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THE STUDY OF NON-ELECTRIC USE OF LOW AND INTERMEDIATE TEMPERATURE GEOTHERMAL RESOURCES IN CHINA

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ABSTRACT

This paper reports that there are more than 120 high temperature geothennal fields with temperatures greater than 150°C in China and many more low and intermediate temperature geothermal areas are spread throughout country. The non-electric use of these resources has been developed in more than 700 areas with in 17 provinces currently. The total used power has reached 412MW (thermal). It has been demonstrated that the development of geothermal utilization is successful in space heating, industry and agricultural uses. Nevertheless, there are some problems which have not yet been thoroughly solved. All of these are mentioned in this paper. Furthermore, the assessment of the resources and current research projects are discussed.

1. LOW AND INTERMEDIATE GEOTHERMAL RESOURCES IN CHINA

China is located in the junction of the Circum-Pacific, Himalayan and Tianshan-Benioff earthquake zones. The geological plate boundaries and recent tectonic stress fields form active faults which are the source of central earthquakes and also provide ducts for geothermal fluid transmission. Extensive distributed basins meet these faults and with a supply of geothermal fluid, geothermal field may exit. [1]

Table 1. Geothermal Potential Basins in China

No.	Name	Area (10^4 km^2)	Thickness of deposit (m)
1	Songliao	25	5000
2	Hailaer	3	2500
3	Shang Heilongjieng	2.8	7000
4	Aihui	1.18	1900
5	Sanjiang	4.1	1000
6	Jiayi Diqian	1.04	...
7	Xia Liaohe	1.77	6000
8	Huabei	7.8	...
9	Da Tong	1.	
10	Linfen	3.17	8308
11	Laiyang	1.2	8308
12	Erlian	9.5	2000
13	Kaifeng Zhoukougu	6.2	3000 - 5000
14	Nanyang	1.56	4500
15	Jianghan	5.9	7000-9000
16	Subei	3.98	5000
17	Sichuan	18.7	2500 - 9500
18	Chuxong	3.53	...
19	Lanping-simao	4.89	...
20	Shan Gan Ning	26	6000 - 7000
21	Liupangshan	1.7	...
22	Wuwei	18.48	...
23	Dunhuang	1.328	1500
24	Akeshai	1.32	1500
25	Jianshi - Jiujing	3.49	6000-8000
26	Chaigamu	11.5	10000
27	Gongji	1.162	...
28	Kekexili	1.29	...
29	Talimu - Tacheng	56.03	...
30	Zhungaer	12.72	5000 - 13000
31	Tulufan	5.17	5000 - 8000
32	Habahe	1.17	400 - 700
33	Santanghu	2.238	4800
34	Yfi	1.325	2300
35	Yangi	2.76	2400
36	Yexierhu	1.18	...
37	Kumukuli	1.78	5500
	Total	2.66x10^{6}km^2	

Investigation shows that the total area of deposit basins is 4x106 square kilometres, occupying 41% of the area of the whole country. There are about 300 basins of which 61 are greater than 1x10^4 square kilometres.[2] Some of these basins with geothermal potential are listed in Table 1. For example, there are 776 hot water wells in the Huabei basin, with 448 wells on line for utilization. Hot water production is 1.25x10^9 m^3 annually.

Hot springs in China are spread all over the country, mainly on Fujian, Guangdong, Hunan, Hubei, Shandong and Liaoning provinces. Most of them are located in mountainous areas where bed-rock appears or thinner cap rock. The quantity of hot fluid emission from below ground is very impressive.

Table 2 indicates the numbers of hot springs and natural heat discharge in different provinces.

Table 2. Hot (or Boiling) Spring and Natural Heat Discharge in China

No.	provinceor autonomous regions	No. of spring	Naturalheat discharge (kJ/y)x10^8
1	Hebei	22	11905
2	Heilomngjang	2	7
3	Jilin	6	960
4	Liaoning	43	25172
5	Nei Mongol	44	2158
6	Shandong	13	6730
7	Shanxi	9	33298
8	Shainxi	8	28335
9	Henan	16	6763
10	Anhui	3	755
11	Jiangsu	10	11610
12	Zhejiang	6	2842
13	Jiangxi	92	19942
14	Hubei	46	35647
15	Hunan	31	27161
16	Fujian	153	35816
17	Taiwan	81	No infomation
18	Guangdong	291	44757
19	Guanagxi	3	61
20	Guizhou	47	3430
21	Sichuan	296	29180
22	Yunnan	706	284732
23	Tibet	354	474554
24	Qinghai	38	414
25	Gansu	24	20663
26	Ningxia	4	843
27	Xinjang	64	4000
	Total	2412	1,111,735

