Geothermal Resources in Turkey

By Liz Battocletti,
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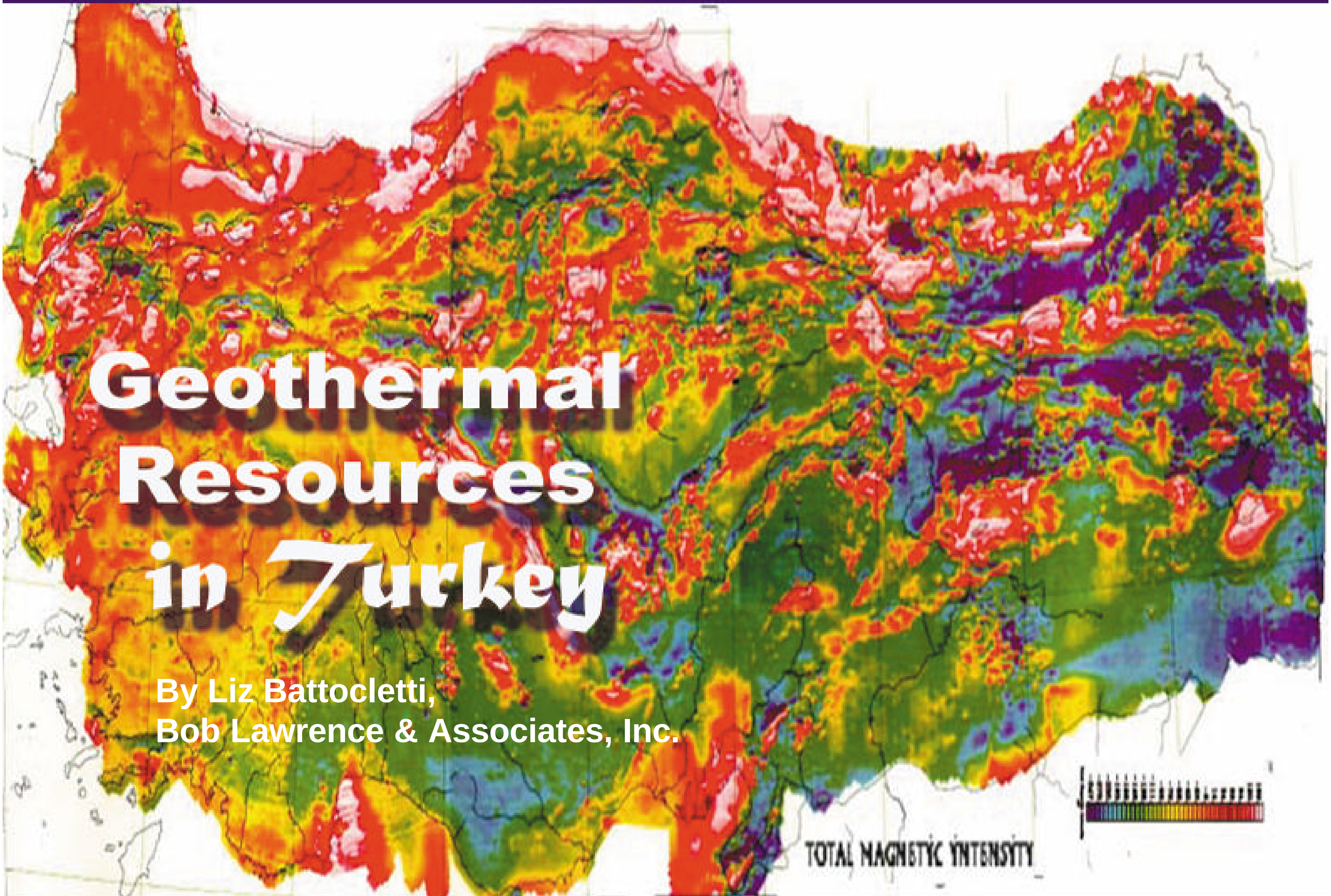

Report No. INEEL/EXT-99-01282

September 1999

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Prepared for Idaho National Engineering
& Environmental Laboratory
Under Purchase Order No. F99-181039
And the U.S. Department of Energy,
Assistant Secretary for Energy Efficiency
& Renewable Energy,
Office of Geothermal & Wind Technologies
Under DOE Idaho Operations Office
Contract DE-AC07-99ID13727

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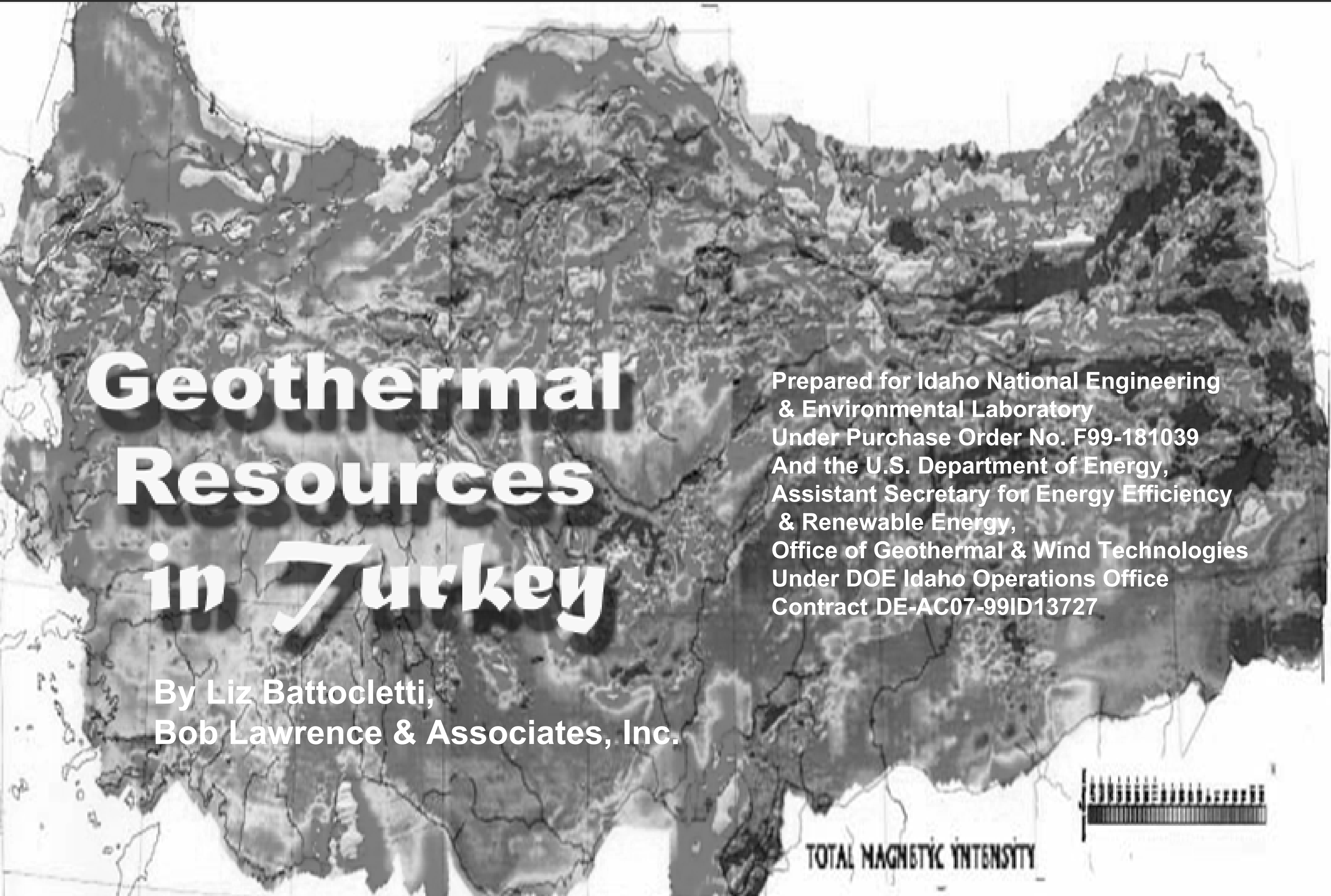

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Introduction

The **Database of Geothermal Resources in Turkey** includes information on 63 specific geothermal sites, representing at least 363* MWe in power potential and 840* MWt in direct use potential. The actual figures are much higher as specific data on potential is not available for all sites.

The Database includes:

- Power Profile - basic information on Turkey, e.g., population, installed capacity, power generation breakdown, electricity prices, etc.;
- Power Summary - brief description of Turkey's power sector and privatization;
- Government / Legislation - relevant Turkish government agencies and laws; and
- Geothermal Sites / Projects - includes a Site Summary for each:

  1. Name
  2. Location
  3. Status
  4. Temperature
  5. Installed Capacity (MWe/MWt)
  6. Potential (MWe/MWt)
  7. Chronology
  8. Notes

Dynamic Database

The Database was designed to be dynamic. Created using Microsoft® Access 97, it can be easily updated or modified to include specific data which the industry would find most useful. In addition, the Database can be made more comprehensive by adding pertinent data, e.g., local population and market data, location of transmission lines and roads, etc., using the Geographic Information System (GIS)[1] of the U.S. Geological Survey, to the present structure. Finally, the Database could be adapted for posting on the World Wide Web and searched using a variety of variables such as country,

[1] In the strictest sense, a GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information , i.e. data identified according to their locations. See http://info.er.usgs.gov/research/gis/title.html.

desired temperature of resource, estimated power potential, and other parameters.

For immediate dissemination to the industry, the Database has been converted to a PDF file.[2]

The Database of Geothermal Resources in Turkey was compiled and built by a team led by Liz Battocletti of Bob Lawrence & Associates, Inc. for Idaho National Engineering and Environmental Laboratory (INEEL) under Purchase Order Number F99-181039, “Collection and Assembly of Published Data on Geothermal Potential.”

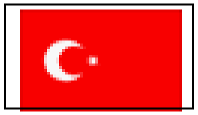
Special appreciation goes to Joel Renner of INEEL and Dr. Marshall Reed of the U.S. Department of Energy Office of Geothermal and Wind Technologies for their support. The author also wishes to thank Serdar Cetinkaya of the Foreign Commercial Service of the U.S. Embassy in Ankara; Gülden Gökçen Günerhan of Ege University-Solar Energy Institute in Bornova-Izmir, Turkey; and Dr. Orhan Mertoğlu of Orme Geothermal for reviewing the document and giving their comments.

[2] PDF files can be read and printed using the free Adobe® Acrobat® Reader which can be downloaded at http://www.adobe.com/prodindex/acrobat/readstep.html).

The cover illustration is courtesy of the General Directorate of Mineral Research and Exploration of Turkey.

Liz Battocletti
September 1999

Turkey



Turkey

Power Profile

Population (millions) - July 1998	64.57
Overall Electrification (% of population)	99%
GDP (billion US$) - 1997 est.	$388.3
Real GDP Growth Rate - 1997 est.	7.2%
Inflation Rate (CPI) - 1997	99.0%
Total Installed Capacity (MWe) - 1998	22,625
Electricity Consumption per Capita (kWh) - 1997	1,784
Energy Demand Growth Rate	11.8%
Prices (US¢/kWh) - September 1999	
Residential	0.10
Commercial	0.09
Industrial	0.07
Source: TEDAS. Residential and Industrial rates represent an average of tariffs for "Provinces Under Development" and "Other Provinces."	

Estimated Geothermal Power Potential (MWe)	4,500
Estimated Geothermal Direct Use Potential (MWt)	32,000

Power Summary

Turkey–with a young and growing population, low per capita electricity consumption, rapid urbanization, and strong economic growth–is one of the fastest growing power markets in the world. Averaging an impressive 10% growth in electricity demand over the past ten years, Turkey is the fourth-fastest growing electricity market after China, India, and Brazil.

Projections by Turkey's state utility, Electricity Generating and Transmission Corporation (TEAS), indicate that the country's demand for electricity will grow by 246% over the next 15 years and require an estimated 160 new power plants. Turkey's installed capacity is expected to be 65,069 MWe by 2010 and 109,218 by 2020 (up from its current level of 22,625 MWe).

The Ministry of Energy and Natural Resources (MENR) predicts the need for 2,500-3,000 MWe of new capacity each year at a total cost by 2010 for generation and transmission alone of $72.3 billion. The Government of Turkey (GOT) expects to finance about a quarter of the projects with the balance coming from private-sector investors.

MENR plans to install 33 lignite-fired units, 27 natural gas-fired units, 12 coal-fired plants, 2 nuclear power plants, and 113 hydroelectric units to meet the country's growing electric power needs. To date, 20 projects have been awarded for a total of 12,270 MWe; 47% of the planned installed capacity will be fueled by natural gas, up from 16% in 1998. The majority of the rest will be coal-fired.

With electricity shortages and blackouts already common (partly as a result of generation and distribution losses as high as 20%), increasing the country's electricity generating capacity is a top priority for Turkish energy officials.

