RESEARCH AND DEVELOPMENTS ON GEOTHERMAL ENERGY IN TURKEY

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KEYWORDS

Geothermal, research, development, international cooperation, Turkey

ABSTRACT

Turkey is located on the Mediterranean Sector of Alpine-Himalayan Tectonic Belt. At the same time, this young belt is an important geothermal potential. Geothermal fields are caused from the graben systems of Western Anatolia, widespread volcanism and tectonism of Central and Eastern Anatolia and right lateral and strike slip North Anatolian Fault Zone. Distribution of thermal and mineral water resources has developed through the zones subjected above. In Turkey, approximately 170 geothermal fields which can be useful at the economic scale and about 1500 hot and mineral water resources (spring discharge and geothermal reservoir temperature) which have the temperatures ranged from 20-242^{o}C, have been determined. As a result of the researches and the drillings carried out by General Directorate of Mineral Research and Exploration (MTA), the temperatures and the flow rates of thermal sources in geothermal fields have been increased very seriously.
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 and than important developments in applications of greenhouse and dwelling heating systems (992 MWt) has been obtained in Turkey.
Main important items for developments of geothermal energy in Turkey are given below;

- To supply the required support about know-how transfer, education, finance and equipment necessities via realization of projects in common with international organizations.
- To provide the validity of related legislations as soon as possible.
- Determination of utilization possibilities of geothermal fields planing of these fields in the form of integrated utilization and encouragement of the geothermal usages.
- To encourage the international organizations for their investments about this sector.

Since the geothermal sources are clean, cheap and renewable there is an expectation for widespread applications all around the country in the near future.

1. INTRODUCTION

Turkey is located on the Mediterranean Sector of Alpine-Himalayan Tectonic Belt. At the same time, this young belt is an important geothermal potential. Geothermal fields are caused from the graben systems of Western Anatolia, widespread volcanism and tectonism of Central and Eastern Anatolia and right lateral and strike slip North Anatolian Fault Zone. Distribution of thermal and mineral water resources has developed through the zones subjected above.

In Turkey, approximately 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). As a result of the researches and the drillings carried out by General Directorate of Mineral Research and Exploration (MTA), the temperatures and the flow rates of thermal sources in geothermal fields have been increased very seriously (Kocak, 1990, Şimşek, 2001).

