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LOOKING BACK AND AHEAD FOR GEOTHERMAL ENERGY DEVELOPMENT IN CHINA

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ABSTRACT

The development process of geothermal research, exploration and utilization in China has been reviewed since 1949 when the People's Republic of China was founded and especially since the policy of reform and opening to the outside world was adopted in 1978. An all-round and systematic summarization is made of the results attained in investigation, exploration and multipurpose utilization of geothermal energy resources. And the experiences are objectively discussed.

In recent years, China's geothermal exploration and utilization have undergone an especially quick advancement against the background of hi-tech development and the leading role played by the market-oriented economy. With the growing attention paid to the development of geothermal energy by the Government of China and the realization of geothermal projects assisted by UNDP and loaned by North European countries, and with the geothermal basic investigation and pre-stage geologic argumentation strengthened, major advancement has been gained. For example, (1) Hot spring maps on various scales and maps of geotemperatures at different depths (1,000 m, 2,000 m, 3,000 m) of China and major sedimentary basins on small scale have been compiled; (2) Due to new technology and new way applied to the integrated exploration of geothermal fields, efficiency in exploration is substantially enhanced; (3) Long-distance transportation proves to be a new way for the development and utilization of geothermal energy resources in the remote areas; (4) Uses of geothermal resources have been transformed from single purpose into multipurpose use systems.

The paper also deals with the environmental problems arising from the large-scale geothermal development and the bright and promising perspectives in the future development of geothermal energy in China.

1. INTRODUCTION

Both "The UN Conference on New Energy Sources" held in Rome in 1961 and "The UN Symposium on Development and Utilization of Geothermal Resources" held in Pisa in 1970 laid special emphasis on the important significance of geothermal energy serving as a new energy source, which offered a partial solution to the shortage of energy and to the improvement of living conditions of the mankind. In 1970s, the eminent late scientist, Prof. J.S. Lee came up with a lot of important inferences in regard to research, development and utilization of geothermal energy of China. At his vigorous suggestion and under his direct guidance, the geothermal prospecting, exploration and multipurpose utilization studies were conducted in over twenty provinces, municipalities and autonomous regions in succession. These studies provided remarkable achievements and laid down a good foundation for the development of geothermal energy and were the basis for the continuation of geothermal development in the last thirty years.

Since 1970s, the geothermal exploration and re-assessment have been done with a view to establishing power plants in several sites in the high-temperature geothermal areas in Zang-Dian and Taiwan Geothermal Zones as Yangbajain, Yangyi, Langju, Nagqu of the Xizang Autonomous Region; in Reshuitang of Tengchong County, Yunnan Province; in Chingshui and Tuchang of Taiwan Province. The five geothermal power plants have been set up (Ren *et al*., 1995; Dunzhu and Zeng, 1998; Chen, 1994). Their installed capacity as a whole amounts is to 28.78 MW, ranking 12th place in the world (Huttrer, 1995; Zhang, 1999).

Besides, the districts of Beijing and Tianjin and some areas in Renqiu, Xiongxian, Cangzhou, Zhengzhou, etc. in North China Basin and also the areas in Fuzhou, Zhangzhou, Xiamen, Shantou, etc. in the Ming-Yue-Qiong Geothermal Zone where low- to medium-temperature geothermal resources are available, prove to be the major districts or areas, where geothermo-geologic exploration and evaluation have been carried out, and, where various types of low- to medium-temperature geothermal resources have been successfully utilized to direct uses in space heating, hot-water supplying for domestic uses, greenhouses, aquaculture, hatchery, drying for agricultural purposes and air-conditioning, industrial uses, convalescent hospital, tourism, bathroom, mineral water drinking, etc. In 1995, the total quantity of geothermal power in direct uses throughout the country reached up to 1,915 MWt, that lept to the forefront in the world (Freeston, 1995). Currently, according to rude estimates, the total thermal power could be 2100 MW ranking first in the world (Huang, 1999).

China is rich in geothermal energy resources. According to incomplete statistics, there are 2,796 localities boasting hot springs with water temperatures ≥ 25°C in China (Huang *et al*., 1993). If geothermal wells drilled in the extensively distributed sedimentary basins or areas of oil fields, industrial and mining enterprises are taken into consideration, a total number will be over 5,000. Geothermal energy resources turn out to be a kind of promising and potential energy sources and boast extensive uses, whose perspective in the development and utilization is bright and enormous. At present, it is necessary to conduct an all-round and systematic investigation on the potential of geothermal energy resources throughout the country as a whole on the occasion when the mankind is about to step into the 21st century, so that geothermal resources could be further ascertained and geologic basis could be provided in making up the long-range plan in the development of geothermal energy resources from 2000 to 2010.

