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The Role of "Xiongxian Model" in China's Large-scale Development of Geothermal Energy

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ABSTRACT

The "Xiongxian Model", jointly developed by Sinopec Star and Xiongxian government of Xiong'an New Area, takes "government-enterprise cooperation, market-based operation, unified development, advanced technology, environment protection and people's benefit" as its core, and has effectively solved the problem that large-scale geothermal development is restricted by multiple factors including resource capacity, policies, development mode, economic feasibility, etc. Taking "Xiongxian Model" as a showcase, Sinopec Star has actively boosted large-scale development of geothermal energy and became the largest geothermal heating enterprise in China, with a geothermal heating capacity of over 80 million sqm. It is capable of replacing 1.85 million tons of standard coal, reducing 3.52 million tons of carbon dioxide emission and offering clean heating for millions of residents annually, which has exhibited significant economic, social and environmental benefits. After the establishment of Xiong'an New Area in China, Sinopec Star has timely upgraded "Xiongxian Model", and further improved the level of geothermal development and core technologies with "geothermal + clean energy integration", which has led the large-scale development of middle and deep layer geothermal energy in China.

1. INTRODUCTION

Documents have indicated that total amount of thermal energy within the earth is about 1.7 times that of the coal around the world, and the geothermal energy which can be utilized with existing technologies is 30 times larger than that of the fossil fuels.

Geothermal is a green, low-carbon and recyclable renewable energy featuring abundant reserves, widespread distribution, cleanness, environmental protection, stability and reliability. Compared with other forms of clean energy such as solar, wind and tide, geothermal is free from natural restrictions such as season, weather, climate or celestial gravitation, and enjoys a high average energy utilization coefficient. It is more economical to provide heating through large-scale geothermal development, whose tariff is 10% of the oil & gas-fired boiler heating and 20% of the coal-fired boiler heating. Some energy experts have pointed out that by the year of 2100, the geothermal energy will account for 30% - 80% of the global energy consumption.

As for China, there exist multiple factors restricting the large-scale development of geothermal energy. From government side, resource capacity, national policies, environmental problems and public awareness have hindered the development scale of geothermal energy; from the side of enterprises, large-scale geothermal development not only requires heavy investment and high technology, but also faces long payback period, slow economic returns and high pressure of environmental protection. Besides, large-scale geothermal development & utilization must obtain the support from local governments and users, the industry has high entry barriers, and the volatile policies have posed challenges to the sustainability of geothermal enterprises, all of which must be taken into consideration by the enterprises when making business planning; from the perspective of users, despite the irreplaceable role of geothermal in pollution treatment and air quality improvement, the public still has little understanding of its benefits. Moreover, since there is little difference in personal experiences with respect to geothermal district heating and municipal coal-fired or gas-fired heating, users usually have no preference for geothermal enterprises.

In the year of 2009, Sinopec Star started to develop geothermal energy in Xongxian of Hebei province and provided heating for local residents. It set up a "Xiongxian Model" featuring "government-enterprise cooperation, market-based operation, unified development, environment protection and people's benefit", which has effectively solved the problems in resources, policies, markets and corporate sustainability during large-scale development of geothermal energy. Therefore, the model has won the favor of local residents. For over 10 years, Sinopec Star, taking "Xiongxian Model" as a showcase, has established a heating capacity of over 80 million sqm, provided heating for over millions of residents, and developed over 10 geothermal heating "zero-emission cities" including Xiongxian, Rongcheng, Bazhou, Boye, Qinghe, Gucheng, Xinji, Wugong, Daming and Shanxi Economic and Development Zone, which is capable of replacing 1.85 million tons of standard coal and reducing 3.52 million tons of CO_2 emission annually, an equivalent of planting 1.96 million trees. As of now, its geothermal business footprints have covered over 50 cities, and achieved notable social and economic benefits.

In Xiongxian Hujiatai village of Xiong'an New Area, local residents used to spend RMB 3k to 4k on coal-fired heating each winter. After coal-fired heating was replaced with geothermal, it only cost RMB 2k to heat a house of

130 sqm each year. It saved both cost and worry of the residents, the indoor temperature is more moderate, and, more importantly, the house has become cleaner. In this village, geothermal heating is well welcomed by local residents.

