KYIV NATIONAL UNIVERSITY OF CONSTRUCTION AND ARCHITECTURE

Engineering systems and ecology
(Faculty)
Heat engineering
(name of the graduating department)

EXPLANATORY NOTE
TO THE QUALIFICATION WORK
FOR OBTAINING A MASTER'S DEGREE

on the topic:

"Practical Education of the Use of Thermal Energy of the Soil and the Sun in China"

Сюелі Лю
(full name of the applicant)

Kyiv 2024

KYIV NATIONAL UNIVERSITY OF CONSTRUCTION AND ARCHITECTURE

Engineering systems and ecology
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Heat engineering
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APPROVED BY
Head of the Department

2024 – 11 -

EXPLANATORY NOTE
TO THE QUALIFICATION WORK
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"Practical Education of the Use of Thermal Energy of the Soil and the Sun in China"

Performed by: Сюелі Лю
(full name, surname and patronymic)
144 «Heat power engineering»
(speciality)
Energy management, energy efficient
municipal and industrial thermal technologies
(study programme)
Group TEM-23
Head of the group: Mychailo Kyrychenko
(surname and initials)
Associate Prof., Candid. of Technical Sciences
(academic title, academic degree)
I confirm my identity

Kyiv 2024

KYIV NATIONAL UNIVERSITY OF CONSTRUCTION AND ARCHITECTURE

Faculty: Engineering systems and ecology
Graduating Department: Thermal engineering
Educational degree: Master's degree
Speciality: 144 «Heat power engineering»
Study programme: Energy management, energy efficient municipal and industrial thermal technologies

APPROVED BY
Dean of the Faculty
____
2024 – 11 -

TASK

TO PERFORMING QUALIFICATION WORK FOR A MASTER'S DEGREE

by Сюелі Лю

1. The topic of the work: "Practical Education of the Use of Thermal Energy of the Soil and the Sun in China" was approved by the order of the rector of KNUCA № ______ from 2024 - ____ - ____ .
2. Керівник роботи: Mychailo Kyrychenko, Associate Prof., Candidate of Technical Sciences.
3. Deadline for submission of the work for defence by the applicant_________________
4. Contents of the explanatory note by sections:

S.1. Title Page and Content

S.2. Overview and Introduction

S.2.1. Background and Rationale

S.2.2. Research Aim

S.2.3. Objectives

S. 2.3.1. To investigate the role of solar and soil thermal energy in supporting China's transition toward a sustainable energy future.

S. 2.3.2. To assess the technological applications of solar thermal, soil thermal storage, heat recovery, and heat pump technologies.

- S.2.3.2.1 Solar thermal
- S.2.3.2.2 Soil Thermal

S.2.3.3 To analyze the energy savings, emission reductions, and financial impacts of multi-energy coupled systems.

- S.2.3.3.1 Solar energy technical and economic analysis for heating in winter
  - S.2.3.3.1.2 Solar Thermal Parameters of building and primary Energy
  - S.2.3.3.1.3 Solar Operation Model in Winter
  - S.2.3.3.1.4 Solar Heating cost analysis in winter
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  - S.2.3.3.2.1 heating parameter definition
  - S.2.3.3.2.2 Pumping and Recharge Tests in the Demonstration Project Area
    - S.2.3.3.2.2.1 Pumping Test
    - S.2.3.3.2.2.2 Recharge Test
    - S.2.3.3.2.2.3 Thermal Physical Parameter Testing of Rock and Soil
    - S.2.3.3.2.2.4 On-site Thermal Response Test Analysis
  - S.2.3.3.2.4 Dynamic Monitoring of Geological Environmental Impacts
  - S.2.3.3.2.5 Calculation of Heating Load for Buildings
  - S.2.3.3.2.6 Soil Thermal Storage Design
  - S.2.3.3.2.7 Automatic Control and Operation of the Soil Thermal Storage System

S.2.3.4 Heat Storage in Spring, Summer, and Autumn from solar energy

- S.2.3.4.1 Heat Release in Winter
- S.2.3.4.2 2019year of Heating Season
- S.2.3.4.3 End of 2020 Heating Season and Continued Storage

S.2.3.4.4 Heating Cost Analysis by Household Electricity Pricing

S.2.3.5 To explore the challenges and limitations of implementing multi-energy systems on a larger scale.

S.3. Significance of Study

S.4. Data Analysis and System Performance

S.4.1 2014 Solar Energy Utilization Project by Legendary Electric (Shenyang) Co., Ltd.

S.4.2 Coupled Energy Source 2: Dual-Source Heat Pump Cooling Project Completed in 2021

S.4.2.1 Year of 2021 Dual-Source Heat Pump Cooling Project by Legendary Electric (Shenyang) Co., Ltd.

S.5. Broader Applications and Adaptability

S.6. Challenges, Limitations, and Future Directions

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5. Graphic material by section:

S.1. Project Overview

S.2. Soil and Solar Thermal Energy in China

S.2.1 Parabolic Trough Solar Thermal Technology and Short-Term Energy Storage Technology

S.2.2 Waste Heat Recovery Technology

S.2.3 Cross Seasonal Long-Term Energy Storage -Geothermal Energy Technology"

S.2.4 Cross Seasonal Long-Term Cooling Storage Technology

S.3. Thermal Energy Cascade Utilization Control System. Economic and Social Benefits of Smart Energy Systems

S.4. Outlook- Lucid waters and lush mountains are invaluable assets

A calendar plan for the execution of the work

Types of work and their content	Execution date
Section 1. Title Page and Content	2024.11.
Section 2. Overview and Introduction	2024.11.
Section 3. Significance of Study	2024.11.
Section 4. Data Analysis and System Performance	2024.11.
Section 5. Broader Applications and Adaptability	2024.11.
Section 6. Challenges, Limitations, and Future Directions	2024.11.
Section 7. Appendices and Supplementary Content	2024.11.
Section 8. Expected Outcomes	2024.11.
Submission of work for plagiarism check	2024.11.
Preliminary defence of work at the graduating department	2024.11.
Submission of work for review	2024.11.

Consultants of the qualification work sections

Sections	Name, initials and position of the consultant	Checked	
		date	signature
Section 1			
Section 2			
Section 3			
Section 4			
Section 5			
Section 6			
Section 7			
Section 8			

Дата видачі завдання ________________________________

Head of the Department __________________ M. Kyrychenko

(signature) (surname, initials)

Head _________________ M. Kyrychenko

(signature) (surname, initials)

Applicant _________________ Сюелі Лю

(signature) (surname, initials)

РЕЦЕНЗІЯ
на кваліфікаційну роботу

здобувача Сюелі Лю
факультету Інженерних систем та екології
спеціальності 144 «Теплоенергетика»
освітньої програми «Енергетичний менеджмент, енергоефективні муніципальні та промислові теплові технології»

Тема роботи: «Практична освіта з використання теплової енергії ґрунту та сонця в Китаї» ("Practical Education of the Use of Thermal Energy of the Soil and the Sun in China")

Обсяг роботи ____

____

Висновок про відповідність завданню_________________________________

Актуальність обраної теми____

____

____

Використання у роботі сучасних досягнень науки і техніки______________

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Використання у роботі комп'ютерних технологій _______________________

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Практичне значення роботи ____

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Якість оформлення роботи ____

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Зауваження та побажання ____

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Загальний висновок стосовно відповідності роботи освітньому ступеню

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Рекомендована оцінка____

Рецензент

____/___________________________/
(прізвище, ініціали) (підпис)

Посада, місце роботи ____

____

“__” _________ 2024 р.

Practical Education on the Use of Soil and Solar Thermal Energy in China" A Case Study by Trench’ Shenyang China Co., Ltd (**The author's own project case as the project manager.**)

------144 Power E Сюелі Лю

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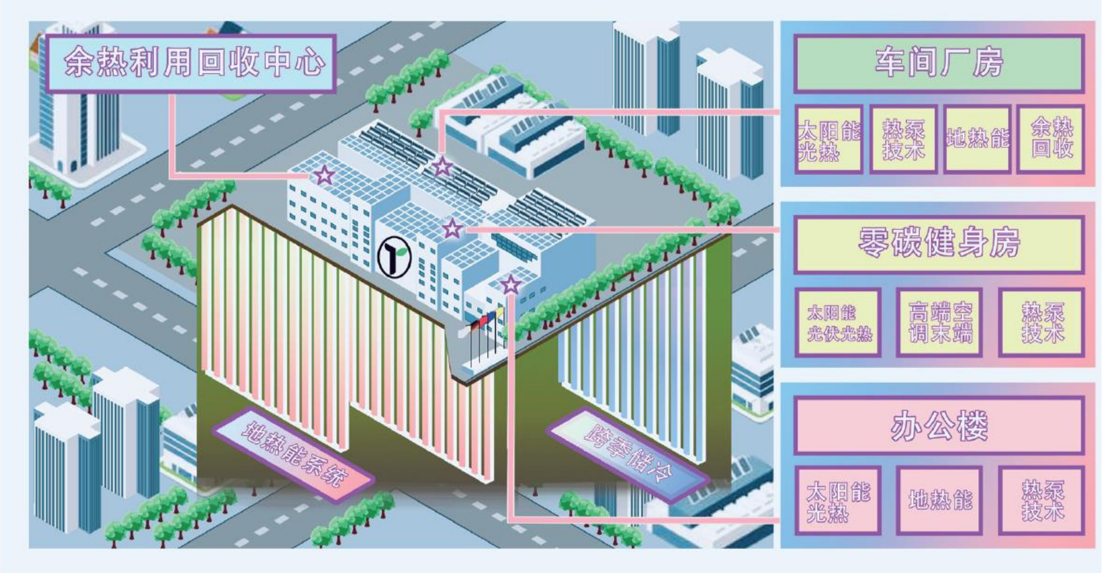


Scope and Structure

1. **Title Page and Content**
   - Title: Practical Education on the Use of Soil and Solar Thermal Energy in China
   - Table of Contents: Outline main chapters, sub-sections, figures, and tables.
2. **Overview and Introduction**

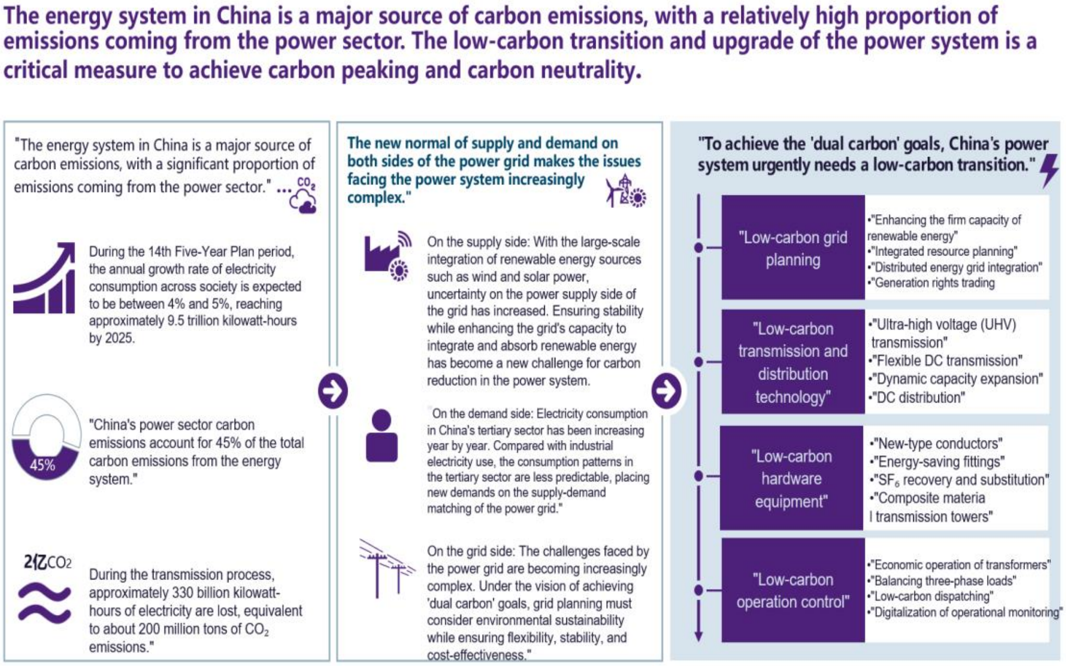
2.1Background and Rationale

Controlling carbon emissions, advancing energy transition, and achieving carbon neutrality around the mid-21st century have become common goals for most countries worldwide. In September 2020, China announced its 'dual-carbon' targets, aiming to peak carbon emissions by 2030 and striving to achieve carbon neutrality by 2060. This goal, known as the '30 60' target, encapsulates China's carbon peak and neutrality ambitions.

At the end of 2023, the 28th Conference of the Parties (COP28) to the United Nations Framework Convention on Climate Change reaffirmed that limiting global temperature rise to within 1.5°C remains a key milestone of the landmark Paris Agreement. The conference underscored the need for urgent action and support to ensure this target remains attainable. The cover decision from COP28 calls on nations to 'reduce dependency on fossil fuels within energy systems in a fair, orderly, and equitable way, urging accelerated action over this critical decade to achieve scientifically aligned net-zero emissions by 2050. During COP28, the host nation, the UAE, proposed the 'Global Decarbonization Accelerator (GDA)' plan, centered on three key actions: rapid expansion of future energy systems, decarbonization of current energy systems, and targeted actions on methane and other non-CO_2 greenhouse gases (GHGs).

Regarding the future energy system, 118 governments pledged to double global renewable energy capacity by 2030, aiming for at least 11,000 GW, along with a twofold improvement in energy efficiency. This widely supported initiative was included in the conference's final statement. Additionally, COP28 established a suite of initiatives aimed at reducing emissions within the energy sector, encompassing nuclear expansion, accelerated industrial transformation, hydrogen standards harmonization, decarbonizing cooling, methane reduction in the oil and gas sectors, and grid technology collaboration. These initiatives are expected to significantly advance the development and deployment of renewable energy worldwide, playing a critical role in achieving both China's dual-carbon goals and global carbon neutrality.

On February 29, 2024, the Political Bureau of the CPC Central Committee held its 12th collective study session on renewable energy technologies and China's energy security. President Xi Jinping noted that since the 18th National Congress of the CPC, China has rapidly accelerated the construction of a new energy system, reinforcing energy security to strongly support economic and social development. With abundant resources for wind and solar power, China holds significant potential for renewable energy development. After years of sustained research and innovation, China now leads globally in several renewable energy technologies and equipment manufacturing. The country has established the world's largest clean power supply system, with competitive advantages in sectors like new energy vehicles, lithium batteries, and photovoltaic products on the international stage. China's renewable energy sector has laid a solid foundation, positioning the nation as a vital driver in global energy transition and climate action. Moving forward, China aims to balance renewable energy development with national energy security by prioritizing planning, strengthening top-level design, ensuring coordinated development, and managing the balance between renewable and traditional energy, government and market forces, and energy production and conservation to achieve high-quality growth in renewable energy.



The energy system in China is a major source of carbon emissions, with a relatively high proportion of emissions coming from the power sector. The low-carbon transition and upgrade of the power system is a critical measure to achieve carbon peaking and carbon neutrality.

"The energy system in China is a major source of carbon emissions, with a significant proportion of emissions coming from the power sector." ...

During the 14th Five-Year Plan period, the annual growth rate of electricity consumption across society is expected to be between 4% and 5%, reaching approximately 9.5 trillion kilowatt-hours by 2025.

"China's power sector carbon emissions account for 45% of the total carbon emissions from the energy system."

During the transmission process, approximately 330 billion kilowatt-hours of electricity are lost, equivalent to about 200 million tons of CO_2 emissions."

The new normal of supply and demand on both sides of the power grid makes the issues facing the power system increasingly complex."

On the supply side: With the large-scale integration of renewable energy sources such as wind and solar power, uncertainty on the power supply side of the grid has increased. Ensuring stability while enhancing the grid's capacity to integrate and absorb renewable energy has become a new challenge for carbon reduction in the power system.

