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Potential of renewable energy in electrical energy production and sustainable energy development of Turkey: Performance and policies

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ABSTRACT

Generating electricity, from renewable energy sources has become a high priority in the energy policy strategies at a national level as well as on a global scale. Although Turkey has many energy resources only coal and hydropower are significant at present, and as demand had risen, it has been necessary to import fuels to meet the total energy demand. The fossil resources, both indigenous and imported, have become expensive and also have undesirably high emissions. Turkey has an extensive shoreline and mountains and is rich in renewable energy potential. The share of renewables on total electricity generation is 35% while that of thermal power is 65% for the year 2010. Turkey is one of those countries that are considered rich and abundant in renewable energy resources.

Turkey is facing serious challenges in satisfying its growing energy demand. To fuel a rapidly growing economy, the country's electricity consumption is increasing by an average of 8–9% every year, and significant investments are needed in generation, transmission and distribution facilities to balance the power system's supply and demand. With very limited oil and gas reserves, Turkey is increasingly turning to renewable energy sources as a means to improve its energy security and curb dependence on imported gas from Russia and Iran. This paper investigates the potential of renewable energy resources in Turkey at present and the magnitude of their present and future contributions to the national energy consumption. Energy politics are also considered.

1. Introduction

There has been a significant increase in electrical energy demand due to the economical and technological developments over the world. Energy is one of Turkey's most important development priorities. Rapid increase in domestic energy demand has forced Turkey to increase its dependence on foreign energy supplies. With a fast-growing economy and a population, half of which is below age of thirty, Turkey is a dynamic and a developing country. Since Turkey is highly dependent on exported energy resources, its basic energy policy approach is to ensure the supply security.

Electrical energy production has been mainly derived from limited sources. Because of this fossil sources will be consumed in the future, studies on electrical energy production with renewable sources such as hydraulic, solar, wind, biomass and geothermal continue on with the energy saving studies at the same time. It is now widely accepted that renewable energy sources are very important for the future of the countries. Within the scope of combating climate change, Turkey's main objective is to contribute to global efforts in the line with the sustainable development policies on the basis of common but differentiated responsibilities and taking Turkey's special circumstances into account. Turkey, to provide its people with welfare and high living standards with less carbon intensity, aims to promote energy efficiency, increase the use of clean and renewable energy resources and to integrate its development policies with climate change policies. This article will investigate the potential of renewable resources in Turkey at present and the magnitude of their present and future contributions to the national energy consumptions. Conclusions will be drawn from the results of this research and recommendations regarding Turkey's future with renewable energy will be made.

2. Development of electricity demand

Turkey as a developing country has a very high rate of increase in demand. By 2011, the peak demand reached to 37.610 MW by an increase of 12.63%, and energy demand to 227 TWh by 8.5%. Thus, the average increase for the peak demand and energy demand in the last eleven years realized as 5.96% and %.5.64%, respectively [1]. Development of energy and peak demand is given in Table 1.

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Table 1
Development of energy and peak demand.

Year	Peak demand (MW)	Rate of increase (%)	Energy demand (GWh)	Rate of increase (%)
2000	19,390	2.4	128	8.3
2001	19,612	1.1	126	−1.1
2002	21,006	7.1	132	4.5
2003	21,729	3.4	141	6.5
2004	23,485	8.1	150	6.3
2005	25,174	7.2	160	7.2
2006	27,594	9.6	174	8.6
2007	29,249	6	190	8.8
2008	30,517	4.3	198	4.2
2009	29,870	−2.1	194	−2.0
2010	33,392	11.8	209	7.9
2011	37,610	12.63	227	8.5
Average		5.96		5.64

(Source: TEIAS).

Development of the peak demand over years is shown in Fig. 1. A reduction has been observed in the peak demand due to effect of the economic crisis in 2009; however, the increase rate realized in 2011 was the highest of the last eleven years and thus it entered into an economical recovery. As to the energy demand, we see a tendency similar to the chance in the peak demand. As shown in Fig. 1, while a reduction occurred in the energy demand by 2009, the electrical energy demand in the last year has been one of the highest one in recent years. Development of electricity energy demand by years is given in Fig. 2 and Fig. 3 shows load duration curve. As shown in the figure, the demand varies between the base of 13.513 MW and peak demand of 33.392 MW in 2010.

2.1. Security of supply

Electricity Market Law No. 4628, Ministry of Energy and Natural Resource (MENR), is responsible for monitoring security of supply for electrical energy and taking measures related to the security of supply [2]. Generation capacity projection made by Turkish Electricity Transmission Company (TEIAS), based on the demand estimations prepared by the distribution companies enters into effect after it approved by the authority. Based on the results of the Electricity Market Development Report prepared by the Authority, MENR prepares and presents to the Council of Ministers the Electrical Energy Supply Security Report by taking into consideration the demand–supply balance, diversity of resources, transmission and distribution and status of the generation facilities. The report covers evaluations concerning development and operation of the electricity market and findings, problems and solutions proposal with respect to security of supply. On basis of the generation capacity projection made concerning the security of supply as a result of evaluations made in the framework of the Law above, the demand series in 2010–2011 was created after a reduction in 2009 due to economic crisis followed up by a recovery in the first 6 months of 2010. Subsequently, a growth of 7.5% in average was anticipated for the high demand scenario; and 6.7% in average for the low demand scenario; accordingly, the peak demand and energy demand for the period till the year 2019 is shown in Table 2. In line with the data above, the peak and energy demand for the high and low scenarios are shown in Figs. 4 and 5 [3]. Apart from these series of demand, as per two different scenarios (Scenarios 1–2) made by taking into consideration the production facilities which are present, obtained license, under construction and expected to put in operation on the specified dates as per the progress reports for the period January 2010 as presented to Energy Market Regulatory Authority (EMRA) [4]. The reliable production amount and the development of the installed capacity of project are shown in Tables 3 and 4.

2.2. Capacity in operation

By the end of 2010, the total installed capacity in Turkey was 49.562 MW; and when the breakdown of the installed capacity in operation is examined by enterprises, we see the public has a dominant concentration in the market. Capacity under the public control, namely, EÜAS, subsidiaries of EÜAS, İHD, BO, BOT account for about two thirds of the total installed capacity. On the other hand, when the breakdown of the installed capacity by resources is examined, about two thirds of the installed capacity belongs to the thermal power plants. Hydro capacity is 32% and wind 3%. Installed capacity of Turkish Electricity Energy (2010) [1], is given in Table 5. Installed capacity in operation by enterprises as of the end of 2010 is given in Fig. 6, and Installed capacity in Turkey by Resources (MW) 2010 is given in Fig. 7 [1].

3. A review on Turkey's energy sources

Because of social and economic development of the country, the demand for energy and particularly for electricity is growing rapidly in Turkey. Turkey's natural energy resources are quite miscellaneous; for example, hard coal, lignite, asphalt, oil, natural gas, hydro, geothermal, wood, animal, plant wastes, solar and

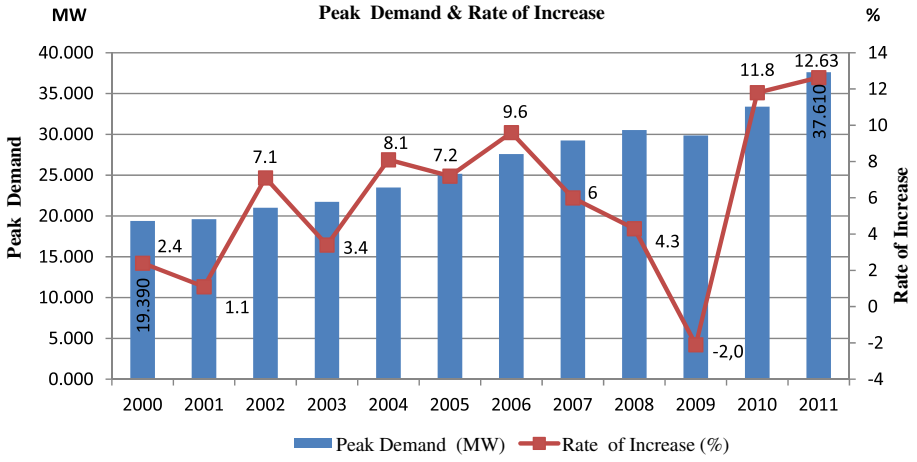

Fig. 1. Development of the peak demand by years (MW). (Source: TEIAS).