2. HISTORICAL REVIEW

During the period of time from 1950s to 60s, one of the originators in the creation of geological cause of China, Prof. H. Zhang put together and published a book entitled *Major Hot Springs in China* (1956), in which China is reported to boast 972 localities of hot springs. The celebrated geoscientist Prof. J.S. Lee in person set up the first Geothermal Research Section in the Institute of Geomechanics attached, at that time, to the Ministry of Geology. At his suggestion, the first geothermal observation well at a depth of 500 m was drilled into a granite mass located in Fangshan County, Beijing, in 1962, and obtained data of geothermal gradients after systematic observations of the well temperatures. Primary surveys or investigations were carried out by hydrogeological parties of various bureaus of geology in some provinces, municipalities and autonomous regions on the geothermal resources of their own and geothermal exploration was conducted as well in some areas where hot springs were present, thus meeting the country's needs to establish new holiday resorts and sanatoria or extend them. On the basis of investigation of mineral springs across the country, the Institute of Hydrogeology and Engineering Geology, Ministry of Geology have compiled the first "Map of Mineral Springs in China" in 1965.

In the early 1970s, as proposed and promoted by the eminent late Prof. J. S. Lee, a new upsurge concerning development of geothermal energy resources went into full swing and very striking achievements were scored in succession in the fields of geothermal research, exploration, development and utilization for power generation and direct uses in more than twenty provinces, municipalities and autonomous regions. In April, 1977, Working Conference on Coal Field Geology and Geothermal Geology for Nine Provinces of Southern China, sponsored by the General Bureau of Geology (i.e. the former Ministry of Geology) was held in the city of Suzhou, Jiangsu Province. Similarly, a Symposium on Geothermics of China, sponsored by the Academia Sinica, was held in Conghua, Guangdong Province in December, 1978. These two conferences gave an impetus to research on the exploration and development of geothermal energy resources.

In the mid-late 1970s to 80s, hydrogeological and engineering parties of the bureaus of geology and mineral resources of various provinces, municipalities and autonomous regions, together with the specially-organized military hydrogeological units of the People's Liberation Army (No. 00939, 00929 and 00919) completed the work on regional hydrogeological survey on a scale of 1:200,000 and then published *Hydrogeological Maps of China*, in the meantime, work on the regional hydrogeology, agricultural hydrogeology and geothermal resources of part of provinces, municipalities and autonomous regions as well as geologic exploration and evaluation of geothermal fields in Yangbajain of Xizang, Beijing, Tianjin, Kunming, Xi'an, etc. drew to a successful conclusion, bringing about fruitful achievements in point of investigation and exploration. The Comprehensive Scientific Expedition Teams and Mountain-Climbing Team attached to Academia Sinica and the Department of Geology of Beijing University carried out surveys one after another on hot springs as scattered in the areas of Ngari, South Xizang, Nagqu, Changdu (Tong *et al*., 1981), Tengchong and Hengduan Shan, and also in the Mt. Namjagbarwa Region, the "Big Turn round " of the Yarlung Zangbo River (Zhang *et al*., 1992), gaining a lot of achievements as regards the existing hot springs. And the relevant institutions managed to compile the distribution maps of hot springs in China in succession on smaller scales (Huang *et al*, 1981; Huang,, 1982; Huang *et al*, 1986). And the 1:6M Distribution Map of Hot Springs in China, and its Explanation— Hot Spring Resources with Nomenclature of Hot Springs in China have been published in 1993 (Huang, *et al*, 1993). Besides, the maps of geotemperatures distribution at various depths of 1,000 m, 2,000 m, 3,000 m and geothermal gradients in China were compiled (Wang, *et al*, 1990).

