PROCEEDINGS, Thirty-Third Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, January 28-30, 2008
SGP-TR-185

ECONOMIC ANALYSIS FOR DISTRICT HEATING OF KÂHTA COUNTY WITH BRINE FROM KARAKUŞ OIL FIELD IN TURKEY

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ABSTRACT

In this study, Kâhta district heating system is projected using hot disposal water from Karakuş oil field. For that purpose, data collected on the last census and distribution of households are at first examined. Of sixty five hundred existing dwellings, half are found suitable for district heating.

The heating requirement for space heating of Kâhta County is estimated taking into account of climatic conditions of that area. Calculations on heat requirement indicated that the space heating of 3100 housings would be technically feasible by using hot water produced together with oil from Karakuş oil field. It is planned that after transferring the heat of brine through a heat exchanger to a secondary loop, the heat contained in fresh water in the secondary loop is transported to the Kâhta County by an insulated 6 km long pipe line, and the heat is distributed to the buildings through a hot water distribution network. The diameter of main pipe line is optimized, and the distribution network within the county is divided into 5 quarters.

Finally, capital and operational expenditures of this project are estimated, and an economic evaluation is conducted and its results are submitted.

INTRODUCTION

As the fossil-fuels phase out in the next century, it is clear that no single energy source will take over their role. Geothermal energy that could be largely used locally could play an integrative role. On the other hand, increasing oil and gas prices will make geothermal energy more economical in comparison with fossil fuels, as it had happened in late 70'ies and early 80'ies

Turkey is very much dependent on imported energy resources. To mitigate this energy dependence our engineers and scientists should work hard and be creative. In this connection, first, we have to focus on our resources. Beside our conventional fossil fuels, we have to pay attention to the alternative energy resources that would contribute our national production and at the same time reduce our energy dependence to more acceptable levels. Achieving additional energy production from other resources would contribute our energy production in a integrative way. One of these alternative resources is geothermal energy.

Geothermal energy involved in this study is the heat energy produced from semi-thermal resources. As known, unlike hydrothermal systems semi-thermal systems take place in sedimentary basins. The most typical examples of this sort of resources are Paris basin (Ungemach, 2005) and Pannonian basin in Hungary (Batocletti, 2000). In Paris basin originally 48 doublet wells have been used for district heating purpose. The temperature found in Karakuş area at approximately 2000 m is 25^{o}C more than the Paris basin.

Kâhta County (Fig. 1) is situated in mid-eastern of Turkey where some oil deposits are found. Heat flow studies conducted in our Petroleum and Natural Gas Eng. Department (Mihcakan, 2006) indicated that several semi-thermal resources might exist in this region of Turkey. The temperature gradient in the Karakuş area is relatively high (7^{o}C/100 m). Some of those resources are related to oil fields. Hot waters are produced with oil in our oil field's exploitation range 65 to 90^{o}C. With increasing water cut during oil production heat from hot water could be utilized for different direct use purposes such as district and greenhouse heating.

The aim of this study is to investigate the utilization of hot formation water produced and reinjected from and to the oil field Karakuş for space heating purpose.

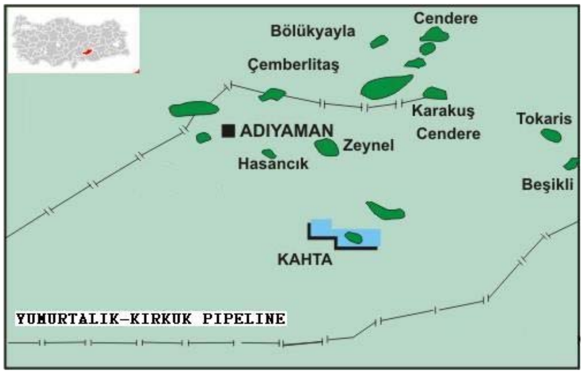

Figure. 1. Location of Kahta and Karakuş.

INFORMATION ABOUT KÂHTA COUNTY

As seen in Fig. 1, Kahta is situated in Midwestern Anatolia at an elevation of 725 m. It is a small county and with a population of 75000 inhabitants according to census conducted in 2000. There are 6550 households in the county and with 3-4 story buildings mostly located in the downtown area of the county. The distribution of buildings with respect to their number stories is shown in Fig. 2. Only 5% of households of the county have central heating system and the rest are heated by old fashion coal or wood fired stoves.

