Chapter 3

Country Reports

1. China

1.1 Current situation of geothermal energy use and national policy

1.1.1 Current energy policy and energy mix

Current energy policy

With the rapid growth of China's economy in recent decades, its energy consumption has also increased significantly. The dominance of coal in China's energy structure has aggravated the country's air pollution situation, prompting an energy revolution in production and consumption that started in 2012. The aim was to control energy consumption, enhance energy saving and cost reduction, and support low-carbon industry and new and renewable energy to protect the national energy security (Hu, 2012).

Promoting clean space heating in winter in China's northern region was emphasised in 2016. The purpose was to reduce haze, change rural lifestyle, and realise energy revolution in production and consumption (Xi, 2016).

Plans for energy and renewable energy had been done before, but the 13th Five-year Plan of Geothermal Energy Development and Utilization in 2017 was the first time that geothermal energy was listed among its specialised plans. Although China's Law of Renewable Energy in 2006 stipulated wind, solar, biomass, geothermal, and ocean energies as renewable energy, the government has only given economic incentives to wind, solar, and biomass energy.

In 2017, a resolute battle was waged for blue sky and a quick resolve made for coal-fired pollution mitigation (Li, 2017). At the same time, the National Development and Reform Committee issued the Development Planning of Strategic Emerging Industries, deploying new energy as strategic emerging industries, including geothermal power generation, geothermal district heating, GSHP, etc. (NDRC, 2017)

Energy mix in China

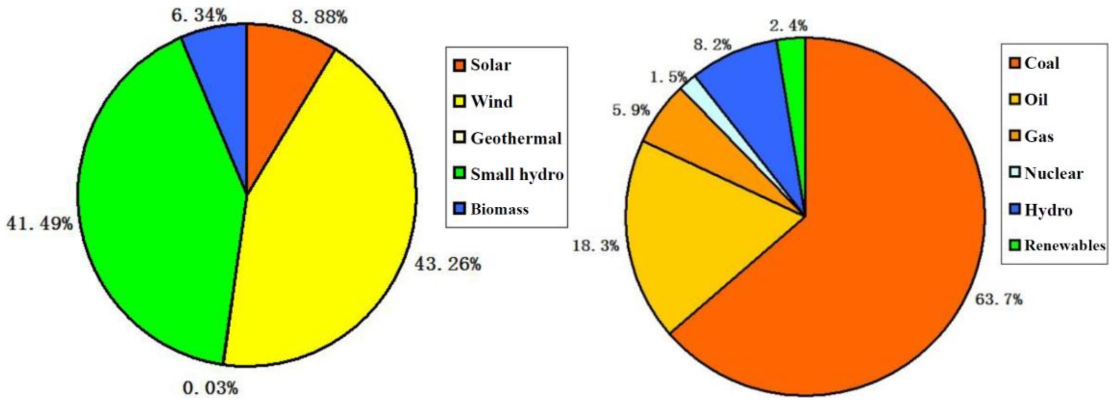
The *China Statistics Yearbook 2016* shows that China's energy mix in 2015 was still dominated by coal (63.7%), although reduced a little from the previous year's 64.0%. During the same year, non-fossil energies increased a bit (12.1%) from previous year's 12.0%, while non-hydro renewable electricity increased from 1.9% to 2.4% (NBSC, 2016 and 2017). However, amongst renewable electricity, wind power and small hydropower remained dominant with a rate of more than 40%. Geothermal electricity was just 0.03%.

Table 3.1.1-1. China’s Energy Structure and Renewable Electricity Mix, 2015

Energy Structure		Renewable Electricity	
Type	Proportion	Type	Proportion
Coal	63.70%	**Solar**	8.88%
Oil	18.30%	**Wind**	43.26%
Gas	5.90%	**Geothermal**	0.03%
Nuclear	1.47%	**Small hydro**	41.49%
Hydro	8.24%	**Biomass**	6.34%
Renewables	2.39%		

Source: National Bureau of Statistics of China, 2016, 2017.

Figure 3.1.1-1. China’s Energy Structure (left) and Renewable Electricity Mix (right), 2015



Source: National Bureau of Statistics of China, 2016, 2017.

1.1.2 Geothermal energy use in China

Geothermal resources

The geothermal resource survey and estimation project in China, funded by China Geological Survey under arrangement with the Ministry of Land and Resources, was completed in 2015. It shows potential for shallow geothermal energy, hydrothermal, geothermal, and enhanced/engineered geothermal (EGS) systems.

Table 3.1.1-2. Geothermal Resource Potential in China

	Type	Temperature	Depth	Potential	Reference
Power Generation	Hydrothermal	>150°C	200~3000 m	8466 MW_e	Huang, 2014
	EGS	>150°C	3000~10000 m	25.2×10^6EJ	Wang, 2015
Direct Use	Hydrothermal	25~150°C	200~3000 m	3.66×10^4EJ	Wang, 2015

EGS = enhanced/engineered geothermal systems, EJ = exajoule, m =metre, MW_e = megawatt electric.
Source: Huang, 2014; Wang, 2015.

