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High-Quality Development of China's Geothermal Industry -- China National Report of the 2023 World Geothermal Conference

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ABSTRACT

With the strong demand for clean heating, China has gradually formed a geothermal development path that focuses on heating and cooling, driving China's geothermal direct utilization to rank first in the world for many years and providing new ideas for international geothermal development. By the end of 2021, China's geothermal heating and cooling capacity reach 1.33 billion square meters, including 530 million square meters of geothermal district heating capacity and 800 million square meters of ground source heat pump heating and cooling capacity. The annual utilization capacity of hot springs is 6665 MW, and the annual utilization capacity of agriculture and food processing is 1108 MW. The actual operating installed capacity of geothermal power generation is 16 MW. The number of geothermal enterprises has increased and become stronger, including Sinopec Group as the largest geothermal enterprise with a heating capacity of over 80 million square meters. A more systematic geothermal standard system consisting of national standards, industry standards and local standards has been gradually formed. Technologies applicable to different types of geothermal resource exploration and development and utilization have been developed, and the R&D and test projects of borehole heat exchange technology and hot dry rock technology are also advancing in an orderly way. Continued acceleration of geothermal professional training. A series of regional geothermal heating and cooling projects with a scale of millions of square meters have been successively built. To support the achievement of the 'Dual Carbon' goal, the Chinese government has introduced a number of geothermal support policies, and the World Geothermal Congress 2023 to be held in Beijing, China is conducive to the government and the public to raise the importance of the geothermal industry. These favorable policies and news will promote the continued high-quality development of China's geothermal industry during the '14th Five-Year Plan' period. In the coming years, geothermal heating in northern China, geothermal heating and cooling in the middle and lower reaches of the Yangtze River, and geothermal power generation in and around the Tibet Plateau will remain hotspots for industrial development.

1. INTRODUCTION

In 2021, China's total energy consumption reached 5.24 billion tons of standard coal. At the same time, the rapid development of renewable energy sources has driven the energy consumption structure to a green and low-carbon transformation.

The National Energy Administration announced that the installed capacity of renewable energy generation reached 1063 GW, accounting for 44.8% of the total installed power generation capacity. Among them, 391 GW of hydropower, 328 GW of wind power, 306 GW of photovoltaic power and 37.98 GW of biomass power installed. Renewable energy generation has reached 2.48 million GWh, accounting for 29.8% of the total social electricity consumption. Onshore wind power and photovoltaic power generation have achieved unsubsidized affordable development, which creates favorable conditions for further large-scale

development and utilization. Compared to hydro, wind, and solar energy, which mainly used for power generation, China's geothermal energy mainly functions as a heating utilization.

As early as the pre-Qin period (before 221 B.C.), hot springs such as Lishantang spring started the history of hot spring utilization in China, and in the 1950s, the use of hot springs began on a large scale, with the establishment of more than 160 hot spring sanatoriums in succession. In the early 1970s, against the background of the world energy crisis, geothermal power generation, heating, greenhouse planting, farming and other forms of utilization began to develop. In the 21st century, geothermal heating gradually developed into the most important utilization mode, driven by the market demand for heating and air pollution control.

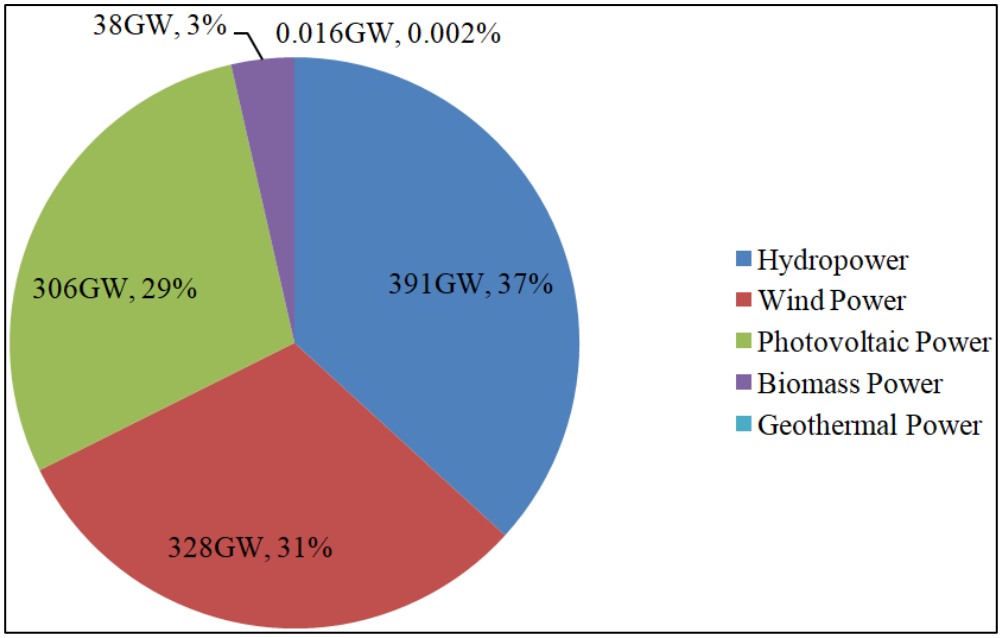

Figure 1: Proportion of the installed renewable power capacity in China

In 2022, the National Geothermal Energy Center complete the geothermal information management platform, carry out online filling of geothermal project data, and organize 17 industry associations, survey and design units, and development and utilization enterprises that grasp the geothermal development in their provinces to count the overall data of each province. The two aspects of micro projects and macro statistics complement and corroborate each other to correct and update the geothermal historical data.

