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Steady Industrialized Development of Geothermal Energy in China Country Update Report 2005-2009

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ABSTRACT

Chinese government has been making effort to save energy and reduce CO_2 emissions. Since the "Law of Renewable Energy" was brought into effect in 2006, the development of geothermal energy, as other renewable energies, was encouraged. Under the market economy, investors are willing to invest in geothermal development. In direct use applications, geothermal space heating has continued a steady increase of about 10% annually. The sum of geothermal district heating area has exceeded 30.2 million m^2 in the country. Traditional hot spring baths and medical treatments have been raised into health care, health preserving and relaxation progressively. It embodies human nature and reflects the connotation of hot spring culture. Looking back at the lack of increase of geothermal power generation in past 20 years, the 1970s' idea of "infeasible economically" for geothermal power generation is recognized as a historical warp. In 2008, a 1MW screw-expansion power generator had been installed in Yangbajain geothermal power plant to use waste thermal water for further electrical production. Geothermal heat pump usage has shown very rapid growth since 2004. Its annual increase is about 20-23 million m^2 of heating (with partial cooling) area. The GHP installed capacity will reach about 5,210 MWt in 2009 compared to 383 MWt in 2004. In addition, research on the resource potential of enhanced geothermal systems (EGS) in China was started in 2007.

Accompanying the progress on the research project of the medium- to long-term strategy for energy development in China, traditional fossil energies with the main body being coal would be restricted. Geothermal development shows commercially competitive cost and steady running hours of over 6,000 hours/year at least without seasonal and weather effects. Geothermal energy will see more steady growth in the future.

1. INTRODUCTION

China has no concrete commitment to the Kyoto Protocol, but China has been devoting effort to energy saving and emissions reduction. It focuses on the development of renewable energy instead of traditional fossil energy. It is an effective way for CO_2 emission reductions. The "Law of Renewable Energy" came into effect in 2006, in which it is defined that "Renewable energy means wind, solar, hydraulic, biomass, geothermal and tide energies, which are not fossil energy". In recent years, with the support of the national preferential policies, wind power generation has developed rapidly in China and there is also a certain development in solar power and biomass power generation. Relatively, geothermal power has not grown as much. Only high temperature wet steam generation is running in Yangbajain geothermal power plant. Due to scaling and other problems, four other geothermal power plants have been shut down in Taiwan and Tibet. Two binary cycle power plants in low- and mid-temperature geothermal resources, each with 0.3MW sets which had run since the 1970s, stopped running in 2008 because of aging equipment. However, there has been a steady increase in the direct utilization of geothermal energy, further to manifest the trend of scalized and industrialized development. The management of geothermal resources tends towards maturity. It can reduce waste, improve energy efficiency and protect resources. Under the new situation, geothermal space heating has developed fast. Geothermal district heating area can reach 30.2 million m^2 at the end of 2009, more than doubled since 2004, and average annual growth rate is about 19%. The hot spring bathing and medical use progressively upgraded to health care and recreation so as to embody humanization and cultural connotation of hot springs. In the last 5 years, there has been a rapid development of the geothermal heat pump, with an annual growth area of 20-23 million m^2 for heating (cooling partly). In 2009, geothermal heat pump use will have a capacity of 5,210 MWt, more than 13 times more than the 383 MWt used in 2004.

There are a lot of advantages for the use of geothermal energy. In power generation, the most significant advantage is the capacity factor of geothermal energy which is much higher than wind and solar power, even higher than hydroelectric power; the geothermal power plant has competitive cost in the construction investment; and it has better stability in power quality. In addition, direct use technology for low- and mid-temperature geothermal resources tends towards maturity and a variety of ways can almost meet the needs in peoples' daily life. It is to facilitate its promotion. Especially in low- and mid-temperature geothermal resources, there is more abundance and distribution in China. There are 3,000 hot springs all over the country and 3,000 geothermal wells on the plains and in the basins. This provides resources and basic conditions for geothermal utilization. There is an advantage of shallow geothermal energy in geographical location and it is suitable for using geothermal heat pump (GHP) for winter heating and summer cooling mostly in the mid-latitude region of China. Research on enhanced geothermal system (EGS), which features more potential, has started in China.

