Renewable Energy Sources and Policies in Turkey

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***Abstract*—Considerable attention has been focused on the energy sources and energy studies in Turkey, recently. More than half of the energy requirement of Turkey is supplied by imports. Domestic oil and lignite reserves are limited, and also the lignites are characterized by high ash, sulfur and moisture contents. Air pollution is the main problem for environment by increasing energy consumption. In this respect, renewable energy resources seem to be one of the most efficient and effective solutions for sustainable energy development and environmental pollution prevention in Turkey. The advantages of Turkey for extensive use of the renewable energy sources depend on its geographical location. This article expresses both Turkey's present and future renewable energy circumstance. In these concepts, present energy situation, the renewable energy potential of Turkey, and the energy politics are investigated.**

***Keywords*— Energy situation, renewable energy, energy policy.**

I. Introduction

SEEING the importance and effects of energy on life, all countries are trying to develop and apply technologies that will allow them to use different energy sources. Although the significance of energy production is an essential component in economic growth, several environmental problems resulting from energy production, conversion, and utilization have caused public awareness in all sectors of the public, industry, and government in developed and developing countries [1].

Turkey is an energy importing country; more than half of the energy requirement has been supplied by imports. Oil has the biggest share in total primary energy consumption. Turkey has large reserves of coal, particularly of lignite [2]. The other conventional and renewable energy resources of Turkey include asphaltite, bituminous shale, natural gas, hydropower, and biomass, as well as geothermal, wind, solar, and nuclear energy. Although Turkey has a wide range of energy resources, these resources are exhausted. Therefore, it is critical to supply its energy demand by using domestic non-renewable resources (such as lignite, hard coal, oil and natural gas) and renewable resources [3, 4].

Renewable energy resources (solar, hydroelectric, biomass, wind, ocean and geothermal energy) are unlimited and offer many environmental benefits over conventional energy sources. Each type of renewable energy also has its own special advantages that make it uniquely suited to certain applications. Almost none of them release gaseous or liquid pollutants during operation. In their technological development, the renewables range from technologies that are well established and mature to those that need more research and development. The other important factor of renewable resources is to create new employment opportunities [3,5].

II. Present Energy Situation

The Turkish economy has been growing very fast, especially after the 1980s. Despite limitations in domestic resource availabilities, primary and secondary energy demand in Turkey is growing very rapidly, parallel with the industrialization efforts. The annual rate of increase is around 8–10% [5].

Turkish coal and lignite are largely inappropriate for the purposes of sustainable development as their usage is cost-ineffective and responsible for air pollution in urban centers during the 1970s and 1980s. This is because Turkish lignite has low calorific value and high sulfur, dust and ash content whereas Turkish hard coal is low grade [6]. Also, Turkey has huge reserves of renewable energy sources. Turkey's renewable energy sources are abundant and extensive. Renewable energy production makes up approximately 14.4% of the total primary energy supply (TPES) [7].

In 2006, primary energy production and consumption has reached 28.2 and 98.3 million tonnes oil equivalents (Mtoe) respectively (Table 1). The most significant developments in production are observed in hydropower, geothermal, solar energy and coal production. Turkey's use of hydropower, geothermal and solar thermal energy has increased since 1990. However, the total share of renewable energy sources in TPES has declined, owing to the declining use of non-commercial biomass and the growing role of natural gas in the system. Turkey has recently announced that it will reopen its nuclear program in order to respond to the growing electricity demand while avoiding increasing dependence on energy imports [8].

The TPES in Turkey grew by 3.2% per year between 1990 and 2006. Hard coal and lignite is the dominant fuel, accounting for 27.1% of TPES in 2006. Oil (34.8%) and gas (27.2%) also contributed significantly. Renewable energy, mostly biomass, waste and hydropower, accounted for 10.9%. Hydropower represented 3.8% of TPES in 2006. Biomass, primarily fuel wood consumed by households, represented almost 5.9%. The economic downturn in Turkey in 2000–2005 caused TPES to decline by 6.0%. But energy demand is expected to increase according to Turkish government sources. On the other hand, gas accounted for 43.8% of total electricity generation in 2005, coal 26.58% and oil at about

5%. Hydropower (as renewable) is the main indigenous source for electricity production and represented 20– 30% of total generation from 1970 to 2005. Hydropower declined significantly relative to 2000 due to lower electricity demand and to take-or-pay contracts in the natural gas market [8].

Table 1: Developments for energy production and consumption in Turkey [8].