The statistics show that by the end of 2021, the direct geothermal utilization capacity is equivalent to 100.2 GW, with an annual utilization of 828,882 TJ.

Among them, the ground source heat pump (GSHP) heating and cooling capacity has reached 800 million square meters, and the geothermal heating capacity has reached 530 million square meters, totaling 1.33 billion square meters; greenhouse planting and aquaculture have spread to more than 20 provinces. Hot spring health and recreation tourism has continued to develop steadily, with the utilization scale reaching 6,665 MWt; geothermal power generation is only about 16 MWe still in operation. Direct geothermal utilization such as agricultural drying, industrial utilization and snow melting are not yet common.

Compared with the 2019 China Geothermal Report data, GSHP heating and cooling as well as geothermal heating areas show a substantial increase, caused by rapid development of the geothermal industry, but mainly caused by the more comprehensive and extensive coverage of the geothermal information management platform and the participating statistical units in each province.

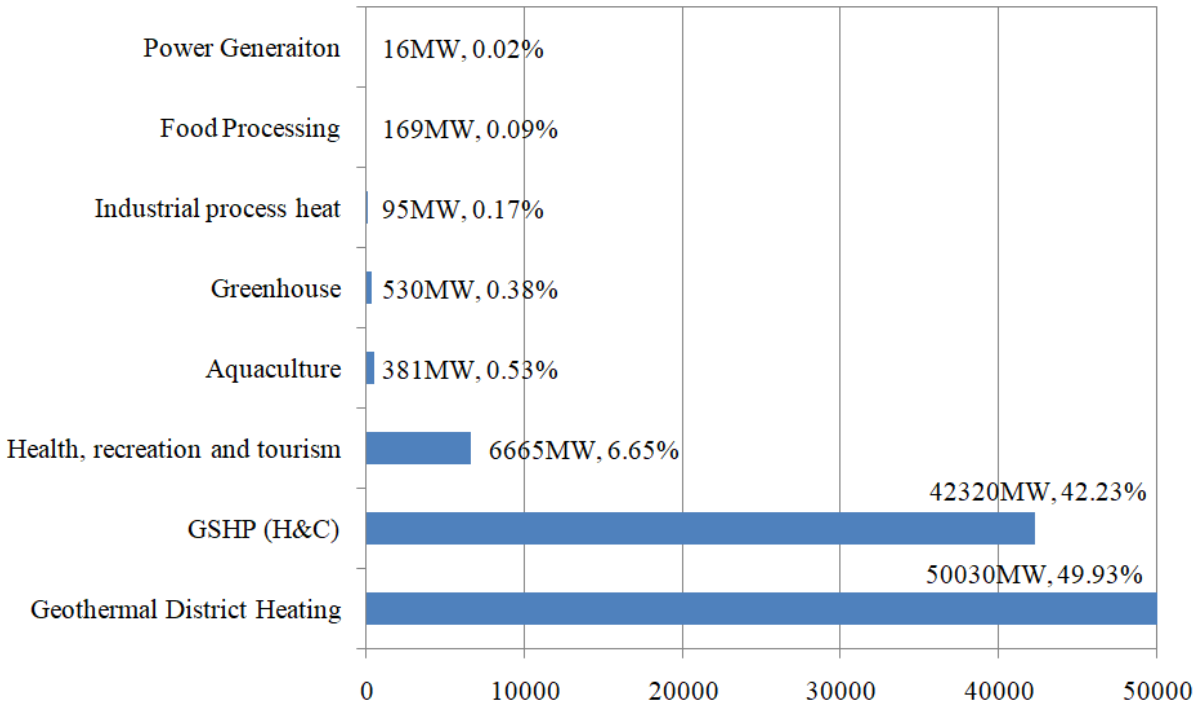

Figure 2: China's geothermal indirect (in electric MW) and direct (in thermal MW) utilization capacity at the end of 2021

2. GEOTHERMAL RESOURCES

2.1 Geological Setting

China is located in the area surrounded by three major tectonic domains, namely, ancient Asia, Tethys and western Pacific, and is geographically located in the eastern part of the Eurasian plate. The influence of the two domains, Tethys and western Pacific, has lasted from the Late Mesozoic to the present, with a wide range of influence and strong tectonic effects, and has exerted a profound influence and control on the present-day tectonic pattern and geothermal formation in China.

