
GEOTHERMAL UTILISATION AND APPLICATIONS IN TURKEY

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ABSTRACT

Geothermal energy exploration and studies were started in the 1960's in Turkey 140 geothcrmal fields have heen explored with a wellhead tempcraturc ahovc 40 °C.

In Turkcy. geothcrmal cncrgy is utilised mostly in heating (dwellings, greenhouses, thcrmal facilities), and in Balneology. Beside these applications, geothermal clectricity generation and production of industrial food grade CO_2 (40.000 tons/year) also exists and associated to the Kızıldere Geothcrmal Power Plant.

X7 % of gcothcrmal cnergy consumption in Turkey results in heating.

Al present, 23.000 dwellings equivalency have hcen hcatcd geothermally in Turkey and the geothermal heating engineering designs of nearly 130.000 dwellings have heen completed. In Gönen, 1500 dwellings. in Kırşehir 1800 dwellings and in Simav 3500 dwellings arc hcatcd geothermally. With the addition of thermal facilities, hotels and greenhouse heating. the installed capacity is 159,67 MWt (23.000 dwellings equivalency), systems under construction (July 1994) 121,10 MWt (17.300 dwellings equivalency), the feasibility studies completed for geothermal heating and air-conditioning systems which is 563.46 MWt (80.500 dwellings equivalency) and finally, with the addition of 1420 MWt which is the capacity of existing geothcrmal natural self flowings and geothermal wells (most of them arc contributing to balneological and hot spring facilities and their exhaust temperature is assumed to he 35 °C) makes the total proven geothermal direct use capacity of Turkcy 2264.2 MWt.

To date the geothermal water is transported from *4* km distance for district heating. A feasibility study for transportation of geothermally heated sea water 46 km distance for heating and air-conditioning in İzmir has hccn completed.

In Turkey. the geothermal tluids can he classified chemically as 95 % incrusting and 2-3 geothermal fields include highly corrosive geothermal tluids. Wc therefore have some experience in preventing scaling, corrosion and gas corrosion togcthcr. Only in 3 geothermal fields, does the gcothermal tluid containing total dissolved solids of over 5000 ppm. In the rest of the geothermal fields (among 140 geothermal fields in Turkey). the total dissolved solids are less than 5000 ppm.

By suitahlc systcm and equipment design and treatment of the geothermal fluids we do not suffer from severe scaling or corrosion prohlcms.

1. INTRODUCTION

10 ycars ago, waling and corrosion was the main problem for utilising geothermal rnergy in Turkcy. Due to the application of downhole heat exchangers, chemical inhibitors, fiberglass epoxy pipes and stainless steel or titanium heat exchangers, the utilisation of geothermal cncrgy has hccn speeded up and we have made very impressive progress during the last 10 ycars in utilisation of gcothcrmal cncrgy in Turkcy.

During the production, transportation and separation of the geothermal tluid. gas corrosion had hccn cncountcrcd due to the free gases of CO_2 and H_2S. Against the gat corrosion, we have increased the pressure and used suitahlc plastics, epoxy fiber glass and AISI 316 stainless steel pipes (also pipes made of special alloys of stainless steel). Sa, we have solved the gas corrosion problem in the rangc and conditions of our geothermal fields in Turkey.

For some of the production casing in wells, PVC, epoxy or polyester fiberglass pipes are used.

Currently at the Rize-Ayder curing centre and at Haymana mosque heating, the geothermal water is used without using heat cxchangcrs and pumps, due to a suitahlc chcmical composition of water (44-55 °C).

