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# Alternative Energy Sources and Existing Power Plants in TURKEY

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**Abstract**

Although our country is rich in natural resources, they are not used consciously. Fossil fuels, our most widely consumed natural resources, meet an important part of our energy deficit. However it is not enough to reduce our dependence on foreign energy. In addition, the negative impact of wastes on the environment and human health has raised the recycling of these wastes. This has resulted in the quest for alternative energy sources. Alternative energy sources include electricity production from rivers, sewage sludge, agricultural and animal wastes, the wind and solar power.

This study discusses alternative energy sources and existing power plants in Turkey and their efficiency.

**Keywords:** Alternative energy, Thermal reactor, Solar power, Wind power

## 1. Introduction

Turkey's energy policy has been defined by the Ministry of Energy and Natural Resources as "making use of the limited natural resources more rationally and thus reducing the negative impacts on the environment and human health to minimum; diversifying the energy with new technologies in addition to new resources; providing a cleaner, safer, more efficient, cheaper and commercially accessible and sustainable energy supply which will help boast country's development and prosperity by offering the alternative energy resources in the most beneficial way".

Mobilizing our renewable energy resources integrated into the elements of indigenousness and novelty will make significant contributions to meeting clean environment demands and energy needs with on-site production methods.

Our country is dependent on foreign sources in meeting its energy needs. The biggest indicator of this is the fact that we import about 70 % of the raw material that we need for generating energy. The solution to this problem is the fact that the renewable energy resources that have enough potential should be studied sensibly, and ways to make use of them at the maximum should be investigated, as well as exploring the existing energy raw materials and reserves wisely and using them effectively (Çağlar, 2010).

According to 6 various scenarios included in "The Global Energy Perspectives" report presented by World Energy Council in 1995 to 16$^{th}$ World Energy Congress (Tokyo Congress), the primary energy consumption in the world is expected to reach at 11,4-15,4 GTEP in 2020 and 14,2 - 24,8 GTEP in 2050. According to the same report, the production from renewable sources will be at around 2,3-3,3 GTEP in 2020 and 4,4-7,3 GTEP in 2050. The proportions will involve classic biomass and classic hydraulic energy, as well as modern biomass and other renewable resources. Table 1 shows a prediction based on resources for year 2020 in order to indicate the potential share of modern biomass comparatively (growing energy forests and energy crops) (Saraçoğlu, 2010).

The 2011 primary energy consumption in Turkey was realized as 32228,9 Btep (thousand tones of oil equivalent). In the same year, the distribution of primary energy production based on resources was lignite (50 %), hydraulic (14 %), wood (8 %), oil (8 %), geothermal energy (5 %) and coal (4 %) respectively (Figure 1). While primary energy production from sources such as lignite, geothermal energy, wind, and sun increased in 2011 compared to 2010, production from wood, and animal and plant waste was found to decrease. Figure 2

 

summarizes the resource-based distribution of total energy consumption in Turkey (the Ministry of Energy and Natural Resources).

## 2. Power Plants in Turkey

### 2.1 Hydroelectric Power Plants

In the production of electric energy, in addition to thermo-power plants running on fossil fuels and nuclear power, geothermal and natural gas power plants, hydroelectric power plants (HPP) have two important functions: they are renewable and they can run at the peak. HPPs can compete with other thermo-power plants and nuclear power plants in terms of initial investment costs, excluding natural gas power plants. They are economical to run and environment-friendly. (Gençoğlu, 2002).

The theoretical hydroelectric potential of our hydraulic resources (Table 2) having the most important part in the renewable energy potential of our country is 433 billion kWh, whereas the technically feasible potential is 216 billion kWh and the economical hydroelectric energy potential is 140 billion kWh/year. As of the end of 2013, 41 % of the potential determined to be economical is already being operated, while 27 %, including projects sustained by private sector, is under construction (www.enerji.gov.tr).

As of the end of 2013, 467 HPPs, already running, correspond to 22.289 MW of installed power and about 34,8 of total potential. 24,8 % of our electricity generation in 2013 came from hydroelectric power (www.enerji.gov.tr).

Hydroelectric power plants are superior to other power plants in that they are renewable; they use local natural resources; they have low operation and maintenance costs; they have a long physical life-span; they have minimum negative impact on the environment; and the boast the economical and social structure in rural areas. Based on these facts, it is necessary to develop and realize hydroelectric projects as soon as possible (www.eie.gov.tr).

