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The Feasibility and Technology to Develop the Chinese Potential Market of Geothermal Source Heat Pump Systems

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Key words
Geothermal heat pump, space heating, air conditioning, China

ABSTRACT
To meet the ever-increasing demand for energy and appeal for environmental protection, geothermal energy is playing an increasing important role in China. As the fastest growing segment, geothermal source heat pump (GSHP) system is quite a promising area in direct use of geothermal energy nationwide in China. This paper analyses the feasibility and the technologies to develop GSHP systems economically and environmentally in China, from which it was concluded that GSHP systems will have widespread use in China. As the GSHP system is still quite new for China, it is important to develop more advanced techniques, as well as to do some basic research; such as on the geology, climate and topography, in addition to applied research, including the standardization of GSHP systems and preparation of manuals. Finally it is pointed out that international collaboration will promote the development of the GSHP system market in China.

Introduction
Under the circumstances of rapid growth in the economy, the energy industry in China faces two challenges from economic growth and environmental protection. On one hand China is facing an increasing demand for energy to ensure rapid economic growth, with 40% of oil consumed in China coming from imports, and expected to increase to more than 50% of the total oil consumption by 2020. Even if the country's Gross Domestic Product growth is kept to 5%, the so called energy bottleneck will be seriously worsened. On the other hand, China is suffering from major energy-related environmental problems. According to a report by the World Health Organization (WHO), seven of the world's ten most polluted cities are in China; one in four deaths in the country is due to lung disease, potentially caused by or certainly exacerbated by pollution. The CO₂ emission in China is second in the world following the USA with 740.38 million metric tonnes of CO₂ emission in 1998, and from 1990 to 1996, the increased volume of CO₂ emission constituted 90% of that total volume of the entire world (Zhang, 2000).

To improve the energy consumption structure by exploring new energy resources such as from geothermal, solar, bio-energy and wind to reduce the use of traditional energy resources like coal, gas and oil, it will be necessary to ensure the sustainable development of renewable energy.

Geothermal is playing an increasing important role in the energy industry. China is rich in geothermal resources and has a long history of its use. High temperature (>150 °C) resources, mainly concentrated in Tibet, Tengchong and Taiwan, are used for power generation, whereas low and medium temperatures (<90 °C and 90-150°C) are used for space heating, industrial processing, agriculture, aquaculture, bathing and spas. China has, of all countries, the largest figure of installed geothermal capacity for direct use in the world. In 1999, the total flow rate of thermal water amounted to 64,416 kg/s, which provided the thermal power of 16,209 MWt and thermal energy of 162,009 TJ/yr (Wang, 2002).

Geothermal resource heat pump system is a relatively new technology in application for geothermal space heating and/or air-conditioning. It represents the fastest growing segment of geothermal energy utilization (Lund, 2002), and is quite a promising area in direct use of geothermal energy nationwide in China.

The Feasibility or Incentives to Develop GSHP System in China
The economic, environmental and technical factors that affect the utilization of GSHP in China can be described as follows:
• GSHP systems can provide heating and cooling with higher efficiency, compared to boiler heating systems, using electricity or fossil fuel, which can transfer 90% or 70-90% electricity or fuel energy to heat (Zhao and Li, 2000). GSHP systems can also save more than two-third of the electricity or other fuel sources. The temperature below 5-10 m depth in most areas of China is stable at that level with average temperature
pipe patterns, in series, in parallel and slinky as closed systems, scaling, clogging and corrosion. Open systems tend to be used for cooling demands, etc.

The climate, too hot and the geology upon well costs. Water is good, e.g. low iron content, and to avoid problems with technological problems to technological problems to...

- GSHP systems come in different types and sizes, and are installed in a decentralized manner, providing flexible needs for heating. The size of individual units can vary from a few to over a hundred kW, which are more suitable for China, where different types and sizes of GSHP systems provide different demands in different regions. To satisfy Beijing's needs for heating, cooling and domestic hot water, GSHP can be installed for both residential and commercial uses. One of the most important advantages of GSHP systems is that these systems can contribute more environment protection than fossil energy conventionally consumed in Beijing, which is significant also for the 2008 Olympic venue. The western regions of China have many different characteristics from the eastern regions, e.g. relatively undeveloped and undisturbed environment, with a shortage of energy. As environment friendly systems, GSHP will play an increasing important role in the development of the western regions.

- GSHP systems require small areas to install with low operating and maintenance costs, and geothermal energy has no transportation risks.

- GSHP systems are more environmental friendly. The GSHP systems operate emission free and help to reduce greenhouse gas emissions like CO₂.

- In terms of cost analysis of lifecycle, GSHP systems are relatively cost-effective.

The Technologies to Promote the Development of GSHP Systems in China

GSHP is quite new in China. To promote the GSHP market in China, there are still a number of technological problems to be solved.

