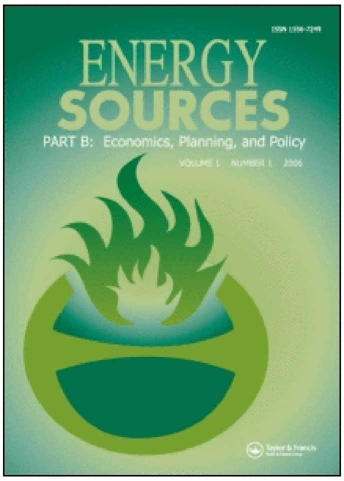

Energy Sources, Part B: Economics, Planning, and Policy
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t716100766

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Online Publication Date: 01 January 2006

To cite this Article Balat, Mustafa(2006)'Current Geothermal Energy Potential in Turkey and Use of Geothermal Energy',Energy Sources, Part B: Economics, Planning, and Policy,1:1,55 — 65

To link to this Article: DOI: 10.1080/009083190881436

URL: http://dx.doi.org/10.1080/009083190881436

Energy Sources, Part B, 1:55–65, 2006

ISSN: 1556-7249 print/1556-7257 online
DOI: 10.1080/009083190881436

Current Geothermal Energy Potential in Turkey and Use of Geothermal Energy

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Turkey is the seventh-richest country in the world in geothermal potential. The first geothermal researches and investigations in Turkey started by the Turkey Mineral Research and Exploration Institute (MTA) in the 1960s. Upon this, 170 geothermal fields have been discovered by MTA, in which 95% of them are low-medium enthalpy fields, which are suitable mostly for direct-use applications. The overall geothermal potential in Turkey is about 38,000 MW. Of this potential, around 88% is appropriate for thermal use (temperature less than 473 K) and the remainder is appropriate for electricity production (temperature more than 473 K). Turkey has extended its involvement in geothermal energy projects, supported by loans from the Ministry of Environment, and geothermal energy is expected to increase substantially in the coming years. Overall, Turkey has an estimated 4,500 MW of geothermal power production potential.

Keywords Turkey, geothermal energy, geothermal potential, use of geothermal energy

Geothermal energy, one of the most promising among alternative energy sources, has proven to be reliable, clean, and safe, and therefore its use for power production, heating, and cooling is increasing. It is anticipated that geothermal energy will partially displace more polluting fossil and nuclear energy sources, and become one of the best candidates of the energy sources in the years to come due to the growing concern about global warming and diminishing fossil fuels. Therefore, the performance evaluation of geothermal energy systems must be performed to produce the most out of geothermal energy (Cerci, 2003).

Geothermal energy for electricity generation has been produced commercially since 1913, and for four decades on the scale of hundreds of MW both for electricity generation and direct use. The utilization has increased rapidly during the last three decades. In 2000, geothermal resources have been identified in over 80 countries and there are quantified records of geothermal utilization in 58 countries in the world.

The worldwide use of geothermal energy amounts to 49 TWh/a of electricity and 53 TWh/a for direct use. A new estimate of the geothermal potential of the world gives the total potential for the resources suitable for electricity generation (resource temperature in excess of 423 K) as 11,000 ± 1,300 TWh/a and the total potential resources for direct use (resource temperature lower than 423 K) in excess of 1400 EJ/a (390,000 TWh/a heat) (Stefansson, 1998). The suitability for electricity generation from geothermal energy has

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been identified in Turkey. It is estimated that Turkey could generate about 10% of their total present electricity needs from geothermal energy.

Geothermal Energy Potential in Turkey

European countries generate more than 4000 GWh/year, predominantly in Italy, Iceland, Turkey, and Russia. Direct uses are much more widespread, with most EU countries having some exploitation in the form of space heating, agriculture, balneology, or process heating. In total, more than 18,000 GWh/y are exploited.

The overall geothermal potential in Turkey is about 38,000 MW (Table 1). Of this potential, around 88% is appropriate for thermal use (temperature less than 423 K) and the remainder is appropriate for electricity production (temperature more than 423 K) (Demirbas et al., 2001).

