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Process and Prospects of Industrialized Development of Geothermal Resources in China --- Country Update Report for 2000-2004

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ABSTRACT

Geothermal development in China reflects some facts of its industrial development in recent years. Along with the restructuring of the economy from a socialist planned economy to a market economy in China, national investment in geothermal exploration has decreased, on the other hand, along with the rise of people's living standard, geothermal development found favor with consumers since geothermal water is used more and more for health, tourism and balneology in various hot spring resorts. Investors look now to further increase their investment in geothermal utilization schemes - although it contains some risks, it also can yield high repayments. This has caused an upsurge in geothermal drilling and utilization, especially in Beijing, Tianjin and towns in coastal regions. Investors intending to enter the existing market should allow for the introduction of new concepts and new styles of design. This could set up a new pattern of enterprise-like operations, which would adapt to the present market economy, replacing the previous pattern of welfare oriented operations. This is a great opportunity for new geothermal development in China. Finally, management of geothermal resources plays a big role in some large cities. Extraction of geothermal energy does not necessarily have to be increased by new development. For example in Beijing the total geothermal extraction of hot water has been kept stable and has even decreased slightly, but energy utilization (in terms of GWh produced) has increased significantly.

1. INTRODUCTION

Although historical books show records of geothermal use some 1,800 years ago, such as bath, medical treatment and irrigation, geothermal exploration, development and utilization of geothermal energy as a new energy source started in China only in the early 1970s. At that time, China was controlled by a socialist planned economy. Geothermal exploration and development were therefore all national investments. When geothermal resources were discovered, the geothermal wells were transferred to the user of the land. Such users were typically factories, institutions or villages which obtained geothermal wells free of charge. There was no incentive to optimize design and utilization of their valuable geothermal resources. Owners therefore tended to adopt a low-level simplified use, such as staff bathing schemes and house heating. This attitude originated from the welfare pattern planned economy representing essentially a charity attitude.

Since the middle of 1980s, along with the restructuring of the economy towards market economy, national investment in geothermal exploration has decreased. After some dormancy for a short time, private developers showed great interest to invest in geothermal developments. They discarded the old traditional pattern, and actively carried out new developments and new operations to earn money. Up to date, passing through renewed exploration and developments for more than 10 years, a new pattern of enterprise-like operations has been established which has grown progressively, especially in recent years. It has saved nationwide funds and exceeded high levels of expectation. Geothermal business has not only earned money, but also has optimized utilization. It also has saved consumption of resources and increased applications of heat energy utilization. In recent years, geothermal exploitation activity has increased slightly, but geothermal capacity factor and economic benefit have increased even more.

2. VARIOUS FEATURES OF GEOTHERMAL DEVELOPMENT IN CHINA

According to the characteristics of geothermal resources, the geothermal developments throughout the country show also some characteristic features.

2.1 New Hot Spring Resorts in Beijing

Early geothermal utilization was limited to staff bathing and space heating in Beijing. There were a few physiotherapeutic facilities and some medium to small scale greenhouse and aquaculture plants. Although the greenhouse and aquaculture plants started to supply their products to the public, their output was not big. A number of new projects have recently been opened to the public which include hot spring recreation facilities with large real estate development.

In the middle of 1990s, the old town Xiaotangshan, located in a northern suburb of Beijing, started to attract investment from outside to develop their local geothermal. Combining with good land resources in their local rural area, the first large scale geothermal project in the Beijing area was the development of the 'Dragon's Veins Hot Spring Resort'. An outside investor from Henan province purchased 13 hectares of land and invested 150 million *yuan**. He constructed 39 villas of various styles, and a Hot Spring Paradise was opened to the public. It includes a standard size swimming pool, a diving pool and a 800 m^2 playing pool, all under one roof. In addition, guest rooms, various lounge areas, saunas and geothermal physiotherapy services are available. This project attracted between 300 to 500 visitors a day and over 1,000 during weekends. Its daily income is between 30,000 to 80,000 *yuan**.

