



## **STRATEGY AND MANAGEMENT OF EXPLORATION AND DEVELOPMENT OF GEOTHERMAL RESOURCES IN CHINA**

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### **ABSTRACT**

The former Ministry of Geology and Mineral Resources (MGMR) has carried out hot spring surveys nationwide, and geothermal resource exploration and assessment in emphasis areas since the 1950s. These have proved the existence of a fair number of exploitable geothermal fields. This ensured that demands for geothermal resources for development and utilization in the country may be satisfied. Since the Ministry of Land and Resources (MLR) was founded in 1988, further exploration, assessment and a plan of geothermal resources have been strengthened. The work of exploration, evaluation and planning of China's geothermal resources in Yinchuan Plain in Ningxia, Beijing City, Guanzhong Basin in Shaanxi, north Shandong, and other places have been carried out by MLR according to the Land and Resource Survey Plan.

### **1. THE INTRODUCTION OF GEOTHERMAL RESOURCE IN CHINA**

MLR and MGMR have input several hundred million CHY for geothermal resource exploration for the past 50 years. The National Committee of Reserves of Mineral Resources has approved the resources of 103 geothermal fields, including some medium-high temperature geothermal fields. Their exploitable geothermal reserves in B+C grade are 332.83 million m<sup>3</sup> per year. In addition, other 214 geothermal fields that were subjected to a detailed survey have D+C grade reserves of about 500 million m<sup>3</sup> per year. In the present economic and technical conditions the annual exploitable geothermal water is about 6,845 million m<sup>3</sup> per year in the country. Its total thermal energy is 972.28×10<sup>15</sup>J, equivalent to 32.848 million tons standard coal. Exploitable resources of geothermal

water of the convection-type is 1.9 billion m<sup>3</sup>/a. Its total thermal energy is  $335 \times 10^{15}$  J, equivalent to 11.42 million tons standard coal. Exploitable resources of geothermal water of Plain-conduction type is 4.9 billion m<sup>3</sup>/a. Its total thermal energy is  $628 \times 10^{15}$  J, equivalent to 21.42 million tons standard coals. The two types of exploitable geothermal reserves account for 35% and 65% of the total and exploitable water accounted for 28% and 72%.

It should be stated that the above estimates only constitute a part of the geothermal resources in our country and do not include shallow geothermal energy resources and geothermal resources in the non-anomalous geothermal gradient areas (depths > 2000m, gradient < 3°C/100m).

## 2. DEVELOPMENT AND UTILIZATION OF GEOTHERMAL RESOURCES

China is one of the countries in the world which have used geothermal resources from early times mainly for the direct use such as hot springs bath spas. Large-scale development and utilization of geothermal resources started after the founding of new China. Some 160 hot spring sanatoria were founded progressively in the 1950s and 1960s in China. In the 1970s geothermal resource development and utilization grew rapidly with the world petroleum crisis. Since the 1990s with the thrust of the market economy, geothermal development and utilization have grown further.

High temperature resources are used for geothermal power generation in Yangbajain, Tibet. The medium-low temperature resources were used directly. About 18.0% are used for space heating and hot water supply, 65.2% for baths, health care and entertainment, 9.1% to greenhouse growing and aquaculture feeding, and 7.7% of other utilization.

According to the statistical information of the Geothermal Professional Committee of China Energy Research Society, we exploited 460 million m<sup>3</sup> of thermal water in 2006. The used geothermal energy is 16,187 GWh, which is the greatest use of any country in the world. The rate of geothermal development in recent years has increased about 10% annually. But it is a very small percentage of national energy use, or less than 0.5%.

Development and utilization of shallow geothermal energy is a new approach to the uses of geothermal resources. It has developed rapidly with the maturing of the v technology of the ground-source heat pump and water-source heat pump. Using heat pump technology for development and utilization of shallow geothermal energy has been widely available in our country especially in the northern region since the 1980s. The areas around Beijing and Tianjin developed most rapidly. Beijing has begun a large scale application of shallow geothermal energy for heating and cooling using heat pump technology since the beginning of the century. Now it grows with a rate of 15 to~20 percent per year. Currently, the area heated by shallow geothermal energy in Beijing has risen to more than 8 million m<sup>2</sup> and in the "11th Five-Year Plan" period an additional 30 million m<sup>2</sup> will be added. Heat pump technology has greatly increased the efficiency of use of the traditional geothermal resources. For example, the Huaxin Community of Tianjin used heat pump technology for the geothermal

heating system. The lowest temperature of discharged geothermal water has reached 10°C and 80°C temperature differences have been used. The geothermal resources have been fully utilized.

