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# Growth of the Use of Geothermal Heat Pumps in China

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## ABSTRACT

Although Chinese researchers had studied and tested heat pumps since the 1960s, there were no practical applications at that time due to the lack of electric power even for civil lighting. Around the period entering the 21st Century, by learning from world's experience, geothermal heat pumps (GHP) started to be used experimentally in the country. In the recent 5 years, based on their superiority for saving energy and reducing $CO_2$ emission, the GHP is supported and proposed by governments and leaderships to gain flying growth. The total area of GHP engineering application was 7.67 million $m^2$ in 2004 but reached 20.35 million $m^2$ in 2006, and its annual increase was about 20 million $m^2$ in following years. Installed capacity grew from 383MWt in 2004 to 5,210MWt in 2009. It has increased by more than 10 times during the past 5 years. A batch of momentous GHP projects gained financial support from the Ministry of Construction and Ministry of Finance. A series of GHP applications were installed in many game halls and stadiums for the 2008 Beijing Olympic Games. China has drawn up the National Standard for GHP application. Manufacturers of heat pumps and auxiliary attachments have been growing. Design and construction companies have been going up as nuclear fission. In universities and institutes, various research projects have been undertaken continuously, such as further raising COP, trials of a high temperature heat pump and absorption-type heat pump, attempting multisource combination (e.g. GHP + solar) etc.

## 1. INTRODUCTION

Heat pump research and application was started by some professors in Tianjin University and Tsinghua University in the 1960s[1]. Tests were carried out in the laboratory and a few engineering sites. There was no condition for practical application due to lack of electricity even for civil lighting at that time.

Since the 1990s, the rapid growth of GHP in the world[2,3], brought the application in China too. A few students returning from abroad created GHP companies. With a few foreign companies they carried out some GHP projects in the cities of Beijing, Liaoyang, Jinan, Ningbo etc.. These pilot projects served as demonstrations to promote progressively further growth of GHP in the country. A few developers also created GHP manufacturers to produce nationally made heat pump products. When entering the 21st century, under the position of energy saving and emission reducing, national preferential policy supported further growth of GHP. To date, the annual increasing rate is still higher than 30%. It is rather higher than the average rate of increase in the world[3,4].

The requirement of the project market brought the manufacturers and sellers. It also attracted foreign companies to sell their products in China. In addition, huge demand of pipes and accessory products were produced in the country. And various ranks of design and construction were expanded very quickly. A burgeoning GHP trade was thus formed in a short period.

## 2. BURGEONING TRADE OF THE 21ST CENTURY

Such a burgeoning GHP trade consists of several main factors as described in the following sections.

### 2.1 Rapid Growth of GHP Project Application

The earliest GHP projects were started in Beijing at the end of the 20th Century[1]. Then some pilot projects were carried out in the cities of Liaoyang, Jinan and Ningbo etc.. Beijing has been showing the demonstration application in various buildings such as government, hospitals, schools and apartments etc.. In 2004 Beijing occupied more than half of the total project area of 7.67 million $m^2$ in the country. The sum of projects reached 369 with total heating (partially cooling together) area of 7.38 million $m^2$ in Beijing in 2006. Beijing has been keeping an annual increase of 3 to 5 million $m^2$. But since 2007 Shenyang has taken first place in China (Fig. 1). Shenyang completed 109 projects with 3.12 million $m^2$ up to 2006. A new 15.00 million $m^2$ and 17.37 million $m^2$ were completed in 2007 and 2008 there respectively. In 2008 the total GHP heating area reached 35.85 million $m^2$ in the city. This number is 18% of the total heating building area in the city. It is equivalent to a heat power of 1,790 MWt. Shenyang has programmed that a further 18.77 million $m^2$ would be implemented using GHP in 2009. So it will complete a total of 54.62 million $m^2$ of GHP building heating. This would be 27% of the total heating building area in the city.

In the country as a whole, the increased GHP heating area is 20-23 million $m^2$ annually in recent years. In 2008 the sum of GHP heating area had reached 62 million $m^2$ of building area with about 3,100 MWt of heat power. In 2009 it will reach 100.7 million $m^2$ of building area with about 5,210 MWt of heat power (Fig. 2). Since GHP has substituted traditional coal boiler heating in such a proportion, the good atmosphere had reached 330 days in Shenyang in 2008. The previous heavy industrial city has created a new way for environmental protection by using clean energy.

### 2.2 Establishing of Enterprises of GHP Products

Around the period entering the 21st century some advanced enterprisers have foreseen a great potential of GHP. Shandong Fureda Company had commenced the earliest production of heat pump (using imported compressor) in China. In the recent 10 years, such manufacturer has grown by a factor of over 200[5]. They distribute in Shandong, Beijing, Shenzhen, Dalian, Hangzhou, Suzhou and Guangzhou etc.. The nationally made product is mainly the large water-water system unit. Most of units are screw-type compressor plus tube-type heat exchanger, but also eddy-type compressor plus plate-type heat exchanger. Big units have power of 2,000-3,000 kWt, but there is also a small unit for home use which is less than 10 kWt. Besides the

main unit manufacturers there are more than 100 plants to produce related auxiliary attachments and PE tubes etc..