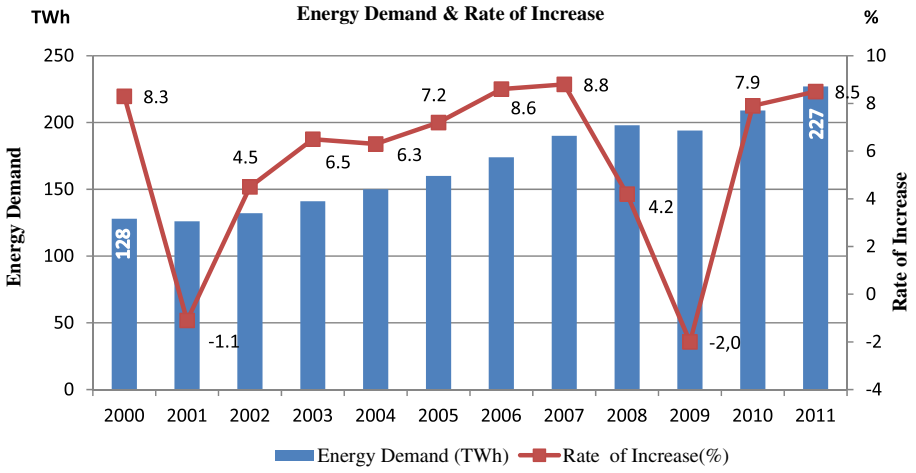

Fig. 2. Development of electricity demand by years (GWh). (Source: TEIAS).

secondary energy resources, coke, and briquettes. These resources are produced and consumed in the country. Turkey does not own large fossil-fuel reserves. In the future, it seems that it will be very difficult to meet the anticipated demand for oil, natural gas, and even coal. Turkey's main fossil energy resource is coal, which has been produced for years domestically, and its share of the country's total energy consumption is about 24%. It is used mainly for power generation, cement production, and steel manufacturing. Turkey is one of the biggest producers of lignite in the world. This comes predominantly from deposits of the Southwest and the South eastern Afsin-Elbistan Basin, where 7339 million tons lignite is economically usable. The government plans to increase the coal supply from 20.1 Mtoe in 1999 to 118.4 Mtoe in 2020 [5]. In Turkey, where there is no nuclear power, tenders to build nuclear power plants were canceled several times because of resistance by environmentalists and potentially high investment and operating costs. The current government plans to have a nuclear power plant with a capacity of 1800 MW at the Black Sea port of Sinop. The plant is scheduled to become operational in 2014, but the project is highly controversial. The government's initial plan was to construct three plants with a total capacity of 5000 MW. Turkey's geographic location has several advantages for extensive use of most of the renewable energy sources. It is on the humid and warm climatic belt, which includes most of Europe, the near east and western Asia. Demographic projections as well as the growing gap between national energy demand and production raised concerns on the economical and environmental impacts of power generation based on Turkey's national energy sources. Turkey's renewable energy sources are plentiful and extensive. Renewable energy production makes up approximately 14.4% of the total primary energy supply and renewable sources represent the second-largest domestic energy source after coal [5].

Clean, domestic and renewable energy is commonly accepted as the key for future life, not only for Turkey but also for the entire world. This is primarily because renewable energy resources have some advantages when compared to fossil fuels. Turkey has to adopt new long-term energy strategies to reduce the share of fossil fuels in the energy consumption [6]. Air pollution is a significant problem and, as the government's projections show, carbon emissions could rise sharply if current trends continue [7]. Turkey is striving to benefit from its geographic location as a transit country linking the oil- and gas-rich Caspian area to the Mediterranean and to the demand centers of the West. Several pipeline projects are under construction. They could have a positive effect on the diversity and security of supply in many consuming countries. They could also help avoiding further environmental strain on the maritime routes through the Bosporus [8].

Hydropower energy and the surrounding seas are Turkey's main potential sources of renewable energies. In addition, geothermal energy beneath the surface of the western Anatolia; wind and solar energy available at western, eastern, and middle Anatolia and nuclear energy by abundant thorium and uranium ores lying throughout Anatolia and hydrogen potential accumulated at the submarine of Black Sea are the other potential renewable energy sources in Turkey. In this regard, the major areas of renewable energy research in Turkey are hydropower, solar thermal, wind, geothermal, photovoltaic energy, and new programs such as hydrogen energy, fuel cells, etc. [9].

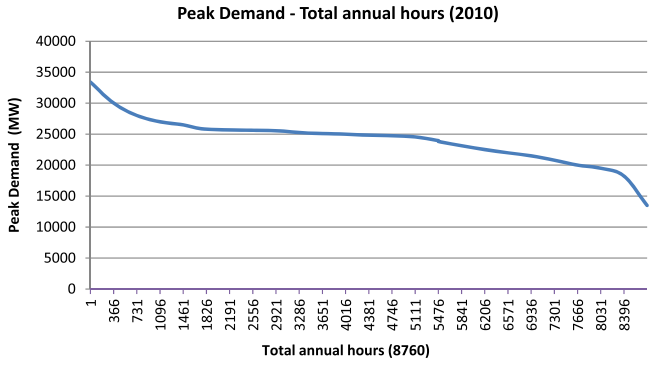

Fig. 3. Load duration curve (MW). (Source: TEIAS).

4. Renewable energy in Turkey

Renewable energy creates multiple public benefits such as environmental improvement, increased fuel diversity, reduction of energy price volatility effects on the economy, national economic security and increase in economic productivity and GDP through more efficient production processes. With a world excessively dependent on decaying fossil fuel resources and with a new appreciation of the damage caused by greenhouse gases (GHG), it is becoming more and more evident that renewable energy resources must be utilized to create a sustainable future. Renewable energies can be broken down into those where the sun is the source of the energy (Solar Energy) and those where it is from another source

Table 2
Estimated peak demand and energy demand according to the high and low scenarios.

Year	High demand				Low demand			
	Peak demand		Energy demand		Peak demand		Energy demand	
	MW	Increase (%)	GWh	Increase (%)	MW	Increase (%)	GWh	Increase (%)
2010	32,170	7.7	209,000	7.7	32,170	7.7	209,000	7.7
2011	33,780	5.0	219,478	5.0	33,780	5.0	219,478	5.0
2012	36,314	7.5	235,939	7.5	36,043	6.7	234,183	6.7
2013	39,037	7.5	253,634	7.5	38,458	6.7	249,873	6.7
2014	41,965	7.5	272,657	7.5	41,035	6.7	266,615	6.7
2015	45,112	7.5	293,106	7.5	43,784	6.7	284,478	6.7
2016	48,450	7.4	314,796	7.4	46,674	6.7	303,254	6.7
2017	52,036	7.4	338,091	7.4	49,754	6.6	323,268	6.6
2018	55,886	7.4	363,110	7.4	53,038	6.6	344,604	6.6
2019	60,022	7.4	389,980	7.4	56,539	6.6	367,348	6.6
2020	65,000	7.4	433,900	7.4	56,539	6.6	398,160	6.6

(Source: Generation capacity projection).

(Non-Solar Energies). Solar energies include biomass, biofuel, solar power, hydro energy and wind energy. Renewable Non-Solar energies include tidal energy and geothermal energy. There is virtually all kind of energy sources available in Turkey. However, these sources except for lignite and hydraulic energy are not enough to meet the energy requirement of the country; hence, more than half amount of this requirement is met by imported energy. The potentials of the main renewable energy sources of Turkey are collectively given in Table 6 [10]. According to this table, depending on the solar belt on which Turkey is located, the technical solar energy potential with an amount of 6105 TWh/year is very high in terms of electricity production, followed by the wind energy potential with an estimated value of 290 TWh/year and the hydro technical potential with 216 TWh/year. Table 7 shows a cost comparison between renewable energy and other energy sources. From this it can be seen that the renewable energy sources such as biomass, geothermal and wind are as economically usable as other common energy sources.

4.1. Biomass and biofuel

Biomass, for the energy production industry, is any material that was once a living organism that can be used in the production of renewable energy such as wood, methane producing waste, sugarcane, leaf, litter or trees such as palms. Biomass can be converted to biofuel using several different methods depending on the type of biomass and the type of fuel required. Biomass is generally burnt as a raw product to generate steam to power turbines for electricity production. Among the different forms of renewable energy, biomass energy is one of the major resources in Turkey [11]. Turkey's domestic energy consumption accounts for about 37% of total energy consumption. Of this, about 52% is from biomass-based fuels [12]. In Turkey, biomass has great potential to provide improved rural energy services based on forest and agricultural residues. Various agricultural residues such as grain dust, wheat straw and hazelnut shell, and municipal solid wastes as energy sources are available economically in Turkey. The potential of important biomass energy sources and animal solid wastes of Turkey has been determined and the potential of these as a source of fuel in thermal generating systems to produce electricity and thermal energy has been studied [13,14]. The importance of agriculture is increasing due to biomass energy being one of the major resources in Turkey.

Agricultural activities are concentrated on the production of industrial plants used for example for the production of industrial products, like edible oils from olive, cotton seed, sunflower, hazelnut, etc. These food processing industries produce large quantities of residues which could be utilized for energy production. The available agricultural and animal residues in Turkey have been estimated to be roughly equal to 22–27% of energy consumption in Turkey [11]. The disposal of this straw in the fields has been by burning or sometimes by plowing it back into the soil. Use of agricultural residues could have negative soil-carbon effects (removing organic material from soil surface). However, woody or

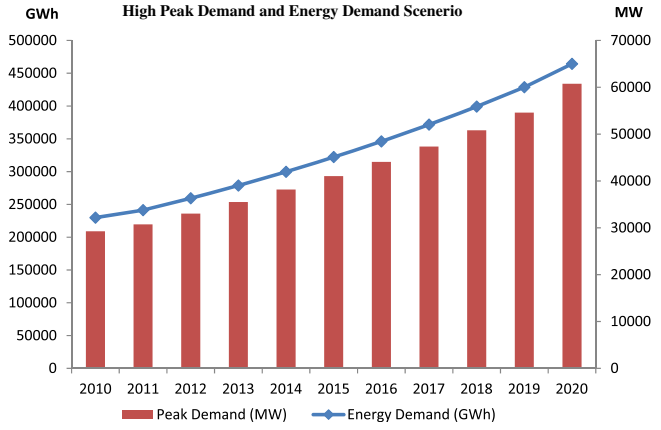

Fig. 4. High peak demand and energy demand scenario. (Source: Generation capacity projection).

