SOLAR DISTRICT HEATING IN THE PEOPLE'S REPUBLIC OF CHINA

STATUS AND DEVELOPMENT POTENTIAL

JULY 2019

ASIAN DEVELOPMENT BANK

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ISBN 978-92-9261-520-8 (print), 978-92-9261-521-5 (electronic)
Publication Stock No. TCS190028-2
DOI: http://dx.doi.org/10.22617/TCS190028-2

Notes:
In this publication, "$" refers to US dollars.
ADB recognizes "China" as the People's Republic of China.

Cover design by Brian Tenorio.

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Foreword

Integrating solar energy into the fossil fuel-based heating system is the way forward to realize low-carbon cities, and reduce urban air pollution.

Solar district heating is a concept that is relatively new in the People's Republic of China (PRC), and application of solar district heating is negligible in the country. Although heating demand is continuously growing in the northern, northeastern, and northwestern PRC in tandem with growing urbanization, heating supply is met by a traditional fossil fuel-based heating system, which contributes to urban air pollution and carbon dioxide emissions.

The study shows that there is significant potential in the PRC to develop solar district heating. The commercial use of this system in northern Europe has proven its technical viability. The PRC has enough technical and production capacity of solar thermal collectors, which is the key technology of solar district heating systems. Solar district heating can be integrated into the existing fossil fuel-based heating system to reduce consumption of fossil fuel, thereby reducing the carbon footprint of heating in the PRC.

Using clean and renewable energy sources, such as solar, in urban heating systems is a key element of low-carbon cities, and of reducing urban air pollution. The Asian Development Bank (ADB) is strongly committed under its Strategy 2030 to tackle climate change and make cities more livable. ADB hopes that this study will raise awareness of the benefits of solar district heating, and contribute to its increased use not only in the PRC but also in many other developing Asian countries that face similar challenges.

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Acknowledgments

Produced under the leadership of the Asian Development Bank's East Asia Department, this publication introduces the solar-based district heating concept which contributes to the low-carbon city development initiative in the People's Republic of China. Teruhisa Oi, Principal Energy Specialist, South Asia Department, directed the overall production of the publication, and Sujata Gupta, Director, Sustainable Infrastructure Division provided guidance and supervision.

The team that studied the subject through desk research and interviews with the resource persons included international consultant Mikael Jakobsson, and national consultant Shaofang Li.

Ma. Carmen Marcelline Felice M. Alcantara and Allisonne D. Legaspi coordinated the development of this publication. We also acknowledge the valuable inputs and comments received from the peer reviewer Yongping Zhai, Chief of Energy Sector Group, Sustainable Development and Climate Change Department at the Asian Development Bank.

Abbreviations

ATES	aquifer thermal energy storage
BTES	borehole thermal energy storage
CHP	combined heat and power
CTES	cavern thermal energy storage
CNY	Chinese yuan
DHW	domestic hot water
DHS	district heating system
ETC	evacuated tube collector
FPC	flat plate collector
HP	heat pump
HOB	heat-only boiler
MPC	model predictive control
PCM	phase change material
PRC	People's Republic of China
PTES	pit thermal energy storage
PV	photovoltaic
R&D	research and development
RE	renewable energy
SDH	solar district heating
STES	seasonal thermal energy storage
TES	thermal energy storage
TTES	tank thermal energy storage
US	United States
UTES	underground thermal energy storage

Weights and Measures

a	annum
GJ	gigajoule
GW	gigawatt
GWth	gigawatt-thermal
kWh	kilowatt-hour
m	meter
m^2	square meter
m^3	cubic meter
MW	megawatt
MWth	megawatt-thermal
MWh	megawatt-hour
tce	metric ton of coal equivalent

Source: Arcon-Sunmark.

Executive Summary

Solar thermal heating is a well-known concept in the People's Republic of China (PRC), where it has been applied to single-household domestic hot water use for decades. However, solar thermal district heating is a concept that is relatively new in the PRC. Unfortunate experiences with poorly installed individual solar heating facilities have led to justifiable skepticism about the technology, which must be overcome through the implementation of successful demonstration projects.

The feasibility of solar district heating (SDH) in the PRC is obvious, not least with seasonal thermal energy storage and complementary heat production in areas where solar resources are abundant and land is available (and cheap). Relatively small community district heating systems in remote areas are typically suitable for SDH. Purchasing power in these areas might, however, have to be considered when favorable policies are planned. SDH is competitive with coal-fired combined heat and power cogeneration, and costs less than technologies based on natural gas and other renewable sources of energy such as biomass.

The market potential for SDH in the PRC is great, and valuable experiences can be drawn from northern Europe, especially Denmark, the world leader in the field of SDH, and also Germany and Sweden.

This study concludes that SDH is feasible in the PRC and deserves further development as it can significantly increase the integration of renewable energy into the country's district heating sector. Awareness of SDH benefits, strengths, and opportunities should be increased to promote wider use of this technology in the PRC.

To help project developers, a feasibility evaluation tool could be developed to provide quick insights into the financial feasibility of SDH projects and evaluate different concepts. Compiling and making available a best-practice handbook covering the entire project value chain could also increase the chances of succeeding in SDH project implementation.

To prove the feasibility of SDH, a pilot project should be identified and developed to demonstrate SDH best practice.

1. Background and Introduction

In the People's Republic of China (PRC), 56% of the population was living in urban areas in 2016, and this proportion is forecast to rise to 70% by 2025. Rapid urbanization has presented energy supply challenges for the authorities, but it has also yielded opportunities for energy-efficient solutions in energy-dense areas. In northern PRC, district heating is a mature technology used for space heating and, in some cases, for domestic hot water (DHW) production. District heating in the PRC is still largely based on coal, but the technology allows for the integration of renewable energy, including solar power. Efficient district heating systems that integrate renewable energy are recognized worldwide for their ability to reduce carbon emissions and local pollution. The growth of the district heating sector in the PRC, as a result of urbanization and increased expectations of comfort and indoor climate control, should spur meaningful compliance with climate commitments through the use of renewable energy in district heating to reduce greenhouse gas emissions.

There are plenty of solar thermal applications worldwide, including (i) swimming pool heating, (ii) solar district heating, (iii) solar process heating, (iv) solar cooling, (v) solar DHW heating systems for individual buildings, (vi) solar DHW heating systems for tourism and the public sector, and (vii) combined solar DHW and space heating systems for individual buildings. Applications v, vi and vii have been used for decades in the PRC and the rapid development of solar thermal technologies can promote their successful integration into district heating systems.

The Asian Development Bank study[1] that led to this report was done to determine the status of solar district heating (SDH) in the PRC, investigate this technology's development potential for the country, and identify geographic areas where implementing SDH systems can feasibly accelerate renewable energy integration.[2]

This report defines the concept of solar thermal district heating and summarizes its benefits and challenges; presents technologies used in solar thermal district heating systems, including solar thermal technologies and thermal energy storage applications; evaluates the financial feasibility of solar thermal district heating projects; goes over the various policies conducive to the use of solar thermal energy in the PRC; looks into the development of solar thermal district heating worldwide and examines the PRC market for the technology in some detail; and recommends

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1 Carried out under the project Solar District Heating in the People's Republic of China Status and development potential (SC 105677-PRC). This report, completed in August 2017, was prepared by NXITY (Beijing) Energy Technology Co., Ltd., Sweden.

2 In this report, SDH refers to centralized or decentralized solar thermal facilities integrated into a neighborhood or city-level district heating system as a significant part of the energy supply mix for the heating needs of end consumers.

geographic areas in the PRC that should be given priority to speed up the development of solar thermal district heating in the PRC.

The information in this report came from desk research and interviews with representatives of the various stakeholders in the PRC's solar thermal and district heating sectors—associations, universities and research entities, manufacturers, and engineering companies, among others.

The International Metal Solar Industry Alliance (IMSIA),[3] a sector alliance initiated by the International Copper Association (ICA)[4] and comprising manufacturers, design and research institutes, and land and real estate developers active in the solar thermal sector, supported this study and provided valuable data and information.

3 International Metal Solar Industry Alliance. http://en.imsia.cn/
4 Copper Alliance. https://copperalliance.org/

2. What Is Solar Thermal District Heating?

Solar thermal district heating, a technology used in SDH, is an application of active solar heating systems. These systems absorb solar radiation (sunlight), transform it into heat, and transfer the heat for use in heating a fluid, for comfort heating, DHW, and other purposes.

In this report, solar thermal district heating refers to solar thermal technologies mainly for hot water production whose integration in sizable proportions into the energy mix for a country's hot water (second- to fourth-generation) district heating systems can significantly reduce that country's carbon footprint.[5] Fourth-generation district heating is a low-temperature district heating technology with high global efficiency, allowing the increased integration of low-value heat sources, such as surplus heat from industry, geothermal heat, and solar thermal energy. However, fourth-generation district heating is not required for the successful development of SDH.

Solar thermal systems for district heating typically comprise a centralized liquid-based active solar thermal collector system, circulating pumps, thermal energy storage, a heat distribution network, substations, and a complementary heat source for times during the heating season when the solar energy system cannot produce enough heat.