Generally, GSHPs are composed of different systems, which should be chosen in accordance with the local parameters, such as the climate, topography, and the geology and hydrogeology of the underground. In addition, the area and utilization on the surface, existence of potential heat sources like mines, the heating and cooling demands, etc.

In some regions, installation of open or groundwater systems should have the priority to be considered. These sites with suitable aquifers, which has sufficient permeability to allow production of the desired amount of ground water, and the quality of the groundwater is good, e.g. low iron content, and to avoid problems with scaling, clogging and corrosion. Open systems tend to be used for larger installations and the cost is comparably low depending upon well costs.

The horizontal ground heat exchangers, with different type of pipe patterns, in series, in parallel and slinky as closed systems, are easiest to install. These systems need relatively larger surface areas.

The vertical ground heat exchanger can provide sufficient heat exchange capacity under a confined surface area. Thus, it is more widely favored. The design of a vertical ground heat exchanger is depended on the type of underground (soil, rock and water). The thermal properties of the underground are the key to the design of the vertical ground heat exchanger. For small systems the design is relatively simple. In Europe, below 30 kW, a table of values and a nomogram is proposed (Reuss, 2001), and there are also rules of thumb that can often be used for the initial planning and cost estimate in the U.S. (Lund, 2001). Larger installations are typically more complex and require more sophisticated methods like computer simulation. Now there are some programs, such as EED – Earth Energy Designer, developed and used mainly in Europe, GchpCalc Geothermal Heat Pump Design Software for Commercial Buildings, from Stephen Kavanagh in the U.S. (Lund, 2001).

Some unusual systems with geostructures such as foundation piles or supporting walls equipped with heat exchanger tubes can be taken as a special case of vertical closed systems (Rybach, 2002). Additionally, the water from mines and tunnels, hybrid system, standing column well and underground thermal energy storage, can also be considered as efficient systems suitable to different regions or sites to provide heating or cooling in China.

To install GSHP efficiently the design of the GSHP should be studied thoroughly, including the research of local basic conditions and the thermal conductivity between borehole heat exchanger and surrounding formations. Good local basic research is important, to include climate, topography, geology, as well as the distribution of a) subsurface temperature, b) geothermal gradients, c) soil thermal conductivity, and d) groundwater flow conditions. All this kind of research has been done in Europe or in the USA, whereas in China the technologies and instruments to determine the local basic conditions should be conducted. The variety of geological formations and properties that affect thermal performance must be investigated, and a database of the formations built. Meanwhile the thermal conductivity model of the thermal properties should be established, and with the aids of a computer the conduction of heat between the fluids flowing in the tubes of the heat exchanger can be calculated more exactly.

In the market investigation, including economical, environmental and potential comparison, the most important factor is the cost of GSHPs. Cost performance evaluation should be the first step to introduce GSHPs in China. Only when GSHPs are cost-effective and competitive to other heating systems, can GSHPs be accepted, especially when used for the decentralized individual needs in China. Results from Europe, USA, and Japan indicate that GSHPs are cost-effective and competitive compared to other heating systems. It is more important to do cost performance evaluation based on the conditions of China.

Heat pump selection, loop design and pumping are also a new technology in China. The material of the heat exchanger (U-tube), circulating fluids and grouting material to fill the void between the U-tube and the borehole etc. should also be studied.

For widespread utilization, standardization of GSHP systems and preparation of manuals are important to understand this system for designers, system builders, and the users.

(5 to 25°C) during the year, with which GSHP systems can provide from 3.3 to 4.5 seasonal performance factor, i.e. for each kWh of heating output, only 0.22-0.30 kWh of electricity are required to operate the system. This is higher than air source heat pump systems by up to 40%, and the operation cost, is only about 50-60% of that of central air conditioner system.

Zheng
The Current Situation and the Prospect of GSHP Systems in China

From 1950s China has begun to study heat pump at Tianjin University, Chongqing Architecture University and Tianjin Business University. By 1999 there were about 100 sets of geothermal source heat pumps (water source heat pumps), most of which were open system. In recent years geothermal heating is being developed rapidly because of the success of the application for the 2008 Olympic Games in Beijing. According to Beijing Technical Institute of Geological Investigation, at present in Beijing, there is more than 100,000m² of space heating being provided by geothermal heat pumps. Beijing Ever Source Science & Technology Development Co.Ltd. has developed the Central Liquid State Cooling & Heating Source systems. There are also some projects of vertical borehole heat exchanger built in China, separately by Chongqing University, Shandong Architectural Engineering College, and Changchun Geothermal Energy Ltd. Presently, there are some new buildings being planned for installation with GSHP systems.

The International Collaboration will be the Most Efficient Way to Develop GSHP Systems in China

The USA and some European Countries have developed GSHPs for many years. Thus, they have a mature technique and rich experience which can help China to develop the GSHPs market. This can benefit the world environment because of reduction of greenhouse gas emission like CO₂. The international collaboration will promote the widespread utilization of GSHP in China.

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