In China, lots of important events in relation to the geothermal research and development took place from 1982 to 1989. For instance, the State Science and Technology Commission and the Ministry of Geology and Mineral Resources acting as co-sponsors convened the 1st National Geothermal Working Conference in the city of Yingkou, Liaoning Province in 1982. In 1985, Chinese Geothermal Commission, which is attached to China Energy Research Association, was formally established. Up to October, 1989, the 1st, 2nd and 3rd National Geothermal Workshops, sponsored by Chinese Geothermal Commission were convened respectively in Fuzhou, Emei and Zibo, and the 2nd National Geothermal Working Conference, sponsored by the State Planning Commission, the State Science and Technology Commission and the Ministry of Geology and Mineral Resources, was also convened. All these interest shown and attention given by the government and relevant organization greatly spurred the research on the, development and utilization of geothermal energy resources in China. Sectors of Ministry of Geology and Mineral resources carried out geological exploration in a series of geothermal fields and succeeded in providing lots of reserved bases for geothermal development and utilization in the future. Led separately by the State Science and Technology Commission and the State Planning Commission, geothermal key-problem-tackling projects and multipurpose-use demonstration localities were picked out and shown throughout the country in the period of time from "The 6th Five-Year Plan" to "The 7th Five-Year Plan" during which time a number of fruitful high-level results has been obtained.

Led and organized in 1989 by the National Commission on Mineral Resources and the Department of Hydrogeology of the Ministry of Geology and Mineral Resources, Beijing Municipal Bureau of Geology and Mineral Resources was given a task, to compile "The Geological Exploration Standard of Geothermal Resources" (GB11615-89) and after that then promulgated in 1990 by the State Bureau of Technical Supervision, consequently playing an active and guiding role in geothermal exploration in China.

Upon entering into 1990s, geothermal work in China started to develop along the road of standardization for development and evaluation, intension for development and utilization, legalization for production and management, and industrialization for making the related equipment to be used in geothermal development. Many fruitful results related to production and scientific researches are obtained. Economic benefits and environmental effects are extended to the market of geothermal development with offering opportunities for investors. Sponsored and organized by the Chinese Geothermal Commission, the International Workshop on China Tibet High–Temperature Geothermal Development and

Utilization was hold in Lhasa, in 1992. The 4th National Geothermal development was hold in Beijing in 1994 and the National development on Industrialization of Geothermal Technology and Economy in Beijing in 1998. Experiences of geothermal exploration, drilling, evaluation and utilization were extensively exchanged among the scientists and investors.

3. MAJOR ADVANCEMENT

The Chinese Government has always attached great importance to the development of geothermal energy. As a result, a nation-wide study for the investigation and evaluation of geothermal resources, and exploration and assessment of geothermal fields as well as development and utilization were vigorously carried out across the country, leading to major advancement in this connection.

3.1 Compilation of Distribution Map of Hot Springs in China (1:6M)

The Distribution Map of Hot Springs in China (1:6 M), its Explanation—*Hot Spring Resources in China with Nomenclature of Hot Springs in China* (Huang *et al*, 1993) have not only put together plenty of working results regarding investigation and exploration of hot spring areas conducted over 40 years since 1949, but also catalogued the hot springs throughout the country in line with the obtaining norms after in situ investigations of the typical hot spring areas, repeated confirmations and detailed analyses and studies. The number of localities of these hot springs enlisted in the *Nomenclature of Hot Springs in China* and whose temperatures are either equal to or more than 25°C amounts totally to 2,796, based on which, the distribution map of hot springs in China is compiled. The temperature, discharge, water quality and geologic features of representative hot springs occurring in 391 localities are also described in the works.

The works are believed to be the first comprehensive and systematic ones on the hot spring resources in China. In the works, an approach is made to macroscopic controlling of global geotectonics over the hot spring distribution in China and analyses and study are given of extending features and their tectonic-thermal background conditions of the two interplate high-temperature geothermal zones— Zang–Dian Geothermal Zone and Taiwan Geothermal Zone, and of the two intraplate low- and medium-temperature geothermal zones — Dian – Chuan Geothermal Zone and Ming – Yue – Qiong Geothermal Zone, as are based on hot spring concentrated zones. Also expounded are the tectonic positions of the outcropping springs and their geological types as composed of three types and six subtypes, which reveals the potential of hot spring resources in China and their bright future in terms of development and utilization. All the above-mentioned research work has not only offered significant reference value as regards researches into the related branches of learning such as active tectonics, seismological geology, lithospheric dynamics, etc., but also been of important practical value and leading role for promoting the research, exploration, development and utilization of hot spring resources in China.

3.2 Compilation of Geotemperature Distribution Maps in China

Since late 1970s, the research work on the geotemperature distribution characteristics of China, in an attempt to compile geotemperature distribution maps at depths of 1,000 m, 2,000 m, 3,000 m and geothermal gradient maps in China and in the sedimentary basins on a small scale has been carried out by Wang *et al.* (1990) with a view to revealing the potential of hidden geothermal resources.

