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# Alternative Energy Sources in Turkey for Sustainable Development

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## Abstract

This study is focused on the potential alterative and renewable energy sources for Turkey. A lot of alternative energy sources present in the world as well as in Turkey including hydro, solar, wind, geothermal and biomass energy. However, we can use a few amount of this sources although they can meets of world's energy need on a large scale. Alternative energy usage has also potential to decrease $CO_2$ emission which is responsible of global warming. Low productivity, high investment and operational cost of these methods minimize their application in a wide range. Therefore, many studies have been carried out to decline the costs and to improve the efficiency of these systems.

***Keywords:*** *Alternative energy source, hydropower, solar, wind, geothermal, biomass, sustainability*

## 1. Introduction

Rapid industrial, social and economic development rates have increased energy usage and energy demand of Turkey as well as world since 1950 [1]. Energy demand was reported to increase at a rate of 1.6% by 2030. Developed countries have increasingly interest on the use of alternative energy sources due to difficulties of energy availability and to obtain sustainable development. Turkey obtains a big amount of energy needs from fossil fuels which lead to greenhouse gas emissions and from importing energy. Expensive energy production from fossil fuels and exports leads to increasing environmental pollution and decreasing competition power. Therefore, Turkey is dependent on the other countries for energy production and energy technology. Commercially used natural energy resources of Turkey have been found in a wide range including hard coal, lignite, asphalt, oil, and natural gas [1]. Also, Turkey has not got any nuclear power station up to now. However, most of these resources are being difficult to meet the energy demand. In addition to this, Turkey has also a lot of alternative energy sources such as wind, solar, hydroelectric, hydrothermal and biomass energy.

In a lot of developed countries such as USA and Japan a little electric energy requirement of houses are provided by using wind and solar energy. Especially, a lot of investments have been carried out on the solar and wind energy in Germany and Denmark. Israel and south region of Cyprus are first two countries in the world for the production of electric from solar energy and their capacity five times higher than Turkey. Germany, Denmark, Spain and Italy are first five countries for the production of electric from wind energy. Unfortunately Turkey could not reach to the first ten countries producing electric from wind energy. For example, Turkey can not reach to 1/28 of Greece for electric production from wind energy. However, European Union countries increasingly support the enterprises in this area. According to European Union's last decisions, European Union have aimed to increase the ratio of renewable energy to 12 % of energy usage up to 2010. Also, European Union has desired the candidate country to reach this target. Our country has rather wide sources of hydropower, solar, wind, geothermal and biomass energy capacities and passes a lot of country in the world on the occasion of being a Mediterranean country. In addition, Turkey has recently published the Renewable Energy Law (Law No. 5346) on 18 May 2005 for promoting of renewable energy utilization.

## 2. Hydropower Energy

Hydropower is one of the most important sustainable, renewable, abundant and cheap energy sources for electric production of Turkey, as well as the world [4]. Average elevation of Turkey is about three times higher than the Europe's average and this level has reached to 1132 m average [5]. This topography makes possible to construct high efficiency hydropower plants. Kucukali [5] reported that Turkey has also an important micro- and small-scale hydropower potential. Kömürcü and Akpinar [4] stated that

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hydropower provides about a quarter part of Turkey's electricity generation. Turkey's gross hydropower potential was also estimated as 433-442 terawatt hours/year; that was equal to 1% of world and 14% of European hydropower potential. Also, the construction of hydropower plants in Turkey has rapidly increased as a result of the Renewable Energy Law [5]. The biggest irrigation and hydroelectric power production project of Turkey is Southeastern Anatolia Project (GAP). Hydroelectric potential of the GAP region will achieved to 22% share of the Turkey's total hydroelectric potential with 19 hydroelectric power plants [6]. Yüksel [7] has reported that electric energy demand can be met by 33–46 from Turkey's hydro electric potential in 2020 and this potential may feasibly be developed. Turkey's present and potential hydroelectric power are given in Table 1.

## 3. Solar Energy

Turkey has been exposed to long sunshine duration and solar radiation which are average 2640 h and 3.6 kWh/m$^2$ day, respectively. The solar systems in Turkey generally consisted of solar water heating systems. These systems mostly include water tank and a solar flat-plate collector to heat the water and can be used for domestic or industrial purposes. Total installed collector capacity of Turkey has been reported as 8.2 million m$^2$ collector area, in 2001 [8]. Therefore, solar energy has reported a technical potential of 8.8 mtoe electricity generation and 26.4 mtoe heating capacity In Turkey. Although, the photovoltaic systems were low level which was about 0.5 MWe according to Germany (1229MWe) [8], it would be a promising investment for Turkey. Turkey's solar energy potential and electric energy production potential by using different PV panels are showed in Figures 1 and 2.

