Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Geothermal Energy Utilisation, Development and Projections - Country Update Report (2000-2004) of Turkey

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Keywords: geothermal, utilisation, development, projections, Turkey

ABSTRACT

Turkey is located on the Alpine-Himalayan orogenic belt, which have high geothermal potential. The first geothermal researches and investigations in Turkey started by MTA in 1960's. Upon this, 170 geothermal fields have been discovered by MTA, where 95% of them are low-medium enthalpy fields, which are suitable mostly for direct-use applications. Around 1500 hot and mineralised natural springs and wells exist in Turkey. With the existing geothermal wells discharge water (2693 MWt) and springs (600 MWt), the proven geothermal capacity calculated by MTA is totally 3293 MWt (exhaust temperature is assumed to be 35 °C). The geothermal potential is estimated as 31,500 MWt (5,000,000 residences equivalence). This figure means also that 30 % of the total residences in Turkey could be heated by geothermal energy.

Turkey is the 7th richest country in the world in geothermal potential. Most of the development is achieved in geothermal direct-use applications by 65,000 residences equivalence geothermal heating (750 MWt) including district heating, thermal facilities and 635,000 m^2 geothermal greenhouse heating. Main cities heated by geothermal energy as Izmir-Balcova, Narlidere, Afyon and Kirsehir City centers, Afyon-Sandikli, Kütahya-Simav, Ankara-Kizilcahamam, Balikesir-Gönen, Nevsehir–Kozakli, Manisa–Salihli, Agri-Diyadin, Denizli-Sarayköy and Balikesir-Edremit. 195 spas in Turkey are used for balneological purposes (327 MWt). Engineering design of about 300,000 residences equivalence geothermal district heating has been completed.

By summing up all this geothermal utilisations in Turkey, the installed capacity is 1077 MWt for direct-use and 20.4 MWe for power production in Turkey, where a liquid carbon dioxide and dry ice production factory is integrated to this power plant.

The district heating system applications have been started with large scale geothermal district heating systems in Turkey. This constitutes an important advantage of GDHS investments in Turkey in terms of technical and economical aspects.

Only 3,5 % of our total geothermal potential has been utilized yet. For the further development and extension of the geothermal applications in Turkey, 20 % financial support of the Turkish Government would be appropriate. 500 MWe power production and 3500 MWt space heating is aimed for the year 2010. With the huge thermal tourism capacity potential of Turkey, the target is to increase the local curist (tourists in thermalism) number to 30 million people until the year 2020. The foreign thermal curist number is targeted as 1 million until the year 2020.

Moreover, the realization of the World Geothermal Congress 2005 in Antalya/Turkey, will benefit to the development and widening of geothermal applications in Turkey.

1. GEOTHERMAL POTENTIAL OF TURKEY

In Turkey, more than 170 geothermal fields which can be useful at the economic scale and about 1500 hot and mineral water resources (spring discharge and reservoir temperature) which have the temperatures ranged from 20-242°C, have been determined (Figure 1). These manifestations are located mainly along the major grabens at the Western Anatolia, along the Northern Anatolian Fault Zone, Central and Eastern Anatolia volcanic regions As a result of the geological, geophysical, geochemical surveys and the drillings carried out by General Directorate of Mineral Research and Exploration (MTA), the temperatures and the flow rates of thermal resources in geothermal fields have been increased very seriously.

These manifestations are located mainly along the major grabens at the Western Anatolia, along the Northern Anatolian Fault Zone, Central and Eastern Anatolia volcanic regions (Figure 1).

With the existing springs (600MWt) and geothermal wells (2693 MWt), the proven geothermal capacity calculated by MTA is 3293 MWt (discharge temperature is assumed to be 35 °C). The distributions of proven geothermal potential accordant to the geographic regions are given at Figure 2. The geothermal potential is estimated as 31,500 MWt.

The installed heat capacity is 1077 MWt for direct-use and 20.4 MWe for power production in Turkey, where a liquid carbon dioxide and dry ice production factory is integrated to the Kizildere power plant . The total production is 104.6GWh/yr (Table.1,Table. 2, Table. 3).

Up to now 500 geothermal explanatory and production wells and 200 gradient wells have been drilled in Turkey (depths up to 2398m).

