Journal of Engineering Research and Applied Science
Available at www.journaleras.com
Volume 8 (1), June 2019, pp 1041-1050
ISSN 2147-3471 © 2019

Geothermal energy for clean and sustainable development in Turkey

A. Kaygusuz[1,a]

[1] Gumushane University, Faculty of Engineering and Natural Science, Department of Geology, Trabzon, Turkey.

Accepted 05 May 2019

Abstract
Turkey has a limited amount of fossil fuel reserve, thus is dependent on foreign energy. Approximately 75% of current energy consumption is met by imports. However, Turkey has a high potential of renewables such as biomass, hydropower, wind, solar, geothermal energy, but the current utilization rate of these resources is very low. Turkey is rich in geothermal energy resources. It ranks seventh in the world for this type of energy resource and among the top five for geothermal heat and thermal spring applications (electricity generation, heating and cooling homes and greenhouses, drying, thermal tourism, balneological use, mineral extraction, agricultural and aquaculture applications, etc.). Interest in this energy field is rising due to government support for renewables. An overview of geothermal energy in Turkey is presented and its potential is evaluated. The study aims to contribute to the future developments of this energy technology in Turkey, with some barriers also considered.

Keywords: renewable energy; sustainable development; geothermal energy; Turkey.

1. Introduction

Energy is a principal motor of economic growth, prosperity and economic development, a prerequisite for meeting basic human needs, while at the same time a source of environmental stress. Energy in itself is a vital component of sustainable development [1]. Different energy types have different types of impacts during their development. Along all energy chains, from the extraction of the resource to the provision of energy services, pollutants are produced, emitted or disposed of, often with serious health and environmental impacts [2]. During an energy project's lifecycle, emissions and wastes may be also associated with the manufacture or construction of energy systems [3]. Yet, the impact differs widely. Fossil fuels are largely responsible for urban air pollution, regional acidification and climate change. The use of nuclear power has created a number of concerns, such as the storage or disposal of high-level radioactive waste and the proliferation of nuclear weapons. Biomass use in some developing countries contributes to desertification and loss of biodiversity, as well as energy crop cultivation having significant impacts on food prices worldwide [4]. Other renewable energy sources such as hydro- and wind power have significant implications for land-use as well as significant ecosystem and visual impact [1-4].

Geothermal energy has not until recently become a significant source of electricity and heat, with of course exceptions in countries such as the USA, Indonesia, Iceland and Italy [3]. In 2008, geothermal energy represented around 0.1% of the global primary energy supply, but estimates predict that it could fulfill around 3% of global electricity demand, as well as 5% of global heating demand by 2050 [4]. Geothermal energy is usually considered a renewable energy source, but its development and use can however have significant multi-dimensional sustainability implications [5]. Given the certainty that geothermal energy usage is set to increase substantially, it is important to ensure that geothermal resources are developed in a sustainable manner, in particular for electricity generation projects. As well as this, the international community has called for the development of indicators to measure progress towards sustainable development [1]. Until now no framework however exists that enables formal assessment of the sustainability of geothermal energy development and use [1-4].

Turkey has a limited amount of fossil fuel reserve, thus is dependent on foreign energy. Approximately 75% of current energy consumption is met by imports. However, Turkey has a high percentage of renewable energy resources including biomass, hydropower, wind, solar, and geothermal energy, but the current utilization rate of these resources is very low [5]. In recent years, in Turkey, hydraulic, solar, geothermal,

[a] Corresponding author; abdullah.kaygusuz@gmail.com

and wind-based energy production has started to become widespread; producing energy out of biomass is widely used only via direct incineration. At present, due to declining fossil fuels, it is inevitable that energy shortage will occur in the near future [6]. In addition to this, when the environmental problems caused by the animal and vegetable-based wastes are considered, in terms of sustainable development, studies show that finding a solution to these two problems is very important [7]. For agricultural and animal wastes, one of the most effective solution practices, which is also environmentally acceptable, is biomass energy conversion systems. With these systems, out of the wastes, energy and organic fertilizer with high nutritional value are obtained [8]. Besides preventing the dissipation of resources, efforts to better the living standards and in order to reduce the negative effects of the resulting energy crisis, developed countries have investigated and developed methods to recycle various wastes [6-11].

Turkey uses the energy sources inefficiently and consumes more energy to produce a product [6]. Coal is the most reliable domestic energy source in Turkey should be consumed more in the industry and electricity production in order to reduce the energy production costs of Turkey and the dependency on other countries [7]. Oil and natural gas are an expensive energy sources and the consumption of these sources are high in Turkey. Also, energy production from renewables should be improved to reduce the dependency and environmental pollution. The author believes that Turkey does not use its renewable energy sources efficiently and should promote new technologies and use all its renewable energy potential. The present study gives renewable and sustainable energy policies in Turkey [6-11].

