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Conceptual Planning of the Extension of Balcova District Heating System

+Macit Toksoy, +Engin Gulsen and *Umran Serpen

+Izmir Institute of Technology, Urla/Izmir, Turkey

macittoksoy@iyte.edu.tr

*Dept. of Petroleum and Natural Gas Eng. of Istanbul Technical University

serpen@itu.edu.tr

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ABSTRACT

The conceptual modeling of district heating systems (technical, economic and political feasibility) is a most important step in realizing this type of geothermal projects. Only projects that have economic analysis that is sensitive to the field developments with known field properties and conceptual planning could provide the basis for correct decisions on investments. Otherwise, big risks would be involved.

In this study, conceptual modeling suggested for geothermal district heating systems is applied to the Balcova System-2 and technical and economic feasibility of the system are investigated. The new system covers an area of a potential of 3917 dwellings. The total space heating area in the extension is around 310700 m^2. The most important factor that affects the economy of district heating systems is the ratio of participation by the dwellings in the area. In the study, different participation ratios (26%-100%), participation fees (1250-1500) and participation years (2-5) are considered, and monthly payments for the energy consumed are calculated. Results of the analysis indicated that reasonable ROR's could be obtained with 1250$ of participation fee, 20$ of monthly payments and average drilling costs. Applying conceptual planning to the Balcova System-2, unit area cost is cut by half, capacity cost is reduced 63% and unit area operation cost is lowered by 37% with respect to the original Balcova district heating system. Besides, in the light of this study, Geothermal Energy Regulation draft would be evaluated for its chapter titled "Essentials of Operation of Geothermal Systems".

1. INTRODUCTION

Turkey is rich in geothermal energy resources and besides the traditional spa applications, in the past 20 years several cities have developed geothermal district heating system (GDHS) projects. These projects that use Turkey's own geothermal energy resources in regional heating systems have a great lack of materializing the stages of conceptual planning properly as well as other problems (Toksoy and Serpen, 2001). By foreseeing the utilization of reservoirs whose characteristics are not properly defined and completing technical and economic analysis with incomplete data, these projects proceed through the planning stage. The results are geothermal district heating systems with extreme technical and economic problems faced by the owner and operator (Aksoy 2003, Sener et al., 2003, Erdogmus et al., 2003 and Toksoy et al., 2003). Although in recent years some technical and administrative standards have been developed (Serpen and Toksoy, 2001) these have not become an official regulation yet.

The very first step of the geothermal district heating system projects is conceptual planning (Aksoy, 2003) which includes technical, economic and political feasibility, as in other systems (ASHRAE, 1996). Completion of conceptual planning sensitive to the known characteristics and possible improvements of the reservoir and economic parameters (such as participation ratio and cost) can lead to the best decisions for the investment. Otherwise, risky investments may result.

The aim of this study is to apply the developed conceptual planning model (Toksoy and Sener, 2003) to the geothermal district heating system called System-2 which is planned to use the same reservoir as the existing system with a new pumping and control center and to discuss the results.

Due to lack of necessary information about the geothermal reservoir and especially of the financial resource (potential users) taken into account in Turkey, some uncertainties appear for evaluation of technical and economic possibility of geothermal district heating system projects. Searching for technical and economic possibilities with deterministic methods becomes impossible, contrary to the examples in the literature (Agioutantis and Athanassios, 2000 and Karytsas et al., 2003) but it is suggested to use stochastic approaches as seen in research done for electricity production using geothermal energy (Goumas et al., 1999). In this study the conceptual planning model developed by Toksoy and Sener (2003) for geothermal district heating systems is applied and the uncertainties in the financial model (participation ratio, participation cost, and monthly fixed energy charge) were overcome by parametric approach using different scenarios.

2. BALCOVA SYSTEM–2 GEOTHERMAL DISTRICT HEATING SYSTEM

Balcova System-2 geothermal district heating system is the first step planned for the enlargement of the existing geothermal district heating system in the east direction. The new system is independent from the present system as a city network but is a system planned to produce the required energy from the same geothermal reservoir. Its geographical location is on the west of Ata Street and on the south of Sakarya Street (Figure 1). The region plan seen in the Figure 1 is the aerial view of existing buildings taken in August 2001 from the city plan. The district has an area of almost 244,600 m^2.

3. CONCEPTUAL PLANNING: THE MODEL

Conceptual planning is a search of technical, economic and political feasibility of any project. Political feasibility is concerning whether the administration and the society support the project or not. Traditional spa applications, low heating costs seen in the operating geothermal district heating systems, being a national resource and relatively less environmental negative impact, create political support for these projects. The technical and economic feasibilities of geothermal district heating projects have some differences from the conventional district heating systems.

