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GEOTHERMAL UTILIZATION AND DEVELOPMENT IN HEBEI PROVINCE

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ABSTRACT

Geothermal resources are abundant in Hebei Province. With the great stress on "energy saving and emission reduction", focus on renewable and clear energy use in Hebei becomes increasingly necessary. Conventional geothermal use and heat pump technology are ranked highly especially in house heating system. Policies encouraging geothermal are substantiated by the provincial government.

1. INTRODUCTION

Hebei Province is located in the northern part of the North-China Plain (Figure 1). The total area is 187,693 km^2, within longitude E 113°27′-119°50′ and latitude N 36°05′-42°40′. The area includes Beijing (the Capital of China) and Tianjin (the third largest city in China), and the total population amounts to 68.98×10^6 (2006).

There are three main physiographic units in Hebei: The Yan Mountain and the Taihang Mountain areas, where natural hot springs occur in fracture zones, these areas together account for 48.1% of the provincial area; The Hebei Plain accounts for 43.4% of the provincial area and this is where the majority of the geothermal resources are retained; the Bashang plateau, with 8.5% of the provincial area. Hebei has a continental climate with seasonal winds.

Mineral resources are rich in Hebei province, with 150 mineral resources having been uncovered, 120 reserves size estimated, and 34 of theses are among the top 5 reserves in China. The 6290 mining enterprises have a total work force of 400,000 workers. Mining of economic system of metallic ore, coal, building materials and oil-chemistry is established. Coal takes up 1/13 of the countries total mineral resources. In the Huabei oil field, the Jidong oil field and the Dagang oil field, the oil reserves are estimated at 2.7×10^9 tons, and natural gas reserves at 180×10^9 m^3.

The total energy of deep geothermal resources is 122773×1016 J, this equals 41.9×10^9 tons of standard coal. However, the energy contents of the minable reserves amounts to 27523×1016 J, which equals 9.4×10^9 tons of standard coal. The 241 deep geothermal wells are distributed in the middle to southern part of Hebei. The average temperatures of these wells are 40-70°C, with a maximum temperature of 118°C. Solar energy is also developing rapidly in Hebei and Baoding City is now also called "China Power Valley". The wind power field in Zhangjiakou City has reached 5 MW/y, and its target is to become the largest wind power field in China.