The objectives of this study are to discussing the literature on sustainability impacts of geothermal power development for electricity generation and thereby identify the most important issues of concern whilst assessing the sustainability of geothermal energy projects. Review the available sustainability assessment frameworks and thereby determine the best structure for an assessment framework for geothermal energy projects. Demonstrate the need for assessing sustainability in the geothermal energy sector and to provide the scientific basis for the creation of a formal sustainability assessment framework.

2. Geothermal energy for sustainable development

2.1. Global energy demand

Global primary oil demand grew by a little more and to reach 87.4 million barrels per day in 2011 [1]. The trajectory that oil use over the coming decades differs considerably, reflecting the different assumptions about government policies to curb rising demand and emissions. According to the Scenarios, oil use increases in absolute terms to 2040, driven mainly by population and economic growth in the emerging economies, in response to strong policy action to curb fossil-energy use. The share of oil in total world energy demand falls and it reaches 27% in 2040 while 32% in 2011 [1-4].

The first of these fundamental trends is that the world's energy needs are set to rise. With the assumed expansion of the global economy of almost 140% and an increase of 1.7 billion in the world's population, more energy will be needed to satisfy growing demand for energy services, even though new policies and programs are put in place to encourage energy savings [1]. World primary energy demand increases by 35% between 2018 and 2040 in the Energy Scenario as shown in Table 1 and Figure 1 [1]. This represents a sharp slowdown in the energy demand growth experienced over the past two decades, testament to the anticipated effect that already implemented and planned policies would have on energy markets [1-3]

Table 2 shows the global renewable energy capacities in 2018 [2]. As shown in Table 1 and 2, the share of renewables in world primary energy demand was reached from 13% in 1990 to 15% in 2018. This increase is underpinned by incentives to overcome market barriers, falling technology costs, rising fossil fuel prices and in some cases carbon pricing.

Most of the growth occurs in the power sector (2378 GW), where their share in total generation grows from 20% to 31%, a near tripling in actual generation. Hydro accounts 1018 GW capacity for power generation and its share is 64%. The second contribution is given by wind energy (319 GW). The amount of transport fuels is around 153 billion liters per year in 2018 [2, 3].

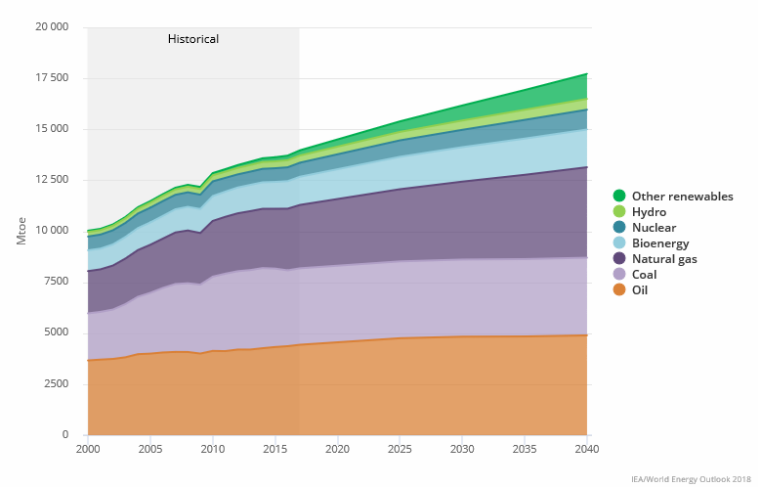

Figure 1. Global energy demand (Mtoe) [1].

Table 1. World primary energy demand by fuel (Mtoe)

	1990	2012	2018
Coal	2 231	3 879	**4 211**
Oil	3 232	4 194	**4 487**
Gas	1 668	2 844	**3 182**
Nuclear	526	642	**845**
Hydropower	184	316	**392**
Bioenergy	905	1 344	**1 554**
Other renewables	36	142	**308**
Total	**8 782**	**13 361**	**14 978**

Source: Ref. [1]

Table 2. Global renewable energy capacities in 2018.