Influenced by the interaction of two tectonic domains, the southern Tibetan-Western Yunnan-Western Sichuan area in the west of China and the Taiwan Central Range in the east of China belong to the plate junction area since the Late Mesozoic, where seismic, tectonic, and magmatic activities are extremely strong.

The southwest of China belong to the Himalayan orogenic belt under the influence of Tethys tectonic domain and southeast of China belong to the South China folded belt under the western Pacific tectonic domain. These two regions are the most developed areas of high-temperature geothermal resources in China, with more surface hot springs displayed, higher geothermal heat flow values, with an average value of 90-150 mW/m^2 and an average geothermal gradient of about 3.2 ℃/100m. Geothermal resources mostly developed in belt-shaped fractured thermal reserves of granite and clastic rocks, and the overall fractured belt convection type geothermal system is dominant, i.e. uplift mountain geothermal resources.

The hydrocarbon-bearing basins in the northern region of China are rich in geothermal resources in the sedimentary basin basement and overlying sedimentary cover because of mantle uplift and the action of huge thick sedimentary cover, which are mostly developed on top of ancient land crust or micro-land masses, such as the Bohai Bay Basin, Ordos Basin and Songliao Basin. Among them, the extensive magmatism in the Mesozoic region of the Bohai Bay Basin reflects the general background of crustal thinning and mantle upwelling, which provides the possibility of upward conduction of mantle-derived heat flow. The geothermal heat flow value of these oil and gas-bearing basins is generally high, up to 80 mW/m^2, and the geothermal resources are mostly developed in the Middle-Cenozoic sandstone pore-type heat reserves and the Middle Paleozoic-Lower Paleozoic carbonate rock karst fissure-type heat reserves, i.e. sedimentary basin geothermal resources.

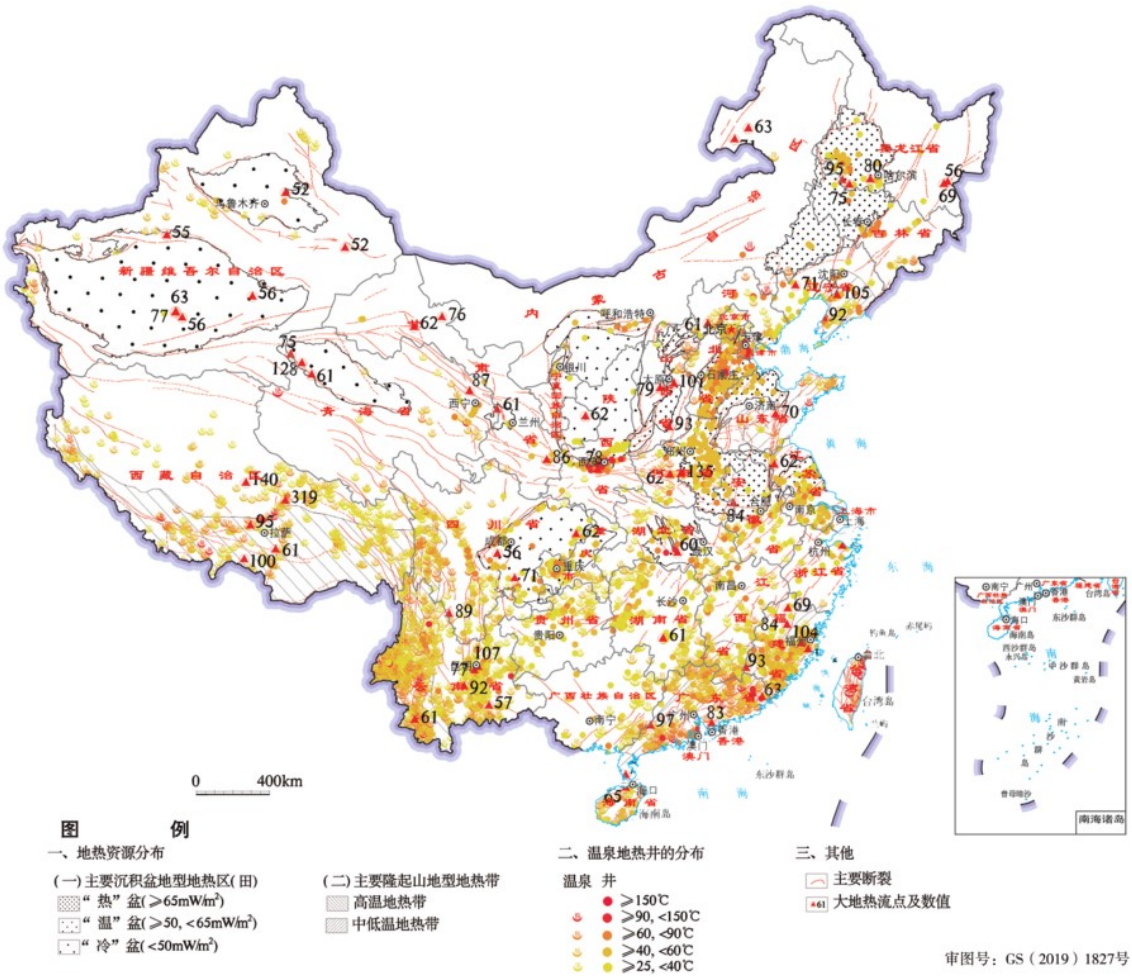

Figure 3: Distribution of geothermal resources in China (After Wang et al., 2020, modified).