	2000	2002	2004	2006
Primary energy production (Ttoe)	27621	24884	24170	28210
Primary energy-consumption (Ttoe)	81193	78322	87778	98350
Consumption per capita (KOE)	1204	1131	1234	1377
Electricity installed capacity (MW)	27264	31846	36824	40565
Thermal (MW)	16070	19586	24160	27420
Hydraulic (MW)	11194	12260	12664	13062
Electricity production (GWh)	124922	129400	150698	174657
Thermal (GWh)	94011	95668	104556	131929
Hydraulic (GWh)	30912	33732	46142	44371
Electricity import (GWh)	3786	3588	464	573
Electricity export (GWh)	413	435	1144	2236
Total Consumption (GWh)	128295	132553	150018	174637
Consumption per capita (kWh)	1903	1914	2109	2391

III. Renewable Energy Sources

Renewable energy appear to be the one of the most efficient and effective solutions for clean and sustainable energy development which accounted for 12.89% of the world's total primary energy supply in 2006 [6, 9]. On the other hand, Turkey, with its young population and growing energy demand per person, its fast growing urbanization, and its economic development, has been one of the fast growing power markets of the world for the last two decades. It is expected that the demand for electric energy in Turkey will be 580 billion kWh by the year 2020. Turkey is heavily dependent on expensive imported energy resources that place a big onus on the economy and air pollution is becoming a great environmental concern in the country. When viewed from this aspect, for green energy development renewables are influential solutions. [10]. Turkey's geographical location has several advantages for extensive use of most of the renewable energy sources which are biomass, hydropower, geothermal, solar and wind [6].

A. Biomass Energy

Biomass is abundant and has remarkable potential in Turkey. It is the term used for all organic material originating from plants, trees and crops and is essentially the collection and storage of the sun's energy through photosynthesis. Biomass can be either obtained directly from plants or indirectly from industrial, domestic, agricultural, and animal wastes and can be thermochemically converted into liquid fuel, gases such as methane, carbon monoxide, or hydrogen by pyrolysis and gasification [11, 12].

Biomass is important because share of total energy consumption is still high in Turkey [10]. The annual biomass potential is approximately 32 Mtoe in Turkey. The total recoverable bioenergy potential is estimated to be about 16.92 Mtoe [13]. Using vegetable oils as fuel alternatives has economic, environmental, and energy benefits for Turkey. Vegetable oils have heat contents approximately 90% of that of diesel fuel. A major obstacle deterring their use in the direct injection engine is their inherent high viscosities, which are nearly ten times that of diesel fuel. The overall evaluation of the results indicates that these oils and biodiesel can be proposed as possible candidates for fuel [10].

B. Hydropower

Hydropower provides unique benefits, rarely found in other sources of energy. These benefits can be attributed to the electricity itself, or to side-benefits, often associated with reservoir development. Hydro-turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator, or other machinery. The power available is proportional to the product of pressure head and water discharge [14].

Turkey has a huge hydropower potential and the second largest energy source after coal is hydro [15]. The gross and technical hydropower potential of Turkey where has the highest hydropower potential in Europe are estimated at 433 and 216 TWh/year, respectively. The economic potentials for installed hydropower capacity and electricity output have been anticipated about as 45 GW and 140 TWh/year, respectively. The gross hydroelectric potential of Turkey is about 1% of the world total and about 14% of the European total [16, 17]. The Turkish government expects the construction of 332 more hydroplants in the long term to make use of the potential remaining hydrosites. This would bring the number of hydroplants to 485, and add more than 19 GW of capacity to the hydrosystem. This increase in the hydrogenerating capacity includes the Southeastern Anatolia Project (GAP) that covers 1/10th (74,000 km^2) of Turkey's total land area, one of the largest hydro developments ever undertaken. Upon its completion, GAP will have an installed capacity of 7476 MW. The construction of all these new dams requires an investment of more than US$ 30 billion. Forecasting that Turkey's hydropower potential can meet 33-46% of its electric energy demand in 2020 (571 TWh) [15, 18].

C. Geothermal Energy

Although geothermal energy is categorized in international energy tables as one of the new renewables, it is not a new energy source at all. The inventorial works and chemical analyses of the hot springs and mineral waters started in 1962 [19]. The geothermal power plants are designed to operate 24 h/day, and the operation is independent of the weather or fuel delivery so it is the most stable renewable energy source. The

geothermal energy source that can be easily converted into electrical power is generally considered renewable, because reservoirs may be recharged by rain or by re-injection of the wastewater [20].

