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Economic Characteristics and Policy Research of Typical Sandstone Reservoir Geothermal Space Heating Projects in North China

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ABSTRACT

In June 2012, National Energy Administration authorized China Petrochemical Corporation to establish National Geothermal Energy Center of China, one of the main functions of which is to study and formulate geothermal development strategies, plans and policies. National Geothermal Energy Center of China has conducted a case study on geothermal space heating in northern China as the basis for formulating a national geothermal policy. This paper mainly analyzes one of the typical cases, a geothermal space heating project in Xianyang, Shaanxi province, summarizes the technical and economic characteristics of such projects from point to area, and makes a comparative study with other clean energy space heating, and puts forward countermeasures and suggestions to promote geothermal development. Typical projects are operated in BOO mode, featuring high investment and large space heating capacity. The depth of geothermal well is about 3,600 meters, the temperature of wells is around 108 ^{0}C. But the returns are modest, with after-tax payback periods of about 13 years. Under the pressure to control air pollution in northern China, local governments have given subsidies for clean energy space heating, about 168 yuan per square meter for coal to electricity and 87.98 yuan per square meter for coal to gas. The financial pressure is increasing. The operation cost of geothermal space heating is the lowest in clean energy space heating, which is very beneficial to residents' long-term stable space heating and suitable for clean space heating.

1. BACKGROUND INTRODUCTION

In June 2012, National Energy Administration based on the professional strength of China Petrochemical Corporation to establish National Geothermal Energy Development and Utilization Research and Application Technology Extension Center (hereinafter referred to as National Geothermal Energy Center of China), It mainly carries out research on geothermal energy development strategy, planning and policy, development and application of key technologies for geothermal energy development and utilization, and training of geothermal energy talents and international cooperation.

Under the guidance of National Energy Administration, National Geothermal Energy Center of China has completed many of the first initiatives to fill the gap in the country. The '13th Five-Year Plan of Geothermal Development and Utilization' was commissioned by National Energy Administration and other ministries and commissions. This is the first time that China has formulated and promulgated a five-year plan for geothermal development, setting an ambitious target of increasing the area of medium depth geothermal space heating from 100 million square meters in 2015 to 400 million square meters in 2020. In terms of actual implementation, by the end of 2017, the area of medium and deep geothermal space heating reached 150 million square meters, which is still a rapid growth although it is difficult to meet the target. As the main compilation unit, China Geothermal Energy Development Report (2018), the first white paper on geothermal energy in China, was compiled and completed, informing the world about the development trend of China's geothermal energy. Currently, National Geothermal Energy Center of China is assisting National Energy Administration in formulating China geothermal energy management measures, which focus on rationalizing the geothermal energy management system and creating a favorable development environment for geothermal. The measures will be released and implemented in the near future.

2. POLICY ANALYSIS ON CLEAN ENERGY SPACE HEATING

In December 2017, National Energy Administration and ten other ministries and commissions jointly issued the 'Winter Clean Space Heating Planning in the North Region (2017-2021)', which aims to achieve a 50 percent clean space heating rate by 2019 and replace 74 million tons of coal used in low-efficiency small boilers. By 2021, the clean space heating rate in northern China will reach 70 percent, replacing 150 million tons of coal used in low-efficiency small boilers. In order to realize the planning goals, Governments at all levels have formulated a large number of supporting policies, among which financial support plays the most direct role.

Ministry of Finance has set up a special fund for air pollution prevention and control, allocating 16 billion yuan (equivalent to $2.3 billion) in 2017 and 20 billion yuan (equivalent to $2.9 billion) in 2018 to 12 provinces and municipalities with severe smog, including Hebei province.

In addition, for key municipalities and prefectures, a pilot city fund for clean space heating in winter has been set up in the north region, providing financial rewards and subsidies to '2+26' cities, 11 cities in Fenwei Graben and Zhangjiakou. The municipality directly under the Central Government arranges 1 billion yuan annually, the provincial capital city arranges 700 million yuan annually, the prefecture-level city arranges 500 million yuan annually, and Fenwei Graben city arranges 300 million yuan annually.

Local governments of provinces (cities) covered by the plan have issued subsidies for coal to gas and coal to electricity, but no special subsidies for coal to geothermal. If converted into 100 square meters per household, the subsidy of coal to electricity is

about 168 yuan per square meter; the subsidy of coal to gas is about 87.98 yuan per square meter (Table 1), which has an obvious extrusion effect on geothermal space heating which belongs to clean energy.