On the demand side: Electricity consumption in China's tertiary sector has been increasing year by year. Compared with industrial electricity use, the consumption patterns in the tertiary sector are less predictable, placing new demands on the supply-demand matching of the power grid."

On the grid side: The challenges faced by the power grid are becoming increasingly complex. Under the vision of achieving 'dual carbon' goals, grid planning must consider environmental sustainability while ensuring flexibility, stability, and cost-effectiveness."

"To achieve the 'dual carbon' goals, China's power system urgently needs a low-carbon transition."

"Low-carbon grid planning
- "Enhancing the firm capacity of renewable energy"
- "Integrated resource planning"
- "Distributed energy grid integration"
- "Generation rights trading

"Low-carbon transmission and distribution technology"
- "Ultra-high voltage (UHV) transmission"
- "Flexible DC transmission"
- "Dynamic capacity expansion"
- "DC distribution"

"Low-carbon hardware equipment"
- "New-type conductors"
- "Energy-saving fittings"
- "SF_6 recovery and substitution"
- "Composite materia l transmission towers"

"Low-carbon operation control"
- "Economic operation of transformers"
- "Balancing three-phase loads"
- "Low-carbon dispatching"
- "Digitalization of operational monitoring"

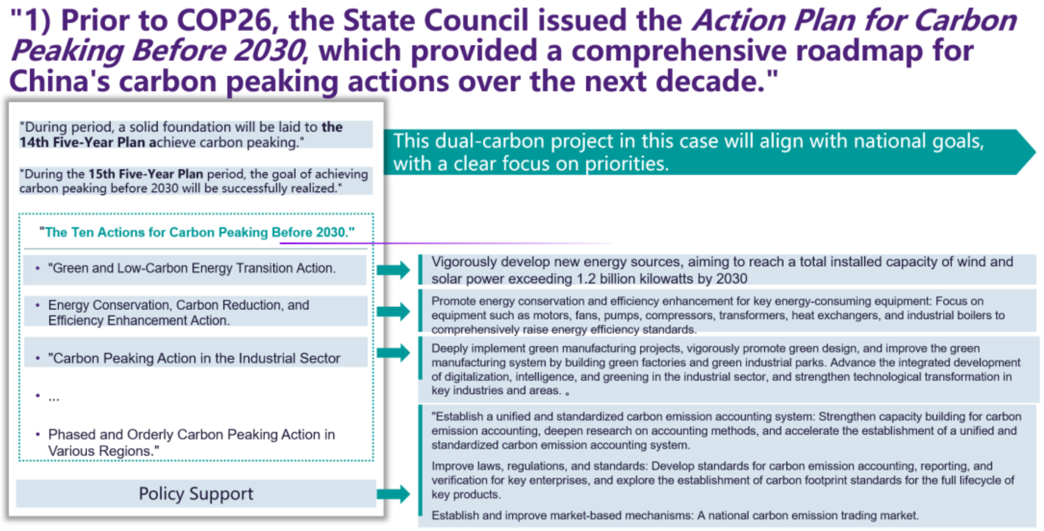
Moreover, the increasing use of advanced technologies, such as artificial intelligence (AI) and Internet of Things (IoT) applications, has transformed the way energy systems are managed and optimized. China's push toward "smart agile" energy solutions, combined with renewable resources, has led to the development of **multi-energy coupled systems.**

In my article I will show this practical case executed by my team is the **multi-energy coupled smart heating and cooling system**, which solar and soil thermal energy through integrated management, storage, and real-time control. The development and expansion of such systems are key to achieving sustainable energy transformation.

Introduction to Renewable Energy in China

Global and National Goals for Renewable Energy

China, as the largest emitter of greenhouse gases globally, has committed to reaching peak emissions before 2030 and achieving carbon neutrality by 2060. This target has driven both policy shifts and technological advancements within the country's energy sector, pushing for innovations in renewable sources like solar, wind, and thermal energy to reduce dependency on fossil fuels.



"1) Prior to COP26, the State Council issued the *Action Plan for Carbon Peaking Before 2030*, which provided a comprehensive roadmap for China's carbon peaking actions over the next decade."

"During period, a solid foundation will be laid to **the 14th Five-Year Plan a**chieve carbon peaking."

"During the **15th Five-Year Plan** period, the goal of achieving carbon peaking before 2030 will be successfully realized."

This dual-carbon project in this case will align with national goals, with a clear focus on priorities.

"The Ten Actions for Carbon Peaking Before 2030."

- "Green and Low-Carbon Energy Transition Action.
- Energy Conservation, Carbon Reduction, and Efficiency Enhancement Action.
- "Carbon Peaking Action in the Industrial Sector
- ...
- Phased and Orderly Carbon Peaking Action in Various Regions."

Policy Support

Vigorously develop new energy sources, aiming to reach a total installed capacity of wind and solar power exceeding 1.2 billion kilowatts by 2030

Promote energy conservation and efficiency enhancement for key energy-consuming equipment: Focus on equipment such as motors, fans, pumps, compressors, transformers, heat exchangers, and industrial boilers to comprehensively raise energy efficiency standards.

Deeply implement green manufacturing projects, vigorously promote green design, and improve the green manufacturing system by building green factories and green industrial parks. Advance the integrated development of digitalization, intelligence, and greening in the industrial sector, and strengthen technological transformation in key industries and areas. 。

"Establish a unified and standardized carbon emission accounting system: Strengthen capacity building for carbon emission accounting, deepen research on accounting methods, and accelerate the establishment of a unified and standardized carbon emission accounting system.

Improve laws, regulations, and standards: Develop standards for carbon emission accounting, reporting, and verification for key enterprises, and explore the establishment of carbon footprint standards for the full lifecycle of key products.

Establish and improve market-based mechanisms: A national carbon emission trading market.

National Policies Supporting Renewable Energy

In recent years, the Chinese government has rolled out a series of policies to support the expansion of clean energy technologies, particularly solar and thermal energy. The National Energy Administration (NEA) has set ambitious goals through the "Renewable Energy Law" and the "13th Five-Year Plan for Renewable Energy Development." These policies promote energy efficiency, provide subsidies for renewable projects, and encourage the development of distributed energy sources in both urban and rural areas. The NEA's "Guiding Opinions on Promoting High-Quality Development of Renewable Energy" provides a framework for boosting technological innovation, financial incentives, and infrastructure development to support the clean energy industry.

Supporting Policies Specific to Solar and Thermal Energy

The Chinese government has also implemented targeted incentives for solar and thermal energy projects. Subsidies for solar installations, particularly solar heating, have been instrumental in expanding this technology across industrial parks and commercial buildings. Policies such as the Solar Heating Development Plan aim to integrate solar heating solutions into urban planning. Soil thermal energy, while less widespread, is gaining attention for its potential in areas with extreme seasonal temperatures, where soil can be used for both heat storage in winter and cooling in summer. Both solar and soil thermal energy are increasingly seen as vital components of microgrid and distributed energy systems, particularly in industrial and manufacturing zones.

Technological Trends in Soil and Solar Thermal Energy

Overview of Solar Thermal Energy Technology

Solar thermal energy involves capturing and utilizing solar radiation to produce heat, which can be used directly for industrial processes, heating, or electricity generation. In China, this technology has expanded rapidly, with applications ranging from residential heating to industrial steam generation. The primary technologies within solar thermal energy include parabolic troughs, solar power towers, and evacuated tube collectors. Among these, parabolic trough systems have gained particular traction in China for their high efficiency and adaptability to industrial-scale heating and steam applications.

- **Parabolic Trough Systems**

  Parabolic trough technology uses curved mirrors to concentrate sunlight onto a receiver tube, heating a fluid, typically oil, to high temperatures. This heated fluid then transfers thermal energy to a heat exchanger, which can generate steam for industrial processes or provide hot water for district heating. China's extensive adoption of parabolic troughs can be attributed to both government incentives and the technology's compatibility with existing heat exchange systems.

Soil Thermal Energy Storage and Utilization

Soil thermal energy, or ground-source heat, refers to the use of subsurface ground layers to store thermal energy, which can later be retrieved using heat pump technology. This method has gained attention in northern China, where the extreme temperatures make heating and cooling requirements more intense.

- **Soil Balance and Seasonal Thermal Energy Storage**

  Soil thermal storage leverages the insulating properties of earth materials to retain heat or cold over extended periods. Seasonal thermal energy storage is particularly valuable in regions like northern China, where energy stored during the summer can be used for heating in winter. This technology can significantly reduce the energy load on traditional heating and cooling systems, especially when integrated with soil balance technology, which maintains a stable ground temperature by cycling stored heat and cold through the seasons.

- **Dual-Source Heat Pumps and Ground-Coupled Systems**

  Dual-source heat pumps are often used in tandem with ground-coupled systems to transfer heat between the building and the ground, depending on seasonal needs. These systems reduce the strain on traditional HVAC systems, as the ground acts as a natural thermal buffer. The combination of solar and ground-source energy, paired with heat pumps, has proven effective in reducing energy consumption in industrial parks in northern China, where temperature fluctuations are more extreme.

Soil and Solar Energy in Industrial Applications

Solar thermal systems have been implemented in various Chinese industries, especially where there is a high demand for heat. For example, solar thermal technology has been applied in manufacturing sectors such as textiles, food processing, and paper production, where steam and hot water are required for processing. The use of solar thermal energy in these industries has led to substantial cost savings and has contributed to emission reductions.

- **Textile Industry**

In textile production, where steam is needed for processes like dyeing and finishing, solar thermal systems can reduce the reliance on fossil fuels. Solar trough systems can meet a significant portion of a facility’s heat demand, especially when paired with thermal storage, allowing operations to continue even on cloudy days or at night.

- **Food Processing Sector**

Food processing often requires heat for sterilization, pasteurization, and drying. Solar thermal energy provides a renewable and consistent heat source, reducing the industry’s energy costs. Case studies have shown that in regions like Shandong and Henan, solar thermal systems have helped reduce fuel consumption in food processing by up to 50%.

Soil Thermal Energy in Industrial Cooling Applications

Soil thermal energy is less commonly used than solar energy but is gaining popularity for industrial cooling applications. In locations with large underground areas, soil thermal energy systems have been implemented to provide cooling for manufacturing facilities, storage warehouses, and commercial buildings.

- **Seasonal Cooling Storage**

Seasonal cooling storage involves storing cold energy in the ground during the winter, which can then be used for cooling during the summer. This approach is increasingly used in industries that require temperature control, such as pharmaceutical manufacturing and cold storage facilities.

Energy-Intensive Sectors Benefiting from Soil and Solar Thermal Energy

Industries such as metallurgy, chemical manufacturing, and cement production, which are highly energy-intensive, also benefit from renewable thermal energy sources. Although adoption in these sectors is still in its early stages, companies are beginning to invest in both soil and solar thermal systems to meet their large heating and cooling needs while reducing costs and emissions.

Theoretical Framework for Renewable Thermal Energy Adoption

Energy Transition Theory

Energy transition theory provides a framework to understand the shift from fossil-fuel-based systems to renewable energy sources, which is particularly relevant in China's context. The theory posits that energy transitions are not only technological but also require supportive policies, economic incentives, and societal acceptance. In China, government support through policies and subsidies has been a key factor in the energy transition. The adoption of solar and soil thermal energy systems is part of a broader shift towards a low-carbon economy, aligning with energy transition theory's emphasis on systemic change.

Microgrid and Distributed Energy Theory

The theory of distributed energy systems emphasizes the decentralization of energy generation, allowing for smaller, self-sufficient units (microgrids) that operate independently from the main grid. In China, industrial parks are increasingly adopting distributed energy solutions to increase energy security and resilience. The integration of soil and solar thermal energy within these microgrids exemplifies the potential for a decentralized, low-carbon energy system.

Behavioral Theory of Corporate Sustainability

This theory explores the factors that drive companies to adopt sustainable practices, including renewable energy. In China, industrial parks and companies are motivated by a combination of economic savings, regulatory compliance, and corporate social responsibility. The behavioral theory of corporate sustainability highlights the role of corporate culture, government incentives, and public image in driving the adoption of renewable thermal energy.

2.2 Research Aim

This practical case is centered around the practical education on utilizing solar and soil thermal energy in China. "The multi-energy coupled smart heating and cooling system integrates a variety of green energy technologies, including parabolic trough solar thermal technology, waste heat recovery systems, ground source heat exchangers. These technologies not only enhance energy efficiency, reduce waste heat emissions, and decrease dependence on traditional energy sources, but also lower energy costs and less environmental impact.

By combining multiple energy technologies and utilizing intelligent control and monitoring, the system optimizes the coordination of diverse energy sources, achieving efficient, safe, and sustainable energy use with broad applicability and value.

This system is especially suitable for phased park projects, as it can flexibly adapt to various energy demands and significantly reduce both energy investment and operating costs. It is a key technology for advancing green economic growth and environmental sustainability.

The system does not require large-scale, full-capacity energy investments or complex auxiliary measures. As a practical case, it serves as a valuable reference for government policies on green economy and energy planning in industrial parks, bringing new vitality to industrial zones through efficient and sustainable energy management.

2.3 Objectives

The primary objectives of this work are as follows:

2.3.1To investigate the role of solar and soil thermal energy in supporting China’s transition toward a sustainable energy future.

Energy awareness has been increased among the industrial sectors in China. It is estimated that successful implementation of energy conservation could reduce the energy consumption per GDP of the country. However, energy cost is only one part of industrial operation cost, the proportion of energy cost will be different based on various types of production. So, it is important to identify

the proper energy saving opportunities during on site investigation and long-term operation process.

Solar energy is helpful for providing an eco-friendly environment to users. This is the main reason why we need to adopt these systems if possible. These systems have been developed to replace others.

energy sources and hence enhancements and improvements are being done continuously. Efforts have been put in to make these systems more efficient and beneficial for us.

This case will assess the possibility and feasibility of using sun heating system to replace the heating center system and make savings in both building heating and production energy usage.

2.3.2 To assess the technological applications of solar thermal, soil thermal storage, heat recovery, and heat pump technologies.

2.3.2.1 Solar thermal:

Energy awareness has been increased among the industrial sectors in China. It is estimated that successful implementation of energy conservation could reduce the energy consumption per GDP of the country. However, energy cost is only one part of industrial operation cost, the proportion of energy cost will be different based on various types of production. So, it is important to identify the proper energy saving opportunities during on site investigation and long-term operation process.