### 2.2 Biomass Power Plants

Biomass energy is perhaps the most important of the resources that might provide the ever increasing energy need of the world with growing population and industry without polluting the environment and sustainably. Biomass is an inexhaustible energy source as long as the sun makes it possible to grow crops and plants (TÜGİAD, 2004). Biomass is defined as all organic matter involving plants that can grow on land and in water, animal waste, food industry and forestry products, and urban waste that is renewable in less than 100 years (Acaroğlu ve Ültanır, 2000). Biomass is either combusted directly as in Turkey or it undergoes various processes (anaerobic digestion, pyrolysis, fermentation, gasification, hydrolysis, biophotolysis, esterification reaction) to enhance fuel quality and produce alternative bio-fuels (biogas, landfill gas, biodiesel, bio-ethanol, synthetic oil) (Şen, 2006). The energy crops farming for modern biomass should be dealt with energy planning and agricultural production planning. While the gross potential of biomass energy in Turkey is theoretically estimated to be about 135-150 Mtep/year based on the energy likely to be gained from photosynthesis apart from cultural farming and food production, the net amount is presumed to be 90 Mtep/year after the deduction of losses. However, it is not possible to allocate all the farming lands of the country along a year only for biomass fuel production. The technical potential is about 40 Mtep/year based on the highest feasible farming. With economical limitations taken into consideration, 25 Mtep/year can be considered Turkey's economical biomass energy potential (Ültanır, 1998).

When the status of biodiesel in our country is examined, it can be seen that there is only one company producing active biodiesel from local agricultural products according to 14 September, 2011 data. In addition, though there seems to be three plants having permission to produce biodiesel from waste oil by the Ministry of Environment, only one of them is licensed by Energy Management and Regulation Agency (EMRA) and actively engaged in production (MMO, 2012; Çanka Kılıç, 2011).

Our country's installed capacity of bio-ethanol meets about 7 % of our gasoline consumption. However, the bio-ethanol in the market is far below 1 % of our gasoline consumption. The bio-ethanol production potential based only on sugar beet in our country is about 2-2,5 million tons. This value meets all of our 2011 gasoline consumption (MMO, 2012; Çanka Kılıç, 2011).

The biogas potential of Turkey is predicted 1400-2000 Btep/year. As of January 2012, The installed power of electric power plants running on biogas, still under construction, licensed by EMRA was 93 MW. On the other hand, the capacity of power plants running on biomass was 12,8 MW (MMO, 2012). Table 3 presents some of the biogas power plants in operation.

### 2.3 Nuclear Power Plants

 

A great energy is released as a result of the breakdown of atom nuclei. This energy, obtained by fission and fusion reactions, is called “nucleus energy” or “nuclear energy”.

Nuclear reactors are systems that transform nuclear energy into electrical energy. Basically, the nuclear energy released as a result of fission is transformed into thermal energy through nuclear fuel and other material, and then this thermal energy turns into kinetic energy. Finally, it is transformed into electrical energy through generator system. A nuclear reactor of 1.000 MW produces about 27 tons (7 $m^3$) of used fuel a year (www.enerji.gov.tr).

The use of nuclear energy is new and its technological development is very fast. There are a lot of uses of this energy. The most important of these is the production of electricity. Apart from this, nuclear energy is used in medicine, industry and arm industry (such as intercontinental ballistic missiles) to a great extent. The nuclear arms existing in the world today are strong enough to destroy many planets. Today countries like the US, Russia, France, England, Israel, China, India, Pakistan and South Korea are the main countries with nuclear weapons. As it is known, these weapons have global significance. In a war, these weapons will not only threaten the belligerent countries but also the entire world (Temurçin ve Aliağaoğlu, 2003).

Throughout the world, the projects aiming nuclear energy investments have started to gain momentum on a global scale, as well as developments promoting the use of renewable energy resources. As of May 20123, while there are 436 nuclear power plants in operation in 31 countries, 68 nuclear power plants with 65.5 GW installed power are under construction in 15 countries (www.enerji.gov.tr).