Turkey has significant potential for geothermal power production, possessing one-eighth of the world's total geothermal potential. Much of this potential is of relatively low enthalpy that is not suitable for electricity production but is still useful for direct heating applications; at the end of 1999, Turkey's total installed capacity for direct heating was 820 thermal MW, of which about 390 MW provided heating for 51,600 residences, about 100 MW provided heating for about 45 hectares of greenhouses, and about 330 MW was used to provide heated water for about 200 spas. By 2010, as many as 500,000 residences could be heated by geothermal power, which would represent the use of about 3,500 MW (FEI, 2003).

Turkey is the seventh-richest country in the world in geothermal potential. The first geothermal researches and investigations in Turkey started by the Turkey Mineral Research and Exploration Institute (MTA) in the 1960s. Upon this, 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 (Mertoglu et al., 2000). Among the remaining 9 fields, Denizli–Kızıldere (473–515 K), Aydin–Germencık (505 K), Çanakkale–Tuzla (447 K), Aydin–Salavatli (444 K), Kutahya–Sımav (435 K), Manisa–Salıhlı (423 K), and Izmır–Seferıhısar (426 K) are high enthalpy fields, which are suitable for electrical energy production (Günerhan et al., 2001).

Around 1,000 hot and mineralized natural self-flowing springs exist in Turkey. With the existing geothermal wells and springs, the proven geothermal capacity calculated by MTA is 2600 MWt (exhaust temperature is assumed to be 313 K). This figure means also that 30% of the total residences in Turkey could be heated by geothermal energy (Mertoglu et al., 2000).

Turkey's considerable geothermal potential is estimated at 4500 MW for electricity production and 31,100 MW for greenhouse and district heating applications. The first

Table 1
Turkey's geothermal energy potential

	Proven (MW)	Probably and possible (MW)
Heat (<2273 K, low enthalpy fields)	2,250 MWt	31,100 MWt
Electricity (>2273 K, high enthalpy fields)	200 MWe	4,500 MWe

Source: WECTNC, 1996.

Table 2
Utilization of geothermal energy for electric power generation as 1999 in Turkey

Locality	Power plant name	Year com.	No. of units	Status	Type of unit	Total installed capacity (MWe)	Annual energy produced, 1999 (GWh/yr)	Total planned (MWe)
Denizli–Kızıldere	Kızıldere	1984	1	Presently operated	Single flash	20.4	91.8	
Aydin	Germencık	2000						25

Source: Mertoglu et al., 2000.

geothermal power plant (20 MW installed capacity) was placed in operation in 1984 in Denizli Saraykoy (the West Anatolia region). It is estimated that this site has enough geothermal potential for an additional 20 MW. Aydin-Germencık is another site with approximately 100 MW potential. As of 1996, approximately 90,000 toe of geothermal energy were used in heating applications, including in 50,000 households, tourist establishments, and greenhouses. The Ministry of Environment believes that 1 million homes could be heated with geothermal energy (Joint UNDP/World Bank Energy Sector Management Assistance Program [ESMAP], 2000).

The overall geothermal energy potential of Turkey is estimated at 35 GW per year. But, geothermal energy production for the year 2001 is only 1.759 Mtoe. Its use is expected to increase to 6.3 Mtoe by 2020, especially for direct heating. The proposed Geothermal Law, currently being drafted by the MENR, should provide the necessary regulatory framework for this purpose.

Geothermal energy can be utilized in various forms such as electricity generation, direct use, space heating, heat pumps, greenhouse heating, and industrial usage in Turkey. Today in Turkey, biomass and hydropower are mostly in use; geothermal is in the third place. Geothermal electricity generation has a minor role in Turkey's electricity capacity, as low as 0.09%, but the projections foresee an improvement to 0.32% by the year of 2020. Utilization of geothermal energy for electric power generation as of 1999 is given Table 2. Opposing the electricity generation, geothermal heat capacity is improving faster (Günerhan et al., 2001).

By summing up all this geothermal utilization in Turkey, the installed capacity is 820 MWt for direct use and 20.4 MWe for power production, where a liquid carbon dioxide and dry ice production factory is integrated to this power plant (Tables 3 and 4). The distribution of geothermal wells drilled by MTA according to the years is given in Table 5 (Mertoglu, 2000).