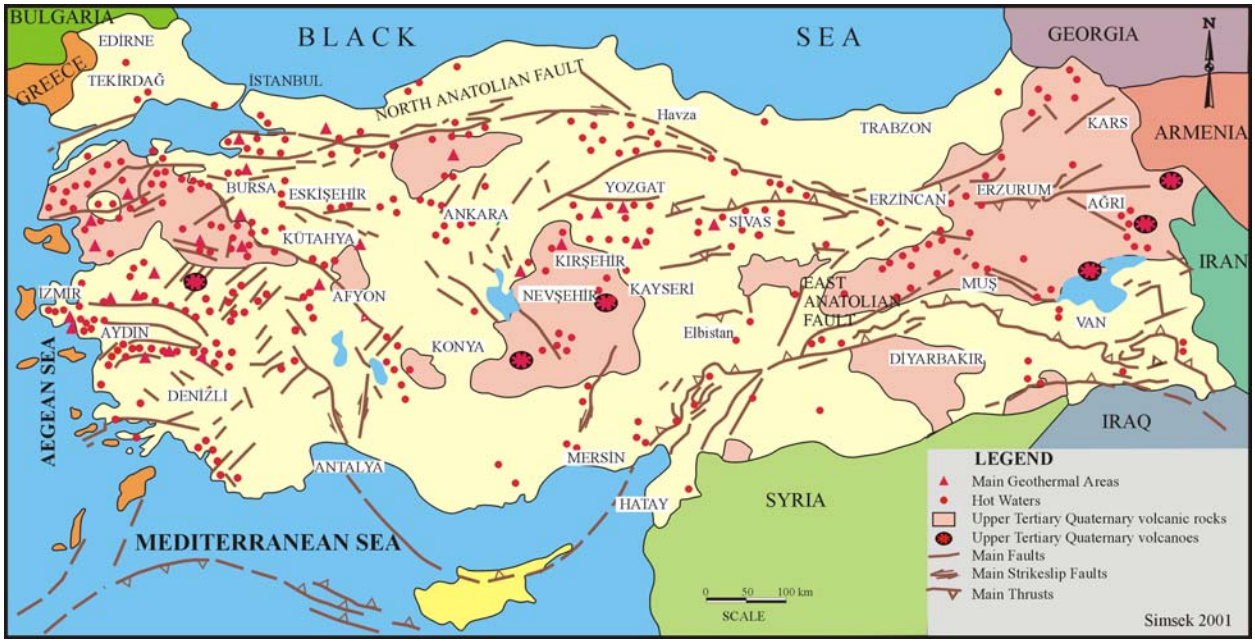

Figure 1. Main neotectonic lines and hot spring distribution of Turkey

As a result of the exploration and development studies, which have been done, a pilot electrical power plant (20.4 MWe) was installed in Denizli-Kizildere field in 1984 and than important developments in applications of greenhouse and dwelling heating systems and balneological uses (992 MWt) has been obtained in Turkey. Since the geothermal sources are clean, cheap and renewable there is an expectation for widespread applications all around the country in the near future. In this paper, the expectations in the commission report prepared by State Planning Organization (SPO-DPT), which includes the geothermal activities in Turkey between 2001-2005, will also be clarified (Şimşek et al. 2000).

2. GEOTHERMAL POTENTIAL OF TURKEY

The first geothermal researches and investigations in Turkey have been 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 1000 hot and mineralized natural springs exist in Turkey. 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.

With the existing springs (600MWt) and geothermal wells (2573MWt), the proven geothermal capacity calculated by MTA is 3173 MWt (discharge temperature is assumed to be 40 °C).(Fig.2). The geothermal potential is estimated as 31,500 MWt. Up to now 400 geothermal explanatory and production wells and 200 gradient wells have been drilled in Turkey (depths up to 2398m). The portion of the wells drilled by MTA in the total number of wells is 342 (Akkuş, 2002). Moreover, the first geothermal well was drilled in 1963 and the number of the wells drilled increase after 1982.

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.
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 (Akkuş, 2002).

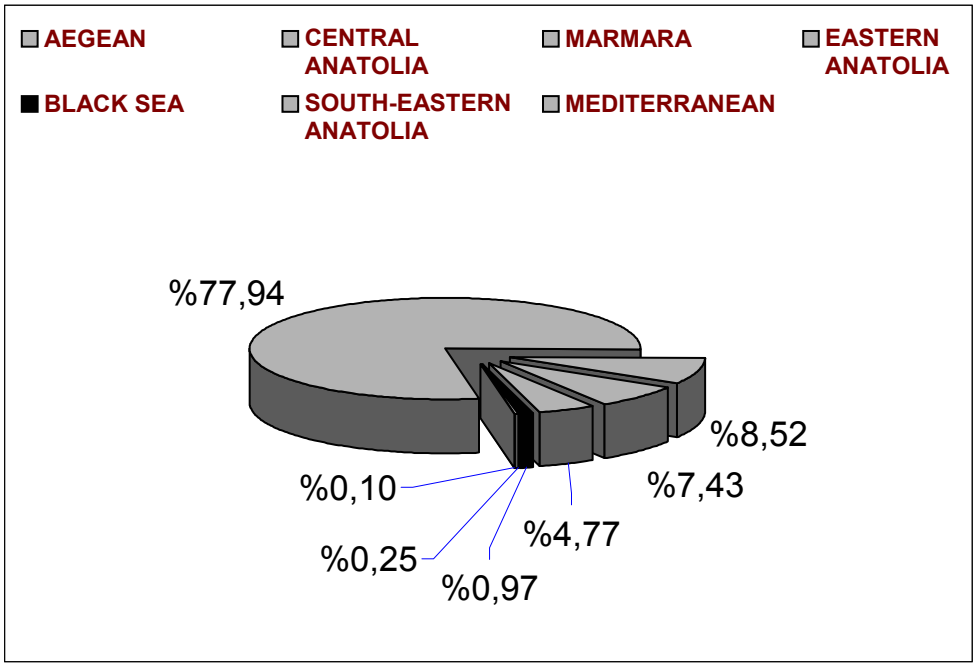

Fig. 2. Proven potential percentage for regions in Turkey (Akkuş, 2002)

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.

