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The application of geothermal energy in agricultural projects——taking a flower project in Shanghe County, Shandong Province as an example

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ABSTRACT

The project is located in Shanghe County in the middle of Huimin Sag. It is an important modern agricultural base in Shandong Province. The abundant geothermal energy underground can be used as an important heat source for agricultural production. In order to analyze the economic and social benefits of geothermal development in flower planting projects, taking a local greenhouse planting project of 160,000 square meters as an example, the investment and construction costs and operating economic benefits were compared with traditional greenhouse planting projects. The results show that 8,900 tons of standard coal can be replaced each year, and the output value of the project will increase by RMB 4.2 million. Geothermal development has good economic benefits in the application of flower planting projects, and has great promotion value.

0. INTRODUCTION

The geothermal resources are the clean and valuable compound mineral resources integrating heat, mine and water, which are suitable for the out-of-season and allopatric cultivation and planting of creatures. In Iceland, the geothermal energy has been developed to supply heating and plant vegetables, and in Japan, Hungary, Italy, New Zealand and other countries, the geothermal energy has also been applied to agricultural cultivation (Shi Deming, 1981). In recent years, the geothermal energy has been applied in the agricultural field to varying degrees in more than 20 provinces and cities in China. The geothermal energy can be used for greenhouse heating, the geothermal water can be used for the cultivation of aquatic creatures in temperate zones, and the minerals in the geothermal water can also provide creatures with required nutrients. In the Northern China, the geothermal energy is mainly applied to plant high-grade melons and fruits, vegetables, edible fungus and flowers and plants, etc. And in the South, it is mainly used for sprout cultivation (Zhou Borui, 2022). Shanghe County in Shandong Province is located in the northwest of Shandong Province, and the Huimin Sag in the geothermal area of northern Shandong. With the shallow buried depth and mass storage of geothermal resources and high water temperature, it is a good region with rich heating sources. To scientifically develop geothermal resources and jointly build Shanghe as a "tourist city and livable city with graceful surrounding" and "hot spring capital", with the substantial support and guidance of Shanghe County Government, in accordance with the relevant regulations of the state, Shandong Province and the regulations on the management and development of renewable energy sources, clean energy and geothermal resources, by virtue of the high-quality geothermal resources in Shanghe County, the flower breeding industry has been jointly developed, and remarkable economic and social benefits have been achieved. This Project was in line with the development of geothermal energy, an important measure taken by Shandong Province to deepen the development of the conversion between the old and the new kinetic energy, and promote the transformation of green and low carbon, which has a good referential significance.

1. BACKGROUND OF RESOURCES

Shanghe County belongs to Jiyang Depression and Huimin Sag of Bohai Bay Basin on North China Plate in geological structure (Gao Yang, 2022). Huimin Sag, located in the west of Jiyang Depression of Bohai Bay Basin, is the largest secondary building unit in Jiyang Depression. North and south are bounded by Luxi Uplift and Chengning Uplift respectively, and east and west are adjacent to Dongying Sag and Shen County Sag respectively. The Huimin Sag is NE-trending, with a length from the east to the west of 130km, and width from north to south of 30-70km.

This area is located in the southeast of Zi Town Depression in Huimin Sag. The geothermal reservoir is located in Guantao Formation. Its lithology is mainly brown yellow mudstone and sandy mudstone with flagstone. A set of igneous rocks and pebbly sandstone are developed at the bottom, with the sand thickness ratio of 38%-61%, and ground temperature of 54-57℃. In this project, a total of four geothermal wells were drilled. The model of two-well irrigation group was adopted. And heat was taken without taking water. The Flower Well 1 is a production well, with wellhead water temperature of 56℃ and water yield of 114.42m3/h; The Well 2 for Flowers and Plants is a recharge well, with wellhead water temperature of 56℃ and water yield of 108m3/h; The Well 5 for Flowers and Plants is a production well, with wellhead water temperature of 56℃ and water yield of 102m3/h; The Well 7 for Flowers and Plants is a recharge well, with wellhead water temperature of 56℃ and water yield of 108m3/h;

2. APPLICATION EXAMPLES

The Geothermal Heating Project for Flowers in Hot Spring was carried out in the south of Xinxing Street, north of National Highway 340, west of Cuiba Road and east of Shangzhong River, Shanghe County. With the advantage of geothermal hot spring in Shanghe County, efforts have been made to create a high-quality brand of flower hot springs in Shandong Province. The planned heating area of the project totaled 16×104m2, and the ground coil pipes were used at the end together with the air-conditioning units. The project has been put into operation (Figure 1).

