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GEOTHERMAL DEVELOPMENT IN CHINA AND THE ROLE OF UNU-GTP

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ABSTRACT

Geothermal resources figures for China are updated and status of utilization is reviewed. The contribution by the Geothermal Training Programme of United Nations University (UNU-GTP) in Iceland is appraised in terms of work done by the trained professionals from China in the past 40 years. The paper considers that: China is rich in geothermal resources and much progress has been made in its exploration and utilization especially in the direct use of geothermal for space heating. The trained professionals from China have been the main task force to these achievements. The country has high demand for geothermal energy and has made ambitious plans of utilization for the future. New discoveries in exploration and successful models of utilization are promising signals for a continued cooperation of UNU-GTP with China, to achieve more in geothermal development.

1. INTRODUCTION

The Geothermal Training Programme of United Nations University (UNU-GTP) is a postgraduate training programme, aiming at assisting developing countries in capacity building within geothermal exploration and development. The programme consists of six-month annual training for practicing professionals from developing and transitional countries with significant geothermal potential. The programme has operated in Iceland since 1979. It is a co-operation between United Nations University and the Government of Iceland and is hosted by Orkustofnun – the National Energy Authority of Iceland.

I first came to Iceland in 1988 on the 10th annual session of the training programme and took part in the training on "Chemistry of Thermal Fluids" for 6 months, which was exactly 30 years ago. It was right after I got my PhD degree in China so it was like postdoctoral work for me. Although it was short in time, it was my first experience out of my country. In my research and teaching career, I have mainly studied groundwater and geothermal systems in China and abroad. During my job with the Water Resources Programme of International Atomic Energy Agency, my duty has taken me to most of the geothermal countries in the world, but my international experience began in Iceland.

On the occasion of the 40th anniversary of the UNU-GTP, I am honoured to be invited to join the celebrations. I have come with warmest congratulations and very best wishes from all of the Chinese fellows of the UNU-GTP. I would like to express our sincere gratitude to the directors and teachers, including the supporting staff of the UNU-GTP, and Orkustofnun – the National Energy Authority of Iceland, where UNU-GTP shared a part of the office building ever since my time and earlier days, to the Icelandic government and its people during the last 40 years, for all the support we enjoyed during the training. Happy birthday to the UNU-GTP!

I am pleased to make a brief review of geothermal development in China with emphasis on recent development and future plans. I will discuss how the UNU-GTP has helped China in geothermal development.

2. GEOTHERMAL RESOURCES IN CHINA

2.1 New heat flow data and geothermal background

Heat flow is a measure of heat loss from the earth's surface through conduction, so it reflects the geothermal background of a region. The Geothermal Research Centre of IGG-CAS has been measuring and compiling data to keep it updated for China (Wang et al., 1988, Wang et al., 1990, Hu et al., 2000). The most recent edition (Jiang et al., 2016) reported 1230 data points. The highest heat flow in China is found in the southwest – in the Qinghai-Tibetan Plateau (90 mW/m^2) and Taiwan, lower heat flow is experienced in the east and southeast (55-65 mW/m^2), and the lowest in the northwest part of the country (50 mW/m^2). This is in good agreement with the tectonic environment of China.

China is a part of the Mediterranean-Himalayan geothermal belt, in which Qinghai-Tibetan Plateau is very rich in high-temperature geothermal resources. China is also a part of the Circum-Pacific geothermal belt, in which Taiwan shows high-temperature manifestations and east China exhibits higher heat flow, as a consequence of the subduction of Western Pacific and the Philippine Sea Plate from southeast.