Turkey's percentage of the total capacity is 0.25% of the total which has an important place among the richest countries in geothermal potential [19, 20]. The first geothermal researches and investigations in Turkey started by Turkish Mineral Research and Exploration Institute (MTA in Turkish initials) in 1960s. Since then, about 170 geothermal fields have been discovered by MTA, where 95% of them are low-medium enthalpy fields, which are suitable mostly for direct-use applications [21]. The present use of geothermal energy in Turkey (105 GWh/year for electricity and 4465 GWh/year for direct use) is a very small fraction of the identified geothermal potential. Only 3% of the total geothermal potential of Turkey has been utilized so far. When Turkey uses all of this potential, it can meet 14% of its total energy need. Geothermal energy has the potential to play an important role in the future energy supply of Turkey [20]. Future supply of geothermal energy depends on energy prices and technical progress, both of which are driven by energy policy priorities [21].

D. Solar Energy

Solar power is one of the most promising and more predictable than other renewable sources and less vulnerable to changes in seasonal weather. Whereas, generation of power from other renewable sources is limited to sites where these resources exist in sufficient quantities and can be harnessed, solar energy can produce power at the point of demand in both rural and urban areas [22].

Due to its location, Turkey has virtually rich solar potential [23]. In spite of this high potential, solar energy is not now widely used, except for flat-plate solar collectors. They are only used for domestic hot water production, mostly in the sunny coastal regions [10]. The electricity generation from the solar is realized by photovoltaics (PV) and solar collectors. Unfortunately, PVs have high installing costs; hence, an economical usage of them is not available today. In Turkey, only the Ministry of Environment and Forestry (forestry observation towers), Turkish Telecommunication Companies (transfer stations), the Highway Board Department (emergency calling, traffic management systems), Electrical Power Resources Survey and Development Administration (EIE) and various research associations (most of them are off-grid) have a common installed PV capacity of 300 kW [23]. PV cells are produced in various research establishments in order to study the feasibility of local manufacturing. So far none of these studies yielded a positive result in order to justify a mass production facility in Turkey. There are more than 30,000 small residential areas where solar powered electricity would likely be more economical than grid supply. Another potential for PV market is holiday villages at the long coastal areas. These facilities are frequently far from the main grid nodes and require additional power when solar insolation is high [25].

E. Wind Energy

Wind energy can be thought of as the indirect conversion of solar energy. It is formed naturally in the atmosphere and does not produce environmental pollution; wind energy represents an appropriate solution for energy-related problems but is not persistent for long durations [25, 26]. Now a global multi-billion-dollar industry, wind energy is regaining its once prominent place in the energy industry [27]. Nowadays total installed wind power capacity reached 120,798 MW in the world. Approximately 62% of the installed wind capacity of the world is in the Europe, 22% in America and 16% in Asia. However, Germany has the highest installed wind capacity with 22,247 MW which is equal the 45% of European and 31.2% of world installed capacity [28].

Turkey is reported as one of the countries with the best wind maps among European countries, after the United Kingdom. Due to its geographic position, Turkey is under the influence of different air masses that give rise to potential wind energy generation possibilities in different areas [25]. It is estimated that Turkey's technical wind energy potential is 88 GW and economical potential is approximately 10 GW depending on the technical condition. The EIE's wind atlas reported that, Turkey's technical wind energy potential was 83 GW and production potential was 166 TWh/year. However, Turkey's total installed wind capacity is only 1300 MW in 2005 and 2800 MW in 2010. At the end of 2009, 120 new wind power plant applications have been made to get generation license with 3564.63 MW up to January 2005, from the Energy Market Regulatory Authority (EPDK). Distribution of the projects to the regions is: Marmara (35 projects) with 966.3 MW, Aegean (62 projects) with 1864.6 MW, Mediterranean (20 projects) with 574.3 MW, middle Anatolia (2 projects) with 120.4 MW, and south east Anatolia (1 project) with 47 MW [28].

IV. RENEWABLE ENERGY POLICY OF TURKEY

The aim of energy policies is to meet the energy needs of increasing population and growing economy in a continuous, qualified and secure manner through primarily private sector investments in a competitive and transparent free market environment [8, 29]. The aims of Turkish energy policy are to satisfy energy demand consistent with economic, sustainable development, and environmental objectives. Because of that, Turkish energy policy is concentrated on assurance of energy supply, reliability, domestic sufficiency, in time, in economic terms, and sustainability [30, 31]. This policy includes consideration for environmental impacts; also it supports and orients targeted growth and social developments. The government focused its efforts on improvement in domestic production by utilizing public, private, and foreign utilities and increasing efficiency by rehabilitation and acceleration of existing construction programs to initiate new investments [31]. Special attention in the Turkish Government's energy policy has been paid to the development of international cooperation [1, 32].

