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Practice of Geothermal Development and Utilization Cooperation Between Chinese and Icelandic Enterprises

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ABSTRACT

By coincidence and joint efforts, Sinopec Star, a Chinese company, and Arctic Green Energy, an Icelandic company, reached an agreement in terms of geothermal development in China and started international cooperation in 2006. After 16 years of development, the JV established by two parties has grown into a professional middle and deep layer geothermal development and utilization enterprise that is "world-renowned and best in China", promoted the development of geothermal industry in China, and contributed to the realization of "Dual Carbon" target. The paper has studied the development history of the JV as well as its achievements with respect to business model, geothermal development technology, carbon assets calculation approach of geothermal projects and "geothermal + clean energy integration". The JV has served as a showcase for international geothermal development and cooperation, and is of great value for promotion and replication.

Sustainable geothermal development delivers benefits broader than power generation. Geothermal projects shall always deliver benefits to communities, residents and the climate.

—— ***Reykjavik Declaration*** **in 2021 (excerpt)**

1. INTRODUCTION

During the 6th World Geothermal Congress held in Iceland in October, 2021, it was proposed that geothermal benefits broader than power generation shall be fully showcased to the world. Mr. Zheng Keyan, a Chinese geothermal expert and former director of IGA, suggested that during the 2023 World Geothermal Congress, China should fully showcase its highlights of direct geothermal utilization "broader than power generation". He proposed to list out the largest operator and equipment manufacturer in direct geothermal utilization, and showcase China's full strengthen in front of global geothermal community.

Apart from power generation, direct geothermal utilization also includes heating, bathing, balneology, farming, aquaculture and snow-melting. At present, the largest enterprise specializing in direct geothermal utilization for residential heating is Sinopec Green Energy Geothermal Development Co., Ltd (the JV) established by Sinopec Star from China and Arctic Green Energy from Iceland in 2006. It has established a heating area of 59 million in 13 cities, districts or counties of 5 provinces, and developed the first geothermal heating "zero-emission city" in Xiongxian, Hebei province, whose geothermal heating areas have surpassed Reykjavik, capital of Iceland, since 2017. The JV's geothermal operations are able to save 1.42 million tons of standard coal and reduce 2.655 million tons of carbon emission annually, which is equivalent to planting 1.49 million trees. Such benefits have made notable contribution to winter heating, energy conservation, carbon emission reduction, and climate change mitigation locally.

The Sino-Icelandic geothermal cooperation has greatly boosted the development of geothermal industry during China's 12th, 13th and even the 14th Five-Year Plan periods. Moreover, the JV, established on the basis of friendly Sino-Icelandic ties, has now become the "cornerstone" of the two states' relationship.

2. SINO-ICELANDIC GEOTHERMAL COOPERATION IS MORE INEVITABLE THAN COINCIDENTAL

The JV is a showcase for countries around the world to cooperate in geothermal development.

China and Iceland has a long history of mutual exchanges, which can date back to the 17th century. In 1971, the two states officially established diplomatic ties, set up respective embassy in the other country, and started cooperation on the basis of mutual benefits. The JV is the largest geothermal enterprise that Iceland has invested not only in China, but also around the world. Iceland is the first European country to acknowledge China's market economy status, and the first European country to sign Free Trade Agreement with China.

2.1 The two states' friendly ties have served as a foundation

During the visit to Iceland in 2002, H.E. Jiang Zemin, former Chinese President, recognized Sino-Icelandic cooperation in the fields of fishery, geothermal and ship building to be fruitful. During the visit to China, H.E. Olafur Grimsson, former Icelandic President, spoke highly of the Sino-Icelandic geothermal cooperation and

emphasized that the JV shall be developed into a showcase for geothermal development and utilization in China and even around the world. During his attendance in the World Economic Forum in 2010, H.E. Olafur Grimsson met with H.E. Xi Jinping, then Chinese Vice President, and expressed his willingness to share geothermal technologies with China and play an important role in China's geothermal development strategy. In 2012, H.E. Wen Jiabao, former Chinese Premier, paid a visit to Iceland and further promoted the geothermal cooperation between two states. Under his witness, the *Framework Agreement on Expanding Geothermal Resources Development Scale, Business and Cooperation* was signed between Sinopec Group and Orka Energy.