Turkey's primary indigenous energy resources are hydropower, which is mainly located in the eastern part of the country, and lignite. Almost all oil and natural gas is imported, as well as high quality coal. The country also has a large potential for renewable energy including wind, solar, and geothermal power.

Marmara, the Aegean and Southeast Anatolian regions of Turkey are rich in wind energy, the Southeast and Mediterranean regions in solar energy, and the Aegean and Marmara regions in geothermal energy.

Although estimates are that geothermal power potential in Turkey could amount to 4.5 GWe, little progress has been made toward exploiting this potential due to technical, financial, administrative, and economic problems, including artificially low electricity prices.

The GOT has kept electricity prices relatively low, setting prices for household consumers at the same level as that for industrial users. This has led to a lack of available funds for investment and contributed to the rapid growth in energy demand. To promote renewable sources, the GOT must create a level playing field by allowing prices of conventional fuels to rise to market levels.

In the fourth quarter of 1998, Turkey produced 28,735.7 GWh gross of electricity, up 4.66% from the fourth quarter of 1997. Of the total, 64% was thermal (lignite, oil, and natural gas), 35% hydro power, and less than 1% came from other sources e.g. geothermal and biomass. Of the total, TEAS and TEAS partnerships produced over 85%. Private power generators account for only 6% of the total electricity generated.

By 2010, Turkey's total capacity will be composed of 28.4% natural gas, 22% lignite and hard coal, 39.1% hydro, 6.5% fuel and diesel oil, and 3.2% nuclear.

Turkey's hydroelectric economic capacity will be fully utilized and its indigenous thermal energy resources exhausted by the year 2010. Turkey currently produces less than 50% of its energy needs; this will decrease to 25.3% by 2020.

Turkey has chosen natural gas as the preferred fuel for the massive amount of new power plant capacity to be added in coming years. This makes sense for Turkey for several reasons: environmental (gas is cleaner than coal, lignite, or oil); geographic (Turkey is close to huge amounts of gas in the Middle East and Central Asia); energy security (Turkey is seeking to diversify its energy import sources); economic (Turkey could offset part of its energy import bill through transit fees it could charge for oil and gas shipments across its territory); and political (Turkey is seeking to strengthen relations with Caspian and Central Asian countries, several of which are potentially large gas exporters).

Turkey's strategic location also makes it a natural "energy bridge" between major oil producing areas in the Middle East and Caspian Sea regions on the one hand, and consumer markets in Europe on the other. Oil and gas transportation is a crucial and contentious issue in the Caspian Sea/Central Asia regions. Turkey, Russia, and Iran are competing to route the rich energy resources of Azerbaijan, Kazakhstan, Turkmenistan, and Uzbekistan through their territories. Turkey is pressing for a "Western route" pipeline that would carry oil from Azerbaijan's port of Baku through Azerbaijan and Georgia and then across Turkey to the Mediterranean port of Ceyhan, at an estimated cost of $1.8-$3 billion. In late May 1998, former U.S. Secretary of Energy Federico Peña during a trip to Turkey reiterated U.S. support for this plan, calling the Baku-Ceyhan route "optimum."

August 17, 1999 Earthquake

Turkey sits astride the North Anatolian Fault and has endured numerous earthquakes this century. On August 17, 1999 a devastating earthquake lasting 45 seconds and confirmed to be 7.4 on the Richter scale, hit Izmit approximately 55 miles east-southeast of Istanbul. The quake killed more than 16,000, injured over 23,000, destroyed over 20,000 houses, and left 100,000 homeless. Aftershocks have since continued.

Geophysicists at the U.S. National Earthquake Information Center described the quake as one of the most powerful recorded in the 20th century, nearly rivaling the 7.9-magnitude temblor that devastated San Francisco in 1906. It was felt as far east as Ankara, 200 miles away, and across parts of the Balkans.

The hard-hit area accounts for a third of the country's gross domestic product. According to Turkish officials, the total estimated cost to reconstruct industrial facilities, homes, public services, and other infrastructure will exceed $25 billion, at a time when the country is struggling to reduce its government deficit and reduce inflation. The World Bank has pledged $120 million in new loans and said that $100 million in existing loans would be transferred to Turkey more quickly.

Despite the challenges, due to its prospects for tremendous growth, the U.S. Department of Commerce has designated Turkey one of the world's ten Big Emerging Markets (BEMs). The U.S. Mission in Turkey will support American firms in their efforts to implement private power generation and electricity distribution projects and ensure the greatest American participation possible in Turkey's privatization process.

Government / Legislation

Turkey's energy sector is characterized by a strong state presence with a large number of monopolistic state enterprises. The State Planning Organization prepares and monitors macro plans and evaluates private sector energy investments with the Ministry of Energy and Natural Resources (MENR). A Treasury Undersecretary coordinates energy sector financing. The State utility, Turkish Electricity Generation and Transmission Company (TEAS), is responsible for generation and transmission while state-owned Turkish Electricity Distribution Company (TEDAS) is responsible for distribution. Finally, the state company, Turkish Petroleum Corporation's (TPAO) principal activities are the exploration, drilling and production of oil, natural gas, and geothermal energy. TPAO entered into geothermal exploration in 1987.

Although Turkey has privatized $20 billion worth of state energy sector assets by 1998, privatization efforts have been hindered by a lack of political consensus over the benefits of a smaller public sector, and legal debates both in parliament and the Turkish constitutional court over the Build-Operate-Transfer (BOT) and Build-Operate (BO) models. Greater availability and easier access to financing and faster approval of BOT, BO, and Transfer of Operational Rights (TOR) projects is anticipated, however, with the August 13, 1999 amendment to the Constitution.

Ministry of Energy and Natural Resources (MENR)

Established in 1963, MENR supervises the overall development of Turkey's energy resources, leads the country's power sector privatization program, and is responsible for preparing a privatization strategy and action plan to implement the recommended institutional and regulatory changes necessary to transfer ownership to the private sector and provide an efficient and reliable electricity supply at least cost. Its energy policies include:

- diversifying energy supplies and avoiding dependence on a single source or country;
- meeting demand as much as possible through indigenous resources; and
- adding new and renewable sources (geothermal, solar, wind, etc.) as soon as possible to the energy supply system;

MENR:

- identifies projects for private power;

- selects (through tender or otherwise) and licenses companies to carry out those projects;

- negotiates for each project the terms of the contract that contains the license as well as the main principles for other Turkish project documents (most importantly the tariff for the purchase of power); and
- establishes the technical parameters for the design and construction of each project (Verrier and Yildirim, 1998).[3]

Turkey's environmental policies related to Global Climate Change and the limitation of CO_2 and other greenhouse gases include:

- economic assessment of environmental factors in energy fuel cycles, from production to consumption;

- support for R&D Programs on renewable energies to increase their utilization; and

[3] The role of MENR is reduced to licensing for Build-Operate (BO) projects.

- extended involvement in geothermal energy projects, supported by loans from the Ministry of Environment.[4]

MENR must license all forms of private power and approve all projects. Its approval initially takes the form of an approved feasibility study (for privately negotiated projects) or a tender award (for tendered projects). MENR has launched 13 tenders for 161 projects since 1996.

Turkish Electricity Generation and Transmission Corporation (TEAS)

State utility, TEAS, owns and operates 15 thermal and 30 hydroelectric plants which generate 91% of Turkey's electricity, and operates the country's transmission network at a voltage level of 66 kV and above. TEAS sells electricity to TEDAS and its companies, to private distribution companies, and to individual customers.

For generation projects, a contract with TEAS (an "Energy Sales Agreement") is required for the power

[4] Black Sea Regional Energy Centre (1997). "Black Sea Energy Review of Turkey." European Commission - Directorate General for Energy (DGXVII), The SYNERGY Programme, http://www.bsrec.bg/turkey/turkey_energyandenvironment.html

purchase. TEAS purchases the power generated or made available by the project company on a long term take-or-pay basis. Negotiations with TEAS are difficult and time-consuming (Verrier and Yildirim, 1998).

Supreme Administrative Court ("Danistay")

The license contract for all private power projects (with the possible exception of the license for the BO model) must be submitted to the Danistay for review and approval. In practice, this has meant delay and revisions to contract terms.

Law 3096 - "Granting Authorization to Institutions other than the Turkish Electricity Authority (TEK) for Generation, Transmission, Distribution, and Trade of Electricity" commonly known as the "Build-Operate-Transfer (BOT) Law" (December 1984)

The heart of private power legislation in Turkey is Law No, 3096 which is commonly referred to as the "BOT Law" although it actually provides the legal basis for all models of private power except the BO model (Verrier and Yildirim, 1998).

Passed in 1984, Law No. 3096 allows private sector companies, (in addition to TEAS and TEDAS), to generate, transmit, and distribute electric power in Turkey. In July 1998, a challenge to the Law by Danistay was overruled by the Constitutional Court Law.

Law No. 4446 (August 13, 1999)

The Turkish Parliament, by a large majority, amended the Turkish Constitution on August 13, 1999 to provide for privatization and international arbitration for concession contracts in which there is a foreign element. The amendment also stipulates that Danistay is charged with "providing opinions, within two months, on concession contracts and agreements in connection with public services" which should hasten the review process.

Law No. 4493 (December 20, 1999)

The new Enabling Law (No. 4493) now includes power projects in the BOT Law (No. 3096), specifically, "electric power generation, transmission, distribution and trading."

Current legal framework allows private companies to construct new power plants either under the BOT model introduced in 1984, the BO model introduced in 1996, or as Autoproducers. Private companies are also allowed to operate existing power plants by receiving their operational rights through a TOR.

Build-Operate-Transfer Model (1984)

The BOT generation model is the classic model in Turkey for private power generation. Under a BOT, the sponsor normally establishes a Turkish company to enter into a contract with MENR. This contract is referred to as the Implementation Contract, the Authorization Contract, or the Concession Contract. (The BO model does not include such contracts, only a short license.) The BOT model is based on a concession agreement and as such is subject to Danistay review and approval.[5] The debate over whether electricity is indeed a "public service" and to be delivered only on the restricted terms of a concession rages on even as blackouts become more frequent.

Under the BOT model, MENR licenses private Turkish companies (i.e., foreigners must establish Turkish project vehicles) to build and operate new generation facilities and to sell the electricity to TEAS for a license period that in practice has been about 20 years. The State owns the site and the plant, reducing therefore, the security that would normally be available to lenders, but the project company is granted a limited right of use that may be registered and mortgaged. At the end of the license period the plant must be transferred to the State (Verrier and Yildirim, 1998).

MENR prefers the BOT model for new hydropower projects. Geothermal projects are permitted under the BOT model as well.

5 The Turkish Constitutional Court held in a landmark decision in 1996 that the generation, transmission, and distribution of electricity constitutes a public service and, as such, private power projects are "concessions" (Verrier and Yildirim).

Build-Operate (BO) Model (1996)

MENR developed the BO model as an alternative for thermal projects to the BOT model, and in order to address some of the problems inherent in the BOT model. The BO model is based on commercial license agreements and contracts and is subject to international arbitration.

The BO model differs from the BOT model in that:

- There is no transfer of the plant to the State at the end of the license period;
- The Treasury guarantee is limited to TEAS's purchase obligations;
- Ownership of the plant belongs to the project company;
- The tendered terms of the Energy Sales Agreement are drastically less favorable than the earlier financed Energy Sales Agreements;
- Buyout of the project (e.g., in circumstances of force majeure or government default) is not apparently available;
- There is no support from the Electrical Energy Fund; and
- The license contract with MENR is replaced by a simple license from MENR (Verrier and Yildirim, 1998).

The BO model has been challenged by the Chamber of Electrical Engineers[6] which asserts that it is a concession rather than a contract. In July 1997, the Turkish Parliament passed a new BO law aimed at overcoming legal obstacles to private power ventures which provoked a further challenge form the Chamber. The BO model is currently under Constitutional review.

Autoproducers (Self-generators)

In the words of a MENR official, autoproduction projects are "just like a BOT, only quicker and simpler" (Verrier and Yildirim, 1998). Autoproduction is a simple, quick, and efficient way for a Turkish company in need of electricity to obtain a license to generate its own power and sell the excess.

Industrial companies, hospitals, and satellite towns having more than 5,000 accommodations may construct and operate electricity generation facilities for their own electricity needs. If the facility is constructed as an autoproduction group, the generated electricity and excess heat may be distributed to the other group members. Autoproducers' excess generation, which

6 The Chamber of Electrical Engineers is a quasi-public professional body that has been attacking many private power initiatives (Verrier and Yildirim, 1998).

cannot be consumed by the autoproducer, may be purchased by TEAS, TEDAS, or an assigned distribution company.