Renewable energy	Capacity
Power generation (GW)	
Wind power	591
Biomass power	130
Solar PV	505
Geothermal power	13.3
Concentrating solar power (CSP)	5.5
Hydropower	1 132
Ocean power	0.5
Hot water/heating (GW_{th})	
Modern biomass heating	320
Solar hot water/space heating	480
Geothermal heating	26
Transport fuels (billion liters/year)	
Ethanol production	112
Biodiesel production	40

Source: Ref. [2]

2.2. Geothermal energy and sustainable development

2.2.1. Geothermal and sustainable development

Sustainable energy development is an emerging paradigm. Its challenges involve reducing negative health and environmental impacts, whilst simultaneously increasing energy access, affordability, security and the efficiency of energy use [4]. Evidencing the move into this new paradigm, energy policy directives of various industrialized countries include common interests such as improving the efficiency of energy production and ensuring a reliable supply, energy security and diversity, economic efficiency, support of research and development and regional partnerships for the development of more advanced technologies [5].

A sustainable energy system may be regarded as a cost-efficient, reliable, and environmentally friendly system that effectively utilizes local resources and networks [4]. Renewability and sustained yield of energy resources is generally agreed to be a necessary but not a sufficient requirement for sustainable energy development [4]. The sustainability perspective requires a much broader assessment of energy development. This implies that there is a need to monitor all of the environmental, social and economic impacts associated with geothermal energy developments [5]. An in-depth overview of the main impacts relating to the utilization of geothermal energy for electricity generation is presented in this section.

2.2.2. Global geothermal markets

Geothermal energy is harnessed for the generation of electricity and for various thermal applications, including space heating and industrial heat input. Total geothermal energy output in 2018 was estimated at 630 PJ, with around half of this in the form of electricity (89.3 TWh). Estimates of thermal energy consumption (also known as "direct use") are more uncertain than those for electricity, due to data collection challenges. Some geothermal plants produce both electricity and heat for various thermal applications [2].

An estimated 0.5 GW of new geothermal power generating capacity came online in 2018, bringing the global total to around 13.3 GW. Turkey and Indonesia remained the leaders for new installations and accounted for about two-thirds of the new capacity installed. Other countries that added capacity in 2018 were the United States, Iceland, New Zealand, Croatia, the Philippines and Kenya [2].

At year's end, the countries with the largest amounts of geothermal power generating capacity were the United States, Indonesia, the Philippines, Turkey, New Zealand, Mexico, Italy, Iceland, Kenya and Japan as shown in Figure 2 [2]. Indonesia continued to expand its geothermal capacity with 140 MW of additions and ended 2018 with 1.95 GW in operation. In North Sumatra, the third and final 110 MW unit of the geothermal plant was commissioned in 2018, following completion of the first two units in 2017 [2].

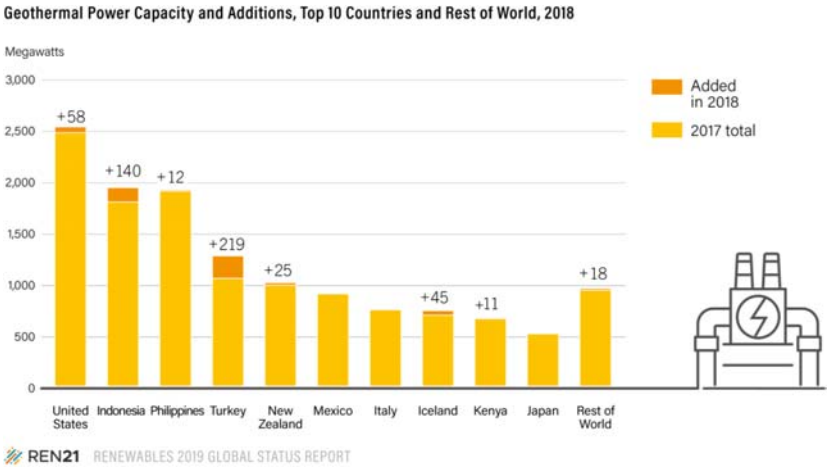

Figure 2. Geothermal Power capacity and addition for top 10 countries and rest of world in 2018 [2].

The United States remains the global leader for installed geothermal power capacity by a wide margin. In 2018, the country brought online at least 58 MW in three facilities, for a total of 2.54 GW of net operating capacity. One addition was the 48 MW third phase of the McGinnis Hills geothermal complex in Nevada, which is said to use two new-generation binary units where three units would have been required with earlier technology [2].