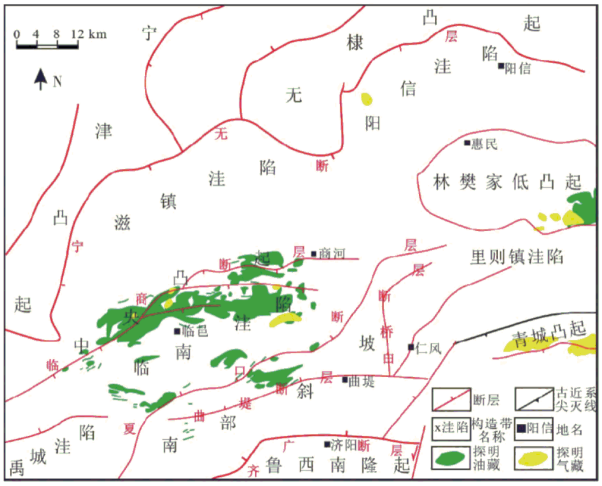

Figure 1 Huimin Depression Tectonic Map

2.1 Management model of project

In this project, BOO operating mode was adopted, and the mode of "autonomous investment, autonomous operation and self-financing" was adopted by the enterprise to provide geothermal heating service for flowers in Shanghe.

The project construction included the construction of heat source system, distribution system and gas peak-shaving system. Enterprises invest in geothermal heating projects, and they partially compensate for the investment in centralized heating through the collection of supporting infrastructure costs, and then they recoup the capital outlay year by year through the collection of heating fees, thus maintaining the heating operation and obtaining profits. With this operating mode, enterprises attach more importance to long-term economic benefits, especially to the engineering quality and heating services, thus ensuring the long-term heating of flower enterprises. However, in the early stage of the project, the geothermal enterprise were under great pressure on capital, and it was difficult for them to develop rapidly. As the prices enjoyed by flower enterprises are more favorable than those for gas and electric heating, they have not been given an increase in the payment burden and thus have a high acceptance level of geothermal heating.

2.2 Technical route and technological process

For the development of geothermal heating projects, the exploration of geothermal resources should be carried out first to verify the distribution law of regional resources, and then to drill geothermal wells after finding out the resources, finally, the geothermal water should be pumped. After the geothermal water (56℃) is converted to 42℃ by the plate heat exchanger, it is utilized to 25℃ by the heat pump, and then is recharged to the underground after filtration. During this process, the heat is transferred to the heating system, and the circulating water of the heating system pumps the heat of the geothermal water through the plate heat exchanger and the heat pump, and then supplies the heat to the heating users. The return water temperature of the heating circulating water is 50/40℃.

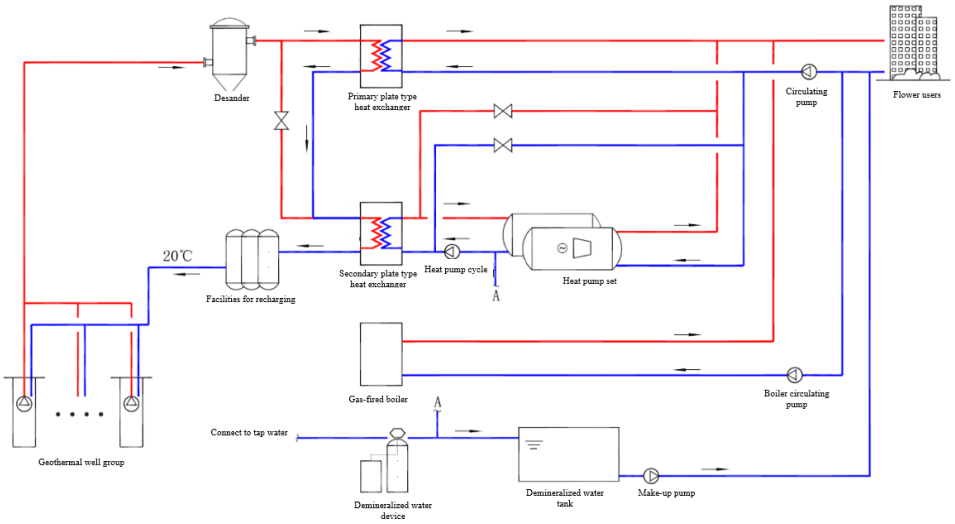

Figure 2 Standard Flow Chart of Agricultural Flowers

2.3 Load calculation

The south elevation of flower greenhouse is covered with 8mm double-layer solar panels, while the other elevations are covered with 5mm tempered coated glass, with partial 360mm brick walls. The heat load index in winter is relatively large. The heat load of greenhouse 1 was calculated.

