Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Rapid Development of China's Geothermal Industry -- China National Report of the 2020 World Geothermal Conference

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Keywords: geothermal, power generation, direct use, country update report

ABSTRACT

With the promotion of clean heating in the northern regions for counteract the air pollution, especially the release of the first national geothermal industry planning, the 13th Five-year Plan for Geothermal Energy Development and Utilization, as well as the geothermal utilization planning and corresponding preferential policies implemented by local governments, the utilization of geothermal resources in China developed rapidly in the past five years. This paper up-dates the geothermal resource reserves and regional geothermal heat flow data in China, the direct use and power generation, as well as the scientific research in the geothermal sector, including the geological exploration of hot-dry rock. In 2018, the service construction area of district heating by hydrothermal resources exceeded 150 million m^2, growing at a rate of 10% per year; ground source heat pump continues to develop rapidly, and the installed capacity reached 26,450 MW and the service construction area exceeds 500 million m^2. Based on technical innovations, some ground source heat pumps projects with very large scale has become implemented, such as the Beijing New International Airport in Daxing, Xiong'an New District, the Deputy Center of the City of Beijing, the Jiangbei urban area in the City of Chongqing, and their service construction area has reached more than 3 million m^2. Traditional hot spring bathing and medical utilization have gradually improved to health care and recreation. In respect to geothermal power generation, a few projects have been invested by state-owned enterprises and private enterprises. In 2018, a 16 MW unit of the Yangyi Geothermal Power Station in Tibet was successfully connected to the national power grid. A test power unit with 400 kW capacity has been set up in the Tibetan area, Kangding, Sichuan Province. A 2MW geothermal power unit has been installed in Dehong, Yunnan Province. At the moment, the total installed capacity of geothermal power generation in China has reached 34.896MW. The actual installed capacity is 27.18MW. At the same time, hot-dry rock exploration also started in China, especially in the Gonghe Basin, Qinghai Province. To realize the goal set up in the 13th Five-year Plan for Geothermal Energy Development and Utilization, the geothermal community in China has to work harder in the coming few years.

1. INTRODUCTION

In the global energy utilization pattern, traditional energy sources such as oil, coal, and natural gas still dominate now. In 2017, China's energy consumption accounted for 23.2% of the global total, ranking first in global energy growth for seventeen consecutive years. However, with the depletion of fossil energy, the problem of ecological environment pollution has become more and more serious, and the application of clean renewable energy has reached a new climax. In February 2017, the National Development and Reform Commission, the National Energy Administration, and the Ministry of Land and Resources jointly issued the "13th Five-Year Plan for Geothermal Energy Development and Utilization". This is the country's first geothermal industry plan, a milestone in the development of the geothermal industry. The plan proposes that by 2020, the geothermal heating (refrigeration) area will reach 1.6 billion square meters, and the geothermal power installed capacity will be about 530 MWe. In 2020, the annual utilization of geothermal energy will be 70 million tons of standard coal, and the annual utilization of geothermal energy heating will be 40 million tons of standard coal. This will greatly promote the rapid and healthy development of China's geothermal industry. In addition, according to Academician Cao Yaofeng, China's geothermal energy ratio in the adjustment of energy structure will reach 1.5%, an increase of 1 percentage point over the current 0.5%, that is to say, three-point increase in the non-fossil energy 2020, geothermal "There is one in three points", indicating that geothermal energy will contribute greatly to the adjustment of energy structure in the future. In response to the country's strategic deployment of geothermal energy, local governments such as Beijing, Tianjin, Hebei, and Shanxi have also introduced many local planning and encouragement policies to promote the development of the geothermal industry. The geothermal industry is bound to attract rapid development.

At present, China's geothermal power generation has no significant growth. As of 2019, the total installed capacity of geothermal power generation in China is 34.896MW. The actual installed capacity is 27.18MW. The direct utilization of medium-low temperature geothermal energy still shows exponential growth. The annual geothermal energy utilization capacity and annual total heat utilization are 14,160 MWt and 197,281 TJ, respectively, which is 2.3 times the total geothermal utilization five years ago. The direct use of geothermal heat still dominates the use of heating. At the end of 2019, the installed capacity of geothermal heating in the country was 7,011 MWt, and the total heating area exceeded 150 million m^2. The traditional hot spring bathing and medical use are gradually upgraded to health care and leisure entertainment, reflecting the connotation of humanization and hot spring culture, with an average annual growth rate of about 3%. The continuous and rapid development of ground source heat pump reached a total installed capacity of 26,450 MW and the annual energy use reached 443,493 TJ at the end of 2019. It ranked first in the world, achieving a heating (refrigeration) area of more than 500 million m^2, which is 55.5% more than 5 years ago.