Such business performance attracted more investors. Later on, various additional geothermal developments took place covering some 130 hectares of land, total investment exceeded 600 million *yuan* in this area. Subsequently, the Jiu Hua Spa Resort was created as a modern geothermal recreation and health care center covering 10 hectares of land. It owns hot spring bath pool, a Chinese-medicine pool and a mineral mud pool. Each villa has a hot spring pool in its courtyard. The resort appealed to retired doctors from all over the country to come and live at the resort. These doctors serve now the medical needs of the people living in the resort and have access to the geothermal physiotherapy facilities when need for patients. The resort owns one geothermal well with average characteristics (44°C at the well head and 1,100 m^3/d flow), but they rely on their health care to attract consumers. The daily income exceeded 280,000 *yuan* on average. Just two years later, the Badaling Hot Spring Resort opened its facilities in Yanqing County, north of the Great Wall. Besides standard facilities for hot spring recreation, it owns hot spring hotel, hot spring apartment, hot spring villa, a tennis hall, bowling hall, and an international conference center. (*About 8.2 *yuan* exchange for 1 $ US)

The most recent geothermal development and utilization scheme in Beijing is its World Geothermal Natural Science Park which exhibits almost all aspects of direct geothermal utilization, e.g. space heating, recreation (swimming, fishing etc.), aquaculture, greenhouse and irrigation plants. There is a Geothermal Popular Science Exhibition Center nearby. The center has a multi-function hall showing geothermal films and an exhibition hall exhibiting popular geothermal science topics. This big project has changed the local cultivating agriculture into a service business. It promotes growth of local economy, and introduced the term: 'Hot Spring Economy'.

2.2 Geothermal District Heating in Tianjin

Low temperature geothermal water was used for washing and dyeing by its textile industry during the early geothermal development period in Tianjin. Local factories also drilled water wells deeper and deeper to found geothermal water with a temperature of 40-60°C in Tertiary sandstones. It was 'soft' water and best to be used in the textile industry. Later on, geothermal exploration found thermal water of 80-96°C in deeper reservoirs of lower Palaeozoic and Proterozoic basement rocks. Unfortunately, the early development did not include installation of public space heating system in the city. Geothermal district heating was only adapted later to satisfy heating demand, because there was no space for installing standard boiler-houses and the environment protection laws did not permit to use of coal-fired boilers in the urban of the city from the 1990s onward. Since that time, geothermal district heating has been growing rapidly. The total floor area with geothermal heating has reached 9.2 million m^2 at present. It occupies c. 78 % of the geothermally heated space area in the country. Depending on different water quality geothermal heating uses either direct throughput or heat exchanger schemes. In order to enlarge the heating area, secondary circulation is now applied using returned water with lower temperature from the first circulation. Floor heating has also been introduced progressively. It increased almost one time the area heated by the same geothermal well. Recently, heat pump technique has been used in geothermal heating projects. This increases the potential heating area further. The present efficiency has reached about 2.5 times that of early use of a given single well.

2.3 The 'Village of Hot Spring of China' in Guangdong Province

Guangdong Province is located in a tropic to subtropic climatic zone Abundant hot springs (282 hot springs in the province) were used for hot spring bathing. There were many hot spring sanatoria in the province. But such installation with the past mark of planned economy did not fit in with recent demands of recreation by the public. In 1998, the Emperor Hot Spring Resort was established as a new business in Zhuhai City. The Japanese style of hot spring bath pools with hot spring fountains, hot spring stone beds, hot spring waterfalls, medicine hot spring bathing and hot spring swimming pools have attracted a large number of visitors. Such development moves fast in Enping. When 4 hot spring resorts opened their facilities progressively from 1997 onwards, hot spring tourism was strengthened. It now accepts 1.33 million person-visits annually during recent years. The geothermal business has generated 480 million *yuan* of annual income. It forms a typical 'Hot Spring Economy'. The city has been named as 'The Village of Hot Spring of China'. The China Mining Association approved the application after expert's appraising. It has further promoted growth of local hot spring economy.

2.4 Geothermal Utilization in Paramos of Helongjiang Province

A large number of exploration wells for oil-gas exploration were drilled in an area surrounding the Daqing Oil Field in order to maintain sustainable production. Some of wells produce hot water with artesian flow in Lindian County, a neighbor county. Local people have re-constituted 2 old exploration wells and drilled 8 new wells since 1998. The thermal water has a temperature of 52-54°C, a total flow of 18,000 m^3/d with a total capacity of 19.7 MWt. A geothermal district heating scheme for a total of 310,000 m^2 space is now operating together with a warm water supply for 3,000 houses; it saves 8,000 tons of coal per year and reduces air pollution in the county. The public bath center and hot spring sanatorium can accept 150,000 persons annually. Geothermal greenhouse and aquaculture have also been developed using the waste thermal water after heating circulation. Such development is a good model for the possible follow-up development of an old oil field.

