

The Exploitation Dynamic and Sustainable Development of Geothermal Resources in Tianjin, China

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ABSTRACT

Tianjin, located at the east of Beijing, has abundant geothermal resources. There have been more than 300 geothermal wells by now. In 2007, the production is $2583.8 \times 10^4 \text{ m}^3$, while the reinjection is $409.3 \times 10^4 \text{ m}^3$, so the reinjection rate is 15.8%. For the positive exploitation of resources, governmental authorities supervise strictly by law in recent years. Meanwhile, new science and technology is taken as guider or driver and used in the economic construction and social development. So the technique level of exploitation and utilization has been improved and the resource utilization is transforming gradually from simple extensive pattern to circle intensivism pattern. Practice for years shows that: Only by strengthening the supervision, establishing the mechanism of technology innovation and achievement transformation on energy-saving and ejection-decreasing, the geothermal can develop healthily and sustainably.

1. INTRODUCTION

According to statistics, annual production of geothermal resources reaches $4.4 \times 10^8 \text{ m}^3/\text{a}$ in 2005, and the total amount of geothermal resources is $68.45 \times 10^8 \text{ m}^3/\text{a}$ which is equal to $3.28 \times 10^7 \text{ t}/\text{a}$ standard coal in China. Tianjin, located at the east of Beijing, is one of the earliest cities exploiting and utilizing geothermal resources. The first neogene system geothermal well which was drilled by French in 1930's is as beginning symbol, the geothermal development come into large-scale stage, and there are more than 300 geothermal wells in 2008. The geothermal resources are widely used in national economy and people's life, such as space heating, industry production, greenhouse, fish farming, bathing and health spa etc, and acquire remarkable economical and environmental benefit. According to preliminary statistics, the geothermal heating area reaches 12 Mm^2 in 2007, which is about 14% of the total heating area in Tianjin, and is about 75% of the total geothermal heating area in China. The geothermal fluid is used for resident living water about 300 thousand families, 100 hotels, 2000 thousand people bathing per month, swimming pool construction area of 20 thousand cubic meters, medical therapy and recreational projects nearly 70 thousand people per month, geothermal mineral water of $4 \times 10^4 \text{ m}^3$ and so on. Tianjin has become a real "Geothermal City", and the utilization of geothermal resources is number one in the world.

2. EXPLOITABLE RESERVES OF GEOTHERMAL RESOURCES

The geothermal fields are typical sedimentary basin medium-low temperature system in Tianjin. According to

the temperature gradient more than $3.5^\circ/\text{100m}$, ten geothermal anomalies are delineated in an area of 8700 square kilometers to the south of the Baodi—Ninghe Fault. There are two kinds of geothermal reservoirs which named neogene system porous reservoir and bedrock karst fractured reservoir. The exploitable reserves of geothermal resources is very rich. Neogene system porous reservoir is $3983 \times 10^4 \text{ m}^3/\text{a}$, and Bedrock karst fractured reservoir is $2014 \times 10^4 \text{ m}^3/\text{a}$ (Table 1).

3. PRESENT STATUS OF GEOTHERMAL RESOURCES EXPLOITATION

The main exploited geothermal reservoirs are Nm, Ng, Jxw in Tianjin. There have been 314 geothermal wells in Tianjin by the end of 2007, that includes 278 production wells and the production is $2584 \times 10^4 \text{ m}^3/\text{a}$, 36 reinjection wells and the reinjection is $409 \times 10^4 \text{ m}^3/\text{a}$, account for 15.8% of the total production. The wells of Nm and Jxw formation are distributed in the urban and suburban districts. The wells of Ng formation are distributed in the coastal area and northwestward (Table 2 and Figure 1).