2. GEOTHERMAL RESOURCE GEOLOGICAL BACKGROUND

China is located on the southeastern edge of the Eurasian plate. Both the western part of the western region and the eastern central mountain range of Taiwan are located on the Indian plate and the Eurasian plate, the boundary between the Eurasian Plate and the Philippine plate, and their adjacent areas, all of these are areas with strong tectonic activities. Therefore, the eastern coastal zone and the southwestern border of China are rich in hot spring resources, and many high-temperature geothermal displays are concentrated.

According to the characteristics of the heat-control structure, China's geothermal resources can be divided into sedimentary basin-type geothermal resources and uplifted mountain-type geothermal resources. The sedimentary basin-type geothermal resources are affected by the paleo-continental block-type heat-control tectonic system, which is a stable continental internal block and is characterized by the deposition of thick sedimentary layers. It is mainly distributed in the main basins of the North China Basin, Songliao Basin and Erdos Basins. The geothermal flow range is 50-80 mW/m2.

The uplifted mountain-type geothermal resources are affected by the orogenic belt-type heat control tectonic system, which belongs to the plate boundary and the orogenic belt and the internal orogenic belt of the plate. It is mainly distributed in the main active structural belts such as the Tibet area, the southeast coastal plate collision zone, the Nanling fold belt, the depression belt, and the Tianshan orogenic belt. Most of them are medium-high temperature geothermal resources, and the geothermal flow value is high, the average value is about 90-150 mW/m2, the average geothermal gradient is between 1.5 ~ 4.0 ℃/100 m, the average value is about 3.2 ℃/100 m.

