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Speeding up Industrialized Development of Geothermal Resources in China -- Country Update Report 2010-2014

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ABSTRACT

Chinese geothermal workers have been thinking how to grow Chinese geothermal industry. Even though China used energy for medium-low temperature geothermal direct uses and is first in the world, China high temperature geothermal power generation is so backward. It is not commensurate with its great country status and energy demand. Geothermal experts proposed national preferential policy support. In 2013, the National Energy Administration, Ministry of Finance, Ministry of Land and Resources, and Ministry of Housing and Urban-Rural Development jointly issued a document "Guidelines of Promoting Geothermal Energy Development and Utilization". Chinese geothermal development at last entered in the second springtime. Ministry of Land and Resources increased input for geothermal survey and exploration. The newest reserves data for Chinese geothermal resources will be shown in the paper. Both state-owned and private enterprises enhanced investment in the geothermal industry. Yangyi geothermal power station has been constructed in Tibet which would double the capacity of Chinese geothermal power. Both state-owned and private enterprises constructed a lot of geothermal district heating in many cities also. Contract energy management made geothermal heat pump sustain a high speed growth. Geothermal as strategic emerging industry springs up and progress from place to place. The industry present is large-scale. Advanced technology is adopted. Benefit has boosted. All newest statistics for geothermal utilization are shown in the paper. Geothermal resources management with key point of reinjection gets reinforce. Sustainable development is carried out since the project started. National supported geothermal research projects are launched including key technology of geothermal development and enhanced geothermal system etc. China will complete its target for 12th Five-year-plan in 2015. Chinese geothermal workers will dedicate plentiful and substantial achievement to WGC2015.

1. INTRODUCTION

Chinese geothermal workers have been thinking how to speed up Chinese geothermal undertaking. Even though China used energy for medium-low temperature geothermal direct uses and is first in the world, China high temperature geothermal power generation is so backward. It does not adapt the great country status and energy demand. Geothermal experts proposed many times to require support of preferential policy from the country. Eventually China's National Energy Administration, Ministry of Finance, Ministry of Land and Resources, and Ministry of Housing and Urban-Rural Development jointly issued a document "Guidelines on Promoting Geothermal Energy Development and Utilization" in January 2013 (NEA, 2013). To the end of 12th 5-year-plan in 2015, ground source heat pump application will reach 500 million square meters; installed capacity for geothermal power generation will reach 100 MWe; total used geothermal energy will be equivalent to 20 million tons standard coal. Meanwhile the guidelines give some preferential policies. Under the policy promoting, Ministry of Land and Resources increased fund for geothermal resource exploration. And the policy also attracted both state-operated and private enterprises to invest in geothermal business.

Another converse promotion is due to the serious fog haze encountered in 2013. The rapid growth of GDP with huge consumption of coal and cars led to the damage of the environment. Thereupon, the State Council issued "Action Plan of Air Pollution Prevention". And then Beijing issued "Beijing Action Plan of Clean Air 2013-2017". It stipulated strategy of "Create clean energy system by mainly electricity and natural gas with assisted geothermal and solar energies". Actual implementation for geothermal space heating replacing conventional boiler heating will get 50% of investment allowance.

Under the policy promoting Chinese geothermal industry development appears delighted progress. We remember the first great progress of geothermal development happened in 1970s in China. Now the situation shows the second springtime for geothermal development in China. High temperature geothermal power generation and medium-low temperature geothermal direct utilization, both shows obvious increase. Geothermal industry grows further. Geothermal resources management becomes mature. Geothermal reinjection has been enhanced. All these implementations has reduced the waste, raised the efficiency and protects the resources.

With comparing to five years ago, geothermal power generation had only 24.18 MWe of Yangbajain power plant. Now we have 4 plants of 27.78 MWe running with annual production of 160 GWh.

