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Development of Geothermal Energy in Chinese Market

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ABSTRACT

Energy shortages have become a major issue in many parts of China since 2003. Frequent use of air conditioners makes power shortages more severe in urban areas. Geothermal energy sources as one kind of sustainable energy are of growing importance in China and have large potential, both for electric power production and for heating and cooling purposes. This paper describes the current situation of energy shortage in China, the national geothermal resource and application, the U.S based heat pump demonstration projects and other international cooperation in China, the geothermal energy market, potential and development policy in China. Although China will rely on coal in the long term, it is reasonable to use geothermal energy to fuel the economic growth especially in coastal regions where coal is not available locally, and to reduce the pollution caused by burning coal. The possibilities of cooperation on project feasibility studies, technical design and training, also the direct investment projects in China and expansion of European products in the Chinese market have been discussed.

1. INTRODUCTION

Recently energy shortage and climate change became more and more important for the world economy and social sustainable development. The energy demand in China, the second biggest country for both energy production and consumption, is continuously increasing. Power shortages have become a major issue in many parts of China since 2003. During the current period of fast industrialization, urbanization, and economic development at an excessive rate, the energy efficiency in China is generally low. Increasing demand for electrical power for heating in winter and cooling off constant high temperatures, as well as the frequent use of air-conditioners make the power shortages extremely severe. The energy consumed for heating or cooling purposes in mega-cities such as Beijing and Shanghai is almost up to 50 % of the total. In China there is an inadequate construction of power resources, too, both in urban and rural areas. Meanwhile in China's rural areas, there are 7 million families, more than 10 million of population still live without electricity. About 600 million tons of SCE of energy are consumed every year, half of them from the burning of stalks and trees, which contributes to the deterioration of the natural environment and the acceleration of the land desertification process.

Sustainable energy consumption systems reduce greenhouse gases and pollutant emissions (Kyoto), increase the security of energy supplies, improve energy efficiency and increase the use of renewable energy, as well as they enhance the competitiveness of industry and improve the quality of life globally (Johannesburg follow-up).

Geothermal energy as one traditional clean, green, and renewable energy combined with modern technologies has a great chance to meet the requirements of energy security and to improve the development of a social economy and ecological environment. With fast economic growth and increasing environmental concerns, the development of geothermal energy in China will continuously increase.

2. GEOTHERMAL ENERGY RESOURCES IN CHINA

It is known that geothermal resources are available in each province in China. According to National Standard of Geological Survey of Geothermal Resources GB11615-89, traditional geothermal resources are classified according to their temperature (Table 1):

Table 1 Temperature division of geothermal resources

Geothermal resources	Temperature (ºC)	
High temperature	T = 150	
Medium temperature	T 90 = 150	
Low temperature	Hot water	T 60 = 90
	Warm – hot water	T 40 = 60
	Warm water	T 25 = 40

Based on the data of 738 geothermal sites, collected by the former Ministry of Geology in 1996, the average temperature amounts to 55.5 ºC. The total dissolved solids (TDS) of 493 samples show that 91 % of the geothermal water has TDS below 3 g/L; the distribution is presented in Table 2:

Table 2 TDS division of geothermal water in China

TDS (g/L)	<1.0	1-3	3-5	>5	Total
Number	327	124	16	26	493
%	66.3	25.2	3.2	5.3	100

The China Geological Survey, Department of Hydrogeology and Environmental Geology, assessed the geothermal energy content in mountainous regions for geothermal sources as thermal springs and wells with water temperatures higher than 25 ºC and in plain areas with geothermal gradients of more than 3 ºC /100m and depths less than 2000 m. The main results of the geothermal water energy assessment in 2006 are as follows:

- heat storage in the main sediment basins: 73.61 x 10^{21} J, equivalent to 2,500 x 10^{8} t standard coal;

- nationwide available geothermal water resources: 68 x 10^8 m^3/a, containing heat energy of 963 x 10^{15} J/a, equivalent to 3,284 x 10^4 tons of standard coal per year, which include

- convection type geothermal water resources in mountainous regions: 19 x 10^8 m^3/a (28 % of total), containing heat energy of 335 x 10^{15} J/a (35 % of total), equivalent to 1,142 x 10^4 t standard coal per year,

- conduction type geothermal water resources in the plain areas: 49 x 10^8 m^3/a (72 % of total), containing heat energy of 628 x 10^{15} J/a (65% of total), equivalent to 2,142 x 10^4 t standard coal per year.

Depending on the assessment methods and other reasons, the above estimated values are only part of the total amount of available geothermal energy in China.