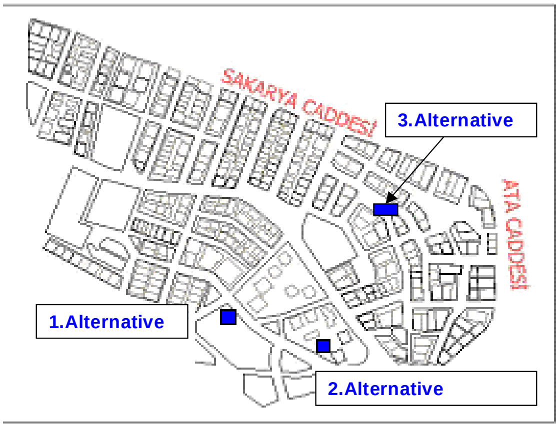


Figure 1: Balcova System-2 GDHS city plan and pumping station alternative locations.

In this study the conceptual planning model (Toksoy and Sener, 2003) developed for geothermal district heating systems is applied and the uncertainties in the financial model (participation ratio, participation cost, and monthly energy utilization fees) were overcome by parametric approach using different scenarios.

4. CONCEPTUAL PLANNING OF BALCOVA SYSTEM-2: DATABASES

4.1 Characteristics of Geothermal Reservoir

An important element affecting the investment and operating cost of a GDHS is the number of the wells that will supply the required energy and their corresponding costs. Balcova-Narlidere geothermal system is the only one for which reservoir performance project (Satman et al., 2001) is completed and is the best-known reservoir in Turkey. To be able to install new geothermal district heating systems, new production and reinjection wells are to be drilled and connected to the existing geothermal pipeline network. The first assumption about the capacities of new wells is that the new wells will have the same capacity as the average capacity of existing ones. The average flow rate of the production wells used in 2003 is 33 l/s and the weighted average temperature is 130^{o}C. The first method for calculating the cost of the wells is to use this average performance and calculate the required number of wells for System-2. However the well named BD-9 was drilled into the same reservoir while the conceptual planning stage has been going on, the capacity of the well BD-9 is more than the average capacities of the existing wells (100 l/s and 139°C) and this well has been planned as production well of System-2. In the economic feasibility calculations, the properties of both of average wells (Scenario A) and the well BD-9 (scenario B) have been considered.

4.2 Regional Properties

The region is an area and growth is almost (80%) completed. The maximum dwelling number in the region is calculated according to the existing dwellings, available land and city regulations for construction for this land.

4.3 Climatic Data and Design Heat Load

The outdoor design temperature is taken as 1.6^{o}C with 99% percentile value for System-2 and as typical year 1993 is chosen (Sen et al., 2000). The balance temperature used for estimation of energy consumption is chosen as 18.3^{o}C. Total number of heating days is 188, and heating period is 4700 hours according to 18.3^{o}C balance temperature and typical yearly data.

4.4 Social and Economic Analysis: Questionnaire Results

The geothermal district heating systems have high investment cost and when the previous feasibility studies in Turkey are viewed, it is observed that investment finance is provided by all householders who will pay their share of participation cost. This approach for investment is a critical decision for the GDHS projects and eventually causes shortage of finance in the stage of implementation. Many GDHS investments that began with those kinds of feasibility studies have longer installation time than expected and unexpected financial problem for the project owner. However, applying a public poll before the feasibility studies can provide more accurate information on energy consumption and on economics of the district where the geothermal district heating system lies. A public poll foreseen in the conceptual planning of a geothermal district heating system (Toksoy and Sener, 2003) was applied (Toksoy et al., 2003) for the district where System-2 GDHS will be developed and summarized below.

<u>4.4.1 The Number of Dwellings Survey Applied</u>

The public poll has been applied on 2049 dwellings out of 2467 dwellings present in the area. Some of the questions in the poll have not been answered because of a lack of information or not making a decision (for being a tenant) or the unused dwellings. However, the number of dwellings answering different questions is quite high and ranges from 83% to 85% of the existing number of dwellings. The number of the buildings that contain 2467 dwellings is 313 in the district. Approximately half of these buildings have 4 stories. One of the necessary inputs that will be used in conceptual planning is the areas of the dwellings. One of the methods that can be used for the prediction of the areas of the dwellings is the servicing maps prepared by the aerial photographs; the other one is getting the needed information from the residents by questionnaires. Both of the methods were used and the results were compared.

