

## **GEOHERMAL SCOURCE HEAT PUMP IN CHINA**

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**Abstract:** Geothermal source heat pump (GSHP) technology and its markets are booming in China, which on the one hand owes to its energy-saving and environment-friendly competitive advantages, on the other hand to the governmental incentive policies. Up to the end of 2007 there are more than 30 million m<sup>2</sup> building areas installed with GSHPs in the whole country, and with 10.52 million m<sup>2</sup> and 18 million m<sup>2</sup> respectively Beijing and Shenyang are taken as the pioneer and demonstration city for GSHPs. In this paper some typical GSHP activities and some policies issued by the governments to motivate and regulate GSHP markets are introduced, furthermore, some questions behind the great prosperity and some suggestions to sustain the development of GSHPs are discussed and analyzed.

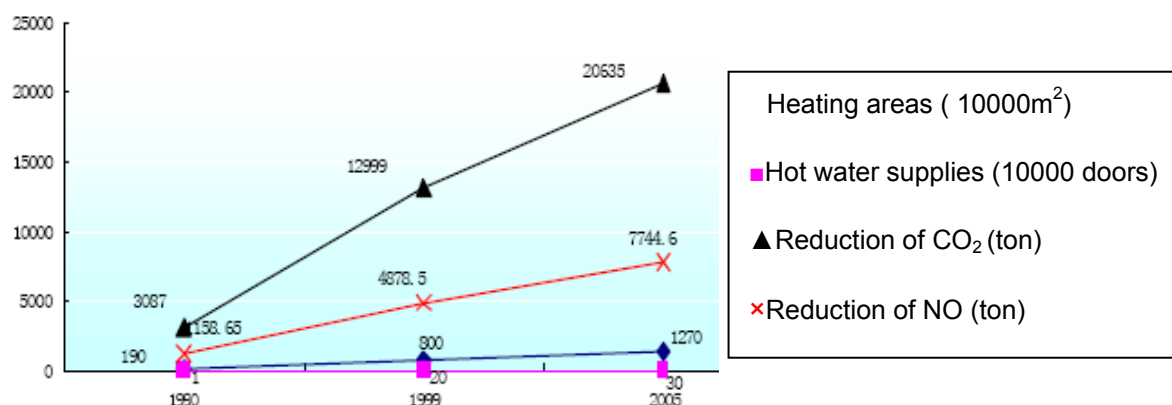
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### **1 INTRODUCTION**

#### **1.1 The History of Geothermal Uses in China**

China has long history of using geothermal energy. The total direct use geothermal energy in 2005 was 12604.6 GWh with 3687 MWt installed capacity, including 65.2% balneology, 18.0% space heating, 9.1% agriculture and aquaculture, and industrial applications, such as evaporating, drying, distillation, sterilization, washing, de-icing, salt-extraction, oil-recovery, milk pasteurization, leather industry, chemical extraction, etc. 7.7%.

Space heating concentrated in the northern cities, such as Tianjin, Beijing, Sian and Daqing, where 60-100°C hot water is pumped directly to the buildings. Figure 1 shows space heating and hot water supply with low-medium geothermal water and the reduction of CO<sub>2</sub> and NO in the years from 1990 to 2005. There were buildings of 1.9 million m<sup>2</sup> in 1990, 8 million m<sup>2</sup> in 1999, and 12.7 million m<sup>2</sup> in 2005 heated with 60-100 °C of underground geothermal water, a fast growth (CGSB 2006).



**Figure 1: Space heating and hot water supply with geothermal water and reduction of CO<sub>2</sub> and NO**

## 1.2 The Three Development Stages of Geothermal Source Heat Pump in China

### 1.2.1 The Start Stage from 1980s

Comparatively GSHPs were started quite late but developed rapidly, and now are booming in the whole China (Lv et al. 2007). In 1980s GSHP technology was caused attention firstly in some universities and academic institutes, whose research focused on GSHP system experimentally and theoretically, such as heat pump and refrigerant, soil thermal capacity and conductivity measurement and modeling, numerical simulation of instantaneous working condition, etc.