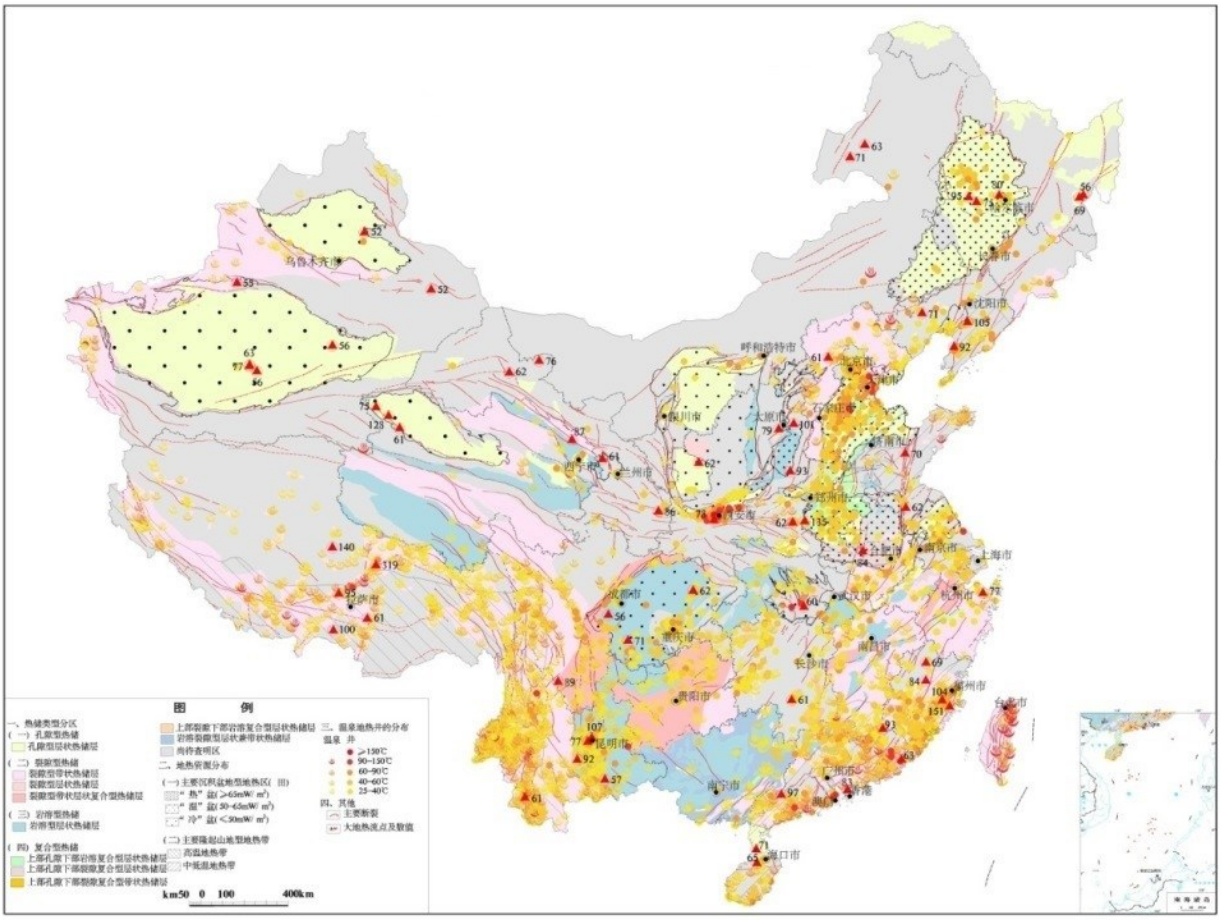

Figure 1: Distribution map of geothermal resources in China.

3. GEOTHERMAL RESOURCES AND POTENTIAL

China is a country with relatively abundant geothermal resources. The total amount of geothermal resources accounts for about 7.9% of the world. According to the characteristics of geothermal resources, China's geothermal resources are divided into three categories: shallow geothermal resources, hydrothermal geothermal resources, and dry-hot rock resources.

3.1 Hydrothermal Geothermal Resources

China's hydrothermal geothermal resources are very rich, with 2,334 hot springs, 5,818 geothermal wells located. According to the results of the "12th Five-Year" regional geothermal survey conducted by the China Geological Survey of the Ministry of Natural Resources, China's hydrothermal geothermal resources are equivalent to 1,250 billion tons of standard coal, and the annual recoverable amount is equivalent to 1.865 billion tons of standard coal, equivalent to 50% of China's coal consumption in 2015. Among them, the amount of hydrothermal high-temperature geothermal resources is equivalent to 14.1 billion tons of standard coal. The power generation potential is 8.46 million KW. It is mainly distributed in the south-east coastal area, the Guanzhong basin, and the Tashkurgan and Jilin Changbai Mountain areas. The hydrothermal medium-low temperature geothermal resources are mainly distributed in 15 large and medium-sized sedimentary basins and mountain fault zones such as the North China Plain, the Subei Plain, the Songliao Basin and the Yanqi Basin. The amount of geothermal resources is equivalent to 1,230 billion tons of standard coal, accounting for 98% of the total. The annual recoverable amount of geothermal resources is equivalent to 1.85 billion tons of standard coal, and the power generation potential is 1.5 million KW.

3.2 Shallow Geothermal Resources

China's shallow geothermal resources are distributed nationwide. According to the survey, the thermal capacity of shallow geothermal resources in 336 prefecture-level cities in China is 1.11×1017 kJ/°C, and the annual recoverable amount is equivalent to 700 million tons of standard coal, which can replace 1.17 billion tons/year of standard coal and 410 million tons/year of coal. The building has a summer cooling area of 32,600 square kilometers and a winter heating area of 32,300 square kilometers. Among them, the groundwater source heat pump system has a cooling area of 5,590 square kilometers in summer and a heating area of 3610 square kilometers in winter. The ground-source heat pump system of the buried pipe has a cooling area of 35,600 square kilometers in summer and 37,500 square kilometers in winter.

From the perspective of shallow geothermal energy development and utilization, the suitable area of the buried tube heat pump system in China accounts for 29% of the total evaluation area; the suitable area accounts for 53%. The suitable area of the groundwater source heat pump system accounts for 11% of the total evaluation area, and the suitable area accounts for 27%. Considering the influencing factors of shallow geothermal energy development and utilization, the areas suitable for the development of shallow geothermal energy in China are mainly distributed in the middle and eastern provinces, including Beijing, Tianjin, Hebei, Shandong, Henan, Liaoning, Shanghai, Hubei, Hunan, Jiangsu, Zhejiang, Jiangxi, Anhui and other 13 provinces (cities).