There is obvious progress for mid-low temperature geothermal direct use. The installed capacity of geothermal direct use is 6,089 MWt, with annual energy use 74,041 TJ/yr. When together with geothermal heat pump the installed capacity and annual energy use are 17,870 MWt and 174,352 TJ/yr respectively. These numbers are two times larger than past numbers of five years ago. Generally to say, geothermal space heating has the most rapid growth. In 2014 it has 60.32 million m^2 in the country. It increased 99.7% than in 2009. The average annual increase rate is 15%. It has become the dominated part (48.4%) among geothermal direct use other than heat pump. Traditional hot spring bath and medical care are transferring towards life cultivation and health preservation, and entertainment. Its average annual increase rate is about 3%-4%. Geothermal heat pump keeps a vigorous growth.

It increased as 3.3 times within the 5 year period. Its average annual progressive increase rate is 27%. The GHP application area will reach 330 million m^2 at end of 2014. Its installed capacity is 11,781 MWt, with 66% of the whole direct use. Its annual energy use is 100,311 TJ, as 58% of whole direct use.

2. SPEEDING UP GEOTHERMAL RESOURCES SURVEY AND EXPLORATION

Along with the conversion from planning economy to market economy, the national input for geothermal resources exploration decreased to almost nothing. Almost no new geothermal field exploration was completed during past 20 some years. There was only a small amount of input by private developers for small part drilling within their own land. Since 2011 with entering the 12th Five-year-plan and as for countermeasures to the global climate change, Ministry of Land and Resources (MLR) asked China Geological Survey to arrange a new round of survey and assessment of geothermal resources in China. From 2011 to 2014 a total of CNY (China Yuan) 600 million (equivalent to US$ 97 million) has supported the project. It will find shallow geothermal energy and conventional geothermal energy resources. Meanwhile includes a preliminary study for hot dry rock resources. This project has estimated a preliminary result (Figure 1) (MLR, 2011; Wang et al, 2013; Lin et al, 2013). The final accurate result will be given soon.

The geothermal resources reserved in the major plains of sedimentary basins are 2.5×10^{22}J, which is equivalent to 853.19 billion tons of standard coal. The total heat released from hot springs is about 1.32×10^{17}J annually. Given that the exploitable coefficient is 5.0, then the exploitable geothermal resources of convective uplift mountains type is 6.6×10^{17}J/yr, which is equivalent to 22.591 million tons of standard coal.

The geothermal resources of hot dry rock at the depth of 3.0-10.0 km in mainland China were calculated and the total value was up to 2.52×10^{25}J, equivalent to 856 trillion tons of standard coal. For 3.5-7.5 km depth and 150-250°C resources are 6.3×10^{24}J. Even though only 2% is explored, 12.6×10^{22}J of heat energy could be obtained, which is equivalent to 1,320 times as much as the total energy consumption of China in 2010.

Besides, shallow geothermal energy was investigated and assessed for 287 prefecture cities. The total energy within 0-200 m depth is 77.1×10^{12} kWh annually, equivalent to 9.486 billion tons of standard coal.