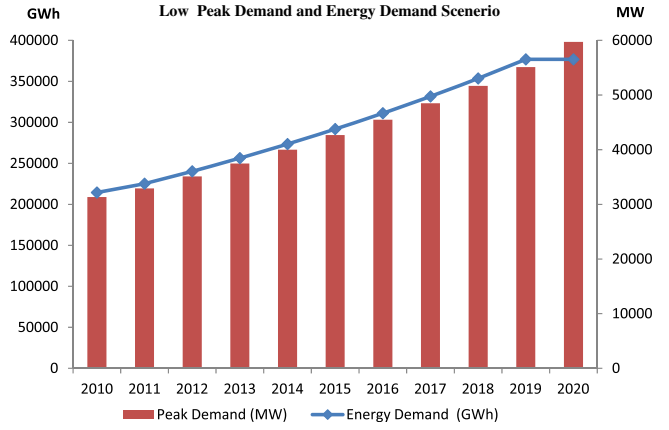

Fig. 5. Low peak demand and energy demand scenario. (Source: Generation capacity projection).

Table 3
Reliable and project generations for scenarios 1–2 (GWh).

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Scenario-1: Reliable production	233.021	247.578	262.009	284.040	292.192	299.367	305.599	304.900	305.740	305.515
Scenario-1: Project generation	270.988	287.173	304.215	325.119	331.819	339.445	346.388	345.168	346.017	345.791
Scenario-2: Reliable production	232.455	245.697	255.699	275.614	287.058	295.963	302.195	301.497	302.336	302.111
Scenario-2: Project generation	270.083	284.313	296.751	315.424	324.867	333.893	340.836	339.616	340.465	340.239

(Source: Generation capacity projection).

grassy energy crops may increase soil carbon if planted on tillage soils. Use of agricultural waste already exists in some industries in Turkey on a small scale. However, because of the financial and technical obstacles to biomass energy as well as current oil and gas prices in Turkey and insufficient policy/market instruments, the private sector is not yet seriously interested in biomass and waste-fueled energy plants.

Direct burning in Turkey for many years has used fuel wood, animal wastes, agricultural crop residues and logging wastes. These sources are often called non-commercial energy sources, but in Turkey, fuel wood is a tradable community, since it the primary fuel for rural and urban poor districts [15]. The consumption of forest biomass compared with total energy has slightly decreased from 22% to 14% during the last decade because the consumption of liquefied petroleum gases (LPG) is increasing continuously. LPG is not expensive and it is easy to transport and to fire, and in addition it is a clean fuel. LPG is probably a cleaner-burning fuel (depends on emissions from new wood stoves), although wood has GHG benefits compared with LPG and is renewable and indigenous. Traditional fuels predominate in rural areas; almost all biomass energy is consumed in the household sector for heating, cleaning and cooking needs of rural people.

Turkey's first biomass power project is under development in Adana province, at an installed capacity of 45 MW. Two others, at a total capacity of 30 MW, are at the feasibility study stage in Mersin and Tarsus provinces [16,17]. A US firm will establish a 10 MW capacity BOT (build, operate and transfer) power plant in Ankara-Mamak, which will use landfill gas generated by garbage. Similar potential exists in large municipalities such as Istanbul, Izmir, Bursa, Adana and Antalya. The electrical production from usable biomass (about 17 Mtoe/year) has a net impact of $4.4 billion in personal and corporate income and represents more than 160,000 jobs [17]. Heat is used to chemically convert biomass into pyrolysis oil. The oil, which is easier to store and transport than solid biomass material, is then burned like petroleum to generate electricity [18]. Fig. 8 shows biomass potential of Turkey.

4.2. Wind power

Increasing demand for power and depletion of conventional fuel resources are forcing the world to produce electricity in a sustainable way renewable energy. One of the most cost-effective renewable energy resources is wind power. A sharp increase in wind power generation can be easily identified around the world and Turkey is no exception. As a first step to meeting the need for renewable generation, Turkey has given permission for the construction of 12 GW of wind power generation by 2015. Because of variations in wind speed and consistency, wind power generation is not spreading homogeneously in Turkey as in other areas of the world. The western area of the country has great wind potential while the eastern and southern areas do not. Turkey surrounded by sea on its three borders Aegean Sea on the west, Black Sea on the north, Mediterranean on the south and Marmara as an inner sea. Aegean, Marmara and East Mediterranean coast have high wind potential. The wind map of Turkey showing the wind power integration capacities based on transformer station eligibility is shown in Fig. 9. The locations of the wind power plants are shown in Fig. 10. The 12 GW of new wind power generation will be constructed primarily in the western areas of Turkey, with some construction in the southern areas. Wind farms require controls similar to those of conventional power plants. Power quality for wind farms, like conventional power plants, is reflected in the level and fluctuation of system voltage and frequency. At the time of grid perturbations a power plant should react very quickly and should support the grid as required. For conventional power plants, voltage and frequency control can be easily maintained by the governor and the excitation system responses. However, the integration of a large amount of renewable energy, if not well planned, will change the effectiveness of voltage and frequency control, which may lead to large scale blackouts. In order to ensure the required support to the grid, additional requirements should be added to grid codes. The potential of wind energy of Turkey is given in Fig. 11. As can be seen in Fig. 11, red color represents the priority sites which satisfy most of the environmental objectives and sufficient wind potential. Therefore, a big proportion of the southwest region within the study area is identified as feasible locations for future wind turbine constructions. Utilization of the proposed approach in the future may help both investors and the governing authorities to identify both environmentally and potentially suitable locations for wind turbines.

4.2.1. Recent market developments

It is estimated that Turkey's technical wind energy potential is 88,000 MW, economical potential is approximately 10,000 MW depending on the technical condition [19]. In 2010, 528 MW of new wind energy capacity was added in Turkey, bringing the total up to 1329 MW [20]. This represents a year-on-year growth rate of 66%. According to TEIAS (the state-owned transmission company and system operator) it is projected that up to 415.8 MW of wind projects might be added in 2011. Recent years have seen the start of a wind energy boom in Turkey. EMRA had received applications for more than 6300 MW worth of wind projects, more than half of

Table 4
Development of the installed capacity for scenarios 1–2 (MW).

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Scenario-1: Installed capacity	49.087	51.807	55.415	58.172	59.700	60.900	61.700	61.700	61.700	61.700
Scenario-2: Installed capacity	48.545	50.664	53.386	56.497	58.062	59.262	60.062	60.062	60.062	60.062

(Source: Generation capacity projection).

Table 5
Installed capacity of Turkish electricity energy (2010).

Company	Type	Number of plants	Installed capacity (MW)	Total power (MW)
EÜAŞ	Thermal	15	8.691	20.369
	Hydro	104	11.678	
EÜAŞ affiliates	Thermal	5	3.834	3.834
Transfer of operation rights	Thermal	1	620	650
	Hydro	1	30	
Mobile power plants	Thermal	2	263	263
Build–Operate	Thermal	5	6.102	6.102
Build–Operate Transfer	Thermal	4	1.450	2.439
	Hydro	17	972	
	Wind	2	17	
Independent Generation Companies	Thermal	88	8.722	12.724
	Hydro	134	2.607	
	Geothermal	6	94	
	Wind	36	1.302	
Autoproducers	Thermal	144	2.636	3.181
	Hydro	4	544	
	Wind	1	1	
Total	Thermal	264	32.317	**49.562**
	Hydro	260	15.831	
	Geothermal	6	94	
	Wind	39	1.320	

(Source: TEIAS).

which are still under evaluation today. To date, close to 3000 MW of wind power projects have been licensed by EMRA Following the call for tender in November 2007, applications for 751 projects were received by EMRA in one day, totaling 78 GW. According to EMRA, all the projects have been considered and 695 of them are eligible for a license. Out of these, 616 (with a total installed capacity of 29,152 MW) will need to go through a tender process because they applied to concurrent areas, and TEIAS will hold a tender for each application area. Only 63 projects (with a total installed capacity of 1378 MW) will not need to go through this process since they are stand-alone projects in their respective application areas.