Table 1 Thermal Load of Exterior-protected Structure

Room number	Room name	Exterior-protected structure		Heat transfer coefficient	Indoor calculation temperature	Outdoor calculation temperature	Indoor and outdoor calculated temperature difference	Temperature difference correction factor	Basic heat loss	Correction of basic heat loss				Heat consumption of exterior-protected structure	Space heating load
		Name and direction	Area	k	tn	to	△t	a	Q	Correction factor for orientation	Additional factor for wind force	Corrected value	Corrected heat	Height addition	
			m^2	W/(m^2·℃)	℃	℃	℃		kW	βch	βf		kW	βg	kW	kW
101	No.1 Greenhouse	North elevation	1230	3	18	-5.3	23.3	1	85.977	5		1.05	90.28	0	90.3	312
		West elevation	90	2.7	18	-5.3	23.3	1	5.6619	-5		0.95	5.38	0	5.4	
		East elevation	90	2.7	18	-5.3	23.3	1	5.6619	-5		0.95	5.38	0	5.4	
		South elevation	1230	4.1	18	-5.3	23.3	1	117.5	-15		0.85	99.88	0	99.9	
		Outer door	10.8	6.4	18	-5.3	23.3	1	1.6105	0		1	1.61	0	1.6	
		Roof	3075	1	18	-5.3	23.3	1	71.648	0		1	71.65	0	71.7	
		Ground	3075	0.53	18	-5.3	23.3	1	37.973	0		1	37.97	0	38	
														Total heat load		312

Table 2 Infiltration Heat Loss

Room number	Room name	Exterior-protected structure				Ventilation rate	Specific heat at constant pressure	Air density	Outdoor calculation temperature	Indoor and outdoor calculated temperature difference	Temperature difference correction factor	Infiltration heat loss
		Depth	Width	Hight	Volume (V)	K	Cp	ρ	tn	to	△t	Q
		m	m	m	m^3	Times / h	KJ/kg·℃	kg/m^3	℃	℃	℃	kW
101	No.1 Greenhouse	205	15	6	18450	0.5	1	1.34	-5.3	18	23.3	80.65

Table 3 Summary Sheet of Greenhouse Heat Load

Room number	Room name	Heat transfer and consumption of exterior-protected structure	Infiltration heat loss	Intrusion heat loss	Total space heating load	Correction coefficient	Corrected load	Heating index
		Q1	Q2	Q3	Q	a	Q'	
		kW	kW	kW	kW	Coefficient	kW	W/m^2
101	No.1 Greenhouse	312	81	1	394	1.05	414	134.6

According to the above calculation, the designed heating load index of greenhouse is 134.6W/m2.

3. COMPARISON AND SELECTION OF PROJECT INVESTMENT AND OPERATION

For flower breeding, in winter, the temperature control in the greenhouse is of great importance. Too high or too low temperature will cause damage to high valued ornamental flowers, thus affecting their prices. Generally, the hot-blast furnaces, heating furnaces and other equipment are used in traditional flower greenhouse projects, and the fire coal and straw are used as fuel. In this way, the energy supply and consumption is high, causing great pollution to the environment, and a special person needs to be on duty to avoid fire. With the advance of the "carbon peaking and carbon neutrality, China has made great efforts to reduce the fossil energy

consumption in energy-intensive industries. Small coal-fired boilers have all been banned. A batch of clean energy sources such as geothermal energy and air energy have been used to supplement large-scale flower cultivation, medicinal material drying and other agricultural fields. In the following, the economic analysis is carried out on the gas-fired boiler scheme, geothermal scheme and air source scheme which are more applied in flower projects.

For the geothermal scheme, heat pump, plate heat exchanger, circulating pump, geothermal well and pipe network system are included; for gas boiler scheme, boiler body, burner, circulating pump, plate heat exchanger, booster station and burning line are included; and for air source scheme, air source heat pump, circulating pump and pipe network system are included. See Table 4 for the investment costs of the three schemes.

Table 4 Comparison of Investment Costs of Multiple Schemes

Investment project	Geothermal scheme		Gas-fired boiler scheme		Air source scheme	
	Investment amount (RMB ten thousand)	Remark	Investment amount (RMB ten thousand)	Remark	Investment amount (RMB ten thousand)	Remark
Heat pump set	600	/	0	/	1800	130 model
Heating circulating pump	90	Two for service and one for standby	89	Two for service and one for standby	50	Multiple step format
Geothermal well	1440	One heating, one recharging, balanced heating and recharging	0	/	0	/
Water treatment device	70	Recharged filter and demineralized water device	10	Demineralized water device	0	/
Pressurization installation	10	Make-up water tank + make-up water pump	10	Make-up water tank + make-up water pump	10	Distributed water replenishment
Water distributor	1.2	Station collection, 4	1.2	Station collection, 4	0	Distributed type
Gas boiler system	40	Boiler peak-shaving	700	Basic heat source	0	/
Booster station	0	/	60	Gas supercharging	0	/
Pipeline	200	Geothermal water pipeline	40	Gas pipeline	0	/
Power distribution	350	Transformer and distribution	40	/	450	Transformer and distribution
Heat exchange station	200	Steel-structure station building	40	Steel concrete station building	0	Distributed type
Total	3001.2		990.2		2310	