Our country started to realize its half century old ideal of establishing a nuclear power plant upon signing an agreement with Russian Federation on 12 May, 2010 regarding the establishment and operation of a nuclear power plant in Akkuyu Region. The agreement was adopted by the Turkish Great National Assembly (TGNA) General Committee on 15 July, 2010 and it was published on 6 October, 2010 in the Official Gazette with No. 27721. The project company, Akkuyu NGS Electric Production Inc. was founded in Ankara on 13 December, 2010. With this agreement, the establishment of a total of 4.800 MW, VVER-1200 type nuclear power plant with four units is expected (www.enerji.gov.tr).

On the other hand, an agreement with Japan was signed in 2013 for the establishment of another nuclear power plant in Sinop and the process is underway.

Based on the electrical energy supply and demand projections, the proportion of nuclear energy power plants in the production of electrical energy is expected to reach at least 5 % level by 2020. For this purpose, the law No. 5710 regarding the establishment and operation of nuclear power plants and energy sale was enacted in 2007 (www.enerji.gov.tr).

2.4 Wind Power Plants

The solar radiation heats the earth’s surface at different temperatures and this causes winds. The different heating of the ground surface causes the temperature, humidity and pressure of air to be different, and this pressure causes the movement of air. About 2 % of the solar energy reaching the world is converted into wind energy.

In Turkey, it has been accepted that a 5 MW wind power plant per square kilometer can be established in areas which has an altitude of 50 meters above ground and 7.5 m/s wind speed (www.enerji.gov.tr).

Turkey is a country which has regions rich in wind. The most profitable area has been identified in Marmara Region. The wind in this area has an altitude of 10 meters. The highest values regarding annual average wind speed and power density are 3.29 m/s and 51.91 $W/m^2$ respectively. The lowest value is in the East Anatolian Region with 2.13 m/s speed and 13.19 $W/m^2$ power density. While the power density of wind energy in 64.5 % of Turkey does not exceed 20 $W/m^2$, it is between 30-40 $W/m^2$ in 16.11 %, and above 50 $W/m^2$ in 5.9 % and above 100 $W/m^2$ in 0.08 % (Tavman ve Önder, 2001).

Though the wind potential of Turkey has not been determined fully yet, it is thought that its gross potential is about 400 billion kWh a year and the technical potential is nearly 120 billion kWh a year. The technical potential in question is 1.2 times of annual electricity production (Tavman ve Önder, 2001).

The amount of annual wind power production in Turkey as of 2013 is 7.518 GWh. The installed power of wind power plants in operation as of the end of 2013 is 2.760 MW. Table 4 presents some of the wind power plants in Turkey.

The annual wind energy production as of the end of 2012 in the world is 557 TWh/year. Its share in the production of energy is 2.6 %. The installed power of wind power plants in operation as of December 2013 is about 300 GW.

 

2.5 Solar Energy

Solar power is clean and free. It is abundant and unlimited. Solar energy has been used as thermal energy for a long time; however, with the advance of technology it is now used to generate electricity. Electrical energy is obtained through solar panels and photovoltaic cells and the costs are decreasing day by day.

Our country has high solar energy potential due to its geographical location. According to the Solar Energy Potential Atlas of Turkey (SEPA), prepared by the General Directorate of Renewable Energy, it has been found that the duration of annual sunshine is 2.737 hours (7.5hours/day) and total annual incoming solar energy is 1.527 kWh/m² .year (4,2 kWh/m² .day) (www.enerji.gov.tr).

By the end of 2012, the total installed solar collector area in our country was estimated to be about 18.640.000 m². It was determined that annual production of flat solar collector was 1.164.000 m² and vacuum tube collector 57.600 m². It is known that 50 % of the flat collectors and 100 % of the vacuum collectors are used in our country. About 768.000 TEP (tons of oil equivalent) heating energy was produced through the solar collectors in 2012. Of the thermal energy produced, 500.000 TEP was used for residential purposes and 268.000 TEP was used for industrial purposes (www.enerji.gov.tr).

The technical evaluation studies of the applications to EMRA for licensed electricity production in 2013 is still underway. A 600 MW installed power will be given photovoltaic power plant license in the first phase. The capacity will be increased gradually in the coming years and according to 2023 plans of the Ministry, a licensed PV power plant of 3000 MW will have its installed power (www.enerji.gov.tr).

The photovoltaic solar electricity systems, already established in our country and used to meet small power demands and for research purposes, have reached 3,5 MW installed power (www.enerji.gov.tr).