The final report of research on mid- and long-term energy development strategy in China, undertaken by the Chinese Academy of Engineering, is being written. Non-hydro renewable energy strategic positioning will transition from supplemental energy to alternative energy gradually, and then one of the mainstream forms of energy, and finally one of the leading forms of energy. There will be a gradual increase in the proportion of the country's total energy demand. In this development strategy, geothermal resources provide geothermal power and direct heat use. With the support of national regulations and policies, it is expected to have a more stable development in the use of geothermal energy.

2. AN OVERVIEW OF GEOTHERMAL RESOURCES IN CHINA

China is located in the eastern part of Eurasia continent. The coastal area in east China, which borders on the Pacific Ring of Fire, is a zone of volcanic eruptions, earthquakes and geothermal activities, so there are a lot of hot springs in Liaoning, Shandong, Fujian, Guangdong, Taiwan and Hainan Provinces. In addition, because China's southwest border lies on the eastern part of Mediterranean-Himalayan belt, hot springs are common in Tibet and western Yunnan, and there are many high-temperature geothermal manifestations, such as boiling springs, boiling fountains and geysers. More than 3,000 hot springs lie mostly in these two belts but other hot springs are scattered in other provinces of the mainland, of which there are some hot springs more than 90°C.

In addition, there are more than 3,000 geothermal wells in China, most of which lie in the large and medium-sized basins in the north and the eastern plains region. Besides Tibet, Yunnan and Taiwan, wellhead water temperature is 40-60°C in most geothermal wells, but some can reach 95-120°C; the majority of geothermal wells yield 30-60m^3/h and some yield 100-300m^3/h. The type of geothermal reservoir includes porous layer and fractured karst reservoirs.

For more than 50 years, a number of mid- and high-temperature geothermal field have been proven up and the basic condition and distribution of geothermal resources have been determined, preliminarily through a series of explorations and assessments by the Ministry of Land and Resources (including the former Ministry of Geology and Mineral Resources). At present, there are 103 geothermal fields, of which exploitable resources with B+C grade reach 332.83×10^6 m^3/yr and have passed exploration and assessment and approval of the National Administration of Reserves of Land and Resources. There are 214 geothermal fields, of which exploitable resources with C+D grade reach 500×10^6 m^3/yr and have passed detailed survey and estimation. Under the current economic and technological conditions, an estimate of the total amount of exploitable geothermal water all through the country is about $6,845\times10^6$ m^3/yr, giving a total thermal energy of 972.28×10^{15} J, which amounts to 32.848 million tons of standard coal equivalent. It should be demonstrated that the estimated amount of geothermal water is only part of geothermal resources in China, which does not include geothermal resources with burial depth of more than 2000 m, geothermal gradient less than 3°C/100m and shallow geothermal energy.

3. STEADY INDUSTRIALIZED PROCESS OF GEOTHERMAL DEVELOPMENT

Since the 1990s implementation of China's Transition from a Planned Economy to a Market Economy, developers have invested in geothermal development in China, especially in the large and medium-sized cities and coastal areas, and continued investment has promoted geothermal development towards scalized and industrialized development. Industrialized development of geothermal energy forming in the early 21st century, has been further developed steadily over the last 5 years. Besides the traditional direct use of geothermal energy, it also represents the emerging GHP industry. Also, there is progress in the geothermal power and EGS.

3.1 Steady Growth in Geothermal Direct Use

Geothermal direct use has had a steady growth during the last 5 years. The total installed capacity for the direct heat use (without GHP) is 3688MWt. It increased 20.7% over the statistics at the end of 2004. The annual utilization for direct use is 12865GWh. It is higher 19.3% than in 2004.

3.1.1 Geothermal District Heating

Building energy consumption, mainly in winter space heating and summer cooling, accounts for about 27.8% of the total energy consumption. Coal, oil, and gas-fired boilers and the thermal power network are used for traditional heating systems. Not only will this traditional method cause pollution of CO_2 emissions resulting from burning, but it will also waste resources, in that high enthalpy sources of coal, oil and gas are converted to low enthalpy hot water at 70-90°C for heating.