The work — "*Basic characteristics of the Earth's Temperature Distribution in China* " turned out to be the ulterior fruit of the research project (Wang *et al*, 1990) and is considered to be the first works dealing the geotemperature distribution regularities in China, in which geotectonics and deep-seated geological structures in China and classification of rock association types of China concerning geotemperature-forming background and conditions are primarily discussed. By compiling the geotemperature distribution maps at different depths and the geothermal gradient maps, China's geotemperature distribution regularities are given in such a way that geotemperatures are generally inclined to progressively reduce in the direction from east to west and from south to north, with major factors and formation mechanism controlling and influencing China's geotemperature distribution discussed, heat flow value of 600 deep wells estimated and relations between heat flow distribution characteristics and regional geological structures and deep crustal structures looked into. And nine examples are given in detail concerning geotemperature distribution in Meso-Cenozoic sedimentary basins, such as Songliao, North China, Ordos, Jianghan, Sichuan, Qaidam, Tarim Basins, et al., with stress laid on the discussion of geotemperature distribution regularities and revealing the potential of basin-type geothermal energy resources and their broad perspective.

3.3 Preliminary Evaluation of Geothermal Energy Resources in China

In the preliminary evaluation, natural heat discharge method was employed to calculate for 2,433 hot spring localities spreading throughout China (Geothermal Energy Resources Evaluation Section of MGMR, 1982). The final result of calculation was 2,512,396.99 x 10^{10} cal/a. It can be converted into 10,518.90 x 10^{13} J/a, which amount to 3.589 million tons of standard coal equivalent. If the thermal intensity of 4900 x 10^{13} J/a as released from other geothermal manifestations of South Xizang and that of 557 x 10^{13} J/a as released from those of West Yunnan Province are added together plus 337.86 x 10^{13} J/a from Taiwan Province (Chen *et al,* 1994), the total natural heat discharge of the country as a whole goes up to 16,313.76 x 10^{13} J/a, which amount to 5.5258 million tons of standard coal equivalent.

Geothermal resources concealed in sedimentary basins are calculated, in volumetric method, to have a result of 139,059.9 x 10^{13} cal. – equal to 582,215.99 x 10^{13} J, which can be converted into 198,600.57 million tons of standard coal, with a total area of 1.01 million km^2 and within the depth of 3,000m from the surface for the calculation. As is well known, in China, there are 193 basin-type plains, whose total area comes to 3.668 million km^2 and the size of each of which is in excess of 500 km^2. However, the total area of 1.01 million km^2 which has been subjected to calculation covers merely less than one third of the total area of the basin-type plains, illustrating that the deeply-buried geothermal energy resources in China boast a bright and promising prospect for future development and utilization.

Besides, Zheng *et al*, (1991), Chen *et al,*(1994) and Wang *et al,* (1996) counted up also the heat discharge of hot springs and evaluated geothermal water potential in major sedimentary basins of China.

3.4 Introducing Advanced Technologies to Conduct Integrated Exploration and Raising the Ratio of Success in Drilling

In the past twenty or more years, progresses have been considerably made in raising the ratio of success in drilling and in avoiding risks in exploration of geothermal energy resources, due to the importation of the advanced technologies from abroad and induction of integrated exploration. And for many geothermal fields, an analysis of geological structures, a complete set of best-chosen geophysical, geochemical, airborne infrared survey and remote sensing method are used so that final results are comprehensively interpreted and a nice and solid basis is provided for correct and determinative disposition of exploration work.

Exploration of Deep High-Temperature Reservoir in Yangbajain Geothermal Field

With repeated argumentation given by geothermal experts both at home and abroad, it was confirmed that deep high-temperature geothermal reservoirs are present in the depth of the northern section of Yangbajain Geothermal Field, whose major bases run as follows:

- Existing of magnetic negative anomalies and Bouguer residual negative gravity anomalies in the northern section were interpreted by Italian experts as due to hydrothermal alteration of granitoid magnetic rocks giving rise to demagnetization phenomena and making reduced the specific density of the original compacted rocks (Zheng, 1991).
- Analyses of results obtained from acoustic magneto-telluric surveys show the same conclusions as drawn by gravity, magnetic and electric methods.
- Results as obtained by magnetotelluric method show that there probably existed low resistivity objects 3km down below the surface in the northern section of the field, which was basically in agreement with those as obtained by acoustic magnetotelluric surveys (Ye and Deng, 1994).
- The results of geochemical exploration demonstrate that high content of Hg, As, Sb, Bi, etc. was determined in the section where low gravity and magnetic anomalies, and low resistivity were recorded, both matching each other quite well.