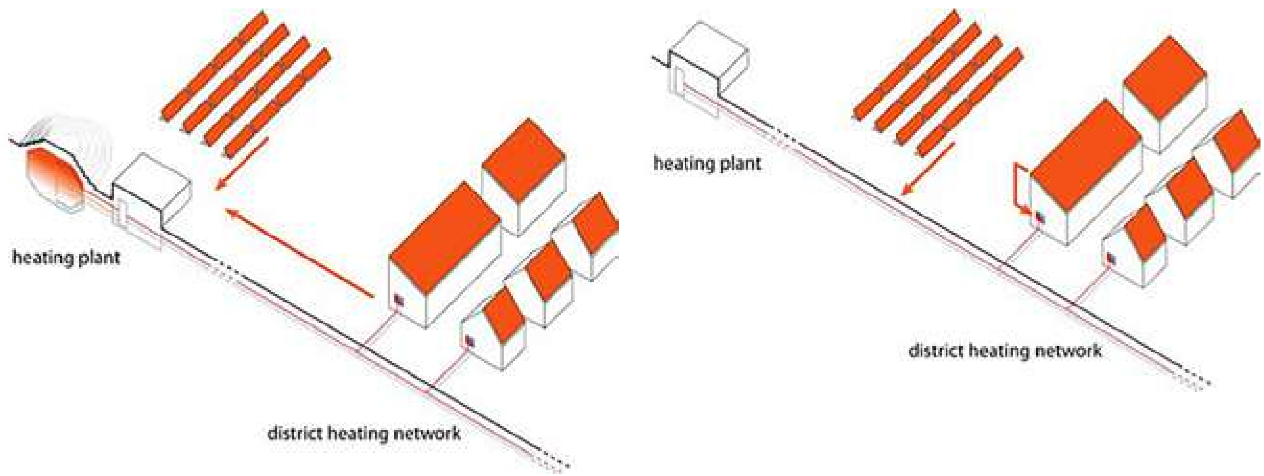
Historically, active solar heating systems, together with heaters, boilers, heat pumps, or district heating, have been used widely in buildings and households. Solar thermal collector facilities that centralize solar thermal energy generation and facilitate the integration of renewable energy into district heating systems have been applied, particularly in northern Europe.

The development of smart heating systems, where prosumers[6] can obtain heating from district heating systems as well as supply excess heat to the systems, has led to new innovations in solar thermal applications. But smart heating systems giving third parties access to district heating systems to enable them to supply heat to those systems often require relevant policy and legislative support, which is not always available.

Figure 1 shows how centralized and decentralized SDH systems differ. In a centralized SDH system, the solar collector plant is close to the heating plant. In a decentralized SDH system, on the other hand, the solar collector plant can be anywhere within the system. The increased use of long transmission lines has made decentralized solar collector plants more viable in the PRC.

5 First-generation district heating systems are steam systems.
6 Prosumers are consumers who can also produce their own energy (i.e., a building with solar panels, who have surplus energy at some point).

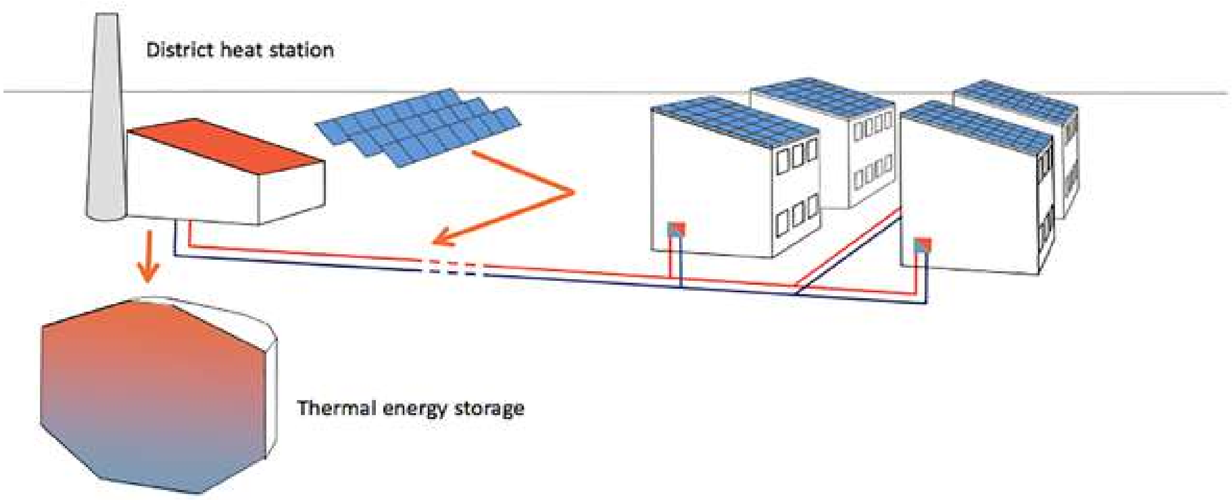
Figure 1: Centralized and Decentralized Solar District Heating



Source: Solites. https://www.solar-district-heating.eu/

Besides ready access to a complementary heat source, SDH systems should have thermal energy storage (TES) facilities to store solar energy during periods when heating demand is low or almost nonexistent. SDH feasibility would thus improve. Figure 2 shows an SDH plant with TES.

Figure 2: Solar District Heating Plant with Thermal Energy Storage



Source: Solites. https://www.solar-district-heating.eu/

3. Benefits and Challenges of Solar Thermal District Heating

This section sums up the benefits and challenges of solar thermal district heating, particularly in the PRC, as brought out in the desk research and the interviews summarized in Appendix 1.

Benefits

1. Financial and economic benefits
    i. investment cost lower than that of biomass plants
    ii. production cost below that of gas-fired plants
    iii. very low operating cost compared to other heating technologies
    iv. energy pricing competitive with that of coal-fired combined heat and power (CHP) systems

2. Environmental benefits
    i. carbon neutrality (with green electricity for auxiliary systems) or close to it
    ii. low pollution
    iii. no noise pollution

3. Other factors that favor development in the PRC
    i. mature local manufacture of solar thermal collectors
    ii. abundance of solar resources in several provinces, particularly in the northwest
    iii. ease of systems construction, installation, and operation and maintenance
    iv. long life span
    v. low safety risk

Challenges

1. Financial and economic challenges
    i. high investment cost
    ii. land availability and acquisition constraints in the PRC
    iii. low purchasing power in the country's rural areas

2. Institutional challenges
    i. lack of policy support in the PRC
    ii. lack of subsidies or other incentives from the government

3. Other challenges
    i. reduced efficiency at high district heating supply temperatures
    ii. weather (including air pollution) dependence
    iii. skepticism about the technology due to unfortunate project experiences
    iv. relative newness of the SDH concept in the PRC

4. Best Available Solar Thermal Technologies

Solar Thermal Collectors

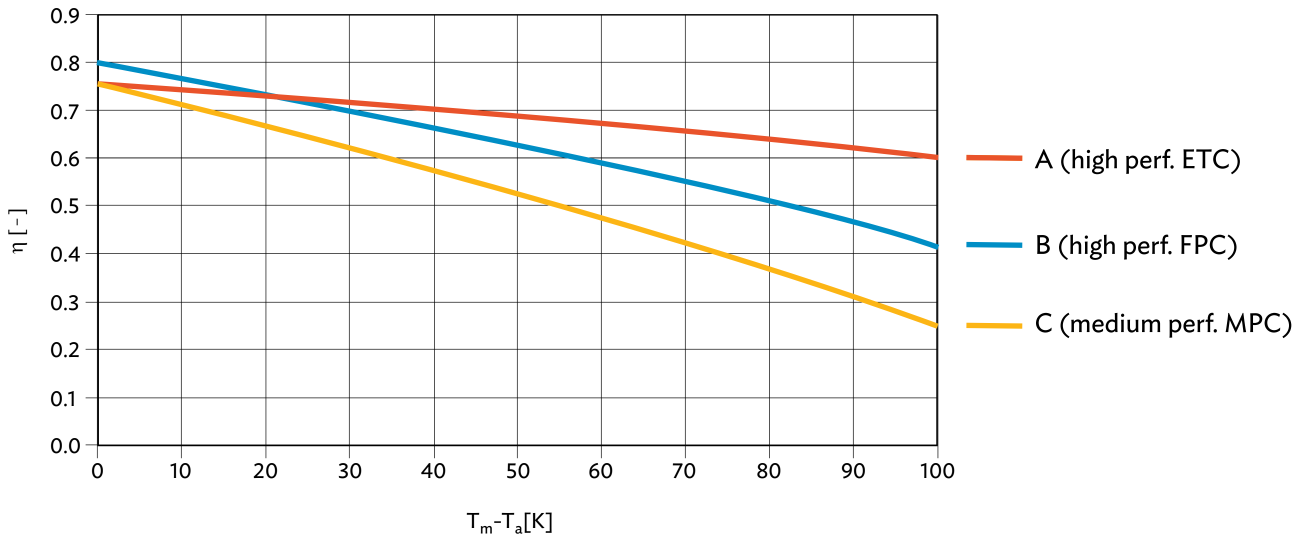
Solar thermal collectors are key components of active solar heating systems and solar thermal district heating systems. There are different types of solar thermal collectors. This report presents the most common ones for producing hot water. Concentrating solar thermal collectors, such as parabolic trough collectors (PTCs), power towers or central receivers, parabolic dishes (dish and engine systems), and compound linear Fresnel reflectors (CLFRs) for heat and power cogeneration, are not included here.

Solar thermal collectors are divided into three main categories: (i) vacuum tube collectors, (ii) flat-plate collectors, and (iii) unglazed collectors. This report does not cover unglazed solar collectors, which are used mainly for low-temperature heating (<30°C), mostly in North America.

There are several types of vacuum tube collectors, which can have either single-layer tubes or two layers of vacuum-insulated tubing. Vacuum tube collectors are divided into two subcategories: (i) glass–glass collectors, and (ii) glass–metal collectors.

The typical efficiency of solar collectors is shown in Figure 3.