As an example to one of our scale and corrosion preventing applications in Turkey ;

Three years ago, we experienced a huge amount of corrosion at the Afyon-Ömer geothermal well, especially at the wellhead. The geothermal fluid can he classified as incrusting and corrosive. For scaling we had applied a phosphonate inhihitor. But, later we cncountcrcd a huge amount of corrosion due to CO_2 and H_2S, especially at the wellhead and in the casing. Afterwards, we had an interesting application :

For two weeks at the beginning, , the wells were on production without using any chemical inhihitor. During that period, we cncountcrcd mainly $CaCO_3$ scale deposition ahout 10 mm thickness. The CaCO, scale deposition covered the inside of the well and also thr production casing and wellhead. During that time we did not operate the system and production speeded up the scale deposition inside of the well. After that. we starred production with the chemical inhibitor. So, the 10 mm scale deposition in the well was a protective film inside of the production casing and wellhead and the gas corrosion impact problem was solved. It has hren running for 3 years, no problems has been encountered. Previously, every 6 months, the wellhead equipment was destroyed due to gas corrosion. This experience constitutes a very interesting and important example for the geothermists of the world.

2. NON-ELECTRIC USES OF GEOTHERMAL ENERGY IN TURKEY

2.1. Geothermal District Heating Applications In Turkey

Unfortunately, the dwellings in Turkcy. arc not well insulated at the walls and windows. And also the average area per dwelling is approximately 100 m^2. Also, the domestic hot water have heen used by people free of charge. For this reason, the energy consumption for each dwelling is high when compared to the Paris geothermal district heating application. For example in Kırşehir, the peak energy demand for each house is approximately 8000 kcallh at - 12 "C outside design temperature. For places having mild climates as in Gönen, the outside design temperature is "0" °C and the consumption is 6600 kcallh.

The geothermal district hating of 1500 dwellings, 5h tanneries, 2000 m^2 greenhouse, 600 hed Hotel and the hot water processing system of tanneries in Gönen (Balıkesir), is continued since 1987 with 16,2 MWt capacity.

Dokuz Eylül University, Campus of Medical Faculty and Hospital Building (approximately 30000 m^2) has heen heated geothermally since 1983 fed hy the Balçova geothermal field. The pay-hack time for the investment was 6 months based on fuel oil hurning. Installing of the additional 110000 m^2 geothermal heating system plus hot usage water of the Medical Faculty of Dokuz Eylül University (1100 dwellings equivalency) has started in February 1492 and is running since November 1992. The total capacity of the systems fed from Balçova geothermal field is 17X MWt.

The downhole heat exchanger was used for the first time in 1981 in Izmir-Balçova Thermal Facilities. İzmir-Balçova Thermal Facilities including Hotels, swimming-pools, curing centre (1500 dwellings equivalency) are heated geothermally.

In Kozaklı and Kızılcahamam, a feasibility and engineering design study of 3500 dwellings and 10000 m^2 greenhouse heating system has heen prepared and the project is ready for investment. In Kızılcahamam the thermal facilities are already heated geothermally.

The spas and hotels in Gediz have been heated by a geothermal water of 7X °C temperature since November 1487 (525.000 kcal/h capacity).

Floor heating is applied in spas of 1000 m^2 area in Havza by 54 "C geothermal water. The system started operation in October 1988 and the capacity is 60000 kcal/h.

In the Rize-Ayder curing centre, thermal water system and the district heating system is fed by 55 °C geothermal water and has a total installed capacity of 210.000 kcallh.

Two mosques in Haymana are hcing floor heated by 41 "C geothermal water. The system begun to operate in December 1988 and November 1989 with a total capacity is 80.000 kcallh.

In the Salihli Thermal Facilities, a 220.000 kcal/h capacity geothermal heating system for 50 hotel apartments is in operation since November 1989.

Geothermal Heating of Sivas Sıcak Çermik Thermal Facilities (2100 m^2), hy 46 °C geothermal water with a complete thermal water and scale deposition prevention-system has started to run in December 1993.

48 "C geothermal water is utilised for geothermal heating of Afyon-Oruçoğlu Thermal Resort Facilities by means of a floor healing system (2.350.000 kcal/h).

In Afyon-Ömer Thermal Units. geothermal heating has hcen applied to 35 apartment hotel villas, spas and 5000 m^2 greenhouses. The system has hcen in operation since November 1989 with a capacity of 2.200.000 kcal/h. In this plant. a system which completely prevents scaling has heen applied.