At present, Beijing, Tianjin, and other areas are gradually setting up construction technology and quality requirements for water wells, well-design and calculation methods, water quality evaluation and treatment and environmental impact evaluation methods for various groundwater source heat pump systems. Recharge technology of water quality control, process technology to plug wells, the simulation calculation method for soil heat pump systems on the wells mining irrigation system heat. Chemical collection and field pressure parameter methods are still under study.

### **3. STRATEGY AND MANAGEMENT OF NATIONAL GEOTHERMAL RESOURCES**

Geothermal resources are classified as energy mineral resources. In the “Detailed Implementation Rules of the Law of Mineral Resources of PRC”, geothermal resources are listed in the 11<sup>th</sup> chapter on energy resources.

According to the Law of Mineral Resources MLR and its assembly regulations, implement unique administration of geothermal resource exploration and exploitation for a period of time. It mainly involves 1) organization and arrangement of regional geothermal exploration, 2) administration of licenses for exploration and exploitation, 3) appraisal and examination of geothermal reserves and data collection, and 4) monitoring and supervision of geothermal exploitation.

After the State Council's institutional reform in 1998, because there are ambiguities in the "three designated" provisions published by Office of the State Council. The relevant departments and the local councils have a different understanding of responsibilities of mineral water, geothermal management and this has caused many disputes. So "The notice about management responsibilities of mineral water and hot water" (Office for the [1998] 14) published on December 16, 1998 made some compromise provisions. First, before the exploitation of the proven mineral water and hot water resources, water permits should be obtained from water administration departments to determine mining limits; Second, if the mineral water and hot water are used for commercial enterprises, the corresponding mining permit could be obtained with a water permit from administration departments of Geology and Mineral Resources; Third, the Geology and Mineral Resources administrative departments charge the fees for mining rights and mineral resource compensation from enterprises in accordance with "The approach of registration and management to mineral resource exploitation" and the "Regulations on management of mineral resource compensation charge " and timely paid financial in full; Fourth, the administrative departments of Geology and Mineral Resources should transfer the mineral rights in accordance with the rule of "Management approach to transferring mineral rights ".Based on the document, the exploitation of geothermal water and mineral water need water permits and mining permits and to pay the charge for mining rights and mineral resources compensation. But in the survey we found that water administrative departments charge the water resource fee for the water permit in some areas.

The MLR manages exploration and exploitation of geothermal resources in accordance with the law. At the same time, it also focuses on the following aspects:

### **3.1 Promoting the making of laws and regulations**

According to the "Mineral Resources Law" and other laws and regulations, the MLR began to draft the management regulations of geothermal resources and work on its feasibility studies in the 1980s. On the basis of a wide range of opinions from various departments, the former State Development Planning Commission and the Ministry of Geology and Mineral Resources drafted "Geothermal Resources Management Regulations" in the late 1980s, and submitted it to the State Council's Legislative Affairs Office. However, for various reasons, "The geothermal resource management" has not been promulgated.

Local governments need to strengthen the making of laws and regulations on geothermal resources for the development of geothermal resources. Beijing, Tianjin, Yunnan Province, Qingyuan City in Guangdong Province, Xianyang City in Shaanxi Province have promulgated and implemented local laws and regulations for geothermal resource management. The "Geothermal resources management approach" of Hebei has also entered the National People's Congress validation process and will be promulgated shortly. The administrative departments of Land and Mineral resources in most other provinces (regions and cities) have also promulgated rules for the management of geothermal resources. The rules have made specific stipulations on the exploration and development of geothermal resources and approval procedures for geothermal wells.

### **3.2 Carrying out planning work on the development of geothermal resources**

The former Department of Geology and Mineral Resources made a unified plan about National Geothermal Resources and divided the major geothermal exploration zones and development zones according to different storage conditions and temperature characteristics. The department also identified the exploitable reserves of each geothermal field. In 1998 the MLR began the work of National Geothermal Resources Planning and in 2002 completed the draft of "China geothermal resource planning". The planning plays a guiding role for geothermal exploration in each area. Currently, planning is continually being revised.

According to the unified demands of the MLR, the provinces (regions and cities) have also begun the work of a geothermal resource planning. For example, clean energy will be widely developed in Beijing to control air pollution and improve the atmospheric environment. The Mayor's office has adopted "The sustainable use of geothermal resources planning in Beijing from 2001 to 2010". Chongqing Municipality has completed the work on the writing and authorizing of "The exploration and utilization of geothermal resource in Chongqing planning"

### **3.3 Setting the technology standards and norms of geothermal exploration**

Geology and Mineral Resources industry standard "DZ 40-85 evaluation method of geothermal resource" which was published in 1985 provides geothermal resource terms, terminology, and evaluation methods of resource and chemical composition of geothermal fluid. "GB 11615-89 Geological exploration of geothermal resources norms" which was published in 1989 provides the survey extent of the geothermal field, the prospecting type and control of exploration engineering, exploration technology and quality requirements, the classification, the calculation and evaluation of geothermal reserves, geothermal fluid and the environment impact assessment of geothermal resource exploration, as well as data compilation and the preparation of reports and other basic requirements. Meanwhile, the "medical thermal mineral water standards (reference)" has been promulgated as annex of "GB 11615-89". Recently, the unit is writing "technical regulations on shallow geothermal exploration and development".

