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# Economic Analysis of Combined Heating System of Geothermal Water and Gas Engine-Driven Heat Pump in Tianjin China

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**ABSTRACT**

The direct utilization of geothermal water with gas engine-driven heat pump are discussed with an engineering example. The process and operation strategy of heating systems combining direct utilization of geothermal water with gas engine-driven heat pump are discussed. Compared to heating systems that combine direct utilization of geothermal water with electric heat pumps, the combined geothermal water and gas engine-driven heat pump yields a large area of heating for a given geothermal resource. Based on economic considerations, it is better to use the direct-use geothermal water combined with a gas engine-driven heat pump system.

## 1. INTRODUCTION

One community is Located in Dongli District, Tianjin, east from downtown at about 2.5 km, The total planned GFA of approximately $45\times10^4$ $m^2$, and in this region there is no gas pipeline network. According to the requirements of energy conservation, the community heating is by geothermal, and the gas engine-driven heat pump is used for peaking. In this paper, an economic comparison of the geothermal district heating system and peaking gas heat pump and electric heat pump system is performed.

### 1.1 Resources Overview

The total planned GFA of approximately $45\times10^4$ $m^2$. The heating system is floor heating. One pair of geothermal wells are drilled . One is used as the production well, and the other is used as the reinjection well. The area is located in the Dongli District. Based on data obtained from other geothermal wells in the same tectonic unit, the occurrence of the region has deep geothermal resources with high development potential.

The target layer for geothermal wells is guantaozu, the depth is 1700 m, the temperature is 60 °C, and water flow is 100 $m^3$/h, Geothermal fluid type of water chemistry is Cl · $SO_4$-Na, PH is 7.5-7.8. The water is slightly corrosive and does not generate carbonate scale and silicate scale, so geothermal system should use indirect ways. In order to achieve the development and utilization of geothermal cascade by gas engine-driven heat pumps, it is useful to make use of lower temperature injection fluid and to increase the heating area.

### 1.2 Heat Index and Heat Parameters

The heating system heat index changes according to the form of building heating. Here, the heat index is 42 W/$m^2$, so the total heat load is 6720 kW. The heating system is floor heating, and the floor heating system heating parameter is 45 °C / 35 °C.

## 2. THE PROCESS OF GEOTHERMAL UTILIZATION

The heating system first meets the heating requirement through the heat pump through the use of a plate heat exchanger, so geothermal water heating load is calculated according to Equation 1:

$$Q = \frac{G \cdot C \cdot \eta \cdot (t_1 - t_0)}{3.6} \quad (1)$$

Where $Q$, $G$, $C$, $t_1$, $t_0$, $\eta$ are heating capacity of geothermal direct use, geothermal water flow, specific heat capacity of geothermal fluid, temperature of geothermal water, geothermal fluid temperature after utilization and efficiency of heat transfer, respectively.

The geothermal fluid temperature after utilization of floor heating for the fan coil system is 38 °C. According to Equation 1, the heat load of geothermal direct use is 2302kW. In order to increase the heat load of geothermal use, make full use of low-temperature geothermal tail water heat. The secondary use through gas engine-driven heat pump, at the end of the process, the geothermal water temperature is 16 °C, the heat load of heat pump is 4548 kW, and so the total heat load is 6850 kW. The gas heat pump units use two pumps. Each has a heating capacity of 2310 kW. For Model DG-544-35/8-35/45s, the natural gas consumption is 148 $m^3$/h and COP is 2.22.

The heating system in the early period, the use of geothermal is an indirect way of geothermal heating. According to Tianjin outdoor temperature and delay load analysis, the final increase in the initial heating and ground water flow, the use of geothermal water between heating for ways to meet the needs of the running time is about 14 days. In the outdoor temperature is below 4℃ to run a gas heat pump, with decreasing outdoor temperature for the heat and gradually increase the gas heat pump, -3℃ lower than outdoors when you start the second gas heat pump to meet heating needs. In the operation gas engine-driven heat pump, the unit

adjustment range 30% to 100%, in order to achieve steps adjustment, natural gas consumption also varies with the gas engine-driven heat pump to adjust the ratio changes. The analysis calculated the entire heating period, the total system heating accumulated heat load is 50074 GJ, where geothermal supplyied an accumulated heat load of 23867 GJ, gas heat pump provides the cumulative heat load of 26207 GJ. The total geothermal mining capacity for the project is 288000 $m^3$, and the total consumption is 331557 $m^3$.

## 3. THE ECONOMIC ANALYSIS OF GEOTHERMAL HEATING SYSTEM

### 3.1 The Investment Analysis of Geothermal Heating System

The investment cost of geothermal heating system mainly consists of drilling geothermal wells, system equipment and other costs. The depth of the geothermal well is 1700 m and the cost of drilling is 1600 CNY/m. The system mainly consists of a circulation pump heating equipment, electric heat pump, heat exchanger and of ancillary equipment. Other expenses mainly included geothermal wells demonstration costs, system design fees, and prospecting fees. Specific costs are shown in Table 1.