Figure 3: Typical Solar Collector Efficiency



η = solar collector efficiency, K = incidence angle modifier, T_a = ambient air temperature, T_m = mean temperature of heat transfer fluid
ETC = evacuated tube solar collector, FPC = flat plate solar thermal collector, MPC= model predictive control.
Source: Solar District Heating. https://www.solar-district-heating.eu/

All-glass (glass-glass) vacuum tube collector

The simplest and most cost-effective solar collector (in terms of investment cost) is the all-glass vacuum tube collector (Figure 4)—one or more rows of double-layer glass tubes with an insulating vacuum between the layers, reducing heat loss to the atmosphere. The inner layer is coated with a selective solar absorber material to increase the collector's efficiency. A water tank can be placed directly above the collector or connected to it by means of a pipeline manifold.

Figure 4: All-glass Vacuum Tube Collector

Source: http://www.beijingsunpu.com.cn/Shop/ShowInfo.asp?ID=50.

Cold water is heated by solar energy inside the coated inner glass tube, and the hot water evaporates, rises naturally to the top of the heating pipe, transfers its heat energy to the fluid in the heat exchanger, and condenses back into a liquid, to be reheated in the heating pipe.

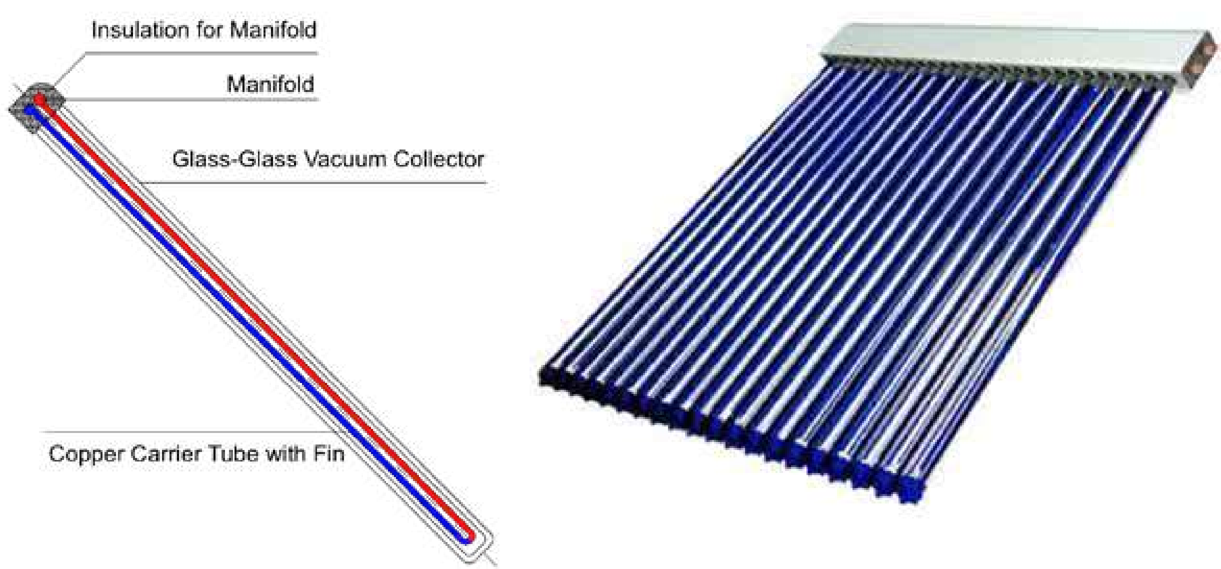
The all-glass vacuum tube solar collector has mechanical drawbacks. It is sensitive to thermal and hydraulic restrictions. Exposure to ambient air pollution can degrade the quality of water in the water tank. In addition, the collector must be installed at a certain angle to maximize effective solar absorption and natural evaporation. In other words, local conditions and available space will affect efficiency.

But because of its simple configuration, ease of installation, and low investment cost, the all-glass vacuum tube collector has been a very popular DHW application for household and small commercial use in the PRC.

All-glass (glass-glass) vacuum tube collector with inner copper heating pipe

The all-glass vacuum tube collector with an inner copper heating pipe (Figure 5) also has a double layer of glass tubing with an insulating vacuum layer between the layers, and it works on the same principle as the all-glass vacuum tube collector. But, unlike the latter, it has a U-shaped copper heating pipe with a surrounding fin, which circulates water in a closed loop. The loop is part of a larger closed system connected directly to a storage tank, or indirectly via a pipeline manifold.

Figure 5: All-glass Vacuum Tube Collector with Inner Copper Heating Pipe



Source: ELCO. http://www.elco.net/

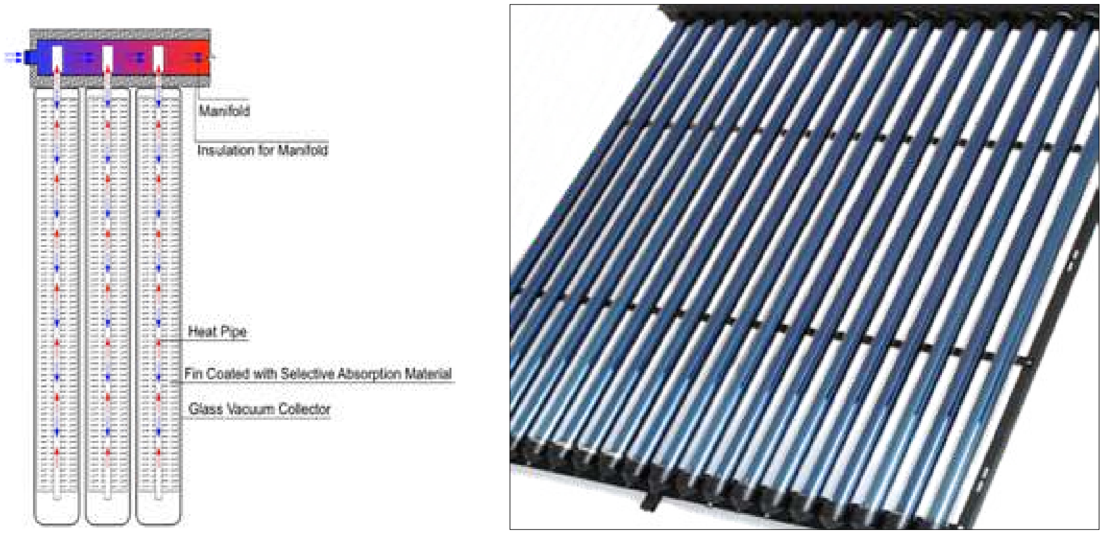
Heat is transferred by the coated fin to the cold water in the copper heating pipe, and the hot water circulates back into the manifold. The closed water loop can operate at relatively high pressure and temperature with assured high efficiency and quality, making it suitable for large water heating systems. If a vacuum glass tube breaks, the closed piping system is not affected.

Thermal efficiency is lower than that of the all-glass vacuum tube collector without an inner copper heating pipe, because of reduced heat transfer between the copper heating pipe and the vacuum-insulated layers of glass tubing. In addition, the use of the copper heating pipe with fin results in a higher investment cost.

Heating-pipe collector with vacuum-insulated glass tubing (glass–metal collector)

A single layer of glass tubing covers the evaporator section, with a heat transfer layer and an internal heating pipe (Figure 6). The heating pipe comprises a copper tube with vaporizable fluid circulating through the tubes at the bottom, a capillary wick structure, and a condenser section at the top acting as heat exchanger, using a flow distribution manifold to transfer heat to the water in the solar loop.

Figure 6: Heating-Pipe Collector with Vacuum-Insulated Glass Tubing



Source: http://www.beijingsunpu.com.cn/Shop/ShowInfo.asp?ID=50.

The heating pipe in the evaporator section vaporizes the fluid and the vapor rises naturally to the top, where it condenses back into water.

The heating pipe collector with vacuum-insulated glass tubing has a life span of over 15 years and is more reliable and efficient than the vacuum tube collectors presented earlier in this report. However, the investment cost is also higher.

Direct-flow tube collector with vacuum-insulated glass tubing (glass-metal collector)

The direct-flow tube collector with vacuum-insulated glass tubing (Figure 7) uses concentric tubing—an inner copper tube carrying hot water through the collector via the manifold, and an outer tube of vacuum-insulated glass containing the fluid to be heated—to enable heat exchange between fluids, taking full advantage of the high thermal conductivity of copper, without any mixing of fluids.

Figure 7: Direct-Flow Tube Collector with Vacuum-Insulated Glass Tubing

Source: http://www.beijingsunpu.com.cn/Shop/ShowInfo.asp?ID=50.

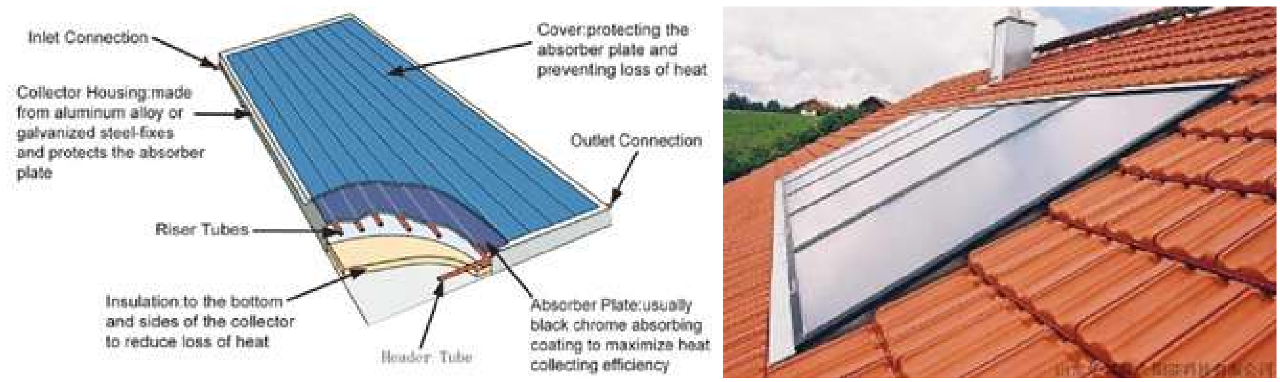
The direct-flow tube solar collector system with vacuum-insulated glass tubing is the most reliable and efficient vacuum tube technology described. It is suitable for large hot water systems, and can meet strict technical requirements. But like the heating pipe collector with vacuum-insulated glass tubing, it has a higher investment cost than all-glass vacuum tube collectors.