At the beginning of 1990s some scholars went abroad to America, Sweden, Germany and Canada investigating the application technology of GSHP, began with some experimentally practical projects. In 1996 two residential buildings of 50 000m<sup>2</sup> were installed with ground water heat pump by Shandong Fuerda Equipment Co. Ltd. in Liaoyang city of Liaoning province, which symbolized GSHP shared the commercial air-condition markets in China.

In November 1997, Chinese government started to collaborate on renewable energy under the Cooperation Agreement about Geothermal Production and Application signed by China Science and Technology Committee and America Energy Department. Then three companies were founded in Beijing, Shanghai and Guangzhou in 1998, and three GSHP systems with the entire building areas of 132 380 m<sup>2</sup> were installed as demonstration projects in each city in 1999, of which the Jiaheyuan International Apartment has the largest area of 88 000 m<sup>2</sup> (Zheng and Si 2005).

### 1.2.2 The Popularizing Stage between the Beginning of 21st Century to 2004

The GSHPs entered its popularizing stage; on the one hand it was developed and extended linger, on the other hand there were many obstacles to hinder its development. Up the end of 2003, except for Hongkong, Macao, Taiwan, Yunnan, Guizhou and Qinghai, GSHPs were installed as air-conditioner on various scales. The annually average number of patents on GSHP technology was 71.75 between 2000 and 2003, which was 4.9 times of that between 1999 and 1999; and the literature number on GSHP in 2003 was 5 times of that in 1999. The

Guidance of GSHP Engineering and Technology was translated in Chinese in 2001. However, the problems with GSHP showed up at this stage too, such as its relative high initial investment compared with other traditional heating systems, the unrecognized significance of its environmental protection and energy saving, the lack of experience, experts and specification, and one thing of more important there were no apparent incentive policies from the government(Zheng 2003).

### 1.2.2 The Booming Stage of Geothermal Source Heat Pump from 2005

From 2005 GSHP market turned its booming stage. Up to the end of 2007, there is more than 30 million m<sup>2</sup> building areas installed with GSHPs. The rapid growth of GSHP activities in China since 2004 is shown in Table 1, and the 8 toppest provinces and cities with more projects air-conditioned by GSHPs are listed in Table 2.

**Table 1; Comparison of GSHPs between 2006 and 2005, 2005 and 2004 in China**

	Growth of Project Number (%)	Growth of Building Area (%)	Increase of Investment (%)
2005 compared with 2004	190.91	218.71	180.36
2006 compared with 2005	121.43	136.81	182.06

**Table 2; The Eight Toppest Provinces and Cities with More Projects Air-Conditioned by GSHPs in China (2005-2006)**

Position	Province /City	Project Numbers	Areas (×10 <sup>4</sup> m <sup>2</sup> )	Position	Province /City	Project Numbers	Areas (×10 <sup>4</sup> m <sup>2</sup> )
1	Liaoning	42	113.58	5	Shanxi	14	89.21
2	Beijing	38	207.52	6	Hebei	12	18.29
3	Henan	34	27.6	7	Jiangsu	10	86.49
4	Shandong	18	31.38	8	Zhejiang	10	37.91

### 1.3 The Progress of Geothermal Source Heat Pump in China

With the booming of GSHP the technology of GSHP is developed in China greatly, which is demonstrated by its application in different kinds of buildings with various models. Besides Underground water and BHE, many other media were tried to be as the sources of heat pumps, which maximizes the resources uses according to local conditions.