2.2 Geothermal Potential and Assessment

China is a country relatively rich in geothermal resources, which can be divided into three categories: shallow geothermal resources, hydrothermal geothermal resources, and hot dry rock geothermal resources.

2.2.1 Shallow Geothermal Resource Assessment

China's shallow geothermal resources are widely distributed throughout the country. The data from the China Geological Survey show that the heat capacity of shallow geothermal resources in 336 cities in China is 1.11×10^{17} kJ/℃, and the annual extractable amount is equivalent to 700 million tons of standard coal. Among them, the groundwater heat pump system can cool an area of 5,590 square kilometers in summer and heat an area of 3,610 square kilometers in winter; the ground-coupled heat pump system can cool an area of 35,600 square kilometers in summer and heat an area of 37,500 square kilometers in winter. The area that cooled by GSHP systems in summer is 35,600 square kilometers, and the area that can be heated in winter is 37,500 square kilometers. Suitable for the development of shallow geothermal areas are mainly located in the central and eastern of China, including Beijing, Tianjin, Hebei, Shandong, Henan, Liaoning, Shanghai, Hubei, Hunan, Jiangsu, Zhejiang, Jiangxi, Anhui and other 13 provinces and cities.

2.2.2 Hydrothermal Geothermal Resource Assessment

China is rich in hydrothermal geothermal resources, with 2,334 outcrops of hot springs discovered and 5,818 geothermal mining wells on the register. According to the results of regional geothermal survey of China Geological Survey, China's hydrothermal geothermal resources are equivalent to 1,250 billion tons of standard coal, and the annual exploitable amount is equivalent to 1,865 million tons of standard coal. Among them, the hydrothermal high-temperature geothermal resources are equivalent to 14.1 billion tons of standard coal, with a power generation potential of 8,460 MW, mainly distributed in the southwest Tibetan, Yunnan, and

Taiwan. Hydrothermal medium and low temperature geothermal resources mainly distributed in large and medium-sized sedimentary basins and orogenic belts such as Bohai Bay Basin, North Jiangsu Basin, Songliao Basin, Fenwei Graben System and South China folded belt. With the amount of geothermal resources equivalent to 1,230 billion tons of standard coal, accounting for about 98% of the total, and the annual recoverable amount of geothermal resources equivalent to 1,850 million tons of standard coal, with a power generation potential of 1,500 MW.

2.2.3 Hot Dry Rock Geothermal Resource Assessment

According to the data of China Geological Survey, the amount of hot dry rock type geothermal resources within 3-10 km underground in China's land area is equivalent to 856 trillion tons of standard coal. According to the international practice of hot dry rock, 2% of its extractable resources is about 3200 times of China's 2022 annual energy consumption. It is usually associated with hydrothermal type geothermal resources, located in its lower part or next to it. It is widely distributed and developed in most of the oil- and gas-bearing basins and areas of strong modern tectonic activity in China.

3. GEOTHERMAL UTILIZATION

3.1 Ground Source Heat Pumps

By the end of 2021, China has a shallow geothermal heating (cooling) capacity of 800 million square meters and an annual utilization of 393,939 TJ. It is mainly distributed in the plains of eastern China, among which, the Bohai Rim is the best to develop, and the middle and lower reaches of Yangtze River plains are the second.

In the Bohai Rim region, due to the strong demand for clean heating, the large thickness of Quaternary rock deposits and the low cost of shallow well construction, it has become the most concentrated area for shallow geothermal heating and cooling in China. The heating and cooling capacity of Hebei ranks first among provinces, followed by Liaoning and Shandong, and Beijing ranks fourth, showing the adaptability of distributed energy in urban heating development.

In the middle and lower reaches of the Yangtze River plain, cities such as Shanghai, Wuhan, and Chongqing, which take water from the main tributaries of the Yangtze River, have large river water source heat pump heating and cooling projects built and put into operation, with single projects capable of reaching more than one million square meters. At the same time, groundwater source and soil source projects are all over the place, in large numbers, mainly providing centralized heating and cooling for building clusters and communities, with an area usually ranging from thousands to hundreds of thousands of square meters, which is the main component of geothermal heating and cooling in the region.

In the bedrock region of the Yunnan-Guizhou Plateau, represented by Guizhou, GSHP for heating and cooling have begun to grow in popularity in recent years. The typical practice is usually to drill boreholes for heat transfer heating and cooling in bedrock such as carbonate rocks that buried only a few meters deep or exposed. Although the investment is higher than the Quaternary in the plains, the higher thermal conductivity and better permeability of carbonate rocks can improve the efficiency of heat exchange and extraction. Driven by green and low-carbon development requirements, shallow geothermal heating and cooling has reached an area of about 5 million square meters.