Afyon-Gazlıgöl Thermal Facilities are heated hy 68 "C geothermal water with a capacity of 550.000 kcal/h and 100 dwellings equivalency.

Afyon-Bolvadin (900.000 kcal/h) and Simav-Eynal (1.900.000 kcal/h) Thermal Facilities and hotels have started to run since the heginning of 1994.

Simav geothermal district hating system begun to operate in December 1992. The system capacity is 3500/6500 dwellings which is the largest geothermal district heating system in Turkey.

Moreover, the engineering designs for a 80.000 m^2 of geothermal greenhouse heating in Simav and geothermal heating for a total of 1500 dwellings in Sakarya-Kuzuluk has heen completed.

Kırşehir Geothermal District Heating System started to run in March 1994. To date nearly 1000 dwellings equivalency are heated geothermally. The total capacity of the system is 1800/6500 dwellings.

Some detailed information about our biggest geothermal district heating systems are mentioned below :

GÖNEN Geothermal District Heating System

Turkey's first geothermal district heating system was at GÖNEN which has heen running for Y years. The total installed capacity is 16,2 MWt where 1500 dwelling,, a hotel With 600 hed capacity and greenhouses are heated geothermally, and the heat and process hot water demand of tanneries was supplied hy the Gönen geothermal district heating system.

At the heginning, we had a very simple reinjection application, where the waste geothermal water with a temperature of 40 °C was discharged to natural sources for seven years. For more than one year we have selected a reinjection well with a depth of 110 m which was used before as a production well. Geothermal waste water is pumped with I bar pressure to the reinjection well. According to observations of the wells, the dynamic water level has increased hy 20 meters and no temperature decline has heen recognised. Therefore, we have obtained good results for reinjection at GONEN. The flowrate of the geothermal fluid for heating in GÖNEN is 80 L/sec. and its average temperature is 80 °C .

In GÖNEN, downhole pumps have hecn installed in the geothermal wells at SO m depth. During the winter time the water dynamic level is reaching a level of ahout - 45 m. But, after reinjection, the dynamic water level has increased to - 25 meters.

SİMAV Geothermal **District** Heating System

Simav geothermal field is one of the first 15 important geothermal fields in 'Turkey. The construction of Simav Geothermal District Heating System was begun in March 1991, and has been operational since December 1992.

The higgest district heating system in 'Turkey is at SİMAV with the 3500/6500 (33 MWU 66 MWt) dwellings heating capacity which has hcen operational for more fhan a year. The geothermal tluid is transported from 4 km distance and after supplying heat for district heating. the tluid is transported again 4 km back where 80 % of it is reinjected, with 0.2 bar pressure back to the reservoir and the rest is used for balneological purposes. The temperature loss is only 1 °C in 4 km. The scaling and corrosion problems have heen solved hy means of an inhihitor (5 g per 1 m^3), epoxy fiberglass pipe, 316 stainless steel plate type heat exchanger and partially hy CO_2 and H_2S separation.

At the wellhead, we aimed two purposes; These are a separator and a kind of direct contact heat exchanger. It means that, we separate the CO_2 mainly. from the geothermal tluid which has a temperature of 143 "C and its return temperature is 40 °C. We inject the geothermal water to the inside of the separator and we condense the geothermal steam to geothermal water phase. If means thnt : the separator and the direct contact heat exchanger produce 95 °C geothermal water with big amount of flowrate and the energy balance is constant.

Therefore, the separator have been used as a kind of condenser which condenses the geothermal steam to the water phase. The water is pumped through the district heating system. Therefore this wellhead separator is a kind of condenser and direct contact heat exchanger. Effective separation pressure is about 1,5 bar.

This system is led from a 720 m deep well by 143 °C and 70 L/sec. geothermal water. Thr temperature of transported geothermal water is 95 °C. The heiting system of dwellings with radiators are working with 80 °C/45 °C cycling temperature of clean water.