2.2 Updated figures on resources

China Geological Survey (CGS) has conducted a nation-wide survey of geothermal resources by adding that of shallow geothermal resources in major cities. The IGG-CAS and the CGS have both estimated the potential of hot dry rock resources in the country. The updated statistics reported by both groups show the new figures on geothermal resources in China (Wang et al. 2017): shallow geothermal resources, in the depth range of less than 200 m from the surface, which is used through ground source heat pump technology, is equal to about 0.7 billion tonnes of standard coal, annually. Hydrothermal resources occurring in the depth range between 200 and 3000 m are equal to 1.9 billion tonnes of standard coal annually. Hot dry rock geothermal resources, in the depth range between 3 and 10 km, has also been estimated to be equal to 856,000 billion tonnes of standard coal. Adding up the shallow geothermal resources and hydrothermal resources, it is equal to 50% of the standard coal consumed by the country in 2015.

3. STATUS OF UTILIZATION AND CASE HISTORIES

Utilization of geothermal resources has seen rapid growth in the last two decades or so. China is now the world's largest user of geothermal energy for direct use purposes (Figure 1). The success is largely due to the development of ground source heat pumps in China, which is now contributing more than 50% in space heating. Utilization of hot water from carbonate reservoirs in North China at a large scale has also contributed to a very successful story. However, power generation has been almost stagnant. The following are some examples.

The high-temperature geothermal system at Yangbajing of Tibet is the largest in terms of power generation potential. It is a typical example for the geothermal systems along the Himalaya belt (e.g.

Tibet, Yunnan, and Western Sichuan). It is located 90 km to the north of Lhasa, the capital city. It has been generating power since 1970s and the current installed capacity is 25.8 MW. It's the only high-temperature geothermal system for power generation in China. The medium-temperature geothermal system in Fengshun of Guangdong Province is a typical example of those hot springs found in the coastal areas of Southeast China, including Guangdong, Hainan, Guangxi, Jiangxi and Zhejiang provinces. There is a slightly higher heat flow background and the reservoir is mainly granite. The Fengshun geothermal field has been used for cascaded utilization including power generation (150 kW installed), cooling, drying and bathing.

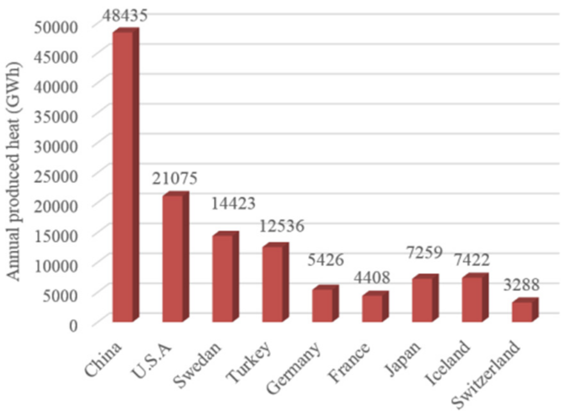

FIGURE 1: World leaders in geothermal direct use (Lund and Boyd, 2015)

The low-temperature geothermal system in Xiongxian of Hebei Province (Pang et al., 2010, Wang et al., 2013, Pang et al., 2015, Kong et al., 2015, Kong et al., 2017a) is a typical example of hot water in large sedimentary basins, including the Bohai Bay basin (BBB), Songliao basin, Subei basin and Erdos basin in China. It's located in BBB in North China. The geothermal reservoir is karstified carbonates with high porosity and permeability. Heat source is re-distributed heat flow by tectonic structures. Neogene mudstone on top of the carbonates forms good cap rock to keep the heat in place. Since 2009, Sinopec Green (a joint venture between China and Iceland) has developed the field for space heating and the IGG-CAS has been providing technical support. Now the project is the largest in the country. There about 70 production and reinjection wells, with a capacity to provide heating for 4.5 million m^2 of houses. Xiongxian City has been a pioneer in the large-scale district heating using karstic geothermal resources.