Making the process easier, both the Implementation Contract (with MENR) and the Energy Sales Agreement (with TEAS or TEDAS) which is used to sell surplus power, are standard forms which require little negotiation. The tariff for the sale of surplus power to TEAS or TEDAS and the wheeling charges for transporting the power are set by statute. The State is not concerned with the price at which the autoproducer sells it power to members of its group. Autoproducers are not limited in size although in practice their size has been between 5 and 20 MWe.

Transfer of Operational Rights (TOR)

Under a Transfer of Operational Rights (TOR), a private company receives a facility against a transfer fee and then manages, operates, maintains, invests, and finances the facility during the predetermined transfer term. At the end of the term, facilities are transferred back to the original owner without any cost or burden.

Electrical Energy Fund

Turkey has established an "Electrical Energy Fund" to help private power, at least BOT and TOR generation projects. It would provide funding to the project company during circumstances of force majeure. For several projects, it has agreed to pay the purchase price for the project if a "buyout" forces a sale to the State upon the occurrence of specified events such as prolonged force majeure (Verrier and Yildirim, 1998).

Proposed Legislation – Energy Market Law

The GOT is currently outlining new legislation, "The Energy Market Law," to liberalize and restructure the power sector. Under a draft of this legislation, energy production and distribution would be privatized, while transmission lines would remain state-owned. A new body, the Electrical Distribution and Centralized Services of Turkey, would be created which would supervise the overall system, and oversee TEAS and TEDAS. (TEDAS will most likely be disbanded after distribution lines have been privatized.)

The new firm would buy energy from producers and sell it to regional distributors at wholesale prices. It would also provide credit to the private sector and operate the subsidy mechanism. In the short-run, there will be a pool system comprised of central buyers and sellers of electricity, while in the longer-term buyers and sellers would act independently under free market conditions.

General Directorate of Foreign Investment

Turkey established the General Directorate of Foreign Investment as a central point of contact for foreign investors. Foreign firms enjoy the same rights and incentive treatment as domestic ones. Major power projects are given incentives including zero customs duty if an incentive certificate is obtained.

While Turkish government policies do not discriminate against foreign investment, all companies–regardless of ownership–are subject to the political uncertainties, excessive bureaucracy, and a sometimes unclear legal environment that prevails in Turkey. For instance, although the Turkish government strongly supports new foreign investment in Turkey's energy sector, successive court rulings have delayed many projects for years.

No Specific Law for Geothermal

Turkey has no specific laws for the development of geothermal resources.

Within the framework of the regulations prepared in accordance with the BOT Law (No. 3096), it is possible to commission local and foreign companies, having special legislative statues, for electricity generation, transmission, distribution, and trade with a geothermal power plant.

The General Directorate of Energy Affairs under MENR is responsible for the development of geothermal projects in Turkey. Studies on a "Draft Law for Geothermal Sources and Mineral Water" is currently being carried out under the coordination of MENR and other related corporations. These will be submitted to the National Assembly in the near future. There is already a law proposal in this regard submitted to the National Assembly as well.[7]

[7] Per a letter received from Cigdem Hatunoglu, Head of Department of Foreign Relations, the Ministry of Energy and Natural Resources, February 11, 2000.

GEOTHERMAL POWER & DIRECT USE POTENTIAL IN TURKEY

Site / Project Status	
2	Prefeasibility study
3	Feasibility study
4	Well(s) or hole(s) drilled
5	Construction underway
6	Power plant(s) on site
7	Direct use -- developed
8	Preliminary identification/report
9	Concession
10	Reconnaissance
11	Direct use -- undeveloped

Site / Project Name	Status	Direct Use Installed Capacity (MWt)	Direct Use Potential (MWt)	Power Generation Installed Capacity (MWe)	Power Generation Potential (MWe)
Afyon-Bolvadin-Gazligöl-Oruçöglu	7	29.2	107		
Afyon-Ömer-Gecek	7	2.6	2.6		
Afyon-Sandikli	7				
Ankara-Avas	7				
Ankara-Haymana	7	0.09	0.09		
Ankara-Kizilcahamam-Ayas-Mürtet-Çubuk	7	21	21		5
Ankara-Meliksah	4				
Aydin	4	30	174		

SITE / PROJECT NAME	STATUS	DIRECT USE INSTALLED CAPACITY (MWT)	DIRECT USE POTENTIAL (MWT)	POWER GENERATION INSTALLED CAPACITY (MWE)	POWER GENERATION POTENTIAL (MWE)
Aydin-Germencik	4				110
Aydin-Salvatli	4				
Balikesir-Gönen	7	37	37		
Balikesir-Havran	7				
Balikesir-Kepekler	8				
Balikesir-Sindirgi-Pamukçu	7		1.6		
Bingöl	8				
Bitlis-Nemrut	4				
Bursa	7		2.8		
Çanakkale-Ezine-Kestanbol	7	3.37	3.37		
Çanakkale-Hidirlar	8				
Çanakkale-Tuzla	4				
Denizli	2				
Denizli-Kizildere-Sarayköy	6			20.4	200
Denizli-Pamukkale-Yenice	8				
Denizli-Tekke Hamam-Karahayit	7				
Diyarbakir	8				
Erzincan-Ilica	7				
Erzurum-Dumlu	8				
Erzurum-Ilica-Pasinler	4				

SITE / PROJECT NAME	STATUS	DIRECT USE INSTALLED CAPACITY (MWT)	DIRECT USE POTENTIAL (MWT)	POWER GENERATION INSTALLED CAPACITY (MWE)	POWER GENERATION POTENTIAL (MWE)
Eskisehir	7				
Gazligöl	8				
Gözlek-Amasya	4				
Istanbul-Termal	8				
Izmir-Agamemnun	3				
Izmir-Balçova	7	62	62		
Izmir-Cesme	4				
Izmir-Dikili-Bergama	7	56	224		
Izmir-Seferihiser	7				6
Kayseri	8				
Kirsehir	7	18.25	83.25		
Kirsehir-Kaman	7				
Kirsehir-Karakurt	8				
Kirsehir-Mahmutlu	8				
Kirsehir-Terme	7				
Kütahya-Gediz	7	0.61	0.61		
Kütahya-Simav-Eynal-Citgöl-Nasa	7	68.2	100.4		
Kütahya-Yoncali	7	0.93	0.93		
Kuzuluk-Sakarya	7	11.2	11.2		
Manisa-Kursunlu	8				

Site / Project Name	Status	Direct Use Installed Capacity (MWt)	Direct Use Potential (MWt)	Power Generation Installed Capacity (MWe)	Power Generation Potential (MWe)
Manisa-Salihli-Alasehir	7	0.26	47.26		47
Manisa-Urganli	8				
Nevsehir-Acigöl	8				
Nevsehir-Kozakli	3		11.1		
Rize-Ayder	7	0.24	0.24		
Samsun-Havza	7	0.7	0.7		
Samsun-Kocapinar	7				
Seben	8				
Sicakçermik-Sivas	7	0.17	0.17		
Süleymanli	8				
Tokat Resadiye	3		7.16		
Tokat-Sulusaray	7				
Van-Zilan	4				
Yozgat-Bogazliyan	7				
Other – spa heating		285	285		
Other – greenhouses		78.9	78.9		
TOTALS		**705.72**	**1262.38**	**20.4**	**368**

Bulgaria
Black Sea
Russia
Georgia
Armenia
Az.
Greece
Straits of Bosporous
Sea of Marmara
Dardanelles
Iran
Turkey
Ankara
Istanbul
Edirne
Kirklareli
Kesan
Zonguldak
Karabük
Inebolu
Samsun
Carsamba
Ordu
Giresun
Rize
Trabzon
Artvin
Kars
Bursa
Bandirma
Canakkale
Balikesir
Bilecik
Adapazari
Eskisehir
Kutahya
Yozgat
Kirikkale
Kirsehir
Amasya
Tokat
Sivas
Erzincan
Erzurum
Karakose
Tunceli
Bingöl
Mus
Tatvan
Van
Van Gölü
Bitlis
Siirt
Batman
Kurtalan
Hakkari
Diyarbakir
Mardin
Nusaybin
Urfa
Akcakale
Adiyaman
Malatya
Elazig
Maras
Gaziantep
Iskenderun
Antakya
Tarsus
Eregli
Nigde
Nevsehir
Konya
Isparta
Burdur
Afyon
Usak
Manisa
Izmir
Aydin
Denizli
Mugla
Bodrum
Marmaris
Antalya
Karaman
Gazipasa
Silifke
Tuz Gölü
Mediterranean Sea
Nicosia
Cyprus
Lebanon
Beirut
Damascus
Syria
Iraq
0 200 km
0 200 mi
30°
36°
42°
40°
36°
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Geothermal Sites / Projects

Geologically, Turkey is composed of the Aegean and Anatolian plates which cover the western and central parts of the country. These plates are bordered in the north by the North Anatolian Fault Zone and in the south and east by the Ecemis Fault Zone, the Aegean Trench, and the Dead Sea-Eastern Anatolian Fault Zone. Tensional stress is typical for the Aegean and Anatolian plates (Geothermal Atlas of Europe, 1992).

Two east-west stretching elongated anomalies of high heat flow (over 80 mW/m²) run parallel to the coastlines of the eastern and western Black Sea. These anomalies are believed to be associated with the upper Cretaceous volcanic and igneous rocks in the east and metamorphic and igneous rocks in the west. Very high heat flow of up to 150 mW/m² is typical for the Paleozoic metamorphic rocks of the Menderes massif in the western part of Turkey where many boiling and hot water springs exist.

Turkey lies on the active Alpine-Himalayan Orogenic Belt, an important geothermal energy zone which is the scene of geologically recent volcanic activities and is characterized by acidic volcanism. The area has more than 600 hot springs with temperatures ranging from 25ºC to as high as 102ºC, fumaroles, and numerous other hydrothermal alteration zones. Geothermal manifestations are widely spread in western Anatolia, extending to the Sea of Marmara. Temperatures are higher in western Anatolia than in the highlands of eastern Anatolia.

The Alpine-Himalayan Orogenic Belt is composed of the Anatolian-Aegean cratonic plates pressed between the great Eurasian plate in the north and the Afro-Arabian plate in the south, both of which are divided into smaller plates. The borders of these smaller plates are zones of active fractures and constitute severe seismic areas. The area’s geological and tectonic evolution has been dominated by the repeated opening and closing of the Paleozoic and Mesozoic oceans (Dewey and Sengör, 1979; Jackson and McKenzie, 1988). Most of the neotectonic activities in Anatolia are caused by the northerly movement of the Arabian plate towards Eurasia (McKenize, 1972; Sengör, 1979).

Four Turkish volcanoes have been active during historical times–Mounts Kula, Erciyes, Nemrut, and Süphan (Kurtman and Sâmilgil, 1975). The area also experiences frequent earthquakes including the devastating earthquake on August 17, 1999 which was centered on Izmit and measured 7.4 on the Richter scale.

Grabens, thought to be important from a geothermal energy point of view, exist in western and central Anatolia. The most important are Menderes, Gediz, Seferihisar, Bergama, Tuzla, Manyas, Afyon, and

Kizilcahamam. Many hot water springs occur along the faults of the grabens.

Although not as important as the grabens, great active fault zones such as the east-to-west-extending Sindirgi-Gediz fault zone in western Anatolia, seems promising in terms of geothermal energy potential (Kurtman and Sâmilgil, 1975).

Turkey can be divided into four main geothermal regions:

1. western Anatolia,
2. the north Anatolian fault zone,
3. eastern Anatolia, and
4. central Anatolia.

Eastern and central Anatolia have been affected by upper Tertiary-recent volcanic activity (Simsek and Okandan, 1990).

In western Anatolia, a study conducted by the Mineral Research and Exploration Institute (MTA Institute) identified 123 hot springs and 36 geothermal areas. The 37 hot springs along the 1500-km north Anatolian fault are mainly used by local people for balneological purposes. Widespread young volcanism and hydrothermal alteration is observed and 44 hot springs occur in central Anatolia. In eastern Anatolia, seven geothermal areas have been identified.

Geothermal fluids encountered in Turkey can be classified chemically as 95% incrusting and two to three geothermal fields have highly corrosive geothermal fluids. In three of the 140 geothermal fields, geothermal fluid containing total dissolved solids (TDS) exceeds 5000 ppm. Turkish geothermal operators claim to have virtually overcome the consequences of scaling and corrosion in both high and low temperature wells, and scientific research continues.

Systematic geothermal exploration began in Turkey in 1961-1962 when the MTA Institute began an inventory of Turkey's hot springs. The inventory was followed by the development and implementation of geological and hydrogeological studies, magnetic maps, gravity studies, hydrochemical analysis, gradient drillings, and resistivity and seismic reflection methods. As a result of these studies, 14 geothermal areas were identified, primarily in western Anatolia. Turkey was divided into six geothermal regions which are being individually and systematically developed.