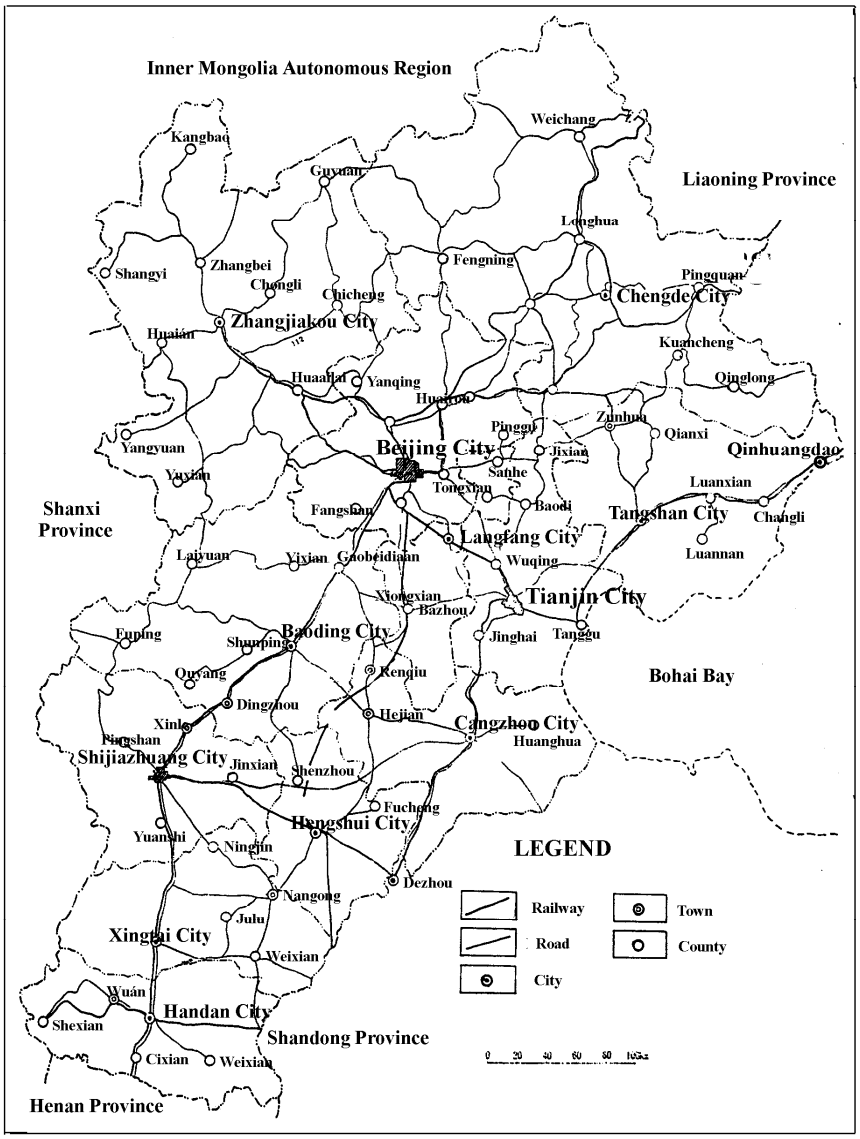

FIGURE 1: Map of Hebei Province (Li Hongying, 2000)

2. GEOTHERMAL RESERVES EVALUATION

The shape and distribution of geothermal resources on the Hebei Plain is mainly controlled by deep tectonics. There are three main types of reservoirs based on their locations in tectonic-fractures, fracture-karsts and voids. According to the principle of minable geothermal reserves, there are 37 geothermal fields, including 19 large scale fields (>50 MW), 16 medium scale fields (10-50 MW), and 2 small scale fields (<10 MW) distribute throughout the Hebei Plain with a total area of 16,240 km^2(see Table 1 and Figure 2).

2.1 Geothermal reserve calculation

The areas included in reserve calculations are geothermal fields, anomalous areas and prospect areas. When the temperature gradient of the Cainozoic layer is ≥ 3.0°C/100 m the drilled wells are mined, and when the temperature gradient of the Cainozoic layer is ≤ 3.0°C/100 m at a depth ≤ 3000 m (i.e. economic developing zone) the wells are kept for reserves in the plain area. Mountain areas are not included in the calculations, as the figures are too small and can be ignored.

