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GEOTHERMAL RESOURCES AND UTILIZATION IN TIBET AND THE HIMALAYAS

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ABSTRACT

Tibet is located in the east section of the Mediterranean-Himalayan Geothermal Zone, one of the world's greater geothermal zones. Various high temperature geothermal manifestations are distributed throughout Tibet. In Yangbajain and Yangyi etc. 10 geothermal fields have been explored or detailed surveys have been made. The total resource potential is 299 GW. Yangbajain has an installed capacity of 24.18 MW_e and has run safely for nearly 30 years. Medium-low temperature geothermal resources are used in greenhouses, baths, for medical care, space heating and industrial washing amongst other aspects. The geothermal resources are suitable for district heating and have great potential. Furthermore, utilization of shallow geothermal energy by means of Geothermal Shallow Heat Pumps (GSHPs) can satisfy the demands for space heating in Lhasa and most other larger towns in Tibet.

1. INTRODUCTION

There are abundant geothermal resources in Tibet. More than 600 hot springs are distributed throughout the area. It ranks second place with regards to available geothermal resources in different provinces, regions and cities in our country. In addition Tibet is the area where most of the geothermal manifestations hotter than 100°C are located; In fact nearly half of the total of geothermal manifestations hotter than 100°C, in China, are located in Tibet, and the total reserve of thermal energy ranks first in the country. Such superiority of resources is able to and should play an important role in development of renewable energy in Tibet. The Yangbajain Geothermal Power Plant located 90 km north-west of Lhasa has been generating for nearly 30 years. Geothermal electricity not only plays a great role in the power supply in Lhasa, but also serves as a reserve for insufficient hydropower in the winter. Geothermal electricity is very important in Tibet. It is absolutely necessary especially in winter. In addition, utilization of geothermal resources has the ability to solve the request for space heating in the winter in Tibet.

2. RICH AND COLOURFUL GEOTHERMAL MANIFESTATIONS

2.1 Himalayan geothermal zone

High temperature geothermal resources are mostly concentrated in the worlds global geothermal zones. These are the Pacific Ring of Fire, the Atlantic Mid Ocean Ridge and the Mediterranean–Himalayan Zone. These zones are controlled by major geological tectonics. Generally speaking, this is where the earth’s crust is abnormally thin due to active tectonic movement resulting in the high heat flow, giving rise to various geothermal manifestations. The Himalayan Geothermal Zone is the eastern part of the Mediterranean–Himalayan Geothermal Zone. It is distributed across Tibet in a west-east direction along the Yarlung Zanbo “suture line”. The suture line is a geological boundary between Eurasian (crust) Plate and the Indian (crust) Plate. The suture line features a weak connection, where the earth’s stress is easily concentrated during earth’s compaction, collision and friction movements, and faults in the suture zone serve as channels of heat up-flow from the inner earth. Almost all high temperature geothermal resources and most medium-low temperature geothermal manifestation are distributed along this wide zone. Its width is about 400 km, and the length is some 2,000 km at our country boundary.

2.2 Natural geothermal manifestations

High, medium and low temperature natural geothermal manifestations are of various types. There are a total of 45 locations of boiling springs, boiling fountains, hydrothermal eruptions and geysers with temperature higher than the boiling point. High temperature springs with temperatures ranging from 80°C to the boiling point occur in 7 locations. Medium-high temperature springs with temperatures ranging from 60 to 80°C occur in 83 locations. Medium temperature springs with temperatures ranging from 40 to 60°C appeared in 109 locations. Low temperature springs with temperatures ranging from 25 to 40°C are found in 62 locations.

Yangbajain is one of most famous geothermal manifestations, located in Dangxiong County, about 90 km north-west of Lhasa. There are many boiling springs, hot springs, hot lake, steaming ground and hydrothermal eruptions etc. In the area the highest temperature is 93°C, higher than the local boiling point and geothermal exploration has been carried out since the mid 1970s. Two phase liquids of steam and thermal water of 141-172°C were found at about 200 m depth. Geothermal power generation started in 1977 and became an important source for the electricity supplying in Lhasa.