The first geothermal exploration drilling took place in 1963 in the Izmir-Balçova field, but the 124ºC fluid was not utilized for almost 20 years due to rapid scaling. Currently, the country's geothermal resources are primarily being used for heating, which accounts for over 90% of total direct use, greenhouses, and balneology.

As of 1995, Turkey's installed geothermal capacity was 159.67 MWt (23,000 dwellings equivalency) with 121.10 MWt (17,300 dwellings) under construction, feasibility studies completed for an additional 563.46 MWt (80,500 dwellings), and 1,420 MWt in natural springs or geothermal wells which are used for balneology and hot spring facilities.

Approximately 40,000 homes are heated with geothermal resources across Turkey. Geothermal energy provides the least expensive heat at a cost of 0.1-0.56 ¢/kWh heat for geothermal compared to 5.6 ¢/kWh for fuel-oil, 4.8 ¢/kWh for natural gas, and 3.9 ¢/kWh for coal (1994 prices) (Mertoğlu and Basarir, 1995).

The total proven geothermal direct use capacity of Turkey is 2,264.2 MWt (Mertoğlu and Basarir, 1995). Geothermal heat production capacity is expected to be 2,520 MWt in 2000 and 6,500 MWt by 2010.

The development of Turkey's high enthalpy geothermal resources for power generation lags far behind direct use applications. The country currently has only one operating geothermal power plant at Denizli-Kizildere (or Sarayköy-Kizildere) field where scaling has caused serious production problems. The plant has an installed capacity of 20.4 MWe. The plant also provides power to an enterprise which produces 40,000 tons of industrial food grade CO_2 annually.

In addition to Denizli-Kizildere, other fields in Turkey which have high enthalpy resources suitable for electric power generation are:

- Aydin-Germencik,
- Canakkale-Tuzla,
- Izmir-Seferihiser,
- Bitlis-Nemrut-Zilan-Suphan-Tendurek,
- Nevsehir-Acigöl,
- Aydin-Salvatli,
- Kütahya-Simav, and
- Izmir-Dikili-Bergama.

Turkey has extensive geothermal resources–4,000-4,500[8] MWe of power generation potential and 32,000 MWe of low enthalpy direct use resources, enough to heat five million homes.

Making greater use of Turkey's high and low enthalpy geothermal resources could significantly help combat serious pollution problems resulting from the use of

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8 According to the *Preliminary Report: Geothermal Energy, The Potential for Clean Power from the Earth*, Geothermal Energy Association, April 1999, Turkey's estimated geothermal potential electrical capacity is 1,380 MWe. The figure used is an estimate of annual electricity production using the Enhanced Technology High estimate.

fossil fuels for heating in many cities, and save foreign currency on natural gas imports. Turkey plans to generate 125 MWe from Germencik, Kizildere, Canakkale and several other fields by the year 2000, 150 MWe by 2005, and 258 MWe by 2010.

Data on the following geothermal sites in Turkey is included in the database:

1. Afyon-Bolvadin-Gazligöl-Oruçöglu
2. Afyon-Bolvadin
3. Afyon-Ömer-Gecek
4. Afyon-Sandikli
5. Ankara-Avas
6. Ankara-Haymana
7. Ankara-Kiziilcahamam-Ayas-Mürtet-Çubuk
8. Ankara-Meliksah
9. Aydin
10. Aydin-Germencik
11. Aydin-Salvatli
12. Balikesir-Gönen
13. Balikesir-Havran
14. Balikesir-Kepekler
15. Balikesir-Sindirgi-Pamukçu
16. Bingöl
17. Bitlis-Nemrut
18. Bursa
19. Çanakkale-Ezine-Kestanbol
20. Canakkale-Hidirlar
21. Canakkale-Tuzla
22. Denizli
23. Denizli-Kizildere-Sarayköy
24. Denizli-Pamukkale-Yenice
25. Denizli-Tekke Hamam-Karahayit
26. Diyarbakir
27. Erzincan-Ilica
28. Erzurum-Dumlu
29. Erzurum-Ilica-Pasinler
30. Eskisehir
31. Gazligöl
32. Gözlek-Amasya
33. Izmir-Agamemnun
34. Izmir-Balçova
35. Izmir-Cesme
36. Izmir-Dikili-Bergama
37. Izmir-Seferihiser
38. Istanbul-Termal
39. Kayseri
40. Kirsehi
41. Kirsehir-Kaman
42. Kirsehir-Karakurt
43. Kirsehir-Mahmutlu
44. Kirsehir-Terme
45. Kütahya-Gediz
46. Kütahya-Simav-Eynal-Citgöl-Nasa
47. Kütahya-Yoncali
48. Kuzuluk-Sakarya
49. Manisa-Kursunlu
50. Manisa-Salihli-Alasehir

51. Manisa-Urganli
52. Nevsehir-Acigöl
53. Nevsehir-Kozakli
54. Rize-Ayder
55. Samsun-Havza
56. Samsun-Kocapinar
57. Seben
58. Sicakçermik-Sivas
59. Süleymanli
60. Tokat Resadiye
61. Tokat-Sulusaray
62. Van-Zilan
63. Yozgat-Bogazliyan

Afyon-Bolvadin-Gazligöl-Oruçöglu

LOCATION
14 km northwest of Afyon (near 38.5º latitude, 30.2º longitude).

STATUS
Direct use -- developed

TEMPERATURE (°C)	48-97
INSTALLED CAPACITY (MWt)	29.2
POTENTIAL (MWt)	107

CHRONOLOGY

1966 - Work began to increase water supply.

1971 - In view of the proximity of the hot springs to the city of Afyon, efforts were directed towards heating the city. Detailed geologic studies, together with geochemical and geophysical work, led to drilling of wells.

1970 to 1974 - The MTA Institute drilled two exploratory wells (120 and 166 m) and AF-1, a production well (905 m). The temperatures and production rates of the exploratory wells were 82-86ºC and 20-29 l/sec. AF-1 had a well-bottom temperature of 106.5ºC, well-bottom pressure of 1195 psig at 900 m, production rate of 20 l/sec, and gas content about 0.350-0.375% CO2 by weight (Tan, 1975).

1975 - Second production well drilled.

November 1989 - Afyon-Õmer Thermal Facility with geothermal heating for a 35-room hotel, spas, and 5000 m²-greenhouses began operation; capacity of 2,200,000 kcal/h. Anti-scaling system installed which completely prevents scaling problems; total installed capacity is 2.60 MWt.

1994 - Afyon-Bolvadin hotel heating system began operating; total capacity is 900,000 kcal/h; 1.05 MWt.

NOTES

Afyon - installed capacity is 24.9 MWt.

Afyon-Bolvadin Hotel - heating system; installed capacity is 1 MWt.

Afyon-Gazligõl Thermal Facilities – 68ºC geothermal water with a capacity of 550,000 kcal/h (0.64 MWt) provides heat for 100 dwellings equivalency.

Afyon-Oruçöglu Thermal Resort Facilities – 48ºC water used for floor heating system as well as heat and hot water for hotel and curing center; total capacity is 2,350,000 kcal/h or 2.73 MWt.

Afyon – Feasibility study completed for geothermal heating of 10,208 dwellings (first stage) and hot water supply for 16,000 dwellings; total capacity is 107 MWt.

Afyon-Ömer-Gecek

LOCATION
North of Afyon (38.5º latitude, 30.2º longitude).

STATUS
Direct use -- developed

TEMPERATURE (°C)	79-160
INSTALLED CAPACITY (MWt)	2.6
POTENTIAL (MWt)	2.6

CHRONOLOGY
1974 - 2 wells drilled, AF-1 and R-260; encountered temperatures of 98ºC and 95ºC with flow rates of 19.80 and 48.02 kg/s respectively.

1975 - 2 more wells, AF-4 and 5, drilled; encountered temperatures of 97ºC and 95ºC with flow rates of 33.59 and 76.92 kg/s respectively.

1982 - 4 wells, AF-5, 6, 7, and 8, drilled; encountered temperatures of 79ºC, 92ºC, 97ºC, and 80ºC with flow rates of 9.80, 9.35, 22.22, and 9.80 kg/s respectively.

NOTES
The system provides heating for theÖmer Thermal Facilities – a spa-hotel, its recreational facilities, a 5000 m² greenhouse complex, bathing and swimming, and fish and other animal farming.

Geothermal fluid is found at an average depth of 120-200 m at a temperature of 98ºC. The flow rate was low due to rapid scaling. Downhole heat exchangers were installed.

Together with other chemical properties, spring waters having either an SiO_2 tenor of 150 mg/l or an rNA/rK ratio value of 20, indicate a hot water system of 160ºC (Kurtman and Sâmilgil, 1975).

Afyon-Sandikli

LOCATION
South of Afyon (near 38.5º latitude, 30.2º longitude).

STATUS
Direct use -- developed

TEMPERATURE (°C)	110
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES
Geothermal used for bathing and swimming and district heating.

Ankara-Avas

LOCATION
In central Turkey, northwest of Ankara.

STATUS
Direct use -- developed

TEMPERATURE (°C)	22-55
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1986 - Well A-1 drilled for direct heat utilization; encountered temperature of 31ºC with a flow rate of 45 kg/s.

NOTES
Well is pumped and used for bathing.

Numerous springs with temperatures between 22 and 55ºC are present in the northern, western, and southern parts of the region surrounding Ankara.

Ankara-Haymana

LOCATION
In central Turkey, southwest of Ankara.

STATUS
Direct use -- developed

TEMPERATURE (°C)	43-44
INSTALLED CAPACITY (MWt)	0.09
POTENTIAL (MWt)	0.09

CHRONOLOGY

1986 - 2 wells drilled, H-3 and H-4; encountered temperatures of 44ºC and 43ºC with flow rates of 1.50 and 52.00 kg/s respectively.

October and December 1988 - Floor heating for two mosques began operating; total capacity of 80,000 kcal/h.

NOTES
Geothermal is used for bathing and district heating.

Numerous springs with temperatures between 22 and 55ºC are present in the northern, western, and southern parts of the region surrounding Ankara.

Ankara-Kizilcahamam-Ayas-Mürtet-Çubuk

LOCATION
70 km northwest of Ankara; numerous hot springs, thermal alterations, and gas emanations exist; Mürtet graben is 40 km northwest of Ankara; Çubuk graben 30 km northeast; and Kizilcahamam graben 80 km north-northwest of Ankara (40.2º latitude, 32.4º longitude).

STATUS
Direct use -- developed

TEMPERATURE (°C)	50-195
INSTALLED CAPACITY (MWt)	21
POTENTIAL (MWt)	21

CHRONOLOGY
Ancient times - Spa in use since.

1984 and 1985 - 5 gradient wells were drilled; results indicated high geothermal gradients but no permeability was observed; wells MTA-1 (180 m) and KHD-1 (1556 m) encountered hot flowing fluid of wellhead temperatures of 75.5ºC and 86ºC and flow rates of 26 kg/s and 32 kg/s respectively.

1:25:000-scale geological mapping covering 4000 km² and 1:10:000-scale mapping covering 30 km² was completed; hydrochemical studies of about 80 water springs, gravity tests of 1000 locations, and resistivity tests on 1500 locations were also conducted. 8 gradient drillings and 3 deep wells were drilled.

First well drilled in the Çubuk Plain encountered water at 113-116 m with a temperature of 32ºC and a flow rate of 150 l/sec. Second well found water at 218-549 m with a temperature of 40ºC and a flow rate of 300 l/sec. Water sources were turned over to the State Water Works (DSI) to help meet local water requirements.

NOTES
Geothermal used for bathing and swimming and

district heating.

Resource is currently used for heating the Kizilcahamam Thermal Hotel with a capacity of 65,000 kcal/h, a 1400 m² greenhouse, and for balneological purposes.

The existence of a geothermal fluid of 90ºC temperature at Çubuk, only 30 km from Ankara, will make possible geothermal district heating which would decrease air pollution.

Power generation is considered at Kizilcahamam where hydrogeochemical studies indicate that a reservoir temperature of 195ºC is expected (Kurtman and Sâmilgil, 1975).

Two wells are rented to Ege Energy by MTA to build a 5 MWe binary power plant, using the waste water for greenhouses and other direct use applications. The company has a partner from Germany (Günerhan, 1999).

Ankara-Meliksah

LOCATION
In central Turkey.

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	22-55
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1974 and 1975 - 2 exploratory wells drilled, MH-1 and MH-1A; encountered temperatures of 32ºC and 43ºC and a flow rate of 35.00 kg/s for MH-1A. Both wells were artesian.

NOTES
Numerous springs with temperatures between 22 and 55ºC are present in the northern, western, and southern parts of the region surrounding Ankara.

Aydin

LOCATION
In western Anatolia about 100 km west of Kizildere in the western part of the Büyük Menderes graben; located in the same graben and in a similar geologic environment as the Kizildere field.

