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POTENTIAL REDUCTION IN CO_2 EMISSIONS BY GEOTHERMAL HEATING IN BEIJING, TIANJIN AND XIANYANG BY 2020

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ABSTRACT

Beijing, Tianjin and Xianyang represent 3 typical types of geothermal space heating in China. Due to the increased Mineral Resources Compensation Fee geothermal district heating decreased by half in Beijing. In recent years GSHP heating (including partial cooling) has grown rapidly in the city. Based on superiority of geothermal resources in Tianjin, including widespread distribution, higher temperature and larger flow rate, plus cascaded uses the geothermal space heating area occupies 70% of the total geothermal heating area in China. Geothermal development came later in Xianyang. It utilizes local superiority of geothermal resources and geothermal space heating has gained an obvious advantage. Geothermal space heating in the three cities substituted 3.2409 million tons of standard coal annually. It equals reduction of 7.732 million tons of CO_2 emissions yearly.

1. INTRODUCTION

Beijing, Tianjin and Xianyang represent three different types of geothermal space heating in China. Beijing started geothermal space heating early. It was not widely applied due to a source temperature of less than 65°C in most of the area. After the increase of the resources compensation fee, the geothermal heating area decreased by a half. Only the reinjection users can survive by political subsidy.

Geothermal water with widespread distribution, higher temperature and larger yield in Tianjin is very suitable for geothermal district heating. The resource compensation fee is much lower than in Beijing. Cascaded use of geothermal energy in Tianjin creates great efficiency in energy savings. The geothermal heating area in Tianjin accounts for more than 70% of the total geothermal heating area in China.

The utilization of geothermal resources in Xianyang is recent.

The geothermal resources there showed superiority in high pressure, high temperature and large yield. The 29 geothermal production wells supply a heating area of 1.6 million m^2 but energy saving and geothermal reinjection need to be considered.

According to developing programs for the three cities, Beijing, Tianjin and Xianyang the geothermal district heating area should reach 100.6 M m^2 (100 M m^2 for GSHP), 18 M m^2 and 8 M m^2 respectively in 2020. It is equivalent of saving 3.2409 million tons of standard coal and a reduction of CO_2 emission of 7.732 million tons annually.

2. STATUS OF GEOTHERMAL SPACE HEATING IN CHINA

2.1 Geothermal space heating for 40 years

Geothermal space heating started at the beginning of 1970s in China. At that time the first petroleum crisis led to development of new energy in the world. Geothermal space heating started in 1971 in Beijing. An artesian geothermal well with a temperature of 53°C was drilled in Beijing Railway Station. Local workers laid pipes through their offices for winter space heating. With more wells drilled, geothermal space heating progressed later.

There were basically no district heating facilities in the buildings in the 1970s. When people wanted to add to the district heating system in the 1980s, geothermal water with temperature above 80°C in the city became the best choice. Tianjin City developed geothermal heating vigorously and became the No.1 in geothermal space heating in our country. The geothermal heating area in Tianjin accounts for more than 70% of the total heating area in the country.

The technology for geothermal space heating has progressed with increased demands of the heating market. The return water has been used for floor heating and GSHP for extracting more heat for extended space heating.

2.2 Rapid growth of GSHP

GSHP was first implemented in China at the end of the 1990s. Due to its high efficiency, energy saving, reduction in CO_2 emissions, and possibility for development almost everywhere, the GSHP market has grown rapidly in recent years. In 2004 GSHP heated 2.74 M m^2 in Beijing and 7.67 M m^2 in the whole country. In 2006 there were 369 GSHP projects being carried out in Beijing for a total area of 7.38 M m^2. Shenyang city has started the largest development. Where, in 2007, the GSHP heating area had reached 18 M m^2. The whole country completed 36 M m^2 of GSHP heating in that year.

3. GEOTHERMAL SPACE HEATING IN BEIJING

3.1 The difficult process

In Beijing's suburbs natural hot springs have been used for bathing and medical treatment for more than 1500 years but geothermal resources for heating since 1971. In August 1971, an artesian geothermal well was drilled in Beijing Railway Station with a temperature of 53°C and a water head of 5 m above surface. The maintenance section is just beside the geothermal well. Workers laid a few water pipes with 2-inch diameter through every office, so that hot water flowed through the pipes and entered a bath room. The artesian water with the flux of 300 m^3/d thus flowed through poor facilities and the temperature in the rooms reached to 16°C. After heating, the temperature of the hot bath water is still more than 50°C.

