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The Status and Trend Analysis of Geothermal Development and Utilization in China

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ABSTRACT

Based on historical review and status analysis of geothermal development in China, this paper attempts to discuss reasons of stagnant development of high temperature geothermal resources for electricity generation and quick development of low-medium temperature geothermal resources for direct utilization of the past decade. It is suggested that China should give more importance to the non-electrical utilization of low-medium temperature geothermal resources. Particularly, it should choose big and medium-sized cities with good resource potential in order to develop space heating and tourism. On the other hand, China should also concentrate on geothermal reinjection and the use of heat pumps so as to achieve success featured by environmentally friendly, highly efficient, and energy saving geothermal developments. This ensures the sustainable development of geothermal resources.

1. INTRODUCTION

Hot springs had been used for bathing when the human entered a civilized history. In China, first such historic development was recorded 2,000 years ago. However, geothermal power generation, space heating, and industrial and agricultural use started only in the beginning of the 20th century. Accelerated process of geothermal development started in the beginning of 1970s. Worldwide petroleum crisis occurred at that time. Many countries made effort to seek available energy replacement. Developing new and renewable energies set off a surge. The same happened in China. Geothermal survey and exploration were carried out all over the country. A series of tests of low temperature geothermal power generation were also carried out in 1970-1977. Total 9 units with each capacity of 50-300 kW were installed in Hebei, Jiangxi, Guangdong, Hunan, Shandong and Liaonin etc. They used geothermal water of 67-92 °C temperature. But their small capacity, low parameters and low efficiency made it difficult to maintain their normal production. Some binary systems caused accident frequently. Therefore, only two units in Huitang of Hunan and in Fengshun of Guangdong using flashing methods with reduced pressure were remained. Meanwhile, due to lack of fossil fuel energy in Tibet, a test unit of 1MW of high temperature geothermal power generation was first successfully operated in october of 1977 in Yangbajain, located 90 km away from Lhasa and was called 'The Pearl on the Roof of the World'. Since the United Nations Global Congress of Environment and Development issued 'The Agenda of the 21st Century' in 1992, sustainable developments have become a main surge. Many technologies and developments on new and renewable energy have further grown. Under such background, the State Council put forward 10 of countermeasures for environment and development in China. It was suggested to 'develop and popularize solar, wind and geothermal etc. clean energies. This made a second surge of geothermal development.

2. GEOTHERMAL DEVELOPMENT STATUS

I abundant medium-low temperature Chinese geothermal resources, which occupy about 7.9 % of the world. Its total energy reserves reached $11*10^6$ EJ/yr (WEC, 1994; EPRI, 1978). High temperature geothermal resources (>150°C) are mainly distributed in South Tibet, West Yunnan, West Sichuan and Taiwan. Medium-low temperature resources are distributed almost all over the country. Due to a later commencement, either geothermal resources exploration or geothermal utilization, including power generation and non-electrical use techniques, scale, equipment, capacity factor and scientific management, have a certain gap compared to other advanced countries.

2.1 Geothermal Power Generation

In China, geothermal power generation started in the early 1970s. Most of small testing power stations using low temperature geothermal water were shut down at the end of 1970s. With one exception in Tibet, where power stations use high temperature geothermal power generation. Currently in China, the total capacity of geothermal power generation is 32.08 MWe. About 88 % of them are concentrated in Tibet (Table 1) (Liu, 2001). During past 14 years, total of 25.18 MWe of capacity was installed in Yangbajain Geothermal Power Plant from 1977 to1991. Since 1993, its geothermal electricity was in 100 GWh annually. Its total generation has reached 1,740 GWh (Fig.1).