4. UTILIZATION OF GEOTHERMAL RESOURCES

As China's demand for clean energy increases, the advantages of developing and utilizing geothermal energy to adjust energy structure and improve the environment quality are becoming increasingly prominent. The way of using geothermal resources in China is mainly on the geothermal power generation of high-temperature geothermal energy and direct utilization of medium-low temperature geothermal energy.

4.1 Geothermal Power Generation

Since the 1970s, the projects of high-temperature geothermal steam power generation began in Tibet. In 1977, the Yangbajing geothermal power plant was built and tested successfully. In 1991, the total installed capacity was 25.18MW. In 2010, 1 MW of full-flow power screw expansion unit was added. The total installed capacity reached 34.896MW, which continues to this day. The Yangbajing geothermal power plant plans to increase the installed capacity by 2.1MW in 2020. By June 2018, the Yangbajing Geothermal Power Plant had accumulated 3.39 billion kWh of electricity and CO_2 emission reduction of 3.38 million tons, which played a pivotal role in the Lhasa power grid. In Tibet, in addition to Yangbajing, the Ali area also established the Langjiu and Naqu geothermal power plants in 1983 and 1993 respectively, but it is currently out of service. In 2011, the Yangyi Power Station in Dangxiong County was completed with a total installed capacity of 0.9 MW, which has been operating well to date, achieving a power generation capacity of 4.8 GWh/yr. The medium-low temperature geothermal power generation started in the first oil crisis. Seven medium-low temperature geothermal power plants have been built, with a single unit capacity of 50-300 kW. However, with the economic benefits and equipment aging, most of them have been shut down. Only one geothermal test power station, Guangdong Fengshun with 300 kW, is running, with a total installed capacity of 0.586 MW and a power generation capacity of 0.026 billion kWh.

In the past five years, the amount of geothermal power generation has not achieved a qualitative leap. However, the enthusiasm of developers to transfer to the geothermal power generation industry is very high. In 2018, the 16 MW capacity of the Yangyi Geothermal Power Station on the first phase was successfully connected to the grid and successfully passed the 72-hour full-load trial operation. In the same period, the first geothermal resource cascade development and utilization (Xianxian) scientific research base was preliminarily built in Xianxian, Hebei province, with the initial installed capacity of 280 kW. It is expected that by the end of 2020, our country will achieve installed capacity 200 MWe in Ganzi, Sichuan, 100 MWe installed capacity in Dehong, Yunnan, 15 MWe installed capacity in Boye, Hebei and Gaoyang, Hebei.

4.2 Geothermal Heating

China has developed and utilized hydrothermal geothermal heating for thousands of years. Its total amount has always been the world leader, especially in recent years, hydrothermal geothermal heating has developed greatly on a scale, depth and breadth of development and utilization.

According to incomplete statistics, by the end of 2019, the capacity of directly used hydrothermal geothermal resource reached 141,60 MWt in China, among which, the use of geothermal heating still occupies the first place. The annual utilization of thermal energy was 90,650 TJ, the heating area exceeded 150 million square meters, with a growth rate of 10% per year, of which Shandong, Shanxi, Hebei, Henan provinces grew rapidly. Nationally, Beijing and Tianjin are the typical cities that use hydrothermal geothermal heating. The 140 geothermal stations in Tianjin have an annual hydrothermal extraction capacity of 26 million tons and the geothermal heating area of 25 million square meters, accounting for about 6% of the city's central heating. Tianjin is the largest city in China using geothermal heating and has completed four medium-sized geothermal field surveys from 2016-2020. It is expected that the newly discovered geothermal fluids can be extracted 6.4 million m^3/yr, the heating area will reach 35 million square meters in 2020. Currently, the geothermal heating area was about 3.36 million square meters in Beijing, Beijing Daxing International Airport, Beijing City Sub-center, Beijing Yanqing Winter Olympics venues. Other large projects are all using hydrothermal geothermal heating. The geothermal heating construction area of Xiong County, Hebei Province is 4.6 million square meters, meeting the needs of more than 95% of the county's winter heating, and creating China's first heating “smoke-free city”, successfully realizing the “Xiong County Model”, from which technology can be replicated and experience can be promoted. Currently, 15 cities (counties) such as Rongcheng, Boye, Xinji, Dongguang, and Gucheng in Hebei province are actively replicating the “Xiong County Model,” the total geothermal heating area will reach 15 million square meters.

