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Pricing Models in Geothermal District Heating Systems: Balcova – Narlidere Case

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ABSTRACT

Pricing is one of the important tasks in the feasibility studies of geothermal district heating investments. It involves many variables that make the task difficult. There are three different applications for billing of energy consumption in geothermal district heating applications throughout the world: energy metering, volume metering, and flat rate pricing. In flat rate pricing, energy is invoiced according to the heated area or volume. If simplicity in marketing or billing is the main consideration, the flat rate pricing could be preferred in a district heating investment. Energy metering or volume metering can be applied when energy saving is aimed. Energy metering involves the measurement of volumetric flow rate of water circulated in energy distribution network and the temperatures of water entering and leaving to the heat exchanger installed at the basement of each building. However, in volume metering, only water flow rate is measured. In this study, flat rate pricing which is applied in Balcova – Narlidere Geothermal District Heating System (BNGDHS) is discussed. First, it is investigated that whether the energy utilization price level in 2004 is appropriate in flat pricing method. It is found that the investment is not feasible with 2004 prices. Then, price is suggested according to zero internal rate of return assumption for this investment. In addition to this, energy utilization price has been calculated with the new existing market price level of equipment for the very same investment. After estimation of required energy amount for a normally sized household, theoretical water flow rate to meet the heating requirement of household is calculated. By using energy price in Grímsnes geothermal district heating system and the theoretical water flow rate, the new flat price for the normally sized household in the BNGDHS is calculated. For the two sample buildings in the BNGDHS, energy is invoiced according to current prices in the BNGDHS, new flat price and unit volumetric flow rate price in Grímsnes geothermal district heating system, respectively. Finally, the studied energy utilization prices are compared.

1. INTRODUCTION

The Balcova Geothermal Field (BGF) lies between Izmir city center and Izmir – Cesme Freeway. It is located 7 km west from the city center and 1 km south from the freeway.

Formerly, geothermal resources were only used spontaneously in bathing and medical treatment in the BGF. Geological and hydrological studies on the BGF were started in 1962. First heating application in this field was applied in 1981. Scaling problems encountered in wells affected the improvement of geothermal heating negatively. As a result of improvements on inhibitors, geothermal well pumps, and plate type of heat exchangers, geothermal district heating system investment had been considered for the BGF.

2. BALCOVA – NARLIDERE GEOTHERMAL DISTRICT HEATING SYSTEM

The construction of the BNGDHS was started in 1996. Balcova part of the system started operating, partially, in 1996. Narlidere part of the system has been operating since 1998. The capacity has extended by new investments after 2001. The capacity of the system reached the heating of 1,150,000 m^2 households at the end of 2003. Capital investment cost of the BNGDHS was US $14,431,307. Yearly operating cost of the system is US $1,099,563 (Erdogmus, 2003). The system is accepted as one of the largest ones in Turkey. The current heating capacity of production wells are calculated as 72 MW_t with regard to the discharge temperature of 60°C.

Basically, three networks constitute the system: energy production, energy distribution, and energy consumption networks. Networks and fluid temperatures are shown in Figure 1

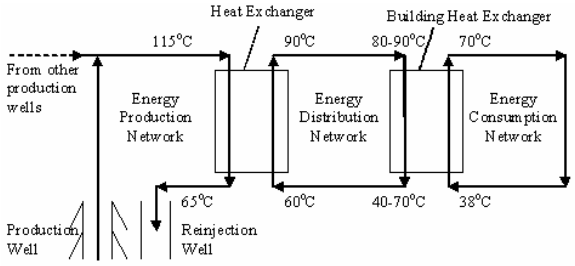


Figure 1: Schematic representation of networks and fluid temperatures in the BNGDHS.

The energy production network is composed of wells and two parallel pipeline systems. The temperatures of wells vary from 95°C to 135°C. The production wells are equipped with lineshaft pumps in order to take geothermal fluid to the surface. The flow of each well is controlled from zero to maximum value by using frequency converters. The geothermal fluid is transmitted from the production wells to eight different heat exchanger stations by the supply lines. Energy is transferred to the energy distribution network by the use of plate type heat exchangers. After transferring the energy, the geothermal fluid is transmitted to the re-injection well. The tap water is circulated in the energy distribution network which is about 80 km long (Sener, 2003). Carbon steel pipes have been used in geothermal transmission and distribution networks.