TABLE 1: Geothermal fields of Hebei plain

No	Field name	Resevoir layer	Useable resources (10^{16} J)	Equal power (MW)	Scale	No	Field name	Resevoir layer	Useable resources (10^{16} J)	Equal power (MW)	Scale
1	Tanghai	Nm	7.071	22.422	L	20	Hujiachi	Nm	25.541	80.99	L
		Ng	12.797	40.579				Ng	19.055	60.423	
		ε+O	8.127	25.771		21	Xianxian	Nm	14.206	45.047	L
2	Langfang	Nm	2.634	8.352	M			Ng	1.136	3.602	
		Ng	1.154	3.659				ε +O,Pt	15.477	49.077	
3	Zhuozhou	Pt	0.175	0.555	S	22	Fucheng	Nm	6.131	19.441	M
4	Rongcheng	Nm	0.711	2.255	M	23	Jingxian	Nm	4.78	15.157	M
		Pt, ε	4.434	13.772		24	Xinji	Nm	12.276	38.927	L
5	Niutuo	Nm	13.454	42.662	L			Ng	12.117	38.423	
		Ng	4.717	14.958				Pt, ε +O	9.922	31.462	
		O,Ch-Jx	23.921	75.853		25	Qianmotou	Nm	7.865	24.94	L
6	Bazhou	Nm	1.03	3.266	S			Ng	10.798	34.24	
		Ng	1.764	5.594				Pt	3.355	10.639	
7	Wen an	Nm	8.741	27.718	L	26	Xinhe	Nm	9.617	30.495	L
		Ng	10.18	32.281				Ng	6.207	19.682	
8	Gaoyang	Nm	13.447	42.64	L			ε +O	7.455	23.64	
		Ng	19.751	62.63		27	Heng shui	Nm	7.846	24.88	M
		Pt, ε +O	5.84	18.519				Ng	2.525	8.007	
9	Renqiu	Nm	14.688	46.575	L			Pt, ε +O	2.124	6.735	
		Ng	12.376	39.244		28	Nan gong	Nm	11.762	37.297	L
10	Su ning	Nm	30.311	96.116	L			Ng	6.984	22.146	
		Ng	33.198	105.27		29	Zaoqiang	Nm	11.429	36.241	L
11	Hejian	Nm	11.867	37.63	L			Ng	13.841	43.89	
		Ng	10.64	33.739				ε +O	2.779	8.812	
		Pt, ε +O	7.787	24.692		30	Gucheng	Nm	13.824	43.836	L
12	Dacheng	Nm	3.747	11.882	M			Ng	10.858	34.43	
		Ng	5.295	16.79				ε +O	4.685	14.856	
		ε +O	5.569	17.659		31	Guangzong	Nm	8.306	26.338	M
13	Qingxian	Nm	4.698	14.897	L			Ng	5.841	18.522	
		Ng	10.422	33.048				Pt, ε	1.159	3.675	
		Pt, ε +O	11.285	35.785		32	Qiuxian	Nm	3.607	11.438	M
14	Cangzhou	Nm	3.649	11.571	M			Ng	5.121	16.239	
		Ng	3.116	9.881		33	Linxi	Nm	3.862	12.246	M
15	Huanghua	Nm	13.877	44.004	L			Ng	5.495	17.425	
		Ng	24.453	77.54		34	Handan	Nm	1.048	3.323	M
16	Mengcun	Nm	9.835	31.187	L			Ng	3.928	12.456	
		Ng	10.932	34.665		35	Guangping	Nm	4.965	15.744	M
17	Xincun	Nm	4.092	12.976	M			Ng	4.444	14.092	
		Ng	4.165	13.207		36	Guantao	Nm	2.004	6.355	M
		ε +O	1.903	6.034				Ng	3.978	12.614	
18	Wuji	Nm	2.176	6.9	M	37	Daming	Nm	2.15	6.818	M
		Ng	4.114	13.045				Ng	2.316	7.344	
		ε +O	1.291	4.094							
19	Shenzhou	Nm	23.149	73.405	L						
		Ng	26.915	85.347							

Notice: L – large; M - medium; S – small.