As it will be considered, the number of geothermal production wells is too few if compared to the high geothermal potential of Turkey. Most of these wells have been drilled by MTA and financed by the Governorships, Municipalities and their companies, which constitutes 66.2 % and followed by MTA with 16.5 % and 11.7 % Private (Akkus, 2002).

Figure 1: Main neotectonic lines and hot spring distribution of Turkey

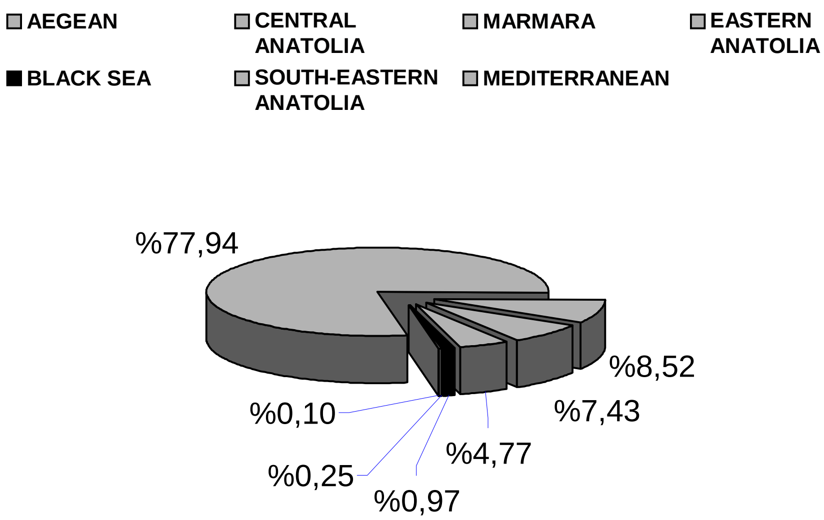

Fig. 2. Proven potential percentage for regions in Turkey

On the other hand, studies on Hot Dry Rock (HDR) systems which develop at zones included high temperature formations at shallow depths are continued very successfully. If the studies on the management of these systems will be economic, the geothermal potential of Turkey will grow up rapidly. From this point of view, especially in Central Anatolia the region of Acigol and the young volcanic fields of Eastern Anatolia are the positive fields.

2. PRESENT SITUATION OF GEOTHERMAL WELLS

Up to 2004, a total of about 500 geothermal exploration and production wells and 200 gradient wells have been drilled in Turkey. The portion of the wells drilled by MTA in the total number of wells is 382. This makes a total geothermal well length as 151,557m. The portion of the wells drilled by MTA in the total number of wells is 382. Moreover, the first geothermal well was drilled in 1963 and the number of the wells drilled increase after 1982. After 2000 a total of 54 new exploratory and production wells have been drilled (Table 4).

There are some important geothermal possibilities have been discovered from existing oil exploration wells at southeastern Anatolia. The reservoir temperatures are changing between 83- 138 °C at 2400-3850 m in the wells (Dagıstan, 2001).

87 % of the wells drilled by MTA have been realised in Western Turkey, 11 % in Central Anatolia and 2 % in Eastern Turkey (Figure 2).

The temperature distribution obtained from the well outputs in Turkey is as follows:

Western Turkey:

Percentage (%)	Temperature (°C)
0,4	240-250
0,4	230-240
1,7	220-230
1,3	210-220
4,3	200-210
1,3	190-200
0,4	180-190
1,7	170-180
3,5	160-170
2,2	150-160
1,7	140-150
2,2	130-140
1,7	120-130
3,9	110-120
2,6	100-110
17,8	90-100
7,0	80-90
7,4	70-80
11,7	60-70
11,7	50-60
9,1	40-50
5,7	30-40

Central Anatolia:

Percentage (%)	Temperature (°C)
3,5	90-100
4,7	80-90
3,5	70-80
5,8	60-70
18,6	50-60
31,4	40-50
32,6	30-40

Eastern Turkey:

Percentage (%)	Temperature (°C)
3,0	100-110
6,1	80-90
12,1	70-80
9,1	60-70
15,2	50-60
36,4	40-50
18,2	30-40

Moreover, the first geothermal well was drilled in 1963 and the number of the wells drilled increase after 1982.