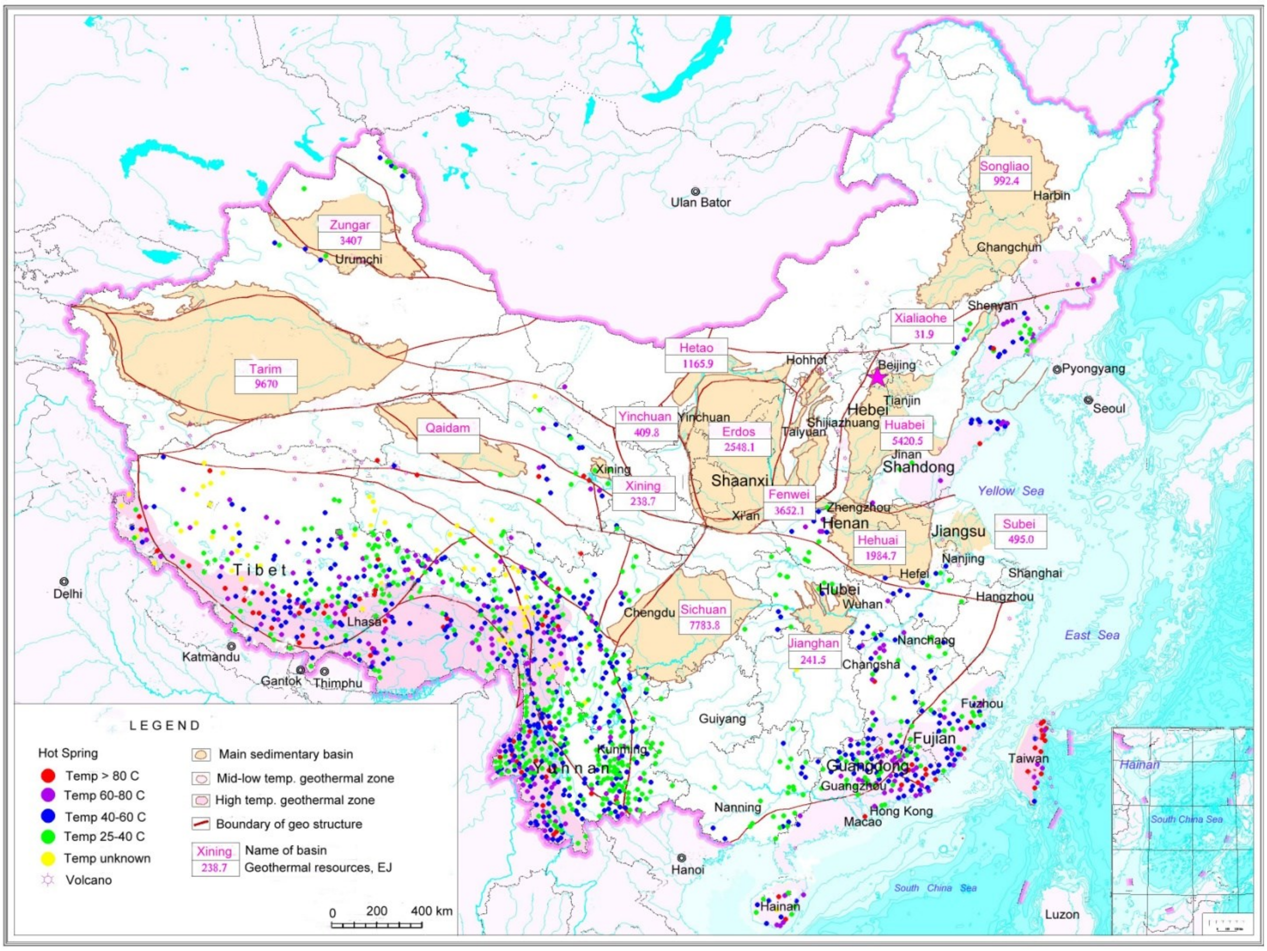

Figure 1: Map of geothermal resources in China (After Wang et al, 2014, modified)

In addition, Wang et. al. of the Geological and Geophysical Institute of Chinese Academy of Science computed and estimated the hot dry rock geothermal resources in the continental area of China, also. They updated the heat flow map of China based on more new heat flow data. Then the HDR geothermal resources are estimated using volumetric method with a thermal physical access in the continental area of China (3-10 km). Results show that the total HDR geothermal energy is 20.9×10^6EJ. It is equivalent to standard coal of 714.9×10^{12}t. If the recoverable energy is 2% by computing it is equivalent to 4,400 times of total annual energy consumption during the year of 2010 in China (Wang et al, 2012).

3. ENHANCED INVESTMENT FROM STATE-OWNED AND PRIVATE ENTERPRISES

Under the 2013 National Guidelines promotion, state-owned and private enterprises increased positivity for developing geothermal power generation and heat direct use.

