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"Hot Spring Capital of China"- Status of the Development and Utilization of Geothermal Resources in Tianjin

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ABSTRACT

Tianjin is a beautiful city, located at the east of the capital Beijing, near the Bohai Gulf. Tianjin bears rich mid- low temperature geothermal resources, the water temperature of the geothermal wells pump out up to 113°C. The history of mining of geothermal resources spans more than 80 years, and direct use of geothermal fluids in Tainjin ranks the first in the world. The Chinese government awarded the first "hot spring capital of China" to Tianjin, and the utilization of geothermal energy brings considerable economic benefits. In recent years, to solve the historical problems such as the pressure of geothermal reservoir declining too fast, low reinjection amount, and the extensive patterns of development and utilization, local administrative authorities adopted a series of measures and enacted laws and regulations, and strictly manage according to laws, to secure benign development of the geothermal resources.

1. INTRODUCTION

Tianjin is one of the four municipalities under the direct administration of the Central Government of the People's Republic of China. There are huge low-to medium- temperature geothermal resources reserves underground. The total area of geothermal abnormal gradient (the average geothermal gradient of cap greater than 3.5°C/100 m) is up to 2300 square kilometers, and the temperature of water pumped out from geothermal wells is up to 113°C. The exploitation history of geothermal resources in Tianjin started very early, now the resources are widely used in various aspects of the national economy and people's lives: space heating, textile washing, greenhouse cultivation, aquaculture, medical rehabilitation, tourism, mineral water, etc. A variety of utilization systems have formed, achieving significant social, economic and environmental benefits.

2. REGIONAL STATUS AND GEOTHERMAL DEVELOPMENT HISTORY

Tianjin, located in the northeast of the China's north plain, near the Bohai Gulf, is the economic center and industrial city of northern China, and has an extremely important strategic position in China's economic development. Due to the geologic condition, Tianjin has relative scarcity of mineral resources, which restricts the city's economic development to some extent. As a renewable resource, the geothermal energy in Tianjin has advantages of large reserves, wide distribution and good location, which can be described as unique. Tianjin is one of the earliest cities in China to develop and utilize the geothermal resources, the history of production is over 80 years. In the 1930s, the French drilled the first neogene geothermal well in Tianjin, which is the starting flag of the geothermal mining history. In the 1970s, with the advocacy of Chinese famous geologist expert Li Siguang, Tianjin started a series of large-scale exploration of geothermal resources. United Nations Development Agency(UNDP) also provided drilling equipment aid in the 1980s, and to the late 1990s Tianjin stepped into the large-scale development phase. The cumulative drilled depth reached nearly 9 million meters over nearly 50 years, and the maximum depth of single-well exploration is up to 4046 m. Tianjin has become the "geothermal city" of the highest research degree, the largest development scale and the best utilization level in China. Geothermal energy plays an important role in alleviating the local energy shortage situation and promoting economic development.

3. GEOLOGICAL CHARACTERISTICS AND EXPLOITATION STATUS QUO

The geological position of Tianjin is located in class I tectonic units. In the northern platform north margin, the geothermal resources are classified as sedimentary basin low-to medium- temperature geothermal type. There are two types of geothermal reservoir (shallow neogene porous and deep bedrock fracture) occuring in the vast plain area. The distribution range is extremely wide, the amount of fluid that can be directly developed and utilized is considerable. The recoverable reserves of geothermal fluid with temperature higher than 25°C and depth above 4,000 meters is 7607×10^4 m^3/a, and the thermal energy that can be utilized is 1.30×10^{16} J/a, equivalent to 44.3×10^4 tons of standard coal per year. The geothermal resources in Tianjin are widely used, universal form, developed early, with the largest urban space heating area. According to statistics, by the end of 2013, there were 474 geothermal wells of different depths, different purposes, different reservoirs in Tianjin, including 359 exploration wells and 115 reinjection wells. Total annual exploitation of geothermal fluid is 32.4 million cubic meters, and reinjection is 13.1 million cubic meters, so the reinjection rate is 40%. In the optimized utilization of geothermal resource for space heating, 82% of annual exploitation is used for heating, and after heat exchange the tail water recharge rate is about 60%. There are 230 projects using geothermal fluid for space heating in winter, used in about 15.53 million square meters of buildings, accounting for 6% of the total area of the city's central heating. This represents 30% of China's domestic geothermal heating area, ranked the first in China.