3.2 Geothermal District Heating

The North China, mainly the five provinces and cities of Hebei, Henan, Shandong, Shaanxi and Tianjin, relying on the rich geothermal resources in the sedimentary basin areas such as Bohai Bay Basin, South North China Basin, and Fenwei Graben System, which are supported by the policy of clean heating in the northern region in winter and the game of geothermal resource tax, gradually developed into the main area of hydrothermal geothermal heating.

Hebei Province has the highest hydrothermal geothermal heating capacity in China, mainly in the vast plain areas south of Yanshan Mountain and east of Taihang Mountains, leading the country and creating a demonstration sample of the whole county (city) promoting geothermal heating represented by the 'Xiong County Model'. In the past two years, the local authorities are adjusting geothermal development and operation by restricting the management of exploration and mining rights and water extraction.

Rapid growth of hydrothermal geothermal heating capacity in Henan Province. In recent years, the Henan Provincial Government has made great efforts to promote the development of geothermal energy, and has successively issued the ‘Guidelines on Promoting Geothermal Energy Heating’ and the ‘Notice on Further Improving the Work Related to Geothermal Energy Heating’, which has greatly improved the environment for the development of geothermal energy. The growth rate of hydrothermal geothermal heating capacity reaches 20% year-on-year in 2021.

Shandong Province has adopted a geothermal development approach based on sandstone thermal reservoirs. In view of the characteristics of geothermal resources in the province, Shandong Province has carried out long-term development of sandstone thermal reservoirs, recharge technology research and project construction, mainly in Dongying, Dezhou, Jinan, Heze, and other cities in western and northern Shandong.

Tianjin continues to lead China’s urban geothermal development and is the city with the largest hydrothermal geothermal heating capacity in China, making it the well-deserved ‘Geothermal Capital’. Tianjin's geothermal development has demonstrated the feasibility of large-scale application of distributed energy in large cities with dense buildings, and has accumulated experience for large-scale geothermal development in large and medium-sized cities.

Hydrothermal geothermal heating in Shaanxi Province is mainly concentrated in the Guanzhong Basin, with Xi’an - Xianyang as the center and extending to Weinan and Baoji, and is becoming an important alternative energy source for clean heating. In recent years, the borehole heat exchange technology has received local support and made significant development, and the heating capacity has increased.

In addition, hydrothermal geothermal heating has also been developed in northern and alpine regions and some provinces in the south, such as Heilongjiang, Jilin, Liaoning, Inner Mongolia, Xinjiang, Gansu, Ningxia, Qinghai, Tibet, Jiangsu, Anhui and Hubei.

3.3 Utilization of Hot Springs

China uses natural hot springs and geothermal well water for bathing, physical therapy, recreation and tourism in almost every province (district and city) in the country. Its development has benefited not only from the long-established hot spring culture and health therapy functions, but also from the increasing recreational functions of hot springs. At present, most of the hot spring exploitation projects are mainly able to provide food, accommodation, and recreation, which are very popular with consumers, while significantly increasing the added value of hot spring exploitation and attracting more investment in the construction of more new projects, so that hot spring exploitation has become the second-ranked direct geothermal exploitation method. By the end of 2021, the annual utilization capacity of hot springs in just the 72 areas designated as hot spring cities (cities and capitals) will reach 6,665 MWt, with an annual utilization volume of 100,889 TJ.

3.4 Agriculture and Food Processing

China's geothermal agriculture utilization has spread to more than 20 provinces, with a total utilization capacity of 1,108 MW, which has become a new growth point for direct geothermal utilization. Among them, geothermal greenhouses have a capacity of 381 MWt with an annual utilization of 4681 TJ, mainly growing flowers and special vegetables, mainly in Tianjin, Hebei, Shandong and other provinces and cities. Aquaculture capacity of 530 MWt with annual utilization of 5518 TJ, mainly of tropical fish, shrimps, crocodiles and other high value-added products, mostly located in the Bohai Sea Rim. Food processing capacity of 197 MWt with an annual utilization of 2,360 TJ, has appeared in Tianjin, Hebei, and other places for drying food products such as chili peppers.

3.5 Geothermal Power Generation

Medium and high temperature geothermal resources in mainland China are mainly distributed on the Qinghai-Tibet Plateau and its neighboring areas. Due to the high investment cost and the lack of price subsidies, similar to wind and solar power generation in the initial stage of development, the scale of geothermal power generation is small and is growing slowly. Among them, Tibetan Yangbajing and Yanyi are the two largest geothermal power plants in China, both of which are connected to the grid for commercial power generation.