Sinopec Star Petroleum Co. Ltd. completed geothermal district heating in Xiong county, Hebei province for 2.80 million m^2. It has reached more than 90% of total heating area. Meanwhile the tail water was implemented for reinjection. It created the "Pattern of Xiong County" of no-smoke town. The company's geothermal development has enlarged to Shandong, Shaanxi, Henan, Hebei, Shanxi, Liaoning, Sichuan, Tianjin and Hubei etc., in 18 provinces. It drilled 170 geothermal wells and the geothermal heating area has reached 22 million m^2. It is the biggest enterprise of geothermal development in China. It has planned also for geothermal power generation.

The Great Wall Drilling Company of the PetroChina Co. Ltd. undertook 100 high temperature geothermal well drilling in Kenya. In 2013, Kenya issued an inventory of PPP (Public, Private and Partnership) national priority projects for 2014, which included 3 geothermal pipeline projects. PetroChina as the large state-owned enterprise is thinking to invest the project in Africa.

Private enterprise Jiangxi Huadian Electrical Power Co. Ltd. has put investment to construct Yangyi geothermal power plant. The designed installed capacity is 32 MWe. It is planned to use its own product screw expander units (full flow type) for the power generation. Two test units of 900 kW totally has been running since 2011. It serves the geothermal production wells drilling and workshop building. The total investment will be over CNY 500 million (equivalent to US$ 81 million). The first stage of 16 MWe is expected to put into operation in 2014.

A large quantity of geothermal leisure tourism projects such as hot spring resorts, hot spring preserve health centers were developed. It expanded successively year by year from large cities and coastal region to inland. They are private enterprises.

4. INDUSTRIALIZED DEVELOPMENT AND UTILIZATION IN VARIOUS ASPECTS

Chinese geothermal development attracted experience from the past. If there is no large enterprise doing scaled emphasis development, the industrial strength would not form. While if there is no development management and technical support, it would not ensure the orderly development of large projects. In the recent 5 years Chinese geothermal industry has accelerated development further.

4.1 Geothermal Power Generation

Geothermal power generation had a positive growth in 1970s. The Chinese first geothermal power test station was established in December 1970 in Dengwo village of Fengshun county, Guangdong province. It made China to the 8th country (later than Italy, NZ, US, Japan, Russia, Turkey and Mexico) to own geothermal electricity. In 1971 the first geothermal binary unit ran 50 kWe by using 67°C thermal water in Wentang village of Yichun county, Jiangxi province. Hereafter, other 5 medium-low temperature geothermal test stations established were successively. The seven units had a total installed capacity of 1.55 MWe with single 50-300 kWe each. However, these test stations stopped later in the 1970s when completed their test task, with excluding the 3rd unit 300 kW flush system using 91°C hot water in Dengwo station which is still working (Zheng, 2012).

The Yangbajain high temperature geothermal power station with 1MWe test unit started running in 1977. It increased to 8 units of 3 MWe each (the 5th Japanese unit 3.18MWe) from 1981 to 1991 progressively to form a total installed capacity 25.18MWe. They still work well. It added two units of total flow system (screw expander) with 1 MWe each in 2009 and 2010 respectively. Its present capacity is 26.18MWe and produces about 140 GWh/yr.

However the growth of Chinese geothermal power generation has lagged over the past 30 years. During the period Langju geothermal power station was established in 1983 in Ali region, Tibet. The 2 MWe installation ran for several years then stopped due to insufficient steam yield. Another 1 MWe binary unit was established in Nagqu, Tibet in 1993. It stopped in 1999 due to heavy scaling problem.

During the expanding stage of Yangbajain power station, the turbine manufacture heard comments from the operation and immediately improved the next unit. The factory had even designed an improved 5 MWe unit. But no growth, no order, so the industry chain was bogged down. Under the great mass fervor of big growth of renewable energies, developers considered investing in geothermal power generation, but the allowance of grid purchase price has not been solved for a long time. It extinguished above positivity.