In the US state of New Mexico, a 14 MW binary power plant was deployed to repower an existing 4 MW facility. Geothermal power capacity in the United States generated 16.7 TWh in 2018. On the other hand, New Zealand has seen only modest growth in its geothermal power capacity in recent years, due mostly to stagnant electricity demand and limited need for any new power generating capacity [2]. In 2018, the country commissioned the 25 MW geothermal plant. Originally considered a 22 MW project, it was subsequently uprated to 25 MW, which has reduced the project cost per megawatt to USD 5.45 million. Geothermal power contributed 17% of New Zealand's electricity production in 2018 [2].

3. Electric and energy situation in Turkey

3.1. Electricity

After 2014, 2015 and 2016, which were striving for a number of regulations and other legislations that were put into effect in the framework of the Electricity Market Law numbered 6446, which entered into force in 2013, a significant process was made in 2017 on the light of these regulations as moving towards a more liberal, competitive, transparent and foreseeable structure on the market [7].

The distribution of licensed electricity generation by resources is shown in Figure 3. The share of natural gas-fired power plants in licensed electricty generation was 32.16 % in 2016 which in 2017 increased to 37,18 %, in wind power plants from 5,69% to 6,10 %, in geothermal power plants from 1,77 % to 2,04 %. For the hydroelectric power plants, the share was 24,69% which decreased to 19,96 % in 2017. On the other hand, the share of domestic coal (lignite, hard coal and asphaltite) power plants was 19,78 % in 2016, which decreased to 15,86%, in imported coal power plants from 17,52 % to 17,49% [7].

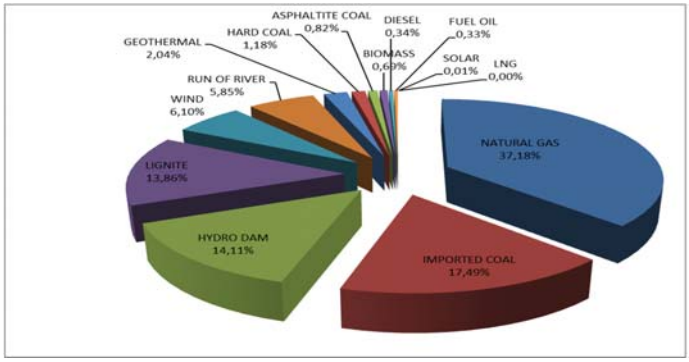

Figure 3. Turkey's distribution of licensed electricity generation by sources in 2017 (%) [7]

The development of peak demand and its rate of increase are provided in Figure 4. In year 2017, the increment of peak demand can be seen as 6,54 %. The development of licensed electricity generation on the basis of resources since 1990 is shown in Figure 5. As can be seen from the figure, the share in electricity generation of resources like geothermal, wind, solar and biomass had increased every year [7].

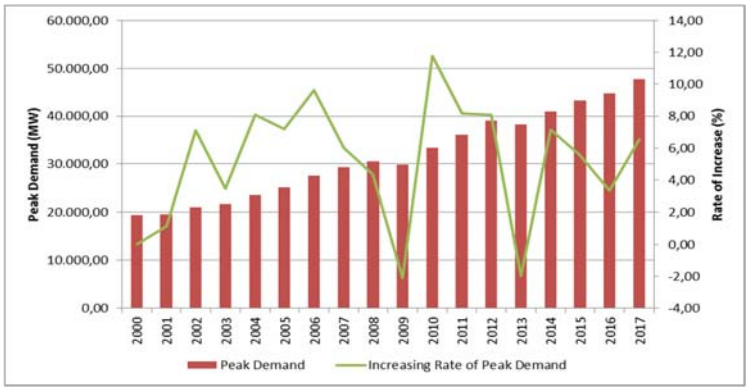

Figure 4. Peak demand and rate of increase by years in Turkey (MW) [7].

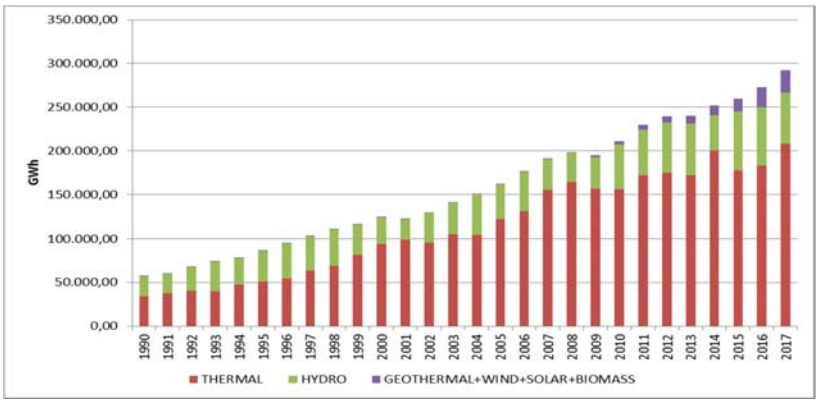

Figure 5. Turkey's licensed electricity generation by years (GWh) [7]