The Dagjia geyser, located in Angren County, is the biggest geyser in China. Its has the highest elevation in the world at 5,080 m above sea level. There is an irregular interval between eruptions reaching up to 20 m. The vent appears on a large terrace of siliceous sinter and more than 200 thermal manifestations are scattered around its location. Amongst these are close to a 100 boiling springs with temperatures of 86°C and there are other hot springs, warm springs and hot ponds, etc. The total flow rate is about 7,000 m^3/d.

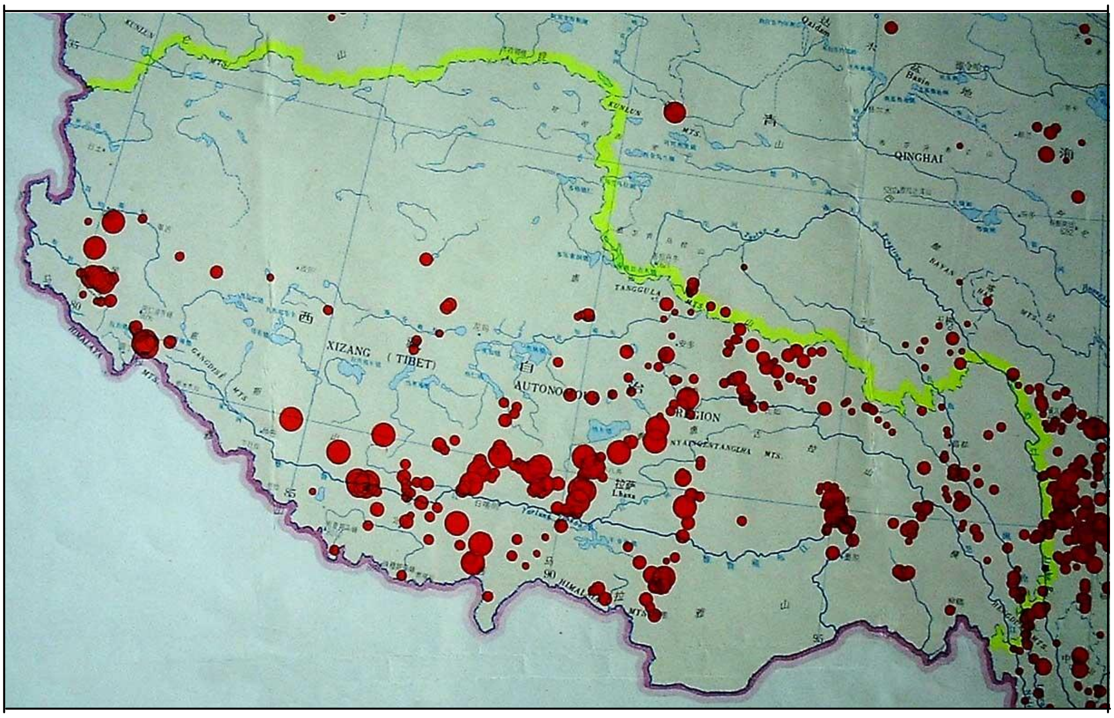

FIGURE 1: Distribution Map of Hot Springs in Tibet

The Gulug boiling fountain is located in Nagqu County nearby the Qinghai-Tibet railway. In association there are various manifestations such as boiling fountains, boiling springs, warm springs, fumaroles and siliceous sinter etc. Most of them are of a temperature of 85-86°C. The highest temperature of 92°C is higher than the local boiling point. The total flow rate is 500-700 m^3/d and the amount of total dissolved solids (TDS) is nearly 4 g/l.

The Langju hot spring is located in Siquanhe Town, in the Arli area. Its temperature is 78°C with a total flow rate 400-600 m^3/d. The thermal water has a TDS content of 2 g/l. Geothermal wells were drilled to a depth of 100 m in the 1980s and a small scale geothermal power plant was constructed then.

The Nagqu warm spring is located in Nagqu Town of Nagqu County. The thermal water has temperature of 40-61°C. A small scale geothermal power plant was also constructed here in the 1990s.

