THE STRATEGY AND PROGRAM ON GEOTHERMAL ELECTRIC GENERATION BY THE YEARS 2000 AND 2020 IN CHINA

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Key words *China-Yangbalin-Tengchong-Power* generalion-Geothermal

ABSTRACT

This paper is a proposal on geothermal energy for the New Energy Electric Generation Program formulated by the Chinese Ministry of Electric Power Industry. It covers the distribution of high-temperature geothermal resources, the status of existing geothermal power stations in China, and also forcast geothermal electric generation by the years 2000 and 2020.

1. INTRODUCTION

Although geothermal direct use in China leads the world, geothermal electrical use is disappointing compared with some other countries

High-temperature geothermal resources in China are mainly distributed in remote areas where conventional energy is limited, and the population is low. Tha small geothermal power plants have played or will play an important role in those areas

Based on the distribution of geothermal resource; and the local demonds on energy, the strategic focal points in China are to develop high temperature gecihermal resources in Tibet anti Yunnan. To maintain a yearly growth rate of 12%, the estimated geothermai elecliric generation in China by the year 2000 will have to be some 100 MW, and considering the reform of energy system which could occur, the aeothermal electric generation will increase to 400400 MW by the year 2020

This material is for "New Enerav Electric Generating Program (years 2000-2020)" which the Chinese Ministry of Electric Power Industry is formulating for the areas where lack conventional energies in order to solve gradually the energy shortage problems by the year 2020.

2. DISTRIBUTION OF HIGH TEMPERATURE GEOTHERMAL RESOURCES IN CHINA

There are four high-temperature geothermal belts in the world. Two of them connect with Chinese territory, one is the Circum-Pacific Geothermal Belt. which passes through eastern Taiwan; the other is the eastern part of Mediteranean-Himalayan Geothermal Belt, which lies in southern Tibet and western Shichuan, turns southward to western Yunnan and then downward to Thailand. The scope of the geothermal belt along the Mts Himaiaya and Hengduan are more than 2800 km long , and 200-400 km wide. The known geothermal system numbers are 112 in southern Tibet, 12 in western Shichuan, and 47 in western Yunnan, 181 in total. The preliminary estimated potential of electric generation is 6744 MW (30a) , of which, 6000 MW in southern Tibet, 174 MW in Western Shichuan and 570 MW in western Yunnan.

The high-temperature geothermal fields in Tibet are distributed mainly along the two sides of the Yarlung zangbo River, which is the junction of the European-Asian Plate and Indian Plate. Among those, 16 high-temperature geothermal fields are located in the area of Gae -Pulan, 12 at Chayu-Changdu, and nearly 80 are concentrated at the areas of Xietongman-Nimu and Dangxiong-Naqu (Fig 1)

Yunnan is the province which has the most numerous hot springs, 914 hot' springs have been discovered mainly in the west part of the province, which is also the area having less conventional energy resources. The high- temperature geothermal systems coexist with the volcanic area of Late Cenozoic age and are along the main faults in this area. The reservoir temperatures are estimated to be more than 200 ^{0}C. Tenchong is famous for its hot springs and volcanos (Fig. 2).

Western Sichuan is an area of highlands and mountains there , 12 high temperature geothermal systems have been discovered Geothermal water is used only for extracting salts at this time

3. THE PRESENT SITUATION, POTENTIAL AND PROBLEMS OF GEOTHERMAL POWER GENERATION IN CHINA

Geothermal electric generation in China began in early 1970s. It has gone on for more than 20 years. Now seven geothermal power plants exist in China, but the total capacity only 32.166 MW (Table 1).