2.5 The Growth of Professional Man-Power Accompanying the Market Economy

To adapt to the needs of the market economy, geothermal professional personnel has been strengthened and is growing. For example in Beijing, there was only one geothermal section with a few people who carried out geothermal exploration as part of a hydrogeological team. At present, 8 units have been established which are concerned with geothermal exploration and development under the control of the Beijing Bureau of Geology and Mineral Resources Exploration and Development. Many geothermal companies and institutes work now together quite well. The Geothermal Council of China Energy Society hosted various geothermal training courses such as geothermal heat pump and geothermal reinjection courses. Technicians also receive training. The China University of Geoscience has established a section dealing with 'Geothermal Resources and Geological Engineering' and had recruited postgraduate (including Ph.D. candidates). Along with the expansion of geothermal market, the manpower appears to be increasing in the geothermal domain. The total number of scientists and engineers undertaking geothermal exploration, development, research and management is about 746 people in the country.

2.6 Successful Exploration and New Development in Some Cities

Either as new energy development or as an industry earning money, geothermal exploration and development has been successful in a series of cities. The local first geothermal wells were successfully drilled in Yinchuan, Nanning, Dalian, and Jinan cities. A new geothermal well of 2,000 m depth produces thermal water with 105°C temperature and 200 m^3/h flow in the Baodi County of Tianjin Municipality.

3. GEOTHERMAL DIRECT USE IS THE MAIN UTILIZATION IN CHINA

Although there are many high temperature geothermal resources in China, their distribution is restricted to distant areas, e.g. Tibet and Taiwan. High temperature geothermal power generation was started in Tibet with a 1 MW testing power station in 1977. Later on, other smaller geothermal power plants with a total capacity of 25.18 MW were installed in the Yangbajain Geothermal Field, Tibet. There is a 2 MW geothermal power plant established in Langju, west Tibet and a 3.3 MW unit installed in Taiwan. The Yangbajain Geothermal Power Plant plays a important role in the energy supply of the Tibetan Plateau which lacks coal and oil resources. Its annual output of 100 million kWh supplies half of the electricity demand of Lhasa City. The geothermal power plant is called ‘The Pearl on the Roof of the World’ but its recent development is not clear due to reasons associated with the development of a national minority region.

Medium to low temperature geothermal resources are distributed widely throughout the country. Both in coastal areas and in the interior of the country, geothermal direct utilization is very extensive. It has been used for space heating, agricultural greenhouse, aquaculture feeding, bathing and health care, and geothermal recreation with tourism appeal.

Geothermal space heating can locally replace heating with conventional fuel boilers. It has been well received by the public due to its effect in reducing air pollution. Geothermal space heating covers now 12.7 million m^2 area in the country with 9.2 Mm^2 in Tianjin City alone. In addition, in Xi’an, Beijing and many other small cities such as Xiongxian, Renqiu, Hebi and Lindian, geothermal space heating is widely applied.

Geothermal greenhouses have changed extensive cultivation of traditional agriculture, especially in northern China. They produce anti-season top-grade, fine and special vegetables and flowers and have increased agricultural output value. There are a total about 1.33 million m^2 of geothermal greenhouses in China with 0.47 million m^2 in Hebei Province alone. Geothermal aquaculture has improved growth and breading of high-grade fish species, which produce high yields and favor warm water. There are about 4.45 million m^2 of geothermal aquaculture ponds in c. 300 locations in the country, especially in Hubei (1.40 Mm^2), Guangdong (0.79 Mm^2) and Fujian (0.55 Mm^2) provinces. Eels from geothermal aquaculture are exported mainly to Japan. Finally, geothermal water is also used in many drying, cooling, washing and irrigation plants.

Hot spring bathing is a traditional custom in China and is part of the civilization of this country. There are about 1,600 public hot spring bathing houses and swimming pools in the country. In addition, the number of hot spring spas, mainly with swimming facilities, has grown rapidly, especially in large cities like Beijing, Tianjin, Xi’an and in coastal areas, e.g. Guangdong and Fujian provinces in recent years. Geothermal balneology, which emphasizes medical care, is practiced at about 430 places. These are the largest geothermal utilization schemes in China.

According to statistical data in the WGC2000 reports, the annual utilized energy of geothermal direct-use schemes in China puts the country at first place in the worldwide ranking of countries with direct geothermal utilization. This use has now reached about 10,779 GWh/a (excluding heat pump utilization). The total capacity of all direct utilization schemes is about 3,056 MWt in 2004. In future we shall still emphasize geothermal direct-use as our main field of application.