Installed wind capacity is expected to grow at between 500 and 1000 MW per year reaching more than 12 GW by 2015. Turkey hopes to install up to 20 GW by 2023, helping the country to source 30% of its electricity generation from renewable sources by that date. In order to reach this target, however, the transmission infrastructure will require substantial upgrades to allow such large

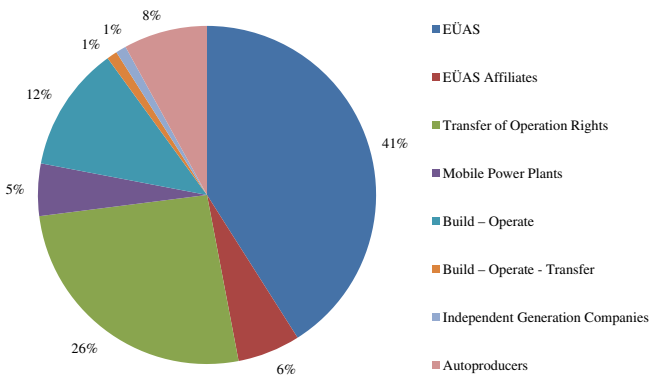

Fig. 6. Installed capacity in operation by enterprises as of the end of 2010. (Source: TEIAS).

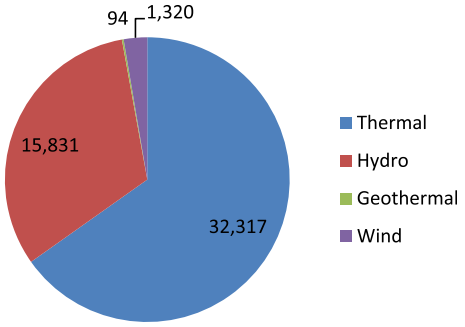

Fig. 7. Installed capacity in Turkey by resources (MW). (Source: TEIAS).

scale developments to be connected to the power grid. This issue will need to be addressed in the near future. Table 8 shows Total installed capacity of wind energy in Turkey.

4.2.2. Players in the Turkish wind market

Currently the Turkish wind energy market is mostly dominated by local developers. Although large international companies such as CEZ, Verbund and EnbW announced and/or undertook plans for building their own wind energy capacity with local partners, these initiatives were small compared to their large thermal and hydro investments. The reluctance of international groups to invest in wind energy essentially stems from the lack of long term fixed price PPAs with viable buyers, but the recent privatization of distribution companies may change this situation.

Enercon continues to be the supplier with the largest market share, followed by Vestas, Nordex, GE and Suzlon. Vestas, however, leads in terms of cumulative installed capacity (30%), followed by Enercon (28%). New suppliers such as Gamesa and Alstom are also entering the market, and GE is considering local turbine manufacturing.

4.2.3. The policy environment for wind power in Turkey

Since the introduction of the Electricity Market Law in March 2001, Turkey has taken substantial steps toward creating a competitive and functioning electricity market, restructuring

Table 6
Renewable energy potential of Turkey.

Renewable energy source	Usage kind of energy	Natural potential	Technical potential	Economic potential
Solar energy	Electrical energy (TWh/year)	977,000	6105	305
	Heat (mtoe/year)	80,000	500	25
Hydraulic energy	Electrical energy (TWh/year)	433	216	127.4
Wind energy				
Direct terrestrial	Electrical energy (TWh/year)	400	110	50
Direct maritime	Electrical energy (TWh/year)	–	180	–
Sea wave energy	Electrical energy (TWh/year)	150	18	–
Geotermal energy	Electrical energy (TWh/year)	–	–	1.4
	Heat (MW_t)	31,500	7500	2843
Biomass energy	Fuel (classic) (mtoe/year)	30	10	7
	Fuel (modern) (mtoe/year)	90	40	25

(Source: Ref. [16]).

Table 7
Comparison of renewable energy to the other energy sources.

Power source	Production cost of 1 kWh (energy cent)	
	Minimum	Maximum
Coal	4.5	7.0
Natural gas	4.3	5.4
Geothermal	4.7	7.8
Biomass	4.2	7.9
Agricultural residues	4.5	9.8
Energy crops	10.0	20.0
Municipal solid wastes	4.2	6.3
Wind generators	4.7	7.2
Solar thermal hybrid	6.0	7.8
Solar PV	28.7	31.0
Nuclear	5.3	9.3
Large hydro	3.0	13.0
Small hydro	4.0	14.0
Hydraulic	5.2	18.9
Wave/tidal	6.7	17.2

(Source: [18]).

public institutions and implementing the market rules that will ensure liberalization of the sector.

Turkey has a target of increasing the country's installed wind power capacity to 20 GW by 2023. In order to boost execution of renewable energy, in May 2005 the Turkish government enacted its first Renewable Energy Law1, which introduced tariff support for electricity produced by renewable sources. In May 2007 a revision of the law increased the tariff slightly to 5–5.5 Euro ct/kWh for a period of 10 years, and in a 2010 amendment, this was converted to USD 7.3 cent/kWh.

While the level of support is low in comparison with other European countries, wind power producers are free to sell to the national power pool or engage directly with eligible customers in bilateral agreements where prices are generally higher than the guaranteed price.

A number of additional policy measures have helped to increase renewable energy production in Turkey in recent years. These include the obligation of the national transmission company to provide grid connection to all renewable power projects and improved transmission links with the EU to stabilize the power system. Furthermore, most restrictions on foreign investment in the Turkish power sector have been lifted.

In 2010, a local content element was introduced to the Renewable Energy Law, which envisages an addition to the feed-in tariff of a maximum of USD 3.7 cent/kWh depending on how much locally produced content was used. Currently, local manufacturing of wind farm components is limited to blades and towers. It is anticipated that in the short term the local content element will not provide an additional incentive for new wind development.

4.3. Hydropower energy

Turkey does not have enough primary energy sources such as petroleum and natural gas, but has huge hydropower potential. Turkey's second largest energy source after coal is hydro. Turkey has aimed to increase domestic production by public, private and foreign utilities, at increasing efficiency, by rehabilitation of existing plants and acceleration of existing construction programs. On the other hand, there are 436 sites available for hydroelectric plant construction, distributed on 26 main river zones. The total gross potential and total energy production capacity of these sites are nearly 50 GW and 112 TWh/year, respectively and about 30% of the total gross potential may be economically exploitable. At present, only about 35% of the total hydroelectric power potential is in operation [21–23]. At present, the average hydroelectric capacity in Turkey is 45 TWh/year which equivalent to only 36% of the total economically feasible potential of the country. Up to 2020, it is expected that about 502 new hydropower plants will be constructed to make use of the full available potential [21,24–27].

Hydroelectricity is well established as one of the principal energy-producing technologies around the world, providing some 20% of the world's electricity. In the developing countries, the proportion rises to around 40%. The capacity of large hydroelectric schemes can be several times that of a conventional power station. They are highly efficient, reliable, and long lasting. They are also very controllable and add an element of storage into an electricity supply system, thereby allowing compensation for the varying intensity of other renewable energy sources and for variations in electricity demand. However, the dams and their large lakes forms also have major environmental and social impacts [28–30].

Turkey has important hydropower potential and has rigorous plans for the development of its substantial potential. Approximately 5500 MW of hydropower capacity is under construction, the largest schemes being Deriner Dam in the north of the country (680 MW) and Berke Dam in the southeast (520 MW). In Turkey, 566 hydropower projects by DSI (State Hydraulic Works) [21] have been identified for development in total, 130 are already in

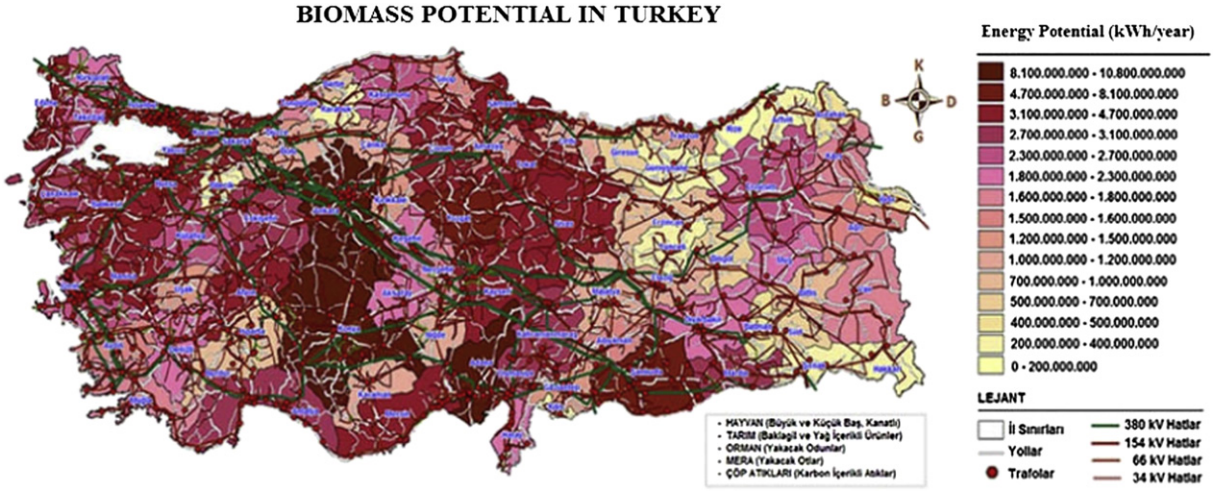

Fig. 8. Biomass potential of Turkey.