Table 1 The Existing Geothermal Power Plants in China (1994)

Name of Plant	Type of System	Temp. of Fluid (^{0}C)	Installed Capacity(MW)	Year of establishment
Dengwu	single fla.	91	0.686	1970
Huitang	single fla.	90	0.30	1975
Qingshui	single fla.	150-130	3.00	1981
Tuchang	binery cyc.	173	0.30	1985
Yangbajian	binery fla.	140-160	25.18	1977-1992
Langjiu	single fla.	104	2.00	1987
Naqu	binery cyc.	113	1.00	1993

These areas are rich in geothermal resources but lack conventional energies, and the national power network will not reach them by the near future. The geothermal resources have been or will contribute greatly to these areas. Now some main geothermal fields are introduced here briefly:

Yangbajian Geothermal Field

It is located administratively at Dangxiong Town, 90 km northwest to Lhasa City of the Capital of Tibet, also it is located geographically in the wide and level basin at the

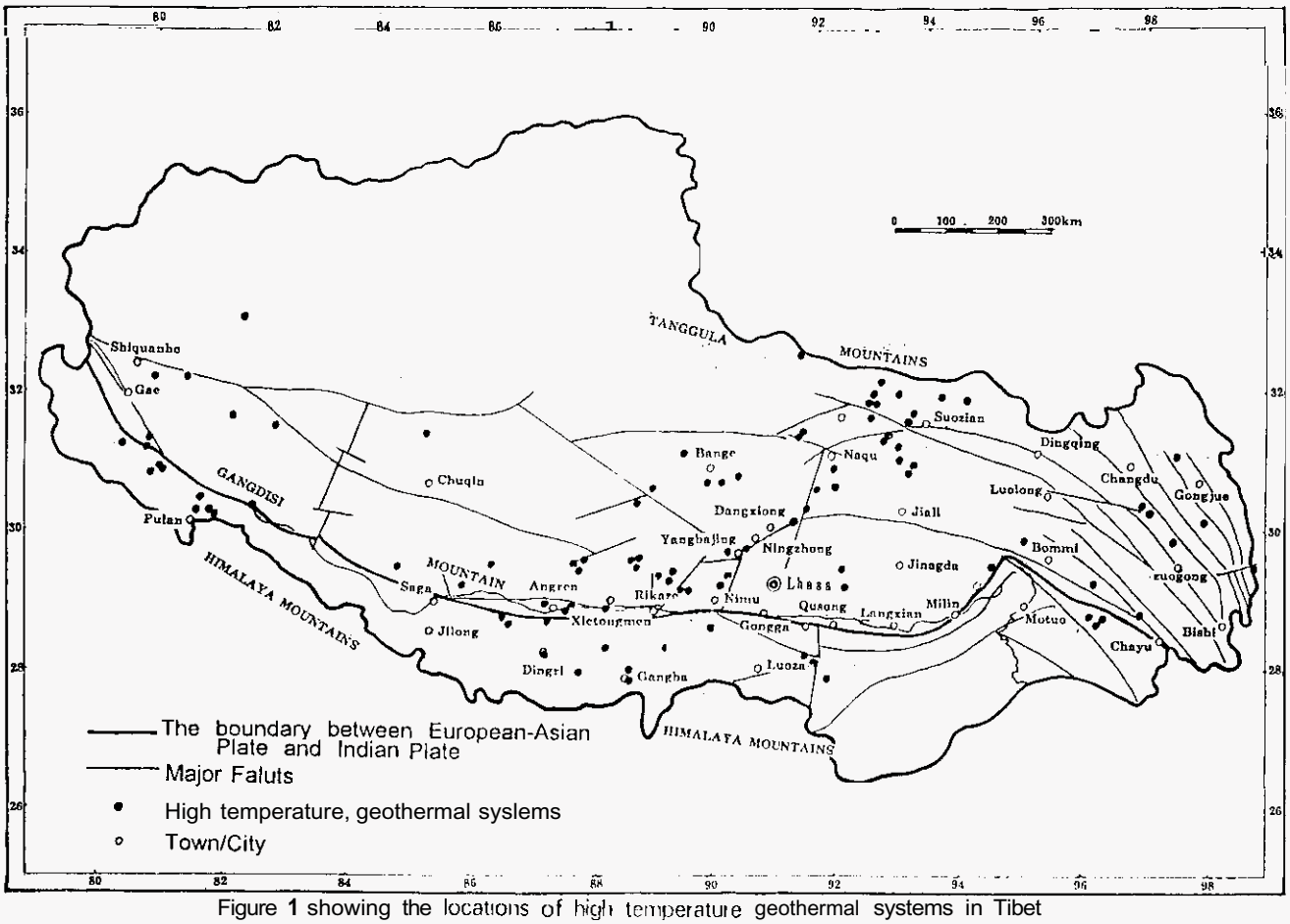

Figure 1 showing the locations of high temperature geothermal systems in Tibet

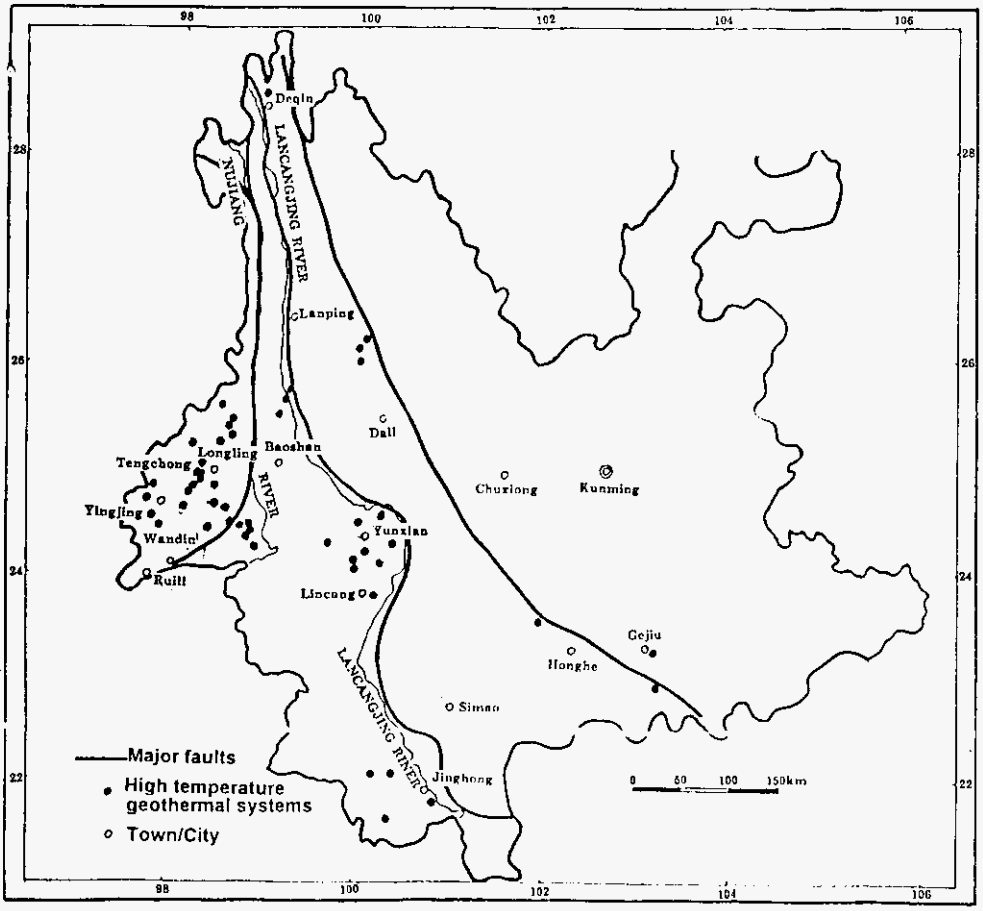

Figure 2 showing the locations of high temperature geothermal **systems** in Yunnan Province