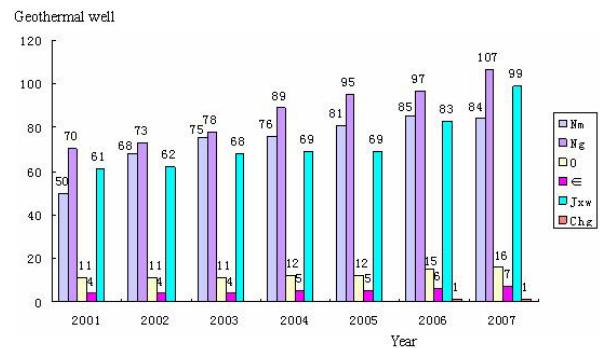


Figure 1: Wells in different geothermal reservoirs

The geothermal wells and the production are increasing with years, but the reinjection rate is still low. The reinjection wells are account for 11.5% of the total wells (Figure 2). New techniques for sustainable utilization were applied in 2007, the production was decreased than before, while the reinjection was increased. But the total reinjection rate is still low (Figure 3).

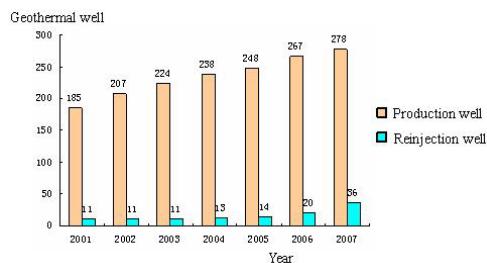


Figure 2. Production well and reinjection well in Tianjin

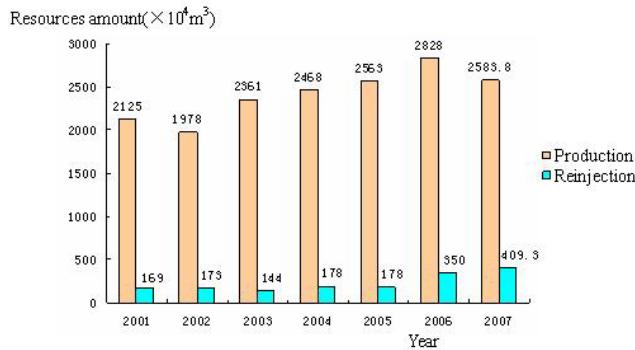


Figure 3: Production and reinjection in Tianjin

4. HISTORY OF GEOTHERMAL REINJECTION IN TIANJIN

Study of geothermal reinjection started in the 1970s, and choosed the Neogene Nm formation geothermal sandstone reservoir for reinjection testing in Dagang District in 1987. After that, every geothermal field carries out reinjection testing in different reservoir (Table 3). In last ten years, the accumulative total reinjection has been reached $2000 \times 10^4 \text{ m}^3$. The depth of reinjection well have been reached 3500m.

In recent years, geothermal reinjection has aroused great attention and reinjection rate has gone up year after year. Because geothermal reinjection can maintain the reservoir press, realize the sustainable utilization of geothermal resources and energy-saving and ejection-decreasing. Reinjection wells are main in Jxw, O and Ng formation (Table 4). The reinjection effect in bedrock karst fractured reservoir is notable, but it is so difficult in neogene system porous reservoir.

5. EXPLORATION OF GEOTHERMAL RESOURCES IN TIANJIN

Geothermal resources exploration has been carried on for 30 years in Tianjin, and has finished the survey of seven geothermal fields. Tianjin was ranked first in China with respect to the geothermal direct utilization. The geothermal resources exploration, development and management is being strengthened progressively. The utilization of geothermal resources not only makes good economical, social and environmental benefit, but also attracts investments. In order to exploite and utilize geothermal resources scientifically, geothermal director and planning departments strengthen management intensity and overall planning, establish and perfect business normalization system. Scientific research technology department also strengthen the study of the basic geology and the utilization technology. The utilization of geothermal resources is

facing on the direction of sustainable development in Tianjin.