3.2. Energy

Turkey is an energy importing country and dependent on the imported energy sources as given in Table 3 [8, 9]. Furthermore this trend seems to be continuing in the future. Energy sources in Turkey are hard coal, lignite, asphalt, oil, natural gas, hydropower, geothermal, wood, animal and plant wastes, solar and wind energy [8]. The proven reserves of lignite, the most abundant domestic energy source, is 7300 million ton and found in almost all of the country's regions. Lignite has the largest percentage in total energy production with its 43% share. After lignite, wood has the greatest share in total energy production with its 20% and oil accounts for 13%, 12.4% hydro and the final 15% includes animal wastes, solar, hard coal, natural gas, geothermal electricity and geothermal heat [8-11].

Table 3. Turkey's energy situation in 2017 (ktoe) [9]

Energy source	Production	Consumption
Coal and Lignite	14 470	38 824
Oil	2 682	44 536
Natural gas	430	45 872
Hydropower	5 112	5 112
Geothermal	7 124	7 124
Bioenergy	2 536	2 536
Solar/Wind/Other	2 754	2 754
Total	35 108	146 758

ktoe: kilo tons of oil equivalent

Turkey's various renewable energy sources represent its second largest energy source after coal. Wood and animal waste account 32 %, hydropower 37 %, geothermal 19 % and wind and solar account for 10.6 % each of total renewable energy production [10]. Table 4 shows Turkey's total installed power capacity in 2017. In Turkey, 24 % of electricity generation was provided by hydropower in 2017, and will be increased to 36 % in 2020 [9]. The largest hydro power project in Turkey is the Southeastern Anatolia Project (GAP). Upon competition, GAP will have an installed capacity of 7476 MW and 22% of Turkey's total estimated economic potential [8-11].

Table 4.Turkey's installed capacity and generation development in 2017 (GWh) [9]

Resources	Installed Capacity (MW)	Share (%)	Generation (TWh)	Share (%)
Natural gas	26 638	31	108.1	37
Hydropower	27 273	32	58.3	20
Domestic coal	9 872	11	44	15
Import coal	8 794	10	51.1	17
Renewables	11 000	13	26.5	10
Other	1 623	3	7.5	1
Total	85 200	100	295.5	100

3.3. Renewables

Renewable supply in Turkey is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating [7]. Total renewable energy supply declined from 1990 to 2012, due to a decrease in biomass supply [8]. On the other hand, the composition of renewable energy supply has changed and wind power is beginning to claim market share [9]. The share of biomass in the renewable share is expected to decrease with the expansion of other renewable sources as shown in Table 4 and 5 [9]. These tables show that there is an important renewable energy potential in Turkey [8-11]. Table 6 shows renewable potentials for investment in Turkey.

Renewable energy assets in Turkey consisting of wind, solar, geothermal and bio showed the highest growth rate in terms of electricity generation for the last five years with an annual average growth rate of 32%. They only had 2.6% share in electricity generation in 2011 but had over 9% share in 2017. In the next five years renewables including the hydro power plants are also expected to achieve highest growth rate of 9% per annum compared to other sources of electricity with an additional capacity of 26 GW by 2023.

Table 5.Installed capacity targets for renewable power plants

	Installed capacity (MW)		
Resource type	2017	2019	2023
Solar power	1 800	3 000	10 000
Geothermal	420	700	1 500
Biomass	540	700	1 000
Wind power	9 500	10 000	20 000
Hydropower	27 700	32 000	34 000
TOTAL	39 960	46 400	66 500

Table 6. Potentials for investment for renewable energies in Turkey

Sectors	Million €	Remarks
Hydroelectric	114	Economical development potential of 28,600 MW, Corresponding 100,000 GWh/a
Wind power	57	Economical development potential of 48,000 MW With wind speed > 7 m/s
Solar thermal	165	Economical development potential of 131,000 GWh/a, Corresponding to approx. 300 million m^2 collector area
Biogas	4	Agricultural residual material and dung, when used for electricity generation, 1,000 MW_e and 7,000 GWh/yr
Total	340	

Source: Ref. [9, 10, 11]