The production of solar power collectors in our country is around 750.000 $m^2$ and some of this production is exported. The annual heat energy production from solar energy is around 420.000 TEP. With its present status, our country is a remarkable solar collector manufacturer and user in the world.

Solar cells are used to meet small power demands and for research purposes mostly in the watchtowers of the Ministry of Forestry, Turkish Telecom, lighthouses, highway lightning, the General Directorate of Electrical Power Resources Survey and Development, and some universities. Therefore, we do not have a remarkable installed solar battery power.

2.6 Geothermal Energy

Geothermal resource is shortly ground heat. It is made of hot water, vapor and gases involving chemicals and formed by heat accumulating at various depths of the earth's crust. Geothermal energy involves all kinds of direct or indirect utilization of geothermal resources. Geothermal energy is a kind of renewable, sustainable, inexhaustible, cheap, reliable, environment-friendly, indigenous, and green energy (Kemik, 2002).

The geothermal reservoirs that rain, snow, sea and igneous waters make up by feeding the porous and fractured rock mass retain their renewability and sustainability characteristics as long as underground and re-injection conditions are maintained. They are not affected by short term atmospheric conditions (Kemik, 2002).

The installed geothermal energy power is 11.766 MW in the world as of August 2013. The annual electricity production is 68,6 billion kWh. The top five countries generating electricity from geothermal energy are the USA, Philippines, Indonesia, Mexico and Italy. Non-electrical utilization is 50.000 MW. The top five countries in geothermal heating and hot springs application are China, the USA, Sweden, Turkey and Japan (www.enerji.gov.tr).

Turkey has a relatively high geothermal potential as it is located on Alpine-Himalayan belt. The geothermal potential of our country is about 31.500 MW theoretically. Of the potential areas in Turkey, 79 % is in Western Anatolia, 8,5 % in Middle Anatolia, 7,5 % in Marmara Region, 4,5 % in Eastern Anatolia and 0,5 % in other regions. 94 % of our geothermal resources is of low and medium temperature and it is suitable for direct applications (heating, thermal tourism, mineral applications, etc.). The rest 6 % is suitable for indirect applications (generating electricity) (www.enerji.gov.tr).

It is estimated that our electricity generation potential from geothermal energy is theoretically 2.000 MW. As of the end of 2013, the geothermal electricity production potential of our country, including those licensed by EMRA, has reached 706,4 MW. It is expected that this figure will reach 1.000 MW as of the end of 2018. There are 13 geothermal power plants in Turkey today (Table 5) and the installed power has reached 310,8 MW (www.enerji.gov.tr).

 

## 3. Conclusion

Foreign dependence on fossil fuels and environmental problems highlighted by the increasing environmental awareness in addition to limited fossil fuel reserves revealed that fossil fuels are not ecologically and environmentally clean and sustainable. The environmental problems caused by the energy production from fossil fuels and the costs of eliminating the negative impacts of such production has led to the quest for efficient, clean and renewable energy sources.

To meet the energy needs, very expensive investments have been made. On the other hand, while these losses continue, foreign dependence on energy has reached serious levels for Turkey. As part of the next energy policy, first, new investments should be made for saving energy, then by considering the savings obtained from these investments, new energy production plants should be planned.

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**Table 1**. The Rank of Renewable Energy Resources in 2020 Energy Budget (Acaroğlu, 2003)

| | minimum in 2020 | | maximum in 2020 | |
|---|---|---|---|---|
| | MTEP | % of the total | MTEP | % of the total |
| Modern Biomass | 234 | 45 | 561 | 42 |
| Sun | 109 | 20 | 355 | 26 |
| Wind | 85 | 15 | 215 | 16 |
| Geothermal | 40 | 7 | 91 | 7 |
| Small Hydraulic | 48 | 9 | 69 | 5 |
| Sea Power | 14 | 4 | 54 | 4 |
| Total | 539 | 100 | 1345 | 100 |
| The percentage of general energy demand | 3-4 | | 8-12 | |