Plate type of heat exchanger is also used to transfer hot tap water's energy to the water circulated in the energy consumption network. In building networks, the hot city water is sent to the radiators or fan coils assembled in each household. In addition to this, geothermal energy can also be used to provide domestic hot water.

The BNGDHS designed according to constant temperature and variable fluid flow principle. There are flow regulators installed in the basements of customers' buildings to restrict the water flow in order to regulate temperature. The return temperature in energy distribution network changes according to heat demand of customers. The temperature sensor of flow regulator measures the change in temperature. Then the flow regulator adjusts cross sectional area of the flow. When heat demand increases, flow regulator also increases the cross sectional area.

Energy saving can not be considered by customers when flat rate pricing is applied. Energy can be wasted by opening doors and windows instead of closing the valves of radiators in households. Energy metering or volume metering can be applied when energy saving is crucial. They have also some disadvantages. Especially energy metering method increase the capital cost of the investment and operating cost. Instead of complexity in energy billing, the least sophisticated method named flat rate pricing has been preferred throughout the world where geothermal energy used as a source for district heating. It is also applied in the BNGDHS (Rafferty, 1996).

The revenue of an investment has an important effect on the economic assessment. It must meet capital and life cycle costs in project life. Therefore, determination or estimation of revenues of an investment is vital for the profitability calculations at the beginning phase of implementation.

2.1. THE REVENUES IN THE BNGDHS

The revenues can be divided into three groups in the BNGDHS: connection charge, energy charge, and others.

Operating company connects the supply pipe to each building's pumping centers normally located on the basement or exterior of the buildings. The customers connect their heating systems into these pumping centers as well. Operating company can access to the connection at all times. Operating company supplies secondary heat exchangers, and flow restriction. The customer supplies all other equipment required. The connection charge is collected only at the beginning of the subscription period and its amount is determined by the operating company. Connection charges from 1997 to 2004 for normally sized household which is 100 m^2 are given in Fig.2.

Customers pay fees to obtain heating. The amount of energy charge which is paid monthly is determined at the end of each year according to the yearly economical indicators presented by the government. The customers do not pay any additional fee to obtain domestic hot water by using geothermal energy in BNGDHS. Energy charge includes the charge for supplying domestic hot water.

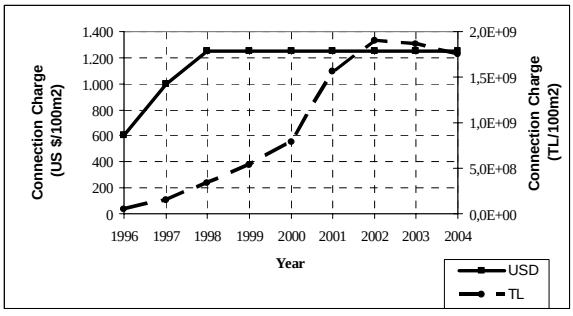


Figure 2: Connection charges in the BNGDHS.

The energy charge was kept at minimum to get as much participation as possible at the beginning of investment. The value loss of Turkish Lira against to foreign currencies has negative effect on meeting highest capital investment cost of the investment. Monthly fees from 1997 to 2004 are given in Fig. 3.

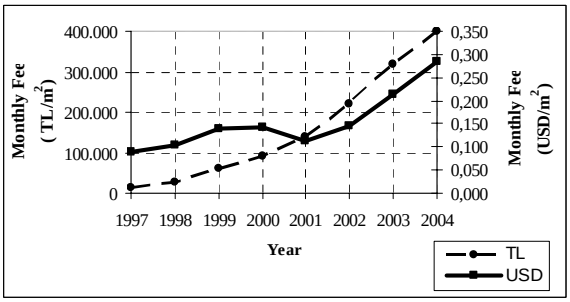


Figure 3: Monthly energy charge in the BNGDHS.

Other revenues are earned by using different investment instruments. However, it is relatively small in overall revenues.

All of the revenues with their percentages are shown in Fig. 4.

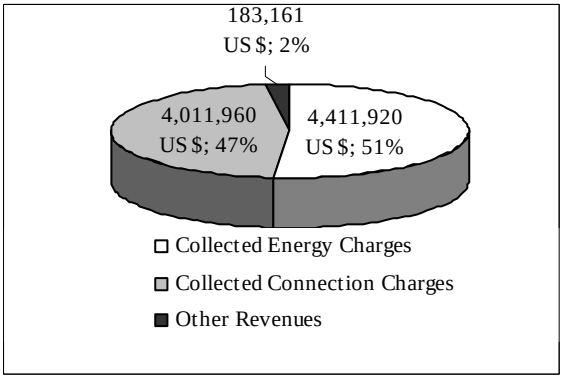


Figure 4: The revenues in the BNGDHS.