3. HIGH TEMPERATURE APPLICATIONS IN TURKEY

First explorations regarding geothermal electricity generation was started in 1968 with the investigation of Kizildere geothermal Field. In 1974 a pilot plant with a capacity of 0.5 MWe has been installed. Afterwards in 1984, the Kizildere Geothermal Power Plant was installed by T.E.K. (Turkish Electricity Authority, renamed as TEAS) with an installation capacity of 20.4 MWe (Table-1). This power plant generates an average of 12-15 MWe electricity annually (Figure. 3). The reservoir temperature in the Kizildere geothermal field is 242 °C (Simsek et al. 2000). The reservoir which feeds the Kizildere Geothermal Power Plant contains 1,5 % non-condensable gases. The amount of these gases at the separation pressure in the single flash plant is 15 % in weight.

A liquid CO_2 and dry ice production factory is integrated to this power plant which produces 120,000 tonnes of liquid carbon dioxide and dry ice annually.

A power plant construction studies have been started at Germencik field (232 ^{o}C)).

Geothermal fields which their reservoir temperatures over than 140 ºC are given below.

1. Denizli-Kızıldere Field (242 °C)

2. Aydın - Germencik -Omerbeyli Field (232 ° C)

3. Manisa –Salihli-Göbekli Field (182 ° C)

4. Çanakkale- Tuzla Field (174 ° C)

5. Aydın-Salavatlı Field (171 °C)

6. Kütahya-Simav Field (162 °C)

7. Manisa- Salihli-Caferbey Field (150 °C)

8. Izmir- Seferihisar Field (153 °C)

9. Izmir-Balçova Field (142°C)

10. Aydın-Yılmazköy Field (142 °C)

It has been estimated that the Aydin-Germencik geothermal field would have 100 MWe power production capacity.

4. LOW TEMPERATURE APPLICATIONS IN TURKEY

The operational capacities of the city based geothermal district heating systems (GHDS) existing in Turkey are as the following: Gönen (Commissioned: 1987, 3400 residences, geothermal water temperature is ~ 80 °C), Simav (1991, 3200 residences, ~120 °C), Kirsehir (1994, 1800 residences, ~57 °C), Kizilcahamam (1995, 2500 residences, ~ 80 °C), Izmir (1996, 10.000 residences, ~ 115 °C), Sandikli (1998, 1600 residences, ~ 70 °C), Afyon (1996, 4000 residences, ~ 95 °C), Kozakli (1996, 1000 residences, ~ 90 °C), Izmir-Narlidere (1998, 1075 residences, ~ 98 °C), Diyadin (1999, 400 residences, ~70 ^{o}C), Salihli (2002, 3000 residences, ~94 ^{o}C), Edremit (2003, 500 residences, ~60 ^{o}C). Today, 40-45 °C temperatured geothermal waters are used for space heating in Turkey without heat-pump.

Most of the development is achieved in geothermal direct-use applications by 1077 MWt. 750 MWt (which equals to the heat requirement of 65000 residences equivalance[1]) of this potential is being utilized for geothermal heating including district heating, thermal tourism facilities heating and 635000 m^2 geothermal greenhouses heating. The remaining potential of 327 MWt of this potential is being utilized for balneological purposes (There exists 195 thermal facilities (Balneology) in Turkey).

*One residence equivalence is assumed to be 100 m^2 floor area.