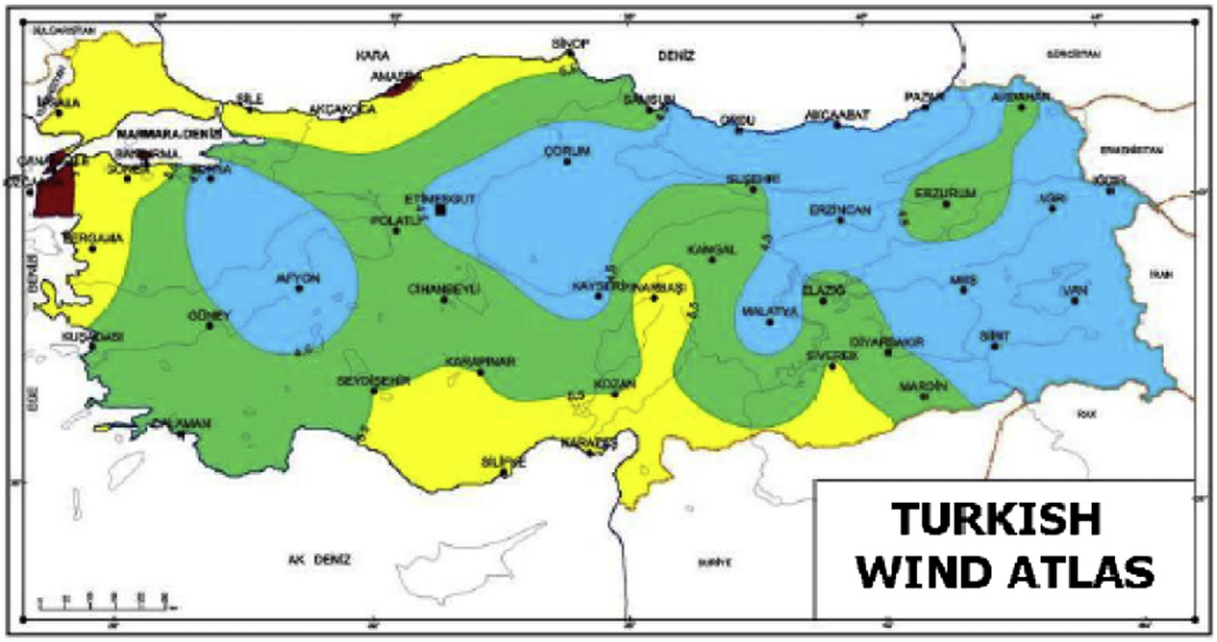

Fig. 9. Turkish wind atlas.

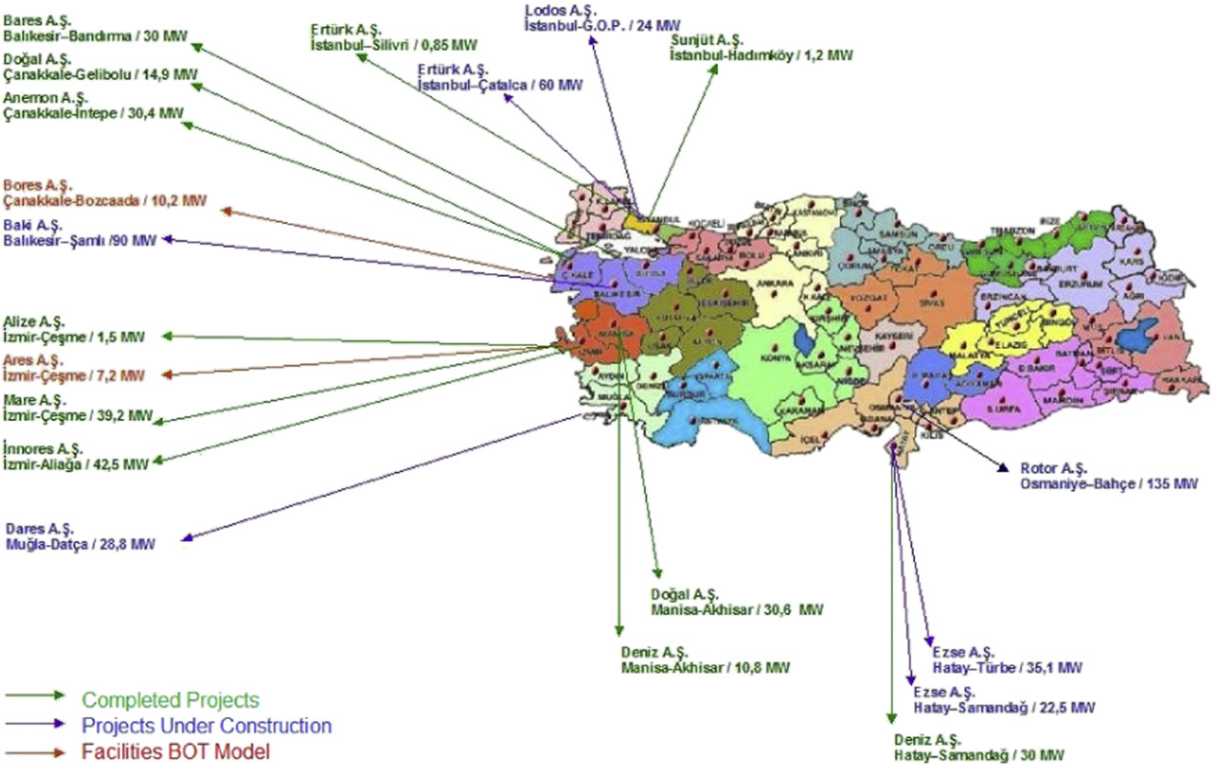

Fig. 10. The locations of the wind power plants of Turkey.

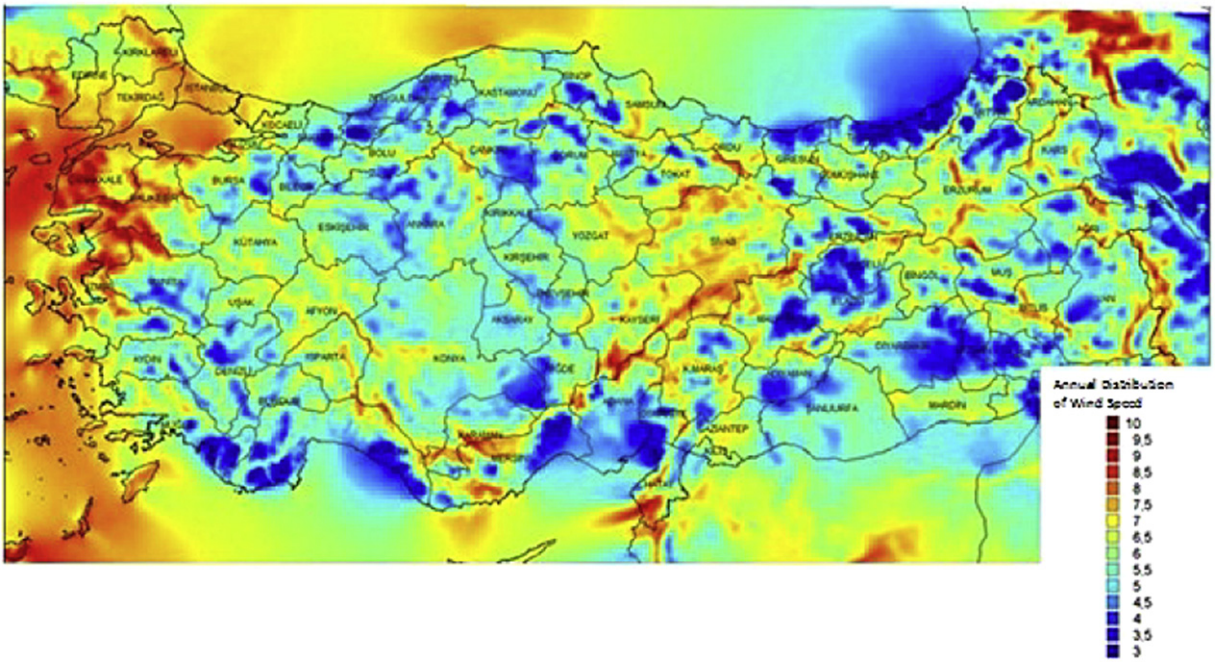

Fig. 11. Potential of wind energy map of Turkey.

operation, 31 are under construction, and 405 (with a capacity of 19,951 MW) are planned [21]. Fig. 12 shows dams and hydroelectric power plants distribution of Turkey. The national development plan aims to harvest all of the hydroelectric potential by 2020 [30].