**Table 1: Present and potential of hydroelectric power in Turkey** (obtained by DSI [9, 10]).

| | Number of power station | Total installed capacity (MW) | Proven production (GWh/year) | Total annual production (GWh/year) |
|---|---|---|---|---|
| Present hydropower plants | | | | |
| In production > 10MW | 74 | 193 | 287 | 722 |
| In production < 10MW | 68 | 12,595 | 33,273 | 45,208 |
| Under construction > 10MW | 8 | 45 | 151 | 228 |
| Under construction < 10MW | 32 | 3152 | 6207 | 10,290 |
| Present total | 182 | 15,985 | 39,918 | 56,448 |
| Future possible potential | | | | |
| >5 MW | 164 | 366 | 571 | 1848 |
| 5–10MW | 82 | 610 | 897 | 2587 |
| 10–50MW | 187 | 4727 | 9234 | 18,959 |
| 50–100MW | 51 | 3692 | 7734 | 13,001 |
| 100–250MW | 37 | 5815 | 11,824 | 19,308 |
| 240–500MW | 10 | 3250 | 5620 | 10,688 |
| 500–1000MW | 2 | 1053 | 2054 | 3173 |
| 1000 <MW | 1 | 1200 | 2459 | 3833 |
| Future total | 534 | 20,713 | 40,393 | 73,398 |
| Total | 716 | 36,698 | 80,311 | 129,846 |