Flat-plate collector

The flat-plate collector (Figure 8) is significantly different from vacuum tube collectors. It usually consists of layers of insulation, selective solar absorber coating on copper or silicon tubes with heating fluid to enable heat transfer, and weather shading—all housed in a glazed rectangular box.

The core component is the absorber. It is made of different materials, including black chrome, black nickel, aluminum oxide, and titanium oxynitride, and comes in different configurations depending on the flat-plate collector technology chosen.

Figure 8: Flat-Plate Collector



Source: Shandong Sunshine Dr. Solar Engineering Co., Ltd.. http://www.sdygbs.com/

In general, flat-plate collectors are slightly less efficient than vacuum tube collectors. However, they have a lower investment cost and a longer life span (over 25 years). Flat-plate collector technology is the most popular solar thermal collector technology in Europe.

Comparative analysis

Table 1 presents in summary form a comparative analysis of the different solar collector technologies. The analysis indicates that the heating-pipe collector with vacuum-insulated glass tubing and the direct-flow tube collector with vacuum-insulated glass tubing have the highest efficiency but are also the most expensive. The flat-plate collector is the cheapest, most feasible solution with the longest life span, but is less efficient than other solar collector technologies. While the flat-plate collector is 20%–40% cheaper than vacuum tube collectors, a flat-plate solar collector plant could require more solar collector area, depending on the application and location, because of its lower efficiency. The project's financial viability would therefore be better-off with vacuum tube collectors.

Table 1: Comparison of Solar Thermal Collectors

	Solar thermal collector type				
Feature	***All-Glass Vacuum Tube Collector***	***All-Glass Vacuum Tube Collector with Inner Copper Heating Pipe***	***Heating-Pipe Collector with Vacuum-Insulated Glass Tubing***	***Direct-Flow Tube Collector with Vacuum-Insulated Glass Tubing***	***Flat-Plate Collector***
Efficiency	High	Medium	High	High	Medium
Working pressure	Atmospheric	6 bars or higher	6 bars or higher	6 bars or higher	6 bars or higher
Installation angle	Certain angle needed to maximize solar energy transfer efficiency	Certain angle needed to maximize solar energy transfer efficiency	Certain angle needed to maximize solar energy transfer efficiency	No requirement	Certain angle needed to maximize solar energy transfer efficiency
Resistance to thermal or mechanical stress	Low	Good	Good	Good	Good
Life span	Short	Longer	Longer	Longer	Longest
Cost	Cheap	Medium	Very expensive	Very expensive	Cheap
Maintenance	More needed	Less needed	Less needed	Less needed	Least needed
Application	One-family houses, apartments, small commercial customers	All kinds of customers	All kinds of customers	All kinds of customers	All kinds of customers

Source: Consultant's compilation.

Thermal Energy Storage

Thermal energy storage (TES) is a key component of solar thermal district heating systems. There are many different TES technologies, for either short-term (a few hours' or days') energy storage or seasonal (longer-term) thermal energy storage (STES).

Tank thermal energy storage (TTES) aboveground is a technology commonly used for short-term storage, optimizing heat supply and power generation by CHP plants worldwide. But TTES can also be fully or partially buried in the ground to take advantage of its insulation features. Buried TTES can be categorized as underground thermal energy storage (UTES), employing various TES technologies. This chapter deals with STES in general and UTES in particular, and the application of TES technology in solar thermal district heating systems.

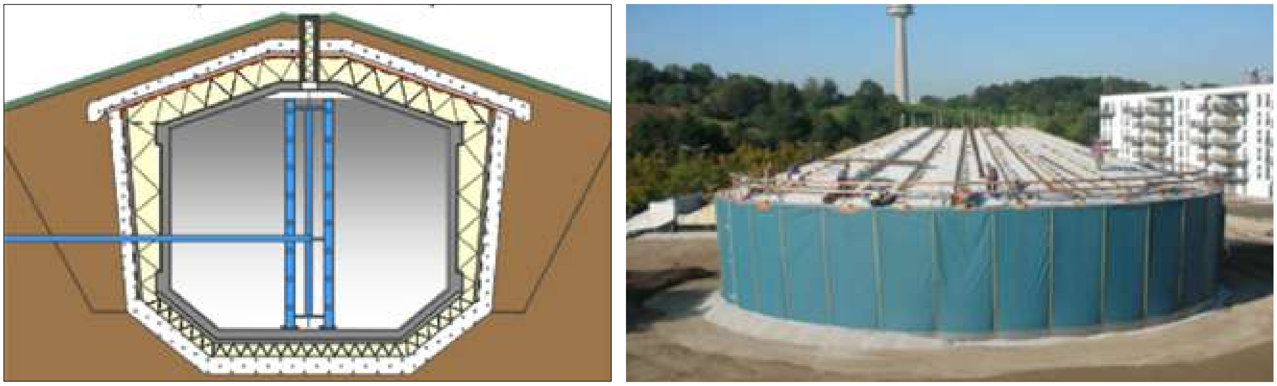
UTES makes use of the ground for both heat and cold storage or for insulation. There are five main types of UTES systems: (i) buried TTES, (ii) pit TES (PTES), (iii) cavern TES (CTES), (iv) borehole TES (BTES), and (v) aquifer TES (ATES).

Besides the local conditions, storage capacity (in megawatt-hours, or MWh), charge and discharge capacity (in MW), and connection, direct or indirect, to the district heating system must be considered. If the TES is directly connected to the district heating system the pressure level in the system will be affected.

1. Tank thermal energy storage

TTES, fully or partially buried in the ground, is built as a steel tank or a prestressed concrete tank (Figure 9) with insulation material around the structure, in addition to natural insulation from the ground. The tank is equipped with drainage and various other features to protect against overflow and maintain the amount of dissolved oxygen in the water. TTES is most often unpressurized; the water charging temperature is therefore limited to below 100°C.

Figure 9: Underground Tank Thermal Energy Storage

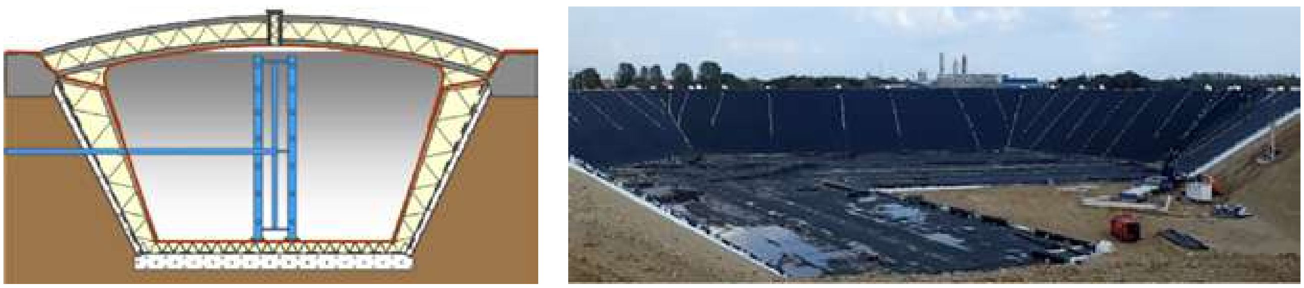


Source: Solites.

2. Pit thermal energy storage

PTES is a shallow, sloped pit, with a heat-insulated bottom, walls, and lid, and no static structures (Figure 10). There are two main types of PTES: (i) water-filled PTES; and (ii) PTES filled with a mixture of water and gravel, sand, or soil. A water-filled pit requires a relatively sophisticated and expensive lid, which is watertight and typically floats atop the water. The lid of PTES filled with water and gravel, sand, or soil as storage material, on the other hand, is simpler in construction and allows the use of the land above the pit for various purposes.

Figure 10: Pit Thermal Energy Storage

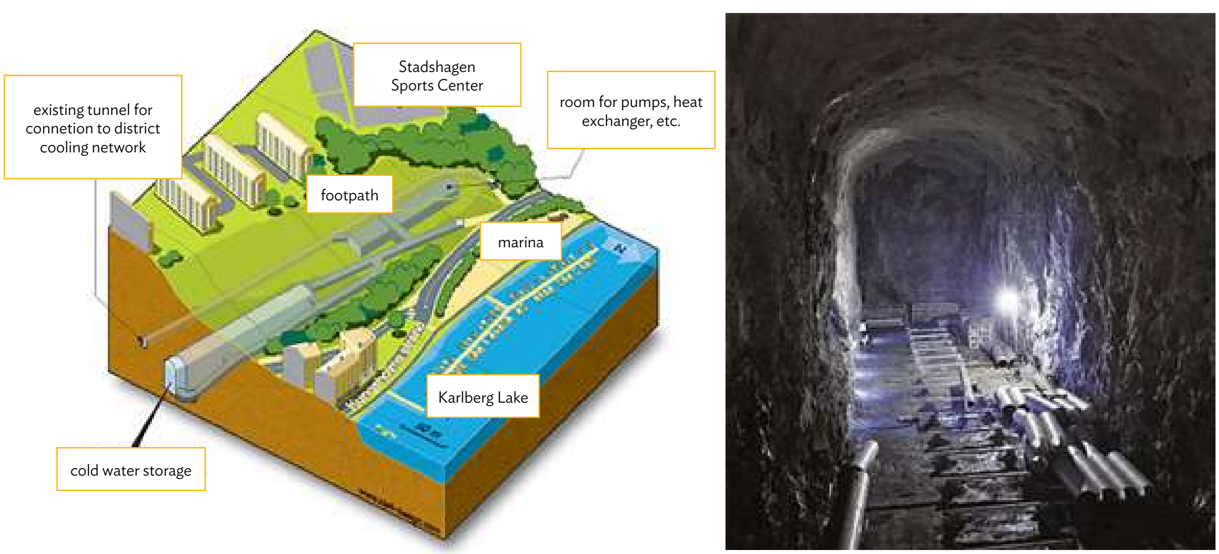


Source: Solites.

