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An analysis of potential contribution by geothermal development to carbon neutrality: country update on technology and market in China

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ABSTRACT

China is rich in geothermal resources of continental nature, mostly low-medium temperature geothermal waters in sedimentary basins at economic depth ranges. China has achieved scalable geothermal development in the past two decades, and fast growth especially in the past ten years. All types of geothermal resources are being utilized including heat from surface water and waste water. Various technologies are being applied especially the doublets in carbonate (karst) geothermal reservoirs at intermediate depth ranges. The deep borehole heat exchanger (DBHE) is being increasingly applied with local innovations to achieve better efficiency. Xiongxian district heating using intermediate depth hot water and Nanjing Jiangbei New City air-conditioning using surface water are most successful business examples for geothermal resources utilization. Both shallow geothermal utilization and intermediate geothermal resources utilization have grown exponentially in China in the past 30 years or so. Emerging technologies such as intermediate depth heat storage, geothermal heat pipe, etc, are promising in enhancing both hydrothermal and petro-thermal resources, respectively. The current share of geothermal energy among the five carbon-free energies is about 5%. Planned increase towards 2025 is 2.1 billion square meters of areas heated, and 4.2 billion square meters by 2035, according to official targets set by National Energy Administration. With a huge domestic market demand stable geothermal energy is expected to grow even faster in the era of booming renewables for energy transition. We predict a long-term share of geothermal energy to be higher than 10% towards carbon neutrality in year 2060.

1. INTRODUCTION

In order to mitigate global warming, countries all over the world are pursuing energy transition from fossil fuels to renewables and carbon-free energy sources [1]. Major emitters are: heavy industry including coal-fired power plants, steel factories and cement producers in China, which takes up to 60%. The construction sector takes about 18%, which also considerably high. According to experience from developed countries, heating, cooling, and lighting of building account for about 40 % of the total societal energy consumption and corresponding CO_2 emission.

Currently, district heating and domestic hot water supply consume more than 75 % and 40 % of the energy in Europe and China, respectively. For building heating, geothermal energy has attracted growing applications due to its stability, environmental friendliness and wide availability [3], which possesses a considerable potential towards realizing the goal of carbon neutrality.

China has been the biggest user of geothermal heat since about 20 years ago. In the meantime, power generation from geothermal energy has been very little. Building on this experience, it is reasonable to expect that geothermal utilization in the building sector may further contribute to the reduction of carbon emission in the future.

In this contribution, we have attempted to analyze the development of technologies in various types of geothermal applications. And predict their potential contributions in the future.

2. DATA AND METHODS

We use the published data of the geothermal industry in China and the world. We make statistics on to find out trends of growth in the total installed capacity and total amount of energy use. In the meantime, we compare the possible choices of energy transition measures in China to come up with an estimate of potential contribution of geothermal energy, and hopefully this would be useful in overall planning of carbon neutrality strategy for the country.

The Chinese government began to publish industry report on renewable energies annual since year 2018[4]. It has now been taken over by the Institute of renewable Energy engineering in Beijing, which is designated by the national energy administration. These data are collected from energy authorities in the local governments. The data on national five-year plans both in geothermal development and in research and development of technologies are also officially issued information by ministry of science and technology or other relevant governmental agencies in China [5].

In year 2017, the authors attended the Geothermal Resources Council (GRC) annual meeting in Salt Lake City of Utah. In year 2018 the authors made a trip to Europe, and the countries visited included Iceland, Finland, Germany and Switzerland. Incorporating the information from WGC2020+1 in Reykjavik, to make it as updated as possible.

The prediction applied is according to what has happened in the past two decades, to choose whether a linear or exponential trend is more applicable. The authors of this analysis come from different professional background, geosciences and thermal engineering, which is an advantage.

3. GEOTHERMAL RESOURCES AVAILABLE

As a continental country, China is rich in geothermal resources of non-volcanic heat sources. Affected by West Pacific Plate subduction in the east and Indian Plate collision on the southwest directions, the geothermal background of China is "high in the East, low in the West" and "High in the South and low in the North", according to heat flow measurements. High temperature geothermal resources suitable for power generation is mainly found in Qinghai-Tibetan Plateau[6-8]. That is far away from the regions of population and dynamic economy. However, geothermal resources are found widely in the major sedimentary basins in the eastern lowlands that are suitable for district heating and other direct use purposes.