In addition, Turkey also has a huge untapped small hydropower potential. The gross theoretical small hydropower potential of Turkey is 50 TWh/year. The technically and economically feasible potential is 30 and 20 TWh/year, respectively. Only 3.3% of economically feasible potential [31] has been exploited with the remaining 96.7% amounting to some 19.5 TWh/year. Turkey would not have become dependent on the outside for its energy production today. All of the country's hydro potential must be activated as soon as possible. Small hydropower potential must be utilized by means of small hydropower plants. The amount of naturally occurring sites suitable is an important factor in the amount of hydroelectricity that can be produced. There are many current locations being used and several under development however the amount of electricity produced is a function of the amount of water being required by the populations for which the dams have been created. This means there is a finite amount of electricity production potential. Above indicates areas of high rainfall suitable for hydropower generation are given in Fig. 13.

4.4. Solar energy and PV

Due to its location, Turkey has virtually rich solar potential as shown in Table 6. According to the solar energy evaluations South Eastern Anatolia Region has the highest solar energy potential and Mediterranean Region has the second highest solar energy potential in Turkey. In spite of this high potential, solar energy generation is only realized by flat plate solar collectors. They are mostly employed in the sunny coastal regions in order to produce domestic hot water. The installed solar collector area was recorded as 7.5 million m^2 in 2001 and 12 million m^2 in 2011. From these collectors, commonly used in Mediterranean and Aegean regions, heat energy about 290 and 450 ktoe/year was provided in 2001 and 2011 respectively [32]. Because of the rich potential, it is possible to benefit from solar energy in the other regions of Turkey, too. The electricity generation from the solar is realized by PV and solar collectors. Unfortunately, PVs have high installing costs; hence, an economical usage of them is not available today. In Turkey, the Ministry of Environment and Forestry (forestry observation towers), Turkish Telecommunication Companies (transfer stations), the Highway Board Department (emergency calling, traffic management systems), EIE (demonstration applications) and various research associations (most of them are off-grid) have a common installed PV capacity of 300 kW. The mentioned EIE study derived benefit from Turkish State Meteorological Service's (DMI) data of solar energy and radiation periods between 1966 and 1982, which determines the total radiation period as 2640 h and total solar energy as 1311 kWh/m^2year, as shown in Table 9 [32]. Germany has the most installed photovoltaic power with 1229 MW_e (2008) in Europa and also approximately 84% of installed photovoltaic power of Europa is being in Germany. Turkey does not have an organized commercial and domestic photovoltaic (PV) programme [33], because the government has no intention in PV technology.

In the result of the technical calculations, solar technical potential has been determined as 6105 TWh/year as seen in Table 6. Only 5% of this technical potential (equal to 305 TWh/year) is economically available for electricity generation [5]. Fig. 14 shows solar map of Turkey. Fig. 15 shows potential sites suitable for solar power plants. Global solar radiation fields greater than 1650 kWh/m^2 × year are

Table 8
Wind energy total installed capacity.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
MW	19	19	19	20	20	20	50	147	458	801	1.329	1.744

(Source: [20]).

Fig. 12. Distribution of dams and hydroelectric power plants of Turkey.

shown in red circle. Turkey's solar energy potential is 380 billion kWh/year. This potential is equal to the natural gas power plant which has a total installed capacity of 56.000 MW for production of electrical energy. The number of houses in Turkey is around 18 million and four million houses benefit from solar energy in various ways. Free solar energy provides 600 million dollars to the national economy. From Fig. 15, Southern, Western and Eastern Anatolia of Turkey could prove to be a good candidate for solar energy gathering though due to size of array needed and the power transmission infrastructure the idea is prohibitive on cost basis and is not commercially viable until more improvements in the technology have been made. The infrastructure however necessary for such projects would require a large amount of capital and the cost per unit of electricity generated is generally higher than other fossil fuel based on renewable energy sources. Currently, large scaled solar energy facilities do not exist in Turkey due to the financial burden of solar technologies. However, as solar energy technologies become financially affordable for the investors, it is expected to have large scale solar power plant installations in Turkey.

4.5. Geothermal energy

Geothermal energy use is based on hydrothermal circulation. Although the use of the geothermal energy lays out to old ages, the

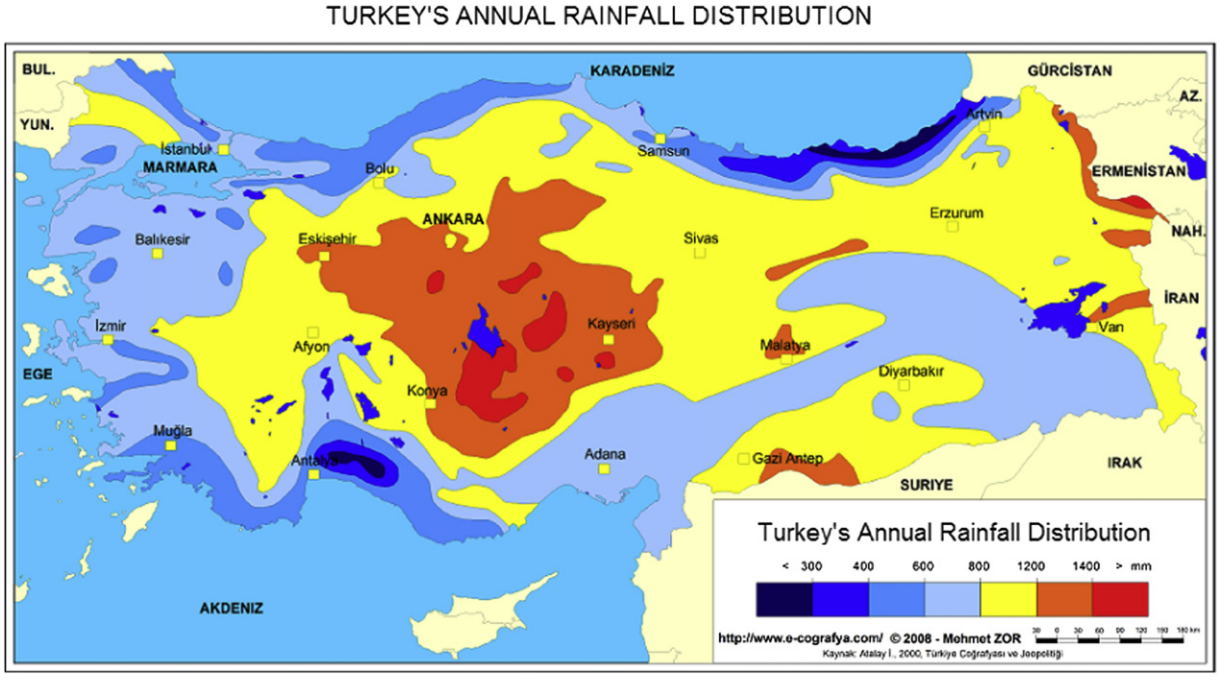

Fig. 13. Turkey's annual rainfall distribution.

Table 9
Turkey's solar energy potential.

Months	Total solar energy		Ins. time (h/month)
	(kcal/cm^2 month)	(kWh/m^2 month)	
Jan	4.45	51.75	103
Feb	5.44	63.27	115
Mar	8.31	96.65	165
Apr	10.51	122.23	197
May	13.23	153.86	273
Jun	14.51	168.75	325
Jul	15.08	175.38	365
Aug	13.62	158.4	343
Sep	10.6	123.28	280
Oct	7.73	89.9	214
Nov	5.23	60.82	157
Dec	4.03	46.87	103
Total	112.74	1311	2640
Mean	308.0	3.6	7.2 h/day

use in electricity generation has started in 1904. Today, the electricity generation from geothermal energy in 24 countries has reached 8912 MW [34]. Although Turkey is among the first seven countries with its potential, it is in the last rank with its installed capacity of 28.3 MW_e (20.4 MW_e in Denizli-Kizildere and 7.9 MW_e in Aydin-Salavatli). Studies performed by the General Directorate of Mineral Research and Exploration (MTA) since 1962, have determined 170 geothermal fields in the Aegean region, Northwest Anatolia and Central Anatolia. However, only 7% of these fields have high enthalpy and are adequate for electricity generation. There are 11 known geothermal fields which are adequate for electricity generation with Rankine and flash cycles in Turkey [34–36]. Although it is aimed to achieve an amount of 500 MW_e by 2010 and 1000 MW_e by 2020 from geothermal power plants, which are considered to be installed on these fields, the level of implementation is quite far away from achieving these goals [37].

Turkey's geothermal gross theoretical, technical and available heat potentials are, respectively, 31,500, 7500 and 2843 MW_t (see Table 6). The amount of proofed geothermal theoretical and available electricity potential is, respectively, 500 and 350 MW_e. The obtainable electricity generation from the available potential is about 1400 GWh/year [37–39].

By December 2011, a district heating using geothermal energy equivalent to the need of 125,000 households (1003 MW_t) was recorded in Turkey while 232 spa centers served the thermal tourism sector for about 11,000,000 people (468 MW_t) per year. It was also recorded that the total heat use from geothermal energy has reached 1500 MW_t (1098,000 ton/year fuel-oil equivalent) in 2011. As a result of all these geothermal activities, the related CO_2 production was recorded as 136,000 ton/year [40].