Most high temperature hot springs are far away from cities. This causes difficulty for development and utilization. However, there are many hot springs near the Qinghai-Tibet railway, distributed in Latogka, Dongweng, Xumai and Jidaguo etc.

3. GEOTHERMAL RESOURCES IN TIBET

3.1 Investigation and surveys

In the 1960s-1970s the Comprehensive Science Investigation Team of the Qinghai-Tibet Plateau of the Chinese Academy carried out preliminary geothermal investigation in Tibet. Temperature, flow rate and other parameters were measured from hot springs at the field sites. From these data the natural heat diffusion was estimated.

Tibet Bureau of Geology and Mineral Resources (TBGMR) is responsible for geothermal resources exploration and assessment in Tibet. The Tibet Geothermal Geological Team, TBGMR implemented corresponding reconnaissance, detailed surveys and exploration of geothermal resources in the Yangbajain, the Yangyi area, and other areas. The Tibet Geothermal Geological Team was established in 1976. It completed detailed surveys and shallow reservoir exploration in the Yangbajain geothermal field during 1976-1984, completed detailed surveys and exploration in the Yangyi geothermal field during 1985-1990, and then completed exploration for deep reservoirs in the Yangbajain geothermal field during 1992-1997. At present only these three reservoirs in two geothermal fields have completed exploration stage. The geothermal resources potential for the Yangbajain shallow and deep reservoirs are 34MW and 31.8MW respectively. The Yangyi geothermal field has a potential capacity of 30MW. The existing Yangbajain Geothermal Power Plant uses shallow reservoir only.

Detailed surveys were, in addition, completed in another ten geothermal fields, including Nagqu, Latogka, Langju, Gulug, Dongweng, Xumai, Jidaguo, Qucain, Gariqiao, Tuoma and Luoma. They are all close to the Qinghai-Tibet railway. The total sum of geothermal potential in these geothermal fields is 137.5 MW of capacity.

3.2 Evaluation of geothermal resources

Geothermal resources assessment has been carried out by the Tibet Bureau of Geology and Mineral Resources. Based on field investigation including geological, geochemical and partial geophysical surveys, according to the ministry standard of “Geothermal Resources Assessment Methods” issued by the Ministry of Geology and Mineral Resources, the estimated geothermal resources in Tibet is $3{,}096.45 \times 10^{18}$ J. The total exploitable geothermal potential is a 298,830.4 MW capacity. Table 1 shows the details.

TABLE 1: Estimated Geothermal Resources in Tibet

Division	**Manifestation locations**	**Average spring temp. (°C)**	**Reservoir temp. (°C)**	**Exploitable resource (MW)**	**Reservoir area (km^2)**	**Resources (10^{18} J)**
S. Tibet	234	58.19	142.76	80,962.9	255.60	1,558.33
Central Tibet	151	46.42	120.19	115,643.0	130.11	729.58
E. Tibet	190	39.73	105.63	76,669.7	82.00	469.70
W. Tibet	49	51.40	134.02	17,639.7	47.49	231.86
N. Tibet	40	9.60	76.58	7,915.1	5.00	106.98
Total	**664**			**298,830.4**	**520.20**	**3,096.45**

4. GEOTHERMAL UTILIZATION IN TIBET

4.1 High temperature geothermal power generation

High temperature geothermal steam is most suitable for power generation. For medium temperature geothermal resources "binary" techniques can be used for power generation. In Tibet there are three geothermal power plants.

The Yangbajain Geothermal Power Plant consists of two plants: the south plant and the north plant. There is a 1 MW test unit and 3 × 3MW units installed in the south plant. In the north plant there is a 3.18 MW Japanese unit and 4 × 3MW units. Total installed capacity for both plants is 25.18 MW. The 1 MW test unit retired in 1985. The operating installed capacity is, therefore, 24.18 MW in Yangbajain and the annual generation is about 100 GWh in recent years. The total generation from the plant reached 2,120 GWh at the end of 2007. Yangbajain geothermal electricity supplies to Lhasa. In the 1980s there were 9.6 MW of diesel oil generators and 19.2 MW of small hydropower generators in Lhasa. The heat engine plant ran at high cost. Hydropower generators are almost out of production in the winter, which previously gave rise to serious power shortage in Lhasa. However, geothermal power generation is not affected by seasonal variation. Before the construction of the Yamzho Yumco Hydropower Plant, geothermal electricity supplied 50% of Lhasa´s demand in the summer and 60% in winter.