<u>4.4.2 Householders Desire for Being an Energy Consumer in Geothermal District Heating System</u>

The region of System-2 GDHS is at the border of the existing geothermal district heating system. For this reason residents are familiar with the GDHS. When asked if they would like to participate unconditionally in the district of geothermal heating system, the answer is mostly yes (89%). However, when the residents are asked if participation of geothermal district heating system result in a participation fee about 1000 to 1500 $ and unless they have got a central heating system there will be an additional investment cost about 1000 $ also, desire to use geothermal energy decreases to 74%.

After installation, how the ratio and process (in time scale) of participation will occur is not known and the subject requires scenarios. As in examples seen in the literature (Summer et al., 2003) the scenarios of 100%, 75%, 50%, and 33% participation rate have been suggested for the forecasts of investment and management costs. Experience from the other GDHS projects suggests that maximum participation ratio can reach a value between 75% and 80% a long time after the erection completed. In this study, 10 participation ratios between 100% and 26% were used.

4.4.3 Participation Distribution

The assumption of participation ratio being homogeneous seems correct since almost all of the buildings in the district are dwellings. This leads to a homogeneous distribution of investment and operating cost in the presence of participation ratio scenarios.

4.4.4 Heat Load Density

The heat load density, which is calculated from heat load inventory of dwellings, affects the investment and operating costs of the pipeline network and is another critical parameter of economic evaluation of geothermal district heating system (Bloomquist, 2000).

It is not possible to obtain an inventory about energy consumption of buildings in the region of System-2. For this reason; the load densities were calculated by using the average peak heating load 54.9 kcal/h.m^2 determined from heating load of 40 buildings in the district by the static heat loss method. By using the economic criterion (Table 1), economic evaluation of the distribution of load density for different participation scenarios were calculated on the total and the parts of district. As it is observed in the calculations; the economic availability increases as the participation ratio increases. Economic feasibility becomes possible for all participation ratios in the case of maximum dwelling.

Table 1: Economic availability related to heat load density.

Construction type	Heat Load Density		Availability for DHS
	MW_t/ha	Kcal/h.m^2	
Skyscrapers	Over 0.70	Over 60	Very available
Multiple story building	0.51-0.70	44-60	Available
Commercial buildings	0.20-0.51	18-44	Applicable
Two story buildings	0.12-0.20	10-18	Questionable
Single houses	<0.12	<10	Impossible

4.4.5 Conventional Energy Sources and Costs

In the region of System-2 most of the dwellings use one type of fuel for heating purposes while the others more than one. The dwellings using more than one type of energy sources are also using different heating systems (electrical and LPG heaters, coal stoves, etc.). According to results of questionnaire, answered by 2049 dwellings:

- The total annual cost of the energy used for heating purposes calculated by using current energy prices is $ 512,416. Fuel oil, with 47%, has the biggest ratio in total costs.
- By January 2003, monthly fixed energy cost per square meter is about 0.2 cents for the dwellings in the Balcova-Narlıdere Geothermal District Heating System. According to this price, total annual energy expenditure of 2049 dwellings in System-2 will be 524,602 $. At first sight, it seems that total annual energy costs of dwellings in the conventional and in the geothermal system are approximately equal to each other. However, the results of the questionnaire show that, merely 23.1% of these dwellings have flat heating systems. Despite having flat heating systems, 3.3% of these dwellings also use other heating devices as coal stoves and electrical heaters. Under these conditions the existence of thermal comfort is not the case either for the mentioned 3.3% of the dwellings or for the remaining 76.9% dwellings using stoves. In other words; with the same energy cost, instead of having thermal comfort only in the 20% of the dwellings, all of the dwellings in the district will have thermal comfort by geothermal energy.
- Total annual conventional energy expenditure of total existing and future buildings can be forecasted by extrapolation as $ 727493 and $ 910128 respectively.
- Annual energy costs of conventional and geothermal energy systems for an average and 100 square meters dwellings are almost the same but, the thermal comfort in the dwellings heated by geothermal energy in System-2 will be incomparably higher than in the conventional heated ones.

4.4.6 Heating Costs of Dwellings Using Flat Heating System

In the dwellings heated by flat heating system the weighted average of annual heating cost per dwelling is $ 616, for a 100 square meter dwelling the average heating cost is $ 514. The geothermal energy cost, on average, is approximately 50% lower. According to the average of two dwellings using coal, geothermal energy seems 68% more expensive. However, there is not any detailed information about either the heating system or the thermal comfort. According to the information collected during in the poll, each of these dwellings has a living area of 230 square meters and is consuming 1.3 ton coal each year for heating purposes. Obviously it is not possible to reach thermal comfort with this amount of coal during heating season in the dwelling with any heating system.