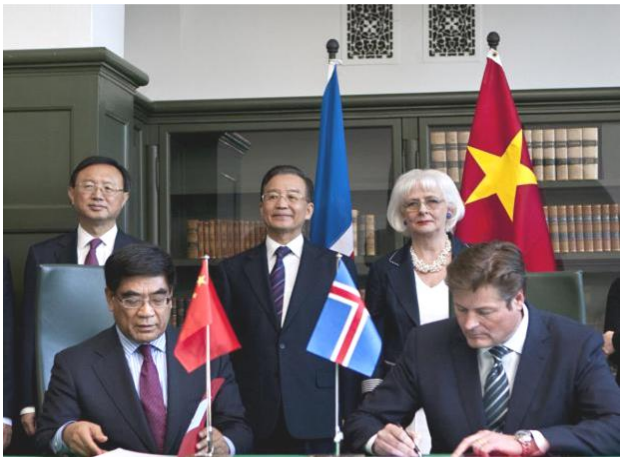

Figure 1: On 20th April, 2012, H.E. Wen Jiabao and H.E. Johanna Sigurdardottir witnessed the signing of *Framework Agreement on Expanding Geothermal Resources Development Scale, Business and Cooperation*

In 2013, the first foreign delegation that H.E. Li Keqiang, former Chinese Premier, received after taking office was from Iceland, at which time the Premier and Prime Minister of the two states witnessed the signing of the Free Trade Agreement. Such visits between the two states' heads at the beginning of this century not only advanced the friendly relationship between the two states, but also facilitated the course of Sino-Icelandic cooperation in geothermal development. As H.E. Olafur Grimsson once put it, "the Sino-Icelandic relationship is a showcase for countries, big or small, to have international cooperation in the 21st century".

2.2 Both states have demand for geothermal development and utilization

Iceland is not only home to rich geothermal resources, but also owns rich experiences and advanced technologies in geothermal utilization. It is one the most developed countries in geothermal development and utilization. As early as 2015, geothermal has accounted for 96% of Iceland's heating sources, fully covering residential, commercial, industrial, agricultural and fishing areas.

The broad benefits delivered by geothermal utilization have greatly boosted Iceland's confidence to export its geothermal technologies. It started to seek partners around the world and then laid its eyes on China. Through multiple important channels varying from state-level exchanges to academic communications, Iceland promoted its geothermal technology and expressed strong desire to export advantageous geothermal technology. With the efforts of Iceland, over 100 geothermal experts and talents from China were trained in the UNU Geothermal Training Programme, of which 5 are serving the Joint Venture.

China is home to one-sixth of the world's geothermal resources. It is the largest developing country in the world, and its economic and social development has a growing demand for clean energy. In particular, due to the huge pressure of energy conservation, carbon emission reduction and air pollution control, the state and governments at all levels have rolled out policies related to geothermal energy. The call for vigorous development and utilization of clean energy such as geothermal as well as the reduction of social primary energy consumption is increasingly growing.

As a result, the perfect match between Iceland's desire to export geothermal technology and China's rich resources as well as its demand for clean energy has enabled the two states' cooperation in geothermal development and utilization, which has facilitate the showcase of international cooperation.

2.3 The JV has further added to the friendly relationship between the two states

After the establishment of the JV in 2006, the geothermal energy in China has been developed in a large-scale manner. Depending on Iceland's advantages in geothermal development and utilization, the JV has innovatively formulated 6 core technologies, built over 700 heat centrals and provided clean heating for over 2 million residents. "Xiongian Model" and "Zero-Emission City" then became renowned in China. Taking the JV as a bridge, China and Iceland as well as enterprises of the two states have conducted exchanges for over 40 times in areas of culture,

education, science and technology. On 7th October, 2007, H.E. Olafur Grimsson visited the JV in Xianyang, Shaanxi Province, who was the first foreign head of the state to come to Xianyang in its modern history.