### **3.4 Summing up and publishing research results of geothermal exploration periodically**

In order to sum up and guide the exploration and development of the nationwide geothermal, MLR irregularly collect, analyze and study the exploration and development results of the national geothermal and published the geothermal research results periodically, such as the publication of "China's distribution of underground water" in 1979 and "China geothermal resources - forming characteristics and potential assessment" in 1992 and other research results. In recent years, the MLR has held geothermal seminars and academic meetings many times and published a number of the meeting proceedings.

### **3.5 Organization of activities for "Village of Hot Spring of China" nomination and construction**

The MLR and China Mining Association organize activities for the "Village of Hot Spring of China" nomination and construction, including setting up nomination standards, validating procedure and management, etc. The purpose of building "Village of Hot Spring of China" is to make full use of its resource advantages, build spas, and promote the utilization, and local economic development. With the building of the "Village of Hot Spring of China", the exploration and assessment of geothermal resources and resources planning are promoted, development and utilization behavior are regulated and the level of development and utilization is improved, the management and protection on geothermal resources is strengthened and the use of geothermal resources made sustainable.

At present, Enping City in Guangdong Province, Lindian County of Heilongjiang, Qionghai of Hainan, Xiaotangshan of Beijing, Chenzhou of Hunan, Qingyuan of Guangdong, Xianyang in Shaanxi, Xiongxian of Hebei have been named as the "Village of Hot Spring of China" or "Chinese Geothermal City". Those cities and towns have played a model role in exploration, development, utilization and protection of the geothermal resources in our country.

### **3.6 Strengthening the sustainable use of resources and protecting resources environment**

In the development and utilization of geothermal resources, each local council seriously implements the basic national policy of saving the resources and protecting the environment, strengthens environmental protection during development and utilization of geothermal resources and sets relevant regulations and technical requirements. For example, Beijing, Tianjin, and other areas clearly defined that geothermal heating projects must be carried out with recharge heating water effluent or the use of water-source heat pump technology, and maintaining the balance between mining and irrigation. A bath Spa project must be equipped with economical facilities and the water must be recycled to reduce discharge. The water discharge must be treated and used for irrigation or artificial recharge to meet the standard requirements. All the projects of Beijing Jiuhua Spa Resort, Fengshan Hot Springs and Tianjin Huaxin Apartment reuse the water in circulation, and finally for the environmental use. Basically the discharge achieves zero effluent.

Geothermal reinjection wells and reinjection volume have increased year by year. Beijing currently has 13 reinjection wells and the reinjection capacity is 2.06 million m<sup>3</sup>, 1/4 of the total exploitation. The geothermal extraction volume of Xiaotangshan geothermal field was increased and the geothermal water level went down year after year from the start of the 1970s. From 1988 to 2001, the water level dropped by an average of 1.9 m/a. Since the beginning of 2000, the reduced exploitation volume and increased reinjection volume have mitigated water level decline year by year and have created a rising trend. The water level rose 1.2 m during the heating period of 2004 and 2005. During 2005~2007, the geothermal water level was higher than the previous year, with an average elevation of 2.04 m. At present, there are 33 reinjection wells in Tianjin and the recharge capacity is 3.6 million m<sup>3</sup>, accounting for 14.4% of the total extraction.

From experience in Beijing, Tianjin, Xi'an, Fuzhou and other places in recent year geothermal reinjection rate can equal its exploitation rate in karst and fractured bedrock areas. But there is a problem of blockage in reinjection into reservoirs of Quaternary and Tertiary strata. The ratio of reinjection is only about 40% of the exploitation and the ratio of production well and reinjection well should be 1:2 to 1:2.5. The cost of the development and utilization of the geothermal resources is high. Most of the area, which uses ground-source heat pumps for development and utilization of shallow geothermal energy, has been required to reinject groundwater. . Geothermal reinjection did not have an impact on the thermal balance of the stratum. The temperature of the groundwater had decreased only slightly at the end of the heating period. However, the groundwater temperature has not changed significantly over the years.

### **3.7 Expropriate mineral resource compensation and other costs incurred by the law**

The MLR Departments charge the fees for mineral resource compensation, mining rights and use for exploration and development of geothermal resources according with Mineral Resource Law and other laws and regulations. The mineral resources compensation is charged according to the volume of hot water used in most areas.