4.4.7 Heating Cost for Dwellings Using Stove

The average and weighted average annual heating costs of dwellings using stove in the district where System-2 GDHS developed for different type of fuel are less than geothermal energy cost. But, stove use in a dwelling means uncontrollable heating of one space (usually living room) at a certain time of period and no thermal comfort in the remaining spaces (bedroom, kitchen, bathroom, sleeping rooms, etc.).

5. SYSTEM-2 CONCEPTUAL PLANNING: TECHNICAL DESIGN

5.1 System Capacity

For the design of System-2 Geothermal District Heating System, total heating area is considered as 391,700 m2 which is the total maximum area of dwellings in the district. By using 54.9 kcal/h.m^2 as the peak heat load per unit area (heating + hot water), the heating load for the existing dwellings is calculated as 19.7 MW_t, and the heating load for maximum area of dwellings is estimated as 24.9 MW_t.

5.2 Energy Transfer System

The energy transfer system chosen for System-2 is a two-stage system (EN253, 1994). The produced geothermal fluid will return to the reinjection wells after it transfers its energy at the main heat exchangers in the pumping station (usually called heating center) to the working fluid in the city circuit. The city circuit will transfer the energy from the main heat exchangers to the heat exchangers in the building. The reason for choosing the two-stage system instead of a one-stage system is to prevent the effects of high pressures (6-7 bars) in the city circuit and to have the convenience of automatic control.

5.3 Technical (service) Life of Materials

While making a choice of material for system components (heat exchanger, pipe, gasket etc.) in the design stage of geothermal district heating systems, mechanical behavior of materials in contact with the geothermal fluid (temperature and corrosion effects) and how the mechanical properties of the materials change in time in working conditions must be considered and finally the materials that minimizes the total cost must be chosen. One of the main components of GDHS is the geothermal and city (pipeline) network. Pre-insulated pipes that are formed in three parts are used for this network: Inner pipe (steel or FRP), insulation material (polyurethane) over the inner pipe and protecting jacket (polyethylene) over all. One of the most critical properties of these materials is thermal endurance. Combined life is the smallest one of all components for the operating temperature. For example, the combined life of Steel (St37) pipe, polyurethane insulation and polyethylene jacket at 140°C is 3 years. The critical component for this example is the polyurethane life of 3 years at 140°C. In the design of the previous system, Balcova-Narlidere GDHS, this property was not considered and in the pipes carrying 130°C -140°C geothermal fluid, polyurethane was used. This material was burned and lost its properties in a short time. The technical life of material also affects the economic analysis as changing replacement time, cost of amortization and salvage value.

5.4 Operating Temperatures

As shown in the Figure 2, by using the control system close to the well site, on the geothermal fluid circuit, the temperature of the produced fluid at 139°C from BD-9 well will be decreased to 120°C and it will be sent to the pumping station. At the pumping station some of the geothermal fluid (21 l/s) coming out of the heat exchanger at 55 °C will mix with geothermal fluid at 139°C and the remaining (72 l/s) will return to the reinjection well. The reason to decrease the temperature of the fluid produced in the geothermal line to 120 °C is to prolong the rapid decreasing of technical life of polyurethane at higher temperatures. Including the heat losses on the geothermal line, the amount of fluid that must be produced for System-2 from BD-9 well at the peak load of 25.4 MW_t will be 72 l/s. Producing geothermal fluid up to 100 l/s from BD-9 well is possible. The production above the requirements of System-2 will be used to foster the Balcova-Narlıdere geothermal district heating system. In order to determine the temperature regime of the water that will circulate in the city network, the analysis of investment and management cost of the pipe circuit is made according to the pipe types, maximum operation temperatures and compound technical life. As a result, the most appropriate temperature regime is found to be 90°C / 50°C (Gulsen, 2004). The temperature regime in the building network is chosen as 70 °C / 45 °C considering the costs of the heat exchangers of the buildings.