Besides, there are 181 geothermal wells provide bathing and living water for residents, employees and hotels, approximately 100,000 residents enjoy geothermal fluid at home. More than 8.25 million people annually use geothermal fluid for bathing, the annual amount of utilization of geothermal fluid for this purpose is about 7.52 million cubic meters. There are 20 enterprises using of geothermal fluids to develop spa and therapeutic projects, with an annual consumption of 140,000 cubic meters, the construction

area of spa tourism facilities is 125,000 square meters. There are 5 enterprises using geothermal fluids to produce mineral water, the annual consumption is about 110,000 cubic meters, accounting for 0.03% of the total annual mining. 15 enterprises utilize geothermal resources for industrial production, annually consuming about 2.43 million cubic meters. 12 enterprises operate in agricultural cultivation and planting, with a total area of 10 million square meters, the annual consumption is about 190,000 cubic meters accounting for 0.06% of the total annual mining.

4. ECONOMIC BENEFITS AND DEVELOPMENT PLAN

The prominent advantage of geothermal utilization is energy-saving and environmental protection. In Tianjin, in addition to initial investment that is slightly higher than coal, the operating cost of geothermal resource for space heating is 14～16 yuan per square meter, which is the lowest economic cost among the current heating sources. According to the statistics, in Tianjin, the direct economic benefits created by using geothermal energy add up to 50 billion yuan annually. Utilizing geothermal for heating is equivalent to replacing 263,000 tons of coal and reducing emissions of carbon dioxide by 632,000 tons, 5,712 tons of sulfur dioxide, 2,016 tons of nitrogen oxides, suspended dust mass 2688 tons, 33,600 tons of coal ash ballast. This has saved 90 million yuan of environment comprehensive management fee, purified the air, reduced urban pollution, made outstanding contributions for the city to implement the "Blue Sky" project and created demonstration of and environment-protecting city. Meanwhile geothermal played a positive role in attracting commercial investment, the accumulated investment relying on geothermal resources has been up to 150 billion yuan, such as Baodi Pearl Hot Springs city, Dongli Lake Resort, Tuanbo New Town and other investment and development projects. Local abundant geothermal resources has brought unique advantages for attracting commercial investment, promoting regional economic development.

Efficient use and high-level research achievement make the influence of Tianjin's development of geothermal resources stronger internationally and domestically. The International Symposium on the direct use of geothermal resources in Asia 2008 was held in Tianjin. The Chinese shallow geothermal energy conference was held in Tianjin on August 30, 2009, while awarding "Chinese Hot Springs Village" title to Dongli Lake Spa Resort, which marks the birth of the first hot springs village in Tianjin. Subsequently Tuanbo new town and Jingjin new town have been successfully awarded the title of "China Spa City". By the end of 2010, with its abundant reserves of geothermal resources and development achievements, Tianjin was awarded the first title "hot spring capital of China" by Chinese Ministry of Land Resource. So far, Tianjin is the sole holder of the titles "spa capital", "spa metro", "spa town" trinity "geothermal city", which is rare in China; also reflecting the large scale of development and utilization of geothermal resources. The authoritative data from 2005 Turkey and 2010 Bali World Geothermal Congresses show that China has the largest scale in the direct use of the low-to medium- temperature geothermal resources, and Tianjin has the largest scale in the direct use of the low-to medium- temperature geothermal resources in China.