3. GEOTHERMAL UTILIZATION IN CHINA

3.1 History of geothermal utilization in China

In China geothermal resources have been used since more than 2000 years; hot springs for space heating and for the treatment of disease since the Ming Dynasty. In the 1950s more than 160 hot springs were used for health reasons. The survey of geothermal resources started during the early 1970s. Geothermal water of 40 - 90 ºC has been exploited by wells of about 1,000 m depth in the areas of Tianjin and Beijing. Following the experiences of geothermal water utilization in these areas, the national geothermal survey and resource development came to a new stage.

Since the 1980s, the utilization of geothermal resources in China has been developed quickly, scientific research and geothermal field survey took place, resource assessment, including the distribution and formation of geothermal anomalies, as well as the development conditions have been investigated, and international cooperation and scientific information exchange have been enhanced, too. Different kinds of geothermal application supported local economic development. Especially after the 1990s, the utilization of geothermal resources developed more quickly, e.g., with the deepest geothermal well of more than 4,000 m.

3.2 Current situation of geothermal energy use in China

At present, geothermal energy is extensively exploited in China. According to the statistics of the Geothermal Department of China Energy Institute, the direct use of geothermal energy volume up to 12,604.6 GWh and the installed capacity has reached 3,687 MW_t in 2005, ranking No. 1 and No. 3 in the world.

3.2.1. High temperature geothermal resources for power generation

Presently, deep geothermal energy is used in China mainly for power generation. There are nearly one hundred of high temperature geothermal systems with hundreds of hot springs in China, most of them are concentrated along the Himalayan Belt, passing through southern Tibet, western Sichuan and Yunnan, and turning southwards through Fujian Province and Taiwan. The Chinese part of the Belt extends with more than 2,800 km length and 200 - 400 km width. Deep wells exploiting high temperature sources produce steam that is used to generate electricity at several geothermal sites in Tibet, Guangdong and Hunan provinces. One of the most productive geothermal fields was found in Yangbajin, located 94 km northwest of Lhasa, the capital of Tibet Autonomous Region, with a geothermal fluid temperature of 329.8 °C at a depth of 2,007 m. As the largest Geothermal Power Plant in China since 1979, this plant has a peak capacity of 25.18 MW_e, generated in 1999 by nine single flash, double flash and hybrid cycle power plants providing about 40 % of the electricity for the Lhasa grid by using 1,095 x 10^7 m^3/a steam of 130 - 170 °C. At the same time China's aggregate capacity is approximately 32.08 MW_e, generating 100 GWh annually.

The development of geothermal power generation has been relatively slow owing to the large hydroelectric resources in those provinces. Small hydraulic power stations (10 - 20 MW_t) are more welcome in Tibet and Yunnan Province because of the lower costs. But during dry seasons geothermal or solar energy is needed complementary. In Yunnan Province another geothermal power generation project is underway, drilling in the Hot Sea geothermal field located near Tengchong.

3.2.2. Direct utilization of medium and low temperature geothermal energy resources

Direct utilization of medium and low temperature geothermal energy resources is widespread in China for heating (Table 3), medical care and health (126 sites), scouring bath and tourism holiday centers (>200 sites), breed aquatics (in 20 provinces, water area 445 x $10^4 m^2$), aquiculture green house farming (133 x 10^4 m^2) and irrigation. Selected industries (textile, printing, drying, etc.) and mineral water producer (about 50 sites, water TDS < 0.6 g/l, t < 50 °C) use thermal water, too. According to statistics about the use of geothermal water in China in 2006, 18 % is used for heating, 65.2 % for medical care and Spa, 9.1 % for aquiculture and breeding, and 7.7 % for other purposes. This application saves a large amount of conventional energy and promotes the national economy, e.g. real estate and tourism industry.

Table 3 Geothermal energy used for heating in China

Year	1990	1999	2005
Space heating (10^4 m^2)	190	800	1270
Warm water supply (10^4 families)	1	20	30
Reduced CO_2 emission (t)	3087	12999	20635
Reduced SO_2 emission (t)	1158.7	4878.5	7744.6

3.3 Development of shallow geothermal energy in China

In China, shallow geothermal resources generally suitable for direct-use applications are widespread, in connection with different kinds of geothermal heat pumps (GHPs).

GHP technology was introduced in China in the 1990s. Since that time, the Chinese market for GHP has developed significantly. According to the Geothermal Heat Pump Application Feasibility Study, China is expanding the direct use of shallow geothermal energy, combining the technical issues with economic considerations for the various applications in different geographic regions, mainly depending on the local climatic, geological, hydrogeological, and market conditions.

The U.S. provided technical support to China for three geothermal heat pump demonstration projects, located in three different climatic regions. The projects are run with different types of heat pump systems, addressing different

functions and market areas in China. The demonstration sites are:

- A commercial building complex in the city of Daqing located in the northern part of China with a cold climate with average temperatures of -10 °C to -30 °C in winter; there geothermal heat pumps can be used to supplement or replace coal-fired heating boilers.