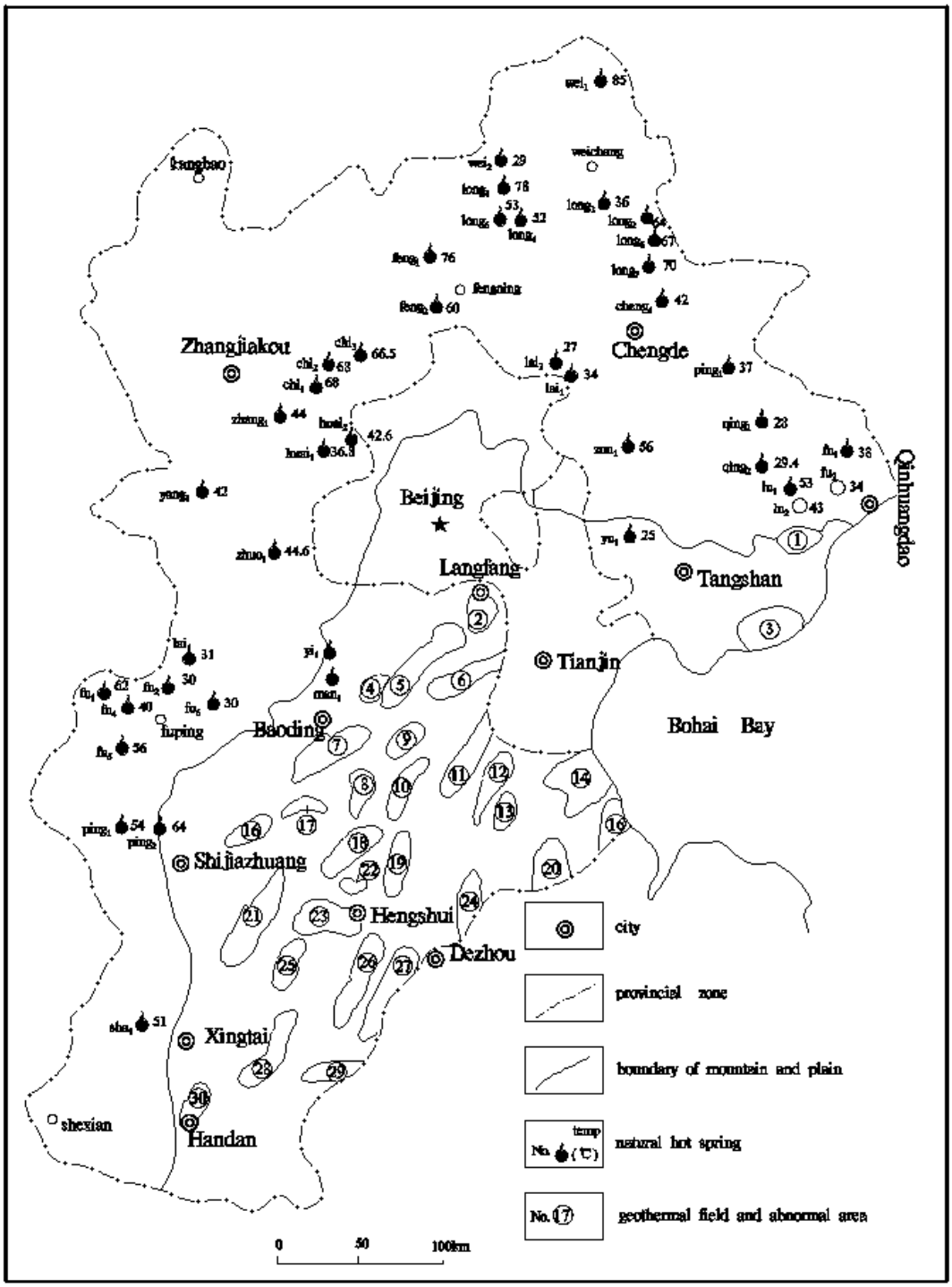

FIGURE 1: Map of Hebei Province (Li Hongying, 2000)

2.2 Calculation formulas

1) Size of geothermal reserve:

$$Q_r = CAd\,(t_r - t_0) \qquad (1)$$

where Q_r = Amount of reserves (J);
A = Reservoir area (m^2);

D = Thickness (m);
t_r = Reservoir temperature (°C);
t_0 = Average ground temperature (°C);
C = Rock and water average heat capacity in reservoir (J/m^3·°C)

2) Minable geothermal reserves:

$$Q_{wh}=Cad\ (t_r-t_0)R_E \quad (2)$$

where Q_{wh} = Minable geothermal reserves (J);
R_E = Recovery (0.25 in Cainozoic layer, 0.15 in rock layer);
Others same as above

3) Geothermal fluid reserve:

$$Wr=Wv+We=Ad\varphi+A\mu^*H \quad (3)$$

where Wr = Geothermal fluid reserves (m^3);
Wv = Volume geothermal fluid reserves (m^3);
We = Elastic geothermal fluid reserves (m^3);
Φ = Porosity;
μ^* = Elastic storage coefficient
H = Elevation head (m)

The geothermal reserves in Hebei are calculated from the above equations and are shown in Table 2.

TABLE 2: Geothermal reserves in Hebei Province

Geothermal reserves in mountain area				**Geothermal reserves in Hebei Plain**					
				Geothermal field				**Perspective area**	
Hot spring outflow (10^4m^3/a)	500.50	Equal coal (10^3t)	29.6	Reserves in Caenozoic layer (10^{16}J)	55987.39	Equal coal (10^9t)	19.1	Reserves in Caenozoic layer (10^{16}J)	34853.31
Geothermal well production (10^4m^3/a)	1502.03	Equal coal (10^3t)	126.3	Reserves in rock layer (10^{16}J)	31932.67	Equal coal (10^9t)	10.9	Equal coal (10^9t)	11.89
Total	2002.53		155.9	Total	87920.06		30.0		
Sum	Geothermal reserves in Hebei are equal to coal 41.9*10^9tons, minable reserves are equal to coal 9.4*10^9tons.								