4. ENTERPRISE-LIKE OPERATION PATTERN REPLACING PREVIOUS WELFARE PATTERN

In the past, all input of socialist enterprise was subordinate to the national planning. Geothermal exploration and development relied on the national input too. This created a welfare pattern within a planned economy. Although nation planners wanted to develop geothermal energy, local units lacked initiative and activity, and so there was only slow progress. The Yangbajain geothermal power plant is a typical example. Prior to its development there was a serious lack in the supply of electricity and conventional energy (e.g. coal and oil) in Tibet. Geothermal power generation has absolute superiority based on the local rich geothermal resources. It was then the best economic and feasible selection and the national government gave it strong support. To implement this project, the nation put vast funds for geothermal exploration, production well drilling, power plant construction and generator installation into the project. Geothermal scientists and engineers were assigned from the whole country to ‘aid Tibet’. Geothermal exploration and drilling lasted for 20 years. Even another geothermal field in nearby Yangyi with similar potential was explored for back-up development. But such large input did not lead to any further growth in the last 13 years.

At present, a new pattern of industrialized development with enterprise-like operation has replaced the previous pattern. The principal part of the market economy is enterprise. Private investors understand now how to develop geothermal resources by enterprise-like operation. Their motivation is profit. With this idea, investors strive for advance from design to construction and to management so that the resulting profit will lead to further advances. Within the market competition the later investor has to be on top of his rivals somehow. Therefore investor can embark on unconventional and unorthodox developments to attract new consumers. China will still carry out this policy with further geothermal development.

5. ENERGY SAVING AND ENVIRONMENT PROTECTION

Energy saving and environment protection laws have been put into the Chinese agenda. In the past, progress of geothermal development was measured in terms of increases of exploitation. More extraction represented a new increase. But part of the geothermal energy was wasted at that time. Some of the water at the exit of space heating schemes, for example, was discharged into drainage with a temperature of about 40°C. This wasted both heat and water resources and caused environment pollution of the groundwater (heat and chemical pollutants, e.g. fluoride). It was also a result of planned economy.

Such waste was reduced later on for two reasons: firstly, geothermal resources management plays now a big role in some large cities and secondly, private investors are careful to avoid wasting energy. Therefore, although exploitation didn't increase much, sometimes it showed even some decrease, the total efficiency of geothermal utilization has been raised and the benefit of geothermal business has increased accordingly. For example, a single well was used for geothermal heating discharging wastewater at 40°C to heat 100,000 m^2, but now it heats 250,000 m^2 through floor heating and heat pump use and discharge wastewater at 15°C. Hence technology, environment protection and economic benefits have been optimized progressively.

6. IMPROVING THE STATUS OF EXPLORATION AND SCIENTIFIC MANAGEMENT

Geothermal development with enterprise-like operation is based on the use of special locations owned by the investor. Some of such locations were not investigated previously by geothermal exploration or even reconnaissance. This involves a high risk for any investor. If a development fails, it will affect the activity of other investors. Such a hypothetical case exposes a certain backward status: the older national survey and exploration for the purpose of the public good did not adapt to the demand of market economy.

In China, decentralized development of medium to low temperature geothermal resources do not lead to concentrated operation on a large scale. This status makes it difficult for geothermal resources management. Geothermal management has been carried out by computerized modeling in Tianjin. Although it is an advancement in technology, the corresponding laws for scientific and proper management are still weak. Up to date, there are still many weaknesses in the management of geothermal resources in other cities and provinces as well. These have to be improved in future.

7. CONCLUSIONS

China was ranked first in the world with respect to the energy utilized for direct-use according to the statistical data from WGC2000. In recent years, geothermal developments of the country have reflected striking features of industrialized development where market economy pushed forward the activity of investors. The enterprise-like operation have adapted to the regulations of market economy. The geothermal resources management is being strengthened progressively, too. Although the magnitude of geothermal exploitation did not increase significantly, the efficiency in utilization did so. Total benefits have obviously increased. Environment protection has been given attention too. In addition, the first geothermal wells were successfully drilled in several larger cities which led to the development of geothermal utilization schemes.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	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	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2004	27.78	95.7	332,550	1,806,740	93,070	297,800	7,000	48,300	352	1,060	433,000	2,154,000
Under construction in December 2004			50,000		9,000		1,700		150		60,850	
Funds committed, but not yet under construction in December 2004												
Total projected use by 2010	33	110	448,400	2,150,000	133,410	426,900	17,140	120,000	1,000	3,000	600,000	2,700,000

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2004

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 2004 if available, otherwise for 2003. Please specify which.

