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DIYADIN INTEGRATED GEOTHERMAL APPLICATION

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ABSTRACT

Turkey is an energy importing country; more than half of the energy requirement has been supplied by imports. Oil has biggest share in total primary energy consumption. Besides this, Turkey is one of the countries with significant potential in geothermal energy. Resource assessments have been made many times by the General Directorate of Mineral Research and Exploration (MTA) of Turkey. The main uses of geothermal energy in Turkey are: space heating and domestic hot water supply, greenhouse heating, swimming and balneology, industrial processes, heat pumps and electricity generation. Since the geothermal resources are mostly moderate and low temperatured in Turkey, they are generally used for direct use purposes.

In this regard, Diyadin Geothermal Energy Integrated Project (DGEIP) is one of the most important applications in Turkey due to its integrated investment. The major areas of this integrated direct utilization are (1) district heating, (2) agriculture (greenhouse heating), (3) bathing and balneology (thermal hotel), (4) aquaculture (fishing pond), (5) industrial processes (liquefied carbon dioxide and precipitated calcium carbonate productions). The system, of which subsections are briefly described in the paper has a total of six wells, of which three are currently in operation and totally a volumetric flow rate of 750 liter per second with average well-head temperature of 78 °C.

1. INTRODUCTION

Turkish energy policy endeavors to assure energy supply; reliably, sufficiently, on time, economically, with consideration for environmental impacts, and in a way that supports and orients targeted growth and social developments. The government focused its efforts on improvement in domestic production by utilizing public, private, and foreign utilities and increasing efficiency by rehabilitation and acceleration of existing construction programs to initiate new investments (WEC-TNC, 1995; Kaygusuz, 1999).

The General Directorate of Mineral Research and Exploitation (MTA) has carried out geothermal energy explorations in Turkey. The inventorial works and chemical analyses of the hot springs and mineral waters started in 1962 (Hepbasli and Gunerhan, 2000).

In Turkey, more than 1000 thermal hot and mineral water springs up to 100°C and 140 geothermal fields with a temperature range of 40-232°C have been discovered. The total proven geothermal electricity generation capacity is 350 MW_{e} while direct use capacity is 2,843 MW_{t}. This proven potential increases by 5% annually with new exploration and drilling activities. The estimated geothermal power and direct use potentials are reported as 4 000-4 500 MW_{e} and 31,500 MW_{t} (5,000,000 residences equivalence), respectively. This means that % 30 of the total residences in Turkey could be heated by geothermal energy. The potential of geothermal development in Turkey is generally considered large in terms of moderate and low temperature resources (<150°C). Therefore, the resources mostly suitable for direct use applications (Gunerhan *et al*., 2000).

Geothermal energy is mostly used in direct use (dwellings, greenhouses, and thermal facilities) and for balneological purposes in Turkey. Today 51,600 residences equivalence is being heated geothermally (493 MWt). Moreover with the balneological utilization of geothermal fluids in 194 spas (327 MW_{t}), the geothermal direct use capacity is 820 MW_{t}. DOGAN Geothermal Inc has completed the engineering designs of over 15,000 residences equivalence geothermal district heating systems (GDHS).

High temperature geothermal fields suitable for conventional electricity generation are Denizli-Kizildere (200-242°C), Aydin-Germencik (232°C), Aydin-Salavatli (171°C), Canakkale-Tuzla (173°C), Kutahya-Simav (162°C) and Izmir-Seferihisar (150°C. The assessment of the other fields is still in progress. The only operating geothermal power plant of Turkey is Kizildere geothermal power plant, located near the city Denizli in Western Anatolia. Electricity generation takes place only in Denizli-Kizildere geothermal field with an installed capacity of 20.4 MW_e, where a liquid carbon dioxide and dry ice production factory are integrated to this power plant (Gunerhan *et al.*, 2000). In addition, the capacity of liquefied CO_2 is 100 tons per year while that of Agri (Diyadin) is 24 ton per day, which will start to produce by the year 2001 (Dogan Geothermal Inc., 2000).

2. PRESENT SITUATION OF GEOTHERMAL WELLS IN TURKEY

Up to date, 400 geothermal production wells and 300 gradient wells have been drilled in Turkey. The distribution of wells drilled is illustrated in Table 1, where 305 wells were drilled by MTA, representing a total geothermal well length of 119,240.85 m (Akkus *et al.*, 1998).