Turkey's Geothermal Field

The only operating geothermal power plant of Turkey is the Denizli–Kızıldere geothermal power plant located near Denizli City in Western Anatolia, with an installed capacity of 20.4 MWe. The total capacity of the field is estimated to be 200 MWe (Mertoglu, 2000). The facility includes nine production wells and also has an integrated liquid carbon dioxide (CO_2) and dry ice production factory that can produce a combined total of 40,000 metric tons per year of the two products. Another 20 MWe power production unit is being planned for this facility (Fossil Energy International, 2003).

Table 3
Categories in geothermal utilization in Turkey

Geothermal utilization categories	Capacity
District heating	493 MWt
Balneological utilization	327 MWt
Total direct use	820 MWt
Power production	20.4 MWe
Carbon dioxide production	120,000 tons/yr

Source: Mertoglu et al., 2000.

Table 4
Summary of geothermal direct heat uses as in 1999

Use	Installed capacity (MWt)	Annual energy use (TJ/yr)	Capacity factor
Space heating (residences plus thermal facilities)	392	4,327	0.35
Greenhouse heating	101	1,115	0.35
Bathing and swimming	327	10,314	1
Total	820	15,756	0.60

Source: Mertoglu et al., 2000.

Table 5
Distribution of geothermal wells drilled by MTA according to years

Year	Number of wells	Depth (m)	MTA Project	Paid
1960–1965	8	852.5	8	—
1965–1970	13	7,869.5	13	—
1970–1975	16	7,484.7	16	—
1975–1980	8	3,597.1	7	1
1980–1985	49	24,101.75	29	20
1985–1990	73	27,211.4	11	62
1990–1995	65	18,188.9	7	58
1995–1998	69	31,752.7	7	62
1998–1999	4	3,027.6	1	6
Total	305	119,240.85	99	209

Source: Mertoglu et al., 2000.

There are six other geothermal fields that have been identified, all in far southwest Turkey, that may be suitable for geothermal power production: (1) the Germencık–Aydin field in Aydin Province, (2) the Çanakkale–Tuzla field in Çanakkale Province, (3) the Izmır–Sefirihiser field in Izmır Province, (4) the Aydin–Salvatli field in Aydin Province, (5) the Kutahya–Sımav field in Kutahya Province, and (6) the Dıkılı–Bergama field in Izmır Province. The Germencık–Aydin field may be the most promising of these as it has a power potential of at least 100 MWe; a new 25 MWe power plant, to be located near the city of Germencık, is in the planning stages. Turkey hopes to generate 500 MWe from geothermal energy by the year 2010 and 1,000 MWe by the year 2020 (FEI, 2003).

The exploration stage is completed in the Aydin–Germencık field, which is located to the west of Kızıldere. Nine wells have been drilled into a 489–505 K reservoir within marbles and quartzites at depths ranging from 285 to 1500 m. The field capacity is estimated to be 100 MWe. The first stage of the field development is planned to build a 25 MWe single flash plus binary power plant (GRC, 1998). This power plant generates an average of 12–15 MWe electricity annually. The reservoir temperature in the Kızıldere geothermal field is 515 K. The reservoir which feeds the Kızıldere Geothermal Power Plant contains 1.5% noncondensable gases. The amount of these gases at the separation pressure in the single flash plant is 15% in weight (Mertoglu, 2000).

Some attempts have been made towards the installation of geothermal power plants in the fields of Aydin–Germencık–Omerbeyli, Çanakkale–Tuzla, and Manisa–Salıhlı–Caferbey. Besides this, there are also some investment attempts for electricity generation in Aydin–Salavatli by applying the autoproduction model.

The third field with power generation potential is the Çanakkale–Tuzla field in northwest Anatolia. The first well was drilled in 1982. The temperature encountered was 447 K in a reservoir at a depth of 333–553 m in volcanic rocks. A second well was drilled to 1020 m. Temperatures up to 447 K were recorded, but the permeability was low. Another two shallow wells (81 and 128 m) also produced fluid at 419 and 438 K. The Aydin–Salavatli field has a reservoir temperature of 444 K. It was planned to build a 5 MWe binary or Kalina cycle plant in the field, but this has not been realized yet (Mertoglu, 2000).