#### 1.3.1 The Application of GSHPs for Different Buildings with Different Areas

The application of GSHPs includes about 31.30% of office buildings, 17.56% of residential buildings, 10.69% of hotels, 8.78% of commercial building, 4.96% of stations, 2.67% of industry building, 2.29% of villas 1.91% of sport buildings, 1.91% of schools, 0.76% of medical building, and 12.21% of other buildings including exhibition, entertainment areas. The projects with largest building areas changed frequently, now there are more than 10 projects with

building areas more than  $25 \times 10^4 \text{ m}^2$ , of which Beijing Jinhua Green Harbor Homestead is in the first position with  $63 \times 10^4 \text{ m}^2$ . Beijing Olympic Village has  $41.3 \times 10^4 \text{ m}^2$  to be air-conditioned with GSHP.

### 1.3.2 The Multi-Sources of Cooling/Heating and Their Hybrid for GSHPs

Taking underground water as sources for heat pump is relatively simple and with less initial investment; however, when some other factors are considered, GSHP with underground water may cause some problems, such as over consumption of ground water when it is not reinjected to the formation, the change of the hydrology, etc. Though GSHPs with underground water are still prominent forms, BHE and the other source heat pump are growing more rapidly in China. In the "China GSHP Technology Application Development Report"(Lv et al. 2007), there are 243 projects were surveyed statistically, including 119 projects of 48.9% with ground water, 94 projects of 38.68% with BHE, 21 projects of 8.64% with sea, sewage and other waste water and 9 projects with hybrid of different sources. The statistic area percents of different sources are compared with those in 2004 and listed in Table 3. From Table 3, it is concluded that the ratios of heat pumps with BHE and other sources are growing, which means the GSHP technology is being developed to meet different projects along with maximizing resource-saving and environment- protection.

**Table 3; the Area Percent of GSHPs with Different Sources Surveyed by Lv**

	<b>Ground Water %</b>	<b>BHE %</b>	<b>Other Sources (Surface Water, Sea Water, Sewage Water, Industrial Waste Water, etc.) %</b>	<b>Hybrid of Sources %</b>
2006	37.53	38.54	17.09	6.84
2004	65.06	30.12	4.82(Surface Water mainly)	

Table 3 shows some installed heat pumps with different cooling/heating sources, from which it is concluded that the effort to use local resources sufficiently can be observed.

**Table 4; the Representatives of Heat Pumps with Different Cooling/Heating Sources**

<b>Project</b>	<b>Cooling/Heating Source</b>	<b>Areas(<math>\times 10^4 \text{ m}^2</math>)</b>
Qingdao International Sailing Boat Medium Center	Sea Water	0.82
Nantong New City Residential Area in Jiangsu	Sewage	34
Tianjin Commercial Technique College	Discharged Geothermal Water	5
Niutoushan Water Works Construction Co.	Water from Reservoir	0.9
Aoruide Photo electricity Co. in Haerbin	Industry Waste Water	0.35
Sian Railway Bureau	Water from Fire Water	0.08
Railway Ferry of Yantai-Dalian in Dalian	BHE+Sea Water	0.9
Railway Ferry of Yantai-Dalian in Yantai	Sea Water+Underground Water	
Ningbo Sate Revenue Office	BHE+Fountain	2.5
Yongyou Software Garden	BHE+ Ice-Cold Storage	18.5
Contemporary Universal City	BHE Buried under Buildings	22

Owing to its energy-saving, environment-friendly competitive and to some extent its cost-effective advantages GSHP technology is recognized and accepted more broadly among the people and by the air-conditioning industry, therefore the governments are taking some measures such as incentive policies to encourage the development of GSHPs in China. This following shall introduce some typical projects executed mainly in Beijing, Shenyang.

