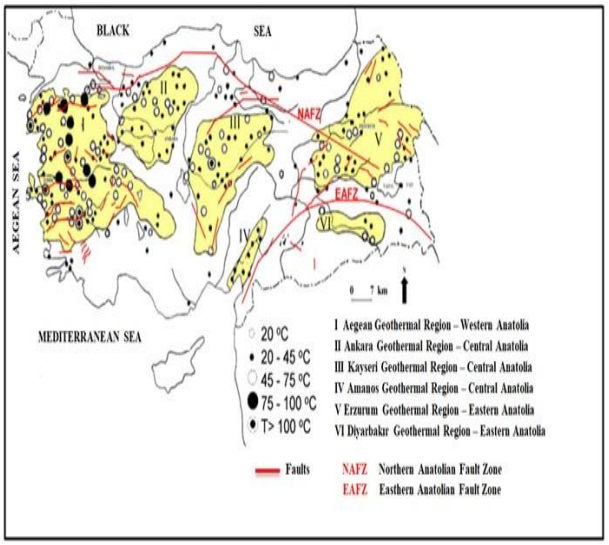

Fig. 9 Geothermal sites and regions in Turkey.

Through the examination of Figure 9, it can be pronounced that geothermal energy resources have parallels with the existing tectonic faults in Turkey. Hence, it should be stated that Aegean region has a very crucial point in terms of geothermal energy. In particular, Izmir has the richest geothermal field of Aegean region and Turkey. Notably Balcova, the towns of Seferihisar, Cesme, Dikili, Bergama, Aliaga and Bayindir are important geothermal fields (Demir & Ufuk, 2015).

Conclusion

The energy and its uses are undoubtedly the most important signs of social development. Today, the problem of climate change has a triggering role in terms of energy conservation, due to countries reducing or abandoning the usual ways. When assessing specific cases in Turkey, the coal in electricity generation is still break open in front of their competitors. However, due to the danger of greenhouse gas emissions and being non-renewable sources, it is of great importance to take necessary measures to increase the use of clean energy and to increase the use of renewable energy sources in the existing thermal power plants. Especially the incentives that states will give in this regard in terms of sensitivity and renewable energy production will contribute to the efficient evaluation of such resources.

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