In the geothermal fields such as in Beijing and Tianjin, natural wellhead water at 70-90°C can supply heat to the heating system directly without combustion. It can have no emissions of CO_2 and be consistent with energy grade. Geothermal district heating area reached 24 million m^2 in 2008 and it can reach 30.2 million m^2 at the end of 2009, near a half of which is in Tianjin. Geothermal heating area reached 9.6 million m^2 in 2004, 12 million m^2 in 2007 and 13 million m^2 in 2008 in Tianjin. There are over 1 million people living in houses with geothermal space heating and another 4 million people enjoying hot water supplied from geothermal water in this city that is rich in geothermal resources at a depth of 1,000-4,000m under the ground. The highest temperature of wellhead water is 103°C and many wells are at 80-95°C. More than 10 years ago, one geothermal well yielded 2,000m^3/d, supplying heat to 100,000m^2. Later, technological improvements allowed geothermal backwater from the radiator to re-enter the floor heating, so the heating area was increased by about 40%. In recent years, relying on the heat pump system, backwater from the floor heating can be heated to re-use and usually one geothermal well may now supply heating to more than 200,000m^2. The total volume of exploited geothermal water in Tianjin is about 26.4 million m^3 annually and geothermal district heating is the main use, saving 1.17 million tons of standard coal equivalent and reducing 2.78 million tons of CO_2 emissions.

In addition, geothermal heating schemes are also applied in Xianyang and Xi'an of Shaanxi Province, Dezhou, Dongying, Binzhou and Liaocheng of Shandong Province, Beijing and some cities of Hebei Province and Heilongjiang Province.

3.1.2 Hot Spring Bath and Medical Care

Geothermal water comes from the geochemical environment in the deep reservoir. Under the high temperature and pressure condition, hot water is rich in dissolved minerals, such as metasilicate, metaboric acid, hydrogen sulfide, radon, radium and fluoride. Usually it constitutes medical mineral water and features precious medical value. This is the reason for bath and medical care with hot spring water for thousands of years in the world. Bath and medical care are the most common use of low-temperature geothermal resources (geothermal water). In many traditional hot spring areas, basically there is only the folk use of bath, including the indigenous medical use, such as steam fumigation and hot water cupping in high temperature geothermal manifestation area in western Yunnan. However, more activities are physical therapy under the guidance of doctors in the hot spring sanatorium and rehabilitation center, including dipping bath, sports bath, jet bath, mud therapy, hydrotherapy, hydro-electrotherapy, drinking therapy and so on.

In the mid-1990s, developers upgraded hot spring bath and medical care and focused on the development of hot spring swimming, resort and tourism projects, in the geothermal development under the market economy. These have found favour in consumers' eyes. At the same time, the value of hot springs and the use of operating profit have been greatly enhanced. It resulted in a high rate of return, so more active developers have been attracted to invest to bring the sustainable development and utilization of geothermal energy in China over the years. Hot spring bath and medical care, as the main direct use of conventional geothermal energy, has grown at an annual rate of about 10% on average.

3.1.3 Greenhouse Planting and Aquaculture

Accompanying the socio-economic development and rise of living standard, the market demands for fresh vegetables, high-grade flowers and fresh aquatic products during the off-season have increased. Greenhouse planting and aquaculture feeding have been conducted with coal fuel in many places. However, fuel costs are high and air is polluted (even in rural areas). In this regard, low- and mid-temperature geothermal resources possess the advantage. Geothermal water can be used directly for greenhouse heating (including soil warming) and warm water aquaculture. Geothermal water can be used for aquaculture of tilapia and other species, and its annual production capacity of adult fish is 100 times more than in the common open water. And fish can be wintered and bred. In North China, bananas can be grown long-term. High-grade flowers such as phalaenopsis and valuable fresh vegetables can be found in Beijing markets in winter. These can upgrade the economic value of geothermal use to create more economic benefits.