The Yangbaijing Geothermal Power Station was successfully tested in 1977 for power generation, with an installed capacity of 26 MW, and is currently almost out of service due to low electricity prices and aging equipment, among other factors. Yang Yi geothermal power station was operated on a trial basis in 2011 and was connected to the grid in 2018 with an installed capacity of 16 MWe, operating for 8,723 hours in 2021 and generating 131 GWh of electricity. Langjiu and Naqu geothermal power plants were established in 1983 and 1993 respectively in Ali, Tibet, but are currently out of operation. Most of the medium and low temperature geothermal power plants are experimental and demonstration in nature. In the 1970s, China built seven medium and low temperature geothermal power plants with a single capacity of 50-300 kW, all of which are now out of operation.

In recent years, there have been new developments in medium- and low-temperature power generation, and in January 2018, a 1.2 MWe geothermal power generation project in Ruili, Yunnan Province, was successfully tested. In October, a geothermal power generation (280 kW) and heating (30,000 m^2) tertiary utilization project in Xian County, Hebei, was completed and tested for power generation. In January 2021, a geothermal research and demonstration test power plant (580 kW) in Datong, Shanxi Province, was tested and generated electricity. These projects are all experimental in nature and have not been put into commercial operation. By the end of 2021, only 16 MWe of installed geothermal power generation capacity is actually in operation in China.

3.6 Oilfield Geothermal and Coupling Utilization

First, the use of abandoned oilfield wells to extract heat energy: In Daqing Oilfield and Liaohe Oilfield, abandoned and long-dormant inefficient oil wells are converted into geothermal wells, and concentric tubular columns are used as borehole heat exchangers to extract heat and provide heat for mine buildings and oil pipelines, which can replace 299 tons of standard coal annually. Second, geothermal energy is used in the process of oil and gas development for oilfield production: In Shengli Oilfield, 22 oilfield geothermal energy utilization projects have been put into operation, which are used for heating oilfield extraction fluid and building heating, and can replace 9,260 tons of crude oil and 40.9 million cubic meters of natural gas annually, and realize heating of 500,000 square meters, saving 42,000 tons of standard coal and 104,000 tons of carbon emission reduction annually. Third, geothermal energy is coupled with other energy sources: In northern China, geothermal energy as the basic heat source and the use of heat pumps to extract waste heat peak has been very common, some projects more step with natural gas, photovoltaic coupling. In Shanxi Taiyuan Tanghuai Industrial Park, first pre-heating with geothermal energy, and then with natural gas to continue to raise the temperature of industrial steam, supplying 130,000 tons of steam per year. In Henan Fanxian Pu three joint station, the use of heat pumps to extract the heat of the oilfield water heating crude oil, and in the idle roof and open space on the construction of photovoltaic power generation system, power supply for the heat pump, to achieve ‘waste heat + photovoltaic’ comprehensive utilization.

4. ACHIEVEMENTS IN GEOTHERMAL DEVELOPMENT

4.1 Geothermal Companies are Increasing and Becoming Stronger

In 2006, in Xianyang, Shaanxi Province, Sinopec started commercial development of hydrothermal geothermal heating projects, which has extended to Beijing, Tianjin, Hebei, Henan, Shaanxi, Shanxi and other geothermal resource advantageous areas, with geothermal heating capacity of more than 80 million square meters, maintaining the advantage of China’s largest geothermal development enterprises and continuing the improvement of industrial and scientific R&D system. China National Petroleum Corporation (CNPC) built several geothermal heating projects in Northeast China and North China relying on oil-field geothermal resources and oil teams, with a cumulative geothermal heating capacity of 15.8 million square meters. China National Nuclear Power has formed China National Nuclear Kunhua Energy Corporation to enter the southwest region and actively explore geothermal power generation. China Energy Conservation has made full use of the capital market to enter the geothermal field through joint ventures and mergers and acquisitions.

The General Administration of Coal Geology has entered the geothermal development engineering market through its Hydrographic Bureau. Beijing Huaqing Geothermal focuses on the development and utilization of shallow geothermal energy in and around Beijing. Local enterprises and institutions, such as Hebei Geomine, Shandong Geomine, and Yankuang Group, have also formed specialized enterprises to develop local hydrothermal geothermal resources, taking advantage of their familiarity with

the resources and markets in their regions. Many private enterprises that entered the geothermal industry earlier, such as Hailifeng, Henan Wanjiang, Zhejiang Lute, Hubei Fengshen and Hengyouyuan, have also started to standardize their development, have set up R&D institutions, gradually pay attention to geothermal recharge, and further enhance their sustainable development capability.

4.2 Systematic Geothermal Standards are Gradually Being Formed

The geothermal industry is a composite industry involving exploration, drilling, heating, and power generation. In the past, the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China organized and issued five national standards, and eight provinces and cities, including Beijing, Tianjin and Hebei, issued a cumulative total of 35 local standards, all for their own fields and regions, lacking a comprehensive geothermal standard system. In November 2016, the National Energy Administration approved the establishment of the Geothermal Energy Standardization Technical Committee for the Energy Industry, which developed a system of industry standards covering five specialties and 111 standards, of which 56 were considered in need of development, and 40 of which had been cumulatively developed and released by the end of 2021. At the same time, the Geothermal Energy Standardization Technical Committee assisted Xiong'an New Area in Hebei Province to develop a geothermal energy standard system and developed and submitted 10 local standards; assisted Sinopec to develop 18 corporate standards; and is currently working with the International Geothermal Association (IGA) to develop the 'Recommended Practices for Geothermal Heating'.