3. Cavern thermal energy storage

CTES is a UTES technology that uses a rock cavern for thermal energy storage (Figure 11). The cavern could be an old oil storage cavern, abandoned military storage, a flooded mine, or a purpose-built chamber. The investment cost of purpose-built cavern storage is often very high, while existing chambers are seldom optimally situated in relation to a heating system.

Figure 11: Cavern Thermal Energy Storage

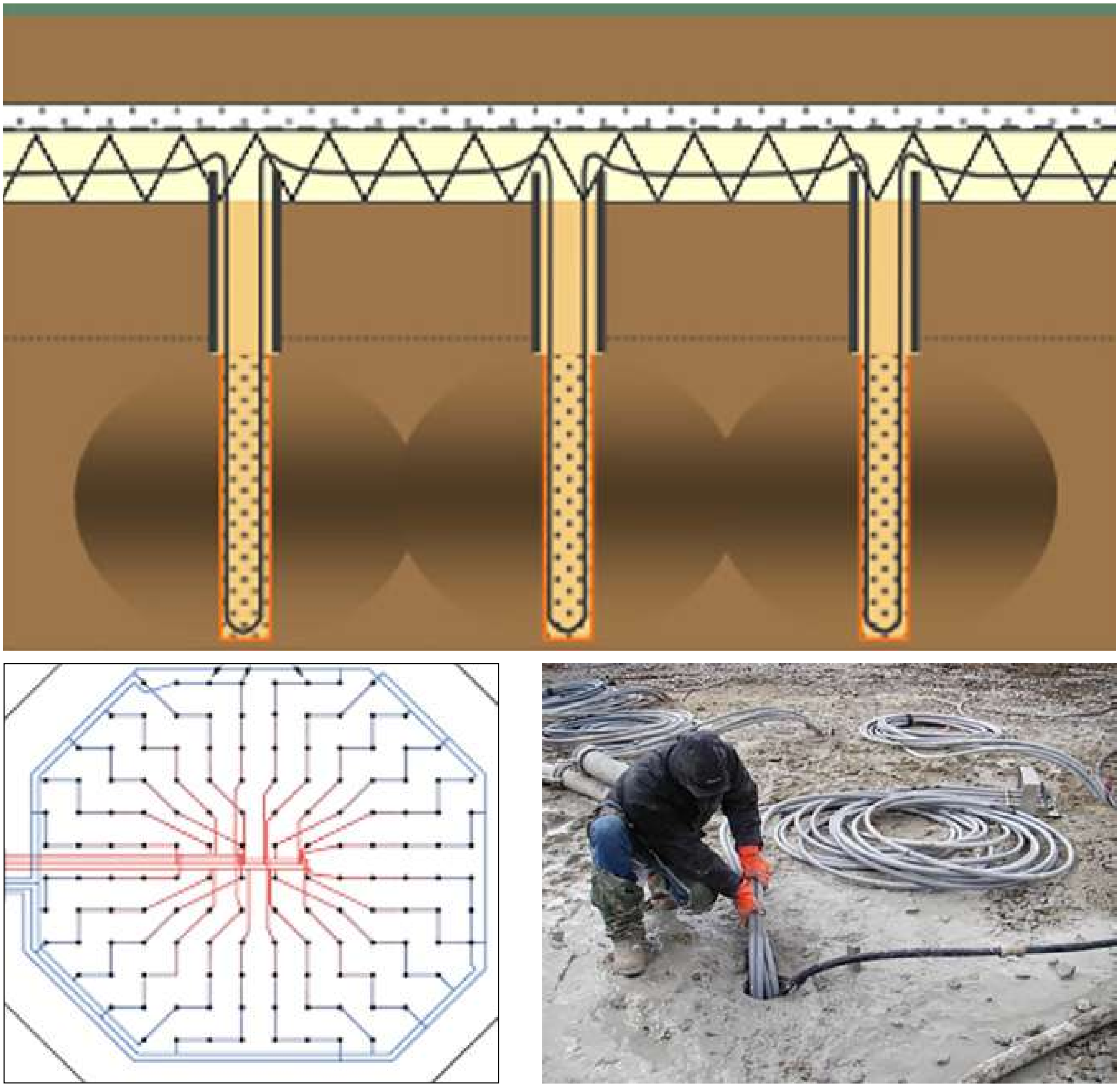


Source: Consultant's compilation.

4. Borehole thermal energy storage

BTES (Figure 12) is essentially a vertical heat exchanger using U-pipes (ducts) inserted into vertical boreholes in underground strata of clay, sand, or rock to charge or discharge heat stored directly in the soil as water runs in the U-pipes. The upper surface of the storage is heat insulated. Borehole storage is often used in combination with heat pumps.

Figure 12: Borehole Thermal Energy Storage

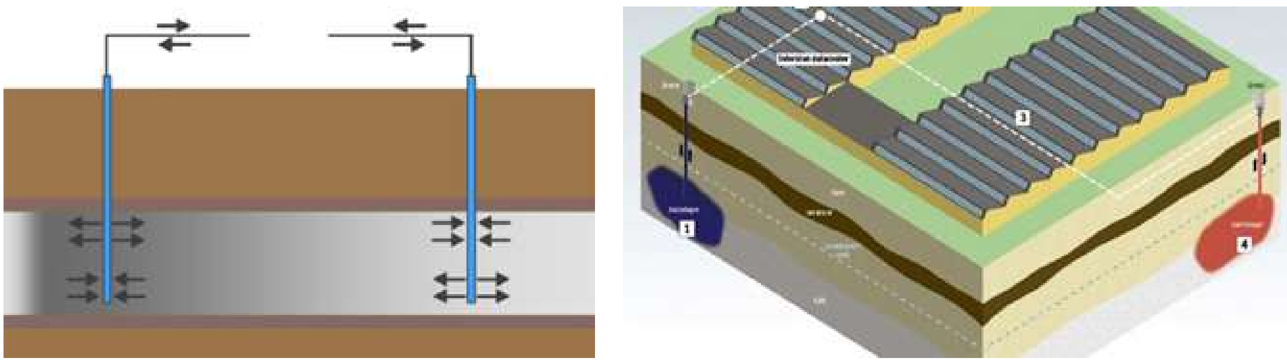


Source: Solites.

5. Aquifer thermal energy storage

ATES (Figure 13) uses aquifers, naturally occurring underground layers of water-permeable sand, gravel, sandstone, or limestone with high hydraulic conductivity, to store thermal energy. Two wells or groups of wells, one for extracting cold groundwater and the other for reinjecting the groundwater after it has been heated by the heat source, are drilled to keep the aquifers in hydrologic balance. Both wells are equipped with pumps and production and injection pipes. A major prerequisite for this technology is the availability of suitable geologic formations.

Figure 13: Aquifer Thermal Energy Storage



Source: www.solar-district -heating.eu.

6. Other thermal energy storage technologies

While sensible heat storage is relatively inexpensive and simple in design, its most important drawback is its low energy density. TES based on phase change materials (PCMs)—latent heat storage materials that absorb and release thermal energy as they melt and freeze—incorporates both solid–liquid and solid–solid phase change processes and energy density can be several times higher. PCM-based TES, for short-term (daily) or long-term (seasonal) energy storage, applies a variety of techniques and materials including ice, sodium acetate trihydrate, paraffin wax, and erythritol.

Another TES technology is thermochemical energy storage (TCES) by adsorption.

Neither PCM nor TCES is used widely, and no SDH project using these technologies has been identified. The technologies are either newly commercialized or still in the research stage, but hold huge potential and the promise of significant development in the future.