In 1968, the MTA found geothermal reservoirs at an average depth of 800 m with temperatures ranging from 443 to 485 K. Until 1973, 16 production wells were drilled by MTA. Later, in 1975, the Turkey Power Department (TEK) built a 0.5 MW pilot geothermal power plant supplied by one of the 16 wells, and the electricity produced has met the power requirements of cities near the region for a long period of time. The pilot plant showed that power generation from the reservoir was feasible, and TEK decided to build a large geothermal power plant. The construction of the plant began in late 1980, and the plant started producing power in February 1984. Currently, the plant has a power rating of about 11.4 MW and receives steam at a mass flow rate of 32.32 kg/s produced from nine production wells. It employs ninety-four people, and operates twenty-four hours a day and seven days a week throughout the year (Cerci, 2003).

Present Situation of Geothermal Applications

In 1997, Turkey's total primary energy supply (TPES) was 71.4 Mtoe. The share of renewable energy in TPES was about 14.4% in 1997, and renewables are the second-largest domestic energy source after coal, almost triple the IEA average, with the majority of total renewable energy supply from biomass and animal products, mostly wood, and some geothermal energy (Tables 6 and 7).

Table 6
Primary energy production
by source in 1997

Energy source	Percent of total
Lignite	42.4
Wood	19.9
Oil	13.1
Hydro	12.4
Dung	5.5
Hard coal	4.9
Natural gas	0.8
Geothermal heat	0.4
Geothermal electricity	0.3
Solar	0.3

Source: WECTNC, 1998.

The operational capacities of the city-based geothermal district heating systems existing in Turkey are as follows: Gönen (Commissioned: 1987, 3,400 residences, geothermal water temperature is ~353 K), Sımav (Commissioned: 1991, 3,200 residences, geothermal water temperature is ~393 K), Kırsehır (Commissioned: 1994, 1,800 residences, geothermal water temperature is ~330 K), Kızılcahamam (Commissioned: 1995, 2,500 residences, geothermal water temperature is ~353 K), Izmır (Commissioned: 1996, 10,000 residences, geothermal water temperature is ~388 K), Sandıklı (Commissioned: 1998, 1,600 residences, geothermal water temperature is ~343 K), Afyon (Commissioned: 1996, 4,000 residences, geothermal water temperature is ~368 K), Kozaklı (Commissioned: 1996, 1,000 residences, geothermal water temperature is ~363 K), Izmır-Narlidere (Commissioned: 1998, 1,075 residences, geothermal water temperature is ~371 K), Dıyadın (Commissioned: 1999, 400 residences, geothermal water temperature is <343 K).

Table 7
Energy consumption
by source in 1997

Energy source	Percent of total
Oil	44.5
Coal	21.7
Electricity	12.1
Wood	9.9
Natural gas	8.8
Dung	2.7
Geothermal heat	0.2
Solar	0.1

Source: MENR, 1999.

Table 8
Turkey's hot field resources

Field	Temperature range (K)
Izmır–Balcova	353–399
Izmır–Seferıhısar	410–426
Kutahya–Sımav	426–435
Aydin–Salavatli	435–444
Çanakkale–Tuzla	413–473
Denizli–Kızıldere	463–485
Aydin–Germencık	473–505

As seen in Table 8, high-temperature geothermal fields suitable for conventional electricity generation are Aydin–Germencık (473–505 K), Denizli–Kızıldere (463–485 K), Çanakkale–Tuzla (413–473 K), Aydin–Salavatli (435–444 K), Kutahya–Sımav (426–435 K), and Izmır–Seferıhısar (410–426 K).

Direct Heat Utilization

Even though the direct use of geothermal energy has a much longer history of use than electric power generation, the numbers are less reliable. In fact, it is difficult to compare installed capacity and annual use, due to the inclusion or exclusion of bathing, swimming, and balneology figures. This has not been consistent, as in the early years this use was not included, but in the current report it is included.

Examples of current district heating costs are 0.23–0.42 cents/1,000 kcal (0.27–0.49 cents/kWh) in Turkey, compared to 3.4 cents/kWh for natural gas and 11.2 cents/kWh for electricity based heating (Mertoglu et al., 1999). Today, 313–318 K temperature geothermal waters are used for space heating in Turkey without a heat pump. The energy amount from the utilization of geothermal energy in Turkey for direct heat as of 31 December 1999 is 6,862.94 TJ/yr (Table 9) (Mertoglu et al., 2000).