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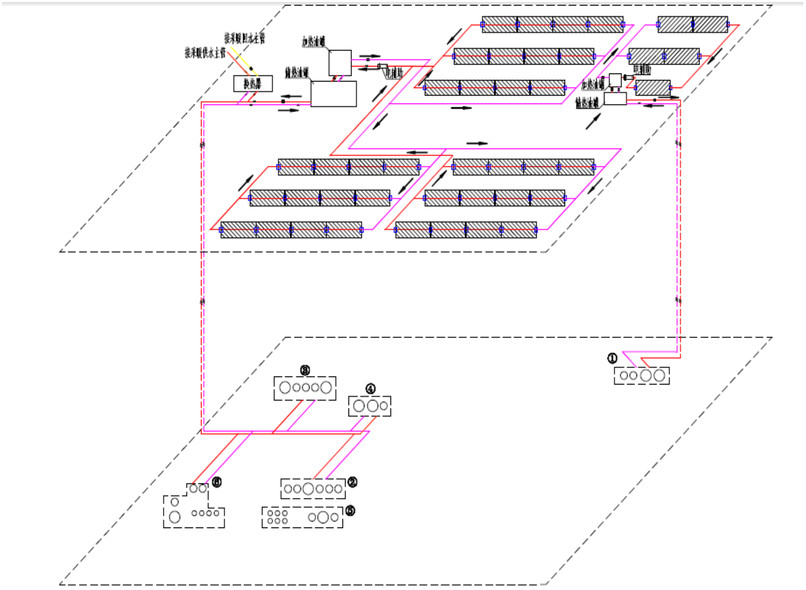
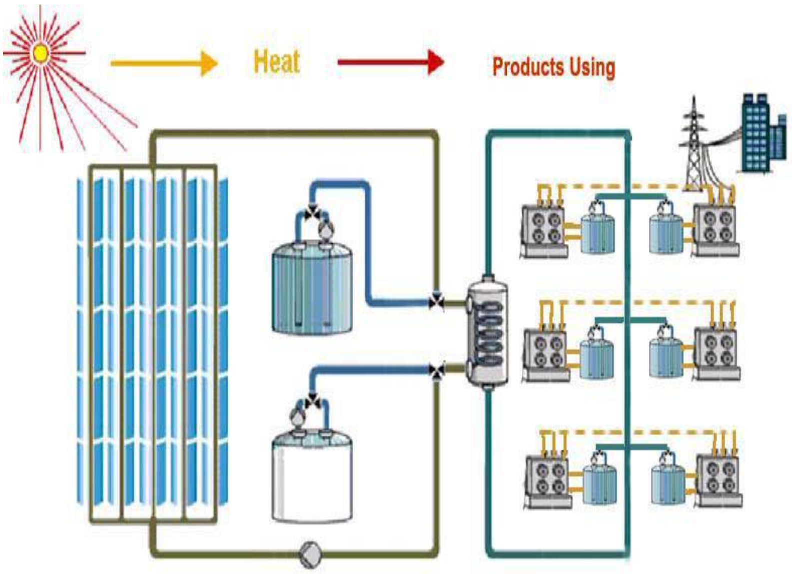
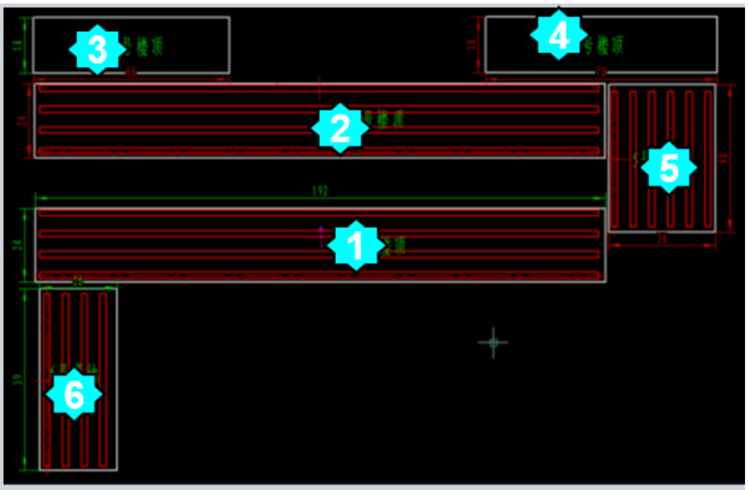




Considering the available sunlight time, we suggest that roof 1, 2 and 5 be used to install solar energy system. In this plan, we calculate 100% of roof area available for sunlight collection. Thereof, we will have 2833sqm for workshop roof. And 462sqm for testing shop roof. Then, the sum total will be 3296sqm for collection.

厂房鸟瞰图Bird-eye map

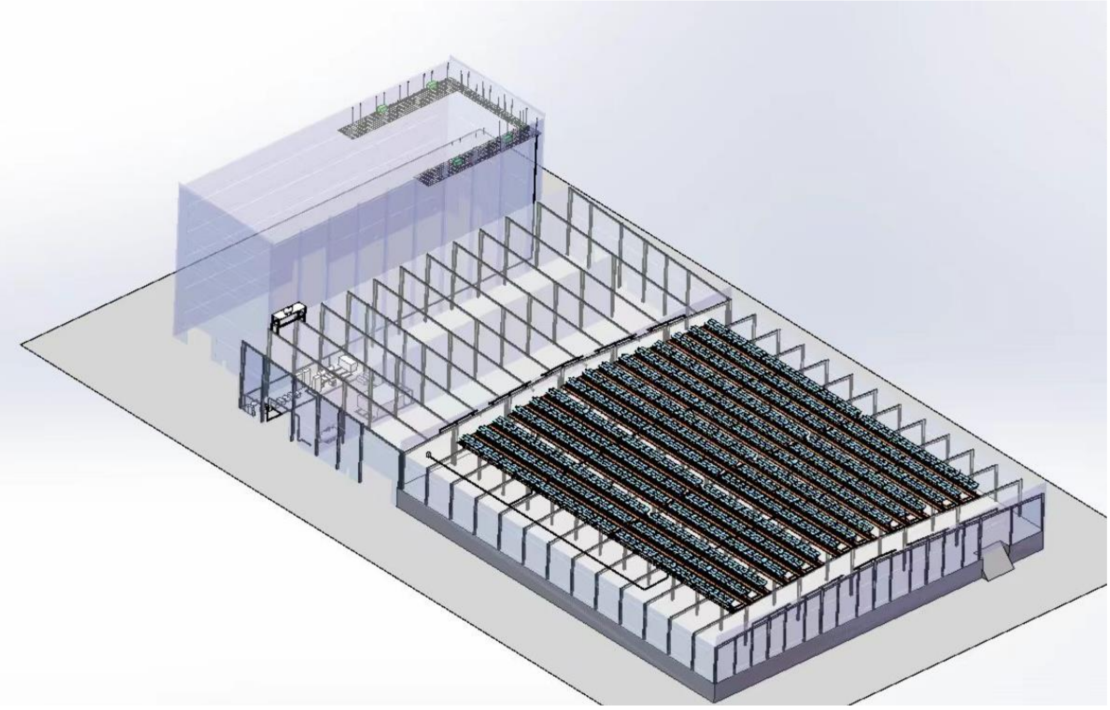
坐标Coordinate 41.912 N,123.391 E



建筑物示意图Building sketch map

	长/length/m	宽/width/m	面积/area/m2
1号屋面	192	24	4608
2号屋面	192	24	4608
3号屋面	66	18	1188
4号屋面	78	18	1404
5号屋面	36	48	1680
6号草坪	26	59	1534

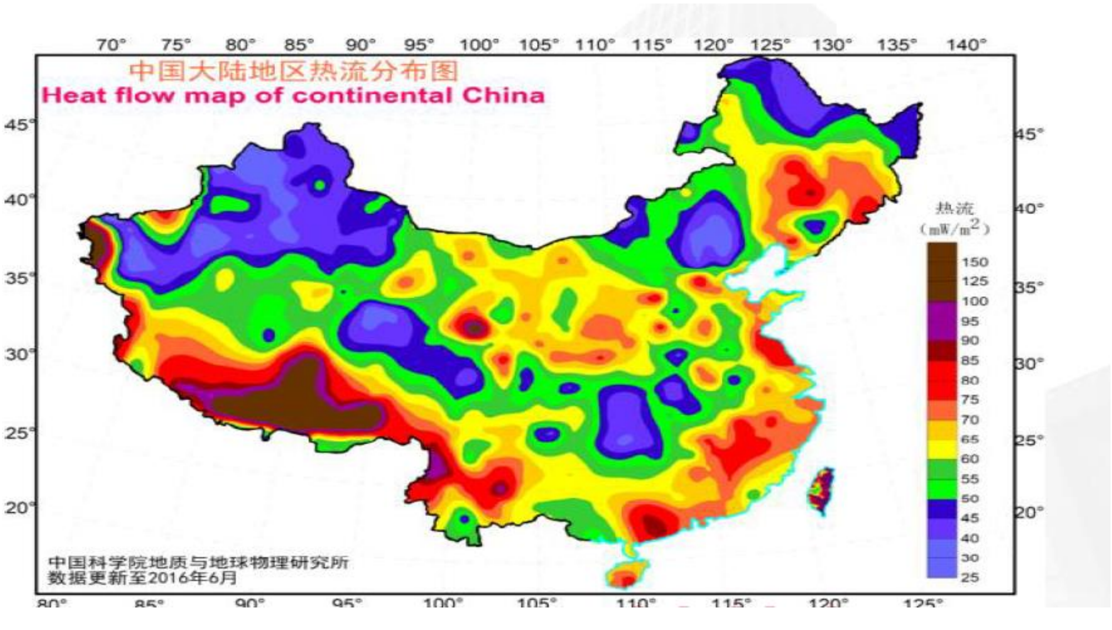
During sunny days, the system collects solar energy and heats the conduction oil, to satisfy the heating requirements for the latter stages of the autoclave process (during the winter, the heat is used for building heating) and save more heat in oil autoclave. During the cloudy or rainy days (and night), the stored, heated oil in the autoclave is first used, with electrical heating to support the autoclave process. In spring, summer and autumn the heat output of the system is enough to support the autoclave processes. During the winter the heat output is enough to support the building heating requirements, (through the heat exchanger heating water for the heating system) and the autoclave process heating is provided by the original electric heating system.

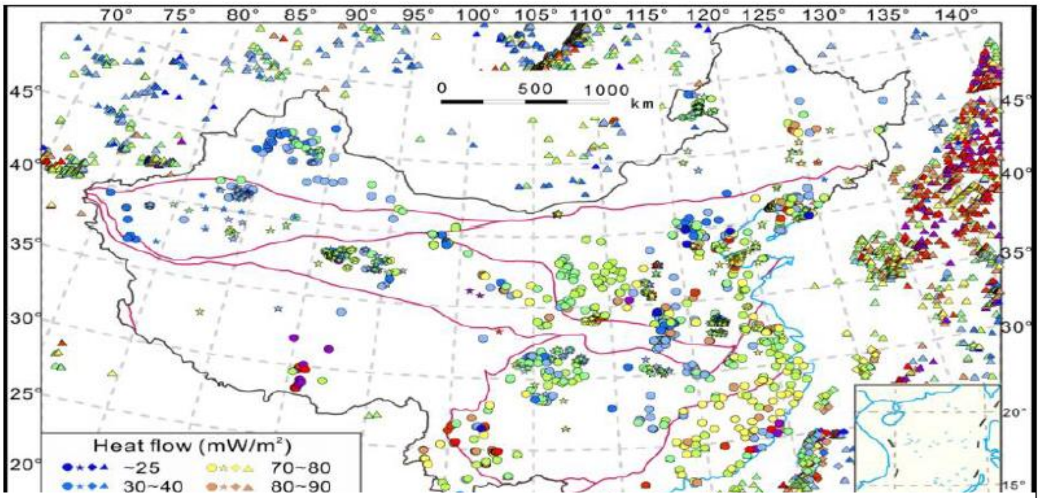


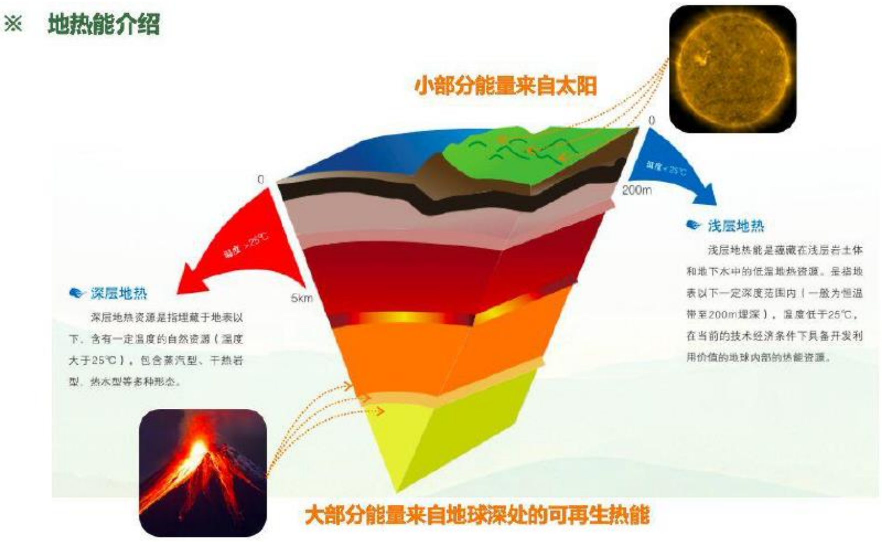
2.3.2.2 Soil Thermal

Shallow geothermal energy is a viable and competitive clean energy source characterized by its vast reserves, widespread availability, green and low-carbon efficiency, and renewability.

In China, 80% of the land area across 366 cities at the prefecture level and above is suitable for shallow geothermal energy development, with an annual exploitable volume equivalent to 700 million tons of standard coal. However, the current extraction rate of shallow geothermal energy is less than 3%, indicating substantial potential for further development and utilization.





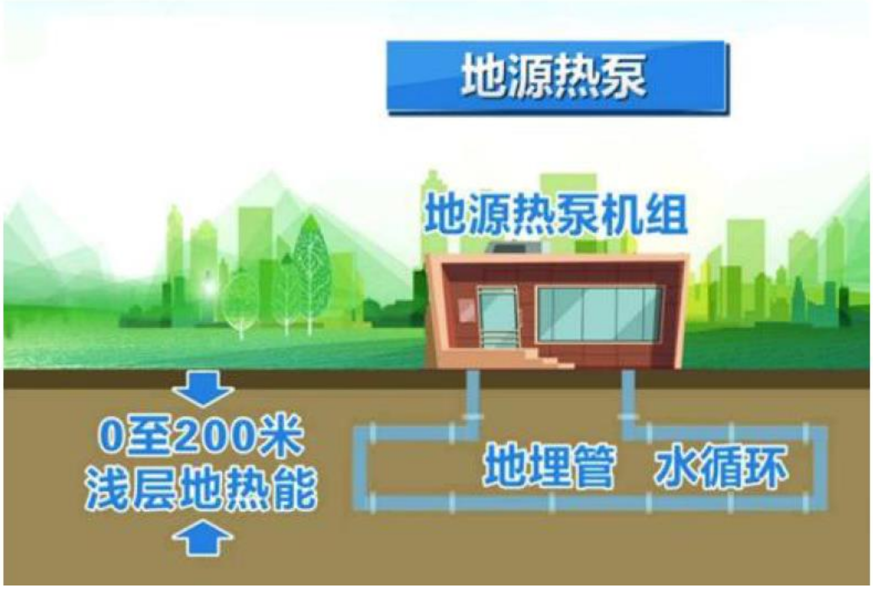


浅层地热

浅层地热能是蕴藏在浅层岩土体和地下水中的低温地热资源。是指地表以下一定深度范围内（一般为恒温带至200m埋深），温度低于25℃，在当前的技术经济条件下具备开发利用价值的地球内部的热能资源。

深层地热

深层地热资源是指埋藏于地表以下、含有一定温度的自然资源（温度大于25℃），包含蒸汽型、干热岩型、热水型等多种形态。



Ground Source Heat Pump (GSHP) technology is the most used method for heating and cooling with shallow geothermal energy. It leverages shallow rock, groundwater, or surface water as low-grade heat and cooling sources, and, through the work of an electric heat pump, it outputs usable high-grade energy.

2.3.3 To analyze the energy savings, emission reductions, and financial impacts of multi-energy coupled systems.

2.3.3.1 Solar energy technical and economic analysis for heating in winter:

2.3.3.1.1 Solar heating parameter definition

1）Annual solar irradiation W=4927.5MJ/m2/y,

2）Direct radiation = 800W/m2

3）Trough annual average thermal efficiency 0.45

4）Electric conversion efficiency = 0.9

5）Thermal exchanger efficiency = 0.8

6）Energy storage efficiency = 0.8

2.3.3.1.2 Solar Thermal Parameters of building and primary Energy

1）Average elec-power cost 0.7RMB/kWh，Off-peak price 0.25RMB/kWh，peak price0.75RMB/kWh

2）Total thermal consumption of building estimated from central distributor，Now central heating pipe inlet temperature around 40 ℃, the return water temperature around 20 ℃.