Table 1. *Distribution of geothermal wells drilled by MTA according to the years.*

Years	Number of Wells	Depth (m)	MTA Project
1960-1965	8	852.5	8
1965-1970	13	7869.5	13
1970-1975	16	7484.7	16
1975-1980	8	3597.1	7
1980-1985	49	24101.75	29
1985-1990	73	27211.4	11
1990-1995	65	18188.9	7
1995-1998	69	31752.7	7
1998-1999	4	3027.6	1
TOTAL	***305***	***119,240.85***	***99***

The temperature distribution obtained from the well outputs in Turkey is shown in Figure 1 (Akkus *et al.*, 1998). It is clear from the Figure 1 that the Western Region of Turkey has the biggest share in this distribution, with a percentage of 87 in the range of 250-40 °C.

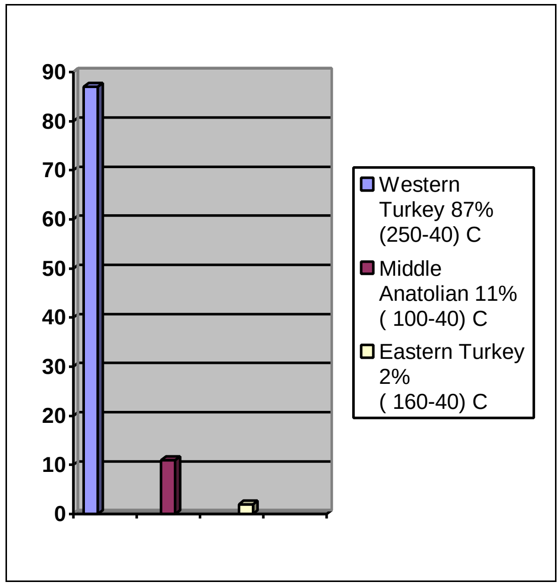

Figure 1. The temperature distribution obtained from the well outputs in Turkey

The first geothermal well was drilled in 1963 while the number of wells drilled increased in the period of 1980-1998. Besides this, as of the end 2000, the wells drilled are a few in numbers when taking into account the geothermal energy potential of Turkey. Most of these wells have been drilled by MTA and financed by Governorships, Municipalities and their companies, which account for 66.2 %, followed by MTA and private with 16.5% and 11.7%, respectively (Figure 2).

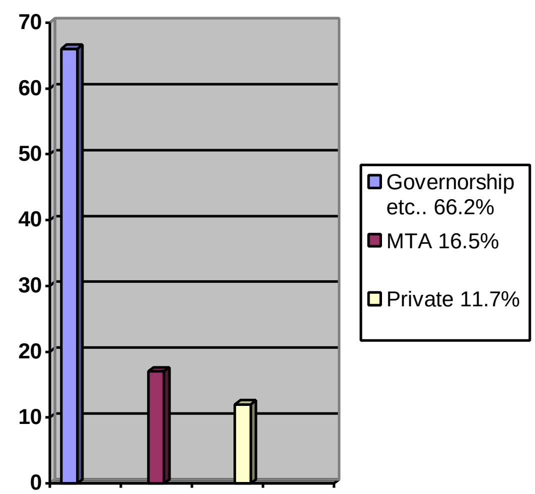

Figure 2. Distribution of the financiers of the existing geothermal production wells in Turkey