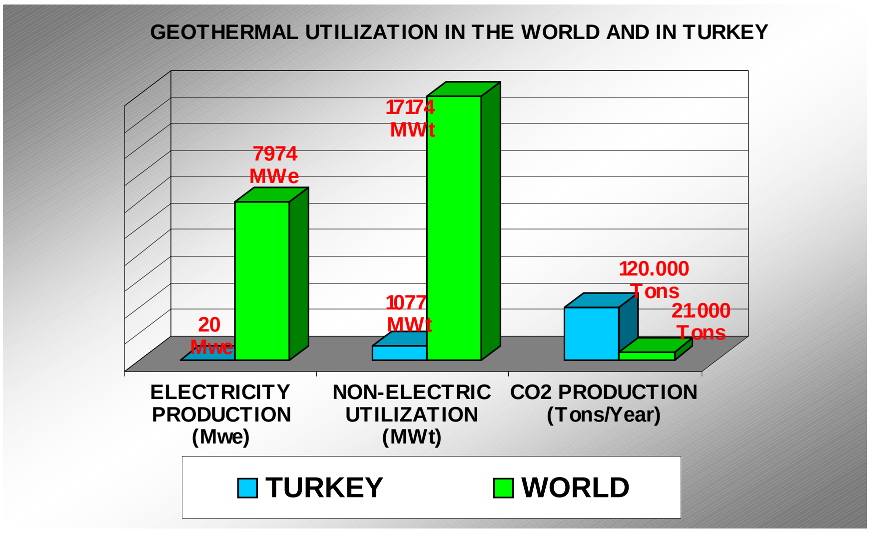

Figure 3. Installed capacities of geothermal applications in Turkey

Additionally, engineering design of more than 300,000 residences equivalence* geothermal district heating has been completed. By summing up all these geothermal utilizations, the geothermal installed capacity is 1077 MWt for direct-use and 20.4 MWe for electricity production in Turkey. Moreover, a liquid carbon dioxide and dry ice production factory (120.000 tons/year) is integrated to this electricity production power plant.

5. RECENT GDHS APPLICATIONS BETWEEN 2000-2004.

Salihli (Manisa) Geothermal Integrated System

The thouths about utilization of the geothermal resources in Salihli area have begun in 1992 with drilling of 3 geothermal production wells by MTA General Directorate in Kursunlu geothermal field. Salihli Geothermal Integrated System includes 20,000/24,000 residences equivalence geothermal district, 2000 residences equivalence geothermal air-conditioning, balneological utilization, greenhouse heating and raisin production which will be explained in further details in this paper.

The geothermal field is at 3-4 km distance to the city with a higher altitude of 100 m. Geothermal fluid is carried to the heating centre located very near to the city center and transported again to the geothermal field for reinjection. 4 production wells exist in the geothermal field, whereas, 3 of them are used for geothermal district heating and 1 well is used for balneological utilization in the spa's. The existing 4 production wells are adequate by now, but to be extended to the total capacity of the integrated geothermal system, 13 production wells with a varying depth of 300 – 1100 m, and 5 reinjection wells with an average depth of 300 m are planned to be drilled in Kursunlu and Caferbeyli geothermal fields. The existing production wells are all artesian wells. LSP will be installed, to increase the production amount of the wells.

Geothermal district heating system has an installed capacity of 24.000 residences equivalence. Now, 3000 residences equivalence are heated geothermally in Salihli City. The extension of the system is continuing by connecting residences to the system. Beside of heating, 2000 residences cooling (air-conditioning) and domestic hot water supply is included in the Salihli Geothermal Integrated System Project. Moreover, studies for geothermal air-conditioning of a hospital with a capacity of 120 residences equivalence are continuing. This air-conditioning system has a capacity of 800 kW and will start-up in 2004.

28 MWt capacity heat exchanger and pump group has been installed in the heating center of the system which is suitable for modular extension. Each modul (unit) has a power of 14 MWt. According to the further plans for the extension of the system the installations and connection of the residences are continuing.

Balneological utilization in Salihli geothermal field refers to many decades. Previously it was in the form of primitive utililization, but now there exist two curing centers and Apart houses with 270 bed capacity and two thermal pools. 300-400 people in average make use of this facility per day during the year.

Additional to the existing spa utilization in Kursunlu geothermal field, a big thermal facility complex (aqua parks, curing centers etc.) is planned to be build as an integration to the system.

Due to;

- the existence of suitable land area for greenhouse construction.
- the convenient outside temperature and other meteorological conditions.
- the progress obtained in agriculture in Salihli region, 240.000 m^2 greenhouse heating application is integrated to the system.

Also, raisin production is taken into account in Salihli Geothermal Integrated Project and 175,200 tons/year capacity (25000 kW heat power) geotermally dried raisin production is integrated to the system.

Edremit Geothermal District Heating System

Edremit is a town of Balıkesir province situated 87 km from the city center with a population of 93,351.

Edremit Geothermal District Heating System (GDHS) is fed from Edremit geothermal field which is 3 km away to the city center. The total flow rate of two geothermal wells is 109 l/sec with a temperature of 60°C. The geothermal potential of the Edremit geothermal field is 35,6 MWt which equals to 20,000 residences heating (ORME, 2004).