## **2 BEIJING THE PIONEER CITY FOR GSHPs IN CHINA**

Beijing started with GSHP relatively earlier and now is taken as the pioneer city for GSHPs in China. Up to the end of 2007, there were 479 projects with 10.52 million m<sup>2</sup> building areas installed with GSHP in Beijing, and it is growing at a rate of 150% annually. Now Beijing is extending the application of GSHPs, and there will be more than 35 million m<sup>2</sup> building areas to be air-conditioned with GSHPs in 2010, which will take up about 6% of the total heating areas of Beijing according to the 11<sup>th</sup> Five-Year Plan. With the 35 million m<sup>2</sup> GSHPs, more than 800 000 ton coals shall be replaced, and the emission of more than 1 800 ton carbon monoxide, 36 ton hydrocarbon, and 300 ton nitrogen oxide, 1 350 ton sulfur dioxide and 800 ton dust shall be reduced. Beijing is now not only one of the biggest markets of GSHPs, but also a pilot city for GSHP technology with various sources for heat pumps, such as ground water with double-/multi-wells, single well for production and reinjection, sewage water, and ground-coupled or borehole heat exchanger (BHE); combining with other energy GSHPs provide air-conditioning environment for various kinds of buildings on different scales from more than 200 000 m<sup>2</sup> of high-class residential buildings, to some villas with areas of a few hundred square meters.

### **2.1 Borehole Heat Exchanger Combined with Ice-Cold Storage for Yongyou Software Garden**

This project was completed in February, 2007, which shall provide air-conditioning for 185 000 m<sup>2</sup> areas of Yongyou Software Garden located in Zhongguan Science and Technology Village. The cooling capability is 15 784kW, and heating plus hot-water supply is 13 391kW +1 722kW. It was designed first time to install borehole heat exchanger combined with ice-cold storage system in Beijing, which drilled 616 boreholes with 120 m depth in clay/medium sand formation. 41 million Yuan RMB was invested for this system and it is expected an operation fee of 17.6 Yuan pro square meter for heating and 14.2 Yuan pro square meter for cooling.



**Figure 2: Borehole Heat Exchanger Combined with Ice-Cold Storage for Yongyou Software Garden**

## **2.2 BHEs Buried under Buildings for Contemporary Universal City**

Beijing Contemporary Universal City is located in the northeast of Dongzhimen with total area of 1 hectare, building area of 222 000 m<sup>2</sup> and 55 000m<sup>2</sup> basement. As a landmark of high-class residential building complex which is more comfortable, healthier, and greener with more environmental protection and lower energy consumption, GSHP was taken as its priority of air-conditioning system. As we know that Dongzhimen belongs to inner city of Beijing, where on the one hand the hydrological conditions can not provide available water for ground water heat pump, on the other hand the building area is uttermost limited; therefore all 635 BHEs with double-U type tubes were buried to 100 meter depth, all of which were constructed under the buildings.

## **2.3 Sewage Water Heat Pump for Beijing Olympic Games in 2008**

To realize green Beijing Olympic Games in 2008, renewable energy, such as solar energy, wind energy and geothermal energy, was introduced to the constructions. Including Volleyball Center, Beijing University Gymnasium and Olympic Village there are 9 projects adopted geothermal, ground-coupled, ground water, and sewage water heat pump system. Recycled water from Qinghe sewage factory was used as water source for heat pumps installed in Olympic Village, saving electricity power about 15-20 % compared the traditional center air-conditioner system.

## **2.4 Nation Theater with Central Liquid State Cooling/Heating Sourced Environment**

In 2001 Ever Source Science and Technology Development Co. Ltd. claimed the patent for its Single Well Supply/Return Water Technology as an energy collection subsystem to collect and use the shallow ground geothermal energy with low temperature to provide heating, cooling and domestic hot water (Triple-Supply System) for buildings. The Single Well Supply/Return Water Technology can perfectly protect groundwater resource. A pond 35 000m<sup>2</sup> around Nation Theater was designed no freezing all-year, even in winter, which was installed with central liquid state cooling/heating sourced environment system.