7. Comparative analysis

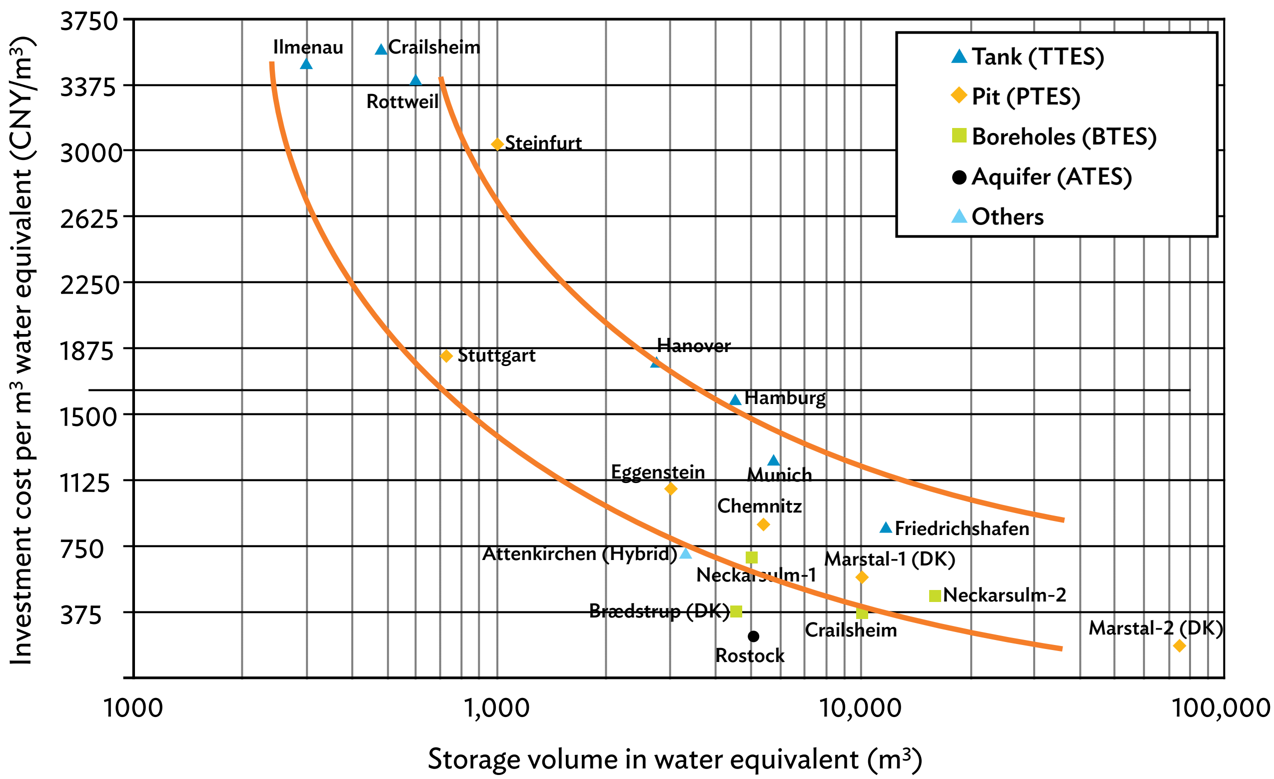
Table 2 is a summary comparison of some TES technologies. The analysis indicates that ATES has the most exacting requirements where local conditions are concerned, followed by BTES. Cost varies significantly depending on the technology, the scale of the application, and local conditions. A cost comparison of TES projects in Europe is presented in Figure 14. It can be concluded that BTES and PTES are the most cost-effective storage solutions for seasonal energy storage and most feasible for SDH.

Table 2: Comparison of Seasonal Energy Storage Technologies

Item	TTES	PTES	ATES	BTES
Storage medium	Water	Gravel–water	Sand–water/ Gravel–water	Soil/Rock
Heat capacity, kWh/m^3	60–80	30–50	30–40	15–30
Storage volume for 1 m^3 water equivalent	1 m^3	1.3–2 m^3	2–3 m^3	3–5 m^3
Geologic requirements	Stable ground conditions Preferably no groundwater 5–15 m deep	Stable ground conditions Preferably no groundwater 5–15 m deep	Natural groundwater layer (aquifer), high hydraulic conductivity Confining layers on top and below No or low natural groundwater flow Suitable water chemistry at high temperatures	Drillable ground High heat capacity High thermal conductivity Low hydraulic conductivity Natural groundwater flow less than 1 m/a, 30–200 m deep

TTES = tank thermal energy storage, PTES = pit thermal energy storage, ATES = aquifer thermal energy storage, BTES = borehole thermal energy storage, m = meter, m^3 = cubic meter, m/a = meter per annum, kWh = kilowatt-hour, kWh/m^3 = kilowatt-hour per cubic meter .
Source: Consultant's compilation.

Figure 14: Cost of Thermal Energy Storage Projects in Europe



ATES = aquifer thermal energy storage, BTES = borehole thermal energy storage, DK = Denmark, m^3 = cubic meter, PTES = pit thermal energy storage, CNY/ m^3 = Chinese yuan per cubic meter, TTES = tank thermal energy storage.
Source: Solar District Heating. https://www.solar-district-heating.eu/

5. Financial Feasibility of Solar District Heating

There are many variables to consider when looking into the financial feasibility of SDH, and each project should be evaluated on the basis of specific local conditions. Only a few SDH projects have been implemented in the PRC, not enough to yield meaningful experience and provide financial indicators. Capital and operating expenses are to a great extent specific to a given locality.

The project-specific items listed below affect capital and operating expenses, and will determine the financial feasibility of the SDH project.

Capital Expenses

i. solar collector technology
ii. size of solar collector plant
iii. TES technology
iv. size of TES
v. distance to district heating system
vi. construction cost
vii. land acquisition cost

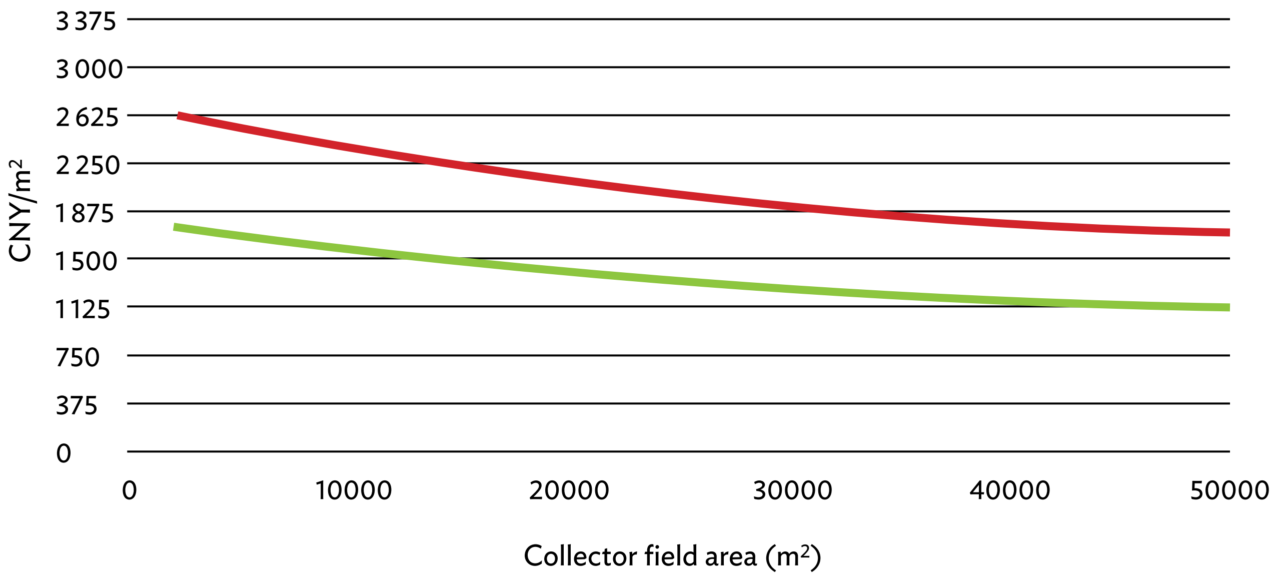
Operating Expenses

i. solar radiation
ii. efficiency of solar collector plant
iii. thermal energy storage capacity
iv. heat losses
v. auxiliary costs
vi. maintenance cost

When carrying out financial analysis, it is important to bear in mind the overall concept of SDH, which generally includes TES and complementary production facilities, such as heat-only boilers (HOBs), CHP, or heat pumps.

Figure 15 shows reference investment costs for solar collector fields in Europe (excluding TES and value-added tax). The costs for any given solar collector field tend to fall between the red line and the green line. These costs can be expected to be about 25% lower in the PRC, in view of its lower production and labor costs.

Figure 15: Investment Cost of Solar Collector Fields in Europe



CNY/m^2 = Chinese yuan per square meter.
Note: The chart shows approximate price per square meter of collector area including installation, piping, heat exchanger unit, etc., but excluding thermal energy storage and value-added tax.
Source: Solar District Heating. https://www.solar-district-heating.eu/

The investment cost of vacuum tube collectors in the PRC is around CNY2,400 per square meter (m^2). For flat-plate collectors, it is around $CNY1,700/m^2$.

The cost of TES depends not only on the storage type but also on the size and complexity of the project. The scale advantages are significant. For PTES, reference projects in Europe show that the investment cost of small PTES (<1,000 cubic meters [m^3]) can exceed $CNY2,000/m^3$, while for large PTES (>50,000 m^3) it can go below $CNY300/m^3$.

Table 3 lists heating cost indicators for heating sources, including capital, operating, and financial costs. It can be seen that SDH costs are competitive with those of gas boilers and gas CHP, and even with those of traditional coal-fired HOBs.

Table 3: Heating Cost Indicators for Different Heating Sources

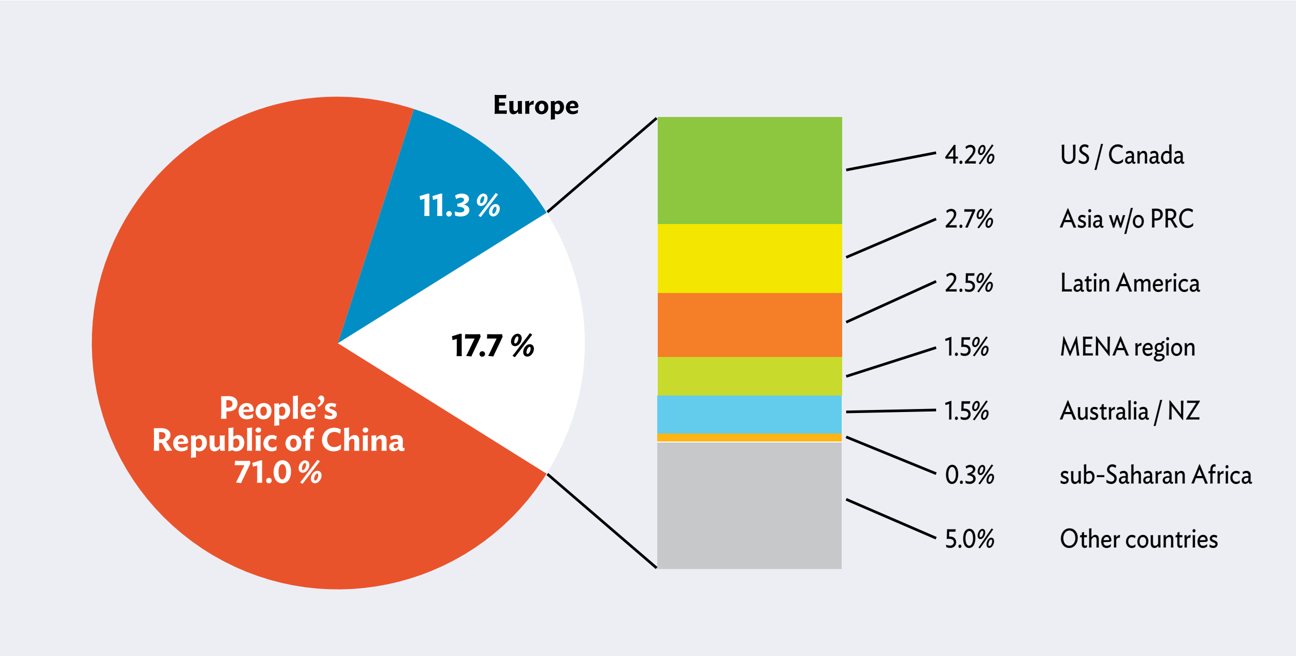
Heating Source	Heating Cost (CNY/MWh)	tCO_2e/MWh
Solar DH	200–300	0.05
Coal HOB	160–250	0.45
Coal CHP	140–200	0.28
Gas HOB	290	0.23
Gas CHP	320	0.16