The Arli region is experiencing a seriously lack of electricity. The Langju Geothermal Power Plant had 2 × 1MW units installed but now only 1MW unit works with an output of about 0.4 MW. It runs 2,000-3,000 hours annually, and annual generates about 1 GWh.

In addition, the Nagqu Geothermal Power Plant installed a 1 MW binary unit in 1993 but production was terminated due to serious scaling problems.

4.2 Medium-low temperature geothermal direct use

There is only little utilization of geothermal for direct use in Tibet. However, geothermal water is used for greenhouses, bathing, medical care and tourism, space heating, industrial washing and drinking mineral water bottling etc.

4.2.1 Geothermal Greenhouse

Yangbajain geothermal power plant discharges about 50,000 m^3 of hot water (80^{o}C) per day. Most of this water is discharges into the Zangbu River, although a small part is used for greenhouses. A typical greenhouse at the highest elevation (4,300 m a.s.l.) in the world is a half spherical shape, covering 1,000 m^2 with steel framework and a glass top. Other small simple greenhouses cover a total area of 26,000 m^2. Over 70 kinds of vegetables are grown, with an annual production capacity of about 300,000 kg. Currently, the existing production is only about 140,000 kg per year due to aged equipment, and the economic gain has decreased from 1 million *yuan* to 0.3 million *yuan*. There are similar greenhouses (about 900 m^2) in Nagqu and Langju of the Arli district.

4.2.2 Hot Spring Bathing

Tibetan people take baths in hot springs if the spring is close by their village. Hot spring baths are usually simple and free of charge in rural areas. There are about 100,000 visits to the baths annually.

4.2.3 Medical Care and Tourism

There are 5 locations using hot springs for medical care and tourism in Tibet. The Riduo Hot Spring Spa was established several years ago. It is close to Lhasa and provides hot spring baths, medical care and tours for guests. There is a geothermal swimming pool in the Yangbajain using waste (separated) water from the geothermal power plant. Similar utilization occurs also in Kangbu in Yadong County, Quzika in Mangkang County and Ningzhong in Dangxiong County.

4.2.4 Geothermal Space Heating

In 1985 geothermal was used for space heating of 30,000 m^2. Due to corrosion problem the area decreased to 5,000 m^2 in 1998. In addition, Cuona County passes hot spring water through private owned ground for geothermal heating purposes in a total of 3,000 m^2. It is believed that 50,000 m^3 per day of thermal waste water from the Yangbajain geothermal power plant could be transported to Lhasa for pace heating. Serious problems with corrosion and temperature loss existed previously, but can be solved at present.

4.2.5 Hot Water Industrial Washing

There is small scale utilization for washing sheep’s wool and tinkalite (a mineral product).

4.2.6 Bottling Drinking Mineral Water

The hot spring water in Longma in Jiangzi County and Xiamula in Anduo County has reached the standard of natural mineral drinking water. This water is being bottled for consume.

5. PROPECTS OF SPACE HEATING DEVELOPMENT IN LHASA

Urbanization is low in Tibet. There are two major cities, Lhasa and Xigaze in Tibet. The rest of Tibet is country side and highland. The urbanization level for Lhasa was 45% in 2000. It is planned to increase by 60% in 2010. The winter space heating needs can be exemplified by the situation in Lhasa. Lhasa's winter weather is affected by the sinking cold air current of the northern Himalaya Mountains. On sunny days rain is rare. In winter it is rather cold and the summer is warm. The climate belongs to the plateau monsoon semi-dry climate. The annual maximum temperature is 29°C, the minimum temperature is –16°C, and the annual average air temperature is 7.4°C. Space heating is designed for outside air temperature below –6°C. The average temperature during the heating period is 0.7°C. There are 149 days total with temperatures less than 5°C. These are the numbers that space heating needs are based on.

