Proceedings World Geothermal Congress 2026, Calgary, Canada, June 8—11, 2026

Low Carbon Energy Supply Solution for Park Public Buildings：Research and Application of " Geothermal+ " Integrated Energy System

Han Zhiguo [1], Zhang Xianyin[1], Ren Xiaoqing[2]*
Sinopec Star CO., LTD.[1], Sinopec Green Energy Geothermal Development Co., Ltd.[2]*
renxiaoqing.xxsy@ssinopec.com

INTRODUCTION

1 Research Background

The global shift toward low-carbon energy is irreversible, with over 130 countries committed to carbon neutrality. Driven by climate and technological factors, this transformation is reshaping energy systems worldwide. China is in a critical phase to achieve its "Dual Carbon" goals. Since 2012, President Xi Jinping's "Four Revolutions and One Cooperation" strategy has guided high-quality energy development, emphasizing clean sources like geothermal and solar power [1–3].

2 Energy Supply for Park Public Buildings

Office parks, as key urban hubs, face high energy demands due to their scale and mixed functions [4][5]. Their energy intensity per unit area is 3–5 times that of standard buildings [6], contributing over 30% of urban building carbon emissions [7]. China's park energy systems have evolved through four phases: from decentralized setups to smart, low-carbon solutions. Key drivers include policy compliance (e.g., 40% emission cuts by 2030 [8]), cost savings (e.g., heat pumps reducing costs by 33–41% [9]), reliability via microgrids [10], and economies of scale shortening payback periods to 6–8 years [11]. Future strategies will prioritize renewable-dominated systems with multi-energy integration [12][13].

3 Company Profile

Sinopec Star Co., LTD., a leading geothermal developer with 20 years' experience, has a cumulative heating capacity of 120 million m². Its "Xiongxian Model" demonstrates technical excellence, supporting integrated energy system advancements.

METHODS

1 Overall Design Framework

The innovation of this study lies in constructing a "geothermal+" integrated energy supply system，refer to Fig. 1. Using digital twin technology for holistic analysis, the system horizontally coordinates the synergistic supply of multiple energy types (e.g., electricity, heat, cooling, gas, water) and vertically optimizes interactions across "Source-Network-load-storage-Consumer" stages to achieve energy conservation and low-carbon operation.