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	216-232

INSTALLED CAPACITY(MWt)	30
POTENTIAL (MWt)	174

CHRONOLOGY
1985 and 1986 - 3 exploration wells (ÖB-7, ÖB-8, and ÖB-9) drilled to 1464-2398 m; encountered temperatures of 220-227ºC and flow rates of 35-99 kg/s.

NOTES
Aydin is the province with the most geothermal resources in Turkey.

A feasibility study for one of the largest geothermal district heating systems in Europe has been completed. It would provide heat for 18,000 dwellings; air-conditioning and hot water for 3,500 dwellings; 200,000 m² of greenhouses; and 22 MWt industrial process heat utilization (Mertöglu and Basarir, 1995).

Due to its high temperatures, the field has electric power generation potential as well which has not been assessed to date.

Aydin-Germencik

LOCATION
In western Anatolia about 100 km west of Kizildere in the western part of the Büyük Menderes graben; located in the same graben and in a similar geologic environment as the Kizildere field.

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	90-232
INSTALLED CAPACITY (MWe)	—
POTENTIAL (MWe)	110

CHRONOLOGY
1982 - Exploration began.

1985 and 1986 - Field studies on geology, geophysics, and geochemistry were conducted by the MTA Institute; 3 new exploration wells were drilled in addition to existing 6 wells; ÖB-7, ÖB-8, and ÖB-9 were drilled to 1464-2398 m and encountered temperatures of 220-227ºC and flow rates of 35-99 kg/s. Water flow was observed from two different layers. The deeper formation exhibiting higher temperatures (216-232ºC) is a marble-quartzite.

NOTES
Aydin is the province with the most geothermal resources in Turkey.

Field is under evaluation for the installation of two 55 MWe plants. Discharge fluid could be used for district heating, greenhouses, agricultural drying, and industrial uses. Ormat International has an agreement to develop the resource.

Although the rNa/rK ratio of 22.5 indicates a reservoir temperature of only 160ºC, springs cropped directly from the metamorphics in the neighboring area have an rNa/rK ratio of 9.5 which indicates a reservoir temperature of 260ºC. The SiO_2 tenor of 230-280 mg/l indicates a reservoir temperature of 180-200ºC (Kurtman and Sâmilgil, 1975).

Aydin-Salvatli

LOCATION
In western Anatolia in the middle part of the Büyük Menderes graben; west of the Germencik, Kizildere, and Denizli fields (37.5º latitude, 28.1º longitude).

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	42-200
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1987 and 1988 - 2 exploration wells drilled (AS-1 and AS-2) to 962 and 1510 m; encountered temperatures of 162ºC and 171ºC with variable degrees of permeability.

NOTES
Proposed utilization of this source is for agricultural purposes, space heating, and balneology, although temperatures are high enough to consider power generation as well.

Geophysical studies carried out by the MTA Institute showed a step-fault structure which is also characteristic of the Germencik and Kizildere fields.

Mineral paragenesis indicates a 200ºC reservoir temperature (Karamanderesi and others, 1989) which is higher than the temperatures measured in wells AS-1 (162ºC) and AS-2 (171ºC).

Balikesir-Gönen

LOCATION
In northwestern Turkey about 30 km south of the Marmara Sea (40.0º latitude, 27.4º longitude).

STATUS
Direct use -- developed

TEMPERATURE (°C)	74-100
INSTALLED CAPACITY (MWt)	37
POTENTIAL (MWt)	37

CHRONOLOGY

1964 - The first direct use of geothermal resources in Turkey was heating the Gönen Park Hotel (Balikesir).

1976 and 1977 - 2 exploratory wells drilled for direct heat utilization, G-1 and G-2; encountered temperatures of 74ºC and 78ºC with flow rates of 14 and 20 kg/s respectively; wells are artesian.

1976 to 1978 - Heating of the Yildiz Hotel began by the Gönen Kaplicalari Isetmesi Inc. with a total capacity of 1200 kcal/h.

1985 - Third well, G-3, drilled for production to 308 m; encountered temperature of 74ºC and a flow rate of 26 kg/s.

April 1987 - System began operating.

1987 to 1994 - Geothermal waste water with a temperature of 40ºC was discharged to natural sources

1994 to present - A former production well (110 m) was adapted to be used for reinjection. Waste water is pumped with 1 bar pressure into the reinjection well. Since reinjection began, the dynamic water level has increased by 20 meters and no temperature decline has been noted. The flow rate is 80 l/sec and the average temperature is 80ºC.

Downhole pumps have been installed in the geothermal wells at a depth of 50 m. During the winter time, the water dynamic level reaches about -45 m. Since reinjection, however, the dynamic water level now reaches -25 m. Wellhead heat exchanger average inlet and outlet temperatures were reported as 70ºC and 45ºC (Mertoğlu, 1990).

NOTES

Gönen was Turkey's first geothermal district heating system. 1,500 dwellings, 2000 m² greenhouse, 600-bed hotel, and the hot water processing are heated geothermally with 16.2 MWt capacity. Industrial utilization include a glue factory, rubber factory, and 60 leather processing sites.

Each dwelling paid US$15 per month in 1994 for heat and hot water. Total heat costs in million kcal of geothermal heat as of March 1993 was US$ 2.2 (9500 Turkey Lira = US$ 1).

Balikesir-Havran

LOCATION

In northwestern Turkey about 30 km south of the Marmara Sea (40.0º latitude, 27.4º longitude).

STATUS

Direct use -- developed

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal used for greenhouses and bathing and swimming.	

Balikesir-Kepekler	
LOCATION In northwestern Turkey about 30 km south of the Marmara Sea (40.0º latitude, 27.4º longitude).	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	62-125
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES	

Balikesir-Sindirgi-Pamukçu	
LOCATION In northwestern Turkey about 30 km south of the Marmara Sea; 60 km southeast of the city of Balikesir (39.1º latitude, 28.1º longitude)	
STATUS Direct use -- developed	
TEMPERATURE (°C)	57-150
INSTALLED CAPACITY (MWt)	1.6
POTENTIAL (MWt)	1.6
CHRONOLOGY 1986 - Geothermally heated 2000 m² greenhouse began operation; system capacity is 45,000 kcal/h. 1989 - TPAO in a joint venture with Unocal drilled exploration well Hisaralan-2 to a depth of 881 m. 1995 - Geothermal heating of Balpas thermal facilities; under construction. Location of hot springs with temperatures of 98ºC and flow rates up to 50 kg/s.	
NOTES Geothermal used for greenhouse heating. Neogene-aged volcanics are widespread in this area.	

Bingöl

LOCATION
In central-eastern Turkey.

STATUS
Preliminary identification/report

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES

Bitlis-Nemrut

LOCATION
North of Lake Van in eastern Anatolia (38.3º latitude, 42.1º longitude).

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	250
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1441 - Youngest volcanic activity in Turkey occurred in this area; hot fumaroles and hot springs are widespread.

1987 and 1988 - TPAO drilled 5 exploration wells in a joint venture with Unocal (Nemrut 3, 4, 5 and 7, 8) to depths of 527-1465 m; 250ºC estimated.

NOTES
The MTA Institute conducted geological, geophysical, and geochemical studies; identified a 4 km-diameter caldera.

Bursa

LOCATION
To the south of the Marmara Sea at the northern slope of Mount Uludag (2543 masl), the highest mountain in western Turkey. Bursa was the first Ottoman capital (1326-1451) and has a population of over 800,000.

STATUS
Direct use -- developed

TEMPERATURE (°C)	52-111
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWe)	2.8

CHRONOLOGY

Under the Ottoman Empire -The use of thermal water in Kükürtlü developed.

16th century - The Yeni Kaplica ("new public bath") which uses water from the Bag spring, was built; is still in use today.

1989 - The Swiss Federal Institute of Technology (ETH Zurich) conducted the multidisciplinary MARMARA project which involved the study of tectonics, geology, hydrogeology, seismology, geodesy, and geothermal prospects in the Marmara Sea region. Installed 14 Global Position Systems (GPS) stations. Study showed that the slip-strike movements of the North Anatolian Fault System and its more extensional regime in the westernmost part still affect the Bursa area (Straub, 1996; Schindler, 1993; Eyidogan et al, 1991).

Evaluation of the GPS data resulted in a deformation field that clearly shows that the main tectonic activity of dextral strike-slip type takes place along the northern strand of the North Anatolian Fault, from the Mudurnu valley passing through the Marmara Sea to the Gulf of Saros. The displacement rates are 17 mm/a on average, with a gradual increase from east to west (16 to 18 mm/a). Realistic horizontal errors are in the range of 4 mm/a (Straub and Kahle, 1994, 1995).

NOTES

The Bursa thermal waters at Çekirge and Kükürtlü are used for bathing and medicinal purposes. Due to the differences in water temperature and chemistry the two thermal water resorts have developed in different ways.

In Çekirge low salinity thermal water flows from four springs and from some shallow excavations and boreholes within the Neogene unit. The temperature varies only slightly, from 46ºC (TDS ~ 504 mg/L) at the highest elevation to 31ºC (TDS~485 mg/L) in lower parts of the district. Bathing at Çekirge dates back to 500 A.D. A well-organized health resort has been established. A common water distribution system shared by private and public rehabilitation centers controls the use of thermal water in this district. The amount of water flowing from the two main natural outflows, Vakifbahçe (Vak) and Zeyni'nene (Zey), the hottest springs, ranges from 700 to 1700 m^3 per day.

The gas composition of both thermal water types is dominated by CO_2 and N_2. The gas from the hottest water in the Çekirge district is made up of CH_4 (0.02 vol. %), N_2 (39.2%). Ar (0.90%), and CO_2 (59.9%). In Kükürtlü, it consists of CH_4 (0.01 vol. %), N_2 (10.4%), O_2 (0.55%), Ar (0.26%), and CO_2 (88.8%).

Using the chaldeony geothermometer, Çekirge has a minimum reservoir temperature of 52ºC; Kükürtlü about 111ºC.

In Kükürtlü, two kilometers east of Çekirge, thermal water flows out within a small travertine complex which covers a tectonic contact.

Temperature and mineralization of the Kükürtlü thermal water vary within the location from 82ºC (TDS~1210 mg/L) at the highest elevation of the travertine complex at the Bagdemlibahçe (Bag) spring to 50ºC (TDS~1088 mg/L) at the shallow excavations and boreholes close to the plain. Between 150 to 400 m³ of water flows from the Bag spring per day.

To date, the geothermal power potential of the thermal waters has not been fully explored. The 80ºC water at Kükürtlü which is cooled to 40ºC by the addition of cold water, could generate 0.8 MWe with the use of heat exchangers. The total geothermal potential of Çekirge is about 2 MWe (Imbach, 1997).

Çanakkale-Ezine-Kestanbol

LOCATION
In northwest Anatolia north of Tuzla.

STATUS
Direct use -- developed

TEMPERATURE (°C)	73-174
INSTALLED CAPACITY (MWt)	3.37
POTENTIAL (MWt)	3.37

CHRONOLOGY
1976 - 1 exploration well drilled, K-1 for direct heat utilization, encountered temperature of 73ºC with a flow rate of 20 kg/s; well is artesian.

Geological studies carried out on a 1:25:000 scale over 1200 km² and 1:10:000 scale over 90 km², along with hydrochemical analyses, gravity and resistivity measurements, and 8 gradient drillings. Hot water was encountered in 2 of the drillings; in 2 others, hot water and steam with blow out were found.

1982 - 4 additional wells drilled; first well encountered temperature of 174ºC at 333-553 m in volcanic rocks; second well drilled to 1020 m encountered temperature up to 174ºC but low permeability; two shallow wells (81 and 128 m) encountered temperatures of 146ºC and 165ºC respectively. Plans are to drill another well to test suspected deep resources.

1995 - Geothermal heating Kestanbol thermal facilities under construction.

NOTES

Geothermal used for greenhouses and bathing and swimming. The high temperatures also indicate the potential for electric power generation.

Çanakkale and Kestanbol are Turkey's main balneological centers.

Canakkale-Hidirlar

LOCATION
In northwest Anatolia northeast of Tuzla.

STATUS
Preliminary identification/report

TEMPERATURE (°C)	80-150
INSTALLED CAPACITY (MWe)	—
POTENTIAL (MWe)	—

CHRONOLOGY

NOTES

Canakkale-Tuzla

LOCATION
In northwestern Anatolia 80 km south of Canakkale and 5 km from the Aegean Sea.

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	102-215
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1982 and 1983 - 2 exploration wells drilled, T-1 and T-2 with temperatures of 173ºC and 171ºC. T-1 is 814 m deep and produced a steam and hot water mixture from the first reservoir in the depth range of 333-553 m in volcanic rock with a temperature of 173ºC, a production rate of 130 t/h and steam content of 13%.

Geological studies carried out on a 1:25:000 scale over 1200 km² and 1:10:000 scale over 90 km², along with hydrochemical analyses, gravity and resistivity measurements, and 8 gradient drillings. Hot water was encountered in 2 of the drillings; in 2 others, hot water and steam with blow out were found.