Daytime: Q=4.2kJ*(40-20)*72m3/h*1000/1000/3.6MJ=1680kW

Night: Q=4.2kJ*(38-28) *72m3/h*1000/1000/3.6MJ=840kW

3）Actual heating space 32,994sqm. equivalent in contract 89,255.54sqm

4）Annual central heating cost = 2,790,000RMB

2.3.3.1.3 Solar Operation Model in Winter

1) Use Solar heating to cover day-time consumption of building, with auxiliary heating from heated liquid in storage tank.

2) Use super off-peak time power to heat liquid and store energy to supplement daytime heating, as well as providing basic nighttime heating.

2.3.3.1.4 Solar Heating cost analysis in winter

1）Overall cost of energy consumption in winter

Total consumption data in winter was deducted from municipal heating distributor meters, power required during daytime is 1680kW, and 840kW in work off time to maintain minimum requirement. The total consumption for all 150days is

3,585,600kWh.

2）Energy provided by solar

The solar can offer 520,540kWh for heating.

3) Energy provided by electricity

Elec-power to compensate for shortfall of 3,961,460kWh comes from using from super-off peak in night. Cost estimated as 1,100,405RMB.

The simulation shows we will have 2,790,000RMB-1,100405RMB=1,689,594RMB savings.

3.5 Soil energy technical and economic analysis for heating in winter:

2.3.2.2 Soil energy technical and economic analysis for heating in winter:

2.3.3.2.1 heating parameter definition

Surface-level water bodies and rock formations act as vast solar collectors, storing 47% of solar radiation energy. High-temperature medium exchange systems leverage this nearly limitless solar energy—or small amounts of geothermal energy—stored in rock, groundwater, or surface water (such as rivers, lakes, seas, and even wastewater) as low-temperature heat sources. By applying the heat pump principle, these systems transfer low-grade thermal energy to higher-grade usable heat using minimal electric input.

In winter, heat pump units extract heat from the ground source (shallow water bodies or rock formations) to supply heating for buildings. In summer, the heat pump absorbs indoor heat and releases it back into the ground source, thus providing air conditioning. The high-temperature medium exchange system consists of an energy collection system, an energy enhancement system, and an energy release system, forming an integrated heating and cooling solution.

Legendary Electric (Shenyang) Co., Ltd. has combined its solar energy system with a high-temperature medium exchange system, allowing excess solar heat in summer to be stored within the exchange system, thereby reducing solar energy waste. The stored heat can also supplement the exchange system's heat needs, creating a mutually beneficial synergy between the two systems."

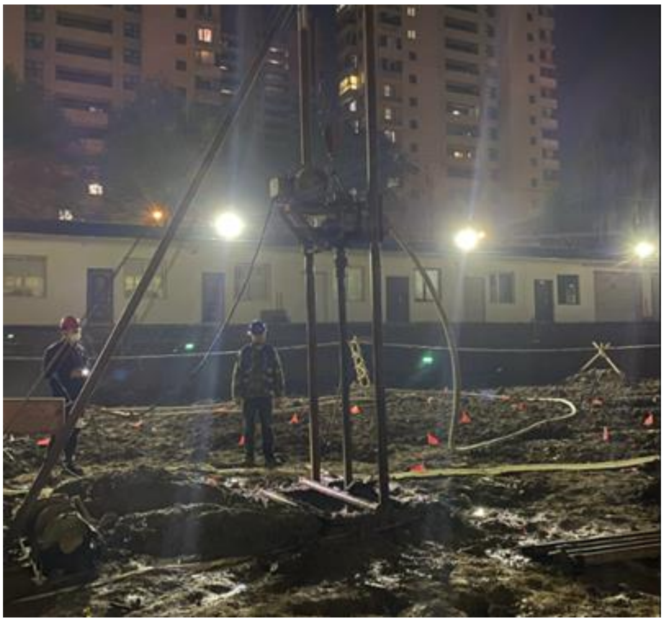
2.3.3.2.2 Pumping and Recharge Tests in the Demonstration Project Area

The demonstration project is located in the northern part of Shenyang. The aquifer mainly consists of fine sand with occasional coarse sand and gravel layers, with a roof depth of 10–15 meters and groundwater level depth between 5 and 15 meters. For this demonstration project, stable flow pumping and artesian recharge tests with three-step drawdowns were conducted in three groundwater environmental monitoring wells at the River Guest House.

2.3.3.2.2.1 Pumping Test Using data from single-well steady flow pumping tests in an unconfined aquifer, hydrogeological parameters are calculated using the following formula:

where:

- KKK = permeability coefficient, measured in m/d,
- QQQ = steady pumping or recharge rate, measured in m3/dm^3/dm3/d,
- HHH = initial aquifer thickness before pumping, measured in m,
- hhh = aquifer thickness during pumping, measured in m,
- SSS = water level drawdown or rise, measured in m,
- RRR = radius of influence, measured in m,
- rrr = filter radius, measured in m."



Key parameters from the 2 sets of pumping tests are shown in Table 1.

As observed in Table 1, the average specific yield across the three tests is 9.36 m³/(h·m), indicating that the aquifer in the construction area has relatively good water-bearing properties.

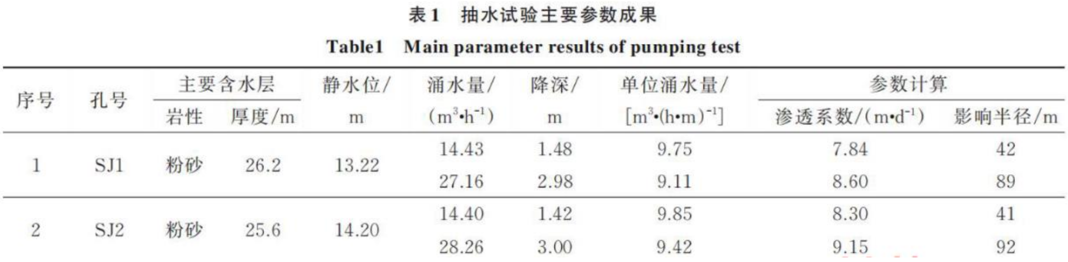


表 1　抽水试验主要参数成果

Table1　Main parameter results of pumping test

序号	孔号	主要含水层		静水位/m	涌水量/($m^3 \cdot h^{-1}$)	降深/m	单位涌水量/[$m^3 \cdot (h \cdot m)^{-1}$]	参数计算	
		岩性	厚度/m					渗透系数/($m \cdot d^{-1}$)	影响半径/m
1	SJ1	粉砂	26.2	13.22	14.43	1.48	9.75	7.84	42
					27.16	2.98	9.11	8.60	89
2	SJ2	粉砂	25.6	14.20	14.40	1.42	9.85	8.30	41
					28.26	3.00	9.42	9.15	92

2.3.3.2.2.2 Recharge Test

The lithology in this area primarily consists of siltstone and fine sandstone, which, as shown in Table 2, indicates relatively low permeability. Using data from the pumping and recharge tests, a recharge rate variation curve was plotted (as shown in Figure 2). During the first 20 minutes of recharge, the water level changed rapidly, but as time progressed, the water level continued to rise while the recharge rate gradually slowed. According to data from the SJ2 borehole recharge test, the recharge volume reached 107.37 m³/d. Additionally, the groundwater table in the aquifer within the construction area lies at a shallow depth of 5–15 meters, leading to an overall assessment of weak recharge capacity for the aquifer."

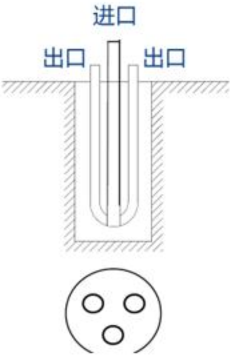
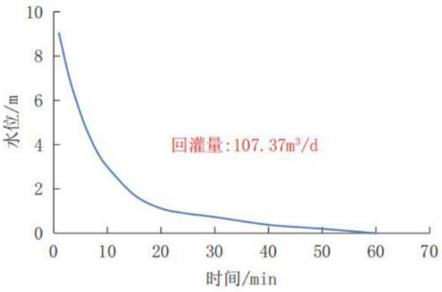


Table 2 Recharge Volume Variation Over Time for Borehole borehole (SJ2).



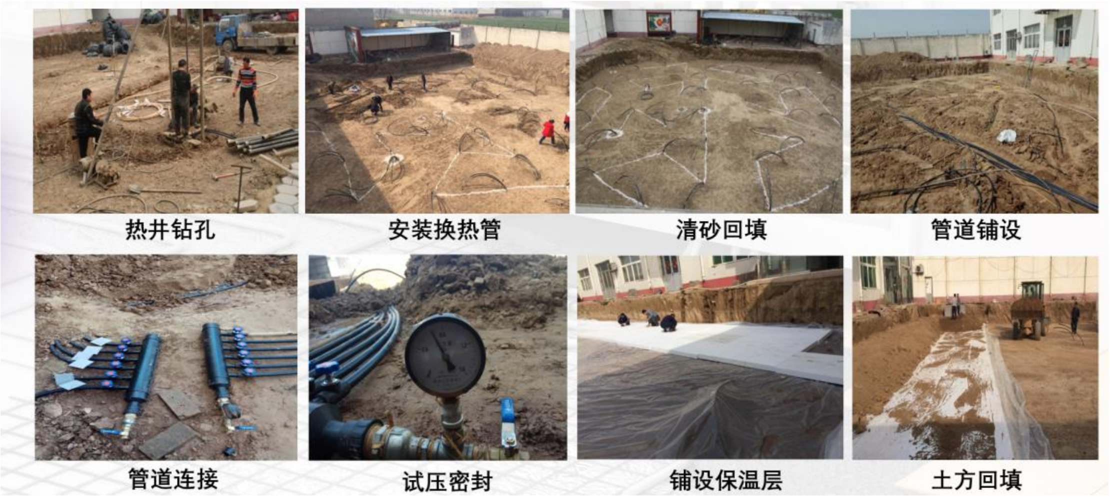
2.3.3.2.2.3 Thermal Physical Parameter Testing of Rock and Soil

A total of 200 undisturbed soil samples were collected from four thermal response test boreholes and 14 geological boreholes to measure thermal physical parameters across various rock and soil types (see Table 3 and Figures 2–2). The relationship curves in Figures 2–2 reflect the following characteristics of the thermal physical parameters for different lithologies:

1. As rock particles become finer, the thermal conductivity (λ) and thermal diffusivity (αtend to increase, while the volumetric heat capacity (CCC) tends to decrease.

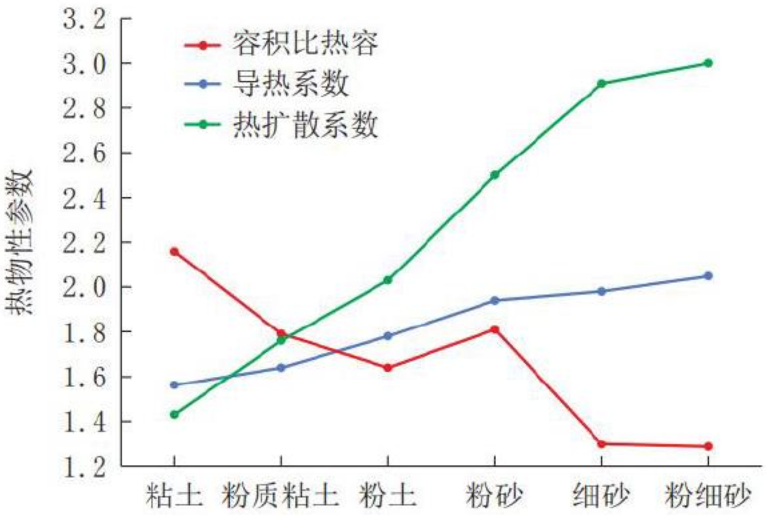
2. In different lithologies, the water content of the rock decreases as particle size becomes finer.

3. Across various lithologies, thermal conductivity (λ) and thermal diffusivity (α) are negatively correlated with water content, while volumetric heat capacity (CCC) is positively correlated with water content.

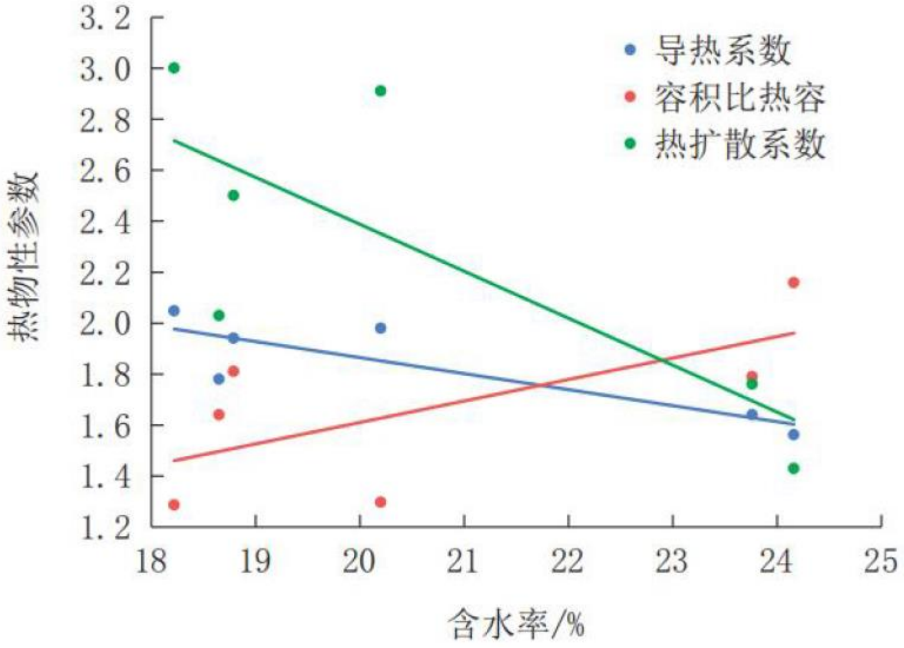


2.3.3.2.2.4 On-site Thermal Response Test Analysis\

Four thermal response tests were conducted at selected points within the demonstration area. The boreholes for these tests were drilled to a depth of 152 meters, with double U-type heat exchangers installed at a depth of 152 meters. The embedded pipe diameter was DN32 mm with a thick wall of 3.0 mm.



te [illegible] d high-power constant heat flow. After each heating (or cooling) load was stopped, a ground temperature recovery test was performed. The test results are shown in Table 3 and Figure 5.



The results indicate the following: The thermal conductivity of rock is minimally affected by different heating conditions (high-power versus low-power). Thus, when selecting heating power and test parameters for on-site experiments, it is advisable to design and choose values based on actual operational parameters of the project. For this study, thermal response parameters were determined by weighted values from tests at varying power levels, as well as from indoor experimental data.

Boreholes DJ1 and DJ3 are located on the same site, 80 meters apart. Under similar high heating power conditions, the thermal conductivity obtained varied by approximately 14.1%. Analysis suggests that this difference could be due to variations in the average inlet water temperature for the embedded pipes. Borehole DJ4 showed the same thermal conductivity value under two significantly different heating power levels, which falls within the allowable error margin.