2.2. CALCULATION OF SUGGESTED FLAT PRICE IN THE BNGDHS

Internal rate of return (IRR) method can be used in profitability calculations of energy investment or pricing. Discount rate is an unknown parameter in the IRR calculations (Park, 1993). A minimum standard of desirability which is determined by an investor is compared against the calculated value of discount rate that sets the net present value equal to zero. If the IRR is higher or equal to the market interest rate, it is profitable to undertake prospective project (Grant et al., 1990). But in this study, due to the high amount of capital investment cost and social benefit of the investment, the proper monthly energy utilization price that makes the IRR zero is calculated. By using this assumption, the energy utilization price which equates the net present value of revenues to the net present value of life cycle cost is investigated. Internal rate of return is calculated by using Eq.1.

$$\sum_{n=m+1}^{t} \frac{R_n}{(1+r)^n} = \sum_{n=0}^{m} \frac{C_n}{(1+r)^n} + \sum_{n=m+1}^{t} \frac{OC}{(1+r)^n} \quad (1)$$

where; R, C, OC, n, t, and m are total revenue, capital investment cost, total yearly operating cost, number of years,

total life of a project and duration of construction period, respectively.

At the beginning of this study, life cycle costs are determined by using the operating cost data of 2002. In addition to this, it is also assumed that the current heating capacity of the system would remain constant.

It is found that the current price which is US $28.57 gives negative cash flow. If the monthly energy utilization price is increased up to US $56, the IRR will be 0.31% for this investment. The price which makes the IRR zero is calculated as US $55.5 by linear interpolation. The net present value of investment at different discount rates is shown in Fig. 5 (Erdogmus, 2003).

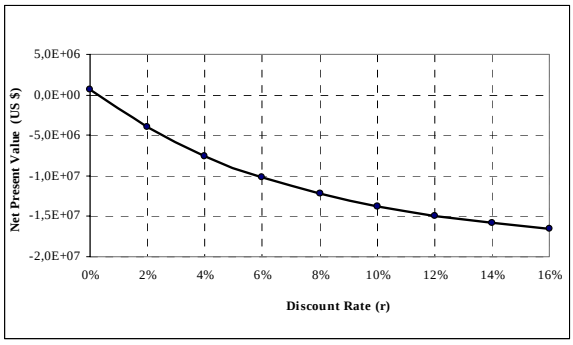


Figure 5: The NPV as a function of discount rate in the case of US $56 monthly price.

On the other hand, because of the uncertainty of operating costs, energy utilization prices at different operating costs are calculated and shown in Fig.6.

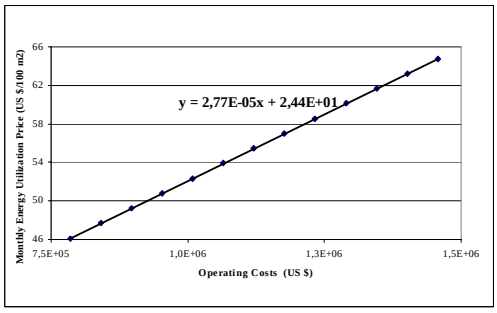


Figure 6: Monthly energy charge values versus different operating cost values.

With the new existing market price level of equipment for the very same investment, monthly energy charge has been calculated as US $21.4. Current energy charges in different city based geothermal district heating systems of Turkey are shown in Fig.7. The average energy charge in Turkey is calculated as US $ 32.84 with 2004 prices. So, it can be said that the current tariffs in BNGDHS is also low when compared with the average value.

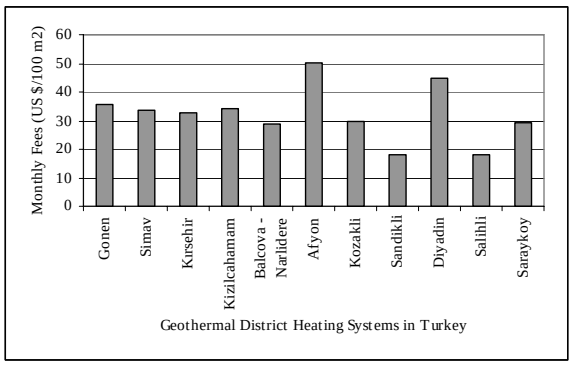


Figure 7: Current energy charges in geothermal district heating systems of Turkey.