Beijing and Tianjin set different levy standards based on geothermal uses and temperature and then approve costs for the volume used. The use in Beijing is classified into: 1 Heating, domestic hot water and industrial production; 2 Farming and aquaculture; 3 Toiletries industry, health spa and entertainment industry, mineral water and other special industry; Divided by the temperature: 50°C below, 50°C ~ 60°C, 60°C ~70°C, 70°C above. Entertainment toiletries and other special industries charge high fees and but heating utilities charge lower. The higher the temperature is, the higher the fees are. The minimum charges 3.5 *yuan* / m<sup>3</sup> and the highest reach 61 *yuan* / m<sup>3</sup>.

Except for Beijing and Tianjin, the geothermal fees are generally low in other provinces (regions and cities). It is lower than the groundwater at room temperature, about 0.1 ~ 0.3 *yuan* / m<sup>3</sup>.

At present, water administration departments of quite a number of provinces also charge the water resource fee except mineral resource compensation which is charged by MLR, such as Hebei, Fujian, Yunnan and other places. But the water administration departments of Guangxi, Hainan and Xi'an only charge water resource fee, not mineral resource compensation

### **3.8 The preferential policies for geothermal exploration and development**

In order to actively promote the use of geothermal resources, local governments have introduced related preferential policies. Beijing exempts the recharge units from geothermal resource compensation and makes geothermal heating units and the total recharge increase year by year. Tianjin has reduced fees for the mining units and charges only 1/3 of the fees for hot water for heating. (0.3 ~ 0.6 *yuan* / m<sup>3</sup>).

In order to optimize its energy structure further and raise energy efficiency, Beijing Municipal Development and Reform Commission, the Planning Commission, the Financial Bureau, the Land and Resources Bureau jointly notice " Guiding Opinions on the development of the heat pump system " , encourage the development and utilization of shallow geothermal energy in new office buildings, industrial plants, hospitals, hotels, schools, shopping malls, commercial buildings and other public buildings as well as residential buildings and heat pump systems in residential buildings. They also encourage the use of heat pump systems instead of coal-fired and oil-fired boilers.

Every year the government will support investment or give one-time grants. The construction grant standards for application of heat pump systems for heating and refrigeration are: a groundwater water source heat pump (Surface water source heat pump) 35yuan/m<sup>2</sup>, ground source heat pump and renewable water source heat pump 50yuan/m<sup>2</sup>. The units which apply heat pump systems in Beijing are charged heating costs according to Beijing clean energy boiler heating prices.

#### **4. THE MAIN PROBLEMS**

1. The evaluation of national geothermal resources exploration is low level. In addition to the geothermal fields which have been explored, the geothermal resources in most areas are unknown and exploration and evaluation lagging behind the development and utilization.
2. The geothermal resource characteristics of flows, that are renewable, but at great depth are different from the general solid minerals. So the existing laws and regulations are imperfect. The development and utilization is in disorder because of poor management in some areas.
3. In some areas, groundwater overdraft has induced surface subsidence.
4. The level of development and utilization of the geothermal resource is still low in some areas and the waste of resources is serious.
5. Since the 1990s, our country input into the exploration of geothermal resources has not been sufficient and made some areas face high risk in the market development.

#### **5. SUGGESTIONS**

##### **5.1 Strengthen exploration and evaluation of geothermal resources and improve the level of the geothermal resource research**

The risk of geothermal resource development is big. We must enhance the work of the geothermal resource exploration and evaluation for reducing the risk costs of the geothermal resource development. The current major tasks are: First, organize the investigation, assessment and regionalization of geothermal resources. Second, evaluate and demonstrate the future resources of geothermal fields which have been developed. Third, further explore the areas which have potential for development and utilization of resources. Fourth, work on the provincial geothermal resource planning.

##### **5.2 Accelerate the improvement of the relevant laws and regulations**

On the basis of the "Mineral Resources Law" and "renewable energy", promulgate "Geothermal Resources Management Regulations" and supporting legislation as soon as possible.

##### **5.3 Strengthen the supervision and management of the development and utilization of geothermal resources**

For the development and utilization of geothermal resources, we must adhere to the principle of "unified planning, scientific feasibility studies, mining with irrigation, and comprehensive utilization", implement the registration and management system of the exploration and mining and processing strictly, and do a good job in feasibility studies for geothermal drilling. Establish and improve



monitoring systems of recharge and dynamic flow. Control the lowest water level and prevent ground subsidence and other geological disasters.

#### **5.4 Rely on technology progress and improve the level of geothermal resource development and utilization**

Introduce techniques and use new technologies and methods and establish the sustainable use demonstration project.

#### **5.5 Set preferential policies to encourage the rational development and utilization of geothermal resources**

Suggestions: First, the central finance allocates special funds for the exploration and evaluation of regional geothermal resources. Second, our country implements preferential taxation policies and encourages the development and utilization of geothermal resources and shallow geothermal energy resources.

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