



Geothermal energy in Turkey and around the World: A review of the literature and an analysis based on Turkey's Vision 2023 energy targets



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ABSTRACT

Turkey's geothermal energy potential suitable for electricity generation was estimated at nearly 4500 MW. In Turkey, work on power production from geothermal energy started in the second half of the 20th century. However, capacity build up and investments accelerated after 2000s. This is mostly related to Turkey's staggering economic growth in the last 10 years, which concurrently increased the country's energy demand. Also, renewable energy, especially geothermal energy, legislations passed and laws enacted in the last 10 years eased the process. The subsidies and supports to the private sector also positively affected the development of geothermal power plants. The growth of Turkey's energy market is a part of Turkey's ambitious Vision 2023 energy targets. One of the main aims of which is to produce 30% of Turkey's electricity demand in 2023 from renewable energy sources. However, geothermal energy has the smallest share (in terms of installed capacity) in the Vision 2023 energy targets set at 600 MW by the year 2023 (target, as of 2015, can be modified). This means geothermal power plants could only provide 0.5% of Turkey's installed capacity, which was estimated as 120,000 MW in the year 2023. In this study, it was pinpointed that geothermal energy installed capacity of Turkey reached to 623.9 MW at the end of 2015. This is critically important for the realisation of the Vision 2023 energy targets, and it is the first renewable energy target that has been fulfilled before 2023. Also, in this study, it was suggested to modify the Vision 2023 targets to increase the geothermal energy installed capacity to 1000 MW. By this way, the share of geothermal energy in Turkey's installed capacity of 2023 could rise to nearly 0.8%.

1. Introduction

Turkey is a developed country and a regional power [1]. Turkey's gross domestic product (GDP) in purchasing power parity (PPP) was estimated at 1.576 trillion US\$ in 2015 [2]. Data about Turkey's GDP (PPP) change between 1990 and 2014 is shown in Fig. 1 [3]. Historically, economic growth and energy consumption have been highly correlated [4,5]. There are various number of studies that have examined the relationship between energy consumption and GDP growth [6]. However, conflicting results emerged from these studies both on the existence and the direction of causality [7]. Although there are plenty of studies in the literature that investigated the GDP growth and energy consumption relationship, there are only few studies, which examined the relationship between renewable energy consumption and GDP growth [8]. There are three main types of causal relationship between energy consumption and economic growth in the literature: unidirectional causality, bidirectional causality, and no causality [9]. For policy makers the direction of the causal relationship is imperative [10].

During the last 25 years, Turkey's energy consumption increased parallel to its economic growth. Net electricity consumption in Turkey between 1990 and 2014 is shown in Fig. 2 [11]. As a result, Turkey's energy infrastructure grew and power plant capacities increased concurrently. Installed capacity of Turkey's power plants based on energy source at the end of 2015 are shown in Table 1 [12]. However, increased energy consumption parallel to Turkey's economic growth ironically had a negative effect on the country's economy. Specifically to the country's foreign trade. This is because Turkey is a net energy importer and most of the country's energy demand is supplied from imported energy sources, mostly coal and natural gas [12]. Turkey, also imports most of the oil it consumes; however, it is primarily used by the petrochemical industry for the production of transportation fuels and petrochemicals [13]. Here it should be emphasized that this problem is not unique to Turkey. Globally, three types of fossil fuels: coal, natural gas and oil provides majority of the global total primary energy supply (TPES) and the share of renewable energy sources is still small compared to these fossil fuels [14]. Turkey spent approximately 60 billion US\$ for energy imports in 2013, mostly natural gas, which was

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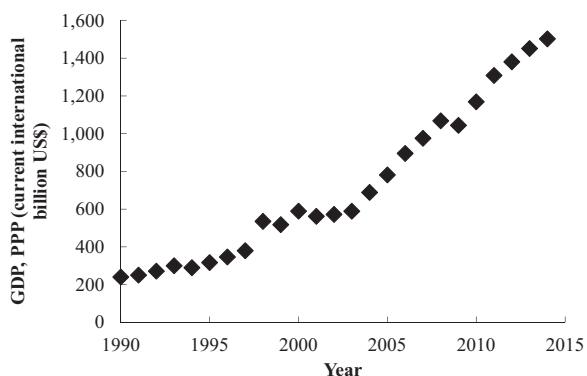


Fig. 1. Turkey's GDP (PPP) in current international billion US\$ change between 1990 and 2014 [3].

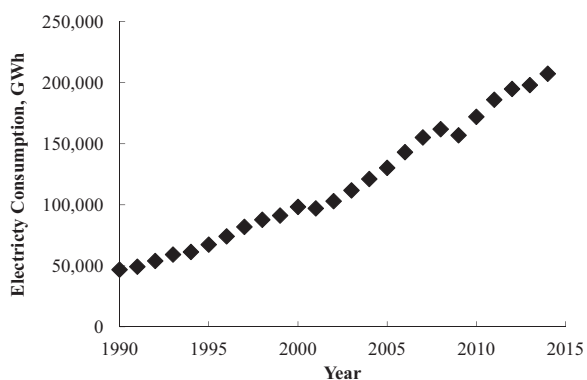


Fig. 2. Net electricity consumption in Turkey between 1990 and 2014 [11].