4. CHINESE FELLOWS OF UNU-GTP

Since the first group of Chinese fellows came for the geothermal training in Iceland in 1980, 86 fellows from China have completed the 6-month training and two additional fellows will start this April. The fellows are from 15 different cities, provinces and autonomous regions of the country, including Beijing (28), Tianjin (25), Hebei (12) and Tibet (5). The rest are 2 or less. The geographical distribution coincides well with the key geothermal development projects in China (Figure 2). From the thematic topics that the Chinese fellows have chosen (Table 1), it is clear that sustainable management of geothermal reservoirs has been an emphasis and chemistry of thermal fluids has also been a favoured topic. It is also true that design and engineering of geothermal utilization, mainly space heating have been very useful to the Chinese fellows and their institutions.

TABLE 1: UNU-GTP Chinese fellows in 1980-2017 and their specialities

Specialty	Number of fellows
Reservoir engineering	30
Chemistry of thermal fluids	22
Geothermal utilization	17
Environmental studies	9
Borehole geology	3
Borehole geophysics	2
Drilling technology	3
Geophysical exploration	2
Total	**88**

In all, 21 of the 88 Chinese fellows are female, accounting for about 25%. One female Chinese fellow has completed her MSc study in Iceland as well as one male. Another female Chinese fellow has received fellowship for PhD studies and is expected to graduate from the UNU-GTP next year. Among the trained professionals, more than half of them are still working on geothermal related subjects and in various parts of the country. The fellows have become leading geothermal experts in China and have been playing a very important role in the geothermal development in the country. In a recently published monograph titled "*Geothermics and its applications*" former UNU fellows are key authors. Nation-wide geothermal survey is lead by former UNU-GTP fellows. They are also responsible for the implementation of key utilization projects. In 2013, the Chinese Fellows Union of the UNU-GTP was established in Beijing, which was witnessed by Mr. Ingimar G. Haraldsson, deputy director of the UNU-GTP, who was visiting China to interview candidates at the time. The organization has enabled more efficient information exchange and collaboration among the fellows.