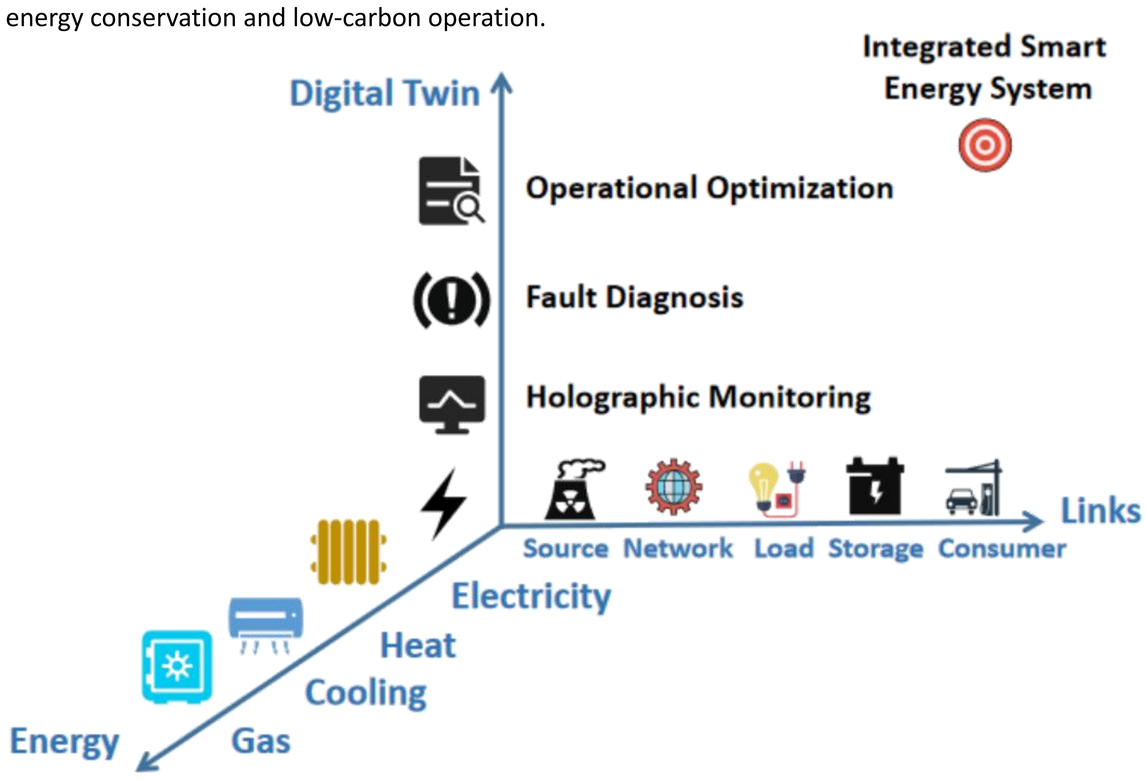


Figure 1."Geothermal+" Integrated Energy Supply

2 System Construction

The "Geothermal+" system integrates a multi-energy thermal system (primarily shallow geothermal) with a green power system ("PV–storage–charging"). It covers energy production to consumption, using a digital twin platform for smart dispatch to manage intermittency and volatility.

2.1 Multi-Energy Complementary Thermal System

Shallow geothermal energy provides base-load cooling and heating via ground-source heat pumps. Supplementary systems—cooling towers, air-source heat pumps, and solar thermal—handle peak demand, ensuring stability under variable building loads.

2.2 Green Power System

A distributed solar PV system, combined with battery storage and charging piles, forms a "PV + storage + charging" microgrid. It reduces grid dependence, supports grid services, and operates in both grid-connected and islanded modes.

2.3 Integrated Smart Energy Management Platform

This platform enables centralized monitoring, dispatch, and management of all energy assets. Key functions include:

- **Digital Monitoring:** 3D real-time tracking of energy flows, with machine learning for predictive analytics.
- **Intelligent Dispatch:** Algorithm-driven optimization (e.g., particle swarm) to balance supply-demand constraints.
- **Operational Diagnostics:** Lifecycle data tracking for fault detection and efficiency improvements.
- **Carbon Emission Management:** Blockchain-based carbon accounting aligned with building emission standards.