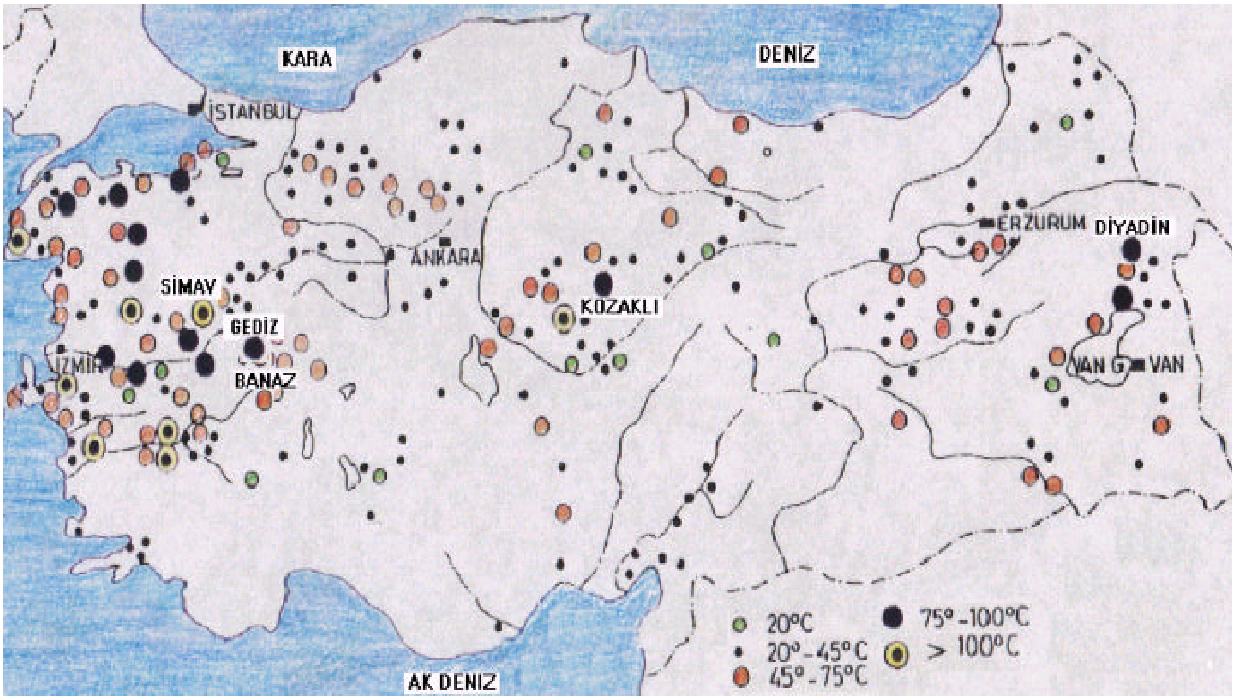

Figure 3. Distribution of the geothermal resources in Turkey

The distribution of the geothermal resources in Turkey according to their temperatures is shown in Figure 3. Geothermal District Heating Systems (GDHS) and Greenhouses Heating are the main geothermal applications in Turkey. The district heating system applications have been started with large-scale geothermal district heating systems in Turkey.

3. INTEGRATED GEOTHERMAL ENERGY APPLICATION IN AGRI (DIYADIN)

It is one of the coldest cities for heating in addition to four major area applications in Turkey.

3.1. LOCATION OF DIYADIN

Diyadin is a city in east Anatolian region that shows cold and terrestrial climate. Here, summers are short and warm while winters are hard and long. The annual average temperature is 8.7 °C, representing a maximum temperature of 37 °C and a minimal temperature of –25 °C.

The tourism center is volcanic area and divided by small streams near the Murat River. Diyadin is far from Mount Ararat that is Turkey's highest mountain. It is nearby to the borders of Iran and Armenia, as shown in Figure 4.