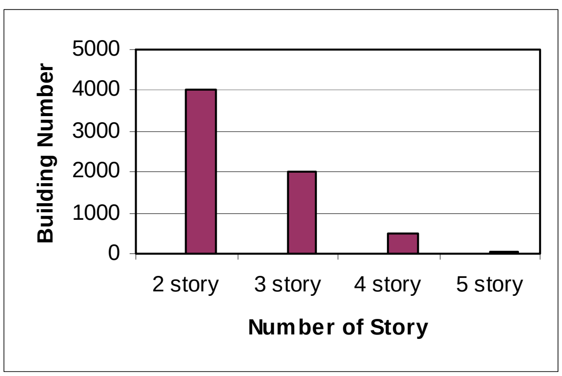

Figure. 2. Distribution of buildings according to their story numbers.

The wells in Karakuş field are situated at an elevation of 844 m and the distance between Karakuş oil field and Kâhta county is approximately 6 km. The first 4.5 km from Karakuş field is plain and then the road descends around 20 m in 1.3 km.

HEAT REQUIREMENTS OF KÂHTA COUNTY

After defining approximate heat losses for different building types, these values are normalized with respect to the number of households. And, by taking their weighted average of normalized values, the average heat loss value per unit household in Kâhta County is determined. Climate data are very important in designing district heating systems. By using climate data, the coldest month in the year is defined, and the heat energy to provide necessary heat in that month is assumed as the average peak load; then, system design is done on the basis of this maximum load.

Kahta had continental type climate in the past, and its climate and the surroundings have become relatively mild with respect to the past after building big dams around that area. Outdoor and indoor comfort design temperatures are chosen 0^oC and 20^oC, respectively. After these assumptions, Kahta's heat loss per household is calculated as 348 kCal/h^{o}C. Degree-day values for the county are computed by using average monthly weather temperatures of Kahta and shown in Table 1. The coldest moth of Kahta is January and its degree-day value is of 328.6 $(DD)_{month}$ (Satman and Yalcinkaya, 1999). January is therefore, the month when heat requirements are the highest, and as a result, the peak load on which the system is based is adjusted with respect to this month.

Table 1. Degree-Day Values for Kahta Area (Satman and Yalcinkaya, 1999)

Months	Average Temp.	Degree-day
January	4.4	328.6
February	6.1	249.2
March	9.9	158.1
April	14.9	3
May	20	-
June	25.8	-
July	30.1	-
August	29.8	-
September	25.7	-
October	19.1	-
November	12.1	87
December	6.7	257.3

To meet the hot water and heating water requirements for one household in Kahta, the necessary total energy is calculated as 5000 kCal/h^{o}C. Kahta is planned to be heated with the available hot water at 80^oC temperature and 615 ton/h flow rate, collected from the oil production wells. The brine from Karakuş oil field will provide heat energy of approximately 15 867 655 kCal/h. Taking into account available energy from the field and the energy needed for a household, it can be easily calculated that 3100 households could be heated (Cömertpay. 2006).

DISTRICT HEATING OF KÂHTA COUNTY

District heating system for heating Kâhta county is projected as follows:

1. The heat of waste water after separated from oil is transferred to a secondary fluid and

will be reinjected into oil field as always done.

2. Heat energy of brine will be transferred to fresh water after both cross-flowing through plate type heat exchanger. On the other hand, the heated fresh water will be pumped through 6 km long insulated pipeline to the county, and after transferring its heat there, it will be returned to the field by pumping through equally long pipeline for another heating cycle (first loop).
3. The distribution of heat energy of circulating hot water within the city distribution network (secondary loop) will be carried out by a third loop within the buildings after transferring its heat through a small plate type heat exchanger at each building.

Selection of heat exchangers, pipes and pump used in this district heating system are closely related to each other. Inlet and outlet temperatures of selected in heat exchanger design affect substantially pipe size and characteristics and sizes of pumps used in the systems that provide heat from the brine.

Prior to selecting pipe and pump sizes, a suitable heat exchanger is designed, and the system is designed by taking into account of frictional loses and velocities calculated for different pipe sizes on the basis of heat exchanger parameters. In selecting pipe sizes flow velocities are assumed between 1 and 3 m/s.

By holding constant the well flow rates that essentially control the district heating, brine coming from wells enters in plate type heat exchangers at 80^{o}C, flows through and exits at 50^{o}C, and then it is pumped to reinjection wells. On the other hand, fresh water coming from Kâhta at 40^{o}C crossflow through the heat exchanger, and is pumped back to the county at 74.6^{o}C. After examining the topography between Karakuş oil field where the heat energy is transferred and Kâhta County, frictional pressure losses for different pipe sizes within the certain velocity limits are computed. In addition, main heat exchanger design is done according to designed system load.