TABLE 1: Summary of Policies and Subsidies Related to Coal-to-Electricity and Coal-to-Gas Conversion

Region	Energy types	Policy	Subsidies (yuan/m^2)
Hebei	Coal-to-Electricity	《Guidance Opinions of Hebei Province Government on Accelerating the Implementation of Coal-to-Electricity and Coal-to-Gas in Langfang, Baoding》	146
	Coal-to-Gas		63
Henan	Coal-to-Electricity Coal-to-Gas	《Notice of the General Office of Zhengzhou Government on Further Promoting the Control of Bulk Coal》	53
Shanxi	Air Source Heat Pump	《Control of Bulk Coal and Implementation Scheme of Clean Space Heating in Winter in Taiyuan City in 2017》	346
	Electric Boiler Electric Space Heater		216
	Coal-to-Gas		185.95
Shandong	Coal-to-Gas Coal-to-Electricity	《Circular on Publishing and Issuing Work Program of "Replacing Coal by Gas and Electricity" for Winter Space Heating in Dezhou City》	70
Tianjin	Air Source Space Heat Pump	《Circular of Tianjin Government on Issuing Work Program for Clean Space Heating in Winter for Tianjin Residents》	278
	Electric Heater		72
	Coal-to-Gas		90
Shaanxi	Coal-to-Gas Coal-to-Electricity	《Special Action Awards and Supplementary Measures for Haze Control with Iron Wrist in the Central Shaanxi Plain 》	10

3. ANALYSIS ON ECONOMIC CHARACTERISTICS OF GEOTHERMAL SPACE HEATING PROJECTS

In order to study the economic characteristics of geothermal space heating, the ZY space heating project in Xianyang, Shaanxi Province was selected for in-depth analysis. The project mainly develops Neogene sandstone reservoir, which is different from the volcanic system. It is the geothermal development of large sedimentary basins. This kind of thermal reservoir is widely distributed in the North China Basin. It shows that the geothermal gradient has little change and has good permeability. It covers most of the above provinces (cities) and can be represented to a certain extent. Therefore, the ZY space heating project in Xianyang, Shaanxi Province was selected as a typical project for in-depth typical analysis to summarize the economic characteristics of this type, and put forward countermeasures and suggestions to promote geothermal development.

3.1 Project Introduction

Typical project is ZY space heating project. The project is constructed and operated by China Petrochemical Corporation and is located in Xianyang Vocational and Technical College. Built and operated in 2009, the current space heating area is 187,700 square meters.

3.2 Geothermal Wells Information

Geothermal wells are located in the gentle slope zone in the north of Xi'an sag. The thermal reservoirs in this area are Lantian-Bahe Formation and Gaoling Group, in which the sand thickness ratio of Lantian-Bahe Formation is 15.00%-34.80%, and the underground temperature is 89.5-126.4 ^{0}C. The sand thickness ratio of Gaoling Group is 12.6%-38.7%, and the underground temperature is 90.8-134.0 ^{0}C. This project drilled two geothermal wells. Well 1 of vocational college is 3624.6 meters deep, wellhead water temperature 118 ^{0}C, water output 174.95 cubic meters per hour. Well 2 of vocational college is 3573 meters deep, wellhead water temperature 99 ^{0}C, water output 108.27 cubic meters per hour.

3.3 Process Flow

This project drills a water extraction well and a reinjection well, which is used to extract the underground heat energy to the ground through the medium of underground hot water. The typical heat exchange technology is adopted for indirect space heating. The water temperature of the geothermal well (118 ^{0}C) is exchanged to 48 ^{0}C by plate heat exchanger, and then injected into the reinjection well by pressure after filtering treatment. In this process, the heat energy is transferred to the space heating system. The circulating water of the space heating system is supplied to users after extracting the heat of geothermal water by plate heat exchanger, and the temperature of the water coming back from the space heating system is 55/45 ^{0}C. The geothermal energy is converted into space heating product (see Figure 1).