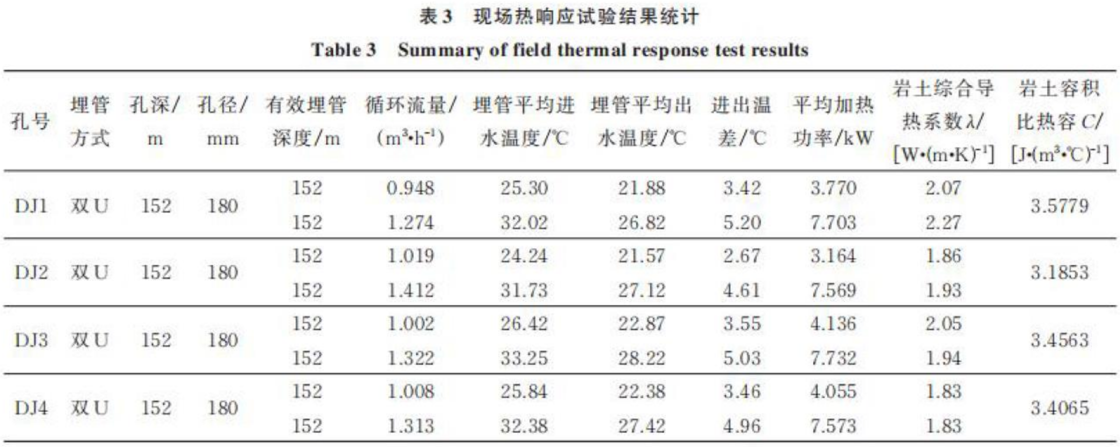


表 3　现场热响应试验结果统计

Table 3　Summary of field thermal response test results

孔号	埋管方式	孔深/m	孔径/mm	有效埋管深度/m	循环流量/($m^3 \cdot h^{-1}$)	埋管平均进水温度/℃	埋管平均出水温度/℃	进出温差/℃	平均加热功率/kW	岩土综合导热系数λ/[$W \cdot (m \cdot K)^{-1}$]	岩土容积比热容C/[$J \cdot (m^3 \cdot ℃)^{-1}$]
DJ1	双U	152	180	152	0.948	25.30	21.88	3.42	3.770	2.07	3.5779
				152	1.274	32.02	26.82	5.20	7.703	2.27	
DJ2	双U	152	180	152	1.019	24.24	21.57	2.67	3.164	1.86	3.1853
				152	1.412	31.73	27.12	4.61	7.569	1.93	
DJ3	双U	152	180	152	1.002	26.42	22.87	3.55	4.136	2.05	3.4563
				152	1.322	33.25	28.22	5.03	7.732	1.94	
DJ4	双U	152	180	152	1.008	25.84	22.38	3.46	4.055	1.83	3.4065
				152	1.313	32.38	27.42	4.96	7.573	1.83	

Subsurface Soil

The test boreholes were each drilled to a depth of 152 meters. In the working area, the initial average temperature of the soil above 152 meters ranged from approximately 17.47 to 18.08 °C. Details on the backfill methods and heat exchange results for each borehole are provided in Table 4 and Figure 6.

The test results indicate that using medium-fine sand for backfill provides the best heat exchange performance (DJ1 double U-type). This is followed by grout backfill (DJ4), which was effective due to a high sand content in the grout mixture, given the significant cumulative sand layer thickness encountered in the drilling. Cement mixed with medium-fine sand, and bentonite mixed with medium-fine sand, were less effective. Compared to grout backfill, using medium-fine sand as the backfill material improved heat discharge and heat absorption capacities by 4.3% and 6.7%, respectively, under modeled conditions. Using a cement and fine sand backfill further enhances heat discharge capacity.

Using cement mixed with fine sand for backfill reduced heat discharge and absorption capacities by 1.5% and 4.8%, based on heat exchange capacity comparisons between the 'double U' and 'single U' configurations in borehole DJ1, it was observed that, while the 'single U' configuration reduces the length of the heat exchange pipe by half, it still maintains significant heat exchange capacity. However, the 'single U' design results in a 20.69% decrease in heat discharge per meter and an 11.99% decrease in heat absorption per meter compared to the 'double U.'

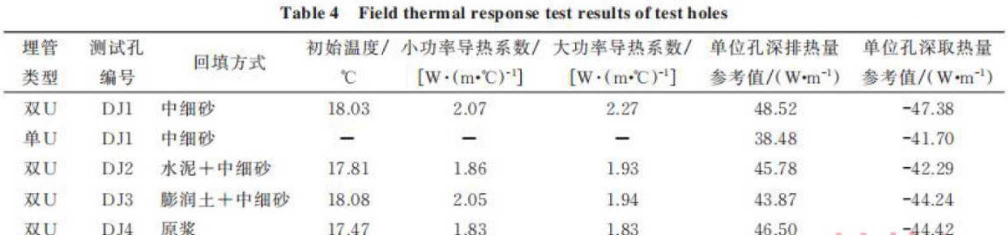


Table 4 Field thermal response test results of test holes

埋管类型	测试孔编号	回填方式	初始温度/℃	小功率导热系数/[W·(m·℃)$^{-1}$]	大功率导热系数/[W·(m·℃)$^{-1}$]	单位孔深排热量参考值/(W·m^{-1})	单位孔深取热量参考值/(W·m^{-1})
双U	DJ1	中细砂	18.03	2.07	2.27	48.52	-47.38
单U	DJ1	中细砂	—	—	—	38.48	-41.70
双U	DJ2	水泥+中细砂	17.81	1.86	1.93	45.78	-42.29
双U	DJ3	膨润土+中细砂	18.08	2.05	1.94	43.87	-44.24
双U	DJ4	原浆	17.47	1.83	1.83	46.50	-44.42

2.3.3.2.4 Dynamic Monitoring of Geological Environmental Impacts

The subsurface soil heat exchange system uses a closed-loop pipeline through which the heat transfer medium circulates, enabling thermal exchange with the surrounding rock and soil layers without direct contact with groundwater. This setup prevents potential disturbances to groundwater quality, water levels, and other parameters. To assess the environmental impact of the project, 15 geological environmental monitoring wells and 3 groundwater environmental monitoring wells were installed at various locations on the site, with sensors placed at different depths. Regular sampling and laboratory testing are conducted to enable long-term dynamic monitoring of changes in subsurface soil temperature fields, groundwater temperature, water quality, and microbiological conditions.

2.3.3.2.5 Calculation of Heating Load for Buildings

The demonstration project and heating building are located in shenyang shenbei Town, the structure is a two-story residential building with a total area of 1,200 m², of which 600 m² has exterior wall insulation. Referring to Shenyang standards, the heat load index for the insulated area is calculated at 50 W/m², and the heating system uses a low-temperature hot water radiant floor system. The remaining 600 m² lacks wall insulation, and the heat load index is calculated at 80 W/m², with fan coil units providing warm air for heating (the effective heating volume is adjusted to

1,500 m²).

The total building heat load is calculated as follows:

50×600+80×600=30000+48000=78000W=78kW。

The daily required heat supply is:

Q=78×60×60×24=6739200KJ=6739.2MJ

For a 120-day heating season, the total heat supply requirement is:

Q=6739.2×120=808704MJ

2.3.3.2.6 Soil Thermal Storage Design

Assuming a 120-day heating period and a 30% solar contribution rate during winter (actual rate expected to be ≥50%), the soil thermal storage system is designed to provide 70% of the heating requirement, accounting for a 20% heat transmission loss and using 80% effective heating.

The total heat release required from the soil thermal storage for the heating season is calculated as:

Q=808704×0.7÷0.8=707616MJ

The heat storage capacity per cubic meter of soil (to be released during the heating season) is:

$$1000\times(1.9\sim2.0)\times(1.4\sim1.5)\times(65-35)=79800\sim90000\,\mathrm{kJ}$$

where:

- Soil bulk density is 1.9–2.0 $\mathrm{g/cm^3}$,

Soil specific heat capacity is **cv：1.4～1.5J/(g·℃)**

- Temperature drop **$t_{\triangle}$：65℃-35℃=30℃**

With a spacing of 2.5 m between boreholes, the thermal storage volume per borehole is:

$$1.25\times1.25\times\pi\times35=171.8\ \mathrm{m}^3$$

Based on the principle of maximizing volume and minimizing surface area to reduce heat loss, the effective borehole depth for thermal storage is set to 35 m.

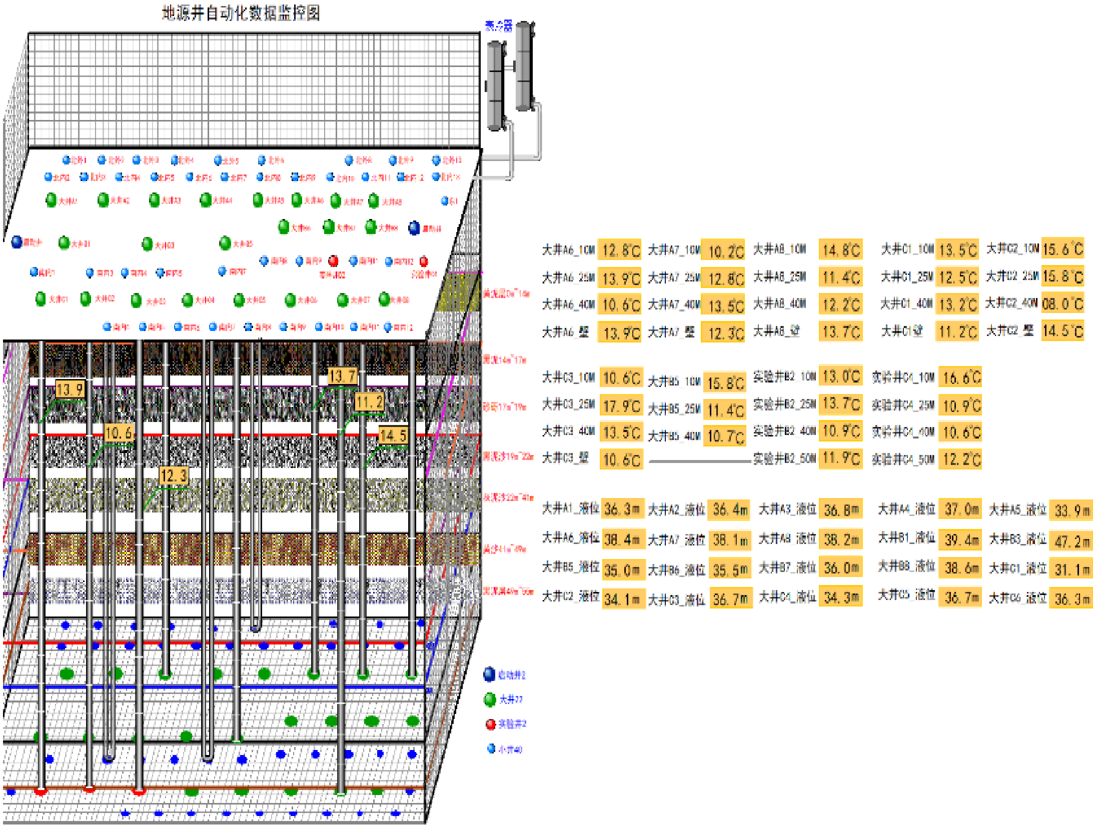
The heat storage capacity per borehole is:

$$(79800\sim90000)\times170=13566\sim15300\,\mathrm{MJ}$$

The required number of soil thermal storage boreholes is:

$707616\div(13566\sim15300)=47\sim53$ boreholes.

Taking into account spatial layout and monitoring wells, the actual engineering design specifies a total of 56 boreholes.

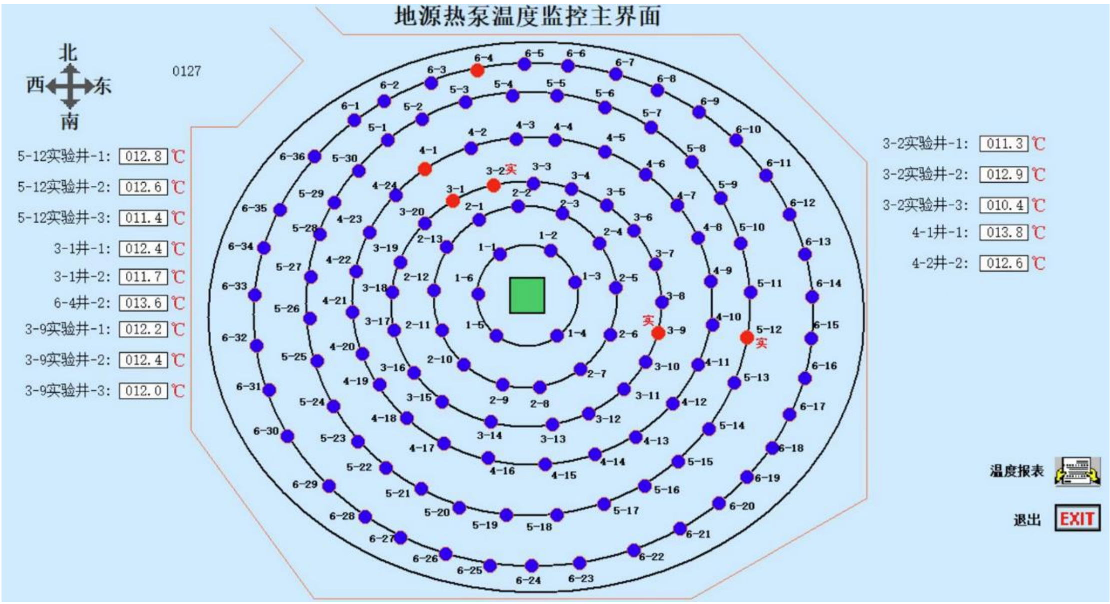


地源井自动化数据监控图

大井A6_10M	12.8℃	大井A7_10M	10.2℃	大井A8_10M	14.8℃	大井C1_10M	13.5℃	大井C2_10M	15.6℃
大井A6_25M	13.9℃	大井A7_25M	12.8℃	大井A8_25M	11.4℃	大井C1_25M	12.5℃	大井C2_25M	15.8℃
大井A6_40M	10.6℃	大井A7_40M	13.5℃	大井A8_40M	12.2℃	大井C1_40M	13.2℃	大井C2_40M	08.0℃
大井A6_壁	13.9℃	大井A7_壁	12.3℃	大井A8_壁	13.7℃	大井C1壁	11.2℃	大井C2_壁	14.5℃

大井C3_10M	10.6℃	大井B5_10M	15.8℃	实验井B2_10M	13.0℃	实验井C4_10M	16.6℃
大井C3_25M	17.9℃	大井B5_25M	11.4℃	实验井B2_25M	13.7℃	实验井C4_25M	10.9℃
大井C3_40M	13.5℃	大井B5_40M	10.7℃	实验井B2_40M	10.9℃	实验井C4_40M	10.6℃
大井C3_壁	10.6℃			实验井B2_50M	11.9℃	实验井C4_50M	12.2℃

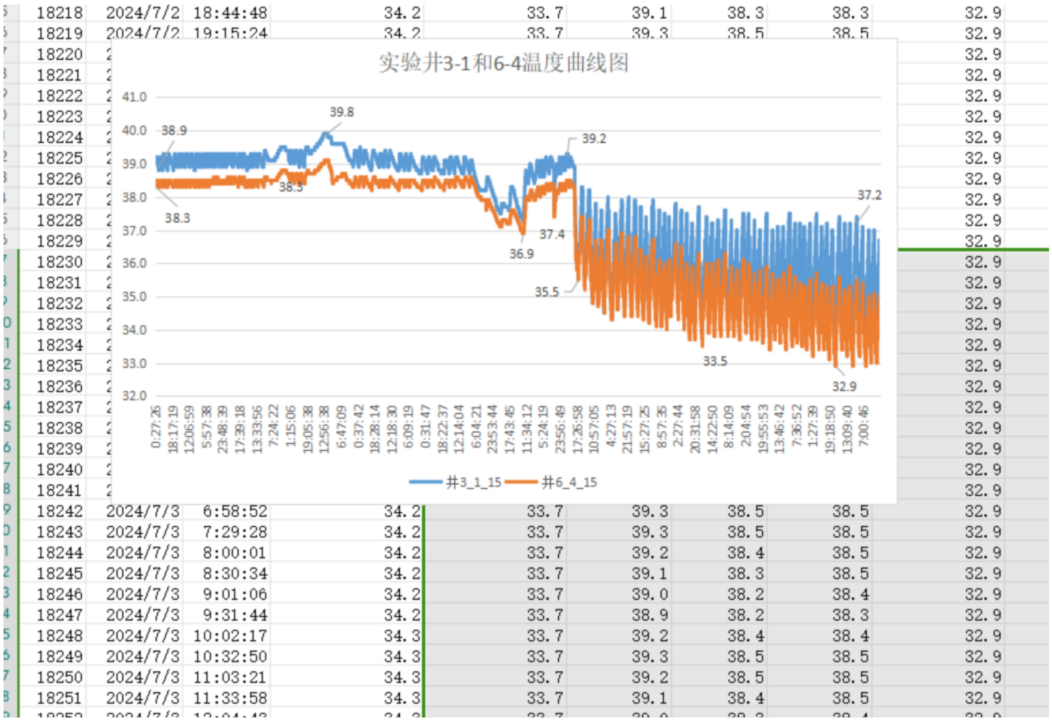
大井A1_液位	36.3m	大井A2_液位	36.4m	大井A3_液位	36.8m	大井A4_液位	37.0m	大井A5_液位	33.9m
大井A6_液位	38.4m	大井A7_液位	38.1m	大井A8_液位	38.2m	大井B1_液位	39.4m	大井B3_液位	47.2m
大井B5_液位	35.0m	大井B6_液位	35.5m	大井B7_液位	36.0m	大井B8_液位	38.6m	大井C1_液位	31.1m
大井C2_液位	34.1m	大井C3_液位	36.7m	大井C4_液位	34.3m	大井C5_液位	36.7m	大井C6_液位	36.3m