Turkey's renewable energy policies are being improved, thus there are a few government-backed incentives to promote renewable energy investments [3, 30]. Energy pricing policy should not be employed as an anti-inflationary instrument. It should be applied in such a way that it does not create cross

subsidies between classes of consumers. Conventional financing of major infrastructure projects would only increase the amount of foreign credit, therefore the Ministry of Energy and Natural Resources (MENR) has conceived other options for financing projects. In 1984, BOT (build, operate, and transfer) model was issued in order to meet the dynamic demand for electrical energy and to attract local and foreign capital to invest in the sector. Private investors build and operate private sector energy generation, at which point they transfer ownership to the state. In June 1996, necessary legislative arrangements were carried out to eliminate difficulties arising from implementation, thus MENR introduced the BOO (build, own, and operate) financing model [1, 3, 30, 32, 33, 34]. The BOT and BOO financing schemes were ended in 2000 and replaced in 2001 by financial incentives within the framework of the Electricity Market Law (Law no. 4628). According to the Electricity Market Licensing Regulation, promotion of renewable energy sources in the electricity market has been assigned to the Energy Market Regulatory Authority (EMRA). Before the Electricity Market Law, the price of energy was decided as a result of negotiations between the energy production companies and the state, which is the buyer [11].

General energy and environmental policies of Turkey can be listed as below [1]:

1) Measure to encourage wider use of natural gas,
2) Support the utilization of clean and renewable energy sources as well as passive solar energy applications,
3) Decentralization in energy generation,
4) Optimizing sustainability of energy supply and environmental costs,
5) Setting integrated energy consumption targets for organized industrial zones.

Renewable energy policies are driven by the well-recognized need for a sustainable society. The protection of environment and public health from pollution arising from energy production and consumption activities is one of the principles of the current Turkish National Energy Policy. In conjunction with this policy, in 1983 "Environment Law" was promulgated in which the general principles of the Turkish environment policies were established. In line with the Environment Law, various regulations (i.e. Air Quality Control Regulation-1986, Water Pollution Control Regulation-1988, Noise Control Regulation-1986, Control of Solid Waste Regulation-1991, Environmental Impact Assessment Regulation-1992, Regulation on Control of Medical Waste-1993, Control of Toxic Chemical Substances and Products Regulation-1993, Control of Hazardous Wastes Regulation-1993) have been issued since 1983 [30]. The main objectives of Turkey's Energy Policy including renewable are [3, 35]:

1) To meet demand using domestic energy resources as the highest priority. In the medium and long term, this is to occur through a mix of public, private and foreign capital.
2) To develop existing sources while accelerating the penetration of new and renewable sources.
3) To diversify energy sources and to avoid dependence on energy imports from a single source or country.
4) To encourage private-sector investment and to accelerate capacity construction and privatization in the power industry. Preparations are to be made for the introduction of nuclear power.
5) To improve the reliability of electricity supply through upgrades in the power transmission and distribution grid.
6) To improve energy efficiency in end use and transformation, e.g. through reduction of losses in energy production, transmission and consumption.
7) To protect the environment and public health.
8) To make use of Turkey's geopolitical location to establish the country as a pivotal transit area for international oil and gas trade ("Eurasia energy corridor").

V. Future Plans for Turkey's Renewable Energy

The energy demand of Turkey was doubled between the years 2000–2010 and will be fourfold between the years 2000–2025. This rapid increase in demand is due to the high economic development rate of Turkey [34, 36].

Turkey has substantial reserves of renewable energy sources, including approximately 1% of the total world hydropower potential [10]. Large hydropower provides around 20-25% of Turkish power requirements. Until very recently this has been the only non-fossil power production in the country. Diversifying the country's natural resource supply and increasing the share of renewable energy sources are at the top of the list of the Turkish Ministry of Energy and Natural Resources' four year strategic plan (2010-2014) [37, 38**]**. In the strategy plan, the following targets are set for 2023, which is the 100th anniversary of Turkish Republic [38]:

1) To be able to make complete use of potential of indigenous coal and hydraulic resources,
2) To make maximum use of renewable resources,
3) To incorporate nuclear energy into electricity generation within the period until 2020,
4) To secure rapid and continuous improvement in energy efficiency in a way that parallels European Union (EU) countries.