**Figure 3; Nation Theater with Central Liquid State Cooling/Heating Sourced Environment System**

### **3 SHENYANG-THE DEMONSTRATION CITY FOR GEOTHERMAL SOURCE HEAT PUMP**

Shenyang is the capital of Liaoning province, a main industry city of northeast in China, where space heating time lasts one half a year from October 15 to April 15. Shenyang was famous for its seriously-polluted air before and greatly improved environment in China. Shenyang did not start its GSHP activities quite early but did all its best to spread its market, which was awarded as Demonstration City by China Construction Ministry in 2006 for its effort to popularize GSHPs in Shenyang.

In August of 2006 Shenyang authorized its Particular Blueprint for Geothermal Source Heat Pump Application in the Period of the 11<sup>th</sup> Five-Year in Shenyang and the Administration Measures for Construction and Operation of Geothermal Source Heat Pump System in Shenyang, based on the investigation on the GSHP technology and its application in the whole country in China. Both of them were issued as government orders, which demanded all buildings of within 455 km<sup>2</sup> areas of the third ring, shall be in principle installed with GSHPs, of which about 409 km<sup>2</sup> areas with suitable ground water and about 46 km<sup>2</sup> with BHE. Along with some favorable policies, such as charging electricity fee as civilian usage and no fee for water resource, were issued. Furthermore, some administrative organizations were established in city, district and county of government all levels. In December, 2006 the Associate of Geothermal Source Heat Pump and Expert Research Group were found in Shenyang, by which a series of scientific research projects were executed, such as edition of technical specification, reinjection of underground water, sedimentation, underground water environment survey, etc.

There was about 1.8 million m<sup>2</sup> space areas were heated by GSHP before 2004, 3.1 million m<sup>2</sup> in 2006, and now up to the end of 2007 18 million m<sup>2</sup>. According to the 11th Five-Year Plan there shall be 65 million m<sup>2</sup>, which takes up 32.5% of the total heating spaces in Shenyang.

### **4 THE GOVERNMENTAL POLICIES AND REGULATION FOR GSHP IN CHINA**

#### **4.1 The Governmental Policies to incent GSHP in China**

Chinese centre government and local governments issued many policies to encourage exploitation and utilization of renewable energy resources to meet the demand of energy saving and environment protection. In 2005 Chinese government called to establish a resource-saving and environment-friendly society, and set the goals to reduce energy consumption by 4%, and the emission by 2%. On the date of January 1, 2006, the Renewable Energy Law became effective in China, in which geothermal energy along with solar energy, wind energy and biomass energy shall be as renewable energy to be motivated by some favorable policies. In August, Ministry of Finance brought forward that the development of fuel-ethanol, bio-diesel oil, solar energy, wind energy and geothermal energy shall be supported intensively with the issue of „ Measures to Administrate the Particular Fund to Develop Renewable Energy“.

Cooperated with the state policies, the local governments stipulated some incentive mechanism for application of GSHPs. In May of 2006 the first policy “ The Instruction to the Guidance Opinion on the Development of Geothermal Source Heat Pump” was issued by Beijing Municipal Commission of Development and Reform jointly with Plan Commission, Construction Commission, Environment Protection Bureau, Water Bureau, Land and Resource Bureau, Scientific Commission, Finance Bureau, and Municipal Administration Commission, in which there is an incentive to install waste water, surface-underground water, and ground-coupled heat pumps. For the office buildings, such as, school, hospital, administration garden concerning the public interest, the government will provide the initial investment, for the others the government will provide subsidies with 35 Yuan RMB per m<sup>2</sup> for surface and underground water source heat pump, 50 Yuan RMB for ground-coupled and waste-water heat pump (Note, the exchange rate in May 2006 was about 8 Yuan RMB for 1 US \$).

For Beijing Olympic Games a series of favorable policies issued by Beijing government, in which geothermal energy is encouraged because of its broad flexibility and relatively mature technology.

In 2005, a city of Zhejiang province, Ningbo government came out with “ the Measures to Administrate the Particular Fund to Development Energy-Saving and Clean Production” to subsidize 20% of the total initial investment to install GSHP.