Table 1
Installed capacity of power plants based on energy source in Turkey at the end of 2015, MW [12].

Fuel Type	Installed Capacity, MW	Share, %	Number of Power Plants
Fuel oil + asphaltite + naphtha + diesel	851.0	1.2	18
Bituminous coal + lignite	9013.4	12.3	28
Imported coal	6064.2	8.3	8
Natural gas + LNG	21,222.1	29.0	233
Renew. + waste + semi-waste + pyrolysis oil	344.7	0.5	69
Multiple fuels solid + liquid	667.1	0.9	23
Multiple fuels liquid + natural gas	3684.0	5.0	46
Geothermal	623.9	0.9	21
Hydro (dam type)	19,077.2	26.1	109
Hydro (river type)	6790.6	9.3	451
Wind	4498.4	6.1	113
Thermal (unlicensed)	56.5	0.1	24
Wind (unlicensed)	4.8	0.0	9
Solar (unlicensed)	248.8	0.3	362
Total	73,146.7	100.0	1514

1/4 of the import of a total of 237 billion US\$ and over 75% of natural gas is being imported just from two states, Iran and Russia [15]. In the long run, this is simply not sustainable.

From energy systems engineering perspective the solution to this problem is straightforward. Turkey should decrease its imported fossil fuel consumption and increase consumption of its indigenous energy sources. However, in reality this is not an easy task. Turkey's only indigenous fossil fuel that is abundantly available is coal, mostly lignite [16]. Unfortunately, increased consumption of lignite would increase Turkey's greenhouse gas emissions. And it is known that increased

Table 2
Turkey's Vision 2023 targets for the energy sector (target, as of 2015, can be modified) [20,21].

Items	Goals
Renewable Energy Sources	
Share of renewable sources in energy production	30%
Hydroelectric generation capacity	Maximum or 36,000 MW
Wind power installed capacity	20,000 MW
Solar power installed capacity	3000 MW
Geothermal power installed capacity	600 MW
Biomass	2000 MW
Infrastructure	
Length of transmission lines	60,717 km
Reaching a power distribution unit capacity	158,460 MVA
Use of smart grids	Established
Natural gas storage capacity	5 billion m ³
Energy stock exchange	Established
Nuclear power plants	2 operational (3rd under construction)
Installed power capacity	120,000 MW

consumption of fossil fuels in the 20th century has led to global climate change [17]. As a result, today, sustainability is the primary goal of global energy market [18]. This means, Turkey should decrease the share of fossil fuels and increase the share of renewable energy sources in the country's energy mix. This is also parallel to the global trend of using more renewable energy sources [19]. Globally, increasing greenhouse gas emissions, which doubled over the last three decades, and the instability of fossil fuels prices encouraged many countries to increase their investment on renewable energy sources [8].

In that context, the Turkish government set an ambitious target of producing 30% Turkey's energy demand in the year 2023 from renewable energy sources. This is part of Turkey's Vision 2023 energy targets, details of which are given in Table 2 [20,21]. To be specific, Turkey's 30% is significantly higher than the 20% target of the European Union (EU) set for the year 2020 [22]. Therefore, meticulous analysis on the realisation of Turkey's Vision 2023 energy targets must be carried out. So far, the author of this paper has carried out majority of this analysis on Turkey's Vision 2023 energy targets [1,16,23–26]. Here it should be emphasized that Vision 2023 targets given in Table 2 are valid as of 2015 and it is possible that some of the targets can be increased if they are achieved before 2023.

The main problem with renewable energy sources is baseload supply. Conventionally, the backbone of power systems are baseload providers, which are power plants able to generate a constant and predictable supply of electricity [27]. In most networks primary source of electrical energy are baseload plants, which use fossil fuels [28]. Therefore, increased share of renewable energy sources in Turkey's power grid could jeopardise baseload supply, if necessary precautions are not taken. As can be seen from Table 2, it is envisaged that a substantial amount of electricity will be generated from wind and solar energy to fulfil the Vision 2023 targets. To be specific, 20,000 MW from wind and 3000 MW from solar energy. Due to the intermittent nature of wind and solar energy, 7 days a week 24 h a day power supply from these renewable energy sources is problematic. Luckily, not all the renewable energy sources have such intermittency problems. Biomass, geothermal and hydropower are considered as renewable baseload energy sources [29].

Hydropower could provide baseload energy supply, conditional that there is not a continuous drought period. However, according to the Vision 2023 targets hydropower energy utilisation will be maxed out (see Table 2); and there won't be room for further improvement, if the Vision 2023 energy goals are realised. Biomass could also provide baseload energy supply conditional that enough biomass is available.

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