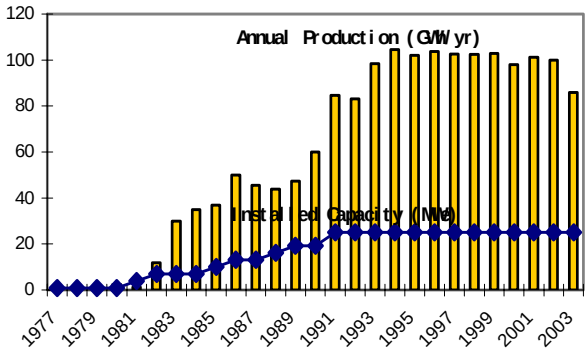

Figure 1: Geothermal Power Production in Yangbajain Geothermal Power Plant, Tibet, China

Yangbajain Geothermal Power Plant operates about 4,300 hours annually on average (Production Section of Yangbajain Geothermal Power Plant, 2002). Geothermal electricity occupies about 30 % of the electric network of Lhasa. Chinese total geothermal capacity is listed in a 14th place in the world (Table 2) (Wang, 2001).

Table 1: The Status of Capacity and Operation of Geothermal Power Station in China

Name	Unit	Capacity MWe	Started in	Capacity total	Status
Yang-bajain, Tibet	No.1[1]	1	Oct.1977	MWe	Shut
	No.2[2]	3	Nov.1981		Run
	No.3[2]	3	Nov.1982		Run
	No.4[2]	3	Sep.1985		Run
	No.5[3]	3.18	Mar.1986		Run
	No.6[2]	3	Dec.1988		Run
	No.7[2]	3	Feb.1989		Run
	No.8[2]	3	Dec.1990		Run
	No.9[2]	3	Feb.1991	25.18	Run
Nagqu, Tibet	No.1[4]	1	Nov.1993	1	Run
Langju Tibet	No.1[1]	1	Oct.1987		Run
	No.2[2]	1	1988	2	Run
Fengshun, Guangdong	No.3[5]	0.3	Apr.1984	0.3	Run
Huitang, Hunan	No.1[5]	0.3	Oct.1975	0.3	Run
Qingshui, Taiwan	No.1	3	Sep.1981	3	Shut
Tuchang, Taiwan	No.1[4]	0.3	1985	0.3	Shut

* Superscript: 1– reformed unit, 2 – made in China, 3 – made in Japan, 4 – ORMAT binary, 5 – flashing unit

In China, until now since 1992, geothermal power generation has not increased, except for a 1 MW unit in Nagqu, which was given free economic aid by UNDP in 1993. Contrarily, geothermal power generation had a rapid growth in recent decade in many developing countries such as in Philippines, Indonesia, Costa Rica and El Salvador etc. Their generation capacity has greatly exceeded that of China. What is the reason to bring about our stagnation?

2.1.1 Restriction of Geothermal Heat Source

Most of high temperature geothermal systems in the world have similar heat source. They are young acidic magma intrusion at shallow depth in crust of the earth. However, there is no such favorable condition in China. Although geothermal fluid with more than 200°C temperature was found in Yangbajain geothermal field in Tibet, its tectonic background is a collision zone between two continental plates (not continental / marine plates). In addition, the heat source in Tengchong area of Yunnan is related to neo-volcanic activity. They are calci-alkalic andesite, dacite and alkalic basalt.

Table 2: The Capacity of Geothermal Power Generation in Main Countries in the World

No.	Country	Capacity MWe		
		1990	1995	1998
1	United States	2,775	2,817	2,850
2	Philippines	891	1,227	1,909
3	Italy	545	632	785
4	Mexico	700	753	755
5	Indonesia	145	310	589
6	Japan	215	414	547
7	New Zealand	283	286	437
8	Iceland	45	50	170
9	El Salvador	95	105	161
10	Costa Rica	0	55	142
11	Nicaragua	70	70	70
12	Kenya	45	45	45
13	Guatemala	6	6	33
14	China	31	32	32
15	Turkey	20	20	20

2.1.2 Restriction of Distribution of Geothermal Resource

High temperature geothermal fields are limited and distributed in Tibet-Yunnan region of China. There are high topography, few populations, inconvenient traffic and poor economy in these areas. Meanwhile, hydropower resources are rich there. Geothermal power generation is difficult in these areas.