From primary investigations, there are more than 120 geothermal fields with temperatures higher then 150°C, mainly in Tibet, Yunnan and Taiwan. Some surveys in shallow aquifers in these high temperature fields have been done, but utilization of these fields is limited. However, from the natural discharge of hot springs and exploration wells drilled by geological and oil organizations, extensive use has been made in the widespread low and intermediate temperature geothermal fields for industry, agriculture and domestic purposes, It is necessary to develop the geothermal resources rapidly and efficiently to achieve maximum benefits. The purpose of our analysis is to maximize economic efficiency, social welfare, or a combination of these,

2. PRESENT STATUS OF LOW AND INTERMEDIATE TEMPERATURE UTILIZATION IN CHINA

Currently, China has developed five different areas of the low and intermediate temperature geothermal resources.

2.1. Electrical Generation

In total seven power stations or experimental plants were installed and tested, with only Yang Bajing proving economic providing 19 MW from 171°C fluid. Details of the others are given in Table 2-1.

Table 2.1 Geothermal Power Plants in China

Name in province	Geothermal water temperature (°C)	Capacity (kW)
Fenshun in Guangdong	91	586
Yichun in Jiangxi	67	50
Huailai in Hebei	85	200
Huitang in Hunan	91	300
Xiongyue in Liaoning	75	100
Zhaoyuan in Shandong	91	200

In comparison with conventional thermal power plants of the same size, costs of 3000-5000 Yuan per kW (in 1975) for geothermal were too high of all the other alternatives. after testing all plants except Fengshun were closed down, some being demolished. The installed capacities provided by geothermal water are of the order between 0.6 kW (67°C) to 3 kW (91°C) per 1 T/hr, which shows a poor economic benefit.

2.2 Industrial Application

In many areas geothermal energy has been applied to various industries such as dyeing, drying, paper processing, bathing rubber, silk and soya. Energy saving by using pre-heated water in boilers also has economic benefits. In Tianjin 35 geothermal wells are used in textile industry and dyeing. In Hubei province the rubber and silk industries in Yingshan use geothermal fluid resulting in a saving of 10,000 tonnes of coal annually.

2.3 Agricultural Applications

The use of geothermal fluid to heat greenhouse has already been applied to the cultivation of new varieties of seeds, several kinds of vegetables or plants, mushrooms, flowers, fruit and even rare medicinal herbs. Many places have built large areas of greenhouses heated geothermally. For example, there are several major geothermal greenhouses in Beijing and Hebei Province producing lager quantity of vegetables. Aquaculture, Fish breeding using geothermal is producing Africa fish, eels, shrimps, turtles, snails etc.. In Hebei there are seven major fish farms producing (in 1988) 9.14 million Africa fish, 43x103 kg of paret fish for wintering as well as 90 million fry to sell to other farmers, and 1.81×10^6 kg of larger fish for marketing.

2.4 Heating

Many cities in the north of China close to geothermal fields have started domestic central heating using geothermal. The area heated was 1.5×10^6 m^2 in 1989, with 0.88×10^6 m^2 of this in Tianjin. In general heat exchangers are used and supplemented by peak load boilers. However in some areas the local organization choose the low cost method of "once through" heating, in which the geothermal fluid is directly used to go through the district heating system, with consequent corrosion problems in time.

2.5 Medical Treatment and Bathing

Currently there are about 490 hospitals and units for convalescence, treatment and balneology - therapy in China with very good results. Bath houses using geothermal fluid directly are found widely wherever there is a suitable hot spring or a geothermal well. In Beijing, Tianjin and Fuzhou bath houses are one of the major use of geothermal fluid.

3. THE BENEFIT ANALYSIS OF LOW AND INTERMEDIATE TEMPERATURE GEOTHERMAL RESOURCES UTILAZATION

Broadly speaking, benefits include economic, social, energy-saving and environmental. The energy-saving benefit is related to the temperature, pressure and flow rate of the geothermal wells and utilization efficiency. The environmental benefit depends on the different chemical composition and treatment of the waste. With improved knowledge and techniques these benefits may become positive. However, the economic and social benefits are not only technological but also problems with respect the location of the geothermal field, geographical environment, the policy of the local authorities, transport, adequate finance, marketing and management. Each area will have different combinations of these problems. Different people assessing these benefits will get different results because they will give different priorities to aspects of the problem.