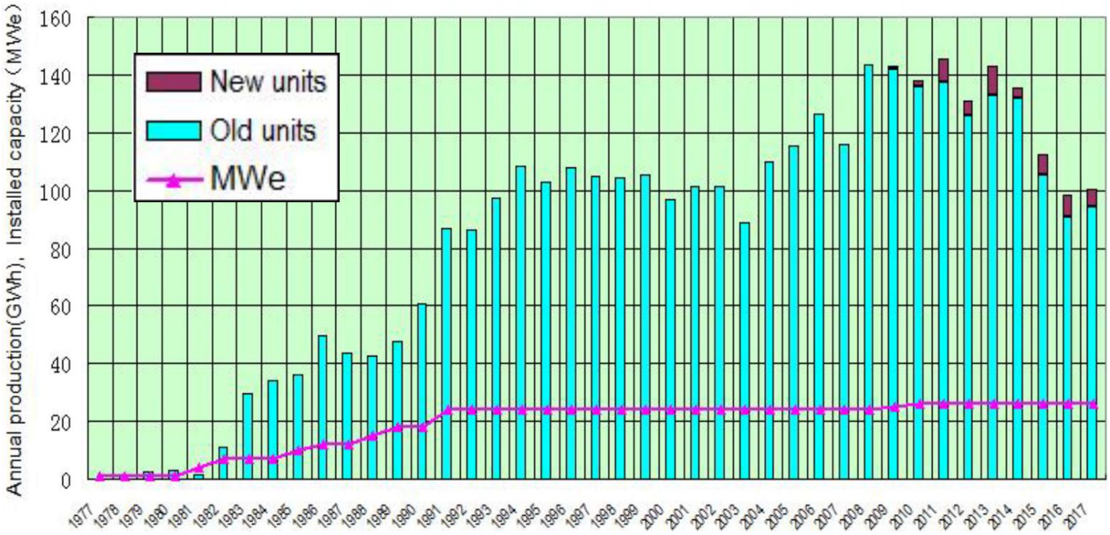
Current geothermal use

(1) Geothermal power generation

During the 12th five-year planning in 2011–2015, a private enterprise started to build the Yangyi geothermal power plant in Tibet. Designed for 32-MW_e installed capacity, the project was not completed due to national preferential policy (economic incentives), impracticability, lack of technology on high-temperature geothermal exploration, lack of experts, lack of loan support, etc.

China's main force of geothermal power generation is still the Yangbajain geothermal power plant in Tibet. It started operation in 1977 and completed its total installed capacity of 25.18 MW_e in 1991 with double flash units. A 1-MW_e test unit was retired in 2009 and two 1-MW_e total flow units were started in 2010. The power plant now has a total 26.18 MW_e capacity. Its high peak of over 140 GWh was reached in 2009–2014. Since three years ago, however, the power plant has started to show its age, with its annual production now reduced to about 100 GWh.

Figure 3.1.1-2. Timeline of the Yangbajain Geothermal Power Plant



GWh = gigawatt hour, MW_e = megawatt electric.
Source: Authors.

Still in operation is a 300-kW_e power plant in Fengshun, Guangdong province. The first geothermal power generation plant in China, it started operation in 1970 and is still operational through the technical support of the Guangzhou Institute of Energy Conservation.

Intermittently operating are some small units such as the Yangyi (400 kW_e + 500 kW_e) and the North China oil field (400 kW_e).

Since 2017, a private enterprise in Henan has been operating a 1.2-MW_e geothermal power unit in Ruili, Yunnan province, and a private enterprise has been operating a 200-kW_e geothermal power unit in Kangding, Sichuan province.

(2) Geothermal space heating

Geothermal space heating allows full play for medium-low-temperature geothermal resources. Geothermal district heating has made more progress after the government started promoting clean space heating and controlling haze problems. In 2014, geothermal district heating expanded to 60.32 million m^2 with installed capacity of 2,946 MW_t and annual energy use of 33,710 TJ (WGC2015, 2014). It reached 90 million m^2 with installed capacity of 4,400 MW_t and annual energy use of 50,300 TJ in 2016.

(3) Baths and swims

Since ancient time, hot spring has traditionally been used for bathing and medical treatment. From the 1990s, China's market economy developers have elevated hot spring baths into hot spring resorts that favour tourism. With the promotion of health and raising culture as its theme, the scheme received favourable response from consumers and increased value and profit for geothermal use. In 2014, geothermal baths and swims had installed capacity of 2,508 MW_t and used energy of 31,637 TJ. They have since increased by about 10% annually.

(4) Geothermal greenhouse and aquaculture breeding

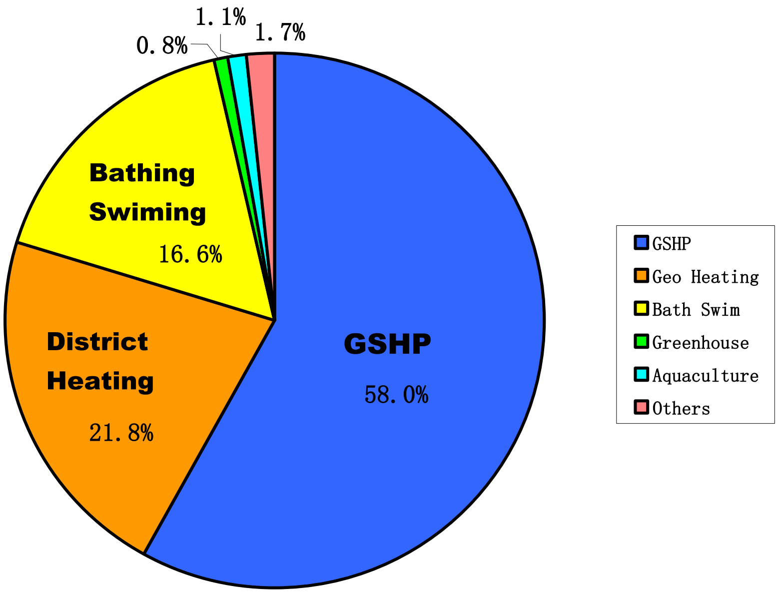
Along with the growth in economy and improvement in people's living standard came high market demand for seasonal fresh vegetables, high-range flowers, and live aquatic products. Geothermal greenhouse planting and aquaculture breeding have taken full advantage of the potential value of low-temperature geothermal power in a bid to satisfy market requirement and, in the process, achieve high economic benefits. By 2014, geothermal greenhouses and aquaculture had installed capacity of 154 MW_t and 217 MW_t, respectively, and used energy of 1,797 TJ and 2,395 TJ, respectively. In 2016, their used energy was about 1,900 TJ and 2,500 TJ, respectively. It has since increased annually by 3% and 2%, respectively.

(5) Ground source heat pump

China's current geothermal direct use is mostly ground source heat pump (GSHP). In the past, the regions located south of latitude 33° had no space heating during winter, where the average January air temperature is 0~1°C. At present, the middle and lower reaches of the Yangtze River have popularly implemented winter space heating, making a vast market for GSHP application. The Wuhan municipal government, for instance, has promoted a 'warm winter and cool summer' project where all new buildings will use GSHP system. China Geological Survey has completed surveys and estimations for shallow geothermal energy in 336 main cities nationwide. The results show suitable, basically suitable, and unsuitable areas for GSHP application. Many local governments have given preferential policy support and subsidies to it. In 2015, GSHP application reached 400 million m^2 using shallow geothermal energy of 109,000 TJ. In 2016, this application reached 490 million m^2 and used energy of 134,000 TJ. The annual progressive increase rate is 22%.

Figure 3.1.1-3 shows the annual energy used for geothermal direct use structure in China in 2016. GSHP's share was 58.0%, while the proportions of conventional geothermal use for district heating and bathing/swimming were 21.8% and 16.6%, respectively.