Kâhta County's hot water distribution network is projected in accordance with the county's plan and afterwards, frictional pressure losses are computed and pumps are selected. On the other hand, an optimization study is conducted for the main pipeline transporting hot fresh water from the field to the county. Fig. 3 indicates the result of optimization study, and resulting pipe diameter is found as 10" inches.

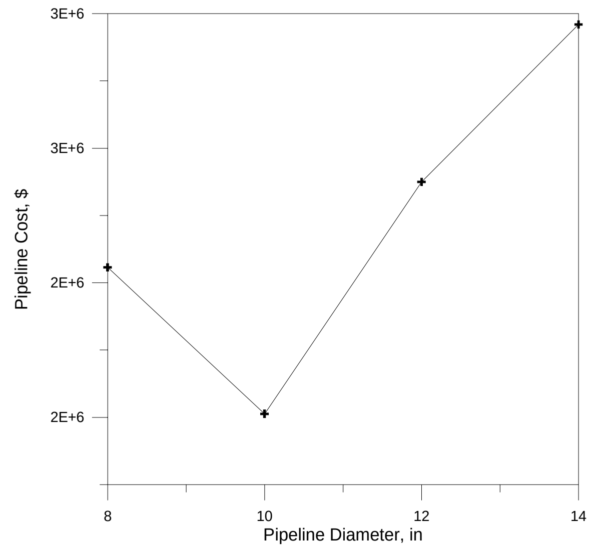

Figure. 3. Results of pipeline cost optimization (Serpen and Cömertpay, 2007).

In choosing 3100 households for the district heating system design, most dense settlement areas are selected by taking into account of regulations concerning construction. A hot water distribution network is established for 3100 households of Kâhta County. Network is designed by using a selected pilot area, and the amount of pipes and their diameters in the pilot area are determined. By projecting the obtained values for the other areas investment cost is obtained.

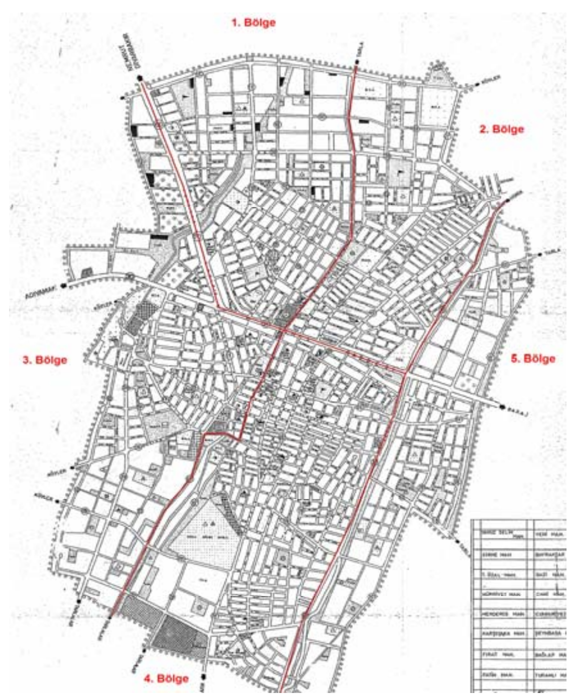

Figure. 4. Main distribution lines and different areas in Kâhta plan.

Fig. 4 shows the settlement map of Kâhta County. The road to Diyarbakir city is shown in the northwestern part of the map, and main pipeline entering Kâhta is installed on this road. Karakuş oil field is found 6 km away on this road. As shown in the map with a scale of 1/5000 (Fig. 4) the county is separated into 5 quarters. Since three of these quarters are less densely populated than the others, they have lower coefficients in the proportional projection. Of the 5 quarters, load density and pipe diameters of second quarter, which is selected as pilot area, are calculated, and finally, a distribution network is established for it. On the basis of this network, other distribution networks for other quarters are estimated by using their coefficients.

In the design, all the pipes involved in the project are assumed to be insulated and inlaid. In the insulation design, highest temperature loss of 0.5^{o}C/km is projected. As for secondary loop, the main heat exchanger which is designed for 74.6/40^{o}C range is installed in the oil field. Then, pumps, valves and fittings that are necessary for the main pipeline are also included.