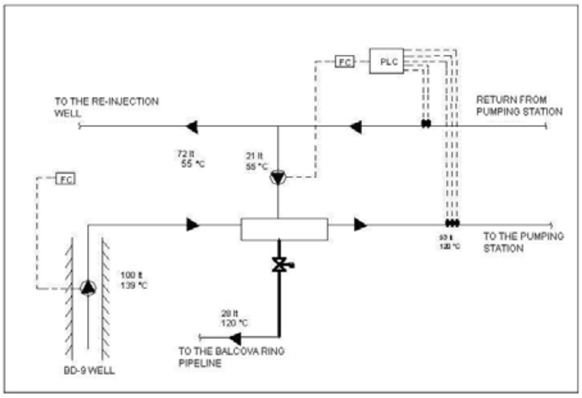


Figure 2: Schematic of mixing and control system at the BD-9 wellhead.

5.4 Selection of Pipe Materials for Geothermal and City Network

Considering all of the pre-insulated pipes alternatives, the pipe type that will minimize the total cost is selected for the pipe network of the geothermal district heating system.

5.5 Geothermal Network (Figure 3)

The alternative pipe types taken into consideration are pre-insulated (polyurethane and polyethylene) steel (St37) and FRP. The isopthalic FRP cannot stand 120°C operating temperature. The total investment costs (net present value) for 20 years system life are presented in Figure 4 for different pipe materials.

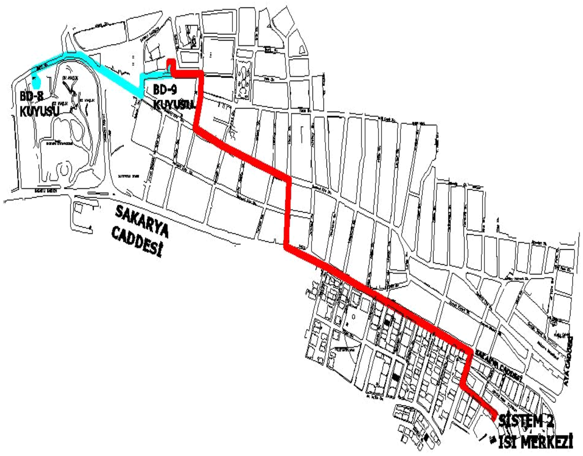


Figure 3: Geothermal network.

5.6 City Network

Three pre-insulated pipe types are taken into account (steel, isopthalic FRP and FRP) for the city network and investment and operating costs are calculated for different system temperatures (Figure 5). Investment cost includes pipe, pipe installation and excavation. Operating cost is including the electricity consumption of circulating pumps and cost of inhibitor for corrosion. One can see in Figure 5 that there are two results for the steel pipe with different service life. Observations in Balcova-Narlidere GDHS show that for small diameter (<250 mm) pipes the service life is much lower than 10 years and for large diameter (>250 mm) pipes it is about 10 years due to improper installation. Observation of previous system suggests 10 years service life for steel pipe system, but the proper installation will result in longer service life as much as 15 years. The costs are net present values for 20 years time period.

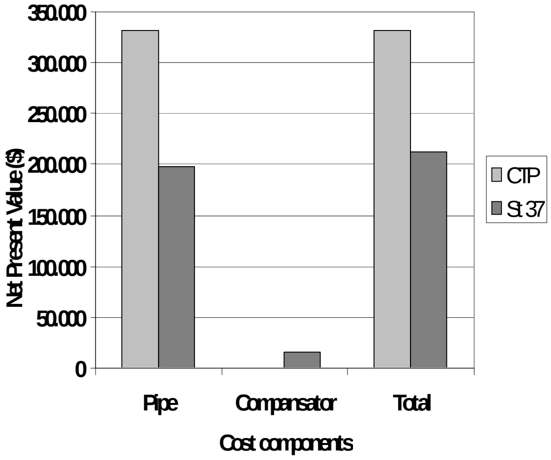


Figure 4: Total costs of geothermal network.

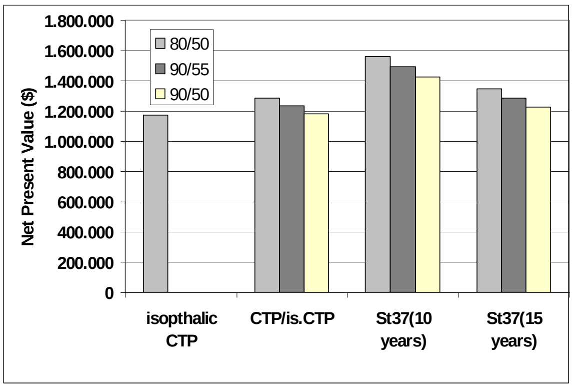


Figure 5: Total costs of city network.