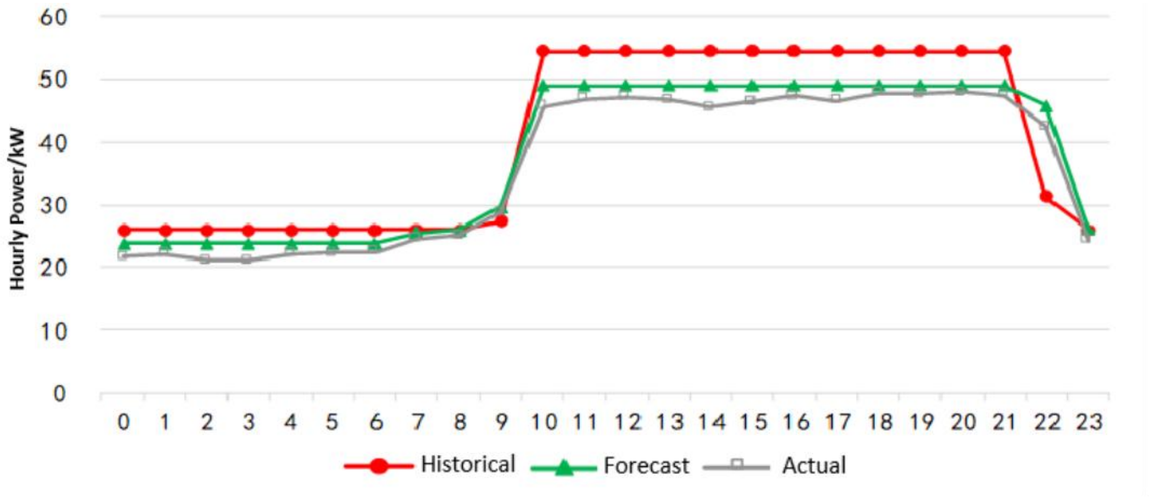


Figure 2. Energy consumption forecast comparison

3 Advantages of the "Geothermal+" System

This system integrates geothermal energy with solar PV and storage, creating a multi-energy complementary structure managed by an intelligent platform[14]. Its key advantages are：

- **Low Carbon Environmental Impact:** The combination of nearly zero-carbon geothermal energy and PV power can replace over 80% of fossil fuels, reducing carbon emissions by more than 40% [11][15].
- **Economic Benefits:** Heat pumps enhance operational efficiency, lowering lifecycle costs by approximately 20% compared to gas systems. Integrated PV helps balance electricity costs [16].
- **High Reliability:** Geothermal provides a stable base-load, while the PV-storage modules enable extended off-grid operation for critical loads, increasing overall system reliability by over 50% [15].

RESULTS

Sinopec Star Co., LTD. has implemented multiple "geothermal+" integrated energy projects for park public buildings, with the Xiong'an Tech Demonstration Park and Beijing Office Park serving as representative cases.

1 Xiong'an Tech Demonstration Park

Located in Xiong'an's Zangang cluster, this park integrates office, R&D, production, and supporting facilities. In 2023, a "geothermal+" system was implemented. As illustrated in Fig. 3,combining ground-source heat pumps, cooling towers, air-source heat pumps, and solar thermal systems to provide cooling, heating, and annual hot water. Rooftop distributed PV systems operate under a "self-consumption with grid feed-in" model, maintaining stable operation for two years

The project utilizes shallow geothermal energy (≤200 m depth), with Phase I providing a maximum heating capacity of 2,205 kW and cooling capacity of 3,525 kW. Rooftop PV systems have a total installed capacity of 1.4 MW, generating 1.68 million kWh annually. Phase I alone saves 39,400 tons of standard coal and reduces CO_2 emissions by 93,900 tons per year, achieving low-carbon park energy supply.

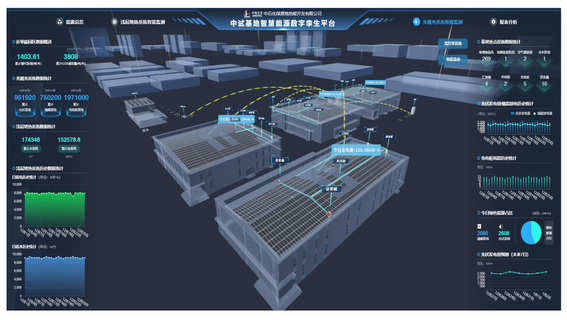


Figure 3.Integrated smart energy control platform



Figure 4.Project building distribution

2 Beijing Office Park

The architectural layout is shown in Fig. 4,situated in Haidian District, the park accommodates offices and employee dormitories, requiring electricity, cooling, heating, and hot water. Ground-source heat pumps supply cooling and heating to Buildings 7 and 8 (total area: 11,500 m²) and hot water to dormitories. Rooftop PV systems prioritize self-consumption, with excess electricity fed to the grid. The system includes 250 ground heat exchangers, one energy station, and designed heating/cooling capacities of 929 kW/951 kW.

DISCUSSION

Early adopters in Europe and North America offer rich case studies. Berlin's Euref-Campus integrates PV, wind, biogas, and microgrids with EV charging stations, using algae bioreactors to absorb CO_2. Google Bay View Campus features large-scale "dragon-scale" PV panels and North America's largest geothermal pile system. Apple Park utilizes natural ventilation, 17 MW solar roofs, and capillary radiant cooling (40% more efficient than conventional AC).