base of Nianqing-Tanggula Mountains. Two rivers. Yangbajian River in the east and Zhanpaqu River in the south respectively, go through this field and snow mountains are surrounded it to the north and south. A total area of 14 .62 km^2 is estimated. The exploration of shallow reservoir occured during the years 1976-1984 With 18 production wells drilled, the total investment was about RMB 30 millions The electrical generation potential was estimated to be 34.11 kW(30a). Since the first unit of 1 MW began operation in 1977, the accumulated electrical supply has reached 63396 **X** 10^4 kWh (Table 2) at the end of 1993 Deducting 12% of electricity for power generation internal use, the net accumulated electric supply was 55788.47 **X** 104 kWh, 41 1% on the average of Lhasa power network, and more than 60% in the winter time. The waste thermal waters have been used for heating greenhouses of 50. 000 m^2.

Table 2 The Yearly Geoth Elec. Gen. in Yangbaijian

Year	Installed capacity(MW)	Electr. (10^4kWh)	Year	Installed capacity(MW)	Electr. (10^4kWh)
1977	1	4.94	1985	1000	363344
1978	1	8315	1986	1318	495498
1979	1	24784	1987	1318	437352
1980	1	31452	1988	1318	426890
1981	4	16359	1989	19 18	476655
1982	7	112307	1990	1918	605958
1983	7	29366	1991	25 18	8659 56
1984	7	339843	1992	25 18	8607 32
			1993	2518	980000

The geothermal power generation is competitive market with small hydro electricity and oil electricity Table 3 shows the comparation of the costs different power generation types in Tibet

Table 3

Type of Energy	RMB/kWh	Performance Hours
Hydro-elec	0 08	less than 3000
Oil-elec	0.58	5000
Geoth -elec	0.12	7500

The Chinese Geothermal Committee suggested exploitating the high temperature geothermal resources at Yangbajian Geothermal Field to the Tibet Government in 1900, and held an International Symposium on Tibet High Temperature Geothermal Resources at Lhass in 1992. The symposium summed up the experience of experts who took part in the meeting and also identified three deep weil locations at the northern part of Yangbajian Geothermal Field. Thanks to experts' good works, a temperature of 329.8 ^{0}C at depth of 2006m was measured on Nov. 8, 1993. Preliminary estimates based on parameters of short testing, the potential of power generation for this single well could reach 10 MW This is the first well with temperature over 250 ^{0}C in the Mainland China. It implies that high-temperature geothermal generation will be possible reach in China in the near future.

Shiquanhe Geothermal Field

It is also called Langjui Geothermal Field and is located at the far western part of Tibet, 30 km east of Shiquanhe, 4500 m above sea level, an area of 0.4 km^2, and has a reservoir temperature of 180 ^{0}C. According to the Tibet-Qinghai Plateau Comprehensive Sciences Investigation Group 1976, the estimated electric generation potential could be 10,000 kW. In the early 1980's, with an average well space of 150 m only, 13 wells were drilled in an area of less than 1 km^2. Because cold water from upper beds leaked down along the well walls, part of geothermal reservoir was damaged. With temperatures ranging from 101-105 ^{0}C, a total installed capacity of 2 MW had been built by 1987 Currently the electrical equipment does not run steadly.

Naqu Geothermal Field

It is located at 2 km south of Naqu Town, 4500 m above sea level One diesel-electric unit had been set up at the town before 1993, but it costed RMB 0.8/kWh, so the people there used candle and butter for lighting. During the years 1985-1989, the geothermal exploitation was carried out by the Tibet Geothermal Team. The investigation reveals that the Naqu Geothermal Field has an area of 10 1 km^2, reservoir temperature of 170 ^{0}C, and well head temperature ranging from 110-113 ^{0}C. With a high pressure downhole electric pump, a binery cycle experimental geothermal generation was set up in Nov. 1993 aidded by UNDP This is the third geothermal field explored for electrical use in Tibet. If it is successful in operation. the small power generation of this kind will be used broadly in China.