Tianjin municipal government plans that by 2015 (by the end of the five-year plan period), the exploitation of geothermal fluid volume will reach 45 million m^3/a, the overall reinjection rate will reach 52%. Annually this can save 367,100 tons of standard coal, reduce carbon dioxide emission 876,000 tons, sulfur dioxide 6,200 tons, nitrogen oxides 2,200 tons, dust 2,900 tons, coal ash ballast 400 tons. Economic and environmental benefits are considerable. Based on the current situation in Tianjin, the city has made plans to construct six types of 15 geothermal utilization demonstration projects including geothermal resource comprehensive utilization, recharge protection, spa treatments, geothermal demonstration town, geothermal cultural show, forming various kinds of geothermal industry base, and playing a demonstration role for national geothermal development and utilization.

5. EFFECTIVE MANAGEMENT AND UTILIZATION TECHNOLOGY

The utilization of geothermal energy brings remarkable economic benefits; however, large scale development may cause a series of negative problems such as high temperature of tail water, low utilization efficiency, water level dropping too fast, increasing development costs, shortened development life of geothermal reservoir, etc. In recent years, in order to solve the historical problems such as geothermal reservoir pressure dropping too fast, low recharge amount, the extensive mode of development and utilization, etc., the local administrative authorities always adhere to the principle of "protection in development, development in the protection", from the aspects of the "administration, planning development, strengthening recharge, cascade utilization, demonstration projects, strengthening monitoring" to manage and protect the development and utilization of geothermal resources. To secure resources under benign development, they have taken a series of initiatives, enacted laws and regulations and strictly managed according to laws. On one hand, to improve efficiency, different geothermal reservoirs adopt different utilization mode; on the other hand, insist on a recharge development model, increase recharge, to improve protection of the geothermal resources. Meanwhile through the conversion of scientific and technological achievements in time to serve economic construction and social development, gradually convert the resource utilization from simple intensive to recycling extensive mode.

Tianjin municipal government attaches great importance to the management of geothermal resources, in order to strengthen the unified management of geothermal. In 1994, Tianjin set up a particular geothermal management department. In 1995 the municipal government promulgated the "Provisions on the Administration of Tianjin Geothermal Resources" (2004 revision). 2001 Urban People's Congress formulated the "Tianjin Mineral Resources Management Regulations", which provided a legal basis for Tianjin Geothermal Development and Management, so that the geothermal resource would be managed with legalization and standardization. While always adhering to planning in advance, after the "Tianjin Geothermal Resources regulations" promulgated, Tianjin immediately drew up the first geothermal resources plan, which established the principles and goals of exploration and development of geothermal resources. With the development of urban and rural regions, and the development and utilization scale of geothermal resources expanding, the management increasingly focuses on enhancing protection of geothermal capacity and conservation and protection of the geothermal resource. For this purpose, Tianjin drew up the second "Tianjin geothermal resource development and utilization plan" (2006-2010), which was approved by the municipal government. In order to protect geothermal resources and realize the sustainable development, Tianjin revised and compiled the "Tianjin Geothermal Resource Planning" (2011-2015) in 2011, considering the urban development and the need to redefine the zone. The compilation of "Thirteen-five" plan is in progress, aimed at exploration and evaluation, recharge conservation, cascade utilization, and construction of demonstration projects, and development of practical objectives and initiatives.

In terms of resource protection, strategies include: (1) actively promote production-reinjection mode, (2) adjusting the approval process of the development and utilization of geothermal resources, (3) establishing new approval that for the new geothermal heating project production well must be combined with reinjection well, (4) the new geothermal heating projects should be 100% recharged, effectively easing the drawdown rate of water table and extending the life of the geothermal field. To solve the serious waste problem of the single well heating system, two adjacent exploration wells should be transformed into a "production-reinjection" system or a recharge well drilled to form a "two production-one reinjection" system, integrating the geothermal resources, to improve and rectify the historically unreasonable geothermal system, and enhance the utilization efficiency of the geothermal resources.