Geothermal greenhouse planting and aquaculture feeding have increased year by year and technical level has improved in China. Geothermal greenhouses with 20,000 m^2 to 30,000 m^2 area, having the automatic control of temperature and humidity, have been built in Beijing and Tianjin. It can reach the world advanced level. However, the growth rate of geothermal greenhouse is less than the geothermal space heating, bath and medical care use, generally around 3% each year in recent years.

3.2 New Understanding of Geothermal Power Generation

Currently, only Yangbajain geothermal power plant (high temperature geothermal power generation) is running in China. Power was generated successfully by the first pilot unit of 1MW in 1977 and another 8 sets of 3MW were completed progressively until 1991, at which time the pilot unit of 1MW was retired. Since then, the total installed capacity has been maintained at 24.18MW, generating about 100 GWh annually. The potential of the power plant has been shown continuously over the last five years. The annual power generation reached 115.4, 126.1, 115.8 and 143.6 GWh respectively in 2005, 2006, 2007 and 2008, repeatedly hitting a record. The total generation has reached 2,270 GWh in Yangbajain geothermal power plant.

Geothermal power plants were built in Langju and Nagqu regions of Tibet, and Qingshui and Tuchang areas of Taiwan in the 1980s and 1990s. These installed capacities were around 0.3-3MW, but the runtimes were not long due to scaling and other problems. These experiences have had some negative impact on the geothermal power development in China.

Seven low- and mid-temperature geothermal power plants, their installed capacity of 0.1-0.3MW, were built in the 1970s in China, five of which had stopped running by the end of the 1970s. At that time, the opinion on low- and mid-temperature geothermal power generation was "feasible technically, but infeasible economically" and the operating cost was higher than electricity from the power grid. Now it is realized that this is a historical prejudice. Geothermal power generation causes no pollution and reduces CO_2 emissions. The cost can be reduced by technical improvements. In fact, two binary cycle power generation units of 0.3MW, in Dengwu of Fengshun County, Guangdong Province and Huitang of Ningxiang County, Hunan Province, stopped running in 2008 because of aging equipment. In the past 30 years, their low-cost had been shown in their operation and power supply in rural areas, demonstrating economic feasibility.

Now, in the bloom of development and utilization of renewable energy, the superiority of the high capacity factor has emerged in the geothermal power generation, so some developers are willing to invest in geothermal power. Only the state preferential policies, such as on-grid power tariffs, have not yet been implemented in geothermal power, and therefore the progress has been hampered.

In 2008, there was an increase of screw-expansion power generator (1MW) and 500m^3/h waste geothermal water of 80°C was used to generate power in the Yangbajain geothermal power plant. The principle is the reverse application of electric compressors. It is to put the geothermal fluid (two-phase flow, hot water or waste water) into screw expansion power generator under some pressure leading to the rotation of the shaft to drive a generator. The new generator can generate a small amount of electricity in intermittent trials. Some issues have been found, and finally they are solved.

3.3 Rapid Development of Geothermal Heat Pump

Research on geothermal heat pumps (GHP) was carried out in the 1960s in China, but conditions were not yet ripe for application (power shortage). The development of GHP started in China at the end of 1990s under the impact of the world; especially it has developed rapidly since 2004. The annual growth rate has remained more than 30%. Most project applications were in Beijing at first, which reached 369 projects in 2006, with a total heating building area of 7.38 million m^2. But then Shenyang has caught up and jumped to the first place, with an annual increase of more than 15-18 million m^2. So the heating area of GSHP reached 18.48 million m^2 and 35.85 million m^2 in Shenyang respectively in 2007 and 2008. It is 18% of the total area of building heating in Shenyang and the installed capacity was 1,790MWt in 2008.

The total GHP heating area had reached 62 million m^2 in 2008 and will be up to 100.7 million m^2 in 2009. The total installed capacity will be about 5,210MWt. Shallow geothermal energy is used for heating instead of the traditional fuel boiler. It can not only save the traditional fuel energy, but also significantly reduces pollution and improves the environment. The number of days with good air quality reached 330 days in Shenyang in 2008! GHP brings a new path for the urban environmental protection and clean energy use in Shenyang.