2.1.3 Restriction of High Risk of Geothermal Exploration

Existing exploration data showed that high temperature geothermal fields were almost all fractured reservoirs. High yield of geothermal fluid is related to fault and fracture in rock formation. So there is a high risk for geothermal exploration in such area. Some exploration or production wells that were drilled in Yangbajain and Tengchong areas got high temperature but not too much fluid.

2.1.4 Restriction of Existing Economic System

Along with the restructuring the economy from socialist planned to market economy, the state cancelled national input for geothermal exploration. Thus, private investors have to bear entire risk themselves. Policy for promoting development of new and renewable energy has not yet been entirely present.

2.1.5 Restriction of Economic Benefit

Usually the operational cost of commercial geothermal power is cheaper than the coal-burning power and a little higher than hydropower. However, the operation cost of geothermal power in Yangbajain of Tibet is several times higher than the that of international level. That is due to lower level in exploration and drilling techniques, lower parameters of geothermal resources, smaller capacity of installation, shorter running hours, lower efficiency of generation and also poor condition in transportation and construction on such plateau of 4,300 m above the sea level.

Therefore, the economic benefit of geothermal power generation is not so obvious.

According to the demand of energy market and limitation of resources condition, developing plan for high temperature geothermal power generation further is not realistic. Based on above reasons, the growth space for geothermal power generation is limited.

2.2 Geothermal Direct Use

In early 1990s, along with the strengthening of consciousness of environment protection in all over the world, a new upsurge in low temperature geothermal direct use was made. Especially in high latitude cold region in north China (including northeast and northwest China) geothermal space heating had a quick growth. The total area of geothermal space heating reached 13.4 Mm^2, with 9 Mm^2 of them currently located in Tianjin.. It has increased by 7 times more than in the year 1990. It reduced air pollution greatly and gained obvious economic benefits. Various heating techniques have been applied including floor heating and heat pump. Geothermal tourism has also been developed in Yunnan, Tibet, Xinjiang, Sichuan and shannxi etc. western provinces. It added new species and new brightness to local tourism business. In addition, geothermal greenhouse planting and aquaculture feeding are still in growth. However, geothermal direct use is developing towards large-scale business and enterprise operation. According to statistical data from WGC2000, the Chinese annual utilized energy of geothermal direct-use is in the first place in the world (Table 3). What is the reason for such a rapid growth?

Table 3: The Capacity and Annual Utilization of Geothermal Direct Use in Main Countries in the World

Country	Installed capacity MWt	Annual utilization GWh/yr
China	2,282	10,531
Japan	1,167	7,482
United States	3,766	5,640
Iceland	1,469	5,603
Turkey	820	4,377
New Zealand	308	1,967
Georgia	250	1,752
Russia	308	1,707
France	326	1,306
Sweden	377	1,147
Hungary	473	1,135
Mexico	164	1,089
Italy	326	1,048
Romania	152	797

2.2.1 Rich Medium-low Temperature Resources

In China, geothermal resources are mainly medium-low temperatures. Such resources can be divided into two types: conduction and convection types respectively. For conduction type, geothermal resource is thermal water reserved in larger sedimentary basin, for example in the North China, Songliao, Erdos, Sichuan etc. basins. This type of resource has widespread distribution and large quantity of reserve. It is easy for exploitation. The sum total of extractable resources was estimated to be as large as 1,845 Mtec (Chen et al, 1994). The other type, convection resource, is hot spring occurring in the mountain area or geothermal water reserved in fault-fracture zone. They were originated by convection through fault and deep circulation. Such resources distributed in Fujian, Guangdong, Hainan, Jiangxi and Hunan etc. southeastern provinces. Up to date medium-low temperature geothermal resources have been found almost all over the country.

2.2.2 Widespread Growth Space

Since reforming and opening were implemented, commercial geothermal market got the opportunity to fit to the increased demand of geothermal heating, health care and tourism etc., especially in large and mid cities with dense population. So it provides widespread growth space for developing direct geothermal use.