In addition, some famous foreign companies have progressively established their production bases or joint venture enterprises in China.

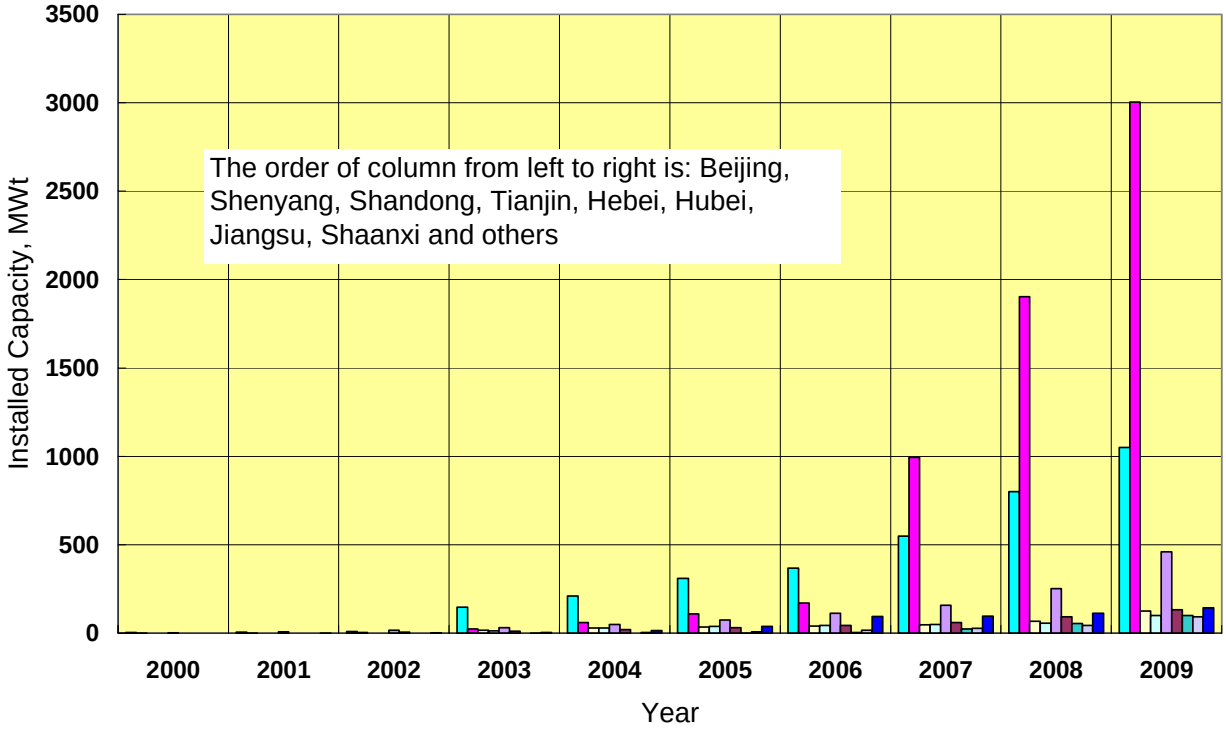


**Fig. 1 Growth of GHP in Different Regions in China**

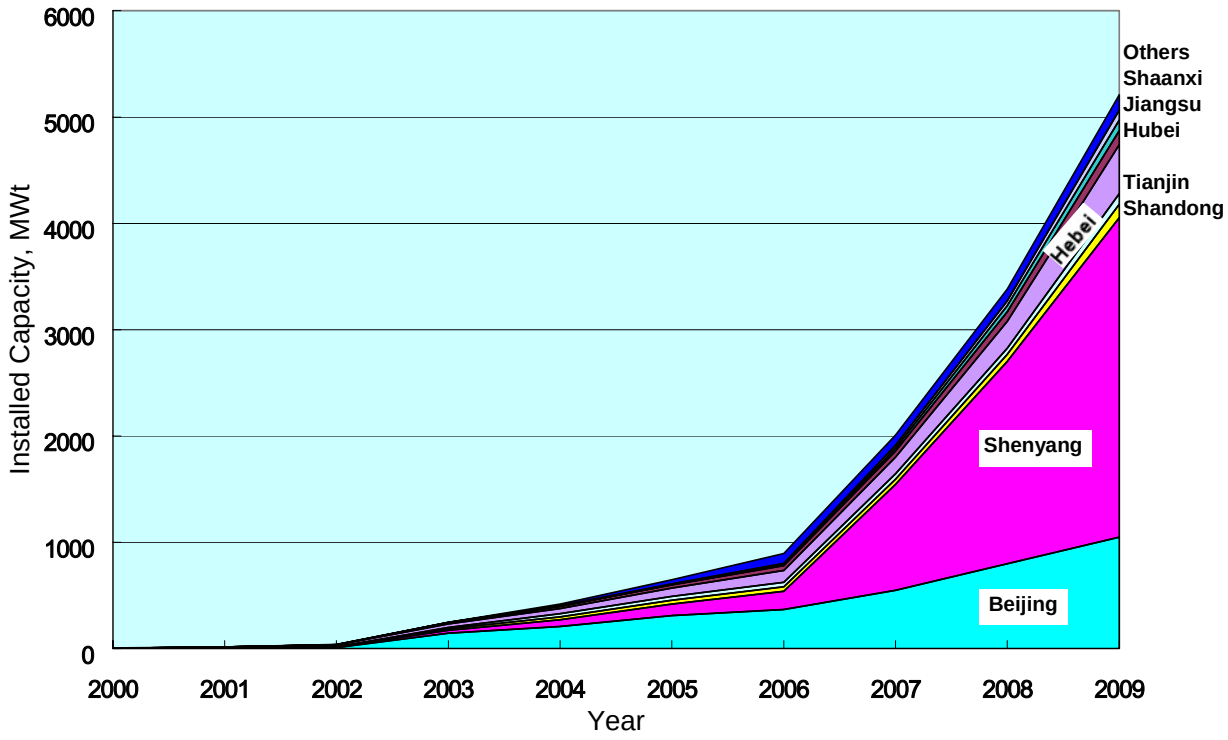


**Fig. 2 Growth of Geothermal Heat Pump in China**

### 2.3 Expansion of Design and Construction Companies

Along with greater demand of GHP project market, the design and construction companies have expanded rapidly. Many new companies have been founded in recent years. The total ranks of the trade include over 100,000 people.

### 2.4 Activity of the Trade Combines and the Medium

Several national and local GHP trade combines have been founded within the recent 5 years. Several websites and journals related to GHP have been established. These represent the foundation of GHP as a new trade.

## 3. TRADE GROWTH BASED ON THE POSITION OF ENERGY SAVING AND EMISSION REDUCTION

"The Law of Energy Saving" was implemented in 2008 in China. Along with continuous growth of social economy and GDP, we could not increase energy consumption without limitation in China. The China Academy of Engineering hosted a research project "China medium-long term strategy of energy development". It concluded that the annual energy consumption had to be restricted to 4,000 million tons of standard coal. Development of renewable energy has to be accelerated. Its strategy should be as follows. Non-hydraulic