Renewable energy has been applied partly in the Olympic venues in Beijing in the 29th Olympic Games in 2008, in order to honor their promise of a "Green Olympics". It accounts for 26% of the total energy, of which there are many applications of GHP. The Olympic Tennis Center is located in the Olympic Green. It has 16 courts (10 for competition, 6 for practice). GHP is used for summer cooling and winter heating in the competition courts. Taking the example of No. 2 court, 35 heat exchange boreholes were drilled with the diameter of 150mm to a depth of 100m and double u-tubes of PE material were put into the boreholes. The cooling capacity of 139.6kWt was obtained with the input power of 32kW and the heating capacity of 138.2kWt was obtained with the input power of 37.5kW. In addition, conventional geothermal use and GHP are applied in Olympic Badminton Hall in Beijing University of Technology and Tianjin Olympic Stadium. GSHP is also applied in part in the National Stadium (Bird's Nest), the National Swimming Center (Aquatics Center) and the National Gymnastics Hall. In addition, sewage source heat pump is used for summer cooling, winter heating and supply of domestic hot water in the Olympic Village with a total building area of 410,000 m^2. Besides, GHP is also used in Beijing Olympic Green Hockey Stadium, and Laoshan Mountain Bike Course. In order to ensure the absolute security of the Olympic projects, GHP was applied only in part, but its effectiveness has been promoted with the significant impact of the Olympic Games, which has been a powerful demonstration effect.

3.4 Enhanced Geothermal System

In 2007, Geothermal China Energy Society and Petratherm Ltd signed a cooperation agreement to jointly undertake the project "Research on the potential of Enhanced Geothermal Systems (EGS) in China". In 2008, experts from China and Australia had a preliminary investigation in the potential areas and collected some test samples. Further testing analysis and model studies combined with geological data are being carried out. For the continuation of this research project, the Australian party has expressed that they would expand investment in 2009, carry out advanced geophysical surveys in the prospect areas initially elected and then do the actual drilling operations in the prospect areas verified.

On the other hand, in 2009 the relevant institutions of research and exploration submitted a project application to the China Geological Survey and the Ministry of Land and Resources in order to undertake suitable tasks, match the cooperation and have an in-depth study in 2010. It is hoped that an evaluation report on EGS, such as "The Future of Geothermal Energy" in USA, can be submitted in a few years to provide the country reference for energy policy and energy planning.

4. STRENGTHENING GEOTHERMAL MANAGEMENT AND RISING EFFICIENCY

The exploration of geothermal resources is managed based on the "Law of Mineral Resources" by the Ministry of Land and Resources in China. Prospecting permits are granted in accordance with national plans or owners' application. However, for the exploitation management of geothermal resources, there is no uniform nationwide implementation of the mining permit and only local management is implemented in the key cities of geothermal development.

The Geothermal Administration Office is in the system of Bureau of Land and Resources in Beijing and Tianjin cities. According to the mining permit issued by the municipal government, geothermal administration includes the implementation of production control, installation of water meters, exploitation plans, monitoring, encouragement of geothermal reinjection, resource compensation fee collection and geothermal research. Since the mid-1980s implementation of the administration, the management has had a remarkable success and serious drawbacks have disappeared, such as mining chaos, resource waste, and rapid decrease of reservoir pressure. At the same time, the application of new drilling is not approved in the intensive exploitation areas in accordance with dynamic monitoring data. In the exploitation areas allowed, it is emphasized that new production and reinjection wells should be approved at the same time in order to control and improve the layout of exploitation wells.

Taking Beijing as a successful example of administration, before the implementation of management in 1984, there were more than 100 geothermal wells in Beijing, with an exploitation of 13 million m^3 and the water level declined by more than 3m; since the implementation of administration over the past 20 years, geothermal wells have increased by twice, but basically the exploitation is controlled to 10 million m^3 in total. Although the total exploitation has decreased, the waste has been eliminated and economic benefit is more than 10 times in former times and the decline in water level is controlled at around 1m annually. The amount of geothermal reinjection has reached more than 36.5% of exploitation in Xiaotangshan geothermal field over the last 5 years, with the highest rate of reinjection reaching 63% (in the heating season of 2007-2008).