Figure 3.1.1-3. China's Geothermal Direct Use (Annual Energy Used), 2016



GSHP = ground source heat pump.
Source: Authors.

1.2 Target of geothermal power generation

1.2.1 Target for 2025

China's geothermal use target in 2025 is presented in the 2016 annual report of the geothermal energy project of the Economic Research Institute for ASEAN and East Asia (ERIA). We summarise it here using data from three channels:

(1) China Academy of Engineering's research report on China's geothermal development roadmap (Huang, 2014).

(2) China Geological Survey's modified data on geothermal project hosted by the Institute of Hydrogeology and Environment Geology (Wang, 2015).

(3) National Development and Reform Committee's 13th five-year planning on geothermal energy development and utilisation (NDRC, 2017).

The data from the above sources are listed in Table 3.1.2-1. We then made an integrated analysis based on the past process of China's geothermal development and considered removing existing best factor to reach most possible target. The ERIA report target is also listed in the table. Further research after the ERIA report is needed to answer the query on how to rely on possible innovation to improve and reach the target and benefits.

Table 3.1.2-1. Target Comparison of Three Groups and Selected Numbers in this Report

Item	**(1) in 2025**	**(2) in 2025**	**(3) in 2020**	**ERIA report in 2025**
Power Generation	200 MW$_e$	700 MW$_e$	500 MW$_e$	400 MW$_e$
EGS	100 MW$_e$	100MW$_e$	-	100 MW$_e$
Direct Use Except GSHP	14,330 MW$_t$	18,000MW$_t$ (in 2020)	18,000MW$_t$ (in 2020)	18,000 MW$_t$
Ground Source Heat Pump	25,680 MW$_t$	19,260MW$_t$ (in 2020)	22,470MW$_t$ (in 2020)	48,150 MW$_t$

EGS = enhanced/engineered geothermal systems, ERIA = Economic Research Institute for ASEAN and East Asia, GSHP = ground source heat pump, MW$_e$ = megawatt electric, MW$_t$ = megawatt thermal.
Source: Modified from Huang, 2014; Wang, 2015; and NDRC, 2017.

Based on Table 3.1.2-1, we made Table 3.1.2-2 to show details of the target value, especially for direct use, in the ERIA report.

Table 3.1.2-2. Target Number of Installed Capacity and Energy Utilisation for 2025

Installed Capacity of Power Generation	**Conventional Geothermal System**	**Enhanced Geothermal System**
	400 MW_e	100 MW_e
	500 MW_e	
	Eighteen times bigger than the 2015 capacity (28 MW_e)	
Energy Utilisation of Direct Use (conventional and GSHP, respectively)	Direct use except GSHP	GSHP
	18,000 MW_t	48,150 MW_t
	221,380 TJ/year	409,980 TJ/year
	400 million m^2 of heating area	1,500 million m^2 of heating area
	66,150 MW_t (631,360 TJ/year)	
	It is 3.7 times bigger than in 2015 (17,870 MW_t)	

GSHP = ground source heat pump, m^2 = square metre, MW_e = megawatt electric, MW_t = megawatt thermal, TJ = terajoule.
Source: Original table of this project.

1.2.2 Target for 2050

1. Geothermal power generation

According to China Academy of Engineering's research report on China's geothermal energy development roadmap, the long-term target up to 2050 is 1,000 MW_e for conventional geothermal power generation and 15 GW_e for EGS (Huang, 2014).

2. Geothermal direct heat use and GSHP

According to the same China Academy of Engineering's research report, the long-term target in 2050 for direct heat use is 67,500 MW_t with capacity factor of 0.36, so annual energy used will be 766,650 TJ; while it is 114,240 MW_t with capacity factor of 0.20 for GSHP, so annual energy used will be 720,530 TJ.

1.3 Barriers to geothermal power generation and necessary innovations

1.3.1 Inquiry and results

1. Results of inquiry from AGS11

Results from AGS11 inquiry were discussed during the ERIA geothermal energy project working group meeting in November 2016, and included in the 2016 ERIA report.

2. Inquiry from the China geothermal symposium

(1) Inquiry from the China geothermal symposium

In August 2017, the Geothermal Council of China Energy Society hosted a geothermal symposium in Dongying, Shandong province, where voluntary inquiries were solicited from the more than 100 participants from universities, research institutes, enterprises, and governments. A total of 37 valid inquiries were taken into statistics. A few of international results from AGS11 were considered but were given up during the ERIA project meeting in Malaysia. Instead, results of inquiry to domestic experts were used in this report.

The statistics and final results for geothermal power generation listed in Table 3.1.5 are shown in Figure 3.1.4.

1.3.2 Analysis of major barriers

(1) Uppermost of barriers are policy barriers. Especially, the lack of economic incentives (9.6%) and national energy policy (7.2%) are listed as first and second amongst 27 detailed policy barriers.

(2) The second main barriers are technical barriers, especially the lack of information and experience (5.1%).

(3) High exploration cost, a fiscal barrier, is also of high proportion (5.8%).

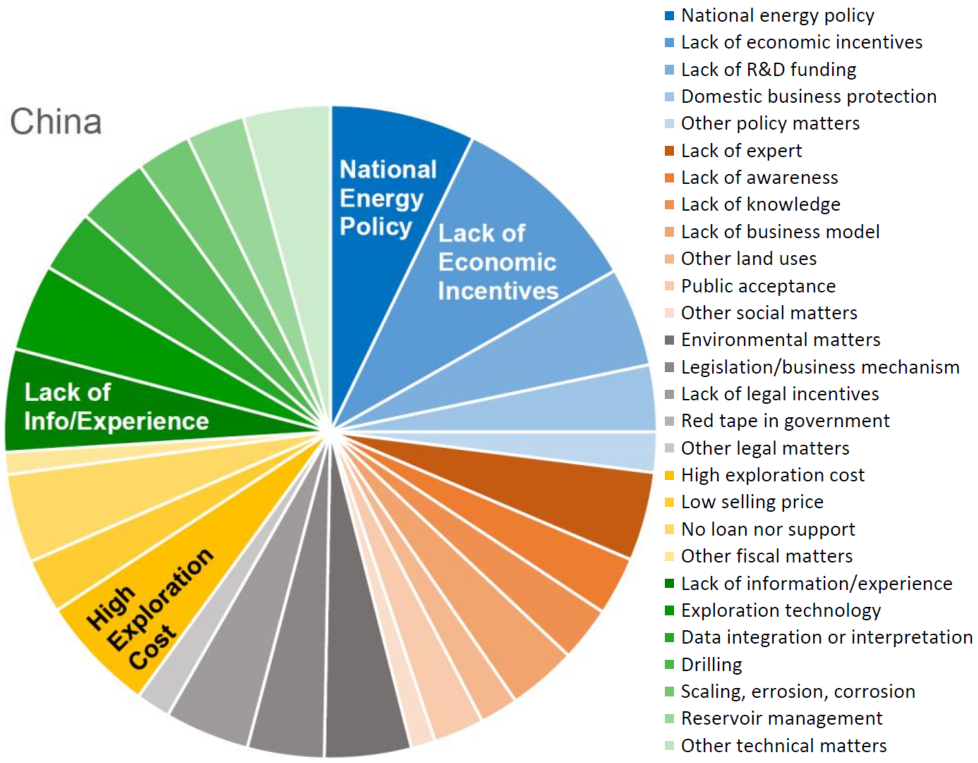
Table 3.1.3-1. Statistics of Barriers to Geothermal Power Generation in China