500 residences are connected to the system by January 2004. Total capacity of the project is 7,500 residences. Additional to the two production wells and one reinjection well, seven production and two reinjection wells are needed in order to realize the whole project. Each residence pays 22.20 US$/month heating fee. With the application of this project, decrease in carbon dioxide emmission value will be 15,483 tons/year.

The system supplies heating in winter, hot tap water during the whole year. The geothermaly heated clean water is transported via pre-insulated pipes until the residences. The returning water is planned to be used for thermal tourism facilities. The outside design temperature of the system is 0 °C. The total heat load during the winter season is met from the geothermal energy. Principally, the geothermal water is transported to the city center.

Heat pump applications have a wide utilization area around the world, which is not the case in Turkey. In Turkey, it is not economical to use heat pumps due to the high electricity costs and low interest. When these conditions will be changed the heat pump utilization will be economical in Turkey.

10 Million m^2 geothermal greenhouse exist in the world. 635.000 m^2 geothermal greenhouses exist in Turkey. In Sanliurfa city nearly 106.000 m^2 geothermal greenhouses exist, where the yield obtained from the greenhouses is exported to Europe. Moreover in Dikili 190.000 m^2 geothermal greenhouse exist.

Geothermal district heating systems (GDHS) are the main geothermal utilization in Turkey, which have an important meaning to the Turkish citizens who are make use of this system, since, a clean environment and comfort has been provided to residences in more economic conditions. In the future wide spread applications have been expected.

Some of the new wells (54) which drilled by MTA between 2000-2004 are given at Table 4.

Energy amount from utilization of Geothermal Energy in Turkey for Direct Heat as of June 2004 is 19623,2 TJ/yr (Table-5).

A total of drilled wells for electrical (4) and direct use (54) of geothermal resources from January 1, 2000 is given Table 6.

Engineering design of more than 150,000 residences equivalence geothermal district heating has been completed. A total of installed capacity is 1077 MWt (Figure 2). This capacity is equivalent of 800.000 tons oil annually.

Moreover, the district heating system applications have been started with large scale geothermal district heating systems in Turkey, whereas, the geothermal district heating distribution networks have been designed according to the geothermal district heating system parameters. This constitutes an important advantage of GDHS investments in Turkey in terms of technical and economical aspects.

One example to the high temperature city heating applications is Izmir GDHS fed from Balçova geothermal field. This system is the largest geothermal system in Turkey supplying 10.000 residences equivalence with heat (Balçova + Narlidere Towns). The system is extending to 15,000 residences. Moreover, additional 20.000 residences are planned.

We use two types of LSP (USA origin Lineshaft Pumps) deep well pumps in Turkey. For the shallow wells, the local manufactured pumps are installed (installation depths are about 70 – 80 m). For the deep wells, Icelandic design deep well pumps (Installation depths are about 150 – 200 m, 40-45 kg/sec. capacity and operating temperature is 150 °C

In order to prevent scaling of calcite, scale inhibitor which has European Specification ISO 9002, is being injected into the well below the pump by using special chemical injection line.

A peaking station does not exist. Moreover, as all the wells are located in the city, there is no high transmission costs. The system has a property that adjusts the flowrates of geothermal and clean waters by frequency converter dependent of the outdoor temperature.

The construction costs of power plants are 850-1250 USD/kW, by heating applications; it is 300 USD/kW in the conditions of Turkey. The geothermal heating cost per residence (including network and system, excluding radiator inside the house) is around 2000 USD, where these investments are paying themselves back in 5-8 years (Mertoglu et al., 2003).

The theoretical probable geothermal heat potential of Turkey is estimated as 31.500 MWt which is equal to 5 million residences heating or 150 million square meter greenhouse heating, or, over 1 million thermal tourism bed capacity, or, 9.3 billion US$/year fuel-oil equivalence (30 million tons/year), or, equivalence of 30 Billion m^3/year natural gas.

The geothermal potential for electricity production according to todays commercial conditions is 500 MWe by the year 2010, this value is estimated as 2000 MWe (16 Billion kWh/year) in case of governmental support (ecologically driven as green power) could be received (like incentive).