2.2. CALCULATION OF PRICES FOR ENERGY METERING OR VOLUME METERING METHODS FOR THE BNGDHS

In energy metering, some devices called energy meters are used. Energy meters measure volumetric flow rate and temperature difference. As the water passes through the piping, the turbine in the flowmeter rotates and sends impulses to the device. The temperature sensors measure the supply and return water temperature.

In this study, first of all, the theoretical volumetric flow rate of water in energy consumption network is calculated by using degree–days method. Degree–hours or Degree-days methods can be used in order to estimate annual heat loads which can be quite accurate if the indoor temperature is constant (Satman and Yalcinkaya, 1999). In these methods, the total number of hours or days at which the outside temperature is lower than the balance temperature, is taken into consideration. The balance temperature for heating of a building is defined as the value of the outdoor temperature where, for the specified value of the interior temperature, the total heat loss is equal to all space heat gains. Therefore, the balance temperature is the average outdoor temperature at which the building requires neither heating nor cooling (ASHRAE). Hourly energy requirement of a building is proportional to the difference between the balance point and the outside temperature. Yearly energy consumption is the time integral of the hourly energy consumption over a heating season. Yearly heat loss ($Q_{h,yr}$) is calculated by using the values of degree – hours or degree - days values, standard heat loss value of a building (Q_{st}), inside (T_i) and outside (T_h) design temperatures. Yearly heat loss calculation is represented by Eq. 4. Previously, Qst was calculated for 40 households in Balcova region and the average heat loss from normally sized households found as 5,490 kcal/h (Canakci, 2003).

$$Q_{h,yr} = \frac{Q_{st}}{(T_i - T_h)} \cdot \sum_{i=1}^{n} (T_{bal} - T_o(t))^{+} \qquad (2)$$

The value of inside design temperature depends on the type and use of the building, degree of activity of occupant, duration of occupancy, presence of radiant heat sources, and outside design temperature. In this study, balance, outside and inside temperatures are 18°C, 1.6°C, and 22 °C respectively. Hourly temperature records obtained from the Guzelyali weather station locates in Izmir city of Turkey are used to calculate yearly heating degree-hours. Hourly temperature data collected for 20 years and a statistical approach was used to accomplish this study. The year at which outside temperatures are proper to the result of that

statistical study was chosen as typical reference year. Year 1993 is the typical reference year (Arisoy et al., 2000).

The hourly outside temperatures are written in an excel sheet and difference between outside and inside temperatures are calculated in this study. If the difference is a positive number, heating would be required at that hour. Monthly average outside temperatures, the numbers of Degree-Days and Degree-Hours are given in Table 1.

Table 1: Yearly Heat Load for a typical household (100 m^2) in BNGDHS.

Mo.	Ave T_o	Heated days	Degree -Days	Heating Hours	Degree -Hours	Heat Load (kcal/h)
1	7.3	31	331	744	7,940	2,872
2	6.6	28	319	672	7,664	3,069
3	11.2	29	214	660	5,017	1,990
4	15.4	25	96	517	2,068	1,034
5	19.6	14	24	308	442	457
6	25.6	0	0	0	0	0
7	27.5	0	0	1	0	0
8	27.9	0	0	0	0	0
9	23.6	0	0	90	0	0
10	20.6	4	6	220	116	436
11	12.6	25	174	585	4,082	1,875
12	11.9	31	189	738	4,499	1,637
Tot.		187	1353,6	4,535	31,829	43,185

Two sample buildings are taken into consideration whether volume metering is applicable for the BNGDHS. Heating load characteristics of the sample buildings are shown in Table 2. Standard heat loss values and total heated areas are taken from the operating company.

Table 2: Heating load characteristics of the sample buildings in the BNGDHS

	Sample building 1	Sample building 2
Total area (m^2)	1,875	825
Max. Heating Load (kcal/h)	141,860	64,896
Heating Load per area	75.66	78.66

To find the energy requirements of these buildings in a month, standard heat load values can be multiplied by the total number of days in a month in which heating is needed. Monthly average volumetric flow rate in order to meet the heating requirement of normally sized household is calculated by using the heat load found in Table 1. Monthly heat loads are divided by specific heat of water and temperature difference between the supply and return pipes. Monthly theoretical flow rates in a heating season are given in Table 3. Then yearly average is calculated. Hot water requirement in a day at which heating is not required can be also taken in to consideration. Daily hot water requirement of a person can be assumed as 50 lt/person for the summer season. For a family of 4 people, it can be estimated as 200 lt/day or 0.0022 lt/s.