4.3 Hot Spring Bath and Medical

The development and utilization of hot springs are mainly concentrated in three aspects. Firstly, medical and recuperation. Modern medical research shows that hot springs have therapeutic effects on dozens of diseases, especially the cure rate of skin diseases is 11.17%. In the geothermal field that has been developed and utilized in China, the area that is all or partly used for bathing is estimated to account for more than 60% of the total number of thermal fields. Secondly, the aspects of industrial, agricultural and fishery areas. In Beijing, many hot spring plants are planted annually, e.g., the area of special vegetables is 20 km^2, the species of precious flowers are more than 70 kinds and the amounts of greenhouse flowers are 8 million. China's use of hot springs for aquaculture has spread over 47 geothermal fields in more than 20 provinces, with about 300 farms and 5.5 million square meters of fish ponds. In 2019, the total equipment capacity of geothermal greenhouse cultivation and aquaculture in China was 346 MWt and 482 MWt, respectively. It increased by 55.4% and 55% compared with 2014, and the annual utilization of thermal energy was 4255 TJ and 5016 TJ respectively. Thirdly, leisure tourism, the use of hot springs for tourism is almost everywhere in China, especially in recent years. Developers have focused on the projects of hot springs, hot spring culture, hot spring resorts, and hot spring towns, which are attracting more and more tourists. The use of hot spring baths has become the second direct use of geothermal energy. By 2019, the total equipment capacity of geothermal hot spring bathing and medical utilization in China was 5,747 MWt, and the annual energy utilization was 86,993 TJ, which was 2.3 times and 2.75 times that of 2014.

4.4 Ground Source Heat Pump

Since the 21st century, the ground source heat pumps have developed rapidly in China, the shallow geothermal resources used by ground source heat pumps have exceeded conventional geothermal resources, with an average annual growth rate of more than 20%. According to incomplete statistics, by the end of 2019, the area of ground source heat pump engineering applications in China has reached more than 500 million square meters, Its installed capacity of shallow geothermal energy reaches 26.45 GWt, and the total annual utilization is 246,212 TJ, which are 2.25 times and 2.45 times of 2014 respectively, with a continually leading position in the world. Ground-source heat pumps are the most widely used in Beijing, Tianjin, Hebei, and Shandong. Among them, at the end of 2018, more than 1,300 heat pump projects were completed in Beijing, with a total application area of 50.97 million m^2, which can replace traditional energy sources of about 650,000 tons. More than 1,000 heat pump projects have been built in the Shandong Province, with a total application area of about 60 million m^2.Shallow geothermal energy replaces traditional fuel boiler heating, which not only replaces and saves fossil fuels, but also significantly reduces pollution, improves the environment, and defends the blue sky. In 2018, Beijing had 227 days of excellent days, accounting for 62.2%, so it is imperative to use clean energy for heating.

Since the 19th National Congress, the promotion of ground source heat pumps has been in dire straits. The Ministry of Finance and the Ministry of Housing and Urban-Rural Development have strengthened the policy support and subsidies for various regions of the country in combination with the actual needs of new energy utilization. This includes Beijing, Hebei, Shandong, Shanxi, and other provinces and cities, where specific policy regulations have been issued. In order to vigorously develop ground source heat pumps and promote the development of the geothermal industry, the government has set up special funds in four provinces and cities, i.e., Nanjing, Tianjin, Changsha and Guangdong.

In addition, the ground source heat pump projects’ scale development is becoming more and more obvious. The Beijing Daxing International airport performed a heating and cooling area of 2.57 million square meters, and the sub-center of the Beijing City performed a heating and cooling area of 3 million square meters. The water-conditioning project of Chongqing Jiangbei City had a scale of 4 million square meters. The coal-fired replacement project of Sinopec Jianghan Oilfield's reached a scale of 5.7 million square meters. The scale will reach 1,600 million square meters in Nanjing Jiangbei New District water-conditioning project. The starting area of Xiong'an New District is planned to achieve a heating and cooling area of 100 million square meters through the “geothermal +” energy supply mode.