The Klamath Falls, the Oregon, USA, district heating system charges 1.6–2.0 cents/kWh (Lund, 1999). This is 50–80% of the natural gas cost, depending upon the efficiency of the gas conversion, and the comparable cost for electricity in the city is 5.5 cents/kWh. Construction costs for heating in Turkey are 850–1,250 US$/kW and the cost per residence is around 2,000 US$, an investment that is amortized in 5–10 years (Lund, 2000).

Direct Utilization

The world direct utilization of geothermal energy is difficult to determine, as there are many diverse uses of the energy and these are sometimes small and located in remote areas. Finding someone or even a group of people in a country who are knowledgeable on all the direct uses is difficult.

Turkey has increased their installed capacity over the past five years from 140 MWt to 820 MWt, mostly for district heating systems. This supplies heat to 51,600 equivalent residences and an engineering design to supply a further 150,000 residences with geothermal heat is complete. The Turkish projections for 2010 are 3,500 MWt, which will heat an equivalent 500,000 residences or about 30% of the residences in the country (Batik et al., 2000).

Table 9
Utilization of geothermal energy for direct heat in 1999

Locality	Type	Capacity (MWt)	Energy (TJ/yr)	Capacity factor
Gönen	H, B, I	32	353.3	0.35
Sımav	H, B	25	276	0.35
Kırsehır	H	18	198.7	0.35
Kızılcahamam	H	25	276	0.35
Izmır	H	90.4	998	0.35
Sandıklı	H	45	496.8	0.35
Afyon	H	40	441.6	0.35
Kozaklı	H	11.2	123.64	0.35
Dıyadın	H	6.3	695.5	0.35
Izmır Medıcal Faculty, Hospıtal, Campus	H	21.7	239.6	0.35
Bolu	H	8	88.32	0.35
Balcova Thermal Facılıty & Thermal Prıncess Hotel	H, B	13.6	150.1	0.35
Afyon–Orucoglu	H, B	5.7	62.9	0.35
Gedız	H, B	0.64	7.07	0.35
Afyon–Gazlıgöl	H, B	5	55.2	0.35
Rıze–Ayder	H, B	0.29	3.2	0.35
Kuzuluk	H, B	20	220.8	0.35
Afyon–Ömer	H, B	2.5	27.6	0.35
Salıhlı	H, B	0.37	4.09	0.35
Haymana	H, B	0.1	1.1	0.35
Havza	H, B	0.07	0.77	0.35
Balıkesır–Hısarköy	H, B	0.12	1.33	0.35
Kızılcahamam	H, B	1	11	0.35
Eskısehır–Sakarıılıca	H, B	0.05	0.55	0.35
Sıvas–Sıcakcermık	H, B	0.6	6.62	0.35
Afyon–Bolvadın	H, B	1.5	16.6	0.35
Sımav	H, B	3.6	39.7	0.35
Kızılcahamam	H, B	0.25	2.76	0.35
Kızılcahamam	H, B	3	33.12	0.35
Kozaklı	H	2.5	27.6	0.35
Alangullu	H, B	0.7	7.73	0.35
Gölemezlı	H, B	0.08	0.88	0.35
Sandıklı	H, B	2.4	26.5	0.35
Resadıye	H, B	0.1	1.1	0.35
Amasya	H, B	2	22.1	0.35
Ayas	H, B	2	22.1	0.35
Pamukcu	H, B	2	22.1	0.35
Urfa	G	15	283.9	0.6
Sımav	G	33	624.5	0.6
Sındırgı	G	0.4	7.6	0.6

(*continued*)

Table 9
(*Continued*)

Locality	Type	Capacity (MWt)	Energy (TJ/yr)	Capacity factor
Afyon	G	1.5	28.4	0.6
Kızıldere	G	2.4	45.4	0.6
Balcova	G	17.6	333	0.6
Kestanbol	G	0.4	7.6	0.6
Saraykent	G	0.6	11.35	0.6
Tekkehamam	G	1.8	34	0.6
Yalova	G	0.12	2.27	0.6
Kozaklı	G	1.2	22.7	0.6
Dıkılı	G	2	35.2	0.6
Golemezlı	G	0.2	3.52	0.6
Seferıhısar	G	1.06	18.7	0.6
Bergama	G	0.4	7.6	0.6
Germencık	G	0.1	1.9	0.6
Edremıt	G	9.9	187.36	0.6
Ezıne	G	0.3	5.7	0.6
Nıksar	G	0.14	2.65	0.6
Kızılcahamam	G	1.45	27.44	0.6
Gedız	G	2.1	39.74	0.6
Çanakkale-Tuzla	G	9	170.33	0.6
Total		493.44	6,862.94	