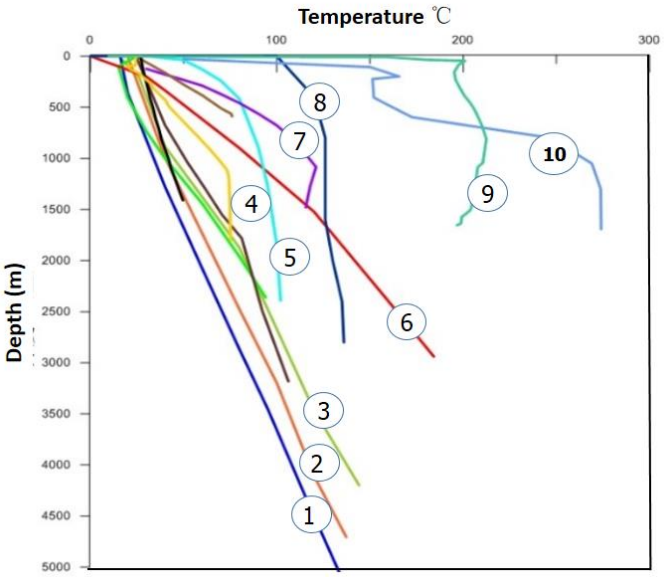

Figure 1: Typical temperature-depth curves of different regions in the continental China.

1) Donghai, Jiangsu; 2) Laizhou, Shangdong; 3) Erdos, Inner Mongolia; 4) Xiongxian, Hebei; 5) Xian, Shanxi;

6) gonghe, Qinghai: 7) Ruili, Yunnan; 8) Guide, Qinghai; 9) Kangdin, Sichuan; 10) Yangbajing, Xizang (Tibet)

The geothermal resources in sedimentary basins in the form of hot water are very convenient to use for space heating and cooling purposes through existing technologies. Shallow geothermal energy is distributed nationwide. Intermediate-depth geothermal energy is distributed mainly in sedimentary basins in large quantities in the form of hydrothermal systems, especially with karst reservoirs. High-temperature geothermal energy is distributed mainly in Himalaya geothermal belt in the Southwest, where geothermal resources are good for power generation, with an estimated capacity to be around 5GW. High-temperature geothermal resources suitable for enhanced geothermal systems development for power generation is expected to be deeper than 6 km in the eastern part of the country that are not economically extractable with existing technologies.

Table 1. Geothermal resources for different uses in China

Types of resource	Depth range (m)	Media	Method of Exploitation	Uses
shallow layer*	<200m	soils or water	ground source heat pump technology	Heating and cooling
intermediate layer**	200-3000m	rocks or water	single-well heat exchange or abstraction and re-injection of multiple wells	Power generation and direct use
deep layer***	>3000m	mainly rocks	artificial reservoirs + fluid circulation	Power generation and direct use
Heat Storage	0-3000m	rocks or water	Corresponds to those above	Power generation and direct use

*including thermal energy stored in surface water such as river, lake and ocean
**high-temperature: >150 ˚C; Medium-deep-temperature: 25-150 ˚C
***geothermal energy with temperatures higher than 180 ˚C stored in impermeable rock is called hot dry rock.

According to official data issued by China Geological Survey, exploitable geothermal resources shallower than 3km from the surface, in 2.6 billion tons of standard coal equivalent, which is about 60%, if compared to the primary energy consumed in the year of 2020. [4]

The exploitation of large carbonate reservoirs in north China for district heating has been achieved great success, due to their advantages in high sing-well yield, low salinity, easy injection etc., [9] An survey has shown that this area of buried carbonate geothermal in China is over 2.5 million square kilometers. Preliminary estimates indicates that the intermediate depth range, the amount of geothermal resources stored are equivalent to the amount between 0.5 to 5 trillion tons of standard coal equivalent [10-12].

4. STATUS OF GEOTHERMAL UTILIZATION

4.1 Industrial Profile

Hydrothermal resources in the intermediate depth range has been traditional resources widely used, in the north for district heating and in the south for bathing. In the past 3 decades, an exponential growth has been achieved, as shown in Figure 2. Geothermal heating is supplied in areas of Beijing, Tianjin, Hebei, Shanxi and Shandong Provinces, with some utilization in the Northeast, Southwest and Northwest. By the end of 2020, China's geothermal heating areas have reached 532 million square meters.