As seen in Figure 5, if isophtalic CTP is used, the entire network with the temperature regime of 80°C/50°C is reaching the minimum cost. However the temperature regime of 80°C/50°C increases the costs of heat exchangers of the buildings and the radiators (heaters) in the dwellings. Because of this reason, the nearest alternative with the minimum cost of pipe material (CTP for the supply line, isophtalic CTP for the return line) becomes the most appropriate pipe material with the temperature regime of 90°C/50°C.

5.7 Selection of the Heat Exchangers

For System-2, plate-type heat exchangers are selected because of their convenience for periodical services (for cleaning) and small volumes. At the pump station, for the lower zone 2 units of heat exchanger with the capacity of 4, 93 MW_t and for the upper zone 2 units of heat exchanger with the capacity of 7, 55 MW_t are considered to be used. The plates of the heat exchangers in the buildings are selected as stainless steel; the plates of the heat exchangers at the pumping station are selected as titanium because the geothermal fluid has a chlorine content which is on the edge of the corrosion value for stainless steel.

5.8 Diameters in the City Network

Investment cost is increasing while operating cost is decreasing with an increase at pipe diameters and an optimization required for the selection of diameters. The diameters of the pipes which make total cost minimum around 17.7 mm/m target head loss in the city network are selected by using Pipelab program (Figure 6). Resulting head losses in the lower and upper zones are given in Figure 7.

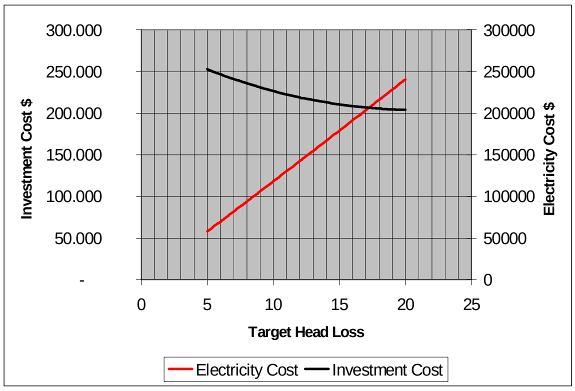
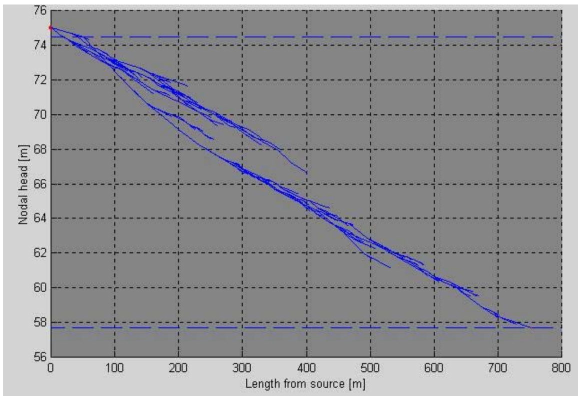
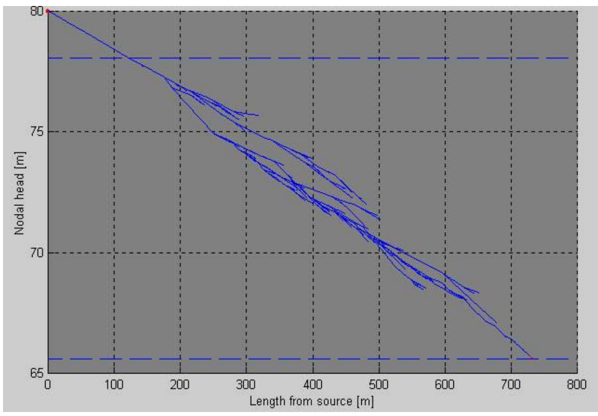


Figure 6: Optimization of target head loss.



Lower zone



Upper Zone

Figure 7: Head losses in the lower and upper zones.

5.9 Selection of the Circulation Pumps

After determining the system characteristics with respect to the changing outdoor temperatures, the most efficient pumps are chosen from the manufacturer catalogues. Since for partial and peak load it is desired that the pump is working with a high efficiency, two in line-type pumps are planned to work in parallel with efficiencies of 70% - 80%. To adopt changing outdoor temperatures the pumps are of adjustable speed driven type.

5.10 Control System

For observation and control aims, an automatic control system is designed (Gulsen, 2004) to control the system load with constant temperature and variable flow. This system will measure the temperatures, flow rate, parameters of frequency converters in networks and then control the pumps according to heat load simulation. Variable flow rate will be achieved by changing pump speed with frequency converters.