Turkey's Politics in the Near Future

One of the most important developments in the energy sector was the implementation of built-operate-transfer (BOT) and BO (built-operate) model investments with foreign capital. And also a new arrangement foreseeing the implementation of a BO model is under evaluation. The energy sector in Turkey is mainly state owned, and the government is heavily involved in the management and corporate decisions of the State Economic Enterprises (SEEs). The government has generally maintained prices below the level at which SEEs could make the necessary investments, and as a consequence most of the SEEs have been dependent upon the capital endowment by the treasury and state guarantees for investments (Demirbas, 2002).

The additional generation capacity for the period of 1997–2020 will require huge investments. Public investments require the contribution of foreign capital because of financial problems. Private sector investment is also inevitable. Therefore BOT, BO, and privatization would be suitable models to solve the energy problems of Turkey in the near future (Demirbas, 2002). In Turkey, geothermal utilization projections of geothermal energy are given in Table 10.

Turkey has no national geothermal energy policy, and there are few government-backed incentives to promote geothermal energy. Turkey is planning to develop the use of geothermal heat (projected to rise from under 62 ktoe in 1996 to almost 685 ktoe in 2000). However, the pace of total energy growth is likely to be more rapid than that of

Table 10
Geothermal utilization projections of geothermal energy in Turkey

Year	Power production (MWe)	Heating (residences equivalency)	Spa/others (MWe)
2010	500	500,000 (3,500 MWt)	895
2020	1000	1,250,000 (8,300 MWt)	2,300

renewable energy development, and the percentage of renewable in total energy supply is likely to continue declining to 2000 and beyond.

Within the context of this local plan, studies are being undertaken on passive solar buildings with the intention of incorporating successful designs into housing legislation. There is some municipal support in the areas of hydro and geothermal heat (Turkish Ministry of Energy and Natural Resources [MENR], 2002).

Environmental Activities

Turkey has made much progress over the last two decades in setting up infrastructure for addressing its environmental problems an Environment Law was enacted in 1983 and the Ministry of Environment was created in 1991. There are also nongovernmental environmental organizations that have emerged. Turkey is a party to many international environmental agreements, including Air Pollution, Antarctic Treaty, Biodiversity, Desertification, Hazardous Wastes, Nuclear Test Ban, Ozone Layer Protection, Wetlands, and Ship Pollution. Turkey has signed but not yet ratified the Arctic-Environmental Protocol and the Environmental Modification treaty. Additionally, Turkey has neither signed nor ratified the United Nations Framework Convention on Climate Change.

The utilization of geothermal energy and its contribution to the economy of Turkey has been increased each day. It is expected that air pollution problems will be minimized by using geothermal energy for heating purposes.

As of 1996, approximately 90,000 toe of geothermal energy were used in heating applications, including 50,000 households, tourist establishments, and greenhouses. The Ministry of Environment believes that 1 million homes could be heated with geothermal energy (ESMAP, 2000).

The problem with the development of geothermal district heating has been the initial investment outlays, which amount to about $2,000 per standard dwelling (100 square meters). However, operating costs are minimal once the systems are installed, and the Ministry of Environment estimates the payback period is six years. Furthermore, the pollution reduction due to the replacement of lignite or heating oil by geothermal heating is considerable. The Ministry of Environment estimates that switching one standard dwelling from fuel oil to geothermal heating reduces annual carbon dioxide emissions by 14 tons and sulfur dioxide emissions by 0.26 tons (ESMAP, 2000).

Conclusions

Turkey is one of the countries with significant potential in geothermal energy. Widespread volcanism, femoral hydrothermal alterations, and the existence of more than 600 hot springs, some of which have 373 K and greater temperatures, indicate that Turkey has important geothermal energy potential.

The most significant developments in production are observed in hydropower and geothermal energy production. Domestic energy consumption accounts for 37% of total energy consumption (World Energy Council—Turkish National Committee (WECTNC), 1995). The production of geothermal and solar energy is negligible compared to biomass and hydropower, varying from 43 to 190 Goe during the 1986 and 1995 period.

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