With this geothermal potential Turkey can meet up to 5% of its total electricity demand and up to 30% of its total heat energy demand. In other words, if we take the weighted mean, Turkey can meet 14% of its energy (electricity+heat enegy) demand by means of geothermal.

If Turkey utilizes its geothermal potential (2000 MWe, 31500 MWt) for electricity production, residence heating, air-conditioning, greenhouse heating, thermal facilities heating, balneological purposes, production of chemicals, industrial -utilization etc. about 20 Billion US$/year net domestic value would be obtained.

Turkey is ranked as the 5th country in the world in geothermal direct use (heating, thermal tourism, balneology etc.) potential. In contrary, we are just using %3.5 of our total estimated geothermal heat potential (January 2004).

The geothermal electricity production investment, the geothermal greenhouse and Balneological Cure (Therapy) House (Thermal Facilities, Thermal Tourism Complex) investments could be realized alone by private sector in Turkey.

In addition to these, big portion of geothermal potential in Turkey is suitable for heating purposes, geothermal district heating investments could be realized and operated with the cooperation of local governments, municipalities, people and private sector.

With integration of the geothermal district heating systems (GDHS) to the above mentioned electricity production, greenhouse heating and balneological applications (cascade use), the technical and economical aspects of the investment also becomes more favorable and convenient.

The portion of the consumers financial contribution (non return as grant) in each geothermal district heating investment is 50-60% in Turkey. This finance model is called as "Turkish Finance Model". The meaning of this model is; 1250-1850 US$/100m^2 residence contribution and connection fee (non return as grant) is paid by the consumers (customers) to the company formed by local government and municipality in order to get connected to the geothermal district heating network (TJD,2004).

In this case, the portion of 50-60 % of each geothermal district heating investment is financed by the consumers in advance and the GDHS's are constructed and the people are heated cheaper with geothermal energy (at least %50-70 cheaper than based on natural gas heating).

For this reason, 10-20% of the investment is put as own capital by the local government and municipality and 50-60% of the investment is financed by the consumers. So, it is important to use the loan for the rest 30-40% portion at the beginning of the investment. Since, at the very beginning of the GDHS investment, the geothermal field research and exploration studies have to be done, wells have to be drilled, feasibility reports and engineering designs have to be prepared and the construction to be started. In this way, the seriousness have to be shown to the consumers that they would be willing to give the financial support. For this reason, at least 30 % of the total investment is needed as pre finance.

In addition to that, the people are heated with environmentally benign and cheap geothermal energy; dependence to natural gas is decreased as well. This results with a commercially payback period of 5-8 years (It varies according to each investment) in investment and a payback period of 3 years in terms of natural gas equivalent foreign exchange savings.

With these investments, the clean and cheap geothermal energy is utilized and the living standard of the people is increased. Accordingly, people show their belief to the geothermal projects by financially supporting the geothermal investments. Therefore, there exists guaranteed demand (permanent customer)for geothermal heat production and distribution investments.

As mentioned before, the probable theoretical potential of Turkey is 31500 MWt, which means 5 million residences[i] could be heated geothermally if all potential is utilized for geothermal heating purpose. According to today's technical and economical convenience, 1.25 million residences equivalance could possibly be heated geothermally in Turkey. However, now only 65000 residences equivalance[*] are heated geothermally.

For the year 2010 the geothermal heating capacity has been estimated as 3500 MWt, power production as 500 MWe, Balneological utilization as 895 MWt. For the year 2020 the geothermal heating capacity has been estimated as 8300 MWt, power production as 1000 MWe and balneological utilization as 2300 MWt.

The professional personnel to geothermal activities, restricted to personnel with a University degrees has been calculated as total 163 for the year 2004 (Table-7)

6. RESULTS

Being one of the richest countries in geothermal potential, Turkey's geothermal activity have been developed mostly to district heating systems between 2000-2004.

The district heating system was established earlier in Turkey using lignite for heating in furnaces. Moreover the people were introduced to a higher living standard by means of geothermal district heating systems. People show a very high demand for geothermal district heating systems is Turkey. The people prefer to buy or rent geothermally heated residences and this causes an increment of the renting or selling prices of these houses 3-4 times in comparison to the other houses.