Chinese geothermal power generation has a little progress in recent years due to the application of the screw expander power unit. Jiangxi Huadian Electrical Power Co. Ltd. dedicated in the development of the total flow system unit. It started test of 1 MWe unit in 2008 in Yangbajain, then completed the test and yielded electric power in 2009, and added one more 1 MWe in 2010. It made Yangbajain geothermal power plant reached 26.18MWe installed capacity and yielded 140 GWh per year. This is a small progress.

Additional screw expanders were applied in Liubei oil field in the North China, by using the byproduct of hot water from oil wells to run a 400 kWe unit. And it also used in Yangji geothermal field for the Yangyi geothermal power plant project. A 400 kWe unit started running in 2011 and a 500 kWe unit started running in 2012. They serve for production well drilling and workshop construction. Two production wells were completed in 2013. The building construction will start soon. It is expected to run the first stage of 16 MWe in 2014.

4.2 Geothermal Direct Use

Profited from the requirement of building energy conservation and CO_2 emission reduction, Chinese medium-low temperature geothermal direct use has the fastest growth of geothermal heat pump (GHP) and geothermal district heating in recent five years. Such growth has resulted in obvious change of the structure of geothermal direct use. The proportion of installed capacity and annual energy use of GHP among geothermal direct use was 53.5% and 51.9% respectively in 2009. But now they are 65.9% and 57.5% respectively (Figure 2). Geothermal direct use other than heat pump was bathing and medical treatment dominated in 2009. However, geothermal district heating dominates now. This is great progress in China.

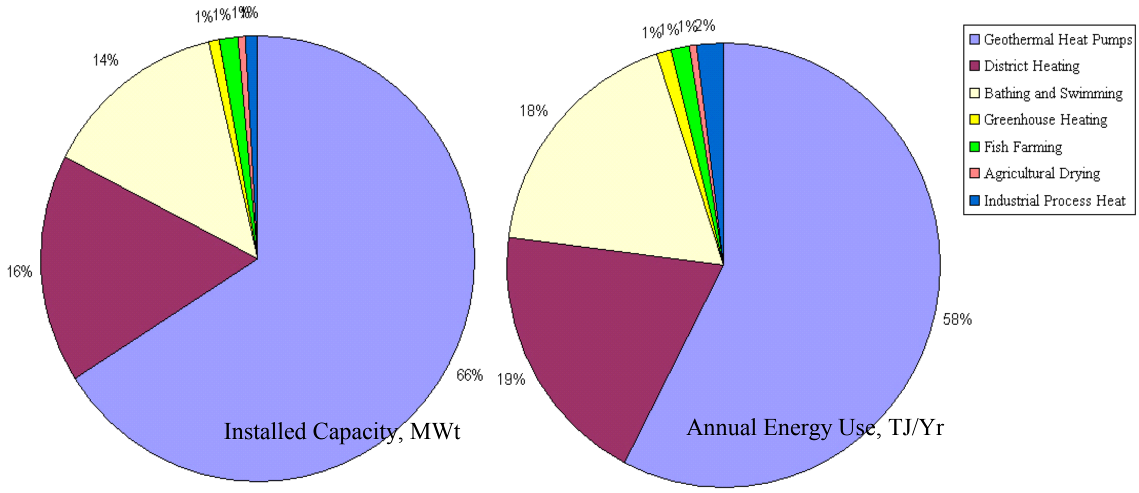

Figure 2: Proportion of geothermal direct use in China

4.2.1 Geothermal Space Heating

Geothermal space heating is the best utilization to give full play to use medium-low temperature geothermal resources. The building energy consumption has increased its proportion in total energy consumption from 10% at end of 1970s to over 30% at recent year in China. And the space heating and air-conditioning are about 55% of the total building energy consumption. Traditional boiler heating not only make CO_2 emission but also waste of resources because of the coal and oil of high grade energy would transfer into low grade hot water with 70-90°C temperature. Building energy saving advocated in the country has promoted the building application for renewable energy including geothermal energy use.