4.3 Significant Progress in Geothermal Technology

In recent years, the practical application of petroleum exploration technology combined with the low profitability of geothermal heating conditions has led to the development of a comprehensive geophysical technology exploration technique which combines seismic + non-seismic technology to find a balance between exploration accuracy and cost, and has become the main means of geothermal exploration. Safe and efficient drilling technology for carbonate thermal reservoirs uses a reduced wellbore fluid column circulation pressure process, resulting in a clear water inflatable drilling process and a double-walled drill stem air lift fast penetration drilling process, reducing the drilling risk of karst-fracture type thermal reservoirs. The sandstone reservoirs recharge gradually formed a series of application technologies such as extraction and filling formation selection and completion, gradient filtration, sand treatment and unblocking.

Monitoring technology for geothermal development and utilization is becoming increasingly sophisticated, and several Chinese provinces and cities and enterprises have established monitoring platforms for geothermal development and utilization to serve the scientific utilization of regional resources, as well as government and enterprise management. In Shaanxi, more than six million heating capacity has been built by drilling boreholes of around 2,000 meters and combining heat pump equipment with heat exchange downhole. Based on the Beijing experience, regional shallow geothermal survey and evaluation techniques were established to promote shallow geothermal development and utilization. In Qinghai Republic, engineering tests on dry heat rock were conducted, and engineering verification and technology accumulation were carried out in terms of resource exploration and drilling and fracturing. At the pilot base of the Xiong'an Science and Technology Innovation Center in Hebei, shallow geothermal energy, light storage and charging integration, and photothermal systems are being explored to provide cold, heat, and electricity energy supply and hot water services for the park, and to provide low-carbon energy technology solutions for the park.

4.4 Continuously Accelerating the Development of Talents

In November 2019, the Sino-Iceland Training Program was officially established. The first training course was conducted by 11 international experts from the UNESCO Geothermal Institute, as well as 15 Chinese experts, providing professional training to 41 technical key personnel for five weeks. Universities and research institutes such as Tianjin University, Jilin University, China University of Petroleum, China University of Geosciences, Institute of Geology and Geophysics, Chinese Academy of Sciences, and Guangzhou Institute of Energy Research, have established geothermal centers, research laboratories and other institutions. Various academic organizations such as the National Geothermal Energy Center, the China Energy Research Society, the China Petroleum Society, the China Petroleum and Petrochemical Engineering Research Society, the Chinese Geophysical Society, the

Chinese Renewable Energy Society, and the China Building Energy Conservation Association regularly hold a series of conferences on topics in the geothermal field.

4.5 Major Projects are Being Completed One After Another

In Xiong County, Hebei Province, Sinopec has promoted geothermal development and complete recharge of the entire county, built a heating surface of more than five million square meters, basically covering the urban area, and created China's first geothermal heating 'smoke-free city', providing useful experience for national geothermal industrialization and sustainable development. In 2017, Xiong'an New Area (a new city covering Xiong County) was established and continued to explore a new model of geothermal development by building a cumulative geothermal clean heating capacity of seven million square meters and being entrusted to operate 12 million square meters in accordance with new concepts and standards. In Wuhan Binjiang International Business District, Hubei Province, a project with a heating and cooling capacity of 2.11 million square meters is under construction using water source heat pump + water storage technology with Yangtze River water as the cooling and heating source.

CNPC has built a hydrothermal geothermal heating capacity of 2.3 million square meters in Caofeidian New City, Tangshan, Hebei Province, and has been running smoothly for three heating seasons with balanced geothermal water extraction and irrigation. Beijing Daxing International Airport GSHP system provides heating and cooling services for 2.57 million square meters of buildings, heating 123 days a year in winter and cooling 120 days in summer, utilizing heat to 560,000 GJ a year. Beijing City Vice Center Office District uses GSHP + deep geothermal + water storage + auxiliary cooling and heat sources, and takes the lead in creating a 'near-zero carbon emission zone' demonstration project through heat pump technology, providing summer cooling, winter heating and domestic hot water for 1.5 million square meters of buildings.

5. GEOTHERMAL DEVELOPMENT PERSPECTIVES

With the full implementation of the Paris Agreement, global energy is accelerating its transformation towards cleaner, lower-carbon, smarter and more diversified energy sources, and countries are participating in the global response to climate change by making 'autonomous contributions'. In September 2020, Chinese President Xi Jinping announced at the 75th General Debate of the United Nations General Assembly that China will "achieve peak carbon by 2030 and carbon neutrality by 2060", pressing the accelerator button for the development of renewable energy in China. In January 2021, the National Energy Administration released the 'Notice on Renewable Energy Heating Work According to Local Conditions', which clearly proposed to actively promote the development and utilization of geothermal energy. And in September, the National Development and Reform Commission, the National Energy Administration and eight other ministries and commissions issued 'Opinions on Promoting the Development and Utilization of Geothermal Energy', proposing that by 2025, the national geothermal energy heating (cooling) area will increase by 50% compared to 2020. A number of geothermal energy power generation demonstration projects will be built in areas with good resource conditions, and the national installed capacity of geothermal energy power generation will double compared to 2020, which depicts a grand blueprint for the development of geothermal energy in China, and the geothermal energy industry is facing good development opportunities.