NOTES
This field could ideally be used for agricultural purposes as well as power generation.

The field is characterized by geyser-type springs with 20 l/sec of total debit and a temperature of 102ºC, with wide alteration zones of special silicification and limonitization.

The area is very interesting from a hydrogeochemical viewpoint. The total salinity reaches 61,000 mg/l which is approximately twice the concentration of sea water. The amounts and ratios of Mg, Mg/Ca, Na/Ca, Cl/F, and Cl/HCO_3 indicate a hot water system. The rNa/rK ratio of 13 indicates a reservoir temperature of ~215ºC while a low SiO_2 tenor (56-100 mg/l) points to lower temperatures of 130-150ºC (Kurtman and Sâmilgil, 1975).

Denizli

LOCATION
In western Anatolia 31 km south of Kizildere

STATUS
Prefeasibility study

TEMPERATURE (°C)	40-147
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1968 - The MTA Institute began exploring the Denizli area.

September 1986 to July 1987 - Virkir Consulting Group, Inc. conducted a prefeasibility study for a district heating system for the city of Denizli. The source of energy is the effluent water from the 20.4 MWe Kizildere geothermal power plant. Main issue is how to deal with the scaling properties of the effluent water.

The Denizli Geothermal District Heating System was not proven to be economical.

The study also concluded that there appears to be a high risk of siliceous deposits from the water by cooling below about 100ºC. Tests are needed to find a way to delay or decrease precipitation or the extent of scaling by a retention tank before entering the supply pipe. The pilot plant would test the use of scale inhibitors, variation of pressure, temperature, and retention time in both a system with direct heating and a heat exchange plant heating system (Lindal and Kristmannsdóttir, 1989).

NOTES
A prefeasibility study of the Denizli Geothermal District Heating System has been completed. The system, which would have a heating capacity of 25,000-35,000 dwellings, will be integrated into the Kizildere Geothermal Power Plant.

Denizli would use the 147ºC waste geothermal water from the plant which has an average flow rate of 1,000 tons/h. The fluid has been discharged since 1984 to the Menderes River.

The Denizli Geothermal District Heating Systemwas not proven to be economical.

Denizli-Kizildere-Sarayköy

LOCATION
In western Anatolia in the northeastern extreme of the Büyük Menderes graben, an important tectonic structure of Quaternary age, where it intersects the Gediz and Çürüksu grabens in western Turkey. Situated on a Neogene-filled basin surrounded by high topographic level metamorphics of the Menderes massif, north of the east-west trending Büyük Menderes graben. Area, which extends from east of Çubujdag town (Kuyucak, Aydin) to Sarayköy and Buldan towns (Denizli) covers approximately 650 km² (Denizli province).

This area is a first degree earthquake zone; annual average vertical displacement is about 2.4 cm. The latest volcanic eruption took place 12,000 years B.P. (Ercan, 1979).

STATUS
Power plant(s) on site

TEMPERATURE (°C)	148-240
INSTALLED CAPACITY (MWe)	20.4
POTENTIAL (MWe)	20.4-200

CHRONOLOGY
1966 - Geological, geophysical, and geochemical studies carried out with support of the United Nations Development Programme (UNDP); included a gravity survey which covered an area of 1500 km². Studies showed the existence of two large low-resistivity areas located parallel to the extension of the hot-water manifestations of Kizildere and Tekke Hamam, on the northen and southern parts of the Büyük Menderes River.

Main, lower reservoir is in the marbles of metamorphics 34with a depth of 400-1100 m and a temperature of 200ºC; upper second reservoir is in the fractured components (limestones, siltstones, conglomerates, etc.), has a depth of 300-800 m, and a temperature of 170ºC.

1967 - Geothermal gradient measurements were taken and 15 deep test and development holes drilled. Found two reservoirs: the Neogene reservoir (300-800 m) has a temperature of 165-175ºC; the lower, main reservoir (400-1100 m) in the marbles has a temperature of 195-205ºC. Limestones of Miocene age with temperatures of 196-200ºC and moderate permeability, and a few hundred meters deeper, marbles of Paleozoic age with temperatures of 200-212ºC and high permeability. Deeper reservoir in micashist, quartzites, and gneisses of Paleozoic age with higher temperatures of 235-240ºC is predicted (Serpen and Gülgör, 1995a). Na/K temperatures of 221-229ºC (Guidi et al, 1990).

Hot waters in Kizildere have high concentrations of Na, HCO_3, B, and F, indicating a metamorphic origin for the waters. All the hot waters in the Menderes graben have approximately constant B/Na ratios (Kurtman and Sâmilgil, 1975).

1968 - First well, KD-1, drilled to 540 m in a limestone reservoir produced a water-steam mixture with a temperature of 198ºC, tapped a liquid-dominated reservoir with 1.5-2% CO_2. A deeper marble zone with temperatures of 200-210ºC was found by drilling 6 more wells; 16 wells drilled between 1968 and 1973 by the MTA Institute. Geochemical survey indicated maximum temperatures of 220-240ºC.

The geothermal fluid produced from the deep wells is saturated with CO_2. Steam separated at 5 bars contains 15% CO_2 by weight. The calculated saturation pressure of this fluid at 200ºC is 62.4 bars (Okandan, 1990). CO_2 content is 10-20% with an average of 13% at the inlet of the turbine.

The thermal waters of wells KD-1A, KD-6, KD-9, KD-13, KD-14, and KD-16 exhibit sodium bicarbonate composition.

1972 - First long-term production test conducted.

1974 - The MTA Institute built and installed a small 0.5 MWe pilot plant. With the assistance of the UN and the Ministry of Agriculture, the MTA Institute set up a pilot greenhouse.

1976 - Second long-term production test conducted.

February 1984 - 20.4 MWe single flash power plant began operation; constructed by GIE, Italy for the Turkish Electricity Authority (TEK). 2.6 MWe of the gross capacity is used by the gas-compressor-extractors coupled directly to the turbine which results in 18 MWe net energy input into the national interconnected power grid (Okandan and Polat, 1986).

The two-phase steam and water mixture produced from the 6 wells at 15 kg/cm² well-head pressure and 196-207ºC temperature is separated in well-head separators. The water separated is drained and used for heating the buildings and the greenhouse constructed near the field. The field yields a hot water-steam mixture which is flashed to 4 bar to obtain steam. This results in 90% waste water (1500 m³/h), with a pH value of 8.9 and high HCO_3 content, requiring a treatment method for its safe disposal.

The plant was initially fed by 6 production wells: KD-6, 7, 13, 14, 15, and 16, producing a total of approximately 1600 t/h of geothermal fluid. Three more wells (KD-20, 21, and 22) were drilled to increase the steam production. The field has generated an average net power of 7.5 MWe.

1984 to 1990 - Power plant production decreased due to $CaCO_3$ scaling in the wells and reservoir; periodic cleaning of the well bores in 3 to 6 month intervals helped. However, decline to well flow rates even after cleaning, indicate either a decrease in productivity index due to scaling in fractures or due to a rapid decline in reservoir pressure due to insufficient recharge and strong interference between wells (Okandan, 1988).

1985 and 1986 - 3 additional production wells KD-21, KD-20, and KD-22 drilled to 892 m, 810 m, and 887 m respectively to supplement declining production rates. Encountered temperatures of 201-204ºC and flow rates of 45.8-58.6 kg/s.

According to the SiO_2 and Na-K-Ca geothermometers a third reservoir with expected temperatures of 250-260ºC may exist in the field (Simsek, 1985).

1986 - KARBOGAZ Company producing 40,000 tons of industrial food grade CO_2 and dry ice began operation.

End of 1989 - TEK announced that power output had declined to a very low level and cleaning in wells would start soon. On the average, wells show 50% yearly decline (Okandan, 1988).

1988 to 1994 - Northernmost wells have higher temperatures; KD-14, 15, and 16 have undergone evaporation. KD-13 has undergone first steam condensation and then boiling, ending in the same position after 10 years. KD-20 and 22 show the same boiling trend as neighboring wells KD-14, 15, and 16. Boiling may not be sustainable and are intermittent probably due to long shut downs of the power plant for periodic scale removal.

1990 - TEK and the Italian Electrical Company (ENEL) began a project to minimize calcium carbonate scaling, dispose of waste water, and assess the horizontal and vertical boundaries of the geothermal field in order to optimize its economical exploitation.

Extensive calcium carbonate scale deposition required frequent cleaning until use of the scale inhibitor Dequest 2066 was begun. Though detailed information regarding the outcome of the scale inhibition has not been reported, scale is claimed to now be minimal.

1994 - Total dissolved solids (TDS) of the geothermal fluid declined by 5% after a decade of exploitation. The degree of hot and cooler water mixing has changed slightly. Reservoir temperatures did not decrease.

The waste brine is discharged into the nearby River Büyük Menderes which is used for irrigation and has a minimum flow rate of 80,000 m^3/h. High silica content of approximately 290 ppm complicates reinjection and high boron content of roughly 30 ppm restricts discharge to the river. The boron content of the river water must be kept to below 1 ppm which is the maximum permissible concentration for the irrigation of boron-sensitive plants. The boron selective resin Amberlite IRA 743 boron removal method is estimated to increase electricity production cost (includes capital and O&M) by 1¢/kWh (Recepoglu and Beker, 1991).

NOTES

The capacity of the plant was limited to 20 MWe to maintain the boron concentration below 1 mg/1 in the Menderese River, due to the high concentration of boron (~25 ppm) in the discharge water. Utilization of the 150-200 MWe total potential of the field is directly dependent on solving the boron problem.

The next geothermal power plants planned for this field will be double-flash cycle with 55 MWe capacities since these are optimum in terms of cost and specific steam consumption (Okandan and Polat, 1986).

Because of its chemical properties, the geothermal fluid is used by Sarayköy Pamuklu Sanayii (Sarayköy Textile Industries) for bleaching materials. Because of the brilliant white obtained with the waste geothermal fluid, textiles produced with material washed in this way are in wide demand in foreign markets . Utilization of geothermal fluid is also cheaper than the chemicals normally used in other bleaching processes (Simsek, 1985).

Geothermal energy is also used for power generation, greenhouses (5000 m^2), and industrial process heat.

Studies for heating the city of Denizli with discharge fluid (140ºC) from the power plant are underway.

Research has been conducted to remove noncondensable gases from geothermal steam upstream from the turbine to decrease the compressor consumption and increase power plant efficiency. A bench scale experimental unit was set up and tested in the field (Günerhan and Coury, 1999).

MTA is working on boron recovery in the field as well.

Denizli-Pamukkale-Yenice

LOCATION

In western Anatolia

STATUS
Preliminary identification/report

TEMPERATURE (°C) 36

INSTALLED CAPACITY (MWt) —

POTENTIAL (MWt) —

CHRONOLOGY

NOTES

Denizli-Tekke Hamam-Karahayit

LOCATION
In southwestern Anatolia south of the east-west trending Büyük Menderes graben; situated on a Neogene-filled basin surrounded by high topographic level metamorphics of the Menderes massif.

STATUS
Direct use -- developed

TEMPERATURE (°C) 70-232

INSTALLED CAPACITY (MWt) —

POTENTIAL (MWt) —

CHRONOLOGY
1966 - Geological, geophysical, and geochemical studies carried out with support of the United Nations Development Programme (UNDP). Studies showed the existence of two large low-resistivity areas located parallel to the extension of the hot-water manifestations of Kizildere and Tekke Hamam, on the northern and southern parts of the Büyük Menderes River.

1967 - Geothermal gradient measurements and 1 deep test and development hole (TH-1) drilled to 700 m; produced steam-water mixtures from the metamorphic reservoir; temperature of 116ºC; flow rate is only 0.05 l/s; outlet temperature is 69.5ºC; gas emission is strong. TH-1 has a Na/K temperature of 232ºC.

NOTES
Geothermal used for greenhouses (3000 m²) and bathing and swimming.

Spectacular and widespread hot springs with temperatures up to 100ºC and a total discharge of approximately 20 l/s are located at Tekke Hamam. The hot springs show variable sodium bicarbonate sulfate to sodium sulfate bicarbonate composition and TDS between 0.08 and 0.12 eq/l.

Tekke Hamam waters could originate from the Kizildere waters through leaching of calcium sulfate from the Neogene sediments, upon cooling, and subsequent precipitation of calcium carbonate, upon CO_2 loss (Guidi et al, 1990).

Diyarbakir

LOCATION In southeastern Turkey, southwest of Nemrut.	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES	

Erzincan-Ilica

LOCATION In the earthquake risk area along the active north Anatolian fault (35.4º latitude, 39.3º longitude).	
STATUS Direct use -- developed	
TEMPERATURE (°C)	30-40
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1985 - Exploration well E-1 drilled to 601 m; encountered temperature of 30-40ºC and flow rate of 11-12.5 kg/s. 1988 - TPAO drilled 2 exploration wells (Erzincan-1 and 2) to 799-801 m.	
NOTES Several 30ºC hot water and mineral water springs exist in this area and are used for balneology.	