Geothermal district heating in Xiong county of Hebei province has satisfied more than 90% demand of building heating. It has established the concept of a non-smoke town. The tail water is used for reinjection to protect the geothermal resource. The nationwide energy bureau director's meeting was held in Xiong county in February 2014. The purpose is to copy the Xiong county pattern for 10-20 cities. The Xiong county geothermal project is operated by Sinopec Star Petroleum Co. Ltd. The enterprise has run geothermal renewable energy industry for many years. Its geothermal district heating projects have reached 22 million m^2. It is the biggest enterprise operating geothermal industry.

The sum of geothermal heating area has reached 60.32 million m^2 in the country in 2014. Tianjin is in first place with over 19 million m^2. The second is Hebei province with heating area of 13.8 million m^2. The other region ranks are Shandong, Shaanxi, Beijing and Henan etc. The total installed capacity of geothermal district heating has reached 2,946 MWt with annual energy use of 33,710 TJ/yr. They increased as 2.83 and 2.81 times respectively than the year of 2009. Geothermal district heating has become the dominated part (48.4%) among geothermal direct use other than heat pumps.

4.2.2 Hot Spring Bath and Medical Care

Hot springs were used for bath and medical treatment popularly since long time ago. Geothermal water contains silica, boron, sulfide, radon, radium and fluorine etc. to form medical mineral water. It has precious medical value. Hot spring bath is the most popular use of low temperature geothermal resources. It is also the main use in economic backward areas of inland. There is traditional rough medical use in the hot spring area of west Yunnan province. They use geothermal water and steam for medical treatment.

Since the mid-1990s under market economy many investors developed hot spring swimming pool, hot spring resort and hot spring tourism projects to fit the demand for public and rich men. It raised conventional use to create a new mode to earn money. Such high rate of return has been attracting more investors to follow it up. It promoted sustainable growth for hot spring industry, including for some villa real estate close by hot spring areas. The total installed capacity of bathing and medical treatment use has reached 2,508 MWt with annual energy use of 31,637 TJ/yr.

4.2.3 Geothermal Greenhouse Planting and Aquaculture Feeding

Greenhouse planting and aquaculture feeding are one of main use for low temperature geothermal resources. Along with the social economic growth and people's living level rising, non-season fresh vegetables and flowers and live aquatic products become a market demand. Geothermal greenhouse has an advantage of lower cost and higher quality than conventional greenhouse using fuel burning. It creates high economic benefit too.

Such application and technical level have been growing progressively. Many various high rank greenhouses appear in Beijing and Tianjin and large cities and coastal regions. Glass greenhouse with 30,000 m^2 of area and automatic control of temperature and humidity is becoming popular. The geothermal greenhouse and aquaculture have reached the installed capacity of 154 MWt and 217 MWt respectively. Their annual energy use is 1,797 TJ and 2,395 TJ respectively. It has annual growth rate about 3% and 2% respectively.

4.3 Geothermal Heat Pump

Using geothermal heat pumps (GHP) to exploit shallow geothermal energy for space heating and cooling, in virtue of the excellent manifestation of energy saving and emission reduction, has won good graces with the government and public, and has gained sustainable development of high speed in the world. The first geothermal heat pump project application is the New Henderson Building in Beijing, China in 1995. It used the heat pump of Carrier brand made in USA. Ten water wells were drilled for pumping and reinjection. Since the project, Tsinghua University combined with Shandong Fulda Co. Ltd to jointly develop chinese products of heat pumps. When it gained success in 1996 the large area application spread since 1997. GHP has a high speed growth when entering the 21st century. The application area was 7.67 million m2 for 2004; and 100.7 million m2 for 2009. Shenyang occupies 22.48% of them is first place in the country. Hereafter Shenyang decreased its very-high-speed for partial adjustment. In 2013, it appears a positive favourable turn perhaps due to the stimulation by serious haze. The installations of 2013 increased 40% more than 2012. The GHP application showed a rapid growth in mid-down streams region of Yellow River and Yangtze River. There was no winter space heating in Jiangsu province in the period of planning economy. But its winter air temperature is lower than 5°C and need space heating. Developers constructed new buildings including geothermal heat pump. It is welcome by the public. In Wuhan city, government comes up with the warm in winter and cool in summer project, new buildings will adopt GHP for heating and cooling.