Volumetric flow rates are also calculated by using 2004 weather data which is collected by operating company. Results are compared with previous values and given in Table 4.

Table 3: Theoretic flow rates (lt/s) for heating of a household in the BNGDHS

Month	Normally sized Household (100 m^2)	Sample Building 1 (1875 m^2)	Sample Building 2 (825 m^2)
1	0.041	1.052	0.481
2	0.044	1.125	0.514
3	0.028	0.729	0.334
4	0.015	0.379	0.173
5	0.006	0.167	0.077
6	0	0	0
7	0	0	0
8	0	0	0
9	0	0	0
10	0.006	0.160	0.073
11	0.027	0.687	0.314
12	0.023	0.600	0.274
Heating Season Average	0.024	0.612	0.280

Table 4: Volumetric flow rates (lt/s) for the samples considered.

	Weather Data of 1993	Weather Data of 2004
Sample Building 1	0.612	0.608
Sample Building 2	0.280	0.278

Since there is not any geothermal district heating system in Turkey at which volume metering or energy metering is used, the monthly energy charges are determined based on the tariffs in Grímsnes geothermal district heating system in Iceland. The tariff in Grímsnes is given in Table 5. It is claimed that the tariff is very low when compared to similar district heating services (Friðriksson, 2003).

Table 5: Tariff in Grímsnes geothermal district heating system (Friðriksson, 2003).

	Cost (US $)
Annual energy charge for normally sized household	
• Minimum 3 lt/min	592
• Additional 1 lt/min	192
Connection charge	1,305

Required flow rate for normally sized household is 3 lt/min in this system. But, customers pay 10.75 $/month for each additional flow of 1 lt/min (Friðriksson, 2003). The flow rate of normally sized household in Balcova is 0.024 lt/s or 1.422 lt/min in a heating season. If a customer who has a normally sized household in Balcova which requires 1.422 lt/min water would pay his/her bill according to the tariff in Grímsnes geothermal district heating system, the monthly energy charge would be US $23. According to this assumption, US $0.023 should be paid per m^2. Therefore, sample buildings 1 and 2 should pay US $438.45 and US $192.92, respectively. But, heating loads needed for

buildings are not directly proportional with their areas. Due to this fact, different heating costs can be calculated by using volumetric flow rate to meet these heating loads. This discrepancy can be seen in Table 6.

Table 6: Monthly energy charges for the sample buildings in the BNGDHS.

	Energy charge by using current flat price in the BNGDHS (US $)	Energy charge by using flat price which is determined according to tariff in Grímsnes (US $)	Energy charge by using volumetric flow rate tariff in Grímsnes (US $)
Sample Building 1	535.69	438.45	604
Sample Building 2	235.70	192.92	278

3. CONCLUSION

Flat rate pricing has been applied in the BNGDHS. The investment is unattractive from an economic point of view with the monthly energy charges below US $55.5 for normally sized households. With the new existing market price level of equipment for the very same investment, it would be US $21.4. The main cost differences are occurred on pipe lines and fittings, heat exchangers, pumps, and setting equipment. It is concluded that, the system is subsidized by the local government at the moment. In this study, it is investigated that whether other pricing models are suitable for the BNGDHS. For this reason energy billing for the two sample buildings in the BNGDHS is examined. The required theoretic volumetric flow rate is calculated with regard to typical year's and 2004 climate data. By using the unit price of energy in Grímsnes geothermal district heating system in Iceland, monthly energy utilization price is calculated for normally sized household. It is found that if the price was determined by volumetric flow rates and with regard to unit price applied in Grímsnes, price would be higher than the current monthly fees. But it is also mentioned that the unit price per m^3 has very important effect on this result. For a normally sized household in Balcova which requires 1.422 lt/min water and the tariff in Grímsnes geothermal district heating system, the monthly energy charge would be US $23. This figure is less than the current price level. Since the investment is subsidized by the local government and additional capital investment costs, volumetric flow rate pricing seems as an unsuitable model with this tariff policy.

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