3. HIGH TEMPERETURE FIELDS AND APPLICATIONS

A first exploration regarding geothermal electricity generation was started in 1968 with the investigation of Kizildere Geothermal Field by MTA and UNDP. 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 TEK. (Turkish Electricity Establishment, renamed as EUAS) with an installation capacity of 20.4 MWe (Table 1, Photo 1). The reservoir temperature in the Kizildere geothermal field is 200-242°C. 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 tones of liquid carbon dioxide and dry ice annually since 1987 (Table 2, Figure 3).

Photo 1. Kızıldere Geothermal Power Plant (20.4 MWe).

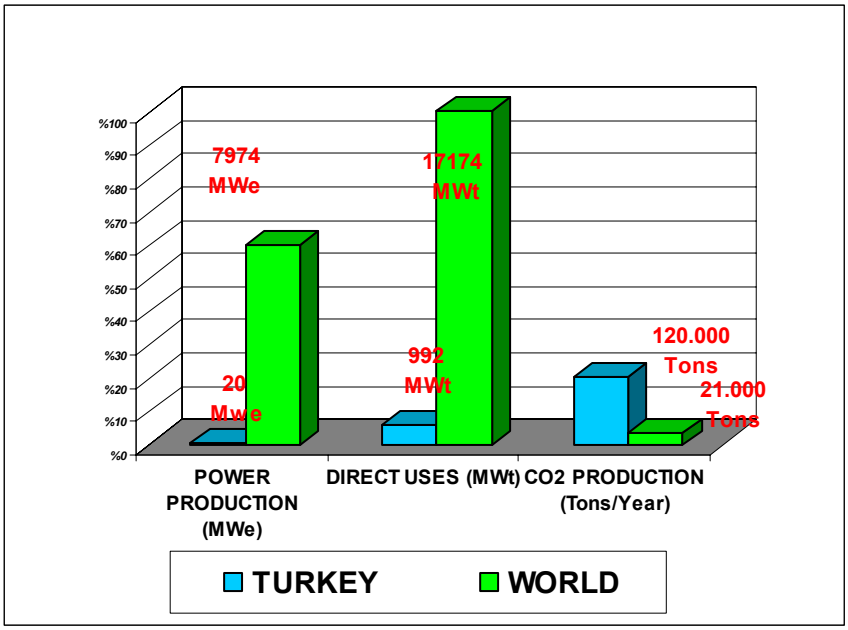

Figure 3. Geothermal energy utilization in Turkey and in the World

Table1: Capacities in Geothermal Utilization in Turkey (August 2003)

Geothermal Utilization	Capacity
District Heating	665 MWt
Balneological Utilization 195 Spa	327 MWt
Total Direct Use	992 MWt
Power Production	20.4 MWe
Carbon dioxide production	120.000 tons/yr

A power plant construction studies have been started at Germencik field (232 ^{o}C) in 2001 (Table 2). Some of the other high enthalpy geothermal fields and their reservoir temperatures are Çanakkale-Tuzla (174 °C), Aydin-Salavatli (171 °C) and Kütahya-Simav (162 °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)

Table 2: Utilization of Geothermal Energy for Electric Power Generation in August 2003

Locality	Power Plant Name	Year Commis.	No. Of Units	Status	Type of Unit	Total Installed Capacity MWe	Annual Energy Produced 2000 GWh/yr	Total planned MWe
Denizli - Kizildere	Kizildere Power Plant	1984	1	Presently Operated	Single Flash	20.4	91.8	-
Aydin	Germencik							25 MWe, planned

4. LOW TEMPERATURE FIELDS AND APPLICATIONS

Geothermal energy currently provides a stable and environmentally attractive heat source to 11 city based district heating systems in Turkey (Table 3). Today, 40-45 °C geothermal waters are used for space heating in Turkey without heat pump.