地源热泵温度监控主界面

5-12实验井-1: 012.8℃
5-12实验井-2: 012.6℃
5-12实验井-3: 011.4℃
3-1井-1: 012.4℃
3-1井-2: 011.7℃
6-4井-2: 013.6℃
3-9实验井-1: 012.2℃
3-9实验井-2: 012.4℃
3-9实验井-3: 012.0℃

3-2实验井-1: 011.3℃
3-2实验井-2: 012.9℃
3-2实验井-3: 010.4℃
4-1井-1: 013.8℃
4-2井-2: 012.6℃



18218	2024/7/2	18:44:48	34.2	33.7	39.1	38.3	38.3	32.9
18219	2024/7/2	19:15:24	34.2	33.7	39.3	38.5	38.5	32.9
18220								32.9
18221								32.9
18222								32.9
18223								32.9
18224								32.9
18225								32.9
18226								32.9
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18237								32.9
18238								32.9
18239								32.9
18240								32.9
18241								32.9
18242	2024/7/3	6:58:52	34.2	33.7	39.3	38.5	38.5	32.9
18243	2024/7/3	7:29:28	34.2	33.7	39.3	38.5	38.5	32.9
18244	2024/7/3	8:00:01	34.2	33.7	39.2	38.4	38.5	32.9
18245	2024/7/3	8:30:34	34.2	33.7	39.1	38.3	38.5	32.9
18246	2024/7/3	9:01:06	34.2	33.7	39.0	38.2	38.4	32.9
18247	2024/7/3	9:31:44	34.2	33.7	38.9	38.2	38.3	32.9
18248	2024/7/3	10:02:17	34.3	33.7	39.2	38.4	38.4	32.9
18249	2024/7/3	10:32:50	34.3	33.7	39.3	38.5	38.5	32.9
18250	2024/7/3	11:03:21	34.3	33.7	39.2	38.5	38.5	32.9
18251	2024/7/3	11:33:58	34.3	33.7	39.1	38.4	38.5	32.9


热井钻孔


安装换热管

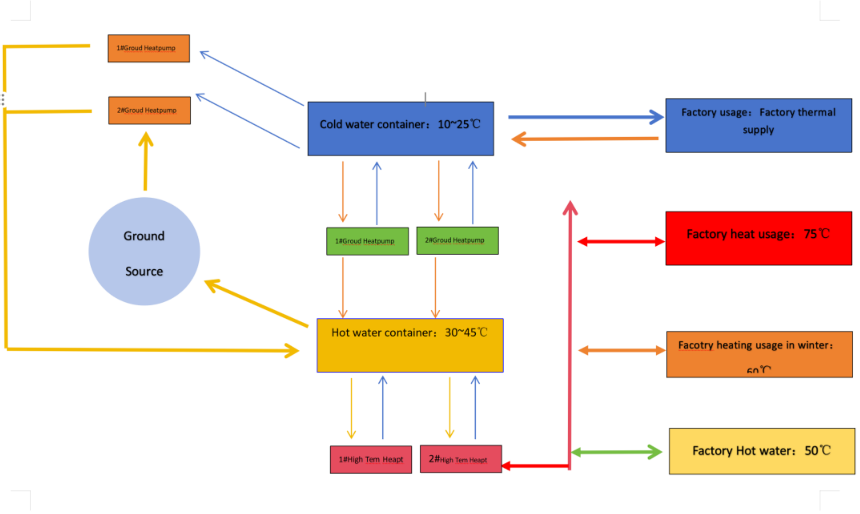

管道铺设


管道连接


试压密封

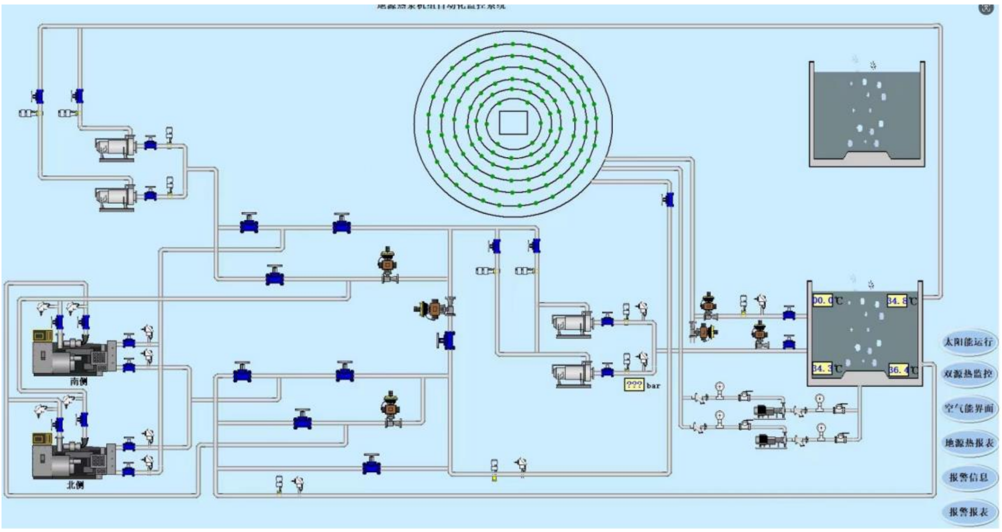

铺设保温层

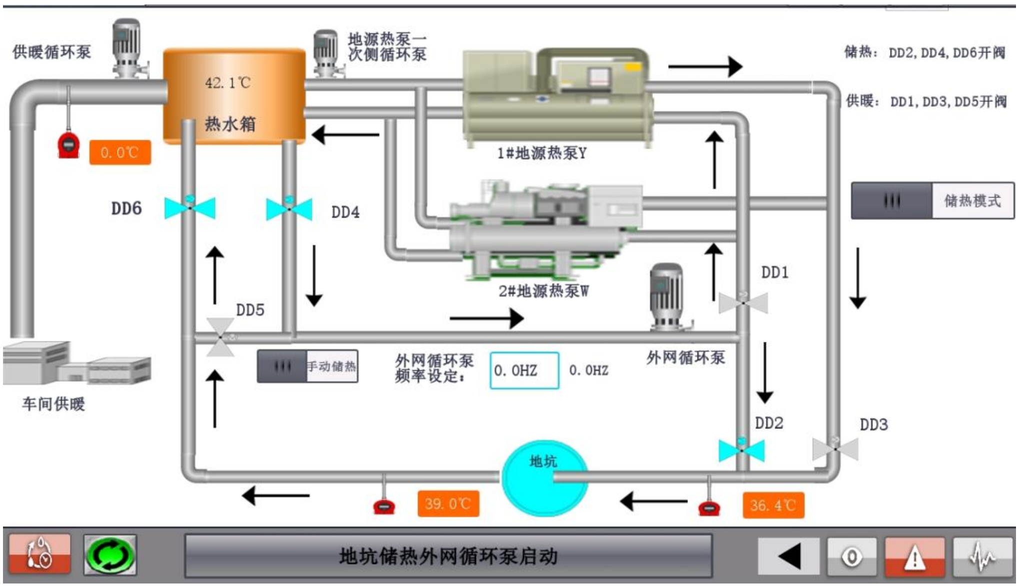

土方回填



2.3.3.2.7 Automatic Control and Operation of the Soil Thermal Storage System

1. Operation Mode: The automatic control system prioritizes solar energy for instant heating in the winter. The thermal storage system operates with a centralized heat storage and release model.





2.3.4 Heat Storage in Spring, Summer, and Autumn from solar energy

These seasons serve as the heat storage phase. During this time, the solar collection system transfers heat to the soil thermal storage. The solar collector heats a thermal buffer tank, and once the tank reaches the set temperature, the automatic control system activates the circulation pump for soil thermal storage. When the tank temperature falls below the set threshold, the circulation pump automatically shuts off.

2.3.4.1 Heat Release in Winter:

Winter marks the heat release phase for heating. The solar collector heats the buffer tank, and when the tank temperature falls below the set value, the circulation pump of the soil thermal storage system is activated to extract heat from the soil and transfer it to the buffer tank. (In the first two years, if the soil thermal storage temperature is insufficient, an auxiliary electric heating system can be activated.) The automatic control system monitors room temperatures and, as needed, activates the circulation pump to deliver heat to the rooms.

Initial Temperature and Heat Storage Performance of the Soil Thermal Pool:

The initial temperature of the soil thermal pool is approximately 15°C at depths of 1 to 8 meters and 14.6°C at depths of 8 to 35 meters.

The solar collector system supplies water at a minimum of 50°C, reaching up to 60°C at peak. The heated water is circulated through the thermal pool for heat release and reuse.

After heat storage begins, the soil temperature rises by approximately 1°C every 10 days initially. Once the soil temperature reaches 22–24°C, the rate of temperature increase slows to about 1°C every 15 days. By the end of the heat storage period on November 15, 2018, the center temperature of the thermal pool was 39°C, with an average temperature of 31.7°C, reflecting an 8-month temperature increase of approximately 17°C.

On November 15, 2018, the solar system was switched to heating mode, and heat storage in the thermal pool was paused, entering a temporary heat compensation mode. When heat storage resumed on March 15, 2019, the initial center temperature of the thermal pool was 31°C, with an average temperature of 29°C. By November 15, 2019, the center temperature had reached 41°C, and the average temperature rose to 37°C, showing an 8-month increase of approximately 8°C.

The original design anticipated an initial heat storage duration of 24 months. However, favorable weather conditions enabled a faster temperature increase, allowing the soil thermal pool to reach the required heating temperature within just 18 months. On November 15, 2019, the thermal pool was utilized to begin providing heat.

2.3.4.2 2019year of Heating Season: Throughout the 120-day heating season, no electric auxiliary heating was required. During nighttime (8–10 hours), the soil thermal pool provided all the heating. During daytime (14–16 hours), solar energy completely met heating demands for 47 days. On 32 days, the pool supplied supplemental heating, and for 41 days, it provided 100% of the heating needs. Indoor heating maintained an average temperature above 20°C throughout the season.

2.3.4.3 End of 2020 Heating Season and Continued Storage: The heating season concluded on March 15, 2020, but heat storage continued. The average pool temperature, which had dropped to 29.6°C, gradually rebounded due to thermal inertia, reaching approximately 31°Cover the following days. Continued heat storage through May 20, 2020, increased the thermal pool's center temperature to 35.2°C, with an average temperature of 33.8°C. By the start of the 2020 heating season, the soil thermal pool had an average temperature of 41°C, providing a robust heat reservoir for the next cycle.

2.3.4.4 Heating Cost Analysis by Household Electricity Pricing

Based on the household electricity rate of 0.52 yuan per kWh:

- **For 1200 square meters:**
    - Average heating cost per square meter per heating season: 4.1 yuan.
- **For 1500 square meters:**
    - Average heating cost per square meter per heating season: 3.3 yuan.

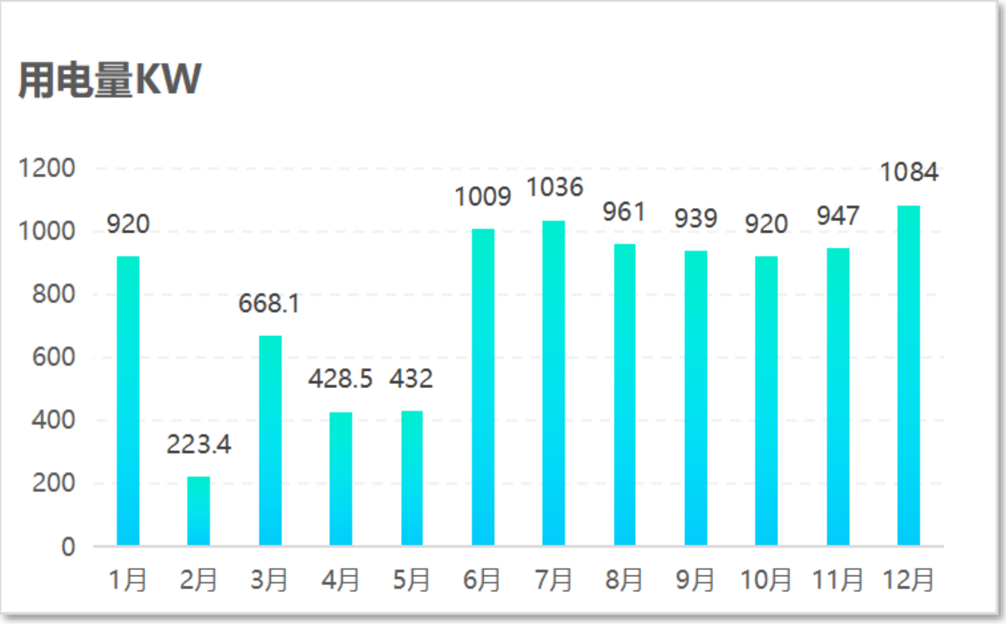
Considering the impact of a tiered electricity rate, with an adjusted average rate of 0.75 yuan per kWh:

- **For 1200 square meters:**
    - Average heating cost per square meter per heating season: 6 yuan.
- **For 1500 square meters:**

  - Average heating cost per square meter per heating season: 4.8 yuan.

This calculation reflects how adjusting for tiered electricity pricing can significantly influence heating costs, especially over large areas.

The total electricity consumption in 2021 was 9,568 kW.



The total project investment was 350,000 yuan. The project design drew on the experience of the Calgary project in Canada, incorporating its own unique innovations:

1. The heat exchange wells in the soil thermal pool are arranged in an isosceles triangular layout, avoiding the uneven thermal gradient and the dead zones in heat storage and release

commonly seen in square layouts in domestic and international projects.

2. By analyzing soil heat capacity variations, a smaller well spacing was chosen, making full use of thermal interference, which shortened the heat storage cycle, reduced the land area required, and enhanced the system's balanced heat storage and release capabilities.

Construction of this case began on March 20, 2018, and was completed by May 5, 2018. Testing concluded on May 15, after which solar energy began to be used for heat storage.

The entire heating system is powered by six 1.1 kW circulating pumps, with only two pumps operating simultaneously, requiring no other energy consumption.

2.3.5 To explore the challenges and limitations of implementing multi-energy systems on a larger scale.

This objective focuses on the practical challenges faced during the implementation and maintenance of multi-energy systems, including technical limitations, the need for skilled labor, and financial constraints. The case will provide recommendations on how these challenges might be overcome through policy adjustments, technological innovations, and increased public awareness.