The geothermal industry in China has established its leading position in the world. At present, the geothermal development situation is improving. The release of “the National 13th Five-Year Plan for Geothermal Energy Development and Utilization” in 2017, together with the northern regions’ promotion and implementation of clean heating, the geothermal utilization plan and corresponding preferential policies have been released one after another, and the country has formed a new upsurge in geothermal development and utilization. China's geothermal heat will live up to expectations and show greater glory on the world stage.

ACKNOWLEDGEMENT

Authors would like to express their thanks to people who provided latest statistics: China Energy Research Society, relevant departments of the Ministry of Natural Resources and members and institutions of Geothermal Council of China Energy Society. It would be very difficult to complete this country update report with the most accurate statistics and analysis without their strong support.

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Table 1: Present and Planned production of electricity

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify) (wind & solar)		Total	
	Capacity Mwe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	27.28 (2017)	1	1143670	49231	352260	12329	44660	2944	358890	5435	1899670	69440
Under construction in December 2019			65000		13000		8600		70400		157000	
Funds committed, but not yet under construction in December 2019	2.1										2.1	
Estimated total projected use by 2020	30		1208670		365260		53260		429290		2056672.1	

Table 2: Utilization of geothermal energy for electric power generation as of 31 December 2019

1)N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2)1F = Single Flash B = Binary (Rankine Cycle)

2F = Double Flash H = Hybrid (explain)

3F = Triple Flash O = Other (please specify)

D = Dry Steam

3) Electrical installed capacity in 2019

4) Electrical capacity actually up and running in 2019

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity	Total Running Capacity	Annual Energy Produced 2019	Total under Constr. or Planned
						MWe[3)]	MWe[4)]	GWh/yr (2018)	Mwe
Guangdong	Fengshun	1970,1978,1984	3	Unit 1&2 N	1F,B,1F	0.586		2.60	
Jiangxi	Wentang	1971	1	R	B	0.05			
Hebei	Huailai	1971	1	R	B	0.2			
Hebei	North China Oil Field	2011	1		B	0.4		1.20	
Hunan	Huitang	1975	1	R	1F	0.3			
Liaoning	Xiongyue	1977	1	R	B	0.1			
Shandong	Zhaoyuan	1973	1	R	1F	0.2			
Guangxi	Xiangzhou	1979	1	R		0.1	0.1		
Tibet	Yangbajing	1977,1981,1982,1985,1986,1988,1989,1990,1991,2008, 2010	11	Unit 1 N （1）	2F,O	27.18	26.18	166.00	2.10
Tibet	Yangyi	2011,2012	2		O	0.9	0.9	4.80	
Tibet	Langjiu	1987	1	R	1F	0.3			
Tibet	Naqu	1993	1	R	B	1			
Taiwan	Qingshui	1981	1	R	1F	3			
Taiwan	Tuchang	1985	1	R	B	0.3			
Hebei	Scientific Research Base of Geothermal Resources Stepped and Comprehensive Utilization (Xianxian)		1		B	0.28		0.00	
Total			28			34.896	27.18	174.60	2.10

Table 3: Utilization of geothermal energy for direct heat as of 31 December 2019 (other than heat pumps)

1) I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish farming
K = Animal farming
S = Snow melting

H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] x 0.004184 (MW = 10^6 W)

or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)

or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171

Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization					Capacity[3)] (MWt)	Annual Utilization		
		Flow Rate (kg/s)	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow (kg/s)	Energy[4)] (TJ/yr)	Capacity Factor[5)]
			Inlet	Outlet	Inlet	Outlet				
Tianjin	D	6,416.00	73.4	38			950.00	2,374.00	11,084.00	0.37
Hebei	D	7,141.00	53.1	40			690.00	2,642.00	8,050.00	0.37
Shandong	D	6,434.00	57.5	40			471.00	2,552.00	5,198.00	0.35
Shaanxi	D	5,541.00	58.9	40			438.00	1,939.00	4,835.00	0.35
Beijing	D	1,298.00	58.8	38			113.00	480.00	1,318.00	0.37
Henan	D	1,180.00	54	40			69.00	413.00	763.00	0.35
Lingdian	D	702.00	53.3	37			48.00	288.00	619.00	0.41
Other	D	2,753.00	54.5	40			167.00	964.00	1,843.00	0.35
China	G	1,226.00	63	33			154.00	454.00	1,797.00	0.37
China	F	2,073.00	55	30			217.00	726.00	2,395.00	0.35
China	I	2,018.00		Δt=20			169.00	1,251.00	3,304.00	0.62
China	A	1,135.00		Δt=20			95.00	454.00	1,198.00	0.4
China	B	29,951.00		Δt=20			2,508.00	11,980.00	31,637.00	0.4
TOTAL							6,089.00	26,517.00	74,041.00	0.39