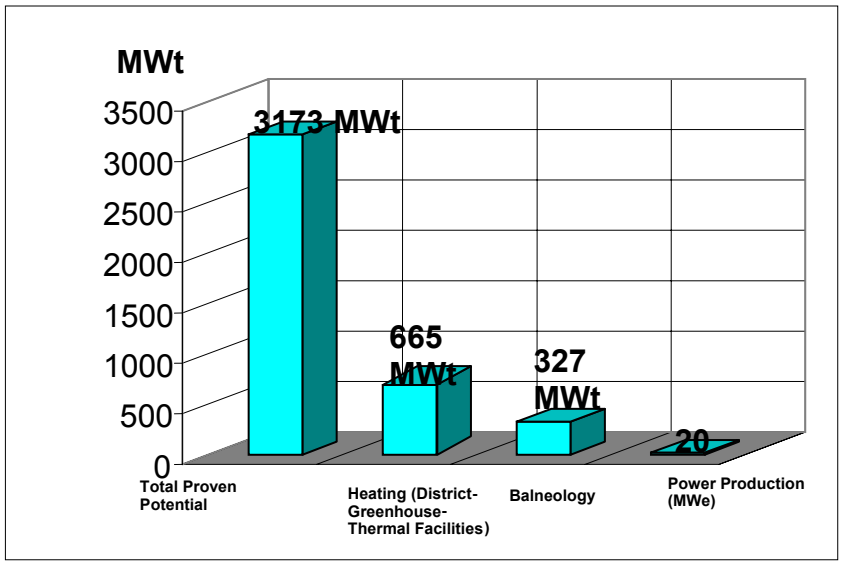

Fig. 4. Geothermal uses of proven potential in Turkey.

Table 3. Some geothermal fields and their fluid temperetures used for heating in Turkey

Geothermal Field	Fluid Temperature (ºC)
Gönen (Balıkesir)	80
Simav (Kütahya)	120
Kızılcahamam (Ankara)	80
Balçova (İzmir)	137
Narlıdere (İzmir)	98
Sandıklı (Afyon)	70
Kırşehir	57
Afyon	95
Kozaklı (Nevşehir)	90
Diyadin (Ağrı)	70
Salihli (Manisa)	94

10 Million m^2 geothermal greenhouse exist in the world. 564.000 m^2 geothermal greenhouses exist in Turkey. In Şanliurfa city nearly 250.000 m^2 geothermal greenhouses exist, where the yield obtained from the greenhouses is exported to Europe.

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 fields (91) which temperatures over than 50 are givin at Table 4 (Akkuş, 2002).

Most of the development is achieved in geothermal direct-use applications by 61.000 residences equivalence geothermal heating (665 MWt) including district heating, thermal facilities and approximately 564.000 m^2 geothermal greenhouse heating. 195 spas in Turkey are used for balneological purposes (327 MWt). Engineering design of more than 150,000 residences equivalence geothermal district heating has been completed. A total of installed capacity is 992 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.

Annually average of 23 % increment of residential connection to GDHS has been achieved since 1983 in Turkey.

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).

Table 4. Geothermal fields have reservoir temperatures over than 50 ^{o}C in Turkey (Akkuş, 2002)

AFYON	Ömer–Gecek	**BOLU**	Sarıot		Gediz-Abide
	Alaplıderesi (Uyuz Hamamı)		Seben-Kösenözü	**MANİSA**	Kurşunlu
	Heybeli (Kızılkilise)	**BURSA**	Karamustafa-Kaynarca		Sart
	Gazlıgöl		Kaya-Sada (Orhaneli)		Saraycık
	Çobanlar	**ÇANAKKALE**	Tuzla		Menteşe
	Hüdai(Sandıklı)		Kestanbol		Kula-Emir
AGRI	Diyadin-Köprüçermik-Yılanlı		Hıdırlar		Urganlı
AKSARAY	Ziga		Ozancık		Horzum Sazdere
ANKARA	Kızılcahamam		Kırkgeçit		Alaşehir-K.Dere
	Ayaş-Çoban	**ÇANKIRI**	Çavundur	**NEVŞEHİR**	Kozaklı
AYDIN	Germencik-Ömerbeyli	**DENİZLİ**	Gölemezli	**NİGDE**	Narlıgöl
	Aydın-Ilıcabaşı		Kızıldere		Çiftehan
	Çamköy-Bozköy-Alangüllü		Tekkehamam	**RİZE**	Ayder
	Salavatlı		Yenice		İkizdere (Ilıcaköy)
	Yımazköy		Karahayıt		
	Ortakcı	**DİYARBAKIR**	Çermik	**SAKARYA**	Akyazı
		ERZURUM	Kıgıhazman	**SAMSUN**	Havza
BALIKESİR	Gönen	**ESKİŞEHİR**	Sarıcakaya-Sakarılıca	**ŞIRNAK**	Hısta Çermigi
	Hisaralan	**İZMİR**	Balçova	**SİVAS**	Sıcak Çermik
	Hisarköy		Seferihisar	**TOKAT**	Sulusaray
	Pamukçu		Dikili Kaynarca		Reşadiye
	Susurluk-Kepekler		Bergama-Dibek-Poyracık	**UŞAK**	Banaz
	Susurluk-Yıldız		Bademli		Hamambogazı
	Edremit-Derman		Çeşme	**VAN**	Hasanabdal
	Edremit-Güre		Nebiler		Özalp-Çaybagı
	Manyas-Kızıkköy		Aliaga		Şorköy
	Şamlıdag	**KIRŞEHİR**	Terme		Zereni
BATMAN	Holi		Mahmutlu	**YALOVA**	Termal
BİNGÖL	Hacıköy		Karakurt		Armutlu
	Harur	**KÜTAHYA**	Eynal	**YOZGAT**	Sorgun
BİTLİS	Nemrut		Naşa-Çitgöl		Saraykent-Kara Magara