The practices indicate that high-temperature geothermal reservoirs really existed at depth of northern section of Yangbajain Geothermal Field, ZK4001 encountered high-temperature fluids, with the temperature of 257°C at the depth of 1,459 m. and a wellhead temperature of 200°C, working pressure of 15 kg/cm^2 and steam-water discharge of 302 t/h illustrating that single well electricity-generation potential reached 12 MW (Dunzhu and Zeng, 1998) – a convincing fact shows that the deduction and interpretation as made by application of up-to-date technology and methods, and carrying out the integrated exploration proved correct, therefore, providing scientific bases for siting of drillholes.

Discovery and Exploration of Sanlihe Geothermal Fields in Yanqing County, Beijing

At the inception of the exploration of the geothermal field, it was deduced according to the exploratory results obtained from gravity, magnetic and electric methods, and seismologic reflection that within the section there existed, two local structures outlined. First of all, a well of 500m-deep was drilled in western local structure and artesian thermal water at a temperature of 33°C was revealed.

According to geological horizons of the borehole and characteristics of gravity and magnetic variations, and seismological profiles, it was inferred that the eastern structure, located between two depressions, seems to be closer to active faults, and, therefore, was chosen as the main structure for geothermal exploration (Zhang, 1994). In 1987, a geothermal well was dug and completed at the depth of 1,300 m, with bottom temperature of 50°C measured; in 1988, another well was drilled of a depth of 1,455 m, hitting dolomite reservoir.

In 1993, local tourism departments concerned funded the drilling engineering, aiming further at finding geothermal resources. According to Zhang, (1994), geothermal target area was still pinpointed at that particular structural position. With drilling verification, thermal water with the temperature of 52.5°C was discovered at the depth of 2,006 m in dolomite reservoir of Wumishan Fm., Jixian System and waterhead was +28.4m, artesian discharge reaching 1,829 m^3/d, demonstrating that a fruitful achievement resulting from the application of geophysical exploration and drilling engineering to the correct choice of target area.

3.5 Long-Distance Transportation – A New Way to the Development of Geothermal Energy in the Remote Areas

There are several examples of long-distance transportation of geothermal water directly to the places densely populated and satisfactory results are obtained.

- In Anxi County, Fujian Province, the geothermal diversion works has been built. The hot spring water at the temperatures of 74.7°C is transported in insulated metal pipes of 21.5km to the county for daily use of about 4000-5000 families. Recently, this distance is the longest one in China.
- Jiaoxi Hot Spring, located at a distance about 7.5 km northeast of Dehua County, Fujian Province. Thermal water discharges out of the fissures of Nanyuan Fm volcanic lava of the Jurassic along banks of a stream. The water temperature is 63.5 – 65.0°C. A pressure pump station and the water pool were built, over 1,000 families benefiting a lot from the thermal water supplying system.

3.6 Multipurpose Use Systems of Geothermal Energy Resources Widely Built in China

In the early stage of geothermal development in China, single-purpose uses were adopted. Since 1980s, in many rural and urban areas of our country, geothermal energy utilization was developed progressively from single purpose uses to multipurpose ones. The multipurpose use system has been widely set up. The cascade development is realized.

Many examples shown in Table 1 indicate that lots of places have mostly 3-4 use types, and some even reach 6-7 types or more. Especially Beijing, Tianjin, Xiongxian and Fuzhou have more than 10 types of uses. It is obvious that they have kept to forefront in the country.

4. PROBLEMS AND COUNTERMEASURES

At present, the problems of excessive exploitation in some geothermal fields are quite serious. For example, in Yangbajain Geothermal Field on the first stage of its exploitation, the shallow geothermal reservoirs in the southern area are greatly over-exploited for a long time. As a result, the earth subsided and the resource dried up that would affect directly the life of geothermal field and the destiny of power plant. According to Dunzhu and Zeng (1998), the maximum value of the earth subsidence reached 176.6 mm and the vaporization surface of the production wells decreased 20-45 m measured both in 1991. And to date, the problem has remained the same. It can be seen that the continuous productive reinjection should be one of the important countermeasures. Besides, the wastewater has already affected the surrounding environment and caused serious pollution. In order to mitigate the problems of the earth subsidence and environmental pollution, it is suggested that the productive reinjection with excessive quantity should be carried out. As a result, the dynamic balance of the shallow geothermal reservoir in the southern section of Yangbajain could be progressively restored.