60 % of thir investment is supported hy the citizens of Simav. This is an autofinance system whereas the citizens are paying the geothermal heiting cost of 2 years in advance and they are geothermally heated free of charge for 3 years. This autofinance system has heen accepted hy the citizens and great participation has heen encountered also from other cities where geothermal district heating applications exist in Turkey or which their feasibility studies are completed. The rest of the Simav Geothermal District Heating investment is supported by Ministry of Environment hy 1 Million US$.

KIRŞEHIR Geothermal District Heating System

This system has a 1800 dwelling capacity, where 240 L/sec. average flowrate is required for the whole year. In this system, 97 % of the energy is supplied hy geothermal energy and 3 % hy means of fuel-oil burning.

The temperature loss in the city centre distribution network is only 0.4 °C/km. The heating systems of the dwellings are working with 54-60/42 °C cycling temperature. Pumping of geothermal water and control of the city circulation pumps are made hy frequency converters in accordance with outside temperature. The necessary amount of flowrate is given to the system hy means of pressure flowrate control.

The annual geothermal water average needed for 1800 dwellings is 240 L/sec., 20 L/sec. of this water is used in thermal facilities and the rest is reinjected to the reservoir.

Kırşehir geothermal district heating system is running for heiting and hot water supply during winter season and hot water supply for the rest of the year. For -5 °C outside design temperature the heat capacity for 1800 dwellings equivalency is 18.25 MWt and 1741 kg/h in terms of fuel-oil hurning. Kırşehir geothermal district heating investment pays hack itself in 4 years.

Some other systems like geothermal heiting of streets in winter, supply of process heat for industrial utilisation, fishfarming. indoor and outdoor swimmingpool complexes for balneological purposes could he integrated to the geothermal district hating system.

Tahle 1 : The Capacities of our Geothermal District Heating Systems on Operation (MWt)

LOCATION	CAPACITY (MWt)	EXPLANATION
GÖNEN	16,20	Geothermal heating of 1500 dwellings, 2000 m^2 greenhouse and 60 tanneries, hot water supply
BALÇOVA	17,80	Geothermal heating of Balçova thermal facilities and Dokuz Eylül University campus
KIZILCAHAMAM	0,76	Geothermal heating of thermal hotel
GEDİZ	0,61	Thermal facility geothermal heating system
HAVZA	0,07	Thermal facility geothermal heating system
AFYON-BOLVADİN	1,05	Geothermal heating of thermal facilities and the hotel
HAYMANA	0,09	Mosque heating
SALİHLİ	0,26	Geothermal heating of 50 separate hotel villas.
AFYON-ÖMER	2,60	Geothermal heating of 35 apart hotel villas, restaurants, thermal facilities and greenhouse
AFYON-ORUÇOĞLU	2,73	Geothermal heating of hotel and curing centre
AFYON-GAZLIGÖL	0,64	Geothermal heating of thermal facilities
KIRŞEHİR	18,25	Geothermal district heating system of 1800 dwellings, hot water supply
SİMAV	66,00	3500/6500 dwelling heating, hot water supply
SİMAV-EYNAL	2,20	Geothermal heating system of thermal facilities, hotel and greenhouse
RİZE-AYDER	0,24	Geothermal heating of curing centre
SİVAS-SICAK ÇERMİK	0,17	Thermal Facility geothermal heating system
OTHERS	30,00	Some greenhouse and small spa heating
TOTAL	**159,67 MWt**	**23000 dwellings equivalency** **6000 m^2 * greenhouse**

* The greenhouses with total 100000 m^2 area located in different areas of Turkey are not included in thir part.