As a result of the exploration and development studies, which have been done, an electrical power plant (20.4 MWe) was installed in Denizli-Kizildere field in 1984 where a liquid carbon dioxide and dry ice production factory is integrated to this power plant, with a capacity of 120000 ton/year and than important developments in applications of balneology (327 MWt), greenhouse and dwelling heating systems(750 MWt) has been installed (total 1077 MWt) in Turkey.

Main important items for research and development for the next period of geothermal energy in Turkey are given below;

- Existing fields should be managed and developed,
- New fields should be investigated,
- Deep reservoirs should be searched,
- More geothermal wells should be drilled and the well risk should supported by the state,
- Determination of utilization possibilities of geothermal fields and planning of these fields in the form of integrated utilization and encouragement of the geothermal uses.
- More financing aids should be received and international cooperation should be developed for the geothermal development projects.
- To supply the required support about know-how transfer, education, finance and equipment necessities via realization of projects in common with international organizations,
- Turkish geothermal law should be finalized as soon as possible,

As a conclusion, geothermal energy in Turkey must be used as the main energy source at the regions where it is found, since it is very cheap, clean, sustainable and for the benefit of the mankind,

World Geothermal Congress 2005 in Antalya-Turkey, this activity is an important international success of geothermal development in Turkey.

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*One residence equivalence is assumed to be 100 m^2 floor area.

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Table1: Capacities in Geothermal Utilization in Turkey (June 2004)

Geothermal Utilization	Capacity
District Heating	750 MWt
Balneological Utilization 195 Spa	327 MWt
Total Direct Use	1077 MWt
Power Production	20.4 MWe
Carbon dioxide production	120.000 tons/yr

TABLE 2. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2002	17.50	104.6	19568.5	95558.9	12249.45	44388	-	-	18.9	48	31854.35	140099.50
Under construction in December 2002					3338	10845						

*WEC - Turkish National Committee Report 2003

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2004

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash; 2F = Double Flash; 3F = Triple Flash; D = Dry Steam; B = Binary (Rankine Cycle); H = Hybrid (explain); O = Other (please specify)

3) Data for 2003.

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe	Annual Energy Produced 2004[3)] GWh/yr	Total under Constr. or Planned MWe
Denizli	Kizildere	1984	1		1F	20,4	104,6	
Aydin	Germencik				B			25
Total								

TABLE 4. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT
AS OF 31 DECEMBER 2004 (other than heat pumps)

1) I = Industrial process heat — H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling) — D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetab — B = Bathing and swimming (including balneology)
F = Fish farming — G = Greenhouse and soil heating
K = Animal farming — O = Other (please specify by footnote)
S = Snow melting