5.1 Legal Management and Ensuring the Positive Development

In order to standard geothermal exploration and utilization, Tianjin has established a series of laws and regulations. For example, "Tianjin Mineral Resource Management Regulations", "Tianjin geothermal resources administrative provisions", "Tianjin Geothermal Reinjection Operation Regulations" and so on.

5.2 Improving the Level of Geothermal Resources Exploitation and Utilization

Long-time geothermal exploitation will bring a series of problems. For example, groundwater level drop seriously in concentration exploitation area, the temperature of geothermal tail water is very high, the reinjection rate of geothermal resources is very low. It will bring thermal pollution and other environmental geology problems.

In recent years, Tianjin improves the level of exploitation and utilization geothermal resources depend on scientific and technological progress. The exploration was carried on in Zhouliangzhuang, Panzhuang, Wanjiamatou, Jinhai and other geothermal fields. At the same time, Tianjin begins to study on geothermal reservoir model, geothermal reservoir engineering, resource optimization exploitation, exploitation and utilization dynamic monitoring, reinjection and so on.

5.3 Transforming Scientific Research Achievements and Serving for Economic and Society Development

Through standardizing exploitation, depending on scientific and technological progress, Tianjin is improving the utilization level and strengthening the consciousness of resource protection. Geothermal development is changed from extensive pattern to intensive pattern. There were 295 enterprises and institutions that have got exploitation right in 2007. The economic benefit of geothermal utilization exceeds 260 million yuan per year. Geothermal utilization reduces $80 \times 10^4 \text{ m}^3$ gas emissions and saves pollution abatement expenditures of 200 million yuan per year.

6. SOME SUGGESTS ON THE SUSTAINABLE DEVELOPMENT OF GEOTHERMAL RESOURCES

In order to realize sustainable development of geothermal resources, we need establish and perfect technology standard and economic policy. Geothermal development has a great innovation space. We need actively publicizing the advantage of geothermal utilization. At the same time, resources worrying and environmental protection awareness should be strengthened.

6.1 Legal Management and Strengthening Monitoring

For the sustainable development of geothermal resources, we need improve administration function and approval procedure of geothermal well, manage geothermal resources according to geothermal exploration criterion, establish the rewards and punishment policy of geothermal reinjection to achieve "protect in the development, develop in the protection". We also need improve the geothermal management regulations and simplify the examination procedures. According to geothermal planning, Tianjin sets up the prohibition exploitation area and limitation exploitation area, builds dynamic monitoring system and increases punishment intensity.

6.2 Establishing the System of Technology Innovation and Achievement Transformation on Energy-Saving and Ejection-Decreasing

Sustainable development of geothermal resources must depend on advanced technology, develop international co-operation and technological exchange, make a positive exploration of new technology, solve the problems of resource development. For early-exploited geothermal fields, we recombine geothermal wells and make up of new exploitation-reinjection systems. Through popularizing new technology, the geothermal utilization ratio is improved. For new geothermal fields, we should carry out the

reasonable planning, controll the exploitation and reduce discharge temperature, improve the reinjection rate.

6.3 Perfecting the Economic System

The government department should provide the economical support for geothermal exploration and development. Much more money should be devoted in geothermal resources protection projects, the construction of comprehensive utilization demonstration project, evaluation of resource potentiality, dynamic monitoring and reinjection study. Perfect the mineral resources compensable system and encourage recharge and exploitation.

Table 1: Authorized exploitable reserves of geothermal fields ($\times 10^4 \text{m}^3/\text{a}$)

Geothermal field Reservoir		Wanglan zhuang	Shanling zi	Coast	Wuqing	Wanjia matou	Panzhuang lutai	Ninghe hangu	Total
Neogene system porous reservoir	Exploitable reserves	1521	601	1044	118	73	310	316	3983
	Reserve degree	B	C	B+C	C+D	C+D	C+D	C+D	-
	Nm	988.65	390.65	678.6	76.7	73	310	316	2833.6
	Ng	532.35	210.35	365.4	41.3	-	-	-	1149.4
Bedrock karst fractured reservoir	Exploitable reserves	626	1178	-	-	210.0	-	-	2014
	Reserve degree	B	C+D	-	-	-	-	-	-
	O	181.54	341.62	-	-	-	-	-	523.16
	ϵ	6.26	11.78	-	-	-	-	-	18.04
	Jxw	438.2	824.6	-	-	210.0	-	-	1472.8
Total						5997.0			