Tahle 2 : The Capacities of our Geothermal District Heating Systems on Construction (MWt)

LOCATION	CAPACITY (MWt)	EXPLANATION
ÇANAKKALE-EZİNE-KESTANBOL	3,37	Geothermal heating Kestanbol thermal facilities
BALIKESİR-PAMUKÇU	1,60	Geothermal heating of Balpaş thermal facilities
KÜTAHYA-YONCALI	0,93	Geothermal heating of Yoncalı thermal facilities
DİKİLİ	56,00	7000 dwellings geoth. district heating and 1000 dwellings geoth. air-cond. integrated system
KÜTAHYA-SİMAV	12,20	Addition of 1500 dwellings geothermal district heating system to existing 2000 dwellings
SALİHLİ	47,00	7000 dwellings geothermal heating, 1000 dwellings air-conditioning
TOTAL	**121,10**	**17000 dwellings equivalency**

LOCATION	CAPACITY (MWt)	EXPLANATION
İZMİR	168,0	Geothermal heating of 25000 dwellings 5000 dwellings air-conditioning, hot water supply
REŞADIYE	7,16	Geothermal heating of 1000 dwellings
KOZAKLI	11,10	1100 dwellings geothermal heating (1. stage) and hot water supply (total 16000 dwellings)
AYDIN	174,00	Geothermal heating of 18000 dwellings, 3500 dwellings geothermal air-conditioning and hat water supply
AFYON	107,00	Geothermal heating of 10208 dwellings (1.stage) and hot water supply (total 16000 dwellings)
KIRŞEHİR	*65.00*	Total 6500 dwellings geothermal heating and hot water supply
SIMAV	20,00	Globally 80000 m^2 greenhouse geothermal heating
SAKARYA-KUZULUK	11,2	Geothermal heating of total 1500 **dwellings** and hot water supply
TOTAL	**563,46**	**80500 dwellings equivalency geothermal heating** **Geothermal heating of globally 80000 m^2 greenhouse**

The feasibility study of İZMİR geothermal district heating system which contributes to the most interesting one in Europe, has been prepared and its technical and economical applicabilities are determined, for a geothermal heating capacity of 25.000/34.000 dwellings and air-conditioning capacity of 5000 dwellings in one system in IZMIR. The geothermally heated sea water as the heating media is transported for 46 km distance. 5 pumping stations exist in this system By using pre-insulated epoxy fiberglass pipes for this pipeline, the temperature loss will he only 5 "C in the whole 46 km distance. In the city distribution network the temperature loss will he only 0.5 °C/km hy means of pre-insulated epoxy fiberglass pipes with mall diameters. The heating system will be cyclic with 70/40 °C clean water.

The treated sea water is transported from 5800 m distance to Cumalı geothermal field, area where the geothermal production wells exist. In this area the energy of geothermal fluid will be transferred hy means of titanium plate type heat exchangers to the sea water. With 110 °C temperature the sea water will be given to the main pipe-line with diameter of 500 mm. Total flowrate will he 2130 m'lh. The produced geothermal fluid will have an annual average flowrate of 168 L/sec. Air-conditioning will be realised with hot sea water using ammonia or lithium bromide absorption units.

After the energy of geothermal fluid is transferred to sea water, it will be reinjected into 4 reinjection wells with an average depth of 500 m. The reinjection wells will be located approximately 4 km away from the production wells. The total capacity of the system is 168 MWt.

The downhole pumps, wellhead, pumping stations and the heat exchange systems are connected to each other by special radio control system. The whole system will work in accordance with outside temperature and loading factor.

Moreover, process heat utilisation for industries located on the path of the main network, 110 °C hot sea water (105 °C clean water) supply will exist.

AYDIN is the richest province in Turkey in terms of its geothermal resources. The feasibility study of AYDIN geothermal district heating system which is one of the largest in Europe have heen prepared and its technical and economical applicabilities are determined, regarding a geothermal heating capacity of 18000 dwellings. 3500 dwellings geothermal air-conditioning capacity, 200.000 m^2 greenhouse heating and 22 MWt industrial process heat utilisation in AYDIN. The total capacity of the system is 174 MWt.

The pre-feasibility study of **DENİZLİ** Geothermal District Heating System, have heen completed which will he integrated to Kızıldere Geothermal Power Plant. This system has a heating capacity of 25.000/35.000 dwellings. The integration to the geothermal power plant is made hy the usage of 147 "C wasted geothermal fluid with an average flowrate of 1000 tons/h. This fluid has heen discharged since 1984 to the Menderes River. Energy of the geothermal fluid will he transferred to treated water of Menderes River and increase its temperature to 115 "C and transported to a distance of 31 km to the City of Denizli. Moreover, this system includes also air-conditioning and process hot water supply of some industries and tanneries. At last, reinjection will he done at Tekkehamam geothermal field.