To decide whether a geothermal project is beneficial it is necessary to optimism the efficiency and profit in relation to the effects on people, the economy and the environment. In practise it is not possible to achieve the maximum benefit in all areas but there are always some benefits after using geothermal. Nevertheless, the assessment will affect the development plan. Currently the standards are based on three benefits.

(1) Direct Benefit - The saving of conventional electrical energy has to be balanced against the cost of geothermal exploration and treatment of waste water.

(2) Sub-direct Benefit - The profit achieved by marketing a product eg. geothermal greenhouse saves coal (direct benefit) but also makes a profit selling vegetables.

(3) Indirect Benefit - Arises from the management and organization of using plants or projects which do not themselves utilize geothermal water near to a geothermal project. eg. Extensive fish ponds do not themselves heat pools through the winter.

In the authors opinion the benefit of using a geothermal based project should be assessed by considering the three benefits above. However in calculating the total benefit it may be necessary to give more importance to the benefit will regard to the local situation in each case. Many locations in China do not have enough energy and parts of rural areas are so poor that there is no way to change their standards. However it has been shown possible to completely change a small area by new buildings, suitable plant systems and economic growth based entirely on the development of geothermal. For example, Tuanbo, a village in Jinghai county south of Tianjin with 562 families and total population 2680, was very poor before the development of a pilot project by Tianjin Geothermal Research and Training Centre (TGRTC) and this substantiates the authors view. Tuanbo is situated in a very good geothermal field (temperature gradient 8°C per 100 m). One well drilled in 1984 to a depth of 986 m, giving a temperature of 78°C at well-head and flow rate of 41 tonne per hour, Commencing in 1985, TGRTC has designed and built a comprehensive geothermal utilization system. By the end of 1989, this system has 13,320 m^2 of wintering fish pools, 3,330 m^2 of greenhouse, one plant producing eatable mushroom, one synthetic material factory, few other plants using geothermal heating, three bathhouses and one fish lake (more than 6.7×10^6 m^2). The value of output and profit had steady growth from 1986 to 1989, with the total output of 24.4 million Yuan annually and total profit of 8.75 million Yuan annually. The average income pre person has increased from 450 Yuan before 1985 to 1200 Yuan in in 1989. Also all housing has been modernized, In 1988 the local government of Tianjin decided to assist the development of Tuanbo into a tourist centre because of the geothermal utilization. [4]

4. CURRENT PROBLEMS

Because of lower enthalpy, any geothermal field with low or intermediate temperature levels require more smct and advanced techniques to achieve better economic results. In China, there are many problems in exploiting and utilizing geothermal energy, some of those listed below probably need to be dealt with urgently.

4.1 To date very little engineering studies of geothermal reservoir and no evaluation or monitoring procedures in the many geothemal fields. They are over - exploited without any management, so that the water table level is rapidly lowered .

4.2 No attempts to reinject geothermal fluid have been done and serious environment pollution problems (mainly due to the drainage of geothermal fluid) have not been solved. In some geothermal fields, however, with the absence of river, sea or sewerage channels nearby, the geothermal fluids were released onto the ground surface directly. Disposal is by evaporation into the air and by seepage, so that the soil were solidified and water in the shallow aquafer becomes polluted because of the accumulation of harmful chemicals contained in geothermal fluids. These adverse affects on the environment will be detrimental to the geothermal utilization in the future.

4.3 The equipment associated with geothermal development is often of low quality, not standardized and having a short lifetime. Other equipment is of high quality, but very expensive thus decreasing the profit margin. For example the present deep well pumps cannot stand

high temperatures and are corroded easily; also the costs of burying pipelines and purchasing plate heat exchangers are very high.

4.4 Unfavorable effects are caused by management not ensuring that practical techniques are up to the standard of high class quipment. For example, modern greenhouses are of good construction and automated, but the quality of seed and fertilizers are not always good and insufficient is known about microclimate control and plant protection from diseases and insect pests.

4.5 Multi-stage utilization is not sufficiently developed to avoid wastage. For example in district heating schemes the temperature of waste water is very high. If this was used for another purpose the economic benefit would increase and the heat pollution of the environment decreased.