Tianjin Geothermal Exploration and Development Institute has been actively exploring the recycle technology, implementing reinjection in the most concentrated heat mining area. Geothermal heating systems use heat exchangers to extract the heat from the fluid, and the water is recharged to its original reservoir forming a relatively closed loop system above and below ground. This consumes only heat without depletion of water, reduces direct discharge of the heating tail water, maintains the pressure of the geothermal reservoir, and truly renews and recycles the geothermal resources. In 1996,Tianjin Geothermal Institute carried out the study of geothermal bedrock reservoir recharge technology, through pilot tests of a variety of techniques and methods, established three different modes of demonstration projects, and launched bedrock tracer and radio-isotope ^{35}S, ^{125}I tracer tests, the achievements reached the international advanced level. Meanwhile developed the nation's first local recharge procedures, ground engineering construction standards. The neogene geothermal reservoir recharge made significant progress in 2010, through perforation and surface purification process, the stable recharge amount of porous geothermal well can reach 120 m^3/h, the maximum amount more than 150 m^3/h. This solves the worldwide difficult problem, providing technical support for the sustainable development of the neogene porous thermal reservoir geothermal resources. Promoting the application of geothermal cascade utilization and recharge technology, actively exploring research on a variety of applications technologies to improve the utilization efficiency, according to the resources condition, a large number of demonstration projects and integrated energy stations have been established. These have included the recycling utilization, group wells linkage, oil well transformation , and energy integration. It is particularly worth mentioning that Tianjin launched surface water recharge work in 2012, and formally implemented it in 2013, which is the precedent of artificial recharge to Wu Mishan geothermal reservoir using surface water. The depth of the recharge well is 2329 meters and the capacity is $152m^3/h$. In the wet season (September), before recharge the surface water is treated through the process of "coagulation + sand filtration + sponge iron remove oxygen + precision filtration + Nano membrane filtration", total recharge was 6.6×10^4cubic meters in 34 days, which is a good supplement for the geothermal reservoir. Surface water recharge technology opened up a new path for the protection of geothermal resources.

6. CONCLUSIONS

Early in 2013, Chinese four ministries, "the National Energy Board, Ministry of Finance, Ministry of Land, Housing and Urban-Rural Development on the promotion of geothermal energy development and utilization of guidance," pointed out: "In connection with the distribution of deep geothermal energy resources and local energy needs, through centralized and large-scale utilization demonstration of geothermal energy, explore new energy management technology and market operation model in favor of the development and utilization of geothermal energy, upgrade the utilize technology and reduce the cost, enhance geothermal market competitiveness, improve the proportion of the cleaning energy in urban energy consumption" to enhance development and utilization of geothermal energy to a new level. In the same year, Tianjin promulgated the "outline of beautiful Tianjin construction", "Tianjin Clean Air Action plan" proposed "expanding the use of natural gas, geothermal and other clean energy", the local government held a particular comprehensive environmental television and telephone conference, decided to implement the "beautiful Tianjin No.1 project", including fresh air, fresh water rivers, clean village and beautification of the community, namely "four clean one green" action, let the public enjoy the blue sky and clear water. They also proposed "increase the utilization of geothermal resources, by the end of 2017 geothermal resource utilization amount should reach 38 million cubic meters". With these specific objectives, a new round of geothermal energy development boom has already begun. The municipal government also proposed that the central city and Binhai New Area replace the fossil energy and combine the heating grid, using the geothermal resource as a clean, environmentally friendly, high-quality renewable energy, to play an important role in terms of optimizing energy structure.

Of course, we must realize that the resources are limited and valuable, geothermal is just a supplement in the urban energy structure, not as the dominant energy source. Therefore, when determining the development and utilization goals we should adhere to the principle of being active and steady, geothermal mining rights must be set with cautious, scientific and rational allocation of the resources, giving full consideration to the actual carrying capacity of the geothermal resources. We should promote the innovation of technology, policy, and other aspects of economic measures to effectively protect the resources.

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