Barrier	Items of Barriers	Final Results from Domestic Inquiry (%)	
Policy	National energy policies	27	7.2
	Lack of economic incentives (subsidies, FiT, tax reduction, etc.)		9.6
	Lack of R&D funding		4.9
	Domestic business/information protection		3.3
	Others		2.0
Social	Lack of experts, lack of geothermal specialisations in universities	19	4.4
	Lack of awareness		2.9
	Lack of knowledge, wrong information		2.7
	Lack of business models		3.4
	Other land uses		1.9
	Public acceptance		2.5
	Others		1.2
Legal	Environmental matters (nature parks and forestry, etc.)	14	4.3
	Legislation or business mechanism		3.8
	Lack of incentives (on environmental or energy security aspects)		4.2
	Others		1.7
Fiscal	High exploration cost	14	5.8
	Low selling price		2.7
	No loans from banks or support from government		4.4
	Others		1.1
Technical	Lack of information or experience (general)	26	5.1
	Exploration technology		4.3
	Data integration or interpretation		3.1
	Drilling		3.6
	Scaling, erosion		2.7
	Reservoir engineering and management		2.9
	Others		4.3
Total		100	100

FiT = feed-in tariff, R&D = research and development.

Source: Authors.

Figure 3.1.3-1. Final Results of Inquiry on Barriers to Geothermal Power Generation in China



R&D = research and development.
Note: Major barriers are labelled.
Source: Authors.

1.3.3 Peculiar barriers hidden behind other superficial barriers

Power generation is the weak spot in China's geothermal energy use. Chinese geothermal energy workers are fervently hoping to change such situation. Other than the lack of economic incentives and national energy policies – which make developers shrink back at the first sight of such barriers – another big barrier is lack of experience and expertise, a peculiarly hidden barrier which, in essence, means the lack of geothermal specialisation in Chinese universities. When it comes to high-temperature geothermal power generation, it is obvious that China has no sufficiently and properly trained engineers.

The Tibetan geothermal geological team that built the Yangbajain geothermal power plant was unique because of its expertise on high-temperature geothermal exploration. However, those experienced engineers and technicians have either retired or transferred to explore other works as there have been no geothermal exploration projects in China in the last 20 years or so. Some provinces have newly established geothermal exploration teams and geothermal research institutes but unfortunately have no experience in high-temperature exploration. Certainly, more than 24 geological and geophysical engineers and researchers built the 24-MW$_e$ Yangbajain geothermal power plant. Now that China is planning to build a 500-MW$_e$ geothermal power plant, how many geothermal engineers would we need? Unfortunately, China has no sufficient geothermal engineers yet and no geothermal specialisation in Chinese universities as well (CERS, 2016). Ageing geothermal energy experts are crying out in alarm that China needs foreign experts to advice its high-temperature exploration and power plant building. But even that is not permitted.

1.3.4 Necessary innovations

Policy Aspect

(1) Issue necessary economic incentives

It is necessary that China issue national policy for economic incentives. At present, solar power, wind power, and biomass power get fixed subsidies for grid purchase price. But there is no formal governmental document for similar subsidy for geothermal electricity. There is no FiT mechanism for geothermal power generation. The renewable portfolio standard mainly serves wind power and solar power projects.

(2) Establish demonstration projects

China should establish national or departmental demonstration projects to show advance template suitable for popularisation. During China's 12th five-year plan, a private company invested in the construction of the 32-MW Yangyi geothermal power plant in Tibet. This project is great progress in China's geothermal power generation after 20 years of stagnation. Although we had suggested the need for national support through the creation of a demonstration project that could ensure successful power generation and establish confidence among investors, the proposal failed to get support and died prematurely due to financial problems.

(3) Open Chinese–foreign cooperation

Opening Chinese–foreign cooperation for national or departmental research projects will gain Chinese experts more experience in technology and management and avoid detours.

Social Aspect

(1) Set up geothermal energy specialisations in universities

Training geothermal energy professionals should fit the demand of geothermal power development. The few graduate students on geothermal technology are insufficient to meet the growth demand. Some experts with doctoral degrees do not even dare venture into geothermal energy front lines and satisfy themselves instead in laboratory and office research.

(2) Enhance publicity on geothermal energy

Various media (internet, TV, cinema, arts, etc.) should be utilised to promote geothermal energy.

Legal Aspect

(1) Issue laws on geothermal resources

The country should issue laws on geothermal resources and their methods of management. At present, geothermal resources are being managed as water resources in many cities where licence for geothermal exploitation is obtained from their water bureaus. Water bureaus do not understand geothermal energy, with most of them erroneously thinking it would drop groundwater level. If ever they approved, they require that geothermal wells be drilled in dense areas. Laws on geothermal resources and their management should clarify that the Ministry of Land and Resources is the authorised department for geothermal resources.

(2) Enhance management for geothermal reinjection

Enhancing management for reinjection of geothermal tail water in a legal framework is a good measure for sustainable use.

Fiscal Aspect

(1) Establish geothermal risk fund

Many developers worry about the risks involved in geothermal drilling. China should encourage investors in geothermal technology by establishing risk fund for geothermal resource exploration.

(2) Provide low-interest loans

Low-interest loans are welcome for small and medium-scaled enterprises involved in geothermal energy projects.