Geothermal heat pump application reaches 330 million m^2 in 2014 in China. The installed capacity reaches 11.78 GWt with annual energy use 100,311 TJ. They are 2.77 and 2.01 times respectively than the year of 2009. Its progressive annual increase rate is over 27%, rather higher than the rest of the world.

5. GEOTHERMAL MANAGEMENT AND KEY TECHNOLOGY RESEARCH

Geothermal resources management plays an important role in geothermal industrial growth in China. The earliest implementation started in Beijing in 1984. There were near 80 geothermal wells in Beijing at that time. The annual exploitation was over 10 million m^3 with water level drawdown of 2-3 m. Under implementation for 30 years there are 496 geothermal wells in Beijing. The thermal water annual exploitation is 13 million m^3, meanwhile the reinjection has reached 5.5 million m^3, the reinjection/production rate is 42%. Water level drawdown has been controlled in each geothermal field as 0.5-2.0 m annually. Geothermal water was exploited about 30 million m^3 per year in Tianjin. Under strict geothermal management its reinjection is about one fourth (with difficulty in sandstone). Such management ensures sustainable development.

Key technology research for geothermal development has put key point into a prospective hot dry rock project. Jilin University combined with other universities and research institutes are responsible for the research named “Key Technology Research on Development and Integrated Utilization of Hot Dry Rock Heat Energy” funded by Ministry of Science and Technology (MOST) as “863 Project”. It includes the target area engineering test, artificial fracturing technology, resources assessment, power generation etc. The phased objectives have gained. Another HDR research topic from Ministry of Land and Resources (MLR) will carry out test drilling. The drilling site selection will be in Tibet and Yunnan or in the southeast coastal region. Geophysical survey will carry out first, then drilling follows.

In order to promote the geothermal power generation technology which had been laggard in the country, another MOST funded “863 Project” named “Key Technology Research and Demonstration of Medium-Low Temperature Geothermal Power Generation” is being carried out. Tianjin University combined with other universities, research institutes and enterprise is responsible for the project. Its target is a 500kWe prototype of binary circle power generator with thermal efficiency higher than 6%.

Chinese Academy of Engineering arranged also a consulting research project, named “Research on the Strategy of Development and Utilization of Geothermal Resources in China”, and is working. Its target is based on the domestic and overseas status to draw up the road map of geothermal development and utilization in China, and to propose scientific and politic suggestions.

ACKNOWLEDGEMENT

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STANDARD TABLES

Table 1: Present and Planned production of electricity

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		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 2014	27.78	155	964200	4596400	275500	1017400	16300	125600	W.75300 S. 9900 B. 8800	44460 11880 36960	1350000	5832855
Under construction in December 2014	16		72000		14500		23700		W.24700 S.15100			
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020	150											

Table 2: Utilization of geothermal energy for electric power generation as of 31 December 2014

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 2014[3)] GWh/yr	Total under Constr. or Planned MWe
Tibet	YangTest	1977	1	R	2F	1	0	0	
Tibet	Yangbajain	1981-1991	8		2F	24.18	24.18	135	
Tibet	Yangbajain	2009-2010	2		O(total flow)	2	2	12	
Tibet	Yangyi	2011-2012	2		O(total flow)	0.9	0.9	4.5	16
Hebei	Liubei	2011	1		O(total flow)	0.4	0.4	1.2	
Guangdong	Fengshun	1970	1		1F	0.3	0.3	2.4	
Tibet	Langju	1987-1988	2	R	2F	2			
Tibet	Nagqu	1993	1	R	B	1			
Taiwan	Qingshui	1981	1	R	F	3			
Taiwan	Tuchang	1985	1	R	B	0.3			
Total			18			35.08	27.78	155.1	16

* Installed capacity is maximum gross output of the plant; running capacity is the actual gross being produced. ; [1)]N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.; [2)]1F = Single FlashB = Binary (Rankine Cycle); 2F = Double Flash, H = Hybrid (explain); 3F = Triple Flash; O = Other (please specify); D = Dry Steam; [3)]Data for 2014 if available, otherwise for 2013. Please specify which.