6. CONCEPTUAL PLANNING: ECONOMIC ANALYSIS

6.1 Investment Cost

The geothermal and city networks are designed according to the maximum load that the system will reach with maximum number of dwellings and it was taken into account in the investment cost with this dimension. The costs of production and reinjection wells are alternatively calculated as given in Section 4.1. The number and costs of wells are calculated with average capacities (Scenario A) or the costs of BD-9 well in addition to the well having the equivalent reinjection capacity (Scenario B). These two scenarios and sub-scenarios for different participation ratios are considered in the economic analysis and the investment costs are tabulated accordingly in Table 2.

6.2 Operating Cost

The annual operational cost of System-2 geothermal district heating system according to 100% participation ratio with the heat load at the maximum dwelling capacity (391,700 m^2) is given in Table 3. The electric consumption is the energy that will be used by the pumps and it is calculated by using the average temperatures per hour of 1993 typical climate year and the existing CEER (Conventional Energy Excess Ratio) values (Sener et al., 2003) calculated for Balcova-Narlıdere Geothermal District Heating System. The operational costs including personnel, service, marketing and general expenses are calculated based on the expenses that exist in Balcova-Narlıdere Geothermal District Heating System (Gulsen, 2004).

6.3 The Finance Model

One of the important steps of economic analysis in conceptual planning is figuring out the finance model. The investment finance of Balcova System-2 geothermal district heating system is suggested to be supplied by the participation cost of the dwellings and the monthly fixed energy cost charged to the dwellings which will benefit from the geothermal district heating system, as it is practiced in the other applications in Turkey. The internal rate of return for different participation costs (1250$, 1350$, 1500$) is computed by finding the monthly fixed energy costs which make internal rate of return positive around 0%. Another parameter in the finance model is the integration schedule of dwellings into geothermal district heating system. Two different periods, 2 and 5 years, has been taken into consideration. For any participation ratio, the increase of the number of the dwelling in the geothermal district heating system assumed linear in each period.

6.4 Internal Rate of Return Analysis

The internal rate of return analysis has been carried out for different well scenarios (A and B), participation schedule (2 and 5 years) and participation costs (1250$, 1350$, 1500$) in order to define monthly fixed energy charge. Results are presented in Table 4.

Table 2: Variation of Investment Cost with Participation Ratio and Wells Scenarios ($).

Participation Ratio (%)	Number of Dwellings	Scenario A	Scenario B
100	3917	3,874,442	3,008,077
89	3468	3,819,135	2,952,771
79	3094	3,768,856	2,902,492
75	2938	3,748,745	2,882,380
71	2781	3,728,633	2,862,269
59	2311	3,181,539	2,801,934
50	1959	3,136,288	2,725,140
40	1567	2,630,793	2,674,862
33	1293	2,595,597	2,639,666
26	1018	2,560,402	2,604,471

Table 3: The operating cost for participation ratio 100%.

Operating Cost Components	Operating Cost (US $ / year)	%	Operating Cost Components	Operating Cost (US $ / year)	%
Cost of Inhibitor	951	0.52	Electricity Consumption	42,357	23.37
Cost of Chemicals	485	0.27	Maintenance Cost	13,541	7.47
Water Consumption	795	0.44	Marketing Cost	3,197	1.76
Cost of Personnel	81,317	44.86	General Expenses	38,617	21.30
TOTAL				181,620	100

The values in shaded area in Table 4 are most acceptable economic figures for the householders since participation cost of $ 1250 and monthly fixed energy charge around $20 are in practice in the existing geothermal district heating system nearby. Attention must be given that a monthly fixed energy charge greater than any value presented in Table 5 will make the internal rate of return positive, so the investment profitability better. Although investment costs of wells in two scenarios are different, participation ratio interval for these two scenarios are quite similar.

Table 4: The Monthly Fixed Energy Charge.