Table 4: Geothermal (ground – source) heat pumps as of 31 December 2019

(This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.)

(rejected to the ground in the cooling mode as this reduces the effect of global warming.)

1)Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2)Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)

H = horizontal ground coupled

W = water source (well or lake water)

O = others (please describe)

3)Report the COP = (output thermal energy/input energy of compressor) for your climate

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5)Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319

6)Cooling energy = rated output energy (kJ/hr) x [(EER - 1)/EER] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Due to room limitation, locality can be by regions within the country.

Locality	Ground or Water Temp. (°C)1)	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type2)	COP3)	Heating Equivalent Full Load Hr/Year4)	Thermal Energy Used5) (TJ/yr)	Cooling Energy6) (TJ/yr)
Shenyang	14	6,007,400		W, V	3.2	2,716	57,341	
Beijing	15	4,006,200		V, W	3.7	2,540	31,684	
Henan	15	2,707,400		V, W	3.5	2,278	21,623	
Shaanxi	15	2,138,600		V, W	3.5	2,190	20,482	
Jiangsu	16	1,850,600		V, W	3.5	2,628	13,912	
Tianjin	15	1,214,100		V, W	3.7	2,540	10,451	
Hubei	16	1,069,300		W, V	3.5	2,365	9,336	
Other		7,456,400		V, W			81,383	
TOTAL		26,450,000					246,212	

Table 5: Summary table of geothermal direct heat uses as of 31 December 2019

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184

or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)

or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)

Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

4) Other than heat pumps

5) Includes drying or dehydration of grains, fruits and vegetables

6) Excludes agricultural drying and dehydration

7) Includes balneology

Use	Installed Capacity1) (MWt)	Annual Energy Use2) (TJ/yr = 10^{12} J/yr)	Capacity Factor3)
Individual Space Heating4)			
District Heating 4)	7,011	90,650	0.41
Air Conditioning (Cooling)			
Greenhouse Heating	346	4,255	0.39
Fish Farming	482	5,016	0.33
Animal Farming			
Agricultural Drying5)	179	2,145	0.38
Industrial Process Heat6)	395	8,221	0.66
Snow Melting			
Bathing and Swimming7)	5,747	86,993	0.48
Other Uses (specify)			
Subtotal	14,160	197,281	0.44
Geothermal Heat Pumps	26,450	246,212	0.30
TOTAL	40,610	443,493	0.35

Table 6: Wells drilled for electrical, direct and combined use of geothermal resources from January 1, 2015 to December 31, 2019 (excluding heat pump wells)

[1)] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)	3	28	3	300	37.20
Production	>150° C	2	9	1	200	5.40
	150-100° C	2	18	2	1000	54.90
	<100° C	1	461	50	2500	1,065.80
Injection	(all)		192	20	1000	460.80
Total		8	708	76	5000	1,624.10

Table 7: Allocation of professional personnel to geothermal activities (Restricted to personnel with University degrees)

(1) Government

(2) Public Utilities

(3) Universities

(4) Paid Foreign Consultants

(5) Contributed Through Foreign Aid Programs

(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	150	600	100			350
2016	190	640	120			400
2017	230	680	140			450
2018	264	725	168	N/A	N/A	527
2019	290	750	200			550
Total	1124	3395	728			2277

Table 8: Total investments in geothermal in (2019) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999						
2000-2004	5.4	80.9	172.8		97.9	2.1
2005-2009	8.2	207.8	1,142.90	2.2	97.7	2.3
2010-2014	28.5	424.7	1,485.80	54.8	91.3	8.7
2015-2019	277.4	536.8	1,634.40	62.1	82.1	17.9