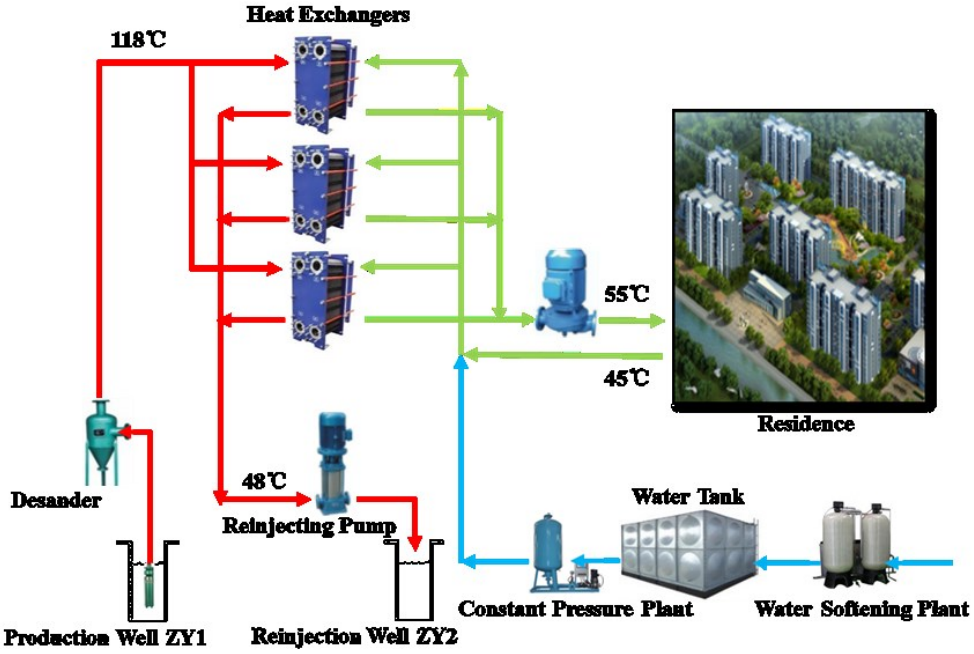

Figure 2: ZY space heating process flow chart.

3.4 Project Economy

The construction investment of this project is 15.435 million yuan. By the end of 2017, space heating fee is 1.7055 million yuan, supporting fee is 6.6993 million yuan and operating cost is 7.9435 million yuan (excluding project depreciation fee, financial fee and enterprise management fee). At present, the after-tax return rate of the project is 9.09%, and the payback period of the after-tax static investment is 7.29 years. Details are as follows:

(1) The project construction investment is 15.435 million yuan.

(2) The price of geothermal space heating is the same as that of coal space heating. The unit price of space heating is 21.6 yuan per square meter and the cost of supporting facilities is 40.8 yuan per square meter. By the end of 2017, a total of 19.7055 million yuan of space heating fees and 6.69993 million yuan of matching fees had been collected. From 2009 to 2017, the annual comprehensive fee rates are 35%, 46%, 47%, 42%, 60%, 34%, 65%, 56% and 90% respectively.

(3) By the end of 2017, the electricity cost was 1.65583 million yuan, water cost was 56,500 yuan, wages and welfare cost was 1.0942 million yuan, and the repair cost was 280,200 yuan. Other expenses, including water resources tax, management and operation fees, sales expenses and other expenses, totaled 4.7767 million yuan.

(4) The project has been constructed since 2009 and operated in the current period. According to the evaluation of the 20-year operation period, the after-tax return rate of the project is 9.09%, the after-tax net present value of the project is 814,100 yuan according to the benchmark return rate of 8%, and the after-tax static investment payback period is 7.29 years.

3.5 Project Management Mode

The project adopts the BOO mode of operation, and the enterprise adopts the mode of "independent investment, independent operation and self-financing". The construction scope not only includes the construction of terminal space heating station, but also includes the construction of heat source system and transmission and distribution system. When enterprises invest in geothermal space heating projects, they collect infrastructure fees to partially compensate the investment in central space heating, and then recover the investment year by year through collecting space heating fees to maintain space heating operation and gain profits. In this mode of operation, enterprises pay more attention to long-term operating efficiency, especially to project quality and space heating service, ensuring the long-term space heating effect of residents. Residents enjoy the same price as other space heating methods, without increasing the payment burden, and have a high acceptance of geothermal space heating.

Typical projects represent the development of deep porosity sandstone reservoir in Xianyang and its surrounding areas. This type of geothermal space heating project has reached 7.14 million square meters in Xianyang and nearly 20 million square meters in the central Shaanxi plain. This type of sandstone reservoir, which belongs to Neogene system as the sandstone reservoir developed in the northern region in need of clean space heating, accounts for the majority of space heating areas in China.

4. COMPARISON BETWEEN GEOTHERMAL ENERGY AND OTHER CLEAN ENERGY SOURCES FOR SPACE HEATING

Electric space heating and natural gas space heating are the main ways to promote clean energy space heating in China. In order to compare the economic differences between geothermal and other two clean energy space heating methods, firstly, the economic data of typical geothermal space heating projects are estimated according to the statistical data of this project and other geothermal projects. Then the cost of electric boiler and gas boiler is calculated according to the same energy consumption as geothermal space

heating. Compared with electric and gas space heating, geothermal space heating is characterized by relatively high investment, low operating cost and long investment recovery period (Table 2).