**Table 1. The investment cost of geothermal heating system.**

| Drilling Cost(CNY) | Equipment Cost(CNY) | Other cost(CNY) | Total cost(CNY) |
|---|---|---|---|
| 5440000 | 8150000 | 1850000 | 16440000 |

According to Table 1, the total investment is 16.44 million CNY; per unit area the investment is 102.8 CNY/$m^2$.

### 3.2 Operating Cost Analysis of Geothermal Heating System

In Tianjin city, heating from November 15 to March 15 in winter, the resource fee for geothermal water (recharge part) is 0.45CNY/ $m^2$, and the resource fee for geothermal water ( no part of recharge) is 1.5 CNY/$m^2$. Electricity is 0.76 CNY/kWh, and the cost of gas is 3.15 CNY/$Nm^3$. The total cost of geothermal heating and unit operating cost specific cost data are shown in Table 2.

**Table 2. The operating cost of geothermal heating system.**

| Resource Cost(CNY) | Electricity Cost(CNY) | Artificial Cost(CNY) | Gas Cost(CNY) | Other Cost(CNY) | Total Cost (CNY) |
|---|---|---|---|---|---|
| 206000 | 406000 | 48000 | 1044000 | 244000 | 1948000 |

According to the Table 2, the total cost of geothermal heating is 1.948 million CNY and the per unit area operating cost is 12.2 CNY/$m^2$.

## 4. CONTRAST WITH ELECTRIC HEAT PUMP

### 4.1 The Contrast of System Program

GHP systems and electric drive pump system are similar except that the former requires natural gas consumption. The project site needs to have the gas pipeline network, which consumes energy, and the electric capacity increase is large. For the gas geothermal heat pump system, the designed tail water temperature is 16 °C, and for the electric drive geothermal heat pump system, the designed tail water temperature 12 °C.

### 4.2 Contrast of the Investment Cost

If the gas engine-driven heat pump in heating system is changed into heat electric driven pump, the investment cost mainly includes the cost of drilling geothermal wells, system equipment, and other costs. The geothermal wells cost is the same. The heating system mainly consists of a circulation pump, electrically driven heat pump, heat exchanger, and of ancillary equipment. Other costs are also the same as for gas heat pump systems. Specific costs aare shown in Table 3.

**Table 3. The investment cost of heat electric driven pump system.**

| Drilling Cost(CNY) | Equipment Cost(CNY) | Other Cost(CNY) | Total Cost(CNY) |
|---|---|---|---|
| 5440000 | 6300000 | 1850000 | 13590000 |

According to the Table 3, electric driven heat pump heating projects require a total investment of 13.59 million CNY, and the investment per unit area of 84.9 CNY/$m^2$. Through analysis, the investment cost of gas engine-driven heat pump system is more.

### 4.3 Contrast of the Operating Cost

According to the system heat load drivers need to configure two heat pumps, the capacity of one heat pump is 2298kW, power 495.9kW, Model PSRHH-5403. When the outdoor temperature is higher than -3 °C only the first heat pump is used, and when the temperature is below -3 °C, both heat pumps are used. Total power consumption is $1.82\times10^6$ kW.

Operating costs mainly include energy costs, resources, water, maintenance and management fees. The total operating cost for the geothermal heating system was 2.459 million CNY, the construction area of the unit operating costs 15.4 CNY/$m^2$, the electric heat pump system operating costs specific costs shown in Table 4.

**Table 4. The operating cost of heat electric driven pump system.**

| Resource Cost(CNY) | Electricity Cost(CNY) | Artificial Cost(CNY) | Heat Pump Cost(CNY) | Other Cost(CNY) | Total Cost (CNY) |
|---|---|---|---|---|---|
| 206000 | 406000 | 48000 | 1565000 | 234000 | 2459000 |

Through comparative analysis of operating costs, the operating cost of electric driven heat pump is higher than the gas engine-driven heat pump system, with an average 51.1 million per year, 3.2 CNY/$m^2$.

## 5. CONCLUSION

A comprehensive analysis of the heating system uses the heat of intensive recycling process, which can effectively reduce the demand for conventional fuels and ash, slag, sulfur dioxide and nitrogen oxide emissions, providing effective protection of the ecological environment and significant environmental benefits. Peaking system through the gas engine-driven heat pump, provides a larger heating area than electric driven heat pump. However, this system needs to consider agas pipeline network. According to the analysis, the investment cost of gas engine-driven heat pump heating system is larger than electric driven heat pump system, but the operating cost of electric driven heat pump system is smaller, so the economic of gas engine-driven heat pump heating system is better.

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