3. STATUS OF UTILIZATION AND DEVELOPMENT IN HEBEI PROVINCE

Geothermal utilization in Hebei Province can be traced 2000 years back in time in mountainous areas. Ancient generations utilized natural geothermal water for bathing and treatment of diseases, such as rheumatism and mange. In Zunhua geothermal sanatorium geothermal is still utilized for curing diseases. Two geothermal springs in Zhang Jiakou City, Chi Cheng County, have been utilized from the Sui-Tang Dynasty till present. Development and utilization of geothermal resources in mountainous areas are decreasing due to their location and the quantity of geothermal water. Investigation result from 2006 showed that there are 33 small scale geothermal fields (31 are developed), include 47 hot springs with water temperatures of 28-98°C and total annual production of 18.56×106 m^3 that are used mainly for bathing, sanatoria, space heating, greenhouses and fish farming. There are 3.27 million recreational tourists per year visiting these fields. The space heating area amounts to 68,390 m^2. The fish farms cover an area of 1×10^5 m^2, and the greenhousing area accounts for 3.8×10^6 m^2. There is large potential in the recreational tourist industry. However, serious

problems caused by over-exploitations have arisen, as springs disappearing and reduced flow rate.
The Geothermal fields on the Hebei Plain are mostly low-to-moderate temperature fields, with temperatures of 35-100°C. Geothermal resources are utilized for bathing, sanatoria, space heating, flax processing, greenhouses, swimming pools, accommodation and recreation, chicken hatching, fish farming, etc. Since the 1980s, geothermal energy has improved on social and economic standards as one of the major renewable energy resource. In recent years, as the neighbour of Beijing and Tianjin, Hebei is pressured by socialists and environmentalists to save on conventional fossil fuel energy and cut back on CO_2 emission. Every year Hebei has to abolish large amounts of coal and oil boilers for domestic and industrial heating. Replacing fossil fuels with renewable energy is a heavy task but geothermal resources and heat pumps are becoming increasingly popular.

In 2004, geothermal production was 28.2×10^6 m^3, supplying heat for an approximate area of 1×10^6 m^2. In 2006, the annual geothermal production reached 31.353×10^6 m^3 from 157 wells (the total number of wells is 210), heating a total area of 4.70×10^6m^2, including space heating areas of 4.42×10^6 m^2, greenhouse areas of 0.13×10^6 m^2, and fish farming areas of 0.15×10^6 m^2. The annual number of recreational tourists reached 4.6×10^6 (Su Yongqiang et al., 2006).

In 2008, the recorded space heating area is 7.336×10^6 m^2, including production from at least 10 new wells. The additional heating area is from new development and by the end of the year it is predicted that the area will increase with another 1×10^6 m^2. This figure does not include water-source and ground-source heat pump use. In fact, heat pump use is becoming increasingly popular in "non-geothermal" areas. They are mostly used in large public facilities such as supermarket, office buildings, and so-called centre-air-conditioner systems.

4. MANAGEMENT SCHEME AND FUTURE PLAN

4.1 Conditions and limitations analysis

The geothermal area in Hebei Province covers 16,240 km^2, this is nearly 1/10 of the provincial area, and the Hebei Plain comprises the majority of this area. The area is dominated by the typical type of low-to-moderate temperature geothermal field found in north China. It is densely populated, social and economically well-developed, and heating is needed for large periods in winter. Geothermal resources are easily mined with the present technology and economy (e.g. wells to a depth of 3000 m are accepted). Exploration has to comply with compulsory policies on "low-consumption and high-efficiency", and "energy-saving and emission-reduction" from the national state. The Hebei province was faced with special environmental restrictions for the Beijing 2008 Olympics, starting 7 years ago in order to clean the air and keep a high quality, fresh air. The restrictions order all fossil fuel boilers to be demolished and replaced by renewable energy resources. Geothermal resources are attractive to the space heating industry and it has vast potential. Meanwhile, the ground and water-source heat pump application is an important complementary.