CNY = Chinese yuan, MWh = megawatt-hour, tCO_2e = metric ton of carbon dioxide equivalent, DH = district heating, HOB = heat-only boiler, CHP = combined heat and power.
Source: Consultant's compilation.

6. Solar Thermal District Heating Worldwide

By the end of 2015, the installed solar collector area worldwide totaled 623 million m^2, corresponding to a capacity of about 436 gigawatts-thermal (GWth). The PRC and Europe together accounted for over 82% of the total solar collector market—71% (309 GWth) for the PRC and 11.3% (49 GWth) for Europe (Figure 16). The total solar collector market referred to includes various applications and both water and air collectors. Water collectors make up about 99% of the total solar collector market worldwide.

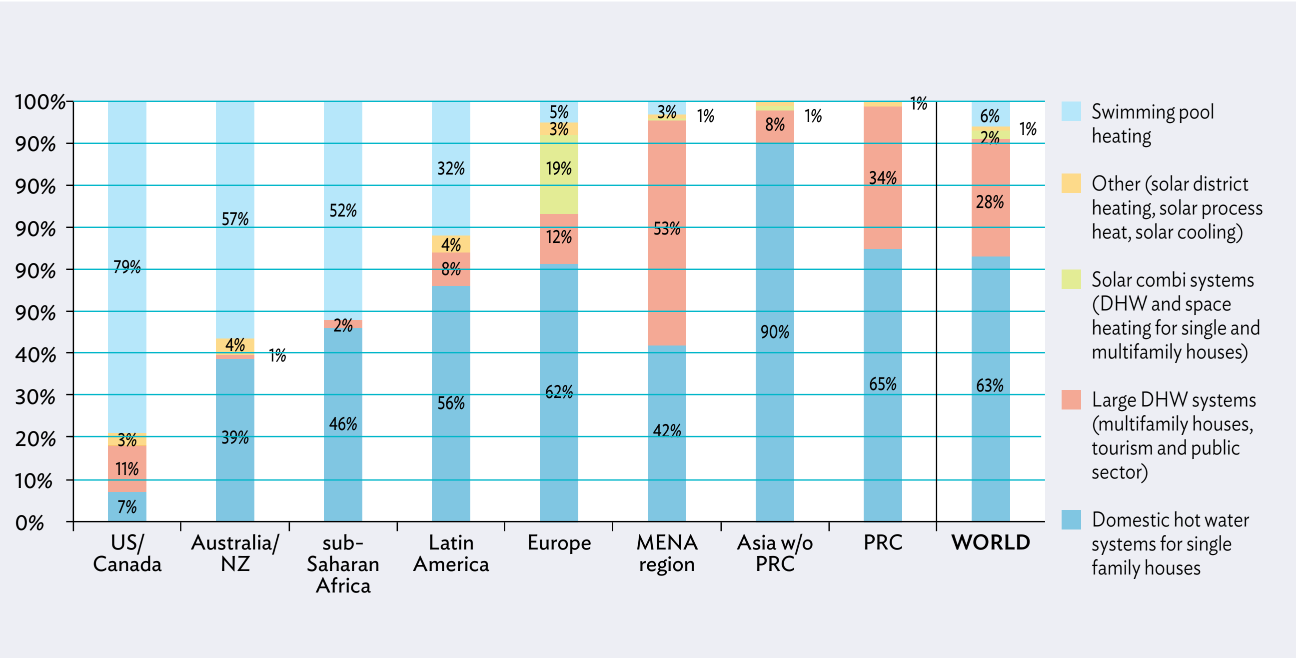
Figure 16: Regional Share of Total Installed Solar Collector Capacity, Year-End 2015



MENA = Middle East and North Africa, NZ = New Zealand, PRC = People's Republic of China, US = United States.
Source: International Energy Agency.

SDH accounts for less than 1% of the total solar collector market worldwide, corresponding to less than 4.4 GWth. DHW systems compose 93% of this total market, corresponding to about 406 GWth.

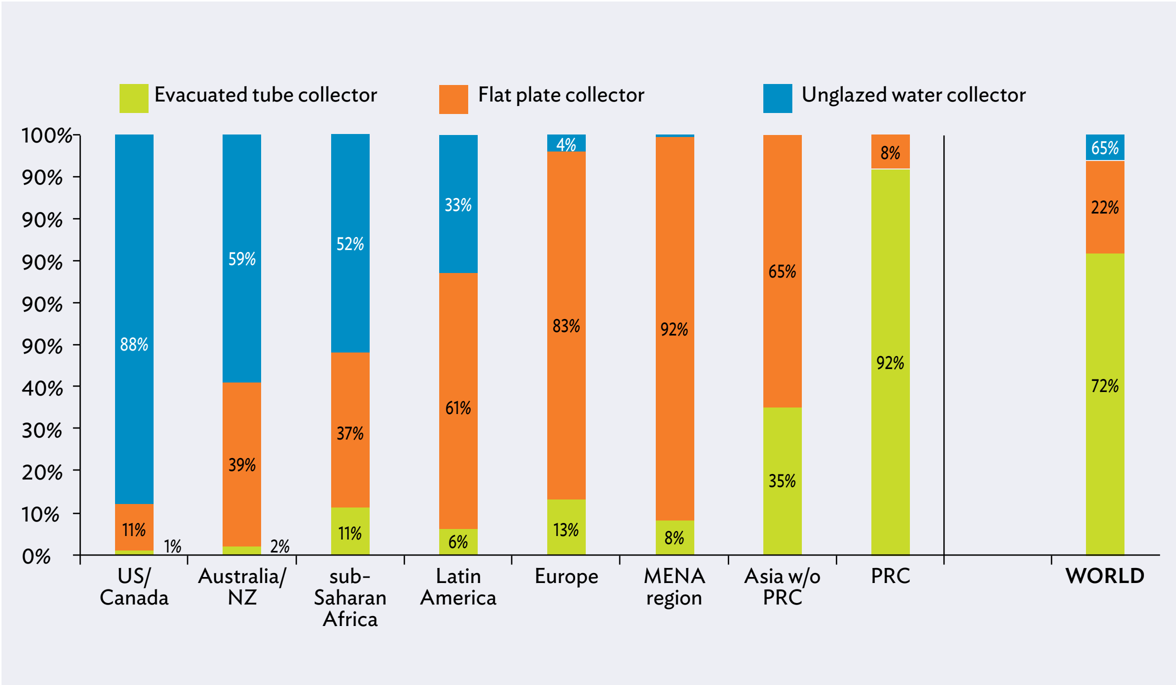
Figure 17: Regional Solar Thermal Capacity According to Use, Year-End 2015



DHW = domestic hot water, US = United States, MENA = Middle East and North Africa, NZ = New Zealand, PRC = People's Republic of China.
Source: International Energy Agency.

Flat-plate collectors are the most popular solar collector technology in most economies worldwide. But in terms of installed capacity, vacuum tube collectors are the most popular, accounting for 72% of total capacity (about 314 GWth). In North America, Australia/New Zealand, and sub-Saharan Africa, unglazed water collectors are the most popular technology.

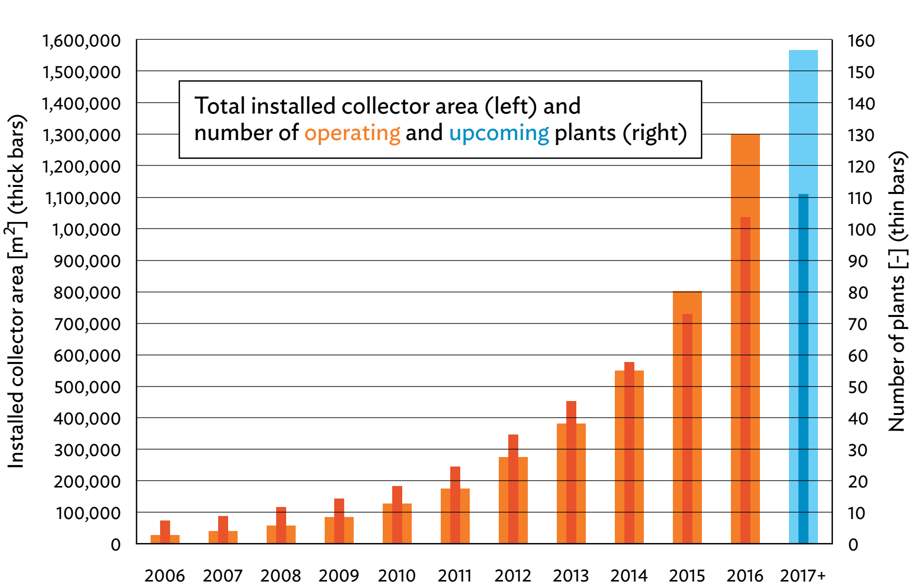
Figure 18: Solar Thermal Collector Technology, by Region, Year-End 2015



MENA = Middle East and North Africa, NZ = New Zealand, PRC = People's Republic of China, US = United States.
Source: International Energy Agency.