Major efforts have been devoted to developing geothermal district heating, and geothermal exploitation has grown rapidly in Tianjin over the last 5 years. The annual exploitation reached 26.4 million m^3 and the water level declined by more than 2m in 2008. So countermeasures have been carried out seriously in the geothermal well approval process and geothermal reinjection implementation. In 2008, there were 264 production wells and 53 reinjection wells, with the reinjection volume of 6.48 million m^3, accounting for 24.5% of production at the same year in Tianjin. It is not easy to achieve such a degree in the geothermal fields in Tianjin.

Geothermal management is undertaken by different departments in other cities. It is undertaken in Fuzhou by the Construction Bureau, management effectiveness of which is same as in Beijing. However, it is undertaken by the Water Authority, management effectiveness of which is not well in Xi'an. The annual exploitation reached 5 million m^3 and the water level declined by more than 5m there.

5. PROSPECTS OF GEOTHERMAL ENERGY DEVELOPMENT

In recent years, the project "Research on mid- and long-term energy development strategy in China" has been undertaken by the Chinese Academy of Engineering, in which more than 50 academicians of CAE participated. They put more focus on applied technology research than academicians of Chinese Academy of Sciences. The amended version of this report has been completed. The report pointed out that the development of renewable energy in China is aimed at large-scale alternative to fossil fuels, reducing carbon emissions and reducing dependence on foreign energy. Strategic objectives are that for non-hydro renewable energy strategic positioning is: to be supplemental energy (around 2010), to provide 60 million tons of standard coal equivalent, accounting for around 2% of the total energy demand; to be an alternative energy sources (around 2020), to provide 180 million to 330 million tons of standard coal equivalent, accounting for 5-10% of the total energy demand; to be one of the mainstream sources of energy (around 2030), to provide 400 million to 800 million tons of standard coal equivalent, accounting for around 10-19% of the total energy demand; and to be one of the leading forms of energy (around 2050), to provide 880 million to 1,710 million tons of standard coal equivalent, accounting for around 17-34% of the total energy demand. For geothermal energy, geothermal power generation and direct heat use are included in this strategy (mainly for building heating).

The aim of this strategy is to provide scientific and practical reference and the basis for national development programming. With the support of national regulations and policies, it is expected to produce a steadier development in the use of geothermal energy.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe		Capac-ity MWe		Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2009	24	144	668020	3184500	173960	642400	12910	99500	W 15000 B 2300 S 85	27600 10100 110	872300	3964400
Under construction in December 2009	1		2000		63790		12220		W 10000 S 10			
Funds committed, but not yet under construction in December 2009												
Total projected use by 2015	50	300	850000	4052100	230000	849400	25000	192700	W 35000 B 2500 S 150	64400 11000 180	1142700	5170100

W-wind, B-biomass, S-solar PV

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2009

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) Data for 2009 if available, otherwise for 2008. Please specify which.

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe*	Total Running Capacity MWe*	Annual Energy Produced 2009[3)] GWh/yr	Total under Constr. or Planned MWe
Tibet	Yangbajain	1981-1991	8		2F	24.18	22.5	150	1
Tibet	Yangb.Test	1977	1	R	2F	1		0	
Tibet	Nagqu	1993	1	R	B	1		0	
Tibet	Langju	1987-1988	2	R	2F	2		0	
Guangdong	Fengshun	1970	1	R	B	0.3		0	
Hunan	Huitang	1975	1	R	B	0.3		0	
Taiwan	Qingshui	1981	1	N	F	3		0	
Taiwan	Tuchang	1985	1	N	B	0.3		0	
Total						24.18**	22.5	150	1

* Installed capacity is maximum gross output of the plant; running capacity is the actual gross being produced.
** Retired units not included.