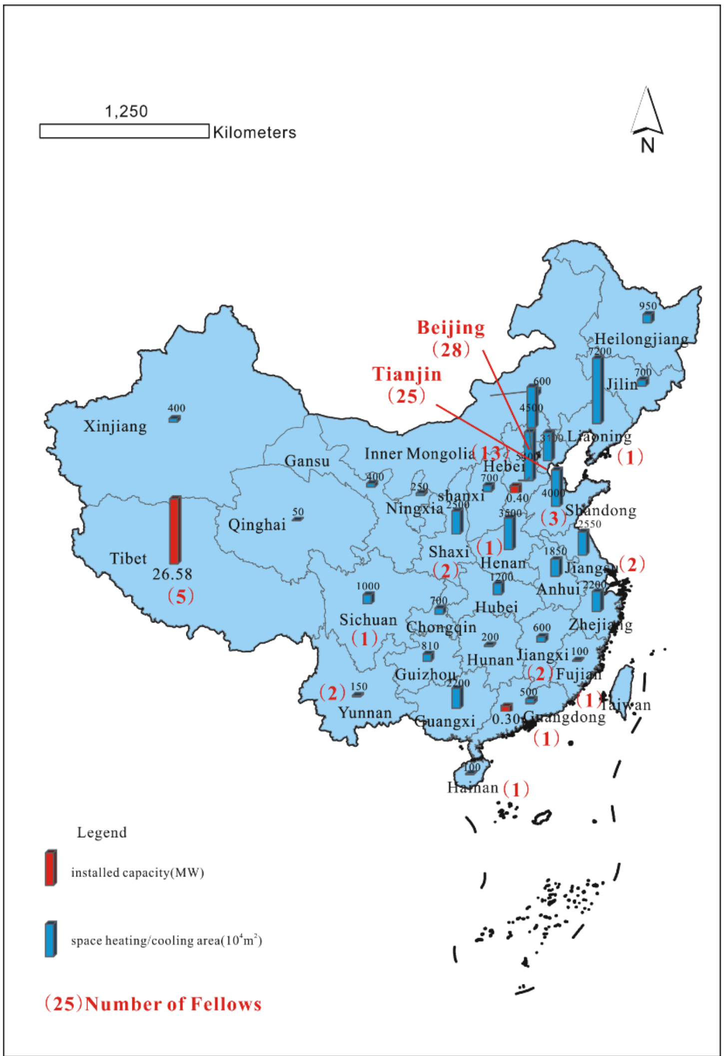

FIGURE 2: Geographical background of the UNU fellows and geothermal projects

5. OUTLOOK OF GEOTHERMAL DEVELOPMENT

In the 13th five-year plan, the government has set very ambitious targets for geothermal development, as follows: by year 2020, the space heating/cooling area should be increased from 0.4 to 1.6 billion m^2, in which, 0.7 billion m^2 is expected from shallow geothermal resource and 0.5 billion m^2 from hydrothermal resource. The installed power generation capacity should be increased to 500 MW.

Hydrothermal reservoirs are mainly Cenozoic sandstone and Ordovician/Proterozoic carbonates in large sedimentary basins (Kong et al., 2014). For the sandstone reservoirs, they are widely found in the sedimentary basins but some of them are with low re-injectivity and require pressurized reinjection.

What is promising is that the carbonate reservoirs take up one thirds of the total area of China so geothermal resources are really abundant (Pang et al., 2012). They offer large yield, low TDS and near 100% re-injectivity, though it is also difficult in some cases due to reservoir heterogeneity and anisotropy.

In April 2017, the central government of China launched a brand new administrative region called "*Xiong'an New Area*" by integrating Xiongxian county with two other counties. Based on a recent study we carried out (Pang et al., 2017), it was found that Xiong'an New Area is rich in geothermal resources, which may play a key role in the construction of the newly planned ecological city. The shallow geothermal energy (< 200 m), and deep geothermal energy stored in sandstone and karstic reservoirs are rich and suitable for exploitation and utilization. The deep carbonate geothermal resources are particularly large and easy to exploit. Geothermal resources stored in super deep layer (>3000 m) also have good potential (Yang et al., 2015). Based on the success in utilization in Xiongxian, the exploration of geothermal resources in Xiong'an is being enhanced, especially with respect to super-deep geothermal resources in the carbonate reservoirs.

Generally, combined use of shallow and deep geothermal energy and sustainable use of geothermal resources (Duan et al., 2011, Kong et al., 2017b) is being emphasized. In addition, more attention is also paid to environmental protection. At the same time, studies are under way to make use of the advantage of storage functionality of geothermal reservoirs, to couple these with other renewable energy sources.

The official target for power generation is more difficult to achieve. There are abundant high-temperature geothermal resource along the Himalaya belt (Xinjiang, Qinghai, Tibet, Western Sichuan and Yunnan) (Guo et al., 2017, Li et al., 2017, Luo et al., 2017). The total installed capacity was around 25.8 MW by 2014 and mainly from the Yangbajing power station in Tibet. However, the potential for power generation from the high-temperature geothermal fields is assessed to be about 5 GW in the Himalayan belt and new discoveries in exploration have covered additional regions. With increasing participation of more industrial partners, it is expected that exploration and power generation will speed up.

6. CONCLUSIONS

China is rich in geothermal resources and significant achievements have been made in the utilization of the resources for direct use purposes, making the country the largest user of geothermal heat. UNU-GTP has been very much welcomed and successful in China and the Chinese fellows have been the main task force in key geothermal projects and have made essential contributions to geothermal development in China. The government has made ambitious plans to tap the huge geothermal potential in the future. Geothermal energy for space heating is strongly encouraged by the government due to the pressing air pollution caused by use of fossil fuels. Geothermal power generation is also expected to grow. In these fields, training of professionals will continue to be a key factor. It is hoped that the UNU-GTP will continue to train geothermal professionals from China, considering that the country has a strong programme in geothermal energy.

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