Technical Aspect

(1) Geothermal reserves preparation

Exploration and assessments should be done prior to geothermal resource development projects. Proper geothermal resource exploration should be funded by the national government. Investment by private developers should not start from resource exploration because it involves high risk and needs long period.

(2) Public geothermal database

Previous achievements in geological exploration are important reference for geothermal resource exploration and well drilling. However, open data are usually not available because these are kept by private companies. Thus, the country’s public data management system should be improved.

(3) Reinjection technology

Research for reinjection technology for geothermal tail water especially in sandstone reservoirs should be enhanced and suitable techniques be popularised to help developers and users solve difficulties.

1.4 Benefits of geothermal power generation in China

1.4.1 Mitigation of CO_2 emission (kg-CO_2/kW)

We recalculated Table 3.1.4-1 for power source and Table 3.1.4-2 for renewable electricity based on the newest data on energy mix.

The conventional power costs (grid purchase prices) for coal and hydropower in Table 3.1.4-1 and for solar PV and wind power onshore in Table 3.1.4-2 were adopted from data from China Energy Research Society (CERS, 2016) while others were based on international data.

Table 3.1.4-1. CO_2 Emission from Power Sources in China, 2015

Power Source	**Power Supply: A**	**Power Supply Ratio: B**		**Unit CO_2 Emission: C**	**Conventional Power Cost: D**	**B x D**	**B×C**
Unit	PJ			(g-CO_2/kWh)	USc/kWh		
Coal	**80,238**	64%		1,000	**6.6**	4.21	637.32
Oil	**23,051**	18%		778	**5.0**	0.92	142.44
LNG	**7,432**	6%		443	**5.0**	0.30	26.151
Nuclear	**1,852**	1%		66	**5.0**	0.07	0.9709
Hydro	**10,379**	8%		10	**4.7**	0.39	0.8244
Renew-ables	**2,948**	2%		**14.2**	**7.2**	0.17	0.3313
TOTAL/ Average	125,900	100%		808	5.9	6	**808**

CO_2 = carbon dioxide, g-CO_2 = gramme of carbon dioxide, kWh = kilowatt-hour, LNG = liquefied natural gas, PJ = petajoule, USc = United States cent.
Sources: A: National Bureau of Statistics of China, 2017; C: Benjamin K. Savacool, 2008; D: China Energy Research Society, 2016.

Table 3.1.4-2. CO$_2$ Emission from Renewable Power Sources in China, 2015

Power Source	Power Supply: A	Ratio in renewables: B	CO$_2$ Emission: C	Power Cost: E	CO$_2$ reduction cost	B×C	CO$_2$ reduction
Unit	GWh		(g-CO2/ kWh)	USc/ kWh	USc/ (g-CO2)		g-CO2/ kWh
Solar PV	**51,713**	**9%**	32	**14**	0.010466	2.8412	776.04
Wind onshore	**251,955**	**43%**	10	**8**	0.002659	4.3258	798.04
Geothermal (natural system)	**155**	**0%**	**13**	**7**	0.001411	0.0035	795.04
Geothermal (HDR)	**0**		**38**	**7**	0.001457	0	770.04
Small hydro	**241,659**	**41%**	13	**5**	-0.001104	5.3938	795.04
Biomass	**36,960**	**6%**	25	**7**	0.001433	1.5864	783.04
Biogas			11	**7**	0.001408	0	797.04
TOTAL	582,442	100%				**14.15**	

CO$_2$ = carbon dioxide, g-CO$_2$ = gramme of carbon dioxide, GWh = gigawatt hour, HDR = hot dry rock, kWh = kilowatt-hour, PV = photovoltaics, USc = United States cent.
Sources: A: National Bureau of Statistics of China, 2017;
C: http://www.japanfs.org/ja/news/archives/news_id035082.html; E: China Energy Research Society, 2016.

The target geothermal power generation, which includes conventional geothermal and enhanced/engineered geothermal system, will have new installed capacity of 500 MW$_e$ if the barriers are removed by innovations in 2025. It would be 17 times bigger than the current generation status (as of 2017).

Calculation of CO$_2$ mitigation by geothermal electricity:

808 – 13 = 795 (g/CO$_2$/kWh).

If with additional capacity of 500 MW (total increased target from 2015) with a capacity factor of 70%:

795 × 500 × 24 × 365.25 × 70% = 2,439,139,500 kg-CO$_2$/year = 2.44 million tonnes of CO$_2$/year.

If with additional capacity of 300 MW (partial increase by removal of barriers) with a capacity factor of 70%:

795 × 300 × 24 × 365.25 × 70% = 1,463,483,700 kg-CO$_2$/year = 1.46 million tonnes of CO$_2$/year.

1.4.2 New employment

We follow the calculation method of the working meeting in this research project using Excel template.

Tibetan region

The main geothermal power generation plant in China is the Yangbajain geothermal power plant, with 200 personnel. It produces 100 GWh annually during the last three years.

Because 100 GWh/year = 200 persons.

It means that 2.00 persons-year/GWh.

The target for 2025 is 3,066 GWh, half (1,533 GWh) in Tibet and another half in other regions.

Therefore 1,533 GWh × 2.00 persons-year/GWh = 3,066 persons for Tibet region.

Other regions

Other regions have higher effect, say 100 GWh/year = 85 persons

or 0.85 person-year/GWh.

Therefore 1,533 GWh × 0.85 person-year/GWh = 1,303 persons for other regions.

Total new employment

For new employment, it will be 3,066 + 1,303 = 4,369 persons or an average of 8.7 persons/MW.

1.4.3 Direct economic benefits

The use of geothermal energy will increase direct economic benefits, which we estimate as follows.

Increased sale of geothermal electricity.

Increased geothermal power of 500 MW_e in 2025.

For capacity factor of 0.70, the operation hours would be 8,760 × 0.7 = 6,132 hours per year.

Thus, 500 MW_e × 6,132 h = 3,066 GWh.

The average electricity price in China is CNY0.80 per kWh.

Annual sale of 3,066 GWh × 0.80CNY/kWh = CNY2,452.8 million = US$368.8 million.

1.4.4 Indirect economic benefits

Indirect economic benefits will come from restaurants, shops, supermarkets, assorted businesses, and services. The indirect economic benefits are about 1.5–3 times more than that of direct economic benefits.

3.1.4.5 Regional development

Geothermal power development can drive regional development. Yangbajain was a small village before the power station was constructed there. Yangbajain's infrastructure has now changed rapidly with the extended road system, water and electricity supplies, telecom and postal services, banks, shops, restaurants, etc. The local population has increased more than 10 times.