ECONOMICS OF THE PROJECT

While the economic evaluation of project is carried out, optimization of main pipeline which has the highest cost in the project is initially conducted, and its results are presented in Fig. 3. As the optimum pipeline diameter from Karakuş to Kâhta is determined, pump costs and operation and maintenance cost are taken into account in addition to pipeline cost. Using optimization, the most economical pipeline diameter is selected considering temperature, flow rate and operational costs. Afterwards, the cost of all elements of the system is added to the optimized cost of main pipeline and initial investment of pipeline is found as 2343982 $ (Serpen and Cömertpay, 2007).

Taking into account of different pipe diameters, longitudes, frictional pressure losses and suitable pump selection, hydraulic design of distribution network of the county is carried out. After defining all these elements, cost of county's distribution network, including construction cost, is calculated as 8586648 $. The initial investment of the project is computed as 10930629 $ (Serpen and Cömertpay, 2007).

The project is evaluated for 20 years and annual operation and maintenance costs are calculated for the first decade and the second decade. Annual operation and maintenance costs are found 682694 $ for the first decade and 720976 $ for the second one.

Economic analysis of the project is conducted for the following 5 finance model:

Finance Model #1

In this model all 3100 households are assumed to be participating to "district heating system", and they would be charged with 180 $ for deposit, which is similar amount to the one natural gas companies are charging. The income obtained from the deposits is considered as equity, and the rest of the investment is financed by commercial credits. All credits are assumed to be withdrawn in the first year, and they will be used in the construction works for the system. Credits and interests would be paid back beginning with the second year in 7 years. The main pipeline and the distribution lines will be built in the first year, and district heating system will start to operate beginning the second year. Subscribers of the district heating system would be charged with a fixed monthly tariff of 40 $ for 20 years. The project life is assumed 20 years.

Finance Model #2

In this model a fixed monthly tariff of 60 $ would be charged to the subscribers.

Finance Model #3

This model differs from the first and the second models only in the monthly payment, which would be about 80 $.

Finance Model #4

In this model, the amount of deposit is increased to 300 $ and monthly fixed tariff is kept as 80 $.

Finance Model #5

In this model deposit is kept 300 $ and monthly fixed tariff is increased to 100 $.

Results of economic analysis for the assumed finance models are shown in Table 2 and Fig. 5.

Table 2. Results of Economic Analysis (Serpen and Cömertsay, 2007)

	Initial Invest.,($)	Tariff ($)	Dep. ($)	ROR (%)	NPV, $, (5%)*	NPV, $, (8%)*
1	10.93 E6	40	180	0	-6.87 E6	-8.04 E6
2	10.93 E6	60	180	1	-6.01 E6	-7.66 E6
3	10.93 E6	80	180	6	-0.13 E6	-2.10 E6
4	10.93 E6	80	300	7	+2.24 E6	-1.06 E6
5	10.93 E6	100	300	10	+6.73 E6	+2.32 E6

* Market interest rates.

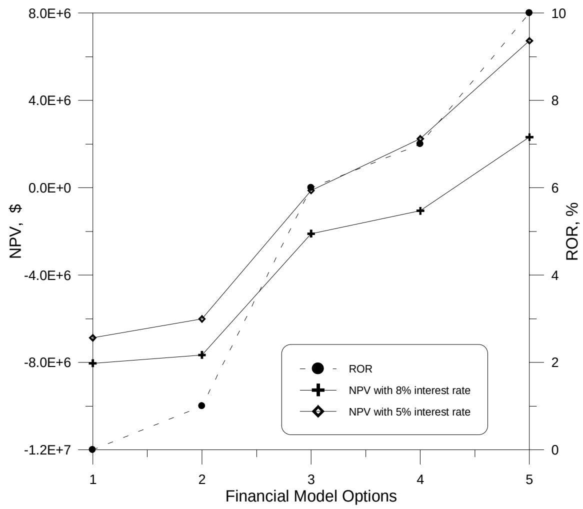

Figure. 5. Results of economic analysis for the finance options.