However, these projects often rely on customized designs, unique conditions, and high costs, limiting scalability. In contrast, Chinese projects like the Xiong'an and Beijing parks demonstrate stronger replicability due to:

- Complete industrial chains and manufacturing capabilities, enabling economies of scale.
- Mature technologies centered on widely available shallow geothermal and solar energy.
- Diverse application scenarios (e.g., campuses, medical complexes, transportation hubs).
- Adaptable "geothermal+" frameworks ensuring security and compatibility with various energy sources, enhanced by smart platforms for full-chain optimization.

Thus, the system offers broader geographical adaptability, lower customization dependency, better economics, and greater viability for large-scale promotion.

CONCLUSION

Park public building energy systems are rapidly evolving from singular, decentralized, high-carbon models to integrated, multi-energy complementary, digitalized, and low-carbon modern regional energy systems. Future park energy centers will transform into "regional energy hearts"—fusion hubs of green technologies, grid interactions, and intelligent management—critical for urban carbon neutrality.

The "geothermal+" system promotes localized energy development, environmental friendliness, and structural optimization. Future directions include exploring "PV + hydrogen" combinations to enhance renewable utilization and developing comprehensive energy services. This pathway aligns with global energy trends and accelerates progress toward China's "Dual Carbon" goals, contributing to efficient, low-carbon energy utilization worldwide.

REFERENCES

[1] Jin X. "Four Revolutions and One Cooperation" Guides China's High-Quality Energy Development [N]. People's Daily, 2025-04-09(006).
[2] National Development and Reform Commission, et al. Several Opinions on Promoting Geothermal Energy Development and Utilization [M]. 2021-09-10.
[3] National Development and Reform Commission, et al. Guiding Opinions on Implementing Renewable Energy Replacement Actions [M]. 2024-10-18.
[4] Kennedy C, et al. Energy and Material Flows of Megacities [J]. PNAS, 2015, 112(19):5985–5990.
[5] Jiang Y, et al. China Building Energy Efficiency Annual Development Research Report 2023 [M]. Beijing: China Architecture & Building Press, 2023:56–59.
[6] IEA. Energy Efficiency in Data Centers [R]. Paris: IEA, 2022:12.
[7] China Association of Building Energy Efficiency. China Building Energy Consumption and Carbon Emissions Research Report (2022) [R]. Beijing, 2023.
[8] Ministry of Housing and Urban-Rural Development. General Code for Building Energy Efficiency and Renewable Energy Utilization: GB 55015-2021 [S]. Beijing: China Standards Press, 2021.
[9] Lund J W, Toth A N. Global Assessment of Geothermal Energy Use [J]. Renewable and Sustainable Energy Reviews, 2021, 144:111028.
[10] Liu X, et al. Resilient Microgrid Design for Office Parks [J]. IEEE Transactions on Smart Grid, 2021, 12(4):3452–3463.
[11] Zhou Z, et al. Economy of Scale for District Cooling Systems [J]. Energy and Buildings, 2020, 223:110186.
[12] Zhang Y, et al. Smart Control of Multi-Energy Systems [J]. Energy Conversion and Management, 2022, 267:115882.
[13] National Development and Reform Commission, et al. Notice on Zero-Carbon Park Construction [M]. 2025-07-08.
[14] Zhang Y, Wang L, Liu Y. Synergistic Operation of Geothermal-Solar Hybrid Energy Systems [J]. Applied Energy, 2023, 331:120418.
[15] IRENA. Geothermal Energy in the Energy Transition [R]. Abu Dhabi: IRENA, 2022.
[16] Gude V G. Cost-Benefit Analysis of Geothermal Hybrid Systems [J]. Energy Conversion and Management, 2023, 277:116631.