Figure 2: On 7th October, 2007, China-Iceland Symposium on Development of Geothermal Resource was held by Sinopec Group in Xianyang, Shaanxi Province

H.E. Olafur Grimsson visited China in 2005, 2008 and 2010 respectively, attended the celebration of the JV's 10th anniversary, and visited the JV in Xiong'an New Area, Hebei Province after his retirement. On 15th April, 2013, H.E. Jóhanna Sigurzardóttir, former Icelandic Prime Minister, visited China, and jointly witnessed the signing of *Framework Agreement on Further Expanding Geothermal Resources Development and Cooperation* with H.E. Wen Jiabao in the Great Hall of the People in Beijing. On 30th June, 2014, H.E. Gunnar Sveinsson, former Icelandic Minister of Foreign Affairs, visited the JV's geothermal operations in Xianyang. In March, 2015, H.E. Illugi Gunnarsson, former Icelandic Minister of Education, Science and Culture, also visited the JV's geothermal operations in Xiongxian. Over 16 years since the JV's establishment, the Icelandic Ambassador to China and the Minister-Counselor of the Icelandic Embassy in China have paid visits to the JV's geothermal projects for several times.

The Sino-Icelandic cooperation in geothermal development has played a critical role in "bonding" the relationship between the two states. Over the years, relevant provincial and municipal governments in China, such as Shaanxi province, Xianyang city and Baoding city, have dispatched delegations to Iceland for communications and Chinese enterprises such as Sinopec Group and Sinopec Star have also visited Iceland's geothermal projects. From 2005 to 2020, China and Iceland have signed nearly 20 bilateral trade agreements. In 2014, the Chinese city of Xianyang and Icelandic city of Reykjanesbær became sister cities. The JV has become a link for the exchanges and communications between China and Iceland, thus increasing the closeness of the two states and providing a good environment for the rapid and large-scale development of the JV in return. China has become Iceland's largest trade partner in Asia, and China's investment in Iceland has grown continuously. The JV was once hailed as the "cornerstone" of the friendly relationship between China and Iceland by the Chinese ambassador to Iceland.

3. EFFORTS FROM MULTIPLE PARTIES HAVE BEEN MADE TO PROMOTE THE JV'S ESTABLISHMENT

Xianyang of Shaanxi province is highly rich in geothermal resources, with stored thermal energy capacity equivalent to 720 million tons of standard coal. Geothermal resources in Xianyang exhibit features of high temperature (80-126°C), high pressure (0.3-1.2 MPa), high flowrate, excellent water quality and wide applications. In March, 2006, Xianyang was awarded as "China Geothermal City" by the Ministry of Land and Resources and China Mining Association.

3.1 Xianyang took the initiative

Since the 1990s, Xianyang has conducted geothermal resources survey in a well-planned manner, formulated an overall planning for geothermal development and utilization, actively developed geothermal projects, initiated geothermal industry associations, won the title of "China Geothermal City", and applied geothermal energy to a wide range of fields including balneology, bathing, heating, and swimming, which produced excellent economic and social benefits. The planning and results of the geothermal development and utilization were well recognized by the National Committee of the Chinese People's Political Consultative Conference, Ministry of Geology and Mineral Resources, Ministry of Land and Resources, China Mining Association, and Chinese Geophysical Society Geothermal Committee. Xianyang also took the initiative to look for geothermal cooperation with multiple parties, introduce investment through various channels, and actively cooperated with Iceland.

3.2 Sinopec made forward-looking endeavors

Sinopec Group's effort to develop geothermal energy is also very forward-looking. As early as October, 2003, CGCOC of Sinopec Group began to look for geothermal project in Xianyang. On 12th January, 2004, CGCOC, Sinopec Star and the Third Census and Exploration Team of Sinopec North China Petroleum Bureau established a JV named Shaanxi Zhongdi Company. From 2004 to 2005, it drilled a high-quality geothermal well with water temperature of 94°C and artesian flowrate of 183m³/h, built a balneology and bathing center covering an area of 80,000 sqm and executed the Xianyang Wenlin Road University Heating Project.

3.3 Iceland found opportunity in China

At the beginning of this century, Icelandic companies and experts were looking for partners and opportunities to develop and utilize geothermal resources around the world. Through multiple sources, it came to them that Xianyang of Shaanxi province in China is highly rich in geothermal resources, that Xianyang government strongly supported geothermal development, and that notable results had been achieved in geothermal development and utilization. From 2002 to 2005, Mr. Osgir, former general manager of Enex from Iceland, and geothermal experts from the UNU Geothermal Training Programme had visited Xianyang for many times. The Icelandic Minister of Industry and Commerce also led a delegation to Xianyang in April, 2004.