In the next few years, we will continue to give full play to the advantages of geothermal energy, which is rich in reserves, widely distributed, stable and reliable, clean and low-carbon, renewable and sustainable, and rely on the development of geothermal clean energy heating in Xiong'an New Area to create and form a standard and model for the high-quality development and utilization of geothermal energy, and to continue to provide reference and guidance for the development of geothermal energy in China. In northern China, depending on the geothermal resources in the Bohai Bay Basin, the South China North Basin and the Fenwei Graben System, geothermal heating will continue to replace coal-fired heating on a large scale, as driven by the clean heating policies of governments at all levels.

The middle and lower reaches of Yangtze River, it is suitable for the development of ground-coupled heat pump systems, underground water heat pump systems, as well as surface water heat pump systems. The hot summer and cold winter climate will prompt governments, enterprises, and residents to make spontaneous investments to improve the quality of life by shallow geothermal heating and cooling. The areas rich in high-temperature geothermal resources will remain hot spots for research and

investment in geothermal power projects, and will give rise to new small-medium-scale geothermal power plants that combine experimental operation with commercial development. The automated monitoring and control of geothermal projects will become more common, the development of intelligent management and control of geothermal field energy will become a new trend, and the efficiency of energy use will be further improved, continue to lead the high-quality development of non-electricity use of renewable energy sources, and jointly respond to global climate change and challenges, and make more important contributions to solving global energy and environmental problems and promoting sustainable development!

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TABLE 1. PRESENT PRODUCTION OF ELECTRICITY

Energy source	Geothermal		Other Renewables		Nuclear		Fossil Fuels		Other sources		Total	
	Installed Capacity (MWe)	Gross Electrical generation GWh/yr	Installed Capacity (MWe)	Gross Electrical generation GWh/yr	Installed Capacity (MWe)	Gross Electrical generation GWh/yr	Installed Capacity (MWe)	Gross Electrical generation GWh/yr	Installed Capacity (MWe)	Gross Electrical generation GWh/yr	Installed Capacity (MWe)	Gross Electrical generation GWh/yr
In operation in Dec.2021	16	131.16676	1063940	2485300	5326	407141	129678	5642168			1198960	8534740

TABLE 2. GEOTHERMAL POWER FIELDS, PLANTS AND UNITS IN THE COUNTRY

Name or number	Type of unit	Year of commission	Status	Turbine manufacturer	Installed Capacity (MW)	GEP (GWh/year)	NEP (GWh/year)
Fengshun	1F / 2F / 3F	1970	Not operating temporarily		0.586		
	B-ORC	1978	Not operating temporarily				
	1F / 2F / 3F	1984	Operating				
Wentang	B-ORC	1971	Decommissioned		0.05		
Huailai	B-ORC	1971	Decommissioned		0.2		
North China Oil Field	B-ORC	2011	Operating	Experimental	0.4		
Huitang	1F / 2F / 3F	1975	Decommissioned		0.3		
Xiongyue	B-ORC	1977	Decommissioned		0.1		
Zhaoyuan	1F / 2F / 3F	1973	Decommissioned		0.2		
Xiangzhou		1979	Decommissioned		0.1		

Yangbajing	1F / 2F / 3F	1977	Not operating temporarily		27.18		
	1F / 2F / 3F	1981,1982,1985,1986, 1988,1989,1990,1991	Not operating temporarily				
	Other	2008,2010	Not operating temporarily				
Yangyi	Back Pressure	2011,2012	Decommissioned		1.2		
	Other	2016	Decommissioned		4		
	B-ORC	2018	Operating		16	131.17	108.97
Langjiu	1F / 2F / 3F	1987	Decommissioned		0.3		
Naqu	B-ORC	1993	Decommissioned		1		
Qingshui	1F / 2F / 3F	1981	Decommissioned		3		
Tuchang	B-ORC	1985	Decommissioned		0.3		
Xianxian	B-ORC	2018	Operating	Experimental	0.28		
Ruili	B-ORC	2018	Operating	Experimental	1.2		
Datong	B-ORC	2021	Operating	Experimental	0.58		

TABLE 3. SUMMARY OF GEOTHERMAL HEATING AND COOLING INSTALLATIONS IN THE COUNTRY

Geothermal Application	Total Installed Capacity (MWt)	Total Energy produced (TJ/year)	Total Energy used (TJ/year)	Number of Installations
Agriculture and food processing	1107.8		12559	
Industrial process heat	95		1198	
Health, recreation, and tourism	6665		100889	
Heating and cooling for buildings	92352		714236	
Other uses				