Yangyi Geothermal Field

It is located 45 km southwest of Yangbajian, 4550 m above sea level, an area of 10.75 km^2, of which, the area of high-temperature(>150 ^{0}C) to be 1.595 km^2. The estimated potential for electrical generation of shallow reservoir is 30 MW. The character of this geothermal field, compared with those above mentioned are as follows

-- shallow high temperature reservoir. In well *No.* 208. a temperature of 207.16 ^{0}C was measured at depth of 312m. This will reduce the cost of production wells;

-- good water quality. The content of CO_2 is relatively low despite a lot of noncondensable gas in the water, *so* that the $CaCO_3$ scalling in the well might be slight;

-- stable parameters of geothermal reservoir The parameters of temperature, pressure and flow rate were stable basically during in 896 hr. of tests from Sept. 18 - Oct. 26, 1990. It is proved that this geothermal field should be the next one to be developed for high temperature geothermal power generation in mainland China

Rehai Geothermal Field

It is located at 11 km southwest of Tengchong township, Yunnan Province, 1460 m above sea level The hydrothermal manifestations are quite strong in an area of 10 km^2. It could be divided into 20 manifestation zones. such as the well- known Liuhuantang and Huangguaqing. A hot spring named "Big Boiling Pat" with temperatures of 96-98 ^{0}C, appears in the densely wooded, colorful and flourishing valley. It has attracted hundreds and thousands tourists and patients who need to recuperate. The reservoir temperature was estimated to be 276 ^{0}C. It is the highest one estimated so far in western Yunnan. and has became a good natural steam bathing place. According to the Second Hydrogeological Team, Yunnan Bureau of Geology & Mineral Resources, the potential installed capacity could be 233 5 MW (30a). Based on the latest information obtened by MT, the area of Rehai Geothermal Field might be larger than previously estimated

Reshuitang (Lanpu) Geothermal Field

10 km south from Rehai, 1119 m above sea level. A hot

spring with temperature of 98 7 ^{0}C is found on the half way up the mountain The reservoir temperatures' estimate range from 161-221 ^{0}C The area of the geothermal field was estimated to be 4 5 km^2 The potential installed capacity could reach 95 8 MW (30a)

Redian Geothermal Field

With an area of 3 2 km^2, 189 ^{0}C of reservoir temperature Redian Geothermal Field is located at 60 km north of Tengchong Township The potential installed capacity is estimated to be 47 2 MW (30a)

Reli Geothermal Field

Reli City is an important southwestern commercial and trade port with three international boundries surrouded by Burma. The Reli Geothermal Field is located on the bank of Lijiang River. It has an area of 11.8 km^2, reservoir temperatures ranging from 215 to 227 ^{0}C. With a temperature of 96-102 ^{0}C, the Peacock Hot Spring is famous for its high temperature and beautiful scenery. The estimated potential installed capacity is 19.8 MW (30a).

The areas of Litang and Chaluo in western Sichuan Province are other zones of high temperature geothermal field, and also the energy shortage zones, 3300-4180 m above sea level. Three groups of boiling springs are distributed in the Kailong Boiling Spring Valley, their temperatures ranging from 80-86.5 ^{0}C, pH=8.62, TDS= 1550 ppm, containing rare elements of Rb(0.77 ppm). Cs(3.04 ppm). The estimated reservoir temperatures are up to 190 - 220 ^{0}C. Because of limited reservoir area, the eletric potentials are estimated less than 10 MW.

4. THE GEOTHERMAL POWER GENERATION DEVELOPMENT STRATEGY AND PROGRAM IN CHINA BY THE YEARS 2000 AND 2020

4.1 The Geothermal Electricity Development Strategy in China

There is little fossil fuel and the national and regional eletrical networks can not reach the areas of the Tibetern Plateau, western Yunnan Prov.. and western Sichuan Prov., but these areas rich in high temperature geothermal energy resources. It is therefore important to give priority to the development of geothermal energy resources. The combination of geothermal energy and small hydro energy in areas of having both resources should be considered, in order to compensate for the generation difference between the rain season and the dry season caused usauaiy by use of the hydro-elecitricity. If it would be done, the electricity shortages will be overcome fundamentally in those areas above mentioned.