- Another commercial project will demonstrate the technology in the central part of China with temperate and warm climate in Shanghai. It includes a multistory commercial office building, which is fully air conditioned by a geothermal heat pump system, and a large apartment. The temperatures in winter range from –5 °C to 10 °C, and it is severely hot in summer with temperature from 30 °C to 40 °C; therefore dual-purpose geothermal heat pump air conditioner systems could be used.

- The third project is a commercial building complex near to the city of Guangzhou located in the southern part of China with subtropical climate; it is representative also for the areas of Guangdong, Fujian, Hainan, Guangxi, and Hong Kong where in the very hot summers air condition is needed seven months per year. But because of the mild winters space heating is not needed.

Studies are underway on the technical and economic feasibility of using geothermal heat pumps in the three climatic zones. Geothermal heat pump units in China mostly have been purchased from the U.S.

4. GEOTHERMAL MARKET CHARACTERISTICS

China's annual consumption of renewable energies was equal to 160 million tons of standard coal in 2005, i.e. there is a huge potential market for renewable energy.

According to research carried out by the China Renewable Energy Development Project under the National Development and Reform Commission, China can produce 7.3 billion tons of SCE (standard coal equivalent) of energy every year, but at present China actually produces only 40 million tons of SCE energy annually.

The Chinese market has been changed from only state-run (1970s) to more private enterprises with commercial domination. The market potential largely developed during the recent industrialization.

Geothermal energy is widely used in China, but the application is still at the beginning with less than 0.5 % of the whole energy supply of the country. Exploitable geothermal energy occurs in a variety of geological situations. Because of climatic reasons, there are certain regional differences of the geothermal market in China. In northern China (cold to temperate climate) geothermal energy can be used for heating in winter in central China (temperate to subtropical climate) it can be applied for both heating in winter and cooling in summer; in southern China (subtropical to tropical climate) geothermal energy can be used for cooling in summer.

The real estate industry in China has been a key driver of the local economy for over two decades. For many organisations, real estate and physical infrastructure are major components of operational costs and typically involve significant investments which dominate the balance sheet. This means real estate decisions can often have a very significant and long lasting impact on shareholder value.

The development of geothermal resources causes many benefits, it

- delivers clean energy for a sustainable environment,
- improves the air quality,
- improves the reformation of energy structure,
- promotes the development of local real estate industry,
- drives the geothermal tourism industry,
- benefits rural economy through geothermal use in agriculture,
- allays the water resource shortage,
- promotes the local economy development,
- increases the living standard.

The risk of failures at exploration and exploitation is limited for resources situated in shallow depths where prior knowledge gained from earlier surveys is available. For deeper resources where only insufficient data are available there are greater uncertainties.

During last decades, geothermal energy industrialization in China started with the help of simultaneously scientific research and technology development for geothermal resources investigation and assessment, including geothermal geology, geophysics, geochemistry, remote sensing, drilling and injection, heat flow computer simulation, geothermal water monitoring, resource management and environmental protection, etc. The results played a very important role for the standardization of geothermal resources utilization and optimization, as well as geothermal reservoir engineering.

In China the Renewable Energy Law is valid since 2006, together with other promoting policies as “2001 - 2010 National New Energy and Renewable Energy Industrialization Plan” and “10th Five Year Clean Energy Technology Development Plan”. The annual geothermal energy utilization increased at a rate of 10 – 20 % due to different sources of data.

The long history of geothermal research and development and expertise available in the U.S. and European countries are very beneficial to China’s program and create mutually beneficial business opportunities.

The U.S. Department of Energy (DOE) supports through the Lawrence Berkeley Laboratory a scientific study about the geological/geothermal mechanisms regarding the exploitation of geothermal energy at the Tengchong site.

Project assistance from the U.S includes project feasibility studies, technical training, and education, joint project evaluation and management activities etc. A request exists from the Chinese side for technical assistance on specialized drilling equipment, materials, and tools, operational safety, and geological - geophysical issues, on-site training, post-drilling analysis; development plans in the future.

Besides Sino-U.S. cooperation, several other international projects on geothermal utilization have been carried out or are about to start in China, for example,

- Germany, Clean Development Mechanism projects, renewable energy, heat pump technology, since 2000,

- France (Compagnie Industrielle d'Applications Thermiques [CIAT group's]), heat pumps systems in Beijing, Tianjing, Hebei, Shandong and Shanxi,

- United Nations (The Japan International Cooperation Agency (JICA)), measurements of deeper geothermal resources in Yangbajing, Tibet, slope drilling and branch drilling techniques,

- Italy (Ministry of Environment and Land) e.g. Tianjin geothermal utilization and rejection technology research, ended on October 2005,

- Iceland (Enex, projects since 2002), the world's largest geothermal district heating system in China's Geothermal Town Xianyang recently under construction,

- Philippines, research on shallow geothermal energy in Hebei Province, 2004-2006.