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2009 (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. (^oC) - outlet temp. (^oC)] x 0.004184
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001 (MW = 10^6 W)

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319
or =Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154 (TJ = 10^{12} J)

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]	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
Tianjin	D	4474.1	73.4	38			602	1655.4	7024.3	0.37
Shannxi	D	3322.3	56.9	40			228	1127.8	2516.5	0.35
Shandong	D	3698.3	55.5	40			240	1294.4	2649.0	0.35
Hebei	D	1187.6	58.1	40			90	439.4	1049.0	0.37
Beijing	D	950.6	57.8	38			75	334.7	874.2	0.37
Lindian	D	527.6	53.3	37			36	216.3	465.0	0.41
Others	D	329.4	54.5	40			20	115.3	220.5	0.35
Hebei	G	422.2	58.1	33			44	156.5	518.1	0.37
Beijing	G	394.1	52.4	33			32	145.9	373.4	0.37
Shannxi	G	169.4	51.6	33			12	59.5	130.2	0.35
Tianjin	G	187.8	67.6	33			27	69.5	317.4	0.37
Shandong	G	79.7	48.6	33			5	27.9	57.4	0.35
Others	G	407.1	48.5	33			26	142.5	291.4	0.35
Hubei	F	577.4	56.4	30			64	202.1	703.7	0.35
Guangdong	F	253.5	58.2	30			30	86.2	320.6	0.34
Fujian	F	237.1	52.2	30			22	80.6	236.0	0.34
Hunan	F	196.5	53.8	30			20	66.8	209.7	0.34
Hebei	F	184.0	58.1	30			16	49.7	184.2	0.37
Beijing	F	138.6	52.4	30			13	51.3	151.6	0.37
Others	F	359.4	52.0	30			32	125.8	365.0	0.35
China	I	1744		△ t=20			145	1081.0	2732.6	0.62
China	A	984		△ t=20			82	393.4	1037.5	0.40
China	B	21872		△ t=20			1826	8749.0	23886.0	0.40
TOTAL		42746					3688	16671	46313	0.39

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2009

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.

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
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or water temp. (°C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load Hr/Year[4]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Shenyang	14	3040000*	15700	W,V	3	2550	18384	
Beijing	15	1050000	4700	W,V	3.2	2040	5301	1500
Hebei	15	460000		W,V	3	2040	2252	
Hubei	17	132000		W,V	3	1700	539	
Shandong	16	126000		V,W	3	1870	566	
Jiangsu	17	100000		W,V	3	1700	408	
Tianjin	36	100000	1290	W,V	3.4	2040	518	
Shaanxi	16	93600		W,V	3	1870	420	
Others	16	144000		W,V	3	1870	646	
TOTAL		5209600		W,V			29035	1500

* Partially use waste water. Those parts of heat are not included in this table.

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009

[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

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1)] (MWt)	Annual Energy Use[2)] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3)]
Individual Space Heating[4)]			
District Heating [4)]	1040.0	11991.7	0.37
Air Conditioning (Cooling)			
Greenhouse Heating	132.8	2030.5	0.37
Fish Farming	196.1	2170.8	0.35
Animal Farming			
Agricultural Drying[5)]	82.2	1037.5	0.40
Industrial Process Heat[6)]	145.4	2732.6	0.62
Snow Melting			
Bathing and Swimming[7)]	1826.3	23886.0	0.40
Other Uses (specify)			
Subtotal	3688	46313	0.39
Geothermal Heat Pumps	5210	29035	0.27
TOTAL	8898	75348	0.32

[4)] Other than heat pumps
[5)] Includes drying or dehydration of grains, fruits and vegetables
[6)] Excludes agricultural drying and dehydration
[7)] Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2005 TO DECEMBER 31, 2009 (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)	1	14			23.9
Production	>150° C					
	150-100° C		4			8.1
	<100° C		229			588.3
Injection	(all)		46			110.3
Total		1	293			730.6

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)
2005						
2006						
2007						
2008						
2009	163	465	86			305
Total						

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2009) 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	1142.9	2.2	97.7	2.3