1.5 Summary of barriers to and benefits of geothermal power generation

- The first barriers to geothermal power generation in China are the policy barriers and the second are the technical barriers. A peculiar barrier hidden behind other barriers is the lack of specialisation on geothermal technology in Chinese universities, resulting in critical shortage of technicians especially for high-temperature geothermal resource exploration and power generation (Zheng, 2017).
- Economic incentives are the main suggested necessary innovation for removing barriers. The national subsidies to wind power and solar PV promoted the great growth of both. Geothermal power generation has never had such subsidy policy
- It is necessary to establish national demonstration projects for geothermal power generation and hot dry rock EGS development. A few years ago, a private enterprise invested in the development of the Tibet Yangyi geothermal power plant. Unfortunately, it did not get support as a national demonstration project and subsequently failed when the developer's fund dwindled. This led to developers losing confidence in pursuing similar projects.
- Geothermal power generation could reduce CO_2 emission. An additional 500 MW generation could contribute to CO_2 mitigation by 2.44 million tonnes annually. It will also lead to about 4,300 additional employment. It will also save fossil fuels and reduce energy costs. Indirect economic benefits include saving costs for CO_2 mitigation and new businesses such as greenhouse agriculture, fish farming, tourism, etc. It will lead to regional development and prosperous local economy.

As quantified, the benefits of removing barriers are summarised in Table 3.1.5-1.

Table 3.1.5-1. Quantification of Barriers to and Benefits of Geothermal Power Generation in China

Item		**Unit**	**Policy**	**Social**	**Legal**	**Fiscal**	**Technical**	**Total**	**Remark**	
Barrier contribution in category		%	**27**	**19**	**14**	**14**	**26**	100		
Target capacity		MW	135	95	70	70	130	**500**		
Target power generation		MWh/year	828,387	582,939	429,534	429,534	797,706	3,068,100	**70%**	capacity factor
	Electricity	J(elect)/year	2.98E+15	2.10E+15	1.55E+15	1.55E+15	2.87E+15	1.10E+16	kWh= 3.6×10^6J	
	Equivalent heat	J(heat)/year	7.46E+15	5.25E+15	3.87E+15	3.87E+15	7.18E+15	2.76E+16	assuming 40% efficiency	
Saving land (compared to same power by PV)		m^2	1.46E+07	1.03E+07	7.58E+06	7.58E+06	1.41E+07	5.41E+07		
Electricity sales	Developer's benefit	US$/year	115,974,180	81,611,460	60,134,760	60,134,760	111,678,840	429,534,000	**0.14**	US$/kWh
Electricity sales tax	Government's benefit	US$/year	9,277,934	6,528,917	4,810,781	4,810,781	8,934,307	34,362,720	**8%**	
Saving oil (barrel of oil equivalent)		boe/year	1,218,216	857,263	631,668	631,668	1,173,097	4,511,912	1 boe≈ 6.12×10^9J(heat)	
CO_2 mitigation		(t-CO_2/yr)	658,568	463,437	341,480	341,480	634,176	**2,439,140**		
Saving energy cost compared to PV	Factor	US$/MWh	18.900	13.300	9.800	9.800	18.200	70		
	Total saving	US$	57,987,090	40,805,730	30,067,380	30,067,380	55,839,420	214,767,000		
Saving CO_2 reduction cost compared to PV	Factor	US$/kg-$CO_2$	0.024	0.017	0.013	0.013	0.024	0.09		
	Total cost	US$	59,632	41,963	30,920	30,920	57,423	220,858		
Land Saving for CO_2 reduction compared to PV	Factor	m^2/kg-CO_2		-	-	-	-	22.72	from ‘Land’ Table	
	Total saving	m^2	14,962,577	10,529,221	7,758,373	7,758,373	14,408,408	55,416,953	for mitigation of 19I	
Direct: New employment for GPP			386	271	200	200	371	1,428		2.71x+73
Indirect: New business profit		US$	241,443	169,905	125,193	125,193	232,501	894,235	1,778	1788.47x NZ example
Indirect: New business economic effect		US$	301,860	212,420	156,520	156,520	290,680	1,118,000	2,236	2236x NZ example

boe = barrel of oil equivalent, CO_2 = carbon dioxide, GPP = geothermal power plant, J= joule, kg = kilogramme, kWh = kilowatt-hour, m^2 = square metre, MW = megawatt, MWh = megawatt hour, NZ = New Zealand, PV = photovoltaics, t-CO_2 = total carbon dioxide.

Source: Authors.

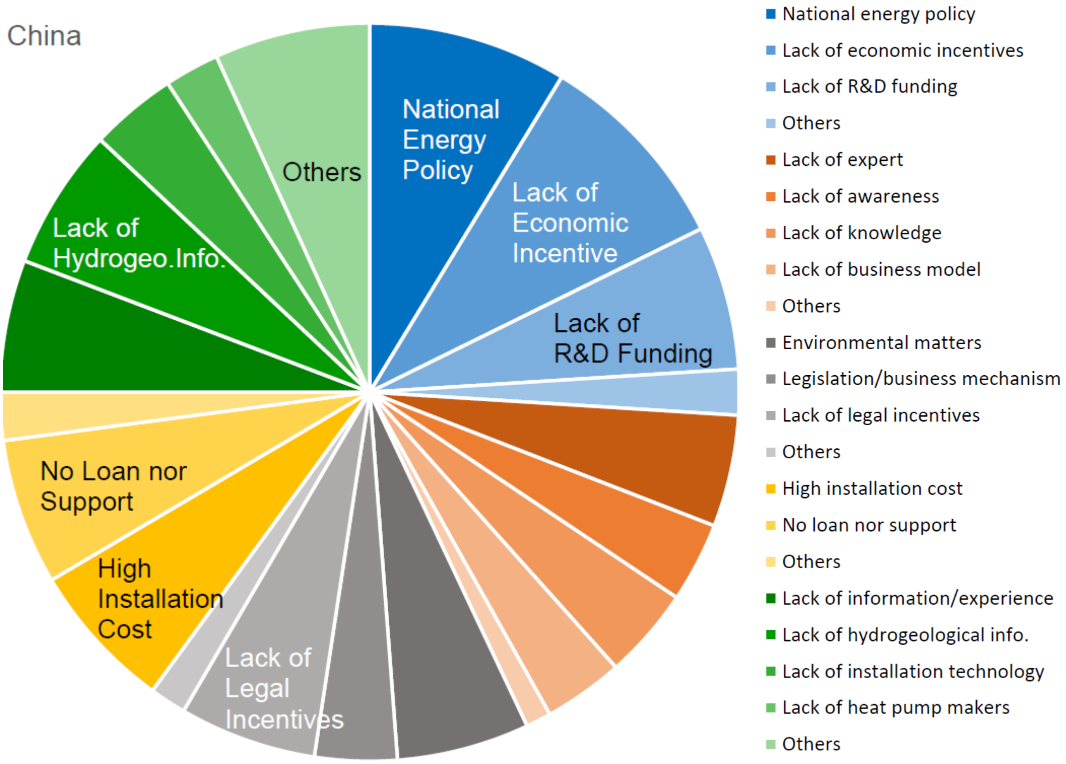
1.6 Barriers to direct use/GSHP and necessary innovations