**Table 2.** Some of the existing hydroelectric power plants in Turkey and their efficiency

| Name of the hydroelectric power plant | Installed Power (MW) |
|---|---|
| Atatürk | 2405 |
| Karakaya | 1800 |
| Keban | 1330 |
| Altınkaya | 702,55 |
| Berke | 510 |
| Hasan Uğurlu | 500 |
| Sır | 283,5 |
| Gökçekaya | 278,4 |
| Batman | 198 |
| Karamış | 189 |
| Özlüce | 170 |
| Çatalan | 168,9 |
| Sarıyar Hasan Polatkan | 160 |
| Gezende | 159,37 |
| Aslantaş | 138 |
| Hirfanlı | 128 |
| Menzelet | 124 |
| Kılıçkaya | 120 |
| Dicle | 110 |

 

**Table 3.** Some of the biogas power plants in operation

| Biogas power plants | Installed Power |
|---|---|
| İzaydaş İzmit Waste and Waste Combustion Inc. Solaklar Köyü Mevkii Kocaeli | 0.75 MW |
| Kalemiler Enerji Electricity Production Co.Ltd. Sezer Biyogaz Manavgat Antalya | 0.5 MW |
| Pamukova Renewable Energy and Electricity Production Inc. Pamukova Sakarya | 1.4 MW |
| Sütaş Farm Karacabey Bursa | 0.25 MW |
| İlci Farming Inc. Çiçekdağı Kırşehir | 0.25 MW |
| Kılavuz Integrated Farms Gaziantep | 100 kW solea energy |
| Devsüt Farm Konya | 50 kW solea energy |
| 1El Farming Isparta | 50 kW solea energy |

**Table 4.** Some of the wind power plants (WPP) in Turkey

| Wind power plant | Installed Power MW |
|---|---|
| Geycek WPP | 150 |
| Balıkesir WPP | 142,50 |
| Soma/Soma WPP | 140,80 |
| Osmaniye WPP | 135 |
| Kangal WPP | 128 |
| Karaburun WPP | 120 |
| Şamlı WPP | 114 |
| Bağlar WPP | 100 |
| Şah WPP | 93 |
| Aliağa WPP | 90 |

**Table 5.** Some of the geothermal power plants in Turkey

| Geothermal Area | Installed Power | Temperature |
|---|---|---|
| Denizli-Kızıldere | 15 MWe | 242 |
| Aydın-Sultanhisar (Dora-1) | 7.95 MWe | 162 |
| Aydın-Sultanhisar (Dora-2) | 9.5 MWe | 162 |
| Aydın-Germencik | 47.4 MWe | 232 |
| Çanakkale-Tuzla | 7.5 MWe | 174 |
| Denizli-Kızıldere (from the waste water of Kızıldere Geothermal area) | 6.85 MWe | 140 |

 

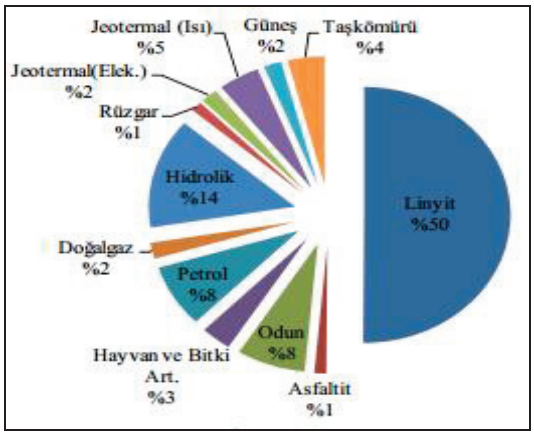


**Figure 1.** The distribution of primary energy production in Turkey based on resources (the Ministry of Energy and Natural Resources).

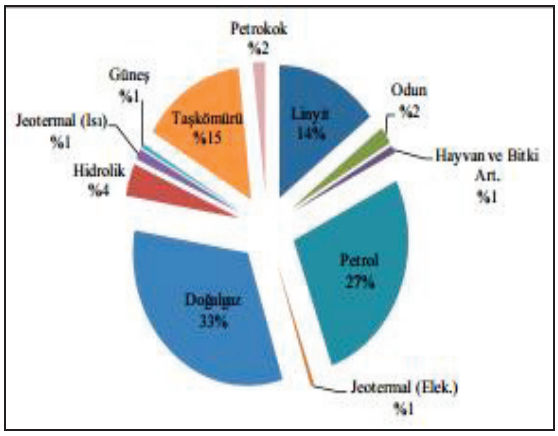


**Figure 2.** The resource-based distribution of energy consumption in Turkey [5]

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