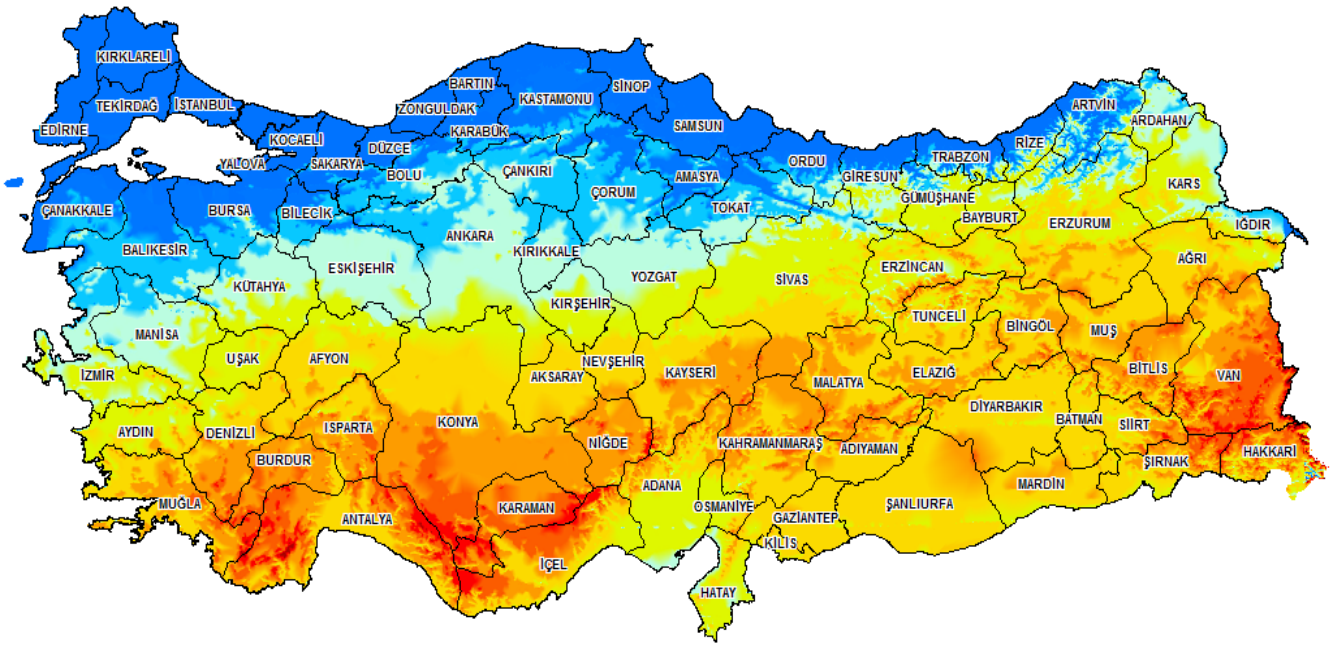


**Fig. 1: Turkey's solar energy potential atlas; potential is maximum for red color** (obtained by GEPA map [11])

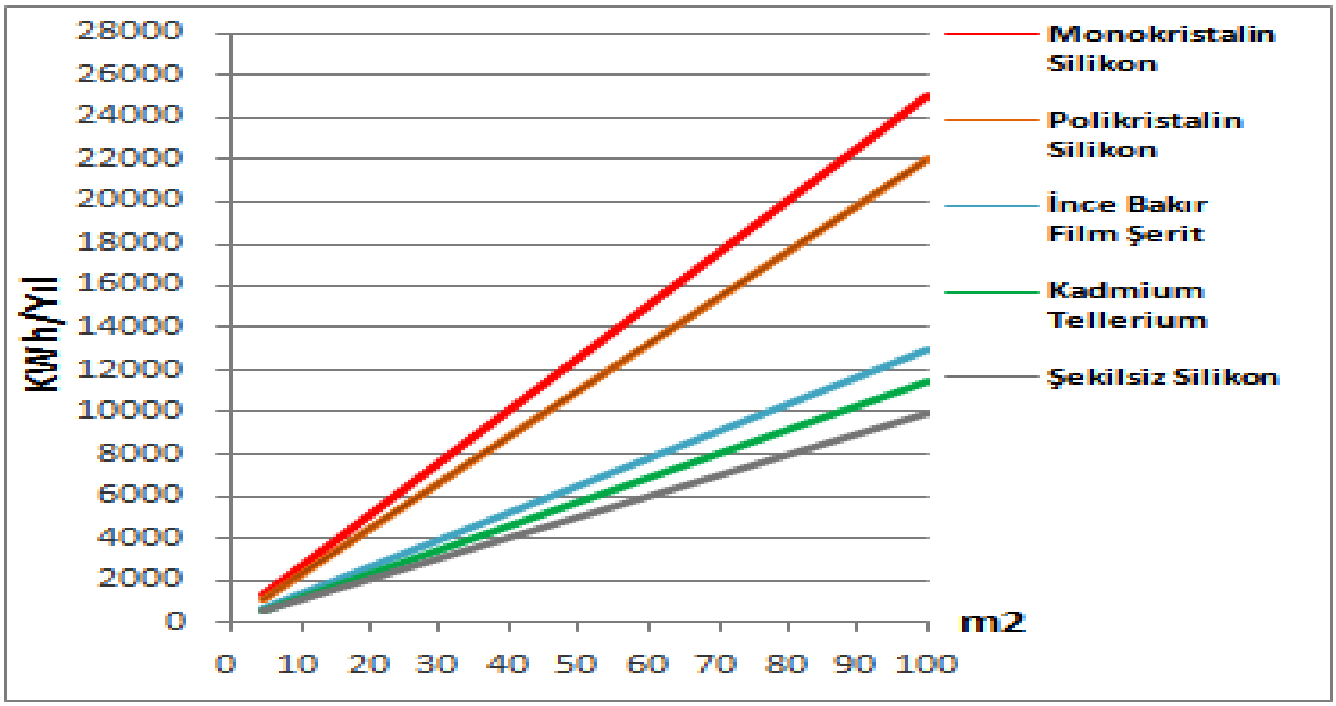


**Fig. 2: Potential electric energy production by different PV panels for various surface areas in Turkey** (by GEPA map [11])