New geothermal wells were drilled continually in the 1970s. The formal geothermal space heating was implemented with the help of the construction design institute. People's Art Publishing House transported the hot water with a temperature of 61°C into the original space heating system and the heating area became 17000 m^2. Due to the old building’s poor thermal insulation and the scatter of a few small buildings radiators were later added in the northern rooms (about 40%) and the finally result is good.

The geothermal heating area reached 1 million m^2 in Beijing in the 1990s. However, since the beginning of the 21st century, the geothermal heating area has been reduced by a half. The reason is the increase in the price of "resources compensation". In 1985 Beijing began to carry out geothermal resources management. AT first, the fee was lower than for tap water. After a price adjustment in 2000, the resources compensation fee for geothermal space heating had reached 2.5~3 CNY/m^3. Now 2500~3000 CNY for 1000 m^3/d are charged for hot water extraction. Many units abandoned geothermal space heating because they can not afford the consumption which is more expensive than using a boiler, except for the units which drilled reinjection wells and implemented reinjection. In order to encourage geothermal reinjection, Beijing Municipal carried out the measure of reinjection offseting extraction, and then this part of water surcharge is not collected.

3.2 Ground source heat pumps are more attractive

In the beginning of the 21st century, ground-source heat pump (GSHP) began to be developed in Beijing and their development has been fast.. The GSHPs use shallow geothermal energy, do not deep wells and are not restricted by geography like traditional geothermal wells. They also save energy with the COP between 3 and 4. China's Renewable Energy Law was implemented in 2006 and nine Beijing Municipal committees and bureaus jointly issued the "The guidance for the development of heat pump systems" that year. All these measures provide a preferential policy and a subsidy for GSHP and promote a rapid development of GSHPs in Beijing.

The history of traditional geothermal heating has lasted more than 30 years in Beijing and the maximum heating area was 1 million m^2. But the GSHP has broken the record several times in just a few years. A total of 369 GSHP projects have been implemented in Beijing and the heating area (some include refrigeration) was 7.38 million m^2 at the end of 2006. The number of GSHP projects rose to 479 until September 2007 and by that time the heating area was 10.52 million m^2. It means an increase of 110 projects and 3.14 million m^2 of heating area in nine months. Now, the GSHP heating area in Beijing is the second largest in our country. It is nearly 30 times larger than the conventional geothermal heating area and plays an important role in the energy-savings of geothermal heating.

4. GEOTHERMAL SPACE HEATING IN TIANJIN

4.1 The main force of geothermal heating in China

Tianjin was the first city which comprehensively used geothermal resources in the country. As a coastal city in northern China, the textile and dyeing industries were the key industries and the water used for printing and dyeing was exploited groundwater. With the development of the urban and industrial economy, the need for water increased and deeper groundwater wells were drilled. Tianjin's located downstream of North China Plain. The sediments are Tertiary sandstone and Quaternary shale and loose sand. Groundwater wells were drilled through Quaternary and entered into Tertiary strata. The warm water emerged from the sandstone layers. The deeper the wells were drilled, the higher the water temperature was. This hot water just about meets the needs of the textile printing and dyeing industry. This was the beginning of utilization of geothermal resource for textile industry in Tianjin.

Tianjin focused on searching for hot water with higher temperature from ancient bedrock which is below the sedimentary Tertiary layers. Several thermal reserves of Ordovician origin, the Longshan Group, the Tieling Group and Wumishan Group of Jixian System were explored progressively. The highest geothermal water temperature in the fractured bedrock is 103°C and most water is above 90°C.

The district heating system in Tianjin is recent. There were basically no district heating facilities in the buildings in 1970s. The residents used stoves in their own small room for cooking and heating. When district heating was developed in the 1980s, the geothermal water with a temperature above 80°C in the city it became the best choice for space heating. There are two reasons. First, there is no additional space for boiler rooms. Second, a coal-fired boiler is restricted by environmental protection. So over the past 20 years, Tianjin City including Tanggu, Dagang, and Wuqing Districts, has developed geothermal heating vigorously and become the No.1 geothermal space heating utility in our country. The geothermal heating area in Tianjin accounts for more than 70% of the total heating area in the country developed during the past 10 years.