Table 2: Geothermal wells and production or reinjection in Tianjin in 2007

Reservoir	Production well	Reinjection well	Production ($\times 10^4 \text{m}^3$)	Reinjection ($\times 10^4 \text{m}^3$)	Reinjection rate (%)
Nm	82	2	401.2	11.0	2.7
Ng	101	6	764.4	1.7	0.2
O	12	4	72.5	107.2	147.9
ϵ	5	2	35.5	0	0
Jxw	77	22	1285.2	289.4	22.5
Chg	1	0	25.0	0	0
Total	278	36	2583.8	409.3	15.8

Table 3: Study of geothermal reinjection in Tianjin

Time	Area	Reservoir	Depth	Work content and method	Achievements
1982-1986	Urban	Nm	800	exploratory development	
1987-1990	Dagang	Nm	500 ~ 700	reinjection test numerical simulation	《Study of reinjection and numerical simulation in medium-low temperature geothermal fields》
1992-1998	Tanggu	Ng	1700 ~ 2000	reinjection test numerical simulation	《Study of geothermal fluid reinjection in Tanggu district in Tianjin》

1996-now	Urban	O Jxw	2000 ~ 3500	reinjection test tracer test numerical simulation	《Study of reinjection in bedrock karst fractured reservoir in Tianjin》 《Study of geothermal reservoir engineering in Tianjin》 《Engineering construction and newtechnology application in geothermal reinjection system》 《Operational manipulation regulations of geothermal reinjection in Tianjin》 (Trial Implementation)
2003-now	Wuqing Dongli	Ng	1360 ~ 2350	Reinjection test	《Study of reinjection in neogene system porous reservoir of medium-low temperature geothermal fields in Tianjin》

Table 4: Production and reinjection ($\times 10^4 \text{m}^3$)

Reservoir	Production Reinjection	2001	2002	2003	2004	2005	2006	2007
Nm	Production	393.1	489.4	611.6	719.7	768.9	524.2	401.2
	Reinjection	0	0	0	0	0	0	11.0
	Reinjection rate	0	0	0	0	0	0	2.7%
Ng	Production	703	647.4	748.4	695.4	722.4	759.8	764.4
	Reinjection	0	0	0	2.2	8.6	12.8	1.7
	Reinjection rate	0	0	0	0.3%	1.2%	1.7%	0.2%
O	Production	83.6	77.1	89.8	95.2	107.9	89.3	72.5
	Reinjection	50.4	48.9	48.0	59.0	59.0	109.4	107.2
	Reinjection rate	60.3%	63.4%	53.5%	62.0%	54.7%	122.5%	147.9%
€	Production	55.9	48.4	41	70.6	72.4	71.5	35.5
	Reinjection	0	0	0	0	0	0	0
	Reinjection rate	0	0	0	0	0	0	0
Jxw	Production	886.4	1200	1200	887	891.9	1361.3	1285.2
	Reinjection	118.4	124.0	96	118.6	118.6	227.5	289.4
	Reinjection rate	13.4%	10.3%	8%	13.4%	13.3%	16.7%	22.5%
Total reinjection rate		8.0%	8.8%	6.1%	7.2%	7.0%	12.4%	15.8%

7. CONCLUSION

Development of renewable clean energy is a energy policy in China. A lot of cities in China have began to think more about geothermal development and utilization. Geothermal development is facing a good opportunity. We believe that geothermal development can make contribution to improve the people's residential level.

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