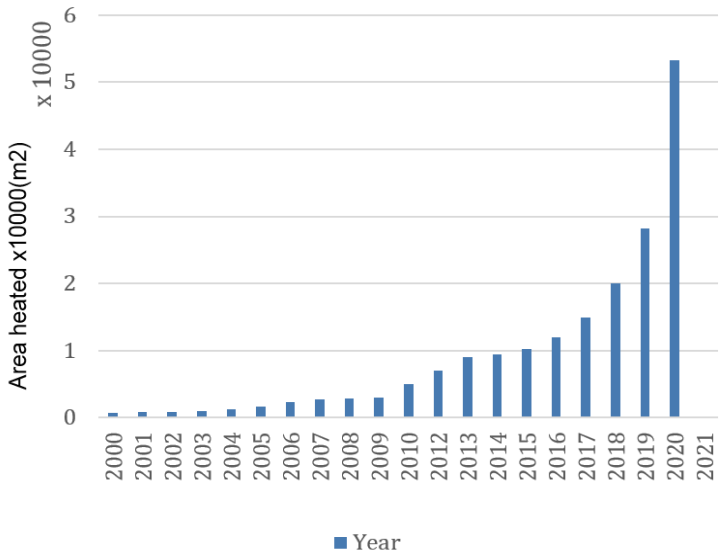

Figure 2: Use of hydrothermal energy (intermediate depth) has seen an exponential growth in China.

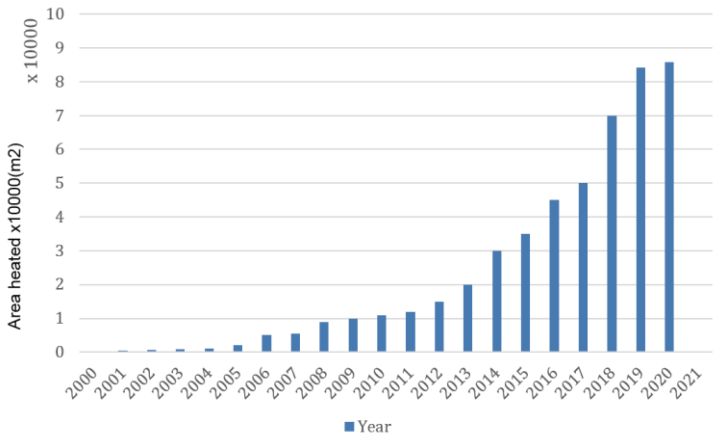

Figure 3: Use of shallow geothermal energy (ground-source heat pumps) also sees an exponential growth in China.

By the end of 2020, China's geothermal heating area has reached nearly 1.4 billion square meters, continuing to rank first in the world. It means that, we are now able to provide one square meter of housing heated by geothermal per capita for a population of 1.4 billion. We have a lot more to do in the future. There has been a club of geothermal power generating countries with installed capacity of 1 GW or above. In order to encourage direct uses, there may be another club accordingly, i.e. a club of big direct users. Figure 4 shows the initial members of this club.

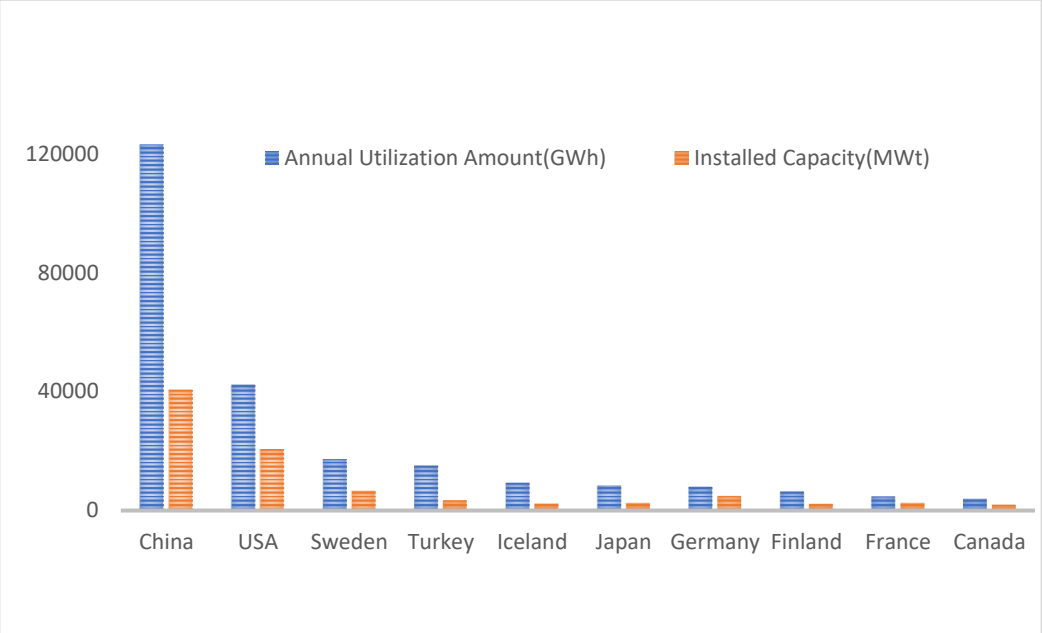

Figure 4: The world's top-10 countries in geothermal direct uses by 2020.