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe	Annual Energy Produced 2004[3)] GWh/yr	Total under Constr. or Planned MWe
Tibet	Yangb.Test	1977	1	R	2F	1	0	
Tibet	Yangbajain	1981-1991	8		2F	24.18	80	
Tibet	Nagqu	1993	1		B	1	4.4	
Tibet	Langju	1987-1988	2		2F	2	8.7	
Guangdong	Fengshun	1984	1		F	0.3	1.3	
Hunan	Huitang	1975	1		F	0.3	1.3	
Taiwan	Qingshui	1981	1	N	F	3	0	
Taiwan	Tuchang	1985	1	N	B	0.3	0	
Total						32.08	95.7	

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2004 (other than heat pumps)

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)

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

Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 ($MW = 10^6$ W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] 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

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	2081	83.4	38			1069	770	4612	0.37
Shannxi	D	791	56.9	40			160	277	617	0.35
Hebei	D	594	58.1	40			122	220	524	0.37
Beijing	D	348	55.8	40			62	129	268	0.37
Lindian	D	245	53.3	37			41	100	216	0.41
Others	D	231	54.5	40			40	81	154	0.35
Hebei	G	358	58.1	33			102	132	438	0.37
Beijing	G	315	52.4	33			69	117	298	0.37
Shannxi	G	141	51.6	33			28	49	108	0.35
Tianjin	G	50	67.6	33			19	18	84	0.37
Others	G	345	48.5	33			64	121	247	0.35
Hubei	F	506	56.4	30			160	177	617	0.35
Guangdong	F	235	58.2	30			81	80	297	0.34
Fujian	F	219	52.2	30			60	75	218	0.34
Hunan	F	178	53.8	30			52	61	191	0.34
Hebei	F	119	58.1	30			38	44	163	0.37
Beijing	F	120	52.4	30			30	45	132	0.37
Shannxi	F	84	51.6	30			21	30	86	0.36
Others	F	213	52	30			56	74	216	0.35
All China	B	23782		¡ t= 20			4978	9513	25095	0.4
China Textile	I	579		¡ t= 20			54	521	1374	0.9
China Others	I	610		¡ t= 20			93	336	885	0.55
China Drink	I	620		¡ t= 15			139	174	343	0.28
China	A	955		¡ t= 20			199	382	1007	0.4
China ***	Monitoring	231		¡ t= 20			19	231	611	0.95
TOTAL		33950*					7756**	13756	38804	0.39

* Total average flow rate is 13756 kg/s
** Total capacity for average flow rate is 3056 MWt
*** Monitoring for earthquake prediction

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2004

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.

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

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)

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

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

Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (^{o}C) - outlet temp. (^{o}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. (^{o}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)
Tianjin Dagang	36	220	1	O*	3.8	2880	2	0.3
Beijing XT build.	15	760	4	W		2880	31.6	7.9
Beijing XQ build.	15	760	2	W		2880	15.8	3.9
Beijing HD build.	18	760	8	W		2880	67.4	16.7
(The above are examples.)								
Beijing total							2857	
Other areas							3712	
TOTAL							6569	

* Geothermal well

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2004

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}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. (^{o}C) - outlet temp. (^{o}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]	550	6391	0.37
Air Conditioning (Cooling)			
Greenhouse Heating	103	1176	0.37
Fish Farming	174	1921	0.36
Animal Farming			
Agricultural Drying[5]	80	1007	0.4
Industrial Process Heat[6]	139	2603	0.62
Snow Melting			
Bathing and Swimming[7]	1991	25095	0.4
Other Uses (specify) *Monitoring	19	611	0.95
Subtotal	3056	38804	0.4
Geothermal Heat Pumps	631	6569	0.33
TOTAL	3687	45373	0.39

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, 2000 TO DECEMBER 31, 2004 (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	16			33
Production	>150° C					
	150-100° C		1			2
	<100° C		266*			502
Injection	(all)		17			37
Total		1	300			574

* A few of them belong to combined Exploration-Production well.

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)
2000						
2001						
2002						
2003						
2004	148	332	78		3	185
Total						

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) 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$	%	%
1990-1994						
1995-1999						
2000-2004	5.4	80.9	172.8		97.9	2.1