3.4. Geothermal energy

Among the renewable energy alternatives, geothermal energy in Turkey has become very attractive [12]. The reason for this interest is features of geothermal energy in direct and indirect use. It is unfortunate that geothermal energy in direct use can only be utilized locally. But, firing fossil fuels at 1500 ^oC, and using the generated heat at only 50-60 ^oC is obviously a thermodynamic waste [13, 14]. Turkey has a significant potential in geothermal energy and there may exist about 2000 MW_e for electrical power generation [15, 16]. Turkey's total geothermal heating capacity is about 31,500 MW_{th}. At present, heating capacity in the country runs at 1220 MW_{th} equivalent to 147,000 households [17]. These numbers can be heightened some sevenfold to 7,080 MW_{th} equal to $760x10^3$ households through a proven and exhaustible potential. Turkey must target 1.2 million households equivalent 7,900 MW_{th} in 2020 [18-27].

Turkey completed several geothermal power projects in 2018, raising its installed capacity by 21% (219 MW), to 1.3 GW [18, 19]. Turkey ranks fourth globally for cumulative geothermal power capacity, having built up more than 1 GW of capability in only six years, between 2013 and 2018. The largest single unit completed in 2018 was the 65.5 MW Unit 2 at the Kizildere III plant, which became Turkey's largest geothermal power plant (165 MW) as a result [20]. Other projects completed during the year include the 19.4 MW Baklaci, the 13.8 MW Buharkent, the 25 MW 3S Kale, and the 32 MW Pamukören Unit 4.9 A final addition, the 30 MW Alsehir Unit 3, joined Turkey's fleet in November [24-27].

Turkey is an energy-importing country, so the country needs to use its sustainable sources to reduce this costly dependence. In this respect, geothermal power is a wise choice, as it is economical, domestic and an environmentally friendly energy source [26]. Moreover, Turkey has many advantages for the use of geothermal energy considering its geographical location. Although there have been important advancements in the last 10 years in geothermal exploitations, there are still some barriers such as economic issues, lack of the legislative and regulatory framework and insufficient infrastructure [22-26].

In terms of geological configuration, Turkey is located on the Alpine-Himalayan belt, and the country has a very high geothermal energy potential [12, 26]. This potential is about 31,500MW. In the country, geothermal energy is one of the most remarkable forms of renewable energies. Hence, increasing the capacity of geothermal electricity generation is of great importance for Turkey's energy needs [24-28]. Figure 6 shows Turkey's main geothermal resources, volcanic areas and geothermal energy applications.

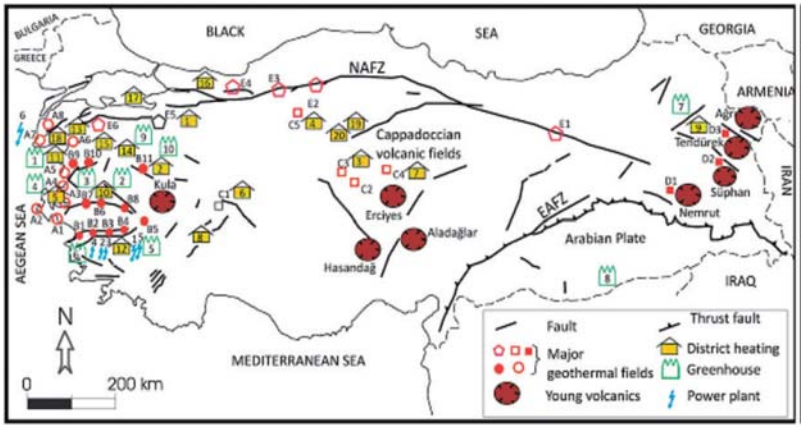

Figure 6. Turkey's main geothermal resources, volcanic areas and geothermal energy applications [5]

The installed capacity of new commissioning power plants based on renewable energy sources in the first nine months of the year 2014 has been around 2002 MW. The geothermal power plants sharing this total value can be defined as 47.6 MW of geothermal sourced electricity generation power plants. Currently, there are 13 geothermal power plants are available based on geothermal energy sources in Turkey [29, 31].

While geothermal installed capacity was only 17.5 MW in 2002, it has reached the value of 397 MW as of today's numbers [26]. On the other hand, in 2018, the applications of geothermal greenhouse heating have reached the value of 4283 thousand square meters with an increase of 466% compared to the number of the year 2002. Also, the residential heating has reached number around 89,443 dwellings with an increase of 198%. Between the years 2008 and 2014, 96 geothermal sites in total have been transferred to investors, 16 sites are for electricity generation and 80 of them for the heating and thermal tourism applications. In this way, the total value of these auctions has reached the amount of $545 million [26].