4.2 Share among carbon-free energies in energy mix

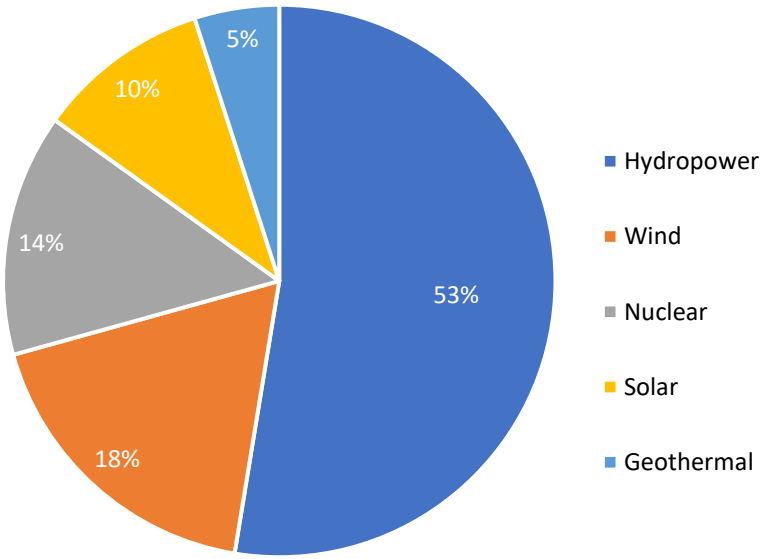

Figure 5: The share of carbon-free energies in China by 2020.

What contribution to carbon neutrality can geothermal energy make? The current share for China is 5%. As a matter of fact, developing countries like China and India are still in the processes of increasing their emissions due to insufficient development and relatively low living standards of the people. Geothermal is a clean, low-carbon, safe and stable renewable energy. Greater efforts should be made in geothermal development and utilization to achieve industrialization, and to increase its contribution to the target of Carbon Neutrality. To reach the goal of carbon neutrality, it is necessary to increase the use of the five non-carbon energy sources: hydropower, solar, wind, nuclear and geothermal in replacement of fossil fuels.

On March 9, 2021, the International Renewable Energy Agency (IRENA) organized a seminar on "Renewable Energy Heating and Refrigeration", which focused on geothermal energy and fully demonstrated the consensus of the international community. The first author of this paper was invited to make speech on progress of new technologies and applications of geothermal heating and cooling in China. It shows that China's efforts in utilizing geothermal energy for direct purposes is recognized by international organizations. On 6 November, 2020, I was invited by the United Nations Environment Program UNEP to introduce China's contribution to the 21st Century Sustainable Development Goals on China's geothermal clean heating at the African Geothermal Conference. The first author introduced the Xiongxian model, and mentioned an interesting figure:

5 FUTURE TRENDS

As shown above, the current geothermal share among carbon-free energies is not high, but is already in the same order of magnitude. It is expected to increase to greater than 10% in 2060 due to the high demand for district heating and due to its nature as stable, clean and safe source of energy. If energy savings for building sector are considered generally, China's geothermal heat utilization currently accounts for only 10% of domestic clean heating. There is still much room for increase in the future.

In the future, building energy will account for about 40% in primary energy consumption, and its low-carbon transformation is an important part to achieve carbon neutrality.

Technology development has been a major part of governmental support to geothermal utilization industry in China. With great progress in raising the reinjection rate in the hydrothermal settings, recent progress has been made in the heat storage at the intermediate depth range and the development of super long heat pipes for geothermal applications. These and other advancement of technologies are the guarantees for further deployment of geothermal utilization for carbon neutrality in the future [11-14].

6. CONCLUSIONS

1. China is rich in geothermal energy in general but more accessible resources are more suitable for direct heat use rather than for power generation.
2. New technological options have turned space heating into a large-scale geothermal industry. China has seen fast growth in geothermal district heating capacity, ranking first in the top 10 club countries. China has stepped up its efforts to develop geothermal energy in recent years. Installed capacity for geothermal energy that could be directly used in China reached 40.6 gigawatts heat, which is 38% of the world's total.
3. China is an example to show that geothermal energy in a non-volcanic country, can make a substantial contribution to district heating and to carbon neutrality of the building sector in the future.

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