4.6. Possible future energy sources for Turkey

4.6.1. Nuclear energy

The country's electricity demand has been growing steadily, averaging 10.6% annual growth over the past two decades. In order to meet Turkey's growing demand, nuclear power must be added to the country's energy mix, despite strong opposition from environmental and anti-nuclear groups. As the country moves forward, nuclear energy will become a vital source of electricity and will help reduce Turkey's dependence on coal and natural gas. In addition, due to the rapid development of thermal power plants in recent years, CO_2 emissions have been increasing quickly. Nuclear power will play a very important role in the sustainable energy supply future of Turkey. The high share of natural gas in electricity generation creates financial burden on Turkish government budget due to take or pay contracts, and endangers electricity generation especially in winter due to supply disruptions in exporting countries. Moreover, high electricity demand along with low efficiency in electricity sector compels at least 40 000 MW new generation capacity until 2020, which will cost nearly 100 billion US dollars including transmission and distribution investments. Nuclear energy seems to be an ideal alternative as an energy source and an economically viable option to combat climate change, to secure energy supply and to achieve sustainable development goals. The experience of some countries shows that developing countries, usually with help from developed countries can use nuclear technology to support economic development, and enhance domestic industries' capabilities, if they formulate a long term nuclear policy [41]. The major problem of Turkey's nuclear energy policy is the lack of a long-term and consistent policy framework, which includes social, economic and technical aspects of nuclear energy.

Nuclear technology has been playing an important role in medicine, industry, science, and food and agriculture, as well as power generation. Nuclear power is one source of energy in some of the major developing countries in the world (for example, it

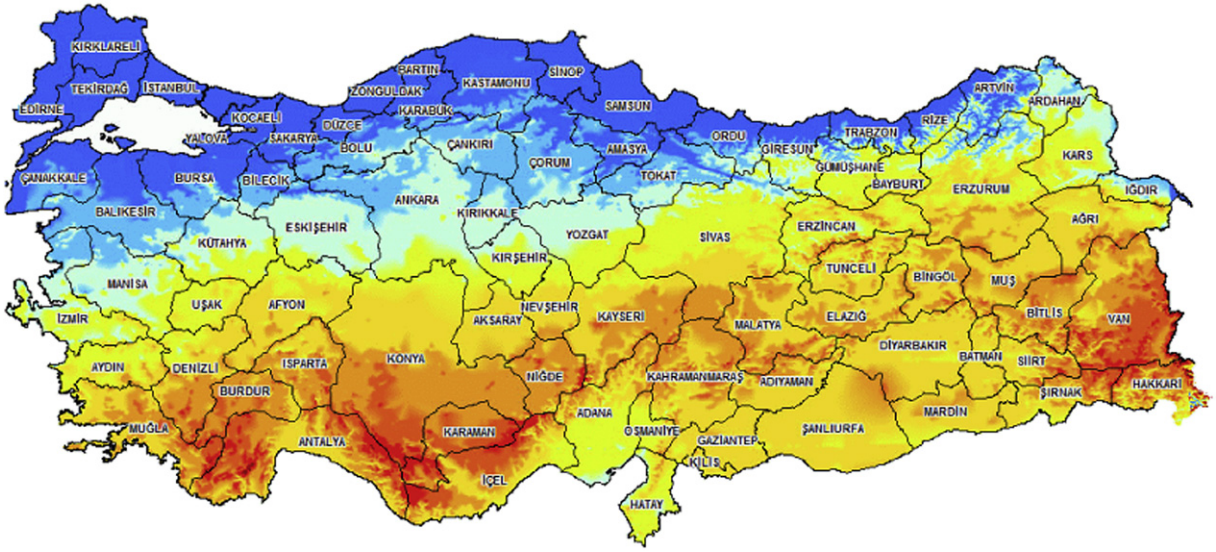

Fig. 14. Solar map of Turkey.

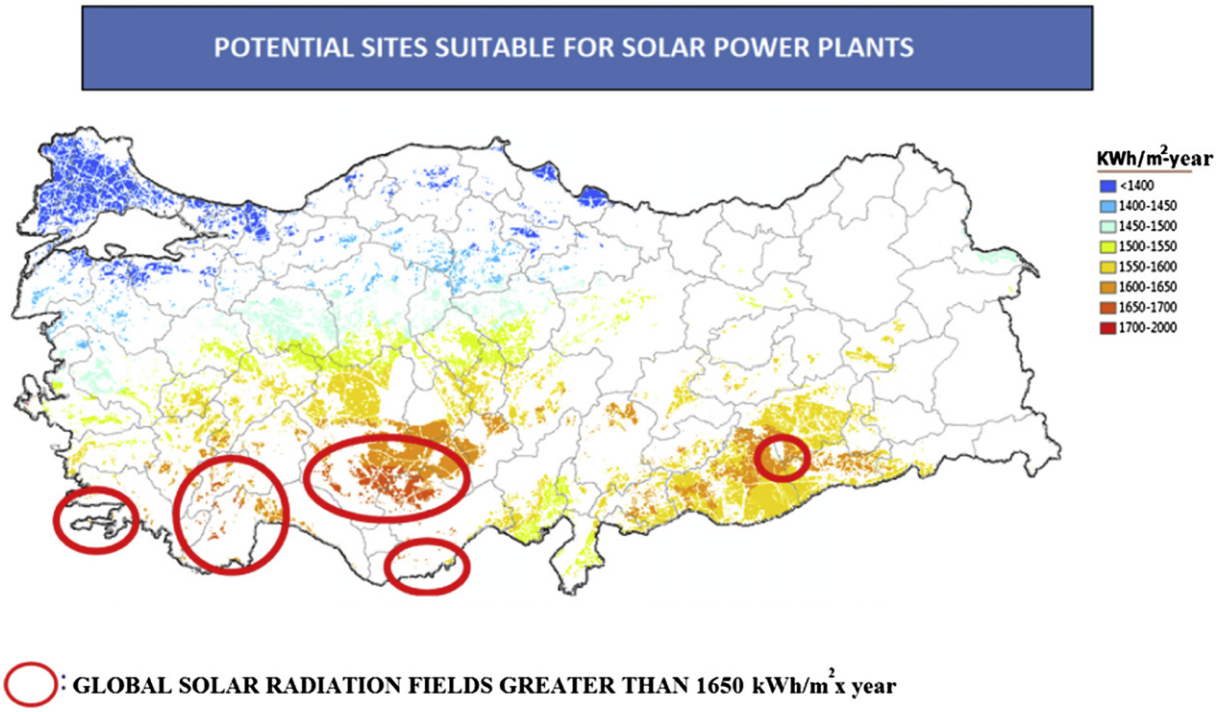

Fig. 15. Potential sites suitable for solar power plants in Turkey.

generates around 2% in China's electricity) and, nuclear currently account for around 13.5% of the global electricity generation [42]. However globally, the number of operating reactors fell from 441 at the beginning of 2011 to 435 in early 2012, a decrease of about 10 GW or 3%, mostly due to Fukushima and then Germany's phase out.

The Turkish government has just declared that nuclear power plant with a total capacity of 1300 MW would be built at Akkuyu in 2012, using imported technology from Russia. However, environmental and antinuclear groups are resisting, following on from the growth of opposition across the EU. A recent report published by BBC Globespan poll found that only 21% supported nuclear energy

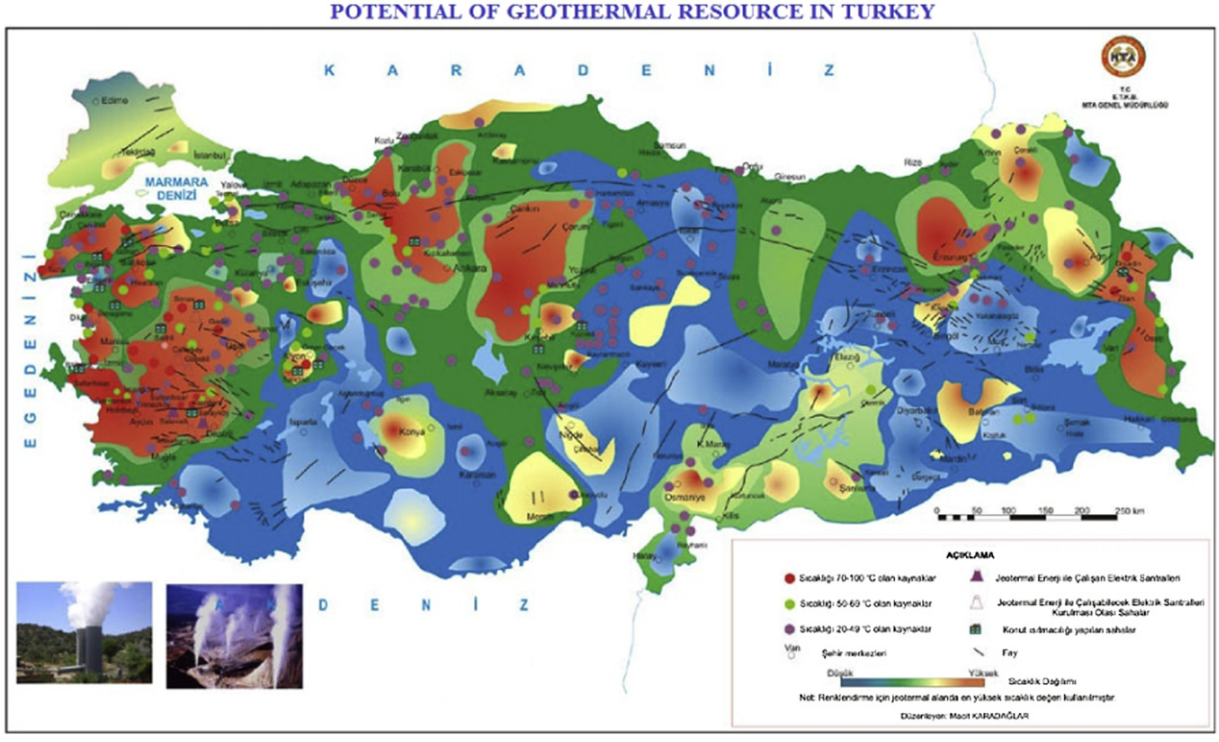

Fig. 16. Potential of geothermal resource in Turkey.