Participating Period	Participation Ratio	Scenario A			Scenario B		
		Energy Usage Fee $			Energy Usage Fee $		
Years	%	1250	1350	1500	1250	1350	1500
5	100	17.0	17.0	17.0	17.0	17.0	17.0
	89	17.0	17.0	17.0	17.0	17.0	17.0
	79	17.0	17.0	17.0	17.0	17.0	17.0
	75	17.0	17.0	17.0	17.0	17.0	17.0
	71	18.1	17.6	17.0	17.0	17.0	17.0
	59	23.2	22.6	21.7	17.8	17.2	17.0
	50	28.5	27.9	27.1	22.2	21.6	20.7
	40	37.3	36.7	35.8	29.3	28.7	27.8
	33	44.4	44.1	43.7	37.0	36.4	35.5
	26	45.6	45.7	45.7	44.9	44.7	44.4
2	100	17.0	17.0	17.0	17.0	17.0	17.0
	89	17.0	17.0	17.0	17.0	17.0	17.0
	79	17.0	17.0	17.0	17.0	17.0	17.0
	75	17.0	17.0	17.0	17.0	17.0	17.0
	71	17.0	17.0	17.0	17.0	17.0	17.0
	59	20.9	20.3	19.4	17.0	17.0	17.0
	50	26.3	25.7	24.7	20.0	19.4	18.5
	40	35.1	33.8	33.5	27.2	26.5	25.6
	33	43.2	42.8	42.2	34.5	33.2	33.3
	26	45.2	45.2	45.1	44.1	43.8	42.9

7. DISCUSSION AND RESULTS

The number of production and reinjection wells is one of the important components of investment cost of the geothermal district heating system. Two scenarios (A and B) are considered for two approximations in the estimation of well numbers and their investment costs. The effects of these two approximations on investment cost can be noticed in Table 2. Although investment costs are different, effect of wells on internal rate of return are not so striking in the case of System-2 (Table 3). Scenario B assumes only one injection well to be drilled with the reinjection capacity similar to BD-9. If the number of reinjection wells increases due to lower reinjection capacity encountered in drilled wells, investment cost will also increase and the interval given in Table 4 for this scenario gets closer to interval of the Scenario A (Table 4, shaded areas).

System-2 Geothermal District Heating System is feasible for both existing and maximum dwelling in terms of heat load density. Although the criterion used in this assessment is not developed for Turkey, researches similar to this one will give more information on the validity of the criterion for Turkey.

Weighted average of conventional heating energy cost of the dwellings in the System-2 district is quite equal to the cost of geothermal energy with current energy price policy. Moreover thermal comfort conditions will be more developed in the dwellings that will be in the geothermal district heating system.

In the Balcova-Narlidere GDHS to which System-2 will be integrated the participating cost is $ 1250, and monthly fixed energy charge is $ 20 during this study. The social and economic structure of the area on which the System-2 is planned to be the same as the area where the Balcova-Narlıdere GDHS is developed. In addition to this information; existing applications and the results of the questionnaire show that $1250 for participation cost and $20 for monthly fixed energy charge will be acceptable for the potential users in the System-2 project.

As can be seen from the shaded areas in Table 5, up to 59% participation ratio for Scenario A and up to 50% participation ratio for Scenario B, the internal rate of return value is positive for $ 1250 participation cost and $ 20 monthly fixed energy charge or less. In similar applications, it is observed that after price based bids, the investment costs of projects decreases by 10-20%. If this decrease in the investment cost is taken into account, it can easily be said that for lower participation ratio, lower monthly fixed energy charge will make the internal rate of return value positive. Obviously, in this case project will be realized with low participation ratio which is critical decision parameter in investment.

Investment cost is changing with the cost of wells but mainly with the participation ratio. The investment cost variation with participation ratio and well scenarios for a dwelling having an area of 100 square meters is given in Figure 8. According to Scenario B, investment cost for a 100 square meters dwelling is less than $1250 in the case of participation ratio is higher than 59%. This result indicates how important is the forecast made by investor on the participation ratio.

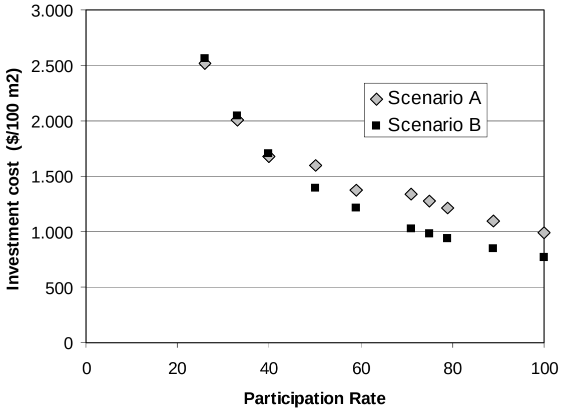


Figure 8: Investment cost for a 100 m^2 dwelling.

This study is the first application of the model (Toksoy and Sener, 2003) developed for conceptual analysis of geothermal district heating system. The investor, Balcova Geothermal Energy Co, has decided to invest for System-2 GDHS Project. Actual economic parameters will give an opportunity to test and develop the conceptual planning model considered at end of project implementation.

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