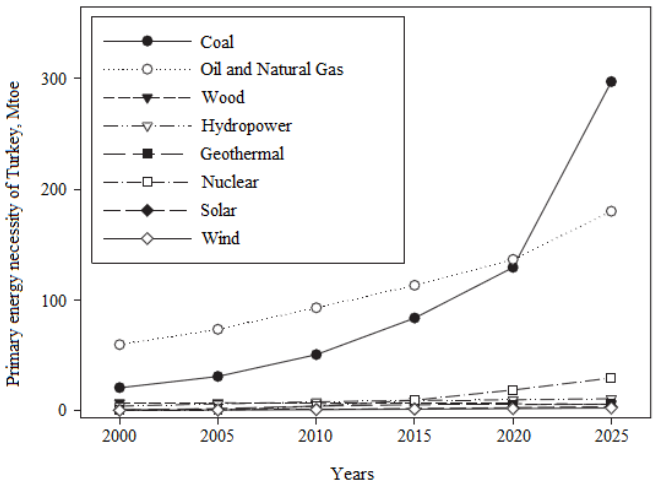

Figure 1. Turkey's primary energy necessity between 2000-2025 in Mtoe [5, 8].

The findings of the MENR suggest that the primary energy demand was equivalent to 91 Mtoe in the year 2002, and it

will be 314 Mtoe in 2020 in Turkey. In line with this trend, in 2023, marking the centennial of the country, the primary energy consumption will reach 367 Mtoe and 407 Mtoe two years later in 2025 [6, 34, 36]. Turkey's primary energy necessity between 2000 and 2025 can be seen clearly in Figure 1. [5, 8].

According to the Ministry's production forecasts, domestic production of primary energy will reach the level of 79 Mtoe by 2020. The projections foresee domestic generation to top 95 Mtoe in 2025 and 106 Mtoe in 2030. In other words, domestic energy production met 35% of the total primary energy demand in 2000, 28% in 2010 and will probably meet 24% in 2020. Table 2 gives the findings related to primary energy resources and their domestic production planning [6, 34, 36,]

Table 2: Primary energy production targets of Turkey from 2005 to 2030 (ktoe) [36]

	2005	**2010**	**2015**	**2020**	**2025**	**2030**
Hardcoal and lignite	21259	28522	31820	39385	42732	45954
Oil and natural gas	2127	1735	1516	1604	1505	1465
Central heating	495	884	1336	2018	2427	2758
Hydropower	5845	7520	8873	9454	10002	10465
Wood and waste	6760	6446	6029	5681	5498	5413
Geothermal	1380	3760	4860	4860	5400	5430
Nuclear	0	3657	9143	18286	26988	29600
Solar	459	907	1508	2294	2845	3268
Wind	250	620	980	1440	1786	2154

Global changes in the energy market, particularly decentralization and privatization, have created new opportunities and challenges for both renewable energy in general and bioenergy in particular [12]. According to World Energy Council Turkish National Committee (WECTNC), in 1999, the amounts of energy obtained by modern and classical biomass technology are 5 and 7012 ktoe, respectively. But, in 2030, they are 4895 and 3310 ktoe, respectively. It seems clear that produced energy by modern biomass technology is estimated to increase dramatically between 1999 and 2030. Otherwise, use of classical biomass technology will decline between 1999 and 2030.

The total solar energy potential of Turkey is calculated as 35 Mtoe per year. In the year 2001 in Turkey, an estimated 287 ktoe for solar heating were produced, especially in the southern and western regions and in the residential and commercial sectors [3].

Geothermal electricity generation has a minor role in Turkey's electricity capacity, as low as 0.10%, but the projections foresee an improvement to 0.32% by the year 2020. As a result of this approach, researchers emphasize that geothermal heat capacity is improving faster [38].

There is also significant potential for wind power development [10]. The number of the wind power plant installations will considerably increase in the future for development of wind energy in the country. The installed capacity of wind energy is expected to reach 11,200 MW by 2025 [39].

VI. Conclusion

Economy of energy, human development, environment, energy supply and its use are related to each other. Economic growth of a country depends on its own energy consumption. Turkey is known as a developing country which imports energy to overcome increasing energy consumption. By using non-renewable energy sources such as hard coal, lignite, asphaltite, natural gas, petroleum, bituminous shale, air pollution is becoming a large environmental interest in Turkey. Combustion of these resources causes SO_2, CO_2, NO_x emissions. To get rid of harmful effects, researchers try to improve utilization of renewable energy. In Turkey hydropower, biomass, geothermal, solar and wind energy have large potential. Although these renewable energy sources cannot provide total energy demand of Turkey, the government has evolved some policies. Moreover, the private sector is related to renewable energy development according to its capacity to mobilize funds. To support gradually rising renewable energy applications, requesting procedures should be implemented. The aim of renewable energy policies is to reduce greenhouse gases emissions by generalizing green technologies. Collaboration between the government, the private sector and consumer is led to Research and Development studies for decreasing cost of energy.

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