The primary investment cost of geothermal generation is nearly the same as for hydro-electric, but lower than coal-electric and oil -electric, and it is running all year round. The annual performance time is more than 7000 hrs, and the environmental effects are obvious.

According to the distribution of high- temperature geothermal resources and the demands of local economic development ,in China, the strategic focai points will be as follows:

-- to produce more than 200^{0}C geothermal fluids at deep reservoir of Yangbajian Geothermal Field and to promote the development of Yangyi Geothermal Field as a whole, in Tibet, in order to increase the capacity of electric generation in these areas;

-- to build the geothermal power generation with geothermal fluid temperature of 200 ^{0}C and more, and the single unit of 10 MW at Tengchong region, west of Yunnan.

The main tasks are:

--to speed up the exploitation of the deep reservoirs at Yangbaijian Geothermal Field in Tibet,

-- to develop the Yangyi Geothermal Field, Tibet, with a modern portable 10 MW grade geothermal power generation;

-- to establish a 3-5 MW geothermal power generation first at Reli Geothermal Field, west of Yunnan, and then to develop Tengchong Geothermal Field with a 10 MW geothermal power generation in the period of 1995-2000;

-- to explorate the geothermal energy as energy bases at the regions of Rekeze, Ningzhong. Laduokan of Tibet and west Sichuan in 2000 and later.

4.2 The Program and Forecast on the Geothermal Electrical Generation

The Program

According to the condition of geothermal electric resources and the local demands on energy, the selected areas for programming should also be the ones where there is good transportation condition and beneficial effects on society economy and environment could happen in a short time.

Tibetan Area:

Taking the Yangbajian Geothermal Field as a center, to satisfy first the Lhasa Electric Network need, and taking account the energy demond in Rekeze region;

-- to develop the deep high- temperatue geothermal reservoir at Yangbajian Geothermal Field and expand the installed capacity first;

-- to develop the explored Yangyi Geothermal Field and to exploit simultaneously Ningzhong and Laduokan geothermal fields as reserve bases for Lhasa area,

-- to exploite the surrounding areas of Langjiu Geothermal Field to guarantee energy in Alee region,

-- to explore the deep reservoirs in Naqu Geothermal Fieid for expanding the existed installed capacity;

-- to carry out exploration at Xietongmen Geothermal Field to provide information for eiectric supply at Rikaze the second largest city in Tibet.

Western Yunnan'

-- launching a pilot project first at Reli Geothermal Field, and then developing Rehai Geothermal Field of Tengchong as well as Pannazhang Geothermal Field of Longling.

Western Sichuan

--developing the geothermal fields at Litang and others of western Sichuan where a Project for non-electric towns will be carried out

The Forecast

It is mainly based on the annual increase rate of geothermal electrical generation in last 12 years and also on the trend of the national economic development first, and then the situation on geothermal resources, the advanced technology used for geothermal development and electrical generation as well as the enviromental consideration.

According to the average annual increase rate of geothermal electrical generation from 7 MW in 1982 to 25.18 MW in 1994 in mainland China, the exact average annual increase rate was 12%. Before the year 2000, the growth rate will be unchanged, thanks to Chinese economic reforms. The energy system reform might cover various aspects including the enterprise management reform, a resonable price of electricity and favourable policy. Therefore, a rapid development of geothermal energy will be expected by the year 2020. The results of forecast are shown in Table 4.