Not only are residents benefited, but also the governments. For coal boiler heating, the government faces severe pressure of air pollution treatment and CO_2 emission reduction; for gas boiler heating, the government has to settle many issues such as coordinating gas supply quota during the winter, and there used to be the case of "gas shortage" which affected residential heating. In contrast, with geothermal heating jointly enabled by governments' policies and enterprises' investment, a sound and effective geothermal utilization can be achieved and the problems hindering residential heating can be solved once and for all.

Led by "Xiongxian Model", Sinopec Star has become China's largest enterprise in middle and deep layer geothermal heating, developed world-level technologies, realized the objective of becoming a geothermal enterprise that is "world-renowned and best in China", and served as a showcase in terms of large-scale geothermal development in China.

2. THE "XIONGXIAN MODEL" THAT HAS FACILITATED LARGE-SCALE GEOTHERMAL DEVELOPMENT

Resources are the fundaments of large-scale geothermal utilization and "Xiongxian Model". Located at Niutuo geothermal field, Xiongxian is blessed with abundant geothermal resources, which account for 50% of the area's resource capacity. It is home to 82.18 billion cbm geothermal fluids, equaling 6.63 billion tons of standard coal, and boasts the best area in North China in terms of geothermal resources conditions.

Since the 1970s, residents of Xiongxian started to develop geothermal resources for heating. However, due to lack of unified planning and effective management, the geothermal resources were developed in a primitive manner by some individuals or real-estate developers who directly extracted geothermal fluids and discharges them onto the ground, which caused serious waste of resources. 30 years of disordered exploitation led to groundwater drawdown in the extraction layer, and the geothermal fluid discharged onto the ground had polluted soils and shallow layer groundwater, causing secondary pollution to the surface environment. The beautiful Hot Spring Lake, located at the downtown of Xiongxian, used to be a 20-meter-deep pit, where geothermal fluids were discharged, with "hot vapors in winter and disordered weed in summer". In August 2009, to solve such problem, the *Cooperation Agreement on Geothermal Development* was signed between Xiongxian government and Sinopec Star to consolidate the wells that directly extracted and discharged geothermal fluids, reinject geothermal fluids back into underground, and collaboratively boost the sustainable development and utilization of geothermal resources in Xiongxian. Since then, the geothermal development in Xiongxian has become sound and environmentally friendly, and the history of disordered geothermal development has completely ended.

"Xiongxian Model" has been replicable and promotable, and has greatly contributed to the development of geothermal industry in China. The model involves the following key actions. Firstly, the government shall issue encouraging polices and supporting measures, and formulate special planning for geothermal utilization and regulating measures for geothermal resources. Xiongxian government has successively released a series of regulations including *Planning for the Development and Utilization of Geothermal Resources in Xiongxian*, *Opinions on Enhancing the Administration of Geothermal Resources Development and Utilization* and *Regulating Measures for the Geothermal Resources in Xiongxian* to guide the sound and standardized development of geothermal resources. Secondly, government organizations shall be strengthened. Xiongxian government has set up a special group on geothermal development led by head of the county, as well as a geothermal administration office to unify the management of geothermal resources and settle the problems during geothermal utilization. Thirdly, Xiongxian government has granted geothermal franchise to the enterprise for comprehensive development, thus achieving a unified and sustainable utilization. Fourthly, following the principle of "unified planning, distributed execution, comprehensive utilization and sound development", the enterprise has achieved the integration of investment, construction, operation and management. The enterprise is responsible for mining right application, feasibility study, investment, construction, operation and maintenances. Government determines the heating tariff, while the enterprise charges the users by itself.

By applying "Xiongxian Model" to a larger scale, Sinopec Star has achieved a heating capacity of 5.6 million sqm in Xiongxian, which accounts for 95% of the county's district heating capacity, marking itself the first geothermal heating "zero-emission city" in China with truly clean and green geothermal development. For over a decade, Sinopec Star has obtained remarkable economic, social and environmental benefits in Xiongxian geothermal utilization. It has totally saved 797,700 tons of standard coal and reduced 2.114 tons of CO_2 and SO_2 emission, which has greatly contributed to the treatment of air pollution locally. The geothermal development in Xiongxian has provided job opportunities for hundreds of local residents and contributed nearly RMB 30 million taxes, which has significantly boosted local economic development. For heating cost only, over RMB 100 million have been saved for local residents.