CPC Xianyang Municipal Committee and Xianyang Municipal Government attached great importance to the cooperation with Iceland in the geothermal development, and dispatched delegations to Iceland for many times. Exchanges were frequently conducted between Iceland and Xianyang with respect to joint geothermal development.

In December, 2003, technicians from the Land and Resources Bureau and the Municipal Heating Office of Xianyang as well as relevant heating enterprises visited Iceland. During communication, 4 geothermal heating enterprises from China were recommended to the Icelandic counterparts by the Land and Resources Bureau and Foreign Affairs Office of Xianyang city. Since Shaanxi Zhongdi Company was very familiar with the geothermal resources in Shaanxi province and had already executed geothermal projects, Enex finally decided to cooperate with it, and the two parties began to negotiate the establishment of a JV.

On 18th May, 2005, at the "China-Iceland Business Seminar" hosted by China Council for the Promotion of Foreign Trade and the Ministry of Industry and Commerce of Iceland, representatives of Shaanxi Zhongdi Company, Xianyang Municipal Investment Company, and Enex signed the *Cooperation Agreement on Developing Xianyang Geothermal Resources*, marking the beginning of the Sino-Icelandic cooperation in geothermal development.

Figure 3: In May 2005, H.E. Olafur Grimsson witnessed the signing of the *Cooperation Agreement on Developing Xianyang Geothermal Resources* in Beijing

On 3rd December, 2006, Shaanxi Green Energy Geothermal Development Co., Ltd., whose name was changed into Sinopec Green Energy Co. Ltd. in 2012, was established in Xianyang, Shaanxi, marking a substantive progress in the Sino-Icelandic cooperation in geothermal development.

Figure 4: On December 3rd, 2006, Icelandic Foreign Minister and Xianyang Mayor attended the inauguration of the JV

4. ACHIEVEMENTS OF THE JV

The JV, by sticking to the principles of "resources being first", "people-benefiting" and "large-scale development", has actively developed core technologies and innovated business models, which not only positively contributed to air quality treatment, energy conservation, carbon emission reduction, and improvement of people's livelihood, but also boosted the development of China's geothermal industry.

4.1 Expanding the share in domestic geothermal market

The JV has businesses carried out in 21 high-quality geothermal markets including Guanzhong, Niutuo, Rongcheng, Gaoyang, etc., and established a geothermal heating capacity of over 59 million in 13 cities and counties including Hebei, Shaanxi, Shanxi, Shandong, Tianjin, etc.

4.2 Building “Xiongxian Model”

“Xiongxian Model” is a business model formed by the JV in Xiongxian, Hebei province, with core values of “government-enterprise cooperation, market-based operation, unified development, advanced technology, environment protection, and people benefiting”. Through “Xiongxian Model”, the JV has established a geothermal heating capacity of 6 million locally, which accounts for over 95% of district heating in Xiongxian, and built the first geothermal heating “zero-emission city” in China, with notable environmental and economic benefits. Over the past years, the JV has totally saved 797,700 tons of standard coal, and reduced 2.114 million tons of CO_2 and SO_2 emission.

In February, 2014, National Energy Administration of China recognized “Xiongxian Model” to be technically mature, economically feasible, promotable and replicable, and decided to promote “Xiongxian Model” nationwide. In 2021, geothermal operations in Xiongxian were listed by IRENA as a global showcase. In 2022, Xiongxian geothermal operations were listed as a 2020-2021 social responsibility showcase project by Sinopec Group.

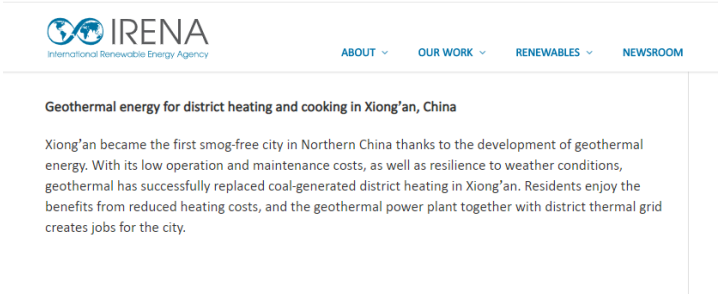

Figure 5: geothermal operations in Xiongxian was Listed by IRENA as a Global Showcase