Table 4, The Forcasting Growth of Geoth Pow Gen in China

Loc	1995	2000	2010	2020
Yangbajian	25 18	50-60	80-100	120-160
Yangyi	20-25	50-60	60-100	
Naqu	1.0	1-2	5-10	10-20
Langjiu	2 0	2-3	5-10	5-10
Others			5-10	10-50
Reli	3-4	5-10	10-20	
Tengchong	5-10	50-80	150-200	
Others		5-10	10-15	
Others		3-5	5-10	
Total	28.18	81-104	208-295	400-585

4.3 Estimation **of** Investment

By the year 2000

Tibetan Area:

For reaching the goals showed in Table 4, the new installed capacity will be 45 - 62 MW, thus the total installed capacity in Tibet will add up to 73- 90 MW. According to the unchangeabie price in 1990, the exploration (production well drilling mainly) expanse is roughly estimated for 14 - 19 production well drilling could be RMB 75-100 millions. asuming the average well depth of 1500 m and each well costs RMB 5.35 millions; also according to the primary estimation of RMB 6000/kW, the total investment for construction of new installed units wiil be RMB 240 - 390 millions. The total investment amount to RMB 315 - 490 millions by the year 2000.

Western Yunnan:

According to the forecast results skowied in Table 4, the total installed capacity there will reach 8- 14 MW The exploration expense (production weli drilling mainly) s estimated to be RMB 27 -38 millions for drilling 5-7 production wells, assuming the average well depth of 1500 m, the cost of singie well to be RMB 5 35 millions; also according the cost of RMB 5000/kW, 8-14 MW of new installed units, the total investment for construction will be RMB 4065 millions. The total investment amount to RMB 67-103 millions by the year 2000.

Therefore, the total investment for geothermal electricity use in China by the year 2000 will amount to RMB 400800 millions.

4.4 The Economic Benefit Analysis

On the basis of the geothermal power station performance and the price of electricity. the geothermal electric generations have run steadily. The total performance time could be more than 7000hr per year in general The electricity used for each power station for its own needs are estimated to be IO-12%

Tibet.

Taking a 10 MW-unit for example, the electric price for user is RMB 0.35/kW, the total investment for a 10 MW station is estimated to be RMB 70.75 millions, the annual income will be: 10(MW) X 7000(hr) X (1-12%) X 0 35(price of 1 kWh) = RMB 21.65 millions.

Therefore, the recovery wiil be 78.7512156=3 65 yr If compare the performance with hydro-electricity and geothermal-electricity. the hydro-electrical performance mainly in summer time and the geothermal electrical performance mainly in winter time, therefore the geothermal electrical performance time is expected less than 7000 hr yearly, thus, the recovery will be up to more than 5 years.

Western Yunnan.

Taking a 10MW-unit for example too, the performance time to be 7000hr, the electricity used for station its own to be 10%. the price to be RMB 0.5/kWh, the total investment amounts to RMB 79. 23 millions, the annual income will be: 10(MW) X 7000(hr) X (1-10%) X 0.5 (the price of 1 kWh) = RMB 31.50 millions

Thus, the recovery is to be 79.23/31.50=2.52 yr.

Also if taking the consideration for the factors above mentioned, the maxium recovery will be no more than 5-6 years.

5. CONCLUSION

The high temperature geothermal resources are concentrated mainly in southern Tibet and western Yunnan of mainland China. So far, the installed capacity totals 28 18 MW only. However goethermal plays an important role in the areas where lack of conventional energy or the regional power networks are difficult to reach. From the views point of economical and social matters. the development strategy for geothermal power generation must focus on exploitation high temperature geothermal resources, in order to solve the energy shortage problems in those areas.

To achieve the goals, there are many difficult tasks for **us.** we should strengthen the international cooperation on research and development in the field of geothermai resources as we did before. Thanks are given to UNDP and other friendly countries for their great contributions to Chinese geothermal development. With the country economic reform to be continued in China, the exploration and construction of geothermal power plant by means of foreign invest alone or in joint ventures are most welcomed

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