In the meantime, China became a world attractive market and itself an active participant in the field of geothermal energy.

5. DEVELOPMENT TRENDS OF THE CHINESE MARKET

To meet the rising energy demand of the country's booming economy, China is paying more and more attention to the development of renewable energies. China has a huge prospective market for the use of geothermal energy.

Recent discoveries and reports covering Beijing, Shanghai, Jiangsu, Shandong, Shaanxi, Liaoning, Xinjiang, Shanxi, Guizhou, Henan, Zhejiang, Yunnan, etc. provinces, show that geothermal energy sources are of growing importance in China and have a large potential, both for electric power production and for heating and cooling.

5.1 Problems

The geothermal industry is a systematic industry whose maximum efficiency requires coordination among survey, plan, production, transportation and consumption. Although utilization of geothermal energy developed very quickly in China, its general utilization scale is still very low. Despite of financial reasons, there is a lack of scientific planning for sustainable development, the research and development, as well as design and production capacities of geothermal equipment and materials, are still very low, the related complex administration system and benefits need to be improved.

Adequate data must to be provided to enable geothermal site management at acceptable costs.

Geothermal water management must be enhanced to avoid environmental problems as land subsidence, ground collapsing caused by over-pumping of geothermal water, and groundwater pollution by water injection.

5.2 Geothermal energy development policies

Current the development policies for promote renewable energy in China can be concluded as

(1) Government support

The Medium and long-term development projects for renewable energies designed by China National Development and Reform Commission (NDRC) in 2005, are expected to fulfill China's energy objectives up to 2020 and meet the government's emphasis on renewable energy. The government has announced incentives in financing to encourage the development of renewable energy utilization in building and constructions, including geothermal heating and cooling techniques e.g. heat pump systems using surface water or groundwater, sea water, soil air and waste water as energy source. Special fund with 1.04 x 10^8 RMB for demonstration projects of renewable energy utilization in buildings and construction are created by China Ministry of Finance in 2006. Also China invites foreign investment in effective and clean utilization of renewable energy including geothermal energy, by 2020, China will have invested 1.5 trillion RMB to develop renewable energy, partly infused by the central government and most from social capital.

(2) Legislative protection

China promulgated a new law on renewable energy in February 2005. The law, which took effect from Jan. 1, 2006, is considered to be of great significance to the development of China's renewable energy industry.

(3) Market competition

(4) Science & technology direction, filling the knowledge gap and information shortage.

The sustainable development of geothermal energy in China means sustainable management and comprehensive and efficient utilization of energy with maximum benefit.

Looking toward the future, it is pretty optimistic about the future development of the geothermal market. Several international and national conferences and seminars and workshops on promoting the large-scale use of renewable resources held in recent years. Some suggestions given to the centre government on arranging special budge for national and regional geothermal resources investigation and assessment, as well as the demonstration projects for target fields exploration and utilization.

6. CHALLENGES AND OPPORTUNITIES IN CHINA

As the economy in China continues to grow, the need for investment in infrastructure remains strong. It is estimated that in 2010 25% of the new buildings will use solar and shallow geothermal energy; in 2020 50%. At the same time the Government is seeking to attract more foreign investment to the utilities sector.

There are many topics for geothermal research and applications important or interesting in China, for example:

- Investigation and Assessment on High-temperature Geothermal Resources
- Shallow geothermal energy capacity evaluation
- System exploitation and utilization planning
- Feasibility evaluation and risk assessment
- On-site exploration and development technologies
- Geothermal anticorrosion drainage and recharge technology
- Geothermal heat pump air-conditioning system
- Draw up atlas of geothermal resources, establish commercialized geothermal space information

system, national and regional geothermal database
- Technical regulations and standards for both deep and shallow geothermal energy
- Tools for planning, prioritisation decision-making and risk-based assessment
- Mechanism of reducing investment risk and increasing socioeconomic guarantee
- Upgrade the technology of the utilization rate on geothermal energy and reducing of the environmental pollution.
- Tracing research on high-temperature dry heat rock technology.
- Research and manufacturing in scale of heat-resisting high-flow high-lift geothermal deep-well submersible pumps.
- Heat exchange from abandoned mines
- The application of geothermal modelling in oil and gas survey
- Produce geothermal energy from former oil fields
- Geothermal energy application for sea water desalination facility
- China offshore geostatic thermal resources study

7. CONCLUSION

Geothermal energy could significantly contribute to China's effort to move toward sustainable development. Sciences and technologies are needed for more sustainable, efficient and innovative use of China's geothermal resources. While many opportunities exist in China, covering a variety of sectors including geothermal power plant, energy saving building and clean production, etc., a successful investment still requires a careful approach with professional skills to assist in risk reduction of implementing the investment strategy, both from financial and technological sides.

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