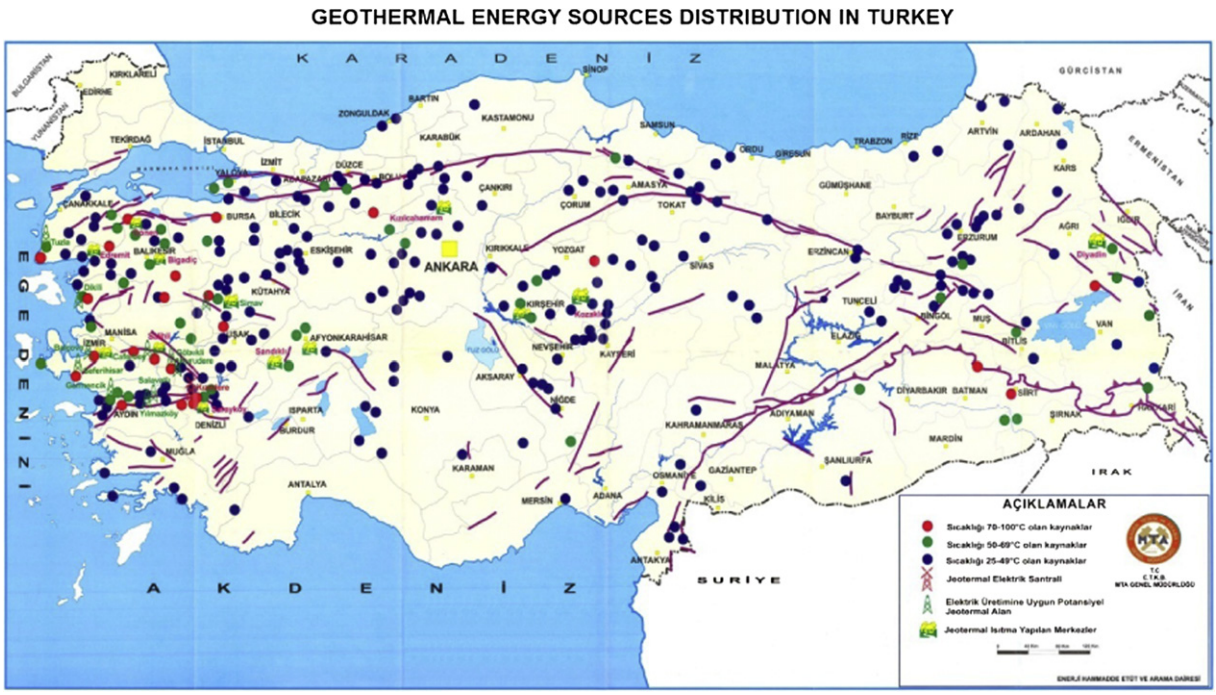

Fig. 17. Geothermal energy sources distribution in Turkey.

in Turkey, with 73% against [43]. Most countries in the western EU are either non-nuclear or, after the Fukushima accident in Japan, are phasing out existing nuclear programmes and backing off new built programmes. In addition to reactor safety, the basic concerns are large quantities of highly radioactive material that are produced and the high and rising cost of building new nuclear power plants. Turkey faces an additional problem: a major part of Turkey's land area is in a seismic zone. However, the Turkish government is still considering establishing nuclear power plant to overcome the possible high electricity demand in the future. Turkey does have the advantage that although it has relatively small uranium reserves, it has very large thorium reserves which could in theory be used in reactors [44]. Turkey has 9129 tons of uranium reserves and 380,000 tons of thorium reserves [45]. Therefore, thorium as a nuclear fuel of the future has a special importance for Turkey.

5. Conclusions

Developing countries like Turkey should plan their energy demand very carefully in relation to critical periods, since, unexpected things may happen, such as economic crises. For instance, economic crisis hit Turkey three times in the last decade, the first in 1994 and the others in 2000 and 2001. During these periods, energy consumption showed fluctuations and presented a decreasing trend. After the economic crises, energy consumption recovers and returns same trend like before the economic crises. Therefore, official energy projections should be formulated in such a way as to ensure that these possible crises are taken into account. Moreover, all relevant bodies in Turkey should take necessary steps to develop more accurate demand projections. Turkey has an advantage of having almost all energy resources existing in the country. Unfortunately the resources except lignite and hydropower are not still used efficiently to meet the needs of the country, and thus, an important part of the energy supply is imported.

Turkey is an energy importing nation with more than 65% of our energy requirements met by imported fuels. Air pollution is becoming a significant environmental concern in the country. The main goal of policies supporting renewable energy sources is to decrease the production of greenhouse gases in a short term. The real objection should be to develop both green technologies and to provide that renewable energy becomes fully competitive in order to ensure a less independent local energy supply in a clean and economical way. In this regard, hydropower and other renewable energy sources becoming attractive solution for clean and sustainable energy future of Turkey should immediately be taken into action in order to meet such requirements from its own sources. It should not be expected that the domestic production covers the consumption within a very short time, but it should be aimed at meeting or minimizing the deficit between the production and import within a long time. On the other hand, although Turkey has sufficient lignite reserves for electricity production, importing hard coal for this purpose is a completely strategic mistake.

Turkey's abundant hydropower potential is among the highest in Europe, but only one-third of this capacity is utilized. It is obvious that, however, hydropower can meet 25–35% of Turkey's electric energy demand in 2020 and new energy plants should be made as soon as possible. The wind energy potential of Turkey, with well-defined criteria 47,849.44 MW has been identified. This scale is equivalent to 1.30% of Turkey's total land area. Turkey is one of the richest countries in terms of wind energy potential in Europe. It is surrounded by three seas and has about 3500 km coastline, with along the Marmara and the Aegean coast, especially, wind speeds being high and regular. Investments in wind energy, starting from these regions, should be initiated quickly. Turkey should also invest in wind turbine technology, both for using its wind potential more cheaply in a long period and for supplying job opportunity to the people. Turkey will become technologically independent and could export technology. Conclusively, the use of present wind potential is very important from both economical and environmental respects. Turkey has also considerable solar energy potential. Three fourths of the economically usable potential is considered suitable for thermal use, with the reminder for electricity generation. Currently, Turkey does not have an organized commercial and domestic photovoltaic (PV) program. On the other hand, there is a good potential for PV applications in the local market since the country is enormously suitable due to high rates of solar radiation

and available land for PV applications. The priority sites for solar power plants are given in Fig. 15. Approximately 477 km^2 of the study area is identified as priority sites for solar power plant constructions [32]. Currently no large scale solar power plants exist in Turkey, so there is a need for new projects. Although the geothermal industry is highly developed in Turkey, excellent geothermal sources still remain undeveloped since cost for a new natural gas plant is just half of a new geothermal plant. If Turkey uses all of its geothermal potential, it will meet 14% of its total energy demand (Figs. 16 and 17).

Turkey could have at least one nuclear power station soon. Turkey has rich thorium reserves, which may be used for nuclear power generation provided the necessary technological steps are taken. Turkey will pay 65–70 billion dollars for energy imports in 2012. Turkey pays almost half of exports income for imported fuels. Turkey does not have nuclear power plants and nuclear power technology. However, if Turkey is to develop, it will need more energy, and nuclear offers a way to avoid emissions as well as reducing the energy supply deficit.

The EU countries use Turkey as a bridge to carry energy source by using the pipelines between them and Turkey's neighbors where there is rich petrol and natural gas sources. This is an important advantage for Turkish energy policy if it is governed properly. In conclusion fueled by renewed social awareness of renewable energy and the associated reduction GHG and government legislation in the form of EMRA renewable energies in Turkey have a large potential. While it takes significant time and effort to reduce its dependence on using natural gas and coal for electricity generation. Turkey has the potential to secure its long term energy future through focus on increasing utilization of renewable energy.

Disclaimer

Although some data taken from governmental document, this paper is not necessarily representative of the views of the government.

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