In recent years, because of progressive extension of the development scale in some low- to medium-temperature geothermal fields, especially in some old ones in Beijing, Tianjing, Xi'an, Kunming and others, the over-exploitation has in different extent, already caused the substained decrease of water level. According to Pan, (1991), the average declined rate of water level per year is 4.11 m in Tianjin. At present, the water level is continually decreased in major areas. In order to solve the problems the Government of Tianjin Municipality and relevant organizations have taken some countermeasures, one of which is the Geothermal Project using the North-European Favoar Loan and being in close corporation with Iceland Government. To date, the great progress has been made in a double–well reinjection, automatization of observation systems and increasing the use rate (Li, 1995, Li, 1988).

5. PERSPECTIVES

It is well known that the special geological settings of China are very favorable for the distribution and formation of geothermal energy resources. The high-temperature ones are mainly located in Xizang, West Yunnan, West Sichuan and Taiwan, and the low- to medium-temperature ones are more widely distributed covering 32 Provinces, Municipalities and Autonomous Regions. In the meantime, the 4 Municipalities of Beijing, Tianjin, Shanghai and Chongqing and about 1/2 Capitals of the Provinces have abundant or more abundent geothermal energy resources. The medium– to small-sized cities and towns, many oil-gas fields and some industrial and mining areas are also rich in geothermal energy resources. Some old geothermal fields in Beijing, Tianjin, Xi'an, Kunming and others are substantially extended and at the same time the new geothermal fields are found one after another.

Besides, the geothermal market also shows bright perspective of geothermal development. In recent years, though geothermal drilling is full of risks, yet investors (businessmen), foresighting people dare to invest large amount of money and run the risk. Sometimes it happened that without sufficient geological argumentation, drilling at the depths general considered uneconomical was still successful. Some of the investors of geothermal enterprises earn an incredible amount of money. It shows that geothermal energy development has high economic returns, which has largely broadened geothermal market and provided good opportunities for investors both at home and abroad.

To sum up, whether from the geothermal energy resource conditions or from the geothermal market, the perspectives of geothermal energy development in China will be bright and promising.

6. CONCLUSION

As mentioned above, in many rural and urban areas of the country the multipurpose use systems are built. Though it is necessary for the geothermal energy development to invest a lot of money for one time, yet it produces relatively quick returns. Social- economic benefits are obvious. In comparison with the traditional energy sources and other new energy ones the geothermal energy boasts certain competitiveness.

Recently, in the geothermal development of China new progress has been made. But problems still exist, e.g. the shortage of capital, being lag –behind in terms of technology, out-of-date equipment. In the future, for further developing the geothermal industry in China, it is necessary to import advanced technology, strengthen corporation with foreign countries and continually to train professional in international training courses and raising funds, etc.

The geothermal energy resources in China have a great potential. Therefore, in the future the geothermal-geological research, exploration, development and utilization remain to be further strengthened in order to develop multipurpose uses. It is expected that the development of the geothermal energy resources will play a major role in developing state economy, enhancing environmental conditions and serving the people and will have made a greater contribution to the change of state energy source structure.

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Table 1. Outline of Multipurpose Utilization of Geothermal Resources in China

	Use Type	Yangbajain	Tuchang	Beijing	Tianjin	Xiongxian	Dongtang-chi	Fuzhou	Linru	Huitang	Dengwu	Xinglong	Xi'an	Zhachangsi
1	Power Generation	*	*							*	*			
2	Space Heating			*	*	*				*			*	*
3	Greenhouse	*		*	*	*	*	*	*	*				*
4	Fish Farming			*	*	*	*	*	*	*				
5	Hatchery			*	*	*	*	*						
6	Agriculture						*	*			*			
7	Industry Use			*	*	*		*					*	*
8	Sanatory, Tourism		*	*	*	*	*	*	*	*		*	*	*
9	Water Supplying			*	*	*		*					*	
10	Bathing			*	*	*	*	*			*	*	*	*
11	Swimming Pool			*	*	*		*				*	*	*
12	Mineral Water			*	*	*			*					
13	Sci. Experiment							*						
14	Earthquake Obs.			*	*				*					