DISCUSSION AND RESULTS

District heating systems operated by the heat energy obtained from sedimentary semi-thermal areas in France and Italy have been installed on the resources discovered during oil exploration (Ungemach, 2005 and Carella, 1999). Initially, they had large heat pumps to provide sufficient heat energy. After some years of operation, supporting natural gas fired cogeneration systems have been introduced in two important geothermal district heating system (Ferrara and Vicenza). These major modifications point out economic and dimensional scale difficulties in big district heating systems supported by the heat energy obtained from semi-thermal areas. On the other hand, in order to develop semi-thermal resources, deep wells to 1500-2000 m have been drilled in those countries. The investment costs of those deep wells are very high. Initially, these district heating systems were supported by complex heat pump systems, which were later dismantled and natural gas fired cogeneration systems were introduced.

As for the application of similar heat energy generating model from semi-thermal areas of our country, no cost will incur for heat generating wells since there are already oil wells producing with 90% water cut, and this will provide a substantial economic advantage. However, to transport hot water that would be heating Kâhta County, 12 km long pipeline (two-way) should be installed. In calculations done within the context of this study, listing prices of pipes are used, and by assuming that insulation on pipes is subsequently installed, its costs are added to the pipe costs. Nowadays, insulated pipes are being manufactured in our country and their prices are relatively lower. On the other hand, costs of main pipeline and distribution system pipes could be drawn below the listing price by negotiating with manufacturers because of huge amount of pipe purchase. This might change substantially the feasibility of the project and turn it to positive.

In the financial model, while initial investment is relatively low because of no exploration and well costs incurred, the amount of deposit and fixed tariffs values are kept relatively high. As a result, it is aimed to maximize the profits. Construction and the pipe costs are the items that would primarily increase the overall costs. An optimization study is conducted for the main pipeline. If further optimization studies are carried out for the network distribution lines more reasonable initial investment costs might be obtained. This would be brought up with the detailed studies of the definite project works. In this connection, hydraulic design of the whole distribution system would determine the optimum pipe diameters of hot water distribution system of second loop.

In the previous section, project rantability with different scenarios has been investigated. By examining NPV and ROR values it is observed that the project is profitable with high deposits and fixed tariffs. The most profitable scenario is found to be finance model #5. Other parameter that will affect the profitability is the interest rate. As can be seen in Table 2 if the interest rate could be reduced to 5%, even finance model #3 became profitable.

In this study, by taking into account geothermal code drafts 3% of royalty has been foreseen for the state and local government. But, this figure is reduced to 1% in the recently approved geothermal code. Therefore, the actual economic state of the project is positively affected.

As seen in Table 2, the results of economic evaluation points out that the last model#5 is profitable. But, in our opinion, it would be difficult for Kâhta County to handle this sort of finance model. It would be more attractive economically sounder for the project to increase the value of deposit to 500 $ and reduce the tariff to 40 $, and ask on the other hand, for the state support for difference amount of 320 $.

Of the more than 10 large district heating system installed on hydrothermal resources in the western Turkey, none is feasible from the point of view of project economics. On the other hand, large amount of deposits ranging from 2500 $ to 3000 $ were collected from the subscribers of these systems. In addition, local governments also provided financial support for those projects. Though central heating is done by utilizing those district heating systems and public somehow benefit, none of those projects had paid back in terms of economy, and funds were largely transferred to the contractors who were aggressively promoting these uneconomic projects.

The main problem with these projects is that no real feasibility studies have ever been conducted for them, whereas the feasibility of district heating system of Kâhta County is sound one. If the local government of Adiyaman City to which Kâhta County is connected, supports this project, it could be possible to build this district heating system.

Since this district heating project will not produce CO_2, 300000$ annual income could be obtained through "Voluntary Emission Reduction" (VER) purchasing agreement. That figure could provide 3 million dollars of financial support for the project in project lifetime, which is a substantial aid that could positively affect the feasibility of the project, increasing NPV and ROR values.

On the other hand, flare gas from Karakuş oil field could be used to heat further the hot water transported to Kâhta County, and by this way heating capacity in Kâhta could be substantially enhanced.

Degree-day values of Kâhta indicate that this county needs only 4 months long heating season. But, the oil field will go on producing yearlong. So, the utilization efficiency of the source will be very low, which is similar in other direct use systems. To increase the utilization efficiency heat energy produced from Karakuş oil field could be used for food drying in other seasons.

The only event that might negatively influence the project rantability is the future abandonment of oil production, since water cut levels have reached 90%. With increasing oil prices this would not occur soon. On the other hand, if this would happen district heating management might go on producing hot brine from the field. We know that cash flows in the first years of the project affects the rantability of the projects much more than the far future cash flows. Therefore we do not expect the whole rantabibility would go to negative figures. But, this issue must be studied carefully before starting the project.

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