Some shortages, however, are restricting geothermal development. Firstly, geological prospecting, in few cases, suffers under the lack of knowledge of geothermal reservoirs which makes the management of the reservoir difficult. Most developers are spontaneous and unstructured, hence geothermal systems are over-mined and lacking reinjection. These deficiencies cause problems for long-term utilization. Secondly, the distribution of most geothermal fields is limited in the countryside and rural areas where the local economy and social conditions are not allowing for large-scale, high-efficient geothermal utilization. The old and small towns are constructed without united pipelines, storage distribution, and waste discharge, and it is difficult to resolve these problems. Furthermore, laws and policies are lacking, and are not covering all aspects of geothermal utilization and development, i.e. dealing with mining rights, shareholders, capital investment, joint ventures, social and public welfare, etc.

4.2 Status of management schedule

According to the"Act of Mineral Resource" and the"Act of Water", geothermal resources are characterized as both mineral and water. Geothermal resources are different to solid mineral resources in its renewability; and therefore there are special laws and regulations.

During the last decades, compared with fossil fuels, the high expenses of geological prospecting and initialization of construction rendered geothermal resources unfeasible for national basic energy supply, and government management was incomplete.

With the increasing attention to the international energy market, climate and environment, the geothermal contribution to CO_2 emission reduction is becoming more recognized, and large domestic and foreign investments are being made in geothermal development. National and local governments must investigate and create new management mechanism to suit the change in energy demand, i.e. focus on the importance of prospecting rights, mining rights, public energy supply, national-owner policies, etc.

Water-source and ground-source heat pump technology have been used in large scale central air-conditioner systems to replace fossil fuel and oil boiler systems and have great potential. The environmental benefit is high but energy saving is low; however, it can with advantage be used as a complementary in parts of the geothermal cascading system.

4.3 Future scheme

Regulations on prospecting and mining rights are urgently being formed. More than 300 rights are waiting for approval in Hebei Province. It is expected that the new policy documents will be published later in 2008.

To improve on resources evaluation, change out-dated techniques of utilization, and guide scientific development, new models on joined venture development between government-investors and public-investors are examined.

According to new policies, reinjection of waste water into the geothermal reservoir will be compulsory as will reinforced monitoring of reservoirs. Policies will favour cascaded use and reinjection systems.

Attention should be paid to capital inflow from natural resources.

5. CONCLUSIONS

Hebei Province is located in the middle of North China, includes Beijing and Tianjin, and has thus a special geographical position.

Faced with the severe international situation on climate, environment and shortage of energy resources, and with the hosting of the 2008 Olympics' in Beijing, Hebei Province has to seek new measures to solve the problems on energy supply and emission reduction.

Geothermal resources are abundant on the Hebei Plain. It can provide adequate renewable energy to abandon fossil fuel and oil boilers for house heating and industrial uses, and can contribute extensively to "energy saving and emission reduction".

The total geothermal reserves in Hebei Province account for 122,819.07×1016 J, equal to 41.906×10^9 tons of coal, the minable reserves account for $27{,}545.79\times10^{16}$ J ,equal to 9.399×10^9 tons of coal. The

annual geothermal production is currently 31.353×106 m^3 in 157 wells (of a total of 210 wells), the heating area is 4.70×10^6 m^2, including space heating of 4.42×10^6 m^2, greenhouse heating of 0.13×10^6 m^2, and a fish farming area of 0.15×106 m^2. The number of annual recreational tourists reached 4.6×10^6 in 2006. In 2008, the new figure on space heating is 7.336×10^6 m^2, with at least 10 new wells drilled.

New heating areas shows urgency for geothermal utilization and it is predicted that the total geothermal house heating area will increase to 10×10^6 m^2 in the next 1-2 years, after the mining rights regulations have been approved.

The utilization of heat pump technology is becoming increasingly popular as a method of emission reduction in "non-geothermal" areas, and is also being used as a complimentary geothermal cascaded utilization.

Geothermal resources are characterized as both mineral and water reserves, in the "Act of Mineral Resources" and the "Act of Water". However, since geothermal was not considered important mineral resources in the past decades, there are limited prospecting and management regulations, and new policies are urgently needed to speed up geothermal development.

The prospecting and mining rights policy will promote integrated government and public investment. More than 300 rights are waiting for approval in Hebei Province.

To guarantee sustainable utilization of geothermal resources, reinjection and monitoring must be carried out strictly.

Attention should be paid to capital inflow from natural resources.

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