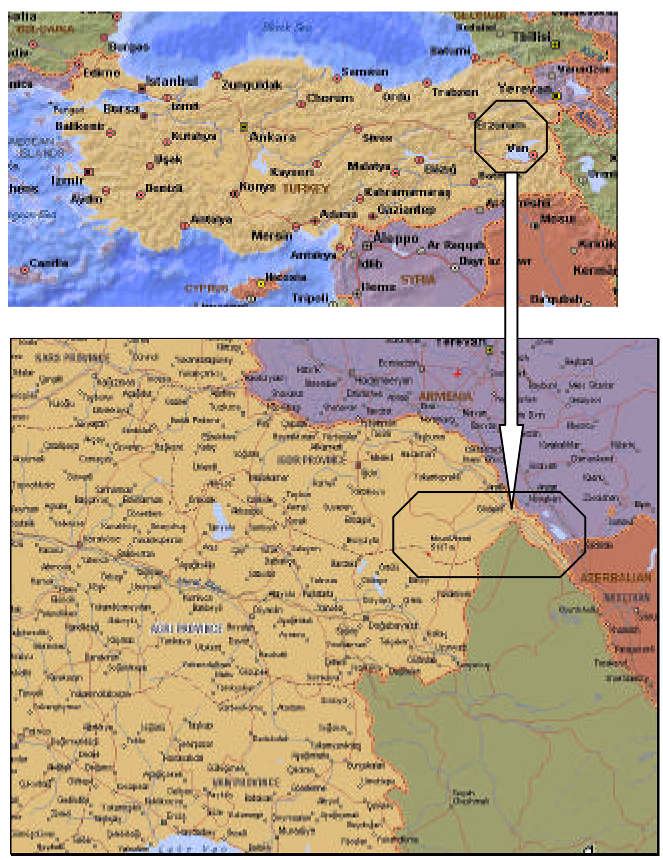

Figure 4. Location of Diyadin in Turkey's map

3.2. PRESENT SITUATION OF GEOTHERMAL WELLS

Location of geothermal area is south and 5-7 km. far from Diyadin city center. The potential of this geothermal area is up to 750 L/s. There are totally six wells with a total volumetric flow rate of 750 liter per second, representing an average well outputs temperature of 78 ^{o}C (Figure 5).

Figure 5. A view from Diyadin geothermal wells

3.3. PRESENT INTEGRATED GEOTHERMAL ENERGY APPLICATION AT DIYADIN

Diyadin Geothermal Energy Integrated Project (DGEIP) is one of the most important applications in Turkey due to its integrated investment (Soylu, 2000). The major areas of this integrated direct utilization are: (1) District heating, (2) agriculture (greenhouse heating), (3) bathing and balneology (thermal hotel), (4) aquaculture (fishpond), and (5) industrial process (liquefied carbon dioxide and precipitated calcium carbonate productions). The system, of which subsections are briefly described below, has a total six wells, of which three are currently in operation and totally a volumetric flow rate of 750 liter per second with an average well-head temperature of 78 ^{o}C (Figure 6).

3.3.1. District Heating: The capacity of the district heating system by geothermal energy is 2,000 dwelling equivalent, of which 1,037 have been completed at the first stage of the project. Geothermal fluid extraction rate is 42 MW_t.

The system uses 78 ^{o}C geofluid from geothermal artesian wells (which are collected to pump station) located 7 km from Diyadin small town, in very economical way. Geofluid is pumped to the heat center located at Diyadin, which is 7 km far from the pump station. Thus, the investment cost of the transportation pipe line (has EN 253 standard) has been optimized. The discharge temperature is 45 ^{o}C.

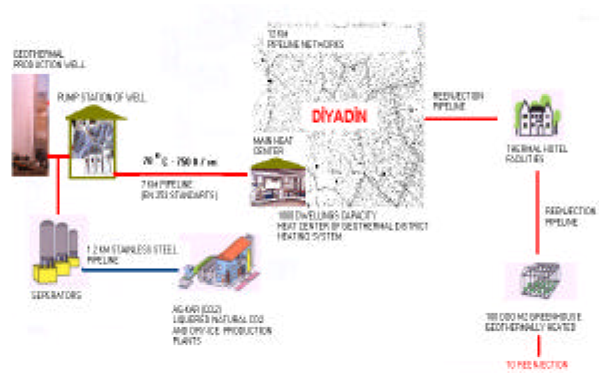

Figure 6. Flowchart of DGEIP

Diyadin city distribution network and branching comprises pre-insulated (manufactured according to EN 253 standard) steel pipes. Temperature loss in these pipes is optimized. In larger dimension, DN 250 and above, it is about 0.1 ^{o}C/km while for small dimension it is about 0.5 ^{o}C/km.

Automatically controlled temperature and flow control devices, circulating pumps, pressure and temperature control devices are used in the heat centers.

In the heat center and residential buildings, heating circulation pumps are divided into three stages. These are high, medium and low flow rate pumps. The outdoor average temperature determines which pumps will operate. The supply and return temperatures are always kept the same. According to Turkish Standard (TS) 2164), the outdoor design temperature is –24 ^{o}C.

The major problem with geothermal fluid at Diyadin wells is the scaling. To minimize the scaling problems, scale inhibitor is injected into the wells. Epoxy (inside surface of the steel pipes) and titanium plate heat exchangers are also used due to the corrosion and scaling. The first stage of the district heating system was commissioned partially in 1998's, with a total residence equivalence of 1,037 for a heat load of 15.74 kW_t (for a residence with a floor surface area of 100 m^2). The second stage of the district heating system will be completed in 2001's, representing a residence equivalence of 2,000.