Table 3: Utilization of geothermal energy for direct heat as of 31 December 2014 (other than heat pumps)

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity Factor[5)]
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	
Tianjin	D	6,416	73.4	38			950	2,374	11,084	0.37
Hebei	D	7,141	53.1	40			690	2,642	8,050	0.37
Shandong	D	6,434	57.5	40			471	2,552	5,198	0.35
Shaanxi	D	5,541	58.9	40			438	1,939	4,835	0.35
Beijing	D	1,298	58.8	38			113	480	1,318	0.37
Henan	D	1,180	54	40			69	413	763	0.35
Lingdian	D	702	53.3	37			48	288	619	0.41
Other	D	2,753	54.5	40			167	964	1,843	0.35
China	G	1,226	63	33			154	454	1,797	0.37
China	F	2,073	55	30			217	726	2,395	0.35
China	I	2,018		Δt=20			169	1,251	3,304	0.62
China	A	1,135		Δt=20			95	454	1,198	0.40
China	B	29,951		Δt=20			2,508	11,980	31,637	0.40
TOTAL							6,089	26,517	74,041	0.39

1) I = Industrial process heat, D = District heating (other than heat pumps), A = Agricultural drying (grain, fruit, vegetables); B = Bathing and swimming (including balneology), F = Fish farming, G = Greenhouse and soil heating,

Table 4: Geothermal (ground – source) heat pumps as of 31 December 2014

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	2,648,800		W,V	3.2	2880	27,568	
Beijing	15	1,788,500		V,W	3.7	2365	15,233	
Henan	15	1,220,900		V,W	3.5	2365	10,396	
Shaanxi	15	1,028,200		V,W	3.5	2365	8,753	
Jiangsu	16	856,800		V,W	3.5	2110	6,486	
Tianjian	15	547,500		V,W	3.7	2365	4,666	
Hubei	16	514,100		W,V	3.5	2110	3,890	
Other		3,176,200		V,W			23,319	
TOTAL		11,781,000					100,311	

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; W = water source (well or lake water) (TJ = 10^{12} J)

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

Table 5: Summary table of geothermal direct heat uses as of 31 December 2014

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]	2946	33710	0.39
Air Conditioning (Cooling)			
Greenhouse Heating	154	1797	0.37
Fish Farming	217	2395	0.35
Animal Farming			
Agricultural Drying[5]	95	1198	0.4
Industrial Process Heat[6]	169	3304	0.62
Snow Melting			
Bathing and Swimming[7]	2508	31637	0.4
Other Uses (specify)			
Subtotal	6089	74041	0.39
Geothermal Heat Pumps	11781	100311	0.27
TOTAL	17870	174352	0.31

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)

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, 2010 to December 31, 2014 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)	2	12			10.6
Production	>150° C	2	6			3.6
	150-100° C	1	9			13.5
	<100° C		275			635.8
Injection	(all)		84			201.6
Total		5	386			864.1

(Include thermal gradient wells, but not ones less than 100 m deep)

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010						
2011						
2012						
2013						
2014	176	558	103			366
Total						

(1) Government

(2) Public Utilities

(3) Universities

(4) Paid Foreign Consultants

(5) Contributed Through Foreign Aid Programs

(6) Private Industry

Table 8: Total investments in geothermal in (2014) 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
2010-2014	28.5	424.7	1485.8	54.8	91.3	8.7