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 (Table 5).

Table 5. Geothermal utilization projections of geothermal energy in Turkey

Years	**Power Prod. (MWe)**	**Heating** (Residences Equivalency)	**Spa/Others (MWt)**
2010	500	500.000 (3500 MWt)	895
2020	1000	1.250.000 (8300 MWt)	2300

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.

5. ENVIRONMENTAL EFFECTS

Geothermal energy is the most environmentally benign source of heat. In geothermal district heating systems nothing must be discharged to the environment and atmosphere.
By heating 61.000 residences equivalence geothermally in Turkey 565.000 tons of CO_2 emission has not been discharged to the atmosphere (Mertoglu et al, 2003). It is equal to cancel 340.000 cars from the traffic (As peak emission amount in January).
On the other hand, since the solution alternatives for waste water problem are increased (as reenjection), with regard to the environment geothermal fields must be activated very rapidly.

6. EXPECTATIONS CONCERNED TO THE 8th FIVE YEARS PLANNING PERIOD (2001-2005)

According to the scope of the report prepared for State Planning Organization (SPO-DPT), it is thought that an important part of geothermal energy potential will be run next years in Turkey. According to the 8th Development Program for Five Years (8. BYKP) (2001-2005), the aims which are expected to realize are as follows (Şimşek et al. 2000):

1) The usage of geothermal energy with integrated installations of 2890 MWt in heating.
2) Exploration of new fields, and for determination of characteristics and capacities of present field, providing the required support to MTA, Universities and Private Organizations for their research, development and application projects.
3) Selection of new type power plants with high efficiency and suitability of these power plants for technology of the heating systems which are used at present (as new type binary cycle systems).
4) The following of the developments related to geothermal energy in the World, to take supply required background of related specialists and to support their experimentation and popularity in this sector.
5) Since the solution alternatives for waste water problem are increased (as reenjection), with regard to the environment geothermal fields must be activated very rapidly.
6) Scaling and corrosion problems which effect the management of geothermal energy, have been solved by the injection of the chemical inhibitor. Consequently, it is necessary to activate the fields and to accelerate the investments at this sector.
7) To supply the required support about know-how transfer, education, finance and equipment necessities via realization of projects in common with international organizations.
8) To provide the validity of related legislations as soon as possible.
9) Determination of utilization possibilities of geothermal fields planning of these fields in the form of integrated utilization and encouragement of the geothermal usages.
10) To encourage the electrical utilization investments to accelerate the explorations and the priorities by the way of Build-Operate-Transfer (BOT) and to attempt to enter the geothermal sector.
11) To encourage the international organizations for their investments about this sector.

7. CONCLUSIONS

Main geothermal utilizations in Turkey, the installed capacity is 992 MWt for direct-use and 20.4 MWe for electricity power production, where a liquid carbon dioxide and dry ice production factory is integrated to this power plant, with a capacity of 120000 ton/year.
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 in 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.
There are some points, which should be improved for the development of geothermal applications. These points could be summarized as follows:

- Turkish geothermal law should be finalized as soon as possible,
- Existing fields should be management 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 planing of these fields in the form of integrated utilization and encouragement of the geothermal usages.
- More financing aids should be received and international cooperation should be developed for the geothermal development projects in Turkey. To supply the required support about know-how transfer, education, finance and equipment necessities via realization of projects in common with international organizations
- 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 will be held in 2005 in Antalya-Turkey, this activity is an international success of geothermal development in Turkey.

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