renewable energy will be supplemental energy (2% of total energy consumption) before 2010; it will transfer into an alternative energy (5-10% of total energy consumption) in 2020; then become one of mainstream source of energy (10-19% of total energy consumption) in 2030 and one of the leading forms of energy (17-34% of total energy consumption) in 2050[6].

GHP has the highest coefficient of performance (COP), as high as 3-4. It is rather higher than air-conditioning (1.8-2), electric heating (1), oil boiler (0.9) and coal boiler (0.6) (Fig. 3). Therefore, its efficiency of energy saving is most significant. GHP will extract heat from groundwater or soil with common temperature at 2-3 kWt for an electrical input of only 1 kW. GHP does not emit $CO_2$ itself. If we include the $CO_2$ emission from electricity generated by a coal-fired power plant, the $CO_2$ emission of GHP will be still be smallest. As an obvious example, GHP created 330 days of good atmosphere in Shenyang, but there were only 274 days of good atmosphere in Beijing in 2008.

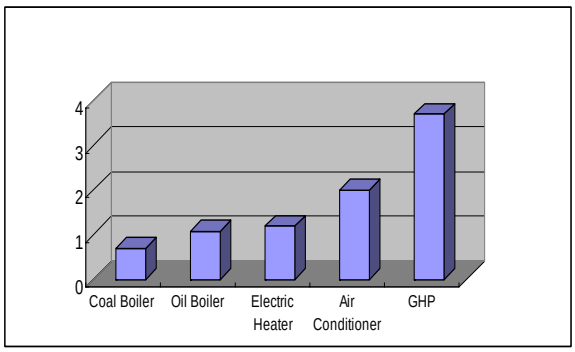


**Fig. 3 A Comparison of the COP for Various Heating Methods**

Market needs effective products and projects for energy saving and emission reduction, GHP is very ideal option. International authorities have forecasted the trend of GHP growth. Although its increase rate will decrease progressively, but the general trend will still be a steep rising curve.