TABLE 2: Comparison of Economic Characteristics between Geothermal Space Heating and Other Clean Energy Space Heating Modes

Number.	Energy type	Investment (yuan/m^2)	Operation cost (yuan/m^2)	Total cost (yuan/m^2)
1	Electric Space Heating	90	31	37
2	Natural Gas Space Heating	30	18	20
3	Geothermal Space Heating	100	7	15

Remarks: 1. Operation cost = electricity fee + water fee + labor cost; Total cost = operation cost + depreciation and amortization + financial cost.

2. Geothermal project calculation includes investment and operation cost of reinjection wells.

3. Geothermal cost varies greatly, mainly due to the difference of resource endowment and heat pump proportion.

Geothermal space heating has not only economic advantages over other clean-energy space heating methods. More importantly geothermal is clean, low carbon, renewable energy. Distribution of geothermal resources in China coincides highly with that of clean energy space heating areas in North China, especially in areas where gas pipeline network is not covered and the load of power grid is unbearable. The advantage of geothermal space heating is more outstanding, compared with gas space heating, geothermal energy does not need to import, storage, load, is advantageous to the steady heat, is advantageous to the energy security (Table 3).

TABLE 3: Advantages of Geothermal Space Heating and Other Clean Energy Space Heating Methods

Number	Energy type	Advantages	Disadvantages
1	Coal-to-Electricity	1. China's power grid covers both urban and rural areas and is widely applicable 2. Partially renewable	1. With concentrated load, it is necessary to transform the power grid, resulting in additional investment. 2. The government subsidizes both investment and operating costs, resulting in great financial pressure to continue subsidizing. 3. High operating cost.
2	Coal-to-Gas	Widely applicable	1. China is short of gas sources and needs to import natural gas 2. Limited by the distribution of natural gas pipeline network. 3. The government subsidizes both investment and operating costs, leading to great financial pressure to continue subsidizing. 4. High operating cost.
3	Coal-to-Geothermal Space Heating	1. Geothermal resources are clean, low-carbon and renewable 2. It has the characteristics of distributed energy, local materials and stable space heating 3. Low operating cost, sustainable operation 4. It has unique advantages in areas where the gas pipeline network cannot be covered and the power grid load cannot be borne	1. Geothermal resources need to be carefully explored in some areas, and space heating facilities cannot be built immediately. 2. There is no subsidy policy like replacing coal with electricity and gas, resulting in crowding out effect. 3. The geothermal management system is still not perfect, with many institutional constraints.

5. SUMMARY AND SUGGESTIONS

(1) The selected typical projects develop the heat storage of middle and deep sandstone, adopt the technology of complete reinjection and indirect heat transfer, and have the typical characteristics of geothermal space heating technology in north China, as well as the obvious economic characteristics of high investment, low operating cost and long investment recovery period.

(2) Due to increasing pressure on environmental protection, some Chinese enterprises, especially some state-owned enterprises such as Sinopec, have implemented full reinjection of geothermal projects. The sustainable development of geothermal resources is realized by adopting the technology of "taking heat without taking water".

(3) The geothermal space heating project was put into operation at the early stage because there were few residents in the newly built residential areas, and the income of space heating fee was very low. Later, as the number of residents increased, the income of space heating fee increased year by year, resulting in a 13-year after-tax investment recovery period of the project. The enterprise was under great pressure to recover funds, and the rolling development of the new project was difficult. The operating cost is about 45% of the income of the space heating fee, which can support the normal space heating and maintenance of the project.

(4) Geothermal is more suitable for clean energy space heating in northern China.

First, geothermal resources are local heat sources, not relying on external input, stable and reliable, do not cause the power and the gas supply facility transformation, save the state and the enterprise investment. Second, the operating cost of geothermal space heating projects is the lowest among clean energy space heating projects, and the space heating fees collected at the current price will be able to operate normally, thus ensuring residents' long-term stable space heating. Third, geothermal resources are widely distributed, highly overlapping with clean energy space heating areas in northern China. Geothermal space heating plays an important supplementary role in areas where gas pipelines are not covered, power grid loads are difficult to bear, and local finance is weak and subsidies cannot be sustained.

(5) It is suggested to introduce special funding policies for geothermal space heating.

‘Winter Clean Space Heating Planning in the North Region (2017-2021)’ plans to replace loose coal 150 million tons in 2021, the total amount is fixed, more geothermal utilization and less consumption of electricity and natural gas, with geothermal subsidies gradually replace coal to electricity and coal to gas, will not increase the new fiscal burden, electricity and gas the high grade energy should be used where they are needed. According to the economic characteristics of geothermal space heating projects studied above, it is suggested to subsidize the initial investment with special support funds for geothermal space heating, among which the key subsidy is the projects that drill reinjection wells, rather than subsidize the operating cost all year round. Favorable to reduce the height of enterprise investment and rapid recovery of investment rolling development.

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