"Xiongxian Model" was widely recognized by National Energy Administration, governments at various levels and all walks of life. On 27 February, 2014, the National Geothermal Development and Utilization & Geothermal Utilization Work Conference was held in Xiongxian of Hebei province. It was pointed out during the conference that the geothermal district heating realized in Xiongxian of Hebei province has met over 90% of the county's

heating demand, developed the first "zero-emission city" in North China, and provided invaluable experiences for national geothermal development and utilization." The conference recognized "Xiongxian Model" as replicable, and promoted it nationwide. "Xiongxian Model" has led the development of China's geothermal industry during the 12th Five-Year Plan, promoted the large-scale development of geothermal industry during the 13th Five-Year Plan, and will continue to lead the rapid development of the geothermal industry in China.

Led by "Xiongxian Model", Sinopec Star successively signed cooperation agreements on geothermal development and utilization with over 40 cities, counties and districts including Jinan Shanghe and Dezhou Laoling of Shandong provice, Xi'an of Shaanxi province, Baoding, Langfang, Hengshui and Xinji of Hebei province as well as Tianjin to jointly develop and utilize the geothermal resources and industrial waste heat. In Hebei province only, a geothermal heating capacity of over 32 million sqm has been established, making it the largest province in terms of middle and deep layer geothermal development and utilization in China; the heating area in Xiongxian has reached over 6.3 million sqm, exceeding that of Reykjavik, the capital of Iceland.

3. CORE TECHNOLOGIES PROVIDE STABLE AND LONG-TERM SUPPORT FOR "XIONGXIAN MODEL"

The establishment of a promotable and replicable "Xiongxian Model" relies not only on the cooperation between the government and enterprise, but also on core technologies for geothermal development and utilization. Without the underpinning of core technologies, it is difficult for "Xiongxian Model" to run in a stable and long-term manner.

The supervisory control and data acquisition system (SCADA System) is one of the 10 core technologies developed by Sinopec Star. At Sinopec Star's IDH Center located in Xiongxian of Xiong'an New Area, an electronic screen has been mounted on a whole piece of wall, and this is the place where the SCADA System is applied and demonstrated. This SCADA System has achieved 4 major targets of large-scale geothermal development. First, full collection of regional data. It can collect and monitor all key parameters of 120 geothermal wells and 60 heat centrals in Xiongxian, and is connected with all production & reinjection wells and heat centrals in regions of Hebei, Shaanxi, Shandong and Shanxi. Second, automatic alarming. Should there be problems such as blackout or pipeline leakage during operation, the system will automatically send out alarms. Third, the system can automatically adjust wellhead flowrate and temperature according to outdoor weather and temperature. Fourth, remote monitoring and unattended operation. SCADA System has contributed to the large-scale, intelligent and green development of geothermal energy.

For years, Sinopec Star has strengthened technological innovations, organized R&D staff to break new grounds, and formulated 10 major technologies including geothermal exploration, reservoir evaluation, geothermal drilling, geothermal cascading utilization, exhausted water reinjection, geothermal plus integration and SCADA System through independent R&D and introducing advanced Icelandic technology.

In Xincheng community of Xiongxian, 5 geothermal wells are used to produce high-temperature geothermal fluids whose thermal energy is extracted by heat exchangers to warm up the softened circulation water which will be transmitted to the residents for heating. The geothermal fluids, after heat exchange, will be reinjected back into underground through 3 reinjection wells. Through this geothermal reinjection technology that takes heat without consuming water, a green and clean heating has been truly achieved. At this community only, 7,958 tons of standard coals are saved and 19,895 tons of CO_2 emissions are reduced each heating season.

In geothermal exploration, Sinopec Star, through comprehensive utilization of geological exploration and geophysical approaches, has conducted area selection and zone selection of geothermal resources, identified different types geothermal reservoirs and corresponding formation mechanism, established the concept models for geothermal reservoirs in Xiongxian and Xianyang, and pinpointed the favorable exploration areas and zones in Central Shaanxi Basin, Southern North China Basin and Taiyuan Basin.

In geothermal drilling and well completion, Sinopec Star has formulated several technology systems applicable to different types of reservoirs, including optimized design of well structure, low-density fluid drilling, physical mud-logging of reservoirs, well logging and reservoir evaluations. It has improved high-temperature directional drilling, shaft cooling, drilling bit selection, air bubble drilling fluid and the well factory" mode of geothermal enterprises that displays its own features.