2.2.3 Ensuring of Exploration Techniques

Geothermal exploration technique had great progress of more than 30 years in development. Geothermal workers have gained valuable experiences for various geological settings, geothermal features and types, especially for widespread large sedimentary basins of conductive type resource. Thus, it can reduce risk and increase activity for individual investor.

2.2.4 Short Period but Obvious Economic Benefit

Geothermal direct use can easily gain obvious benefits, especially for geothermal heating and tourism projects. This is due to a short period and weak risk for such development. It is easy to develop step by step. Gaining more benefits leads to investing more aspects.

3. THE TREND OF DEVELOPMENT

Based on rich experiences of past geothermal works, in order to implement both strategies of sustainable and great developments, geothermal direct use should be the main direction of China for the early stage of the 21st century. According to the demand of geothermal market in China, we should pay attention to the following aspects:

3.1 Developing Geothermal District Heating in Cities

Medium-low temperature geothermal water is suitable to be utilized for geothermal district heating in most of cities in northern China. It can replace previous coal-boiler heating to reduce air pollution and to increase economic benefits and social effects.

3.2 Developing Geothermal Tourism in Cities

Modern tourism has become one of biggest businesses with the strong growth trend. There are very rich tourism resources in China. Developing geothermal tourism around cities has not only added a new species and brightness, but also promoted growth of local economy. Ornamental type of high temperature geothermal manifestations, such as geyser, hydrothermal eruption, boiling spring, volcanic cone, caldera lake and various sinters are distributed along the Tibet-Yunnan Geothermal Zone. Traditional hot spring culture showed different styles in different areas. New geothermal recreation has been growing to fit to the demand of the modern public. It has become a low risk, but high repayment business.

3.3 Multi-Purpose Use as the Principle of Development

Geothermal resources involve heat, mineral and water. It should be utilized for multi-purpose use. Its heat energy should be used in its fullest to avoid waste and to increase the efficiency.

3.4 Choosing Large-Mid Cities as Key Developing Area

Most large-mid cities are located in big basin or plain. These regions are sedimentary basins. Geothermal resources are usually reserved in such deep basins. Cities are also a big consuming market, and are key area for environmental protection. Therefore, most of large-mid cities can be chosen as key developing area for geothermal development.

3.5 Accelerating Geothermal Exploration in Key Cities

We should accelerate essential geothermal exploration in key cities or key areas. Its purpose is to reduce the risk of development, in order to attract more individual developers to put their investment into the geothermal development.

4. CONCLUSIONS

In China, there are rich geothermal resources which are mainly of medium-low temperature. In recent ten years, geothermal direct use has an annual increase rate of about 10% on average. Its utilized energy is in the first place in the world. Although there was no increase of capacity of geothermal power generation recently, the Yangbajain Geothermal Power Plant has the great importance in the electric network of Lhasa, Tibet.

In the beginning of the 21st century, direct use of medium-low temperature geothermal resources should be the main way for geothermal development in China. Large-mid cities should be given the priority for exploration and development of the geothermal resources. District space heating and geothermal tourism can be the key for developing. Then multi-purpose comprehensive utilization should be developed. In the statistic data of 2000, space heating and geothermal tourism occupied 35% and 42% of geothermal direct use respectively. Thus, they are very important for medium-low temperature geothermal development.

At the meantime with the development of geothermal direct use, scientific management of geothermal resources has to be strengthened. Geothermal reinjection is important measure for resources protection. The application and popularization of geothermal heat pump is an important method for saving resources. The improvement and creation of geothermal techniques is effective way for extending further growth.

In order to encourage the competition between geothermal resource and conventional energy source, and further push the growth of geothermal market in China, national government and its concerned administration should draw up and implement a series of priority policy and bylaws for promoting the development and utilization of new and renewable energies.

Global energy experts have widely recognized that new and renewable energies had great potential of growth in the 21st century. It was predicted that new and renewable energies would occupy 30-80% of total energy value. We should grasp this opportunity to not only accelerate developing, but also to protect environment and save resources.

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