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.00418 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality		Type1)	Maximum Utilization					Capacity3)	Annual Utilization		
			Flow Rate	Temperature (^{o}C)		Enthalpy2) (kJ/kg)			Ave. Flow	Energy4)	Capacity
			(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor5)
Afyon-Çobanlar(Ç-1)	2000	B+D	32	55				2,68			
Afyon-Çobanlar(Ç-2)		B+D	50	56,4				4,48			
Afyon-Sandıklı(AFS-3)		B+D	25	40				0,52			
Afyon-Sandıklı(AFS-4)		B+D	60	68				8,29			
Afyon-Sandıklı(AFS-5)		B+D	58	68,5				8,13			
Afyon-Sandıklı(AFS-6)		B+D	60	68				8,29			
Amasya-Terziköy(T-2)		B+D	32	40,1				0,68			
Aydın-Yılmazköy(Y-1)		B+D	30	142				13,44			
Balıkesir-Bigadiç(BH-1)		B+D	0,5	42				0,01			
Balıkesir-Edremit(ED-1)		B+D	75	60				7,85			
Erzurum-Pasinler(PS-4)		B+D	50	43				1,67			
Erzurum-Pasinler(PS-5)		B+D	65	39				1,09			
Kayseri-Erciyes(KB-1)		B+D	110	38				1,38			
Van-Erciş-Şorköy(ZG-2)		B+D	6	85				1,26			
Van-Erciş-Şorköy(ZG-3)		B+D	20	92				4,77			
Balıkesir-Bigadiç(BH-2)		B+D	60	98				15,82			
Balıkesir-Bigadiç(BH-3)	2001	B+D	60	98				15,82			
Balıkesir-Edremit(ED-2)		B+D	2	55				0,17			
Afyon-Bolvadin(H-4)		B+D	31	56,5				2,79			
Denizli-Gölemezli(DG-1)		B+D	15	88				3,33			
Manisa-Urganlı		B+D	22	61				2,39			
Balıkesir-Bigadiç(BH-4)		B+D	2	57				0,18			
Balıkesir-Edremit(ED-3)		B+D	18	59				1,81			
Balıkesir-Pamukçu		B+D	11	58,5				1,08			
Afyon-Bolvadin(H-1/A)		B+D	73	56,3				6,51			
İzmir-Çeşme-Ilıca(I-2)		B+D	57	57				5,25			
Kırşehir-Çiçekdağı(ÇB-1)		B+D	4,5	41				0,11			
İzmir-Balçova(BD-8)	2002	B+D	55	128				21,41			
Denizli-Yenicekent(YK-1)		B+D	20	57				1,84			
Denizli-Yenicekent(YK-2)		B+D	140	67				18,75			
Uşak-Banaz(HB-3)		B+D	34	71,7				5,22			
Kırşehir-Terme-KT-12		B+D	105	56				9,23			
Sivas-Şarkışla-Ortaköy		B+D	24	36				0,10			
Denizli-Yenicekent(YK-3)		B+D	4,5	36,5				0,03			
Denizli-Gölemezli(DG-2)		B+D	140	75				23,44			
Uşak-Banaz(HB-4)		B+D	44,00	62				4,97			
Bursa-Kaynarca(BK-1)		B+D	10,00	49				0,59			
Elazığ-Karakoçan-Golan		B+D	25	41				0,63			
Denizli-Gölemezli(DG-3)	2003	B+D	110	70				16,12			
Kütahya-Yoncalı (YON-6)		B+D	7	41				0,18			
Afyon-Sandıklı (AFS-7/A)		B+D	85	70,1				12,49			
Afyon-Sandıklı (AFS8)		B+D	40	54				3,18			
Kütahya-Harlek(HR-2)		B+D	45	37				0,38			
Afyon-Sandıklı (AFS10)		B+D	105	68				14,50			
Denizli-Gölemezli(DG-4)		B+D	45	70				6,59			

continue Table 4.

Locality		Type[1]	Maximum Utilization Flow Rate (kg/s)	Temperature (°C) Inlet	Outlet	Enthalpy[2] (kJ/kg) Inlet	Outlet	Capacity[3] (MWt)	Annual Utilization Ave. Flow (kg/s)	Energy[4] (TJ/yr)	Capacity Factor[5]
Bursa-Kaynarca(BK-2)		B+D	50	88				11,09			
İzmir-Balçova(BD-9)		B+D	50	136				21,14			
Denizli-Gölemezli(DG-5)		B+D	30	62				3,39			
Manisa-Demirci		B+D	5	42				0,15			
Balıkesir-Gönen-6		B+D	30	84				6,15			
Van-Özalp(VS-1)		B+D	30	87				6,53			
Balıkesir-Gönen-7		B+D	50	70				7,33			
Çanakkale-Çan-Etili		B+D	8	62				0,90			
K.Maraş-Ilıca	2004	B+D	25	47,6				1,32			
TOTAL											

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2004

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	74	816,8	0,35
District Heating [4]	645	6015,45	0,35
Air Conditioning (Cooling)			
Greenhouse Heating	131	2478,7	0,6
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	327	10312,2	1
Other Uses (specify)			
Subtotal	1077	19623,2	
Geothermal Heat Pumps			
TOTAL	1077	19623,2	

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2000 TO DECEMBER 31, 2004 (excluding heat pump wells)

[1] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)		3			1.318
Production	>150° C	1				1.447
	150-100° C	3				2.903
	<100° C		51			18.909
Injection	(all)					
Total		4	55			24.577

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	62	22	12	-	-	32
				-	-	
2001	65	25	15	-	-	34
				-	-	
2002	68	27	17	-	-	35
				-	-	
2003	69	30	18	-	-	38
				-	-	
2004	70	32	20	-	-	40
				-	-	
Total	334	136	82	-	-	179