Erzurum-Dumlu

LOCATION In northeastern Turkey north of Nemrut (near 39.4º latitude, 41.1º longitude).	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	37
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES	

Erzurum-Ilica-Pasinler

LOCATION In northeastern Turkey northeast of Erzurum (39.4° latitude, 41.1° longitude).	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	38-80
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1985 - Exploration well, ED-1, drilled to 605 m; encountered temperature of 48°C with a flow rate of 6 kg/s; 60°C estimated.	
NOTES	

Eskisehir

LOCATION In western Anatolia northeast of Kütahya (near 39.0° latitude, 28.4° longitude).	
STATUS Direct use -- developed	
TEMPERATURE (°C)	36-80
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1986 - 2 wells drilled, E-2 and E-3; encountered temperatures of 36°C and 45°C with flow rates of 6 kg/s for both.	
NOTES Geothermal used for bathing and swimming and district heating.	

Gazligöl

LOCATION In western Anatolia north of Afyon-Ömer-Gecek.	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES	

Gözlek-Amasya

LOCATION 20 km southwest of the city of Amasya (40.3º latitude, 35.4º longitude).	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	42-50
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1987 - 1 exploration well drilled to 400 m is producing water with a 10.5 kg/s flow rate; 42ºC wellhead temperature.	
NOTES	

Istanbul-Termal

LOCATION In northeastern Turkey north of the Sea of Marmara.	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	65
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES	

Izmir-Agamemnun

LOCATION In western Anatolia (near 38.2º latitude, 27.0º longitude).	
STATUS Feasibility study	
TEMPERATURE (°C)	110
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1962 - Combined geophysical studies of hot-water areas begun in order to develop geothermal field.	
NOTES Feasibility study completed for the geothermal heating of 25,000-34,000 dwellings, air-conditioning for 5,000 dwellings, and hot water. The geothermally-heated sea water will be piped 46	

km through 5 pumping stations. By using small diameter pre-insulated epoxy fiberglass pipes for the pipeline, only 5ºC/km will be lost. The heating system will be cyclic with 70/40ºC clean water.

The treated sea water will be piped 5800 m to the Cumali geothermal field and production wells. In this area, titanium plate type heat exchangers will be used. The sea water will pass through the 500 mm-diameter pipeline at a temperature of 110ºC and a total flow rate of 2330 m³/h. The annual average flow rate will be 168 l/sec.

Air conditioning will be produced using ammonia or lithium bromide absorption units.

Four reinjection wells with an average depth of 500 m will be located approximately 4 km from the production wells. Downhole pumps, wellhead pumping stations, and the heat exchange system will connected and controlled by a special radio control system which will adjust for the outside temperature and loading factor.

Process heat utilization for industries located on the path of the main network (110ºC of sea water, 105ºC clean water) supply will also exist (Mertoğlu and Basarir, 1995).

Izmir-Balçova

LOCATION
In western Anatolia; the wells and facilities are located 11 km southwest of the city of Izmir (38.2º latitude, 27.0º longitude).

STATUS
Direct use -- developed

TEMPERATURE (°C)	72-124
INSTALLED CAPACITY (MWt)	17.8
POTENTIAL (MWt)	17.8

CHRONOLOGY
1962 and 1963 - Resistivity, thermal probing, and self potential surveys conducted (the first time a geothermal area received systematic, scientific delineation in Turkey); 3 wells drilled including the first geothermal exploratory well in Turkey. First well (S-1) drilled produced a mixture of hot water and steam at 124ºC at a depth of 40 m. S-2 and S-3/A were drilled to 100 m and 140 m, with downhole temperatures of 102ºC, and 101ºC respectively. S-3/A did not flow.

The single hot water manifestation, a spring, had a temperature of 72ºC. The survey revealed a fault zone delineated by low resistivity and huge temperature closures under 30-50 m-thick alluvium.

Due to the high carbonate content and rapid scaling, the field could not be used until 1981-82.

1981 to 1983 - 16 wells, including 7 thermal gradient and 9 production wells (100-150 m), were drilled; encountered temperatures of 50ºC to 126ºC with flow rates of 4-20 kg/s. Downhole heat exchanger were used for the first time.

1982 - System of geothermally heated hotels, curing center, swimming pools, and hot water began operation; 9 wells produce 4,500,000 kcal/h for surrounding hotels, buildings, and greenhouses.

1983 - Geothermal heating for Dokuz Eylül University, Medical Facility Campus and Hospital Building (~ 30,000 m²) with a total capacity of 2.2 MWt began operation. Payback time on investment was 6 months.

February 1987 - Heating for Turkey's largest indoor swimming pool began operation; capacity of 1,600,000 kcal/h.

1989 - 2 new wells (B-10 and B-11) drilled to 125 m; encountered temperatures of 109ºC and 114ºC and flow rates of 5 kg/s and 3 kg/s.

September 1989 - Geothermal heating of a 11,000 m² curing center began operations with a capacity of 1,200,000 kcal/h.

February 1992 - Heating system for an additional 110,000 m² (1100 dwellings) plus hot water for the Medical Faculty Hospital at Dokuz Eylül University was installed.

November 1992 - Additional system with capacity of 6,900,000 kcal/h (9.3 MWt) began running.

NOTES
Geothermal used for greenhouses (60,000 m²), bathing and swimming, and district heating.

Izmir-Balçova Thermal Facilities includes hotels, swimming pools, and a curing center composed of 1500 dwellings; capacity is 7 MWt.

The total capacity of the systems fed by the Balçova geothermal field is 17.8 MWt.

Izmir-Cesme

LOCATION
In western Anatolia (near 38.2º latitude, 27.0º longitude).

STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	56
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1974 - Well I-1 drilled for direct heat utilization; encountered temperature of 56ºC with a flow rate of 42 kg/s.	
NOTES	

Izmir-Dikili-Bergama

LOCATION In western Anatolia; 70 km north of Izmir; young volcanoes are widespread in this area (39.0º latitude, 27.0º longitude).	
STATUS Direct use -- developed	
TEMPERATURE (°C)	90-200
INSTALLED CAPACITY (MWt)	56
POTENTIAL (MWt)	56-224
CHRONOLOGY	

1989 - MTA drilled well DK-1 to a depth of 1500 m found temperatures up to 171ºC with variable degrees of permeability; well was dry.

The MTA Institute and JICA jointly conducted geological, geochemical, and geophysical exploration (gravity, CSAMT, Misse a-la masse)

1995 - A geothermal heating district (7,000 dwellings) and air-conditioning integrated system (1,000 dwellings) is under construction (56 MWt).

Feasibility study completed for geothermal heating of 25,000 dwellings, air-conditioning for 5,000 dwellings, and hot water (168 MWt).

NOTES
Geothermal is used for heat and hot water and air-conditioning.

Hot springs with temperatures of 41-98ºC and flow rates of 20 kg/s are present.

Izmir-Seferihiser

LOCATION
In western Anatolia along the Aegean coast 40 km southwest of Izmir; on the southwest extension of the Çubuklu Dag graben (38.0º latitude, 26.5º longitude).

STATUS Direct use -- developed	
TEMPERATURE (°C)	65-230
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWe)	6

CHRONOLOGY

1963 - Subsequent to preliminary investigations in the Agamemnun area, 3 wells were drilled; 2 of these yielded hot water and steam for the first time in Turkey. Work was temporarily discontinued due to encrustation in the wells.

1967 - The MTA Institute began geothermal surveys of the area as an integral part of the Geothermal Energy Project of Western Turkey. Included geological studies on 1:25:000 and 1:10:000 scales covering 750 km² and 50 km² respectively, numerous hydrochemical analyses, and 18 gradient and 2 deep well drillings. Two deep wells produced hot water-steam mixtures with a blow out.

1971 - Drilling began; 2 deep bore holes drilled, SH-I and SH-II. SH-I was drilled to 442 m in the Yeniköy formation and encountered a temperature of 107ºC. SH-II was bored in the Doganbey horst to 1232 m and encountered a temperature of 43ºC.

1972 and 1973 - 18 gradient drill holes were opened–17 in Graben-I southwest of Çubuklu Dag graben and one in Graben-II; found three major anomalies. Showed that the field has considerable geothermal potential which is further supported by the blow out of No. G-2 gradient hole at a depth of 85.45 m in 1972; temperature at 70 m was 137ºC.

Surveys established the existence of two geothermal regions in the area–the Cumali-Tuzla and the Kavakli-Orta-Tepe. The Cumali-Tuzla region contains numerous hot water springs with comparatively high temperatures. The Kavakli-Orta-Tepe region is located around the rhyolite domes and includes five low-temperature springs.

1982 and 1987 - 5 shallow wells drilled (151 to 315 m); encountered temperatures from 75ºC to 153ºC with variable degrees of permeability; one well was dry. Temperature measurements indicate sea water mixing from southwest–75ºC was measured in well G-12A; 153ºC was measured to the northeast towards Cumali; 230ºC estimated.

Second deep well drilled to 200 m; did not encounter a second reservoir with higher temperatures as expected.

Downhole heat exchangers are now set in 3 wells.

System tested under conditions with 1 well and a three-loop downhole heat exchanger obtained a 6 MWe capacity (Karul, 1988).

NOTES
Geothermal used for greenhouses and bathing and swimming. In addition, the field has potential for at least 6 MWe of power generation.

The most important belt in the area is a northeast-southwest trending graben formed at the beginning of the Tertiary. Paleozoic metamorphic schists and Upper Crustaceous clayey schists, claystone, limestone, serpentine, and diabases occupy the southeast end of the graben, while Upper Crustaceous flysch with dominant limestone facies occur at the northwest end.

Geothermal indices include five groups of springs with a total approximate flow of 110 l/sec and a maximum temperature of 82ºC (Kurtman and Sâmilgil, 1975).

Spilite forms the reservoir rock while Neogene sandstones, conglomerates, and claystones form the caprock.

Tectonics are very active in this area. Faults generally strike northeast-southwest and they are transversed by relatively younger faults striking northwest-southeast. At their intersection numerous hot water springs can be found, e.g., Doganbey, Tuzla, Karakoç, and Cumali, originating from the Izmir flysch. Hot water springs in this area have high NaCl contents (Esder and Simsek, 1975).

Kayseri

LOCATION
In central Turkey

STATUS
Preliminary identification/report

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES

Kirsehir

LOCATION
In central Turkey.

STATUS
Direct use -- developed

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	18.25
POTENTIAL (MWt)	18.25-83.25

CHRONOLOGY
March 1994 - District heating system began operation for 1,800 dwellings. The annual geothermal water average needed is 240 l/sec; 20 l/sec of the water is used in thermal facilities; the rest is reinjected into the reservoir. The system had a payback period of four years.

1995 - Feasibility study completed to provide heat and hot water to an additional 6,500 dwellings; 65 MWt.

NOTES
Peak energy demand for each house is approximately 8000 kcal/h at -12ºC outside design temperature, much higher than the Paris geothermal district heating application.

Average flow rate for the whole year is 240 l/sec. In this system, 97% of the energy is supplied by geothermal, 3% by fuel-oil.

The temperature in the city center distribution network is only 0.4ºC/km. The heating system works with 54-60ºC/42ºC cycling temperatures. Frequency converters control the city circulation pumps.

Kirsehir-Kaman

LOCATION
In central Turkey.

STATUS
Direct use -- developed

TEMPERATURE (°C)	34
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1985 - Well K-1 drilled; encountered a temperature of 34ºC with a flow rate of 5 kg/s.

NOTES
Geothermal is used for bathing.

Kirsehir-Karakurt

LOCATION
In central Turkey.

STATUS
Preliminary identification/report

TEMPERATURE (°C)	50
INSTALLED CAPACITY (MWt)	—

POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES	

Kirsehir-Mahmutlu

LOCATION In central Turkey.	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	62
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES	

Kirsehir-Terme

LOCATION In central Turkey.	
STATUS Direct use -- developed	
TEMPERATURE (°C)	28-40
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	
CHRONOLOGY 1986 - Wells KT-2 and KT-3 drilled; encountered temperatures of 28ºC and 40ºC with a flow rate of 45 kg/s for both.	
NOTES Geothermal used for bathing.	

Kütahya-Gediz

LOCATION In western Anatolia (near 39.0º latitude, 28.4º longitude).	
STATUS Direct use -- developed	
TEMPERATURE (°C)	78
INSTALLED CAPACITY (MWt)	0.61
POTENTIAL (MWt)	0.61
CHRONOLOGY November 1987 - Geothermal heat for spas and hotels began; 525,000 kcal/h capacity.	

NOTES
Geothermal is used for heat and hot water.