Multiple green energy technologies—such as parabolic trough solar thermal technology, waste heat recovery systems, geothermal buried pipe systems, and photovoltaic-thermal technology—play a crucial role in improving energy efficiency, reducing waste heat emissions, decreasing reliance on traditional energy sources, and lowering both energy costs and environmental impact.

These green energy technologies follow several core ideas and actions, with broad applicability and a pivotal role in creating a sustainable industrial future:

1. Driving Green Economy with Multi-Energy Coupling for Industrial Parks

Amid escalating global energy and environmental challenges, achieving high-efficiency energy use and sustainable environmental development is increasingly critical for governments and businesses. The "multi-energy coupling and intelligent climate control" system enhances energy efficiency and ensures stable system operation.

Core Advantages: This advanced system integrates various energy technologies and optimizes their combination through intelligent control and monitoring. This enables efficient, safe, and sustainable use of energy. The multi-energy coupling concept and technology have high generalizability and application value across various industries and regions.

Applicable Scenarios: This system is ideal for phased industrial park projects, as it flexibly adapts to diverse energy needs and effectively reduces energy investment and operating costs. It is also well-suited for government-operated industrial parks as a key technology for promoting green economy and environmental sustainability.

2. Government Collaboration and Decision-Making

Implementing such a multi-energy coupling system does not require large-scale or full-load energy investments or complex government support. Instead, it provides a reference framework for green economy policymaking and energy planning for industrial parks.

Call to Action: We encourage all levels of government and industrial parks to incorporate the "multi-energy coupling and intelligent climate control" system into future energy and environmental plans. Through efficient and sustainable energy management, we can invigorate industrial parks while contributing to global environmental protection and sustainable development.

3.Waste Heat Recovery System

The waste heat recovery system converts waste heat from production processes into thermal energy for heating. This recovery method can be applied to other industrial processes to minimize energy waste and environmental pollution. Instead of dissipating surplus heat through cooling towers, this solution reuses valuable low-grade heat in closed-loop applications, as seen in the modified heat pump solution adopted by Shenyang Legend, where passive building concepts are applied in the workshop setting.

4.High-Temperature Medium Exchange System for Seasonal Heat Storage

By utilizing buried pipe systems, excess heat is stored underground and then retrieved in winter via heat pumps for heating purposes. This method can be widely adopted in other regions for long-term heat storage and use. As long as there is open parking space, investment in this low-cost, quickly replicable project is feasible.

Through these green energy applications, industrial parks can achieve energy resilience, cost-efficiency, and environmental sustainability.

3. Significance of Study

The significance of this case lies in its focus on both theoretical insights and practical applications of soil and solar thermal energy within the context of China’s clean energy transition. As China seeks to transition to a low-carbon economy, this study can serve as a useful reference for policymakers, engineers, and researchers interested in developing efficient and sustainable energy systems.

This research also highlights the practical challenges and opportunities of using soil and solar energy at a large scale, drawing insights from the case study of the multi-energy coupled system established in a 30,000m^2 industrial park in China. This system utilizes a variety of clean energy technologies—including solar thermal collectors, thermal storage solutions, and heat pumps—to supply heating and cooling to the park, effectively reducing energy consumption and emissions. By presenting a real-world example, this study can contribute to a broader understanding of how multi-energy systems can be optimized for diverse industrial and commercial applications.

4. Data Analysis and System Performance

This section will present data on energy savings, emissions reductions, and financial impacts of implementing the multi-energy system. The analysis will also compare this system to traditional energy systems, quantifying the advantages and identifying areas for potential improvement.

4.1 2014 Solar Energy Utilization Project by Legendary Electric (Shenyang) Co., Ltd.:

During the heating season of 2014, the project reduced coal consumption by 1,173 tons of standard coal. According to the 2014 national "Energy Audit Guidelines," the carbon dioxide (CO_2) emission coefficient is 2.5 tons of CO_2 per ton of standard coal. This translates into an annual reduction of CO_2 emissions by **2,933 tons**.

During the non-heating season, the project reduced electricity consumption by 1.47 million kWh. Based on the National Development and Reform Commission's CO_2 emission coefficient for Liaoning Province (0.7753 kg CO_2/kWh), the annual reduction of CO_2 emissions amounted to **1,140 tons**.

Total Annual CO_2 Reduction: 4,073 tons.

Cumulative CO_2 Reduction Over 9 Years:

4,073 t/year×9 years=36,657 tons CO_2

4.2 Coupled Energy Source 2: Dual-Source Heat Pump Cooling Project Completed in 2021

4.2.1 Year of 2021 Dual-Source Heat Pump Cooling Project by Legendary Electric (Shenyang) Co., Ltd.:

The project reduced electricity consumption by 810,000 kWh annually. Using the Liaoning Province CO_2 emission coefficient of 0.7753 kg CO_2/kWh, this results in an annual reduction of CO_2 emissions by **628 tons**.

Cumulative CO_2 Reduction Over 2 Years:

628 t/year×2 years=1,256 tons CO_2

Coupled Energy Source 3: Seasonal Soil Source Heat Pump Storage Project Completed in 2022

2022 Waste Heat + Soil Source Heat Pump Heating Project by Legendary Electric (Shenyang) Co., Ltd.:

The project reduced electricity consumption by 2.09 million kWh annually. Using the Liaoning Province CO_2 emission coefficient of 0.7753 kgCO_2/kWh, this led to an annual reduction of CO_2 emissions by **1,620 tons**.

Cumulative CO_2 Reduction Over 1 Year:

1,620 t/year×1 year=1,620 tons CO_2

CO_2 Emission Conversion Factors

1. **CO_2 Emission Coefficient for Standard Coal:** 2.5 tons of CO_2 per ton of standard coal.

2. **CO_2 Emission Coefficient for Electricity in Liaoning:** 0.7753 $kgCO_2/kWh$.

3. **Standard Coal-to-Electricity Conversion:** 1 kWh (1 unit of electricity) equals approximately 0.4 kg of standard coal.

Cumulative Reductions (2014–2022)

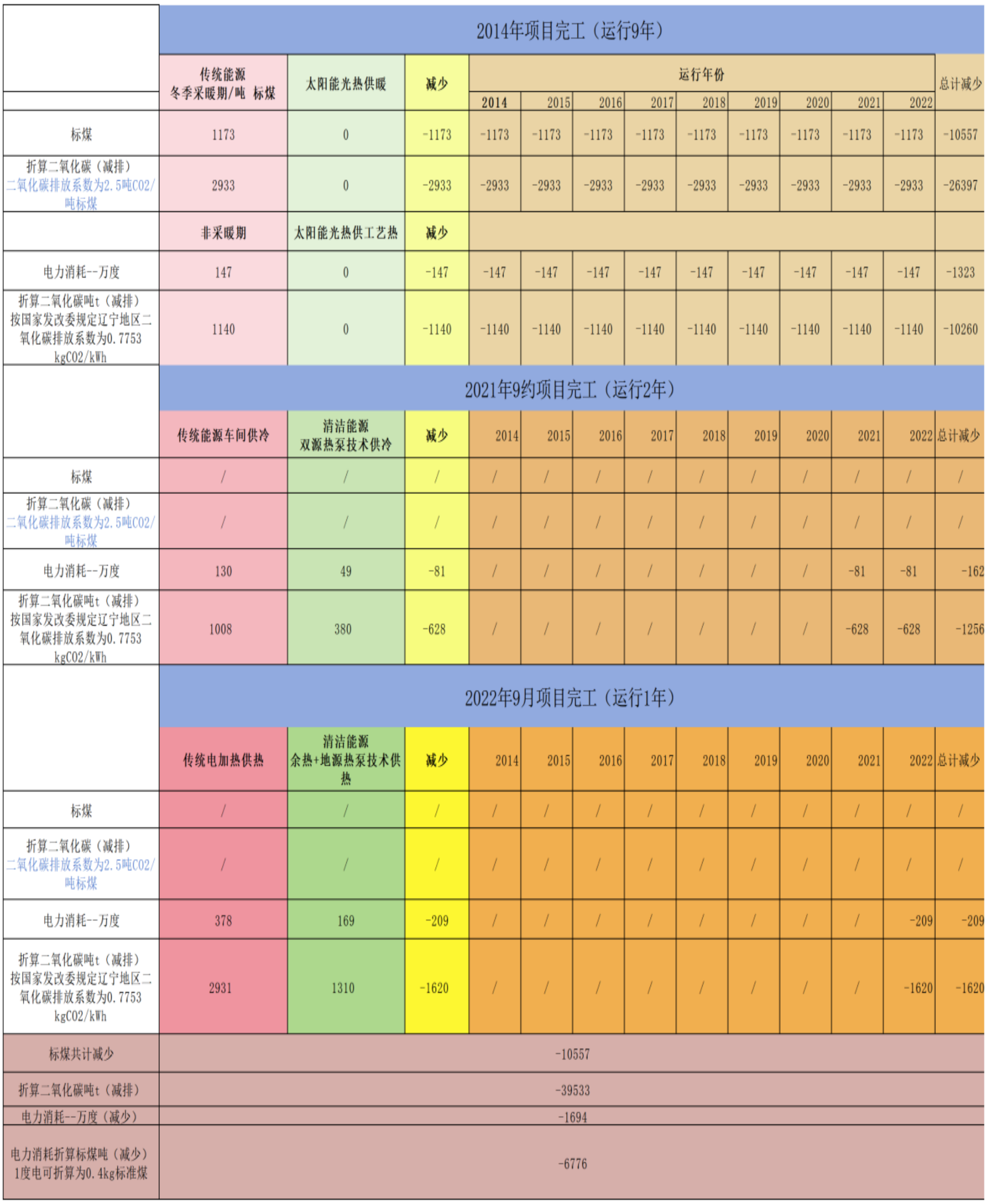
1. **Total Reduction in Standard Coal Consumption:** 10,557 tons.

2. **Total CO_2 Emissions Reduction:** 39,533 tons.

3. **Total Reduction in Electricity Consumption:** 16.94 million kWh.

4. **Reduction in Standard Coal from Electricity Savings:** 6,776 tons.

Summary Table of Key Results



	2014年项目完工（运行9年）												
	传统能源 冬季采暖期/吨 标煤	太阳能光热供暖	减少	运行年份									总计减少
				2014	2015	2016	2017	2018	2019	2020	2021	2022	
标煤	1173	0	-1173	-1173	-1173	-1173	-1173	-1173	-1173	-1173	-1173	-1173	-10557
折算二氧化碳（减排） 二氧化碳排放系数为2.5吨CO2/吨标煤	2933	0	-2933	-2933	-2933	-2933	-2933	-2933	-2933	-2933	-2933	-2933	-26397
	非采暖期	太阳能光热供工艺热	减少										
电力消耗--万度	147	0	-147	-147	-147	-147	-147	-147	-147	-147	-147	-147	-1323
折算二氧化碳吨t（减排）按国家发改委规定辽宁地区二氧化碳排放系数为0.7753 kgCO2/kWh	1140	0	-1140	-1140	-1140	-1140	-1140	-1140	-1140	-1140	-1140	-1140	-10260
	2021年9约项目完工（运行2年）												
	传统能源车间供冷	清洁能源 双源热泵技术供冷	减少	2014	2015	2016	2017	2018	2019	2020	2021	2022	总计减少
标煤	/	/	/	/	/	/	/	/	/	/	/	/	/
折算二氧化碳（减排） 二氧化碳排放系数为2.5吨CO2/吨标煤	/	/	/	/	/	/	/	/	/	/	/	/	/
电力消耗--万度	130	49	-81	/	/	/	/	/	/	/	-81	-81	-162
折算二氧化碳吨t（减排）按国家发改委规定辽宁地区二氧化碳排放系数为0.7753 kgCO2/kWh	1008	380	-628	/	/	/	/	/	/	/	-628	-628	-1256
	2022年9月项目完工（运行1年）												
	传统电加热供热	清洁能源 余热+地源热泵技术供热	减少	2014	2015	2016	2017	2018	2019	2020	2021	2022	总计减少
标煤	/	/	/	/	/	/	/	/	/	/	/	/	/
折算二氧化碳（减排） 二氧化碳排放系数为2.5吨CO2/吨标煤	/	/	/	/	/	/	/	/	/	/	/	/	/
电力消耗--万度	378	169	-209	/	/	/	/	/	/	/	/	-209	-209
折算二氧化碳吨t（减排）按国家发改委规定辽宁地区二氧化碳排放系数为0.7753 kgCO2/kWh	2931	1310	-1620	/	/	/	/	/	/	/	/	-1620	-1620
标煤共计减少	-10557												
折算二氧化碳吨t（减排）	-39533												
电力消耗--万度（减少）	-1694												
电力消耗折算标煤吨（减少） 1度电可折算为0.4kg标准煤	-6776												

5: Broader Applications and Adaptability

This section will discuss the broader applications of soil and solar thermal energy, examining how similar systems can be adapted across different sectors and geographical areas in China. It will also consider how geographical factors, such as regional climate and soil characteristics, influence system performance.

通过与几个权威组织合作，THVS已获得了多个有影响力的认证。

SBTi

SCIENCE BASED TARGETS

DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

温室气体清单

- Scope 1和Scope 2以碳基准数量的形式进行报告。
- 选择2019年作为基准年，2020年作为最接近的年份。

THVS承诺从2019年为基准年，到2030年将一二级温室气体排放量绝对减少80%。

绿色工厂

绿色工厂公示名单

序号	地区	工厂名称	第三方评价机构名称
129	辽宁	喀左丛元号水泥有限责任公司	辽宁省电子信息产品监督检验院
130	辽宁	辽宁艾海滑石有限公司	辽宁省能源研究所有限公司
131	辽宁	辽宁山水工源水泥有限公司	辽宁省电子信息产品监督检验院
132	辽宁	东方国际集装箱（锦州）有限公司	辽宁省电子信息产品监督检验院
133	辽宁	沈阳海为电力装备股份有限公司	中环联合（北京）认证中心有限公司
134	辽宁	通用技术集团沈阳机床有限责任公司	辽宁省电子信息产品监督检验院
135	辽宁	传奇电气（沈阳）有限公司	辽宁省电子信息产品监督检验院
136	辽宁	[illegible]	辽宁省能源研究所有限公司
137	辽宁	沈阳法雷奥车灯有限公司	中环联合（北京）认证中心有限公司
138	辽宁	沈阳敏能汽车零部件有限公司	辽宁省能源研究所有限公司
139	辽宁	延锋汽车饰件系统（沈阳）有限公司	辽宁省能源研究所有限公司
140	辽宁	欧福科技（沈阳）有限公司	辽宁省能源研究所有限公司
141	辽宁	蒙牛乳业（沈阳）有限责任公司	方圆标志认证集团有限公司
142	辽宁	沈阳蒙牛乳制品有限公司	济南经纬方达节能技术有限公司
143	辽宁	辽宁傲农饲料有限公司	沈阳沈化院测试技术有限公司

国家级绿色工厂

- THVS 被列为2022年度绿色制造名单

南德 ISO14067 碳足迹认证

产品碳足迹核查声明

Product Carbon Footprint Verification Statement

TUV认证的产品碳足迹
基于ISO14067标准的从摇篮到门槛的碳足迹认证

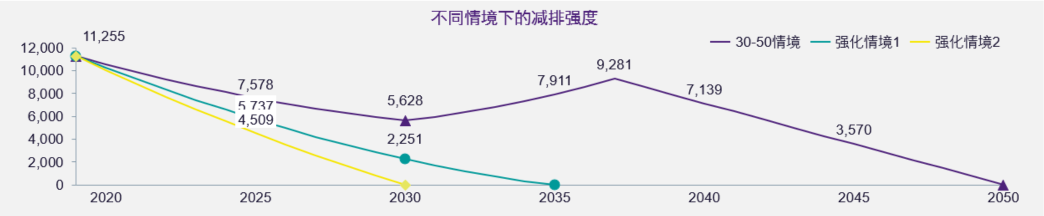
THVS Multiple Influence Certifications

Compared to the conservative "30-50" scenario, the emission reduction targets promoted by major competitors are more aggressive. Taking into account the early focus on climate issues in international markets and the demands of upstream and downstream enterprises for zero-carbon supply chains, we have further analyzed and calculated a more proactive enhanced emission reduction scenario:

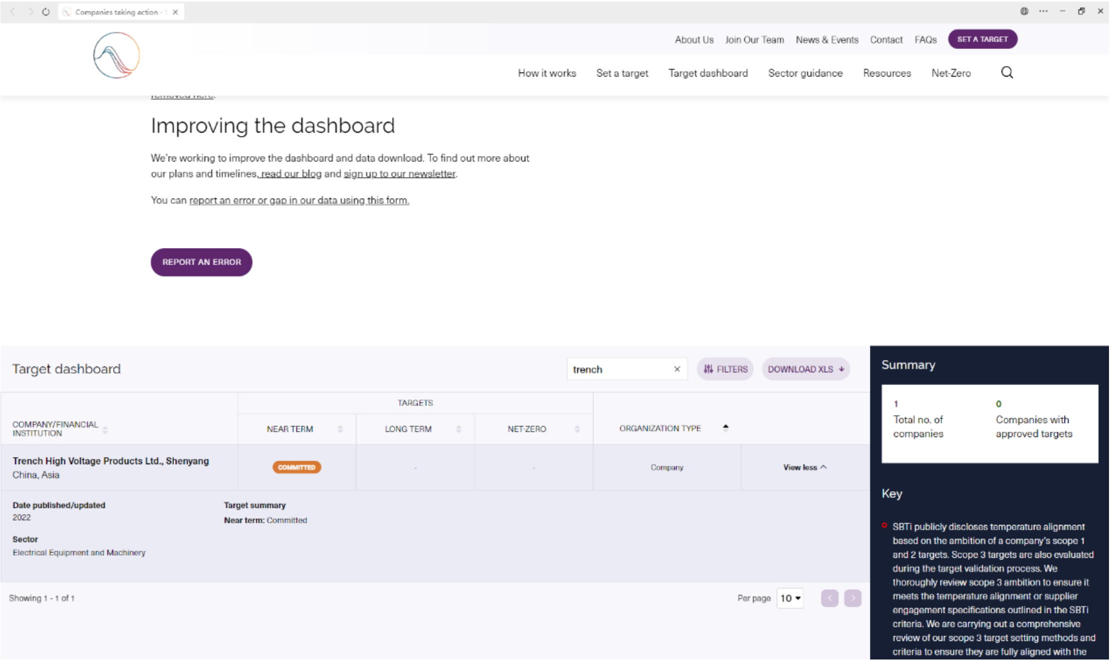
- 30-50 Scenario: 50% emission reduction by 2030 and carbon neutrality by 2050.
- Enhanced Scenario 1: 80% emission reduction by 2030 and carbon neutrality by 2035.

- Enhanced Scenario 2: 100% emission reduction by 2030, achieving carbon neutrality.

Ultimately, we have selected Enhanced Scenario 1 as the carbon reduction target. Figure 3 illustrates the carbon reduction targets.



emission reduction targets



Improving the dashboard

We're working to improve the dashboard and data download. To find out more about our plans and timelines, read our blog and sign up to our newsletter.

You can report an error or gap in our data using this form.

Target dashboard

COMPANY/FINANCIAL INSTITUTION	TARGETS			ORGANIZATION TYPE	
	NEAR TERM	LONG TERM	NET-ZERO		
Trench High Voltage Products Ltd., Shenyang China, Asia	COMMITTED	-	-	Company	View less

Date published/updated
2022

Sector
Electrical Equipment and Machinery

Target summary
Near term: Committed

Showing 1 - 1 of 1

Summary

1
Total no. of companies

0
Companies with approved targets

Key

SBTi publicly discloses temperature alignment based on the ambition of a company's scope 1 and 2 targets. Scope 3 targets are also evaluated during the target validation process. We thoroughly review scope 3 ambition to ensure it meets the temperature alignment or supplier engagement specifications outlined in the SBTi criteria. We are carrying out a comprehensive review of our scope 3 target setting methods and criteria to ensure they are fully aligned with the

https://sciencebasedtargets.org/companies-taking-action?country=China&ambitionToggle=1#table

Legendary Electric (Shenyang) Co., Ltd. has adopted various green energy technologies, including parabolic trough solar thermal technology, waste heat recovery systems, ground pipe systems. These innovations have improved energy efficiency, reduced waste heat emissions, decreased reliance on traditional energy sources, and lowered energy costs and environmental burdens.

Key Approaches and Actions for Green Energy Deployment

1. Promoting Green Economy: Multi-Energy Coupling Technology Leading the Future of Industrial Parks

Against the backdrop of global energy and environmental challenges, efficient energy use and sustainable development have become unavoidable priorities for governments and businesses. Legendary Electric has implemented a "Multi-Energy Coupling, Smart Cooling and Heating" system, which not only enhances energy efficiency but also ensures stable system operation.

Core Advantages:

This advanced system integrates multiple energy technologies with smart control and monitoring to optimize energy utilization. It achieves high efficiency, safety, and sustainability, demonstrating strong adaptability and application potential across various industries.

Applicable Scenarios:

The system is particularly suitable for gradual industrial park projects, addressing diverse energy needs flexibly while minimizing energy investment and operational costs. It is ideal for government-operated industrial parks, serving as a key technology for advancing green economies and sustainable environmental development.

Government Collaboration and Policy Recommendations:

The system requires no large-scale, full-capacity energy investments or complex government measures, making it a practical reference for policymakers. Governments are encouraged to include this system in future energy and environmental plans for industrial parks.

2. Technologies Driving Energy Efficiency

Waste Heat Recovery Systems:

Legendary Electric utilizes waste heat recovery systems to convert production waste heat into thermal energy for heating. Unlike traditional heat pumps that dissipate excess heat through cooling towers, this system reuses low-grade heat sources in a closed-loop cycle. This method can significantly reduce energy waste and pollution, making it replicable in other industrial processes. The approach applies passive building concepts to workshop production environments.

Winter-Summer High-Temperature Medium Exchange Systems:

The company employs a ground pipe system to store surplus heat underground during summer and recover it in winter using heat pumps for heating. This technology enables long-term thermal storage and utilization, providing an affordable, replicable solution for areas with available parking space for installation.

Advantages of "Multi-Energy Coupling, Smart Cooling and Heating" System Cost and Energy Efficiency:

Reduces energy costs while improving economic benefits.

Demonstration Potential:

Suitable as a model project for promotion in industrial and commercial sectors.

Sustainability:

Supports sustainable development by achieving efficient energy use, environmental protection, and economic sustainability.

Aligns with modern society's demand for green growth and environmental conservation.

Call to Action

Legendary Electric's innovations underline the importance of sustainable energy management. Governments and stakeholders are encouraged to integrate "Multi-Energy Coupling, Smart Cooling and Heating" systems into energy and environmental planning. These efforts can inject new vitality into industrial parks while contributing to global environmental protection and sustainable development.

This scalable, practical approach demonstrates a roadmap for other industries and regions to emulate, paving the way for a greener and more efficient energy future.

6: Challenges, Limitations, and Future Directions

This section will outline the technical and financial barriers to scaling up multi-energy systems, proposing potential solutions and exploring future research directions in the field of renewable thermal energy.

- Conclusion and Recommendations

National Rollout of Demonstration Projects:

- Expand the implementation of exemplary renewable energy projects across the country to showcase best practices and drive widespread adoption.

- Evaluation of New Energy Investment Proportion:

  Assess the share of new energy applications in the annual fixed asset investment of provincial, municipal, and district governments.

- Investments should be tied to measurable returns, with monthly reporting of project investment yields to serve as the basis for KPI formulation and evaluation.
- Encouraging Government-Driven Centralized Energy Systems:

  Motivate local governments to prioritize renewable energy revenue contributions.

- Recognize that energy is well-suited for centralized control and encourage the establishment of centralized cooling or heating centers across regions.
- Develop model projects, including centralized energy systems for office buildings, schools, and hospitals.
- Energy Education and Public Awareness Campaigns:
- Use educational initiatives to reshape societal perceptions, fostering a collective mindset around "low-temperature heating and high-temperature cooling."

- Leverage new media platforms to educate the public on the importance of adopting diverse energy types and sustainable practices.
- Transforming Decision-Makers' Perspectives:

Incorporate energy conservation training into Party School curricula to embed awareness at leadership levels.

Strengthening oversight by architectural review centers, implementing an energy accountability system.

Mandate the submission of new building blueprints to a national-level AI-powered platform for random audits, reducing decision-making errors caused by incomplete knowledge.

Adapt academic “plagiarism detection” technology to review individual building energy consumption designs, enhancing accuracy in regulatory processes.

7. Appendices and Supplementary Content

Additional resources, including figures, diagrams, and supplementary data, will be provided to support the findings and conclusions of the research.

[1] European Commission. Delivering the European Green Deal: On the path to a climate-neutral Europe by 2050[EB/OL].

2024.

[2] Gao C, Zhu S, An N, et al. Comprehensive comparison of multiple renewable power generation methods: A combination analysis of life cycle assessment and ecological footprint[J]. Renewable and Sustainable Energy Reviews, 2021, 147: 111255.

[3] Gielen D, Boshell F, Saygin D, et al. The role of renewable energy in the global energy transformation[J]. Energy strategy reviews, 2019, 24: 38-50.

[4] Guo X, Lin K, Huang H, et al. Carbon footprint of the photovoltaic power supply chain in China[J]. Journal of cleaner production, 2019, 233: 626-633.

[5] IEA. Net Zero by 2050-A Roadmap for the Global Energy Sector[R/OL]. 2021.

[6] ISSB. IFRS S1 General Requirements for Disclosure of Sustainability-related Financial Information[EB/OL]. 2023.

[7] ISSB. IFRS S2 Climate-related Disclosures[EB/OL]. 2023.

[8] Lauri Myllyvirta, Qi Qin, et al. Analysis: Clean energy was top driver of China's economic growth in 2023[R/OL]. 2024.

[9] Liang H, You F. Reshoring silicon photovoltaics

manufacturing contributes to decarbonization and climate change mitigation[J]. Nature Communications, 2023, 14(1): 1274.

[10] Liu P, Liu L, Xu X, et al. Carbon footprint and carbon emission intensity of grassland wind farms in Inner Mongolia[J]. Journal of Cleaner Production, 2021, 313: 127878.

[11] Xie Y, Yu H, Ou Y, et al. Environmental impact assessment of recycling waste traction battery[J]. Inorg. Chem. Ind, 2015, 47(4): 43-46.

[12] Zhai P, Williams E D. Dynamic hybrid life cycle assessment of energy and carbon of multicrystalline silicon photovoltaic systems[J]. Environmental science & technology, 2010, 44(20): 7950-7955.

[13] Elco。http://www.elco.net

[14]国际能源机构。http://www.iea.org

[15]国际金属太阳能产业联盟。2017年，《中国太阳能区域供热》。

[16]黄俊鹏、樊建华和西蒙·福波（Simon Furbo）。2017年，《中国太阳能区域供热

可行性研究》。

[17] Løgstrup 区域供热公司。2015年，《太阳能供热项目

（含现场新建锅炉)》。

[18] P. A. Sorensen 等人。2012 年，《太阳能区域供热指南》。http://www.euroheat.

[19] org/ wp-content/uploads/2016/04/SDHtake-off_SDH_Guidelines.pdf

[20] SDH 太阳能区域供热。http://www.solar-district-heating.eu

[21] Solargis。http://www.solargis.info

[22] Sunmark。2012 年，《可持续太阳能解决方案》。

[23] TIanpu。2016 年，《天普王家堡村太阳能区域供热项目》。

[24] W. Weiss 等人。2017 年，全球太阳热能。http://www.iea-shc.org/Data/Sites/1/

[25] publications/Solar-Heat-Worldwide-2017.pdf

8. Expected Outcomes

The expected outcomes of this study include a clearer understanding of the role that Soil and Solar thermal energy can play in supporting China’s renewable energy goals. The research should offer practical insights into how multi-energy systems can reduce energy consumption, lower emissions, and offer economic benefits, particularly in industrial and commercial settings. It is also expected to highlight the broader applicability of these technologies across different industries, potentially inspiring other regions and sectors to adopt similar clean energy solutions.

In conclusion, this research is expected to contribute significantly to the understanding and application of renewable energy technologies in China. By examining the practical and theoretical aspects of multi-energy coupled systems, this study aims to showcase the effectiveness of solar and soil thermal energy as part of a larger strategy to achieve sustainable and low-carbon energy solutions.

With well-designed systems and appropriate site selection, SDH (Solar District Heating) projects are viable in China. Solar collector technologies, particularly flat-plate collectors, are generally the most suitable due to their adaptability to local conditions. Efficient solar collectors, such as flat-plate and vacuum tube collectors, are readily available in the Chinese market. The final choice of technology can be determined during the feasibility study phase of project development.

The market potential for SDH（Solar District Heating） in China is substantial. Conservative estimates suggest that 150–200 projects could be implemented over the next few years. China is poised to surpass Denmark as the country with the highest number of SDH projects.

Although existing policies in China indirectly support SDH, more specific policies and incentive mechanisms are essential to accelerate the development of SDH systems. Increased project deployment will also drive the regional heating sector towards greater reliance on renewable energy.

Analysis of various SDH development scenarios indicates that solar collectors should be integrated with seasonal thermal storage and complementary production facilities. Typically, solar energy contributes 20% to 50% of the annual heat supply in SDH systems.

The following SWOT analysis summarizes the business environment for SDH in China:

Strengths

i. Minimal or zero greenhouse gas emissions

ii. Enhanced environmental efficiency

iii. Long lifespan exceeding 25 years, leading to reduced maintenance costs and improved management efficiency

iv. Financial competitiveness compared to coal-based CHP (Combined Heat and Power), natural gas, and biomass (under favorable conditions)

Weaknesses

i. High initial costs (capital investment)

ii. Dependence on land availability for technological feasibility

iii. Lack of incentives and regulatory support

iv. Requirement for meticulous planning, design, and coordinated implementation

Opportunities

Increasing demand for renewable energy in district heating

Governmental support for sustainable development initiatives

Emerging technologies to enhance efficiency and cost-effectiveness

Threats

Uncertain policy framework and incentives

Competition from other renewable energy solutions

Potential delays in project execution due to complex logistics and planning

Current Challenges and Solutions

In China, most solar thermal projects are designed for single households, often utilizing low-cost but substandard solar collector technologies. This has led to a high project failure rate, resulting in dissatisfaction among end users and negatively affecting public perception of SDH systems. However, when properly planned, designed, implemented, and operated, SDH can deliver substantial benefits, including higher efficiency, reliability, comfort, and environmental sustainability in regional heating.

Recommendations for Promoting soil & solar combined thermal energy in China

Prioritize Areas with Optimal Conditions:

Focus on regions with abundant solar resources and sufficient land availability, especially in smaller, centralized communities with moderate temperature requirements.

Increase Public Awareness:

Enhance understanding of the benefits, advantages, and opportunities provided by combined systems among both the public and policymakers.

Develop Feasibility Assessment Tools:

Create standardized tools for evaluating the viability of combined projects, ensuring accurate planning and resource allocation.

Prepare a Best Practices Manual:

Publish a comprehensive guide on combined best practices in China, covering the entire project lifecycle—from planning to operation.

Establish Pilot Projects:

Identify and implement combined pilot projects to serve as benchmarks for international best practices in district heating.

By addressing these challenges and implementing the recommended measures, China can significantly advance the adoption of combined systems, contributing to a more sustainable and environmentally friendly district heating sector.

By leveraging its strengths and addressing weaknesses through targeted policy support and technological innovation, China can unlock the full potential of combined thermal system with soil thermal and cross seasonal systems, paving the way for a greener and more sustainable district heating industry.