4.6 A shortage of geothermal technicians and technical managers is common in most geothermal fields. China is a large country and about 0.8 billion people live in the countryside. Geothermal energy is a new technology to them. Knowledge of geothermal utilization is minimal in these areas and it is difficult to develop the resources. In recent years, Tianjin Geothermal Research and Training Centre (located in Tianjin University) has organized six special nation-wide training short courses on geothermal use, with a total of about 150 people participating. Even though the duration of the training courses is short, these people on their return to their organization become specialists in various fields. Obviously, it has been realized that the importance of possessing qualified technicians and engineers.

5. SCIENTIFIC RESEARCH ON THE UTILIZATION OF GEOTHERMAL ENERGY IN CHINA (1986- 1990)

During 1986-1990, the country-wide exploration and evaluation of geothermal fields were still arranged individually by the Ministry of Geology and Mineral Resources, and carried out by each provincial or municipal Bureau of Geology and Mineral Resources. Some research organizations also carried out a part of this work.

The research on the technology of the utilization of geothermal energy was listed under the national development plan and was under taken jointly by Universities, research Institutes and some enterprises. Research work was carry out in the following seven areas:

(1) Evaluation of Geothermal Resources and the Establishment of Databases.

This included the developing and evaluation of geothermal resources in typical agricultural areas, investigating the monitoring of thermal-fields, the proper utilization of the resources and establishing the national geothermal resources database and the national geothermal utilization database

(2) Geothermal Greenhouse Applied Techniques

Research has been carried out on the optimum structure for geothermal greenhouses as well as heating and ventilating systems. Studies have been done on the monitoring and the control of parameters, the characteristics of the micro-climate and modelling.

(3) Research on Geothermal Aquatic Products, Breeding, Overwintering and High Production Techniques

Research has been on the development of techniques for the overwintering protecting, high density breeding and early maturing of the aquatic products such as African fish, ells, turtles, Chinese fish, prawns etc. Computer software has been developed for the calculation of the over wintering fish pond design, multi-control of the parameter such as water temperature and dissolved oxygen.

(4) Geothermal Heating, Drying and Hatching Techniques

Research has included the technical details and the installation of low temperature geothermal hot-air ventilation heating systems. Also studies have been made on the design and assembly of a geothermal drying equipment and a geothermal hatching equipment (for 10×10^3 chicken eggs).

(5) Study of the Key Techniques of Engineering Equipment Utilizing Geothermal Energy

This has included development of techniques for anticorrosion and antiscaling, well-head equipment and monitoring systems, low-cost underground insulated pipeline and efficient, maintenance free pumps for deep wells. Also research for enhanced heat transfer techniques for the application of geothermal down-hole heat exchangers in China.

(6) Study of the Geothermal Water impact on the Environment and the Protecting Techniques

Research has included the monitoring of environmental pollution and the geothermal water disposal hygiene with research into the biological effect of the harmful trace elements in the water. Techniques are being developed for the purification of the discharge water, defluorination using mineral material. Research has also included the development of reinjection techniques.

(7) Establishing of the Bases for the Research and Test of the Techniques of Cascade Utilization of Geothermal Energy

Four different geothermal sites located at northern and southern part of the country have been chosen as the test areas which including the earlier mentioned Tuanbo base of multi-application of geothermal energy, located in Jinghai County, Tianjin.

By December 1990, most of the above projects in the seven areas will be completed. At this time, the techniques for geothermal energy exploitation and utilization as well as designs for the necessary equipment in China will have made a significant progress. But still, some techniques and problems, as described in section 4, have not yet been solved because of the lack of financial support, some are management problems. These unsolved techniques will be the basis of the major research topics for the development of geothermal energy in the next decade in China.

6. FURTHER COMMENTS

During the nineties, China has entered a new stage of geothermal development, with Chinese and foreign scientists making valuable contributions to the exploration and exploitation of the geothermal resources in China: We have grasped some fundamental exploitation and utilization techniques and information about these geothermal fields. Nevertheless, there is still much to develop in advanced techniques, equipment, technical man power, legal provisions and management. Apart from our own efforts, we hope that we can cooperate and/or exchange information with foreign geothermal scientists and engineers to explore and develop the geothermal resources in China, making some contributions to the world *geothermal* development.

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