Turkey's geothermal resources can provide very high thermal tourism capacities. This offers great opportunities for thermal tourism in Turkey [27]. To meet the market and investment criteria, domestic and foreign private sectors should also be encouraged to invest in this energy field. Geothermal power generation does not associate any combustion, which means CO_2 emissions into the atmosphere are very low [28]. Consequently, geothermal power generation can help prevent global warming [29]. The supply of energy from the Earth is potentially enormous and endless, deficiency is not a concern. Furthermore, unlike other forms of renewable energy such as solar, photovoltaic or wind power, geothermal power is independent of weather conditions [30-36].

4. Conclusions

Turkey uses the energy sources inefficiently and consumes more energy to produce a product. So, the production costs in this country are higher than the world's average. Energy policies of Turkish government should support the domestic energy sources and use the installed power plants efficiently in Turkey. On the other hand, the phenomenon of global climate change is a very serious economic, social and environmental problem. In order to diminish of this problem, the governments should be

supported to utilizing renewables most effectively. Turkey is rich in bioenergy and has adequate facilities and environmental conditions in terms of the development of this resource. In order to reduce the dependence of Turkey on foreign energy, transition to energy forestry and energy agriculture, development of obtaining biofuel from them and wastes, and biogas obtained from fertilizers, waste and garbage are required to be given importance.

Geothermal energy is clean, cheap and environmentally friendly, which is our domestic energy source. Turkey is located on an active tectonic zone as geological and geographical location and for this reason our country is rich in terms of geothermal energy resources. Turkey have approximately 1.000 geothermal springs that located all over the country that have various of temperatures. Increasing activities of geothermal development especially in the last three years result in a geothermal boom in Turkey. Not only the addition of new sites, but also updating the data of existing ones increased the currently identified capacity significantly. With the discoveries of 13 new geothermal fields, power potentials increased by 1.6 times.

The geothermal capacity of our country is very high. 78% of these geothermal fields are situated in Western Anatolia, 9% in Central Anatolia, 7% in the Marmara Region, 5% in Eastern Anatolia and 1% in the other regions. 90% of our geothermal resources are low and medium enthalpy geothermal areas which are suitable for direct applications (heating, thermal tourism, industrial usage, etc.), while 10% are suitable for indirect applications (generation of electricity). First geothermal electricity generation held in 1975 was initiated by Kızıldere power plant with 0.5 MWe power.

In order to develop existing resources and to search for new resources/fields, drillings reached from 2.000 meters to 28.000 meters. Since 2005, with the support of our Ministry, the development of existing geothermal resources initiated and began to search for new potential areas. As the end of 2004, the available heat capacity of 3.100 MWt increased to 5.000 MWt by an additional 1.900 MWt heat energy. 173 discovered geothermal fields reached to 239 fields which 10 of them are suitable for electricity production. So far, total of 632 drillings with total of 410.000 meters of depth and approximately 5.000 MWt of heat energy (including natural springs) obtained from these wells.

In 2008, in conjunction with the Geothermal Resources and Natural Mineralized Waters Law, private sector began to introduce development and investment of geothermal projects also. In conjunction with this development, the country's total geothermal heat capacity (visible amount of heat) reached to 35.500 MWt. On the other hand, 78 % of geothermal potential is in Western Anatolia 55 % of the geothermal areas in Turkey are suitable for heating practices ~115,000 households in 21districtsheated with geothermal energy 658 MWe is under operation as of April, 2018 Totally 42 projects of 634 MWe capacity are licensed

.

Acknowledgement: The author greatly acknowledge to Prof. Dr. Kamil Kaygusuz for him valuable suggestions and supports for preparation of this manuscript.

References

[1] IEA, International Energy Agency. World energy outlook 2016. OECD/IEA, Paris, 2016.
[2] REN21. Renewables 2019 Global Status Report. Paris, France: REN21 Secretariat.
[3] WEC, World Energy Council. World Energy Survey 2016, WEC, London, 2016.
[4] Glassley, WE. Geothermal energy: renewable energy and the environment, Second Ed. CRC Press, Boca Raton, FL, 2015.
[5] Korkmaz ED, Serpen U., Satman A. Geothermal boom in Turkey: growth in identified capacities and potentials. Renew Energy 2014; 68: 314–325.
[6] Republic of Turkey, Ministry of Energy and Natural Resources. 2017 Budget presentation.Ankara, Turkey: Department of Strategic Development, 2016.
[7] EMRA, Energy Market Regulatory Authority. Electricity market development report 2017. EMRA, Ankara, Turkey, 2018.
[8] MENR, Ministry of Energy and Natural Resources. Blue Book. Available from http://www.enerji.gov.tr (accessed date 16 July 2018).
[9] MENR, Ministry of Energy and Natural Resources. Energy Statistics in Turkey. Available from http://www.enerji.gov.tr (accessed date 16 Jan 2019).
[10] IEA, International Energy Agency. Energy Policies of IEA Countries: Turkey 2016