5.1 Thinking about geothermal space heating

The Yangbajain geothermal power plant discharges thermal water from steam of 80^{o}C and with a flow rate of 50,000 m^3 per day. A share of the energy is used for geothermal greenhouse and swimming pools. Test is carried out with reinjection of a small part of the water. Most of the water is discharged into the local Zangbu River. The waste heat pollutes the river water with high contents of fluoride and boron etc. The thermal waste water would be utilized better for winter space heating in Lhasa 90 km away. Previously there have been concerns about corrosion problems, temperature loss, high pressure in pipelines and environmental pollution but all of these problems can be eliminated today.

The potential of space heating can be estimated as follows: The thermal waste water will lose 5^{o}C when passing through heat exchanger. In transmission pipelines the water will lose an additional 6^{o}C. When arriving in Lhasa the water will be 69^{o}C. With a heating index of 60 W/m^2 and a waste water temperature of 35^{o}C, the total thermal energy can cover a heating area of 1.37 million m^2. It is 35% of total build-up area in Lhasa.

With the use of GSHPs the water can be utilized to a temperature of 15^{o}C, which will give an additional 1.09 million m^2. In this scenario the total geothermal energy can cover 60% of the total build-up area in Lhasa.

When the Yangbajain deep reservoir is developed, supplementary discharge can be used for geothermal space heating.

5.2 Possibility of ground source heat pump

GSHPs have had an immense and continuous growth in the world in the recent 10 years or more. They have the highest efficiency of 300-400% (COP= 3-4) and do not cause environment pollution. Consequently, GSHPs is an obvious solution, to solve winter space heating needs.

For open system GSHPs, there are rich groundwater resources especially along the Lhasa River basin. Lhasa city is mainly located on the Lhasa River basin. Groundwater is available in drill wells of 30-50 m depth. It is feasible to use 5^oC temperature difference between geothermal water and surface air temperature. A shallow well drilled on the Lhasa River flood plain and bench can obtain production rate of 80 m^3/h. For a total build-up area of 3.91 million m^2 in Lhasa, with a heating index 60 W/m^2, the total heat load is 234.66 MWt, this requires 504 production wells and other 504 reinjection wells with a total flow rate of 40,354 m^3/h. The constructed 51 km^2 urban area in Lhasa, cover 60% of the land. With 2x504 wells the space between wells will be 174 m. This density is no problem for flood plain and bench and there will be no interference among wells.

For closed system GSHPs, heat exchanger drill holes are spaced 5 m apart. This is equivalent to one hole per 25 m^2. The depths of the holes are 200 m. A 7^oC temperature difference is feasible. The thermal conductivity for soil and rock is 2.1 W/m^oC without anomaly. By these parameters a hole with a U-type circulation pipe will be able to collect about 5.6 kWt thermal power and can supply heating for approximately 100 m^2 of built-up area. In other words, 25 m^2 of land can satisfy a thermal demand of 100 m^2 of build-up area, or 1 m^2 of land can satisfy a thermal demand of 4 m^2 of build-up area. Density will never be a problem for the application of closed system GSHP.

6. CONCLUSIONS

The east section of the Mediterranean-Himalayan Geothermal Zone passes through Tibet. Various high temperature geothermal manifestations are distributed throughout i.e. Yangbajain, Yangyi . In 10 other geothermal fields exploration or detailed surveys have been carried out. The total resource potential in Tibet is 299 GW. Yangbajain has an installed capacity of 24.18 MW for power generation and has run safely for nearly 30 years. Medium-low temperature geothermal resources are used in greenhouses, baths, medical care, space heating and industrial washing etc. Geothermal is suitable for district heating and has great potential. Shallow geothermal energy can be used everywhere by GSHP and can possibly satisfy the total demands for space heating in Lhasa and larger towns in Tibet.

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