## 4. DEMONSTRATION OF GHP APPLICATION IN BEIJING OLYMPIC GAMES

In order to fulfill the promise of the Green Olympics, renewable energy was partially used in the 29th Olympic Games in Beijing. It equalled about 26% of the total energy consumption. A series of GHP were used in many main stadiums and gymnastics halls.

We see an example for #2 game hall in the Olympic tennis courts located in Beijing Olympic Forest Park. GHP was used for summer cooling and winter space heating. 35 holes were drilled to 100 m depth with diameter ϕ150mm. They are in a 7m × 7m layout. Double U pipes of PE material were installed in the holes for heat exchange. The GHP unit has 138.2 kW heating capacity (input power 37.5 kW) and 139.6 kW cooling capacity (input power 32 kW). The Olympic National Stadium (Bird's Nest) drilled 140 holes each with a depth of 80-100 m as heat exchangers for summer cooling and winter space heating use. GHP were used also in the National Swimming Center, Olympic Gymnastics Hall and Olympic Badminton Hall.

In order to ensure the Olympic security absolutely, GHP was used partially in Olympic projects. Various companies attended the bidding competition. Some foreign companies, experts and engineers took part in these projects. In virtue of Olympic Games, GHP helped propagandize the great efficacy of renewable energy. These strong demonstrations have a domino effect.

## 5. ANALYSIS OF EXISTING PROBLEMS

Along with the rapid growth of GHP market and the fast expansion of GHP trade, it is inevitable that something wrong occurred.

### 5.1 A Few Weak Design and Construction Teams

Accompanying the great GHP market demand, the initial design institutes and construction teams had insufficient ability to bear such huge tasks. The big lack of market required new companies to be involved in the work. For example, there were about 10 related companies in Shenyang in 2005. But they grew into more than 70 companies in 2007. New bosses came from various businesses including some who had sold wine before. Some of the new companies employed professional experts and engineers, trained their staffs, and they performed well. However, a few companies won jobs by lower bidding, but they had no qualification or experience. Especially for construction teams, about half of the workers had no qualification, the others are air-conditioning and building construction workers with only a few who had worked on GHP before. We could not say there would be no latent defect for these projects.

### 5.2 Improper Matching between Surface and Subsurface Parts of GHP System

Some problematic projects have been found. The problem is mainly caused due to improper matching between surface and subsurface parts of the GHP system. It is usual that heat pump manufacturers or selling agencies design the GHP system with less experience in hydrogeology. They asked help to understand the hydrogeological conditions, or carried out thermal response test at the beginning. But later on they claim to "have understanding" and used improper hydrogeological and thermal response parameters in their design. In addition, hydrogeological engineers also used their small experience to design surface GHP systems. Such errors have been improved in authorized companies and

enterprises. But it still exists in some new companies and enterprises.

### 5.3 Weak Thermal Response Test and Modeling Prediction

Sweden owns the most GHP projects in the world. Overall, completed GHP projects have been running successfully in Sweden. Thermal response test has to be carried out at the project site. Then modeling prediction will confirm the design or adjust it. Such steps are important but this process is weak in China. Site thermal response test was carried out in only a few projects. Modeling calculation is usually lacking. Most of projects rely on past experience to draw the design.

## 6. NEW RESEARCH AND EXPLORING

In order to promote further GHP growth in China, we should make efforts for normalization of market, increase efficiency and decrease cost. These need new research and exploration.

### 6.1 Persist in Qualification of License in GHP Market

National standard "Technical Code of GHP System" GB50366-2005 has been put into effect in 2006. It has stipulated that engineering exploration should be carried out by qualified professional teams, indoor system design and installation should accord with existing national standard. Several professional trainings have been undertaken in Beijing. Professional license and further countermeasures are still necessary.

### 6.2 Research and Implementation of Compounded Pattern Systems

GHP has advantages in energy saving. Its coefficient of performance (COP) for heating and cooling can usually reach 3 and 4.5 respectively. However, this is a theoretical value. In practical engineering projects many compounded pattern of systems can be used. If so, the GHP actual COP will be able to increase significantly. It will make brighter prospects for GHP.

(1) Using GHP as basic load, plus other energy for example peak boiler as adjustment, will save total electrical consumption significantly.

(2) Using electrovalence discrepancy of peak electric and valley electric consumption periods, making storage of ice or heat when lowest electrovalence at valley electric consumption periods, will save the payout of electrovalence significantly.

### 6.3 Considering Multisource Methods to Reduce Comprehensive Cost

There is higher initial investment cost for GHP. Application on a large scale is really a burden. Cost reduction can be considered in every link in the system chain, including heat pump production, equipment installation, subsurface exploration, thermal response test and modeling. However, we are missing the factor usually for improvement of building capability of heat insulation. By German study it could reach an energy saving of 27-76%, thus the comprehensive cost will reduce 17-38%. This should be our direction in future.

## ACKNOWLEDGEMENT

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