Review, OECD/IEA, Paris, 2016.
[11] ECS, Energy Charter Secretatiat. In-depth energy efficiency policy review of the republich of Turkey. Brussels, Belgium, 2014, available from www.encharter.org.
[12] Türkiye Jeotermal Derneği. Available from www. www.jeotermaldernegi.org.tr
[13] Parlaktuna M, Mertoglu O, Simsek S, et al. Geothermal country update report of Turkey (2010–2013). In: European geothermal congress 2013, Pisa, Italy, 3–7 June 2013.
[14] Tufekci N, Suzen ML and Gulec N. GIS based geothermal potential assessment: a case study from Western Anatolia, Turkey. Energy 2010; 35: 246–261.
[15] Celiktas MS., Kocar G. Telescopic drilling view for future: a geothermal foresight study in Turkey. Technol Forecast Soc Change 2013; 80: 148–160.
[16] Hepbasli A., Ozgener L. Development of geothermal energy utilization in Turkey: a review. Renew Sustain Energy Rev 2004; 8: 433–460.
[17] Erdogdu E. A snapshot of geothermal energy potential and utilization in Turkey. Renew Sustain Energy Rev 2009; 13: 2535–2543.
[18] Oktay Z., Aslan A. Geothermal district heating in Turkey: The Gönen case study. Geothermics 2007; 36: 167–182.
[19] Komurcu MI., Akpinar A. Importance of geothermal energy and its environmental effects in Turkey. Renew Energy 2009; 34: 1611–1615.
[20] Kaygusuz K and Kaygusuz A. Geothermal energy in Turkey: the sustainable future. Renew Sustain Energy Rev 2004; 8: 545–563.
[21] Köse R. Geothermal energy potential for power generation in Turkey: a case study in Simav, Kütahya. Renew Sustain Energy Rev 2007; 11: 497–511.
[22] Aksoy N. Power generation from geothermal resources in Turkey. Renew Energy 2014; 68: 595–601.
[23] Serpen U, Aksoy N, Ongur T. Geothermal energy in Turkey: 2008 update. Geothermics 2009; 38: 227–237.
[24] Akpınar A, Komurcu MI, Onsoy H, et al. Status of geothermal energy amongst Turkey's energy sources. Renew Sustain Energy Rev 2008; 12: 1148–1161.
[25] GEA, Geothermal Energy Association. Geothermal: international market overview report. Washington, DC: Geothermal Energy Association, 2018.
[26] Canka Kilic F. Geothermal energy in Turkey. Energy & Environment 2016; 27: 360-376.
[27] Aksoy N. Power generation from geothermal resources in Turkey. Renew Energy 2014; 68: 595–601.
[28] Kaygusuz K. Energy and environmental issues relating to greenhouse gas emissions for sustainable development in Turkey Renew Sustain Energy Rev. 2009; 13: 253–270.
[29] Kaygusuz, K., Kaygusuz, A. Energy and sustainable development in Turkey, Part I: Energy utilization and sustainability. Energy Sources 2002; 24: 483–498.
[30] Kaygusuz, K., Kaygusuz, A. Geothermal energy: Power for a sustainable future. Energy Sources 2002; 24: 937–947.
[31] Kaygusuz K. Energy services and energy poverty for sustainable rural development.Renewable and Sustainable Energy Reviews 2011; 15: 936-947.
[32] Kaygusuz K. Energy for sustainable development: a case of developing countries. Renewable and Sustainable Energy Reviews 2012; 16: 1116-1126.
[33] Kaygusuz K. Clean energy policies for sustainable development in Turkey. Journal of Engineering Research and Applied Science 2012; 1(2): 1-10.
[34] Kaygusuz K and Toklu E. Energy issues and sustainable development in Turkey. Journal of Engineering Research and Applied Science 2012; 1(1): 1-25.
[35] Yüksel I and Kaygusuz K. Renewable energy sources for clean and sustainable energy policies in Turkey. Renewable and Sustainable Energy Reviews 20111; 15: 4132-144.
[36] Kaygusuz, K., Toklu, E., Avcı, AC. Energy security in a developing world: a case of Turkey. Journal of Engineering Research and Applied Science 2015; 4(1): 265-277.