In cascading utilization, Sinopec Star has adopted the concept of "grades matching and cascading utilization" to fully utilize the extracted geothermal energy. In Wugong of Shaanxi province, different projects are series connected to fully utilize the heat of geothermal fluid; in Sanpu East District of Xianyang, Shaanxi province, after the 90°C geothermal fluids have been utilized for residential heating, the exhausted water is then re-utilized for bathing and balneology; in Shanghe of Shandong province, the geothermal energy has been utilized to heat the flowers in a 200k sqm greenhouse. As a result, multiple utilization of geothermal energy has been achieved.

4. UPGRADE "XIONGXIAN MODEL" WITH "GEOTHERMAL +"

"Xiongxian Model", explored by Sinopec Star, is a replicable and promotable approach and roadmap towards large-scale development and utilization of urban geothermal energy. Since the establishment of Xiong'an New Area on 1st April, 2017, under the backdrop of "national project of millennial significance" and building a "city of

intelligence" and "city of future" with " blue sky, fresh air and clean water", Sinopec Star has moved its largest subsidiary, which specializes in geothermal development and utilization, to Xiongan New Area from Xianyang of Shaanxi Province, and began to upgrade "Xiongxian Model" and provide clean energy for Xiong'an New Area development through "geothermal + clean energy integration".

On 7th July, 2020, the consortium, led by Sinopec Star, won the bid for the agent-construction, operation, management and service of heating (cooling) project in the Rongdong Area of Xiong'an New Area which covers an area of over 12 million sqm. This is Sinopec Star's first large agent-construction, operation, service and management project featuring "geothermal + clean energy integration" in Xiong'an New Area.

Agent-construction, operation, management and service of the project were achieved by the combination of "geothermal + clean energy integration", advanced green energy comprehensive utilization technology and intelligent energy management & control technology. The project has agent-constructed and operated 3 large central energy stations, 22 satellite stations and several geothermal wells, and provided heating for nearly 6 million sqm building areas during the 2021 – 2022 heating season.

Sinopec Star has been constantly upgrading"Xiongxian Model" to facilitate Xiong'an New Area's goal of "smart city" and "smary energy". Currently, Sinopec Star has developed 2 "zero-emission cities" in Xiong'an New Area, which are Xiongxian and Rongcheng with geothermal heating; in Shaxinzhuang and Daying town of Xiong'an New Area, the coal-fired heating was replaced with geothermal in 11 villages to develop geothermal heating "smoke-free villages". It has completed the first "heating & cooling" project characterized by deep-layer geothermal heating and shallow layer cooling in Rongcheng of Xiong'an New Area, and provided clean geothermal heating for Jinxiong High-speed Rail Administration. Sinopec Star not only cooperated with Xiongxian government in replacing existing heat source with air source heat pump in 31 communities, which is the first large-scale air source heat pump heating project in Xiong'an New Area, but also extended this cooperation to Anxin of Xiong'an New Area. It has businesses carried out in all 3 counties of Xiong'an New Area.

As of now, Sinopec Star has achieved a total geothermal heating area of 20 million sqm, including constructed, agent-operated and under-construction projects, in Xiong'an New Area, and provided clean heating for over 250k local residents. Despite the unprecedented covid-19 pandemic, Sinopec Star has never slowed its pace in replicating and promoting the "Xiongxian Model" and forged ahead in geothermal development. Through continuous market expansion, the incremental heating capacity in 2021 reached 12 million sqm, and the total heating capacity amounted to over 80 million sqm in over 50 cities, marking Sinopec Star's leadership in terms of domestic middle and deep layer geothermal heating areas. In 2021, the Xiongxian Geothermal Utilization Project was listed by IRENA as a global showcase, which has served as a model case in terms of large-scale global renewable energy development.

In recent years, with China's strategic target of Carbon Emission Peak and Carbon Neutrality, the advantages of geothermal are increasingly evident in promoting national energy restructuring and clean heating. The state, ministries, provincial and municipal governments have successively formulated encouraging policies to support geothermal development and the replacement of traditional heat sources with clean energy. Especially with the release of *Action Plan for Carbon Dioxide Peaking Before 2030*, geothermal enterprises are facing valuable development opportunities. We firmly believe that the "Xiongxian Model" will play a greater role not only in the domestic large-scale development of geothermal energy, but also in the promotion and application of renewable energy around the world.

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