1.6.1 Inquiry and results

We used the domestic inquiry from the geothermal symposium and adopted the results.

The corresponding statistical results and final used results for direct heat use/GSHP are shown in Table 3.1.6-1 while the final results are shown in Figure 3.1.6-1.

Fig. 3.1.6-1. Barriers to Geothermal Direct Heat Use/GSHP as Final Results in China



Note: Major barriers are labelled.
Source: Authors.

1.6.2 Analysis of major barriers

(1) The uppermost barriers are policy barriers, especially the lack of economic incentives (9.0%) and national energy policy (8.7%), which are listed as first and second amongst 27 detailed items.

(2) The second main barriers are technical barriers, especially the reinjection technique (6.8%), which is listed third amongst 27 detailed items.

(3) Also of high proportion (6.5%) is exploration cost. It belongs to the fiscal barriers and is listed fourth amongst 27 detailed items.

Table 3.1.6-1. Statistics of Barriers to Geothermal Direct Heat Use with Main Portion of GSHP in China

Barrier	Items of Barriers	Final Results of Domestic Inquiry (%)	
Policy	National energy policy	26	8.7
	Lack of economic incentives		9.0
	Lack of R&D funding		6.3
	Others		2.0
Social	Lack of experts, lack of geothermal specialisation in universities	17	4.9
	Lack of awareness		3.5
	Lack of knowledge, wrong information		4.0
	Lack of business models		3.5
	Others		1.1
Legal	Environmental matters (nature parks and forestry, etc.)	17	5.8
	Legislation or business mechanism		3.6
	Lack of incentives (from environmental or energy security aspects)		6.0
	Others		1.6
Fiscal	High installation cost	15	6.5
	No loans from banks nor support from government		6.4
	Others		2.1
Technical	Lack of information or experience (general)	25	5.8
	Hydrogeology information		6.2
	Lack of installation technology		3.8
	Lack of heat pump makers		2.4
	Others		6.8
Total		100	100

GSHP = ground source heat pump, R&D = research and development.
Source: Authors.

1.6.3 Peculiar barriers hidden behind superficial barriers

As with geothermal power generation, there is no direct heat use and GSHP specialisation in Chinese universities.

1.6.4 Necessary innovations

Policy Aspect

There are aspects in policy that serve as major barriers to direct heat use/GSHP since there is no uniform national policy on economic incentives for them. Unbalanced local policies exist in different provinces or cities that make unbalanced growth for direct heat use and GSHP. There has been rapid growth in places with preferential policy. The Beijing government, for instance, promotes using clean energy for winter heating, with the government-subsidised geothermal power or GSHP replacing coal. Although the Hebei provincial government is learning from Beijing, it gives lesser subsidy.

Social Aspect

As with geothermal power generation, Chinese universities should set up geothermal specialisation to develop geothermal professionals.

Legal Aspect

Present environmental administrations usually rely on penalty but despise reward. Geothermal power utilisation should be encouraged and given economic or legal incentives. To promote winter clean heating in the northern China region, some local governments have planned to subsidise geothermal heating or ground source heat pump instead of coal heating. For rural areas planning to shift from coal use to geothermal power use, some GSHP companies are willing to undertake projects even if these would yield lesser benefits for them. Thus, the suggestion for local governments is to award economic or honorary incentives to the best projects.

Fiscal Aspect

Establishing geothermal risk fund is necessary, especially for hydrothermal-type geothermal well drilling due to certain risks involved in such undertaking. Providing loans of low interest, for example, is necessary for GSHP projects.

Technical Aspect

Reinjection for direct heat use and GSHP of groundwater circle has yet to fit the demand of fast growth. Mid-small installation companies have yet to possess the ability for operating reinjection. Proper training on reinjection technique should be popularised as it is necessary for sound development of geothermal energy development.

1.7 Benefits of direct use/GSHP in China

1.7.1 Mitigation of CO_2 emission (kg-CO_2/kW)

If the barriers are removed by innovations in 2025, the target geothermal direct use will have new installed heat capacity of 66,150 MW_t, which includes conventional heat use and GSHP. We can calculate the CO_2-emission reduction.

With installed heat capacity of 66,150 MWt,

The annual energy use (TJ) = MWt × Capacity Factor ÷ 0.03171,

For direct heat use: 18,000 MWt × 0.39 ÷ 0.03171 = 221,380 TJ,

For GSHP: 48,150 MWt × 0.27 ÷ 0.03171 = 409,980 TJ,

Total direct use equals the above put together: 221,380 + 409,980 = 631,360 TJ/year thermal energy used.

Then, 1 tonne of standard coal = 1,000 kg × 7,000 kcal/kg × 4186.8 J/kcal = 29.3×10^9 J,

It is, therefore, the equivalent 1 million tonnes of standard coal = 29,300 TJ,

Thus, we can calculate the annual energy saving in terms of coal equivalent:

631,360 TJ/year ÷ 29,300 TJ/(tonne_{ce}) = 21.55 million tonnes of standard coal.

In China, we use 1 tonne of standard coal = 2.386 tonnes of CO_2,

Thus, 21.55 million tonnes of standard coal × 2.386 = 51.42 million tonnes of CO_2,

Therefore, an additional 51.42 million tonnes of CO_2/year of emission reduction from geothermal direct heat use/GSHP.