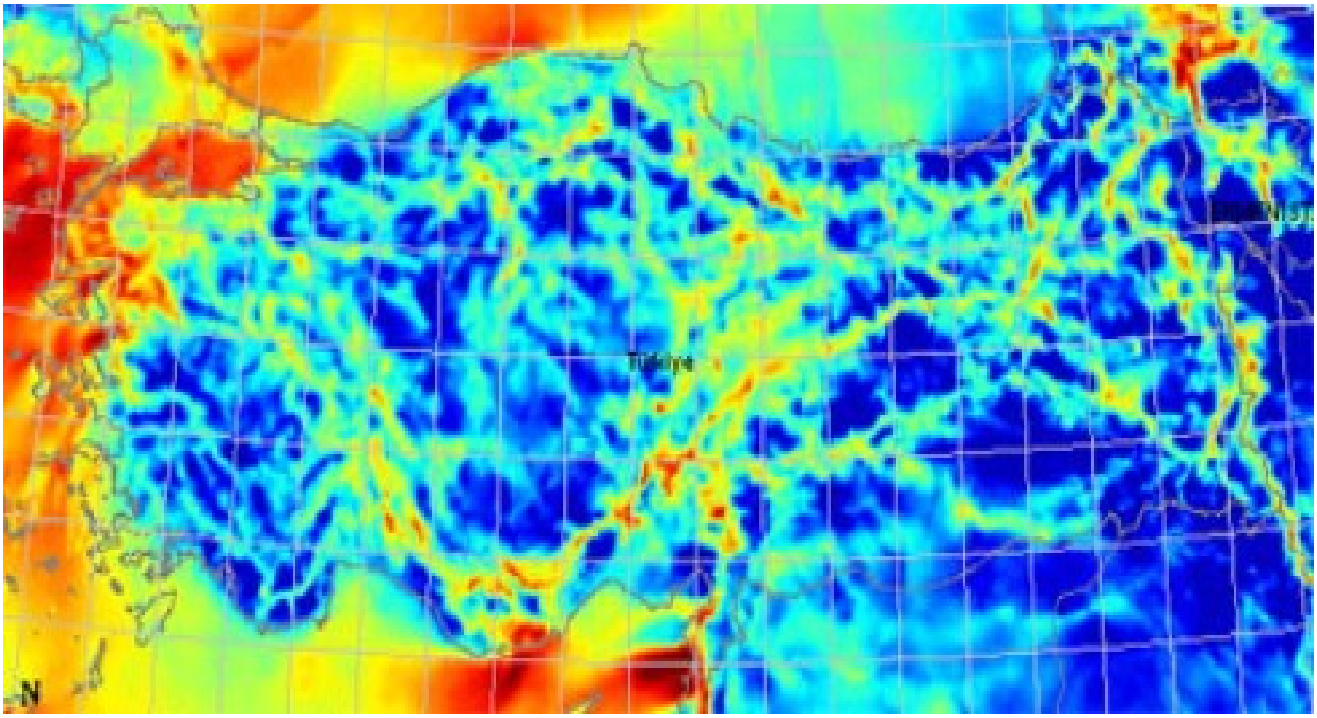

**Fig. 3: Turkey wind energy potential atlas; potential is maximum for red color** (obtained by REPA map [11])

## 4. Wind Energy

Wind is one of the major promising alternative energy sources that can meet energy demand of Turkey in comparison to the classical sources [1]. Total theoretically available wind potential of Turkey (88,000 MW and 160 TW h a year) has doubled of the current electricity consumption [12]. Turkey's installed wind-energy-generating capacity was reported about 51, 131 and 333 MW for 2006, 2007, and in the first half of 2008, respectively [13-15]. According to Europe, Turkey is the first in technical wind energy potential [16]. Although the installed wind energy capacity of Turkey is very small, it has increased from 9 MW in 1998 to 333.35 MW in the first half of 2008 [1,16]. Wind energy potential atlas of Turkey is showed in Fig. 3.

## 5. Geothermal Energy

Geothermal sources have some advantages according to other renewable energy sources such as higher availability since they are not dependent on weather conditions, economically and environmentally applicable. Geothermal energy has generally been used for heating of a region. The constructed heating systems in Turkey were reached 17, even in the period of 1991-2006 which the first one was Gönen in 1987 [17]. Beside of heating purposes geothermal energy could also be used for electricity generation even at low temperatures with available conversion technologies [18-20]. Geothermal sources are generally classified in three parts such as low-, medium- and high temperature sources. Turkey are generally have low- and medium-temperature sources. Serpen et. al [17] stated that geothermal energy usage for district heating or greenhouse heating would be more profitable than electricity generation due to high investment cost. Nevertheless some geothermal power generation station exist in Turkey which is showed in Fig. 4 and Table 2.

## 6. Biomass Energy

Another potential, important and promising alternative energy source is biomass energy which is mostly comprised of biogas and biofuels. Biomass energy sources is one of the most used renewable energy sources [22] and have found a wide range in Turkey including crop residues with the potential equivalence of 55.9 TWh (4.81 Mtoe), forestry and wood processing residues with 50 TWh (43 Mtoe), firewood with 48.3 TWh (41.6 Mtoe), animal wastes with 27.3 TWh (23.5 Mtoe), and municipality wastes with 15.1 TWh (13 Mtoe) [23, 24]. Total recoverable biomass potential was reported as 196.7 TWh (16.92 Mtoe) in 1998 [24].

## 7. Conclusions

Alternative and renewable energy sources are known as clear and promising for meeting Turkey's energy needs as well as world. Although hydropower and biomass energy sources are playing an important role in total energy requirements of Turkey now, another sources such as wind, solar, geothermal energy are also promising. These type of energy sources must be increased for sustainable development. Therefore governments may be supports entrepreneurs to enhance of alternative energy investments. Also, Turkey must constructed several nuclear power station as soon as possible.

**Table 2: Geothermal power generation stations in Turkey** (obtained by Serpen et. al [17])

| Power plant | Commissioned in (year) | Installed capacity (Mwe) | Max. temp. (°C) |
|---|---|---|---|
| Kızıldere-Denizli | 1984 | 17.8 | 243 |
| Dora-I Salavatlı-Aydın | 2006 | 7.35 | 172 |
| Bereket enerji-Denizli | 2007 | 7.5 | 145 |
| Gürmat-Germencik-Aydın | 2009 | 47.4 | 232 |
| Tuzla-Çanakkale | 2009 | 7.5 | 171 |
| Dora-II Salavatlı-Aydın | 2010 | 9.7 | 174 |

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**Fig. 4: Turkey geothermal sources and application atlas** (obtained by MTA General Directorate [21])

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