Kütahya-Simav-Eynal-Citgöl-Nasa

LOCATION
In western Anatolia; Simav graben is located north of the city of Simav; identified geothermal areas–Eynal, Citgöl, and Nasa–are located at the northern part of the graben (39.0º latitude, 28.4º longitude).

STATUS
Direct use -- developed

TEMPERATURE (°C)	32-236
INSTALLED CAPACITY (MWt)	68.2
POTENTIAL (MWt)	100.4

CHRONOLOGY
1985 to 1988 - The MTA Institute drilled 6 wells: four in Eynal, one in Citgöl, and one in Nasa; 5 wells to depths of 100-725 m found temperatures of 162-171ºC with varying degrees of permeability.

The deep wells in Eynal (700-800m) had a flow rate of 73 kg/s. The other wells in Eynal, Citgöl, and Nasa are shallower wells used for hotel heating, balneological purposes, and greenhouses.

Waters from eight hot springs were analyzed and geothermometric estimates of reservoir temperatures ranged between 157ºC and 236ºC (Erisen, 1989).

March 1991 - Construction began on Simav Geothermal District Heating System.

December 1992 - Simav Geothermal District Heating System began operating; heats 3500-6500 dwellings with a total installed capacity of 33-66 MWt.

1994 - Simav-Eynal Hotel began to be heated geothermally; 1,900,000 kcal/h capacity (2.2 MWt); system includes the thermal facilities, hotel, and a greenhouse.

1995 - Addition of 1,500 dwellings geothermal heating district to existing 2,000 dwellings; under construction; 12.2 MWt. Feasibility study completed for 80,000 m² greenhouse; 20 MWt.

NOTES
Simav District Heating System is the largest geothermal district heating system in Turkey. Geothermal is used for district heating and a greenhouse.

Simav geothermal field is among the 15 most important geothermal fields in Turkey.

The geothermal fluid is transported from a reservoir 4 km away, used for district heating, and then 80% of it is transported back 4 km for reinjection at 0.2 bar; the balance is used for balneology. The temperature loss is only 1ºC over 4 km. The scaling and corrosion problems have been solved by an inhibitor (5 g per 1 m^3) epoxy fiberglass pipe, 316 stainless steel plate type heat exchanged and partially by CO_2 and H_2S separation.

At the wellhead, there is a separator and a kind of direct contact heat exchanger which produce 95ºC geothermal water with a large flow rate and a constant temperature. The geothermal water is injected into the separator and condensed from steam to water. The geothermal fluid has a temperature of 143ºC and a return temperature of 40ºC.

The separator is used as a kind of condenser. Effective separation pressure is about 1.5 bar.

The system is fed by a 720-m deep well by 143ºC fluid with a flow rate of 70 l/sec. The heating system of dwellings with radiators works with 80ºC/45ºC cycling temperature clean water.

Sixty percent of the US$ 2.2 million investment for the first stage (3,500 houses) and US$ 4.2 million for the second stage (6,500 houses) in the system is provided by an autofinance system whereby the citizens pay the geothermal heating cost two years in advance and receive free heat for three years. The remaining 40% of the system is supported by MENR (US$ 1 million). The project payback period is 6 years.

The scaling and corrosion problems have been absolutely solved by means of a chemical phosphonate inhibitor and epoxy fiber glass pipe and stainless steel plate heat exchanger.

Each dwelling paid $US15 per month in 1994 for heat and hot water.

Kütahya-Yoncali

LOCATION
In western Anatolia (near 39.0º latitude, 28.4º longitude).

STATUS
Direct use -- developed

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	0.93
POTENTIAL (MWt)	0.93

CHRONOLOGY
1995 - Geothermal heating of Yoncali thermal facilities under construction.

NOTES

Kuzuluk-Sakarya

LOCATION
South of the city of Akyazi in a very fertile region of northwestern Turkey; 150 km east-southeast of Istanbul and 50 km south of the Black Sea; in the western part of the north Anatolian fault (40.4º latitude, 30.4º longitude).

STATUS
Direct use -- developed

TEMPERATURE (°C)	20
INSTALLED CAPACITY (MWt)	11.2
POTENTIAL (MWt)	11.2

CHRONOLOGY
1987 - 1 exploration well, AK-1, drilled for a local enterprise to 230 m; encountered water of 86ºC with a 40 kg/s flow rate; well equipped with a downhole heat exchanger.

1994 - Currently, only the small but very picturesque Çökek Hamamlari thermal baths are used. A new spa is under construction (Greber, 1994).

1995 - Feasibility and engineering designs to heat and provide hot water to 1,500 dwellings completed; 11.2 MWt.

NOTES
The circulation of hot and cold mineral waters at Kuzuluk is closely related to major fracture zones. In contrast to other systems, however, the tectonic structures around Kuzuluk are still seismically very active. The release of large amounts of CO_2 is probably related to the seismically active tectonics.

The tectonic setting is dominated by the dextral North Anatolian strike-slip fault (NAF), which has been active as a transform fault separating the two minor plates of the Black Sea and Turkey since the late Miocene (McKenzie, 1972; Sengör, 1979).

The area around the Kuzuluk basin is rich in normally mineralized spring waters of essentially $Ca\text{-}HCO_3$ type. More than 40 cold (~20ºC) and hot (up to 55ºC) mineral waters are located in the Kuzuluk basin, an area of less than 3 km². The springs are restricted to a basin (~115 masl) surrounded to the north, east, and south by the Keremali Mountains (highest peak:1543 masl).

The Kuzuluk mineral waters can be divided into “marginal” and “central” waters for geographical and chemical/physical reasons. The marginal springs emerge at the margin of the Kuzuluk basin and are characterized by low mean temperatures (24.2ºC) but high mean electrical conductivities (4110 S/cm). The central waters (including the borehole samples Kuz1 and Kuz2) have a higher mean temperature (40.8ºC) but lower mean conductivities (3200 S/cm).

The total discharge of all springs is small, about 103 l/min; the artesian outflow of the now unutilized and closed thermal water wells is very high (2520 l/min) compared to the natural spring flow and may only be a short-term discharge.

The two borehole samples, Kuz1 and Kuz2, coming from a depth of 90 m with temperatures of 84ºC, do not differ chemically or isotopically from the central spring waters which have temperatures of 36 to 55ºC. Therefore, a heat loss of about 40ºC occurs during their ascent through the cap rocks.

Two boreholes (160 and 250 m) found artesian water (up to 6 and 2.5 bar) at more than 80ºC in limestones and micaschists beneath 90 m cap rocks consisting of low permeable sediments and volcanic rocks (Sentürk and Demirel, 1987). The most reliable reservoir temperatures can be calculated with a chalcedony geothermometer for the central waters that have very similar SiO_2-contents. The calculated temperatures are about 120ºC.

Manisa-Kursunlu

LOCATION In central western Anatolia.	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	78
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES	

Manisa-Salihli-Alasehir

LOCATION In central western Anatolia.	
STATUS Direct use -- developed	
TEMPERATURE (°C)	210
INSTALLED CAPACITY (MWt)	0.26
POTENTIAL (MWt)	0.26-47.26
CHRONOLOGY	

November 1989 - Heat for 50 separate hotel villas began operating; total capacity is 220,000 kcal/h; 0.26 MWt.

1995 - Addition of 7,000 dwellings heating and 1,000 dwellings air-conditioning; under construction; 47 MWt.

NOTES
Geothermal is used for district heating.

Manisa-Urganli

LOCATION
In central western Anatolia.

STATUS
Preliminary identification/report

TEMPERATURE (°C)	90-150
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES

Nevsehir-Acigöl

LOCATION
In Central Anatolia.

STATUS
Preliminary identification/report

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES
Geological and geophysical studies indicated the presence of an active heat source composed of young extrusives at shallow depth. Detailed studies of a Hot Dry Rock project are planned (Karul, 1988).

Nevsehir-Kozakli

LOCATION
In Central Anatolia.

STATUS
Feasibility study

TEMPERATURE (°C)	42-95
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	11.1

CHRONOLOGY
1987 - Feasibility study and engineering design completed for 1,100 to 3,500 dwellings, hot water supply for 16,000 dwellings, and a 10,000 m² greenhouse heating system prepared. The project is ready for investment.

NOTES
The total discharge of all natural hot springs, distributed over an area of roughly 0.5 km² is 91 l/s with a temperature of 42-92ºC.

Rize-Ayder

LOCATION
In northeastern Turkey near the Black Sea.

STATUS
Direct use -- developed

TEMPERATURE (°C)	55
INSTALLED CAPACITY (MWt)	0.24
POTENTIAL (MWt)	0.24

CHRONOLOGY
1986 - Well AK-2 drilled; encountered a temperature of 55ºC with a flow rate of 14 kg/s.

NOTES
Geothermal is used for bathing, a curing center, district heating and hot water system; total installed capacity of 210,000 kcal/h.

Samsun-Havza

LOCATION
In north central Turkey south of the Black Sea.

STATUS
Direct use -- developed

TEMPERATURE (°C)	54
INSTALLED CAPACITY (MWt)	0.07
POTENTIAL (MWt)	0.07

CHRONOLOGY
1986 - Well SHC-1 drilled; encountered a temperature of 54ºC with a flow rate of 55 kg/s.

October 1988 - Floor heating for spas with an area of 1000 m² began operation; capacity of 6000 kcal/h.

NOTES
Geothermal is used for bathing and district heating.

Samsun-Kocapinar

LOCATION
In north central Turkey near the Black Sea.

STATUS
Direct use -- developed

TEMPERATURE (°C)	38
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1986 - Well KP-1 drilled; encountered temperature of 38ºC with a flow rate of 35 kg/s.

NOTES
Geothermal is used for bathing.

Seben

LOCATION
In western Anatolia west of Kizilcahamam.

STATUS
Preliminary identification/report

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES

Sicakçermik-Sivas

LOCATION
In north central Turkey 22 km west of Sivas city (39.4º latitude, 36.4º longitude).

STATUS
Direct use -- developed

TEMPERATURE (°C)	36-70
INSTALLED CAPACITY (MWt)	0.17
POTENTIAL (MWt)	0.17

CHRONOLOGY
1976 - 1 exploration well (C-1) drilled to 240 m produced 48ºC water with a 45 kg/s flow rate; 70ºC estimated.

December 1993 - Geothermal heating and hot water system covering an area of 2100 m² including a complete thermal water and scale deposition prevention system began operating.

NOTES

Geothermal is used for heat and hot water.

Hot water springs with 36-45ºC temperature and 10 kg/s flow, are located along faults that extend in north-south and northwest-southeast directions.

Süleymanli

LOCATION
In southeastern Turkey

STATUS
Preliminary identification/report

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES

Tokat Resadiye

LOCATION
In north central Turkey southeast of Havza.

STATUS
Feasibility study

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	7.16

CHRONOLOGY

NOTES
Feasibility study completed for the geothermal heating of 1,200 dwellings.

Tokat-Sulusaray

LOCATION
In north central Turkey southeast of Havza.

STATUS
Direct use -- developed

TEMPERATURE (°C)	27-54
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1986 - 3 wells drilled, SS-2, 3, and 5; encountered temperatures of 53ºC, 54ºC, and 27ºC with flow rates of 2, 21, and 9 kg/s respectively.

NOTES
Geothermal is used for bathing.

Van-Zilan

LOCATION In eastern Anatolia north of LakeVan; 15 km north of the city of Ercis (39.0º latitude, 43.2º longitude).	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	20-220
INSTALLED CAPACITY (MWt)	
POTENTIAL (MWt)	
CHRONOLOGY 1988 - The MTA Institute began exploring the field; 2 wells drilled: 1 deep (1196 m), 1 shallow (394 m); both wells encountered hot water; 105ºC measured, 220ºC estimated; flow rate of 35 kg/s. 1989 - The MTA Institute drilled exploration well ZD-1 to 1172 m; well was dry.	
NOTES A prefeasibility study was started for district heating for the town of Ercis. Hot springs with temperatures of 20-78ºC are present.	

Yozgat-Bogazliyan

LOCATION In central Turkey southeast of Ankara.	
STATUS Direct use -- developed	
TEMPERATURE (°C)	46
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1987 - Well BB-2 drilled; encountered a temperature of 46ºC with a flow rate of 50 kg/s.	
NOTES Geothermal is used for bathing and swimming.	

Conclusion

Turkey is facing an ever increasing demand for power in the coming decades. The country's installed capacity is expected to almost triple in the next 10 years to 65,069 MWe, and to more than quadruple in the next 20 years to 109,218 MWe.

The development of Turkey's high-enthalpy geothermal resources suitable for power generation, estimated at 4,000-4,500 MWe, and its low-enthalpy resources estimated at 32,000 MWt which could be developed for district heating and other direct uses, could help the country to:

- diversify its energy sources,
- ameliorate pollution,
- offset its need to import gas, and
- improve its balance of payments.

To facilitate this, however, legislation specific to geothermal resource development should be developed.

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