4.2 Cascaded uses

The market demand in heating will also increase with reform, opening up and economic development. The temperature of geothermal water in Tianjin is high and the flow is large. So, the average single well can heat an area of 100,000 m^2 (two times that in Beijing). In order to meet the growing market demand, the geothermal heating area is made to reach $18\sim20\times10^4 m^2$ through two aspects of cascaded uses.

(1) Floor heating: The temperature of the return water from the heating-cycle is 40~48°C when it enters the floor heating system and is used down to a temperature of 30~35°C, the heating area of $2\sim4\times10^4 m^2$ can be increased.
(2) Ground Source Heat Pump: Collect the returned water with temperature of 30~35°C from floor heating system and use it as a heat source for heat pump. Extract heat from the water and finally discharge it at a temperature of 20~15°C or even 10°C. Thus the heating area can be increased by $5\sim6\times10^4 m^2$.

5. GEOTHERMAL SPACE HEATING IN XIANYANG

5.1 The superiority of resources promote utilization

The utilization of geothermal resources in Xianyang is recent. A deep oil exploration well drilled in the Guanzhong Basin to 2600 m depth had a wellhead temperature is 105°C. The well was known as the "The first well in Shaanxi" with a flow of 4,560 m^3/d then. The good prospects attracted the developer for geothermal drilling and use.

The geothermal resources in the Wei River Basin show the superiority of a high pressure, high temperature and large yield. Up to 2006 29 geothermal production wells have been drilled in Xianyang. Their temperature is from 65°C to 104°C and the depth is between 1,464 m and 3,608 m. Eight of them yield more than 4,000 m^3/d.

Xianyang took advantages of the resource and used it for geothermal district heating. In 2006, the heating area reached 1.6 million m^2.

5.2 Long-term planning

The area of Xianyang is 300 km^2 and the geothermal energy in the south and central areas covers 20.963×10^{18} J. The quantity of the exploitable geothermal fluid is 6.98×10^8 m^3 and the average temperature of the geothermal wells is 88.1°C. Now, only 29 geothermal wells have been exploited, so the geothermal potential is enormous. Xianyang City is planning to develop and provide more heating area which amounts to 5 million m^2 in 2010 and 8 million m^2 in 2020.

In 2006, the subordinate enterprises of SinoPec in Xianyang cooperated with Iceland to set up the Luyuan Geothermal Development Co., Ltd and learn the advanced technology and experience from Iceland to develop the geothermal district heating system of Xianyang.

The geothermal development and utilization in Xianyang is still in the initial stage and the hot water in the 29 geothermal production wells has not been fully used yet. Because the temperature of returned water after heating is still 40~50°C, it is not cascaded use like in Tianjin. At the same time, geothermal reinjection is just planned, but needs an actual test.

Now thermal reserve in sandstone of Tertiary age is being explored in Xianyang . All the geothermal wells are flowing well and the pressure at wellhead is 0.32~1.2MPa. Reinjection into sandstone and pressured reinjection into a Tertiary formation are difficult problems.

6. CONTRIBUTION OF REDUCING CO_2 EMISSION

Although geothermal district heating accounted for a very small part (less than 1%) of winter space heating market in China, it contributed however to reduction of CO_2 emission in the country.

6.1 Exploring for reduction of CO_2 emission

Almost all cities, provinces and autonomous regions have not reached the target for reduction of CO_2 emission in China. Only Beijing is an exception due to the movement of two of the largest pollution enterprises out of Beijing. People are looking for effective methods. Solar PV, wind energy and others have been tested but are not satisfactory. However, geothermal district heating, especially using GSHP is a good way to contribute to the effort.

6.2 New calculation for reduction of CO_2 emission

Previously the Menu of Environment Protection provided a wrong calculation for reduction of CO_2 emission. At that time the CO_2+CO emission from coal burning was only recorded as 2.637% of weight. However, according to a new calculation method based on a new theory created by B.D. Hong and E.R. Slatick of US DoE: one carbon atom would combine with 2 oxygen atoms to become one molecule of CO_2. Considering the net carbon contents in coal and the burning efficiency, one ton of coal would cause about 2.2002~2.3861 tons of CO_2, 1.7% of SO_2, 0.6% of NO_x and 0.8% suspended dusts.