4.3 Providing a road map for urban energy restructuring

The JV focuses on middle and deep layer geothermal development & utilization, with other forms of clean energy including waste heat, shallow-layer geothermal, sewage, clean electricity and natural gas as supplement, and vigorously expands new heating market, thus forming a "geothermal + clean energy integration" industrial layout

and providing a geothermal roadmap for the energy restructuring towards "zero emission cities". In Xianyang, Shaanxi Province, the JV has achieved a heating area of more than 7 million sqm with 27 "distributed" heating projects; in Hebei province, the JV has built 217 "distributed" heat centrals in 14 counties and cities and achieved a heating capacity of more than 32 million sqm.

Utilizing the industrial waste heat generated from the refineries of PetroChina Changqing Petrochemical Plant in Xianyang, the JV enabled a heating area of 550k sqm. In Dongguang, Cangzhou, Hebei Province, a heating area of 3.2 million sqm has been established through the utilization of industrial waste heat of a fertilizer plant. In Qinghe, Hengshui, Hebei Province, the "geothermal + sewage source heat pump" heating model was adopted to achieve an urban heating area of more than 5 million sqm. From 2020 to 2021, the JV has executed a large-scale air source heat pump heating project with a heating area of 1.2 million sqm in Xiong'an New Area, and utilized "geothermal +" heating model to protect clean rivers and green lakes in Baiyangdian.

4.4 Creating geothermal “zero-emission” cities and villages

In 2009, the JV started the cooperation with Xiongxian government in geothermal development and coal-fired boilers replacement. It achieved "full coverage" of geothermal heating in the county, and developed it into China’s first geothermal heating "zero-emission city", which can replace 140k tons of standard coal each winter and reduce carbon emissions by 360k tons. In Wugong, Shaanxi Province, 454 coal-fired boilers were replaced with geothermal heating in the urban areas and urban-rural fringes, creating the first geothermal heating "zero-emission city" in Northwest China. The JV also actively replaced coal-fired heating with geothermal in the villages. From 2016 to 2017, the coal-fired heating in Shaxinzhuang and Daying Zirancun of Xiongxian, Hebei province was replaced with geothermal heating by the JV, and 11 geothermal heating “zero-emission villages” were established, ending the history of coal-fired heating for more than 5,000 rural households. The “zero-emission” cities and villages developed by the JV are new trials in China’s geothermal development history, and serve as new models for achieving clean heating in the villages of North China where geothermal resources are abundant.

4.5 Innovating “Six core technologies”

For years since its establishment, the JV has absorbed geothermal technologies from both shareholders, and reinforce self-reliance in R&D based on its actual conditions, thus forming 6 core technologies which are geothermal exploration, geothermal drilling, cascading utilization, exhausted water reinjection, supervisory control and data acquisition (SCADA System) and geothermal + integration.

With the application of supervisory control and data acquisition technology (SCADA System), four major targets of large-scale geothermal development have been fulfilled, including full coverage of regional data, automatic alarming, automatic adjustment of flowrate and temperature, and remote monitoring & unattended operation.

Figure 6: the IDH Control Center built by the JV in Xiongxian of Xiong’an New Area is connected with all subsidiaries’ networks to realize remote monitoring.

In Xincheng community of Xiongxian, 8 geothermal wells (5 for production and 3 for reinjection) have been built to ensure full reinjection of geothermal exhausted water and “heat extraction without water consumption”. In Wugong, Shaanxi province, geothermal cascading utilization is achieved through “series connection” of different projects to fully tap energy of geothermal fluids. In Sanpu East District, Xianyang, Shaanxi Province, after the thermal energy of 90°C geothermal fluids has been utilized for heating, the exhausted water is re-utilized for residential bathing and balneology in Xianyang Geothermal City, therefore enabling multiple geothermal utilizations.

The JV indicates that 3 factors are necessary for different states to successfully cooperate in geothermal development and utilization. First, the governments must provide strong support, and create good policy environments for project development. Second, the two states must share the common wish to develop geothermal energy for the benefit of mankind. Third, there must be advanced systems and mechanisms to support the cooperation. The Sino-Icelandic cooperation in geothermal development has met these three requirements, and there will be a broader future for the JV under the backdrop of the “Dual Carbon” target.