1.7.2 New employment

Here, we analyse as an example the Nangong village of Fengtai district in Beijing. A total of 3,000 peasants living in the village were formerly engaged in field husbandry. Since drilling three geothermal wells in 2000–2006, the village has been hailed as 'the first geothermal village in China'. The agricultural economy has changed into geothermal economy. Except for the aged, children, and students, Nangong's young adult labour force are now employed at the geothermal site, working at various levels of geothermal integrated utilisation such as hot spring hotels, hot spring water world, hot spring fishing halls, etc. Agricultural technicians work in geothermal greenhouses and aquaculture halls. Maintenance workers serve in geothermal district heating and thermal water supply facilities. More people work in restaurants, shops, and supermarkets, etc. (Pan, 2003).

We now calculate benefits using results of the above case study. Two geothermal wells are used for production and one for reinjection. The production wells yield 72°C geothermal water with a total flow rate of 170 m^3/h. Because the production wells are not utilised round the clock for the whole year, their annual production is 120 million m^3.

The temperature of the geothermal water used ranges between 72°C and 15°C.

The annual energy used: 120 million m^3/year × 1,000 L/m^3 × (72–25)°C × 4,186.8 J/L.°C = 286.37 TJ.

With an estimated 40% of young adults forming the labour force in the village, the geothermal business has 1,200 employees.

Consequently, the annual energy used is 286.37 TJ equals 1,200 employees.

286.37 TJ ÷ 1,200 employees = 0.239 TJ/employee.

Thus, 0.239 TJ/year of geothermal energy used equals one employee.

The Nangong village, however, is implementing rural-level employment, which means 'low salary, high employment'. Compared with other hot spring business examples, the Nangong index is rather low. Therefore, we correct nationwide geothermal employment level. The corrected index is 0.5 TJ/employee.

For direct heat use of 221,380 TJ (see Table 3.1.2-2) in 2025: 221,380 TJ ÷ 0.5 TJ/employee = 443,000 employees.

For GSHP of 409,980 TJ (see Table 3.1.2-2) in 2025: 409,980 TJ ÷ 0.5 TJ/employee = 820,000 employees.

Thus, with direct heat use and GSHP: 443,000 + 820,000 = 1,263,000 new employees.

1.7.3 Direct economic benefits

Taking Beijing as model, each 1 m^3 of geothermal water could create: district heating – CNY10; domestic hot water supply – CNY8–12; greenhouse – CNY15; hotel with bath – CNY53, hot spring resort – CNY293 (BBLR, 2006). Beijing gets direct economic benefits of CNY1.1 billion based on the above values and corresponding proportions used.

Meanwhile, Beijing exploits geothermal water at 7.72 million m^3 per year with temperature range of 37–89°C.

The total used geothermal energy can be calculated: 720 million m^3/year $\times$ 1,000 L/m^3 $\times$ (37+89)/2 °C $\times$ 4,186.8 J/L.°C = 2,036 TJ TJ.

We use the relationship for 2,036 TJ as equivalent to CNY1.1 billion of benefits.

CNY1.1 billion ÷ 2,036 TJ = CNY0.54 million/TJ.

We use this index to calculate direct economic benefits in 2025.

The 2025 target of direct use will be 221,381 TJ (see Table 3.1.2-2).

So, 221,381 TJ ÷ CNY0.54 million/TJ = CNY410.0 billion = US$64.0 billion.

(3) Benefits from GSHP

Space heating can collect heating fee from users.

In North China, the heating fee is CNY25/m^2. This can be used as the average rate.

The 2025 target for GSHP will reach 1,500 million m^2.

So, 1,500 million m^2 $\times$ CNY25/m^2 = CNY37.5 billion = US$5.8 billion.

1.7.4 Indirect economic benefits

We use the same case study of the Nangong village in Fengtai district, Beijing. Indirect economic benefits come from restaurants, shops, supermarkets, and assorted businesses and services. There are more employees in such businesses than those in direct use business. Indirect economic benefits are about 1.5–3 times more than direct economic benefits.

1.7.5 Regional development

Nangong was a typical rural village before. After implementing geothermal power economy, the village has thoroughly changed its old features with 200,000 m^2 of commercial and residential buildings forming a block of streets, featuring assorted restaurants, shops, supermarkets, schools, banks, telecom companies, etc. Indeed, geothermal development can drive regional development.

1.8 Summary of barriers to and benefits of direct use/GSHP

- For geothermal direct heat use/GSHP in China, the first barriers are policy barriers and the second are technical barriers. Peculiar barriers hidden behind superficial barriers include the lack of geothermal specialisation in universities.
- A necessary innovation suggested for removing barriers is to have a uniform national policy on economic incentives for direct heat use and GSHP. It affects developer's positivity and reduces speed of growth.
- A benefit for geothermal direct heat use/GSHP is the reduction of CO_2 emission. New direct heat use/GSHP of 66,150 MW_t would contribute 51.42 million tonnes of CO_2 reduction annually. Also, it will increase employment to about 1,263,000 persons. The direct economic benefit would be US$5.8 billion annually. Indirect benefits would be about 1.5–3 times more than that of direct economic benefits. They will push regional development and create prosperous local economy.

The quantified barriers to and benefits of direct heat use/GSHP are in Table 3.1.8-1.

Table 3.1.8-1. Quantified Barriers to and Benefits of Direct Heat Use/GSHP

	Policy	Social	Legal	Fiscal	Technical	Total
Barrier Contributions as Results of Census (%)	26%	17%	17%	15%	25%	100%
Expected Additional Geothermal Capacity if Barriers are Removed (MW_t)	17,199.0	11,245.5	11,245.5	9,922.5	16,537.5	66,150
Expected Additional Annual Energy Used (TJ)	164,154	107,331	107,331	94,704	157,840	631,360
Expected Annual CO_2 Mitigation (k tonne-CO_2)	13,377.0	8,746.5	8,746.5	7,717.5	12,862.5	51,450
Expected Annual Toxic Gas (NO_x and CO_x) Mitigation (tonne)	128,960	84,320	84,320	74,400	124,000	496,000
Expected Annual New Employment for the Plant	328,380	214,710	214,710	189,450	315,750	1,263 k
Expected Direct Effects to l Local Economy (million US$)	1,508	986	986	870	1,450	5,800
Expected Indirect Effects to Local Economy (million US$)	3,393	2,218	2,218	1,958	3,263	13,050

CO_2 = carbon dioxide, CO_x = carbon oxides, GHSP = ground source heat pump, MW_t = megawatt thermal, NO_x = nitrogen oxides, TJ = terajoule.

Source: Authors.

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