6.3 Potential energy savings in the three cities

Beijing, Tianjin and Xianyang have different features of geothermal district heating. We calculate them separately.

6.3.1 Beijing City

- Conventional geothermal district heating will have small increase a little concurrent with reinjection. It is predicted at 0.6 million m^2 in 2020.
- Demand of heating installations: 600,000 $m^2 \times 50$ W/m^2 = 30 MWt,
- Heat used per year: 30 MWt × 120 d × 17 h × 3600 s ÷ 1000 = 200,320 × 10^9 J,
- It is equivalent to coal savings of: 220,320 ÷ 4.1868 ÷ 7 = 75,175.5 ton/yr;
- In addition, GSHP will serve for 100 million m^2 in 2020,
- Demand of heating installations: 100,000,000 $m^2 \times 50$ W/m^2 = 5,000 MWt,
- Heat used per year: 5,000 MWt × 120 d × 17 h × 3600 s ÷ 1000 = 36,720,000 × 10^9 J,
- It is equivalent to coal savings of: 36,720,000 ÷ 4.1868 ÷ 7 = 1,252,917.3 ton/yr;
- If summer cooling for 60 days running 10 hours per day is added, then the cooling is equivalent to coal savings of 368,505.1 ton/yr.
- The total coal savings are1.2604 million tons without cooling and 1.6289 million tons with cooling respectively

6.3.2 Tianjin City

- Geothermal district heating has been growing fast. It amounted to 9.20 million m^2 in 2004 and 12 million m^2 in 2007. 18 million m^2 are predicted in 2020.
- Demand of heating installations: 18,000,000 $m^2 \times 50$ W/m^2 = 900 MWt,
- Heat used per year: 900 MWt × 120 d × 17 h × 3600 s ÷ 1000 = 6,609,600 × 10^9 J,
- It is equivalent to coal savings of: 6,609,600 ÷ 4.1868 ÷ 7 = 225,525.1 ton/yr.
- Xianyang City
- Xianyang has great potential for extending geothermal district heating. Its existing heating area is 1.6 million m^2. The projected area is 8 million m^2 in 2020.
- Demand of heating installations: 8,000,000 $m^2 \times 45$ W/m^2 = 360 MWt,
- Heat used per year: 360 MWt × 120 d × 17 h × 3600 s ÷ 1000 = 2,643,840 × 10^9 J,
- It is equivalent to coal savings of: 2,643,840 ÷ 4.1868 ÷ 7 = 90,210.0 ton/yr.
- Therefore the above three cities would save 1.9446 million tons of standard coal annually by using geothermal heating. Assuming a burning efficiency of 60%, the savings would be 3.2409 million tons annually.

6.4 Potential for reduction of CO_2 emissions in the three cities

Geothermal district heating area would reach 100.6 million m^2 (including GSHP), 18 million m^2 and 8 million m^2 in Beijing, Tianjin and Xianyang respectively. This area constitutes 1/5 of the total building area in Beijing but less than 10% in Tianjin and Xianyang. By estimation, this amount of geothermal heating is equivalent to standard coal savings of 3.2409 million tons annually. It would reduce the CO_2 emissions by7,732 million tons annually. Other reductions can be seen in Table 1. These are potential contributions of geothermal district heating in the Beijing, Tianjin and Xianyang cities.

TABLE 1: Geothermal Space Heating & Potential Reduction of Emissions for 3 Cities in 2020

	Heating area ($\times 10^6 m^2$)	**Coal savings ($\times 10^3$ton)**	**Assumed burning efficiency 60% ($\times 10^3$ton)**	**Re-duction in CO_2 ($\times 10^3$ton)**	**Re-duction inSO_2 (ton)**	**Re-duction in NO_x (ton)**	**Re-duction in TSP (ton)**
Beijing*	100.6	1,628.9	271.48	647.7	46,151	16,289	21,718
Tianjin	18	225.5	37.58	897	6,389	2,255	3,006
Xianyang	8	90.2	15.03	358	2,555	902	1,202
Total	126.6	1,944.6	324.09	7,732	55,095	19,446	25,926

* Beijing coal savings include GSHP for cooling, which is about $22.6^{o}/_{oo}$

** TSP -- total suspended particles

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