With a 10 year experience regarding the usage of epoxy fiberglass pipes against scale deposition and corrosion, en excellent corrosion and thermal resistance is obtained in geothermal applications. In thr usage of these pipes the geothermal fluid temperature is between 40 °C - 110 °C

When we do not use the scale inhibitor, the special fiberglass pipes with smooth inner surface are used which decrease the occurrence of scaling inside of the pipe. And also with the aid of high partial pressure of CO_2.

The pressure range up to 10 bars and the temperature loss gradient is 0.5 °C per km for the diameter of up to 200 mm and for upper diameters 0.1 " C per km, have been realised in Turkey.

The thermal resistance and insulating (polyurethane duck.) of these pipes leads to decrease of the temperature difference in the pipe walls and this case minimises or prevents forming of silica scale deposition. The epoxy resin used in these pipes, shows resistance to general corrosion and gas corrosion. These serve important advantages for application of these pipes in Turkey.

Against carbonate scaling, we are applying chemical inhibitor in most of our geothermal systems (totally 24 in July 1994). At 10 of our geothermal plants the chemical inhibitor is applied.

By burying of these pipes directly into the earth and not using heat expansion joints, decreases the cost of there pipe installations. Moreover, since no concrete trenches are used with these pipes, it brings advantages to geothermal district heating and geothermal water transportation applications.

By preparing sensitive engineering designs, making sensitive assembling and hy preventing the pipes from shock effects which may occur due to large amounts of temperature and pressure differences, we have ensured successful results in our geothermal applications.

3. OTHER USES OF GEOTHERMAL ENERGY IN TURKEY

Production of chemical substances as production of liquid CO_2 as well as dry ice, is realised hy KARBOGAZ Company with a capacity of 40.000 tons/year. This system is integrated to Kızıldere

Geothermal Power Plant.

First explorations regarding geothermal electricity generation has started in 1968 with the investigation of Kızıldere geothermal Field. In 1974 a pilot plant with a capacity of 0,5 MWe has been installed. Afterwards in 1984, the Kızıldere Geothermal Power Plant was installed hy T.E.K. with a capacity of 20 MWe.

Moreover, according to the prepared feasibility reports. the geothermal power generation capacity in Aydın - Germencik geothermal field is reported as 100 MWe.

4. CONCLUSIONS

We believe that the natural, clean, reliable and sustainable geothermal energy will hc more important in future as alternative energy resource.

In the year 2000, the geothermal heat production capacity is expected to hc increased to 2520 MWt, geothermal power generation capacity to 125 MWe and hy the year 2010, these values are expected to hc 6500 MWt and 258 MWe.

The share of the general total cost of geothermal district heating systems per dwelling for the year 1994 is approximately 750 US$.

Each dwelling in Gönen and Simav pay 1S US$ per month for the year 1994, for heating in winter and domestic hot water supply throughout the year.

The heiting costs in Turkey as U.S. cents, according 1994 figures and their comparison with geothermal energy are:

Electricity hased heating	**: 6,0**	**cents/ kWh heat**
Fuel-oil hased heating	**: 5,6**	**cents/ kWh heat**
Natural Gas based heating (average)	**: 4,8**	**cents/ kWh heat**
Coal hased heating (average)	**: 3,9**	**cents/ kWh heat**
Geothermal hased heating	**: 0,1 - 0,56**	**cents/ kWh heat**

Reinjection has hcen applied for more than one year in Gönen and Simav geothermal district heating systems and successful results have been obtained.

It is very important to use the most suitable technology for productivity, sustain and success of geothermal heating systems. The development of geothermal technology has solved many prohlems in Turkey. Scaling and corrosion problems have hcen solved hy means of choosing a suitahle equipment, correct engineering design and hy correct treatment of the geothermal fluid.

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