The actual operation time of the project is 6 months, the electricity price is the general industrial and commercial electricity price, and the natural gas price is RMB 3.4-5.2 yuan/m³.

Table 5 Distribution of Project Operating Cost per Unit Area

Operating projects	Geothermal scheme		Gas-fired boiler scheme		Air source scheme	
	Operating cost (RMB10,000)	Remark	Operating cost (RMB10,000)	Remark	Operating cost (RMB10,000)	Remark

Project area	160,000 ㎡					
Total expenses	180.8	Electric charge, water charge	433.6	352 RMB 22 yuan/ ㎡	Electricity charges	
Operating cost per unit area	RMB 11.3 yuan /㎡		RMB 27.1 yuan /㎡			

4. APPLICATION ADVANTAGES OF GEOTHERMAL IN AGRICULTURAL PROJECTS

4.1 Good endowment of geothermal resources

First, the temperature of geothermal resources is high, with large water yield. The water temperature in Flower Well 1 drilled in a typical project is 56℃, with the water yield of 114 cubic meters per hour. The heating capacity of a single well can reach 80,000 square meters. Second, there are many geothermal reservoir layers with large thickness. In this project, the average water intake section of the well is 1297-1525 meters, and the thickness of available geothermal reservoir is over 160 meters.

4.2 "Taking heat without consuming water" for the sustainable development of geothermal resources

In the project, advanced technologies such as sandstone recharge, gradient utilization, directional drilling and indirect heat exchange were adopted. After 10 years of continuous research, Sinopec has made significant progress in sandstone recharge technology. After the geothermal water is extracted, the geothermal tail water is not discharged after the heat is used up, but is recharged into the original geothermal reservoir with the sandstone recharge technology. The technical process of "taking heat without consuming water" has been used for geothermal development, which ensures the sustainable development of geothermal resources. The gradient utilization technology is applied to extract low-temperature heat energy from geothermal tail water, so as to reduce the temperature of tail water, and then it is recharged into the original reservoir, thus further improving the utilization efficiency of geothermal resources.

4.3 Good economic benefits have been achieved

Since 2019, in the Flower "Geothermal Energy+" Clean Energy Heating Project, with the continuous increase of area for flower cultivation, the investment scale of geothermal clean heating is also increasing. According to the requirements of the "14th Five-Year" Clean Energy Plan of Shandong Province and the overall plan for flower cultivation of Shanghe County, the Flower Geothermal Project in Shanghe will be expanded to 1 million square meters with an investment of about RMB 80 million in the future. The project has been put into operation for three years since its completion, and has achieved good benefits. The operating cost is about 60% less than that of gas system with the same heating capacity, and good economic benefits have been achieved.

4.4 Saving energy and reducing emissions, and good social benefits have been achieved

After the completion of the project, through the comprehensive utilization of clean energy, the effect of energy saving and emission reduction in the project is good. After its completion, compared with the coal-fired centralized heating project, it can save 8,900 t of standard coal, reduce carbon dioxide emission by 21,700 t and sulfur dioxide emission by 302t per year. The effect of energy conservation and emission reduction is obvious, making greater contributions to the realization of the carbon peaking and carbon neutrality goals in China.

5. CONCLUSION

The Geothermal Heating Project for Flowers in Hot Spring is not only a breakthrough in geothermal development and utilization in addition to heating for residential and public buildings, but also a key demonstration project for promoting cleanliness in Shanghe County. The successful implementation of this Project not only brings good economic benefits to enterprises, but also establishes an example of energy conservation and emission reduction. In addition, it is also a major measure for development of geothermal energy, which has laid a foundation for the follow-up promotion of the conversion between the new and old kinetic energy. After the success of the Project, the leaders at all levels of the County Party Committee and County Government highly recognized that creating the image of Shanghe with geothermal hot spring cultivation can not only scientifically and effectively develop and utilize the rich geothermal resources in Shanghe County, but also successfully attract many enterprises to invest, and also make outstanding contribution to the ecological civilization construction of Shanghe, which is worth being vigorously promoted.

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