## **4.2 The Regulations and Specifications for GSHP in China**

### **4.2.1 Exploration Specification of Geothermal Resources ( GB 11615-89 )**

The criterion was effective out on the 1<sup>st</sup> June, 1990. It stipulates the research level of investigation on geothermal field, the style of investigation and the control of exploration engineering, the technology of investigation and quality requisition, geothermal reservoir's sort, classification, calculation and evaluation, assessment on geothermal heat flow and environmental influence, the basic requisitions of arranging investigation documents and editing report.

### **4.2.2 Technical Specification for Ground-Source Heat Pump System ( GB50366-2005 )**

The criterion was the first Specification for GSHP system, which was effective on the 1<sup>st</sup> January, 2006. It was formulated for the design, construction and check of GSHP system to make technology advanced, economy reasonable, security ensured, quality guaranteed. It was fit for designing, constructing, checking the systems, whose low temperature heat sources with rock and soil, groundwater, surface water, and the conductive mediums with pure water solution or added antifreezes, adopt heat pump technology to supplying heating, cooling and heating water.



#### **4.2.3 Technical Regulations for Shallow Geothermal Energy Investigation and Evaluation**

It will be the first professional code for exploitation of shallow geothermal energy, and now have finished the second draft. In this draft, it defines the concepts and jargons related shallow geothermal energy, brings up the calculating and evaluating method of shallow geothermal energy resource firstly and systematically, orders the investigation of regional shallow geothermal energy and the exploring work's purpose, task, content, control and quality. This code will be published in a short term.

In August 2006 Beijing Land and Resource Bureau issued a provision to regulate the GSHP installation, in which it is required to apply for permission from the Beijing Land and Resource Bureau by providing the corresponding geological, hydrological and geothermal investigation report in advance.

Besides these, there are some other criterions, such as Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ134-2001), Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Warm Winter Zone ( JGJ75-2003) , Code for Design of Heating Ventilation and Air Conditioning (GB50019-2003) , Design Standard for Energy Efficiency of Public Buildings (GB50189-2005) , Design and Construction for Cooling and Heating Source Room of Ground-Source Heat Pump System ( 06R115 ) ,etc.

## **5 THE SUSTAINABLE DEVELOPMENT OF GSHP IN CHINA**

GSHPs have many advantages to be the first choice for heating, cooling and hot water supplying, anywhere. In additions its application in cities, GSHP shall play significant roles in areas where there is lack of conventional fossil energy, where the environment is relative fragile and the residents are rare and scattered, and so on. For its sustainable development some suggestions are listed as follows:

**The Policies and Specifications issued by the Governments.** The technology and efficiency of GSHPs are still to be developed and improved, and the government will play significant roles to encourage and sustain GSHPs in many aspects by favorable policies and specifications, such as to support the research project as well as the installation, to regulate the development markets, and to qualify the companies and their technical engineers, etc.

**The High Efficiency of GSHPs with Suitable Sources and Reasonable Design.** The geological and hydrological conditions should be considered to install GSHPs to avoid groundwater overexploitation and significant environmental disturbance. The utilization of water resource should be on the base of reasonable exploitation considering problems induced by over-development of ground water. Chinese government has enacted some laws

and regulations about groundwater which shall be followed strictly to avoid water resource pollution and geological calamity. Reinjection technology shall be investigated and adopted for ground water heat pump.

**The Balance of Borehole Heat Exchanger.** It holds the opinion that shallow geothermal energy is infinite because it is supplied by sun. Actually, it is not correct. Many projects exist that the heating loads are not equal to cooling loads, which means that the energy which extracted from ground is not equal to the energy which discharged to ground. For a long period of time, it not only influences the effect of GSHP system, but also leads heat pollution. The Investigation and assessment of shallow geothermal energy shall be done to sustain the development of GSHPs in China.

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