3.3.2 Greenhouse Heating: Total capacity of the greenhouse to be geothermally heated is 100,000 m^2. However, 5,000 m^2 of greenhouses were currently constructed. Feasibility studies of second and third stages of greenhouse heating (50,000 and 100,000 m^2) projects were carried out. Pipeline and equipments for greenhouse heating by geothermal energy were also completed.

3.3.3. Thermal Tourism: Thermal Resort, which was completed in a period of eight months, has been operated for 1.5 years. This resort has a thermal potential of 300,000 people per a day (Figure 7).

Figure 7. Views from Diyadin thermal facilities

3.3.4. Fishing Pond: It will be possible to raise 400,000 kg per year of fishes after completing the project.

3.3.5. Liquefied Carbon Dioxide and Precipitate Calcium Carbonate Production:

Liquefied carbon dioxide production: The capacity of this plant is 100 ton per year while that of the dry ice is 1 ton per hour.

According to result of the gas analyses obtained from geothermal production wells of Diyadin, geothermal fields have a purity of 95%. These figures and data are suitable for the production of liquefied CO_2 and dry ice.

Gas (CO_2) that is taken from geothermal wells is separated from geofluid by separators. Blowers (see Figure 8) blow gas CO_2 then to CO2 plant. Transport pipeline was made of stainless steel. Firstly, sulphide and moisture are removed from gas CO_2. Gas CO_2 is liquefied in the plant and supplied into the storage tanks (Figures 9 and 10).

Figure 8. A view from liquefied CO_2 production plant

Precipitated production: The capacity of this plant completed is 7,000 tons per year.

Figure 9. A view from inside of liquefied CO_2 production plant

Figure 10. A view from outside of liquefied CO_2 production plant

Table 2. Some parameters in several applications based on optimisation values

PARAMETERS	UNIT	SYMBOL and LIMITS	KOZAKLI 237 day/year 2,000 dwelling heating	DIYADIN 268 day/year 1,000 dwelling heating	...
Parasitic losses	MW_e	X1	1	0.5	
Thermal losses	MW_{th}	X2	0.98	0.9	
Net thermal power	MW_{th}	X3	19.7	15.7	
Thermal power of geothermal wells	MW_{th}	X4	21.6	17.1	
Population using geothermal energy	Kisi	X5	10,000	5,000	
Flow rate of geofluid	t/h	X6	424	451	
District heating area	km^2	X8	1.5	0.6	
Length of the main pipeline	m	X9	23,000	10,000	
Maximum thermal load	MW_{th}	X10	34.5	31.4	
Electricity generated	MW_e	X11	-		
GFE =X3/X6 (Geofluid system efficiency)	$MW_{th}.h/ton$		0.05	0.03	suitable
SE =X3/X4 (System efficiency)	%	0.65<SE<1.0	0.91	0.92	suitable
GE=X11/X6 (Geothermal power effectiveness)	$MW_e.h/ton$	0.04<GE<0.22	-	-	-
IYY=X3/X8 (Thermal load density)	MW_t/km^2	IYY>12	13	26	suitable
BB=X9/X5 (Unit pipeline length)	m/person	BB<200	2.3	2.0	suitable

4. OPTIMIZATION STUDIES

Table 2 shows some performance indicators used in the evaluation of geothermal systems (Eltez and Kilkis, 1995). These indicators are applied to two geothermal applications (Kozakli and Diyadin) and compared with each other. It can be seen from the table that these parameters are in the acceptable range (Dogan, 2000).

5. CONCLUSION

Geothermal energy is a clean, proven and reliable resource for supplying the needs of a sustainable society and helping to improve the global environment (WGC, 2000).

Turkey is located on the Alpine-Himalian Oregenic Belt and has a place among the world's first 7 countries with respect to the abundance of its geothermal resources. However, only 2% of its potential is used (Eltez, 1997). This means that considerable studies on geothermal energy could be conducted in order to increase energy supply and to reduce atmospheric pollution in Turkey (Hepbasli and Gunerhan, 2000).

In this regard, in the implementation of the geothermal studies in Turkey, optimization criteria should be taken into account.

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