For SDH, Denmark is the leading economy worldwide, in regard to number of installed systems and installed capacity. The country has a total installed SDH capacity of about 922 MWth, and average installed capacity per project of about 8.4 MWth. The largest SDH plant in Denmark has a total installed capacity of 110 MWth and is in Silkeborg. Figure 19 shows the development of SDH in Denmark over the last 10 years. Appendix 3 lists the SDH projects implemented in Denmark.

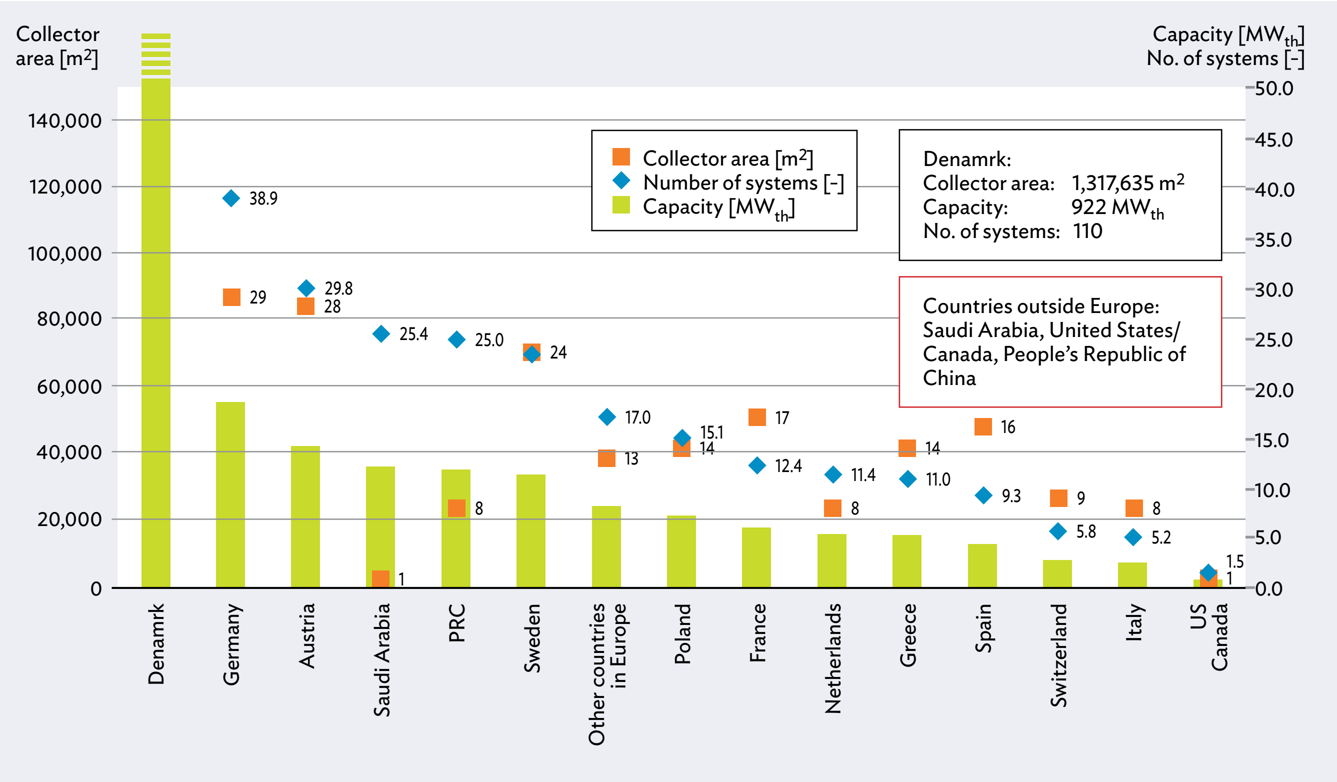
Figure 19: Total Installed Solar Collector Area and Number of Plants in Denmark



Source: Danish Board of District Heating (DBDH).

Figure 20 presents the installed capacity (MWth), the number of installed SDH systems, and the total collector area (m²), for selected economies worldwide. Denmark's leadership position in SDH is evident.

Figure 20: Solar District Heating Capacity, Number of Systems, and Total Collector Area in Selected Economies

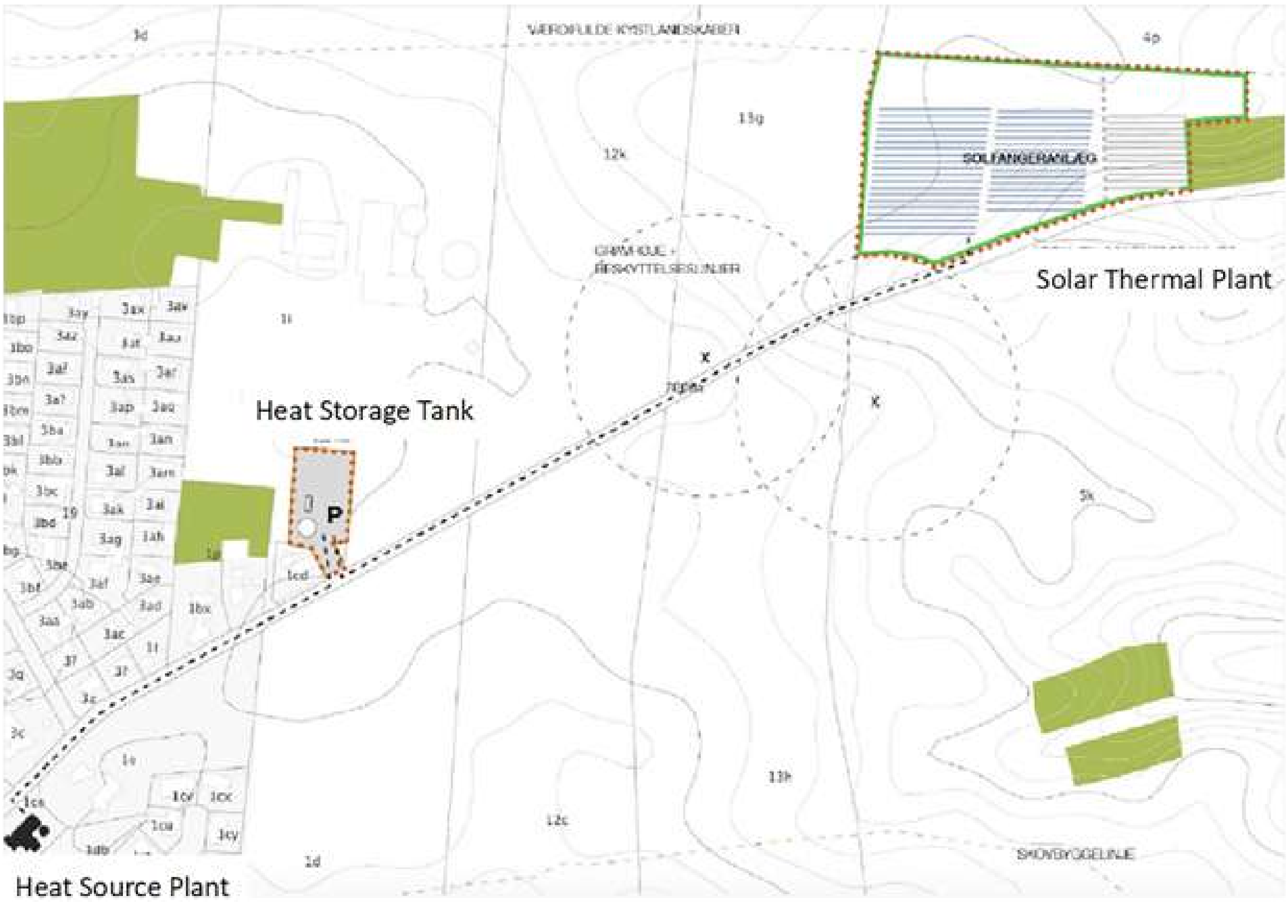


m² = square meter, MWth = megawatt-thermal.
Source: International Energy Agency.

The Løgstrup Solar District Heating Project

The Løgstrup SDH project comprises the establishment of a new large-scale solar thermal plant and a heat storage tank, and the expansion of the heat source plant. Figure 21 gives an overview of the project site, including the main facilities.

Figure 21: Overview of the Løgstrup Solar District Heating Project



Source: Løgstrup District Heating Company.

The project has the following main components:

i. 7,000 m^2 solar thermal collector
ii. 2,000 m^3 heat storage tank
iii. Heat exchanger station with pumps, valves, and other auxiliaries
iv. 6 megawatt (MW) gas boiler

Table 4 presents energy balance and key economic data for the project baseline and two alternative projects. It can be seen that the operating costs for the SDH project are 21% lower than those for the alternative case without a solar thermal plant. However, the investment cost for the SDH project is DKK21.5 million, compared with only DKK2.8 million for the gas boiler project. The simple payback period for the SDH project, compared with the baseline, is 11.8 years. In the financial analysis for the project (not presented here), a depreciation period of 20 years was used. It should be noted that the life span of SDH assets is longer than 20 years.

Table 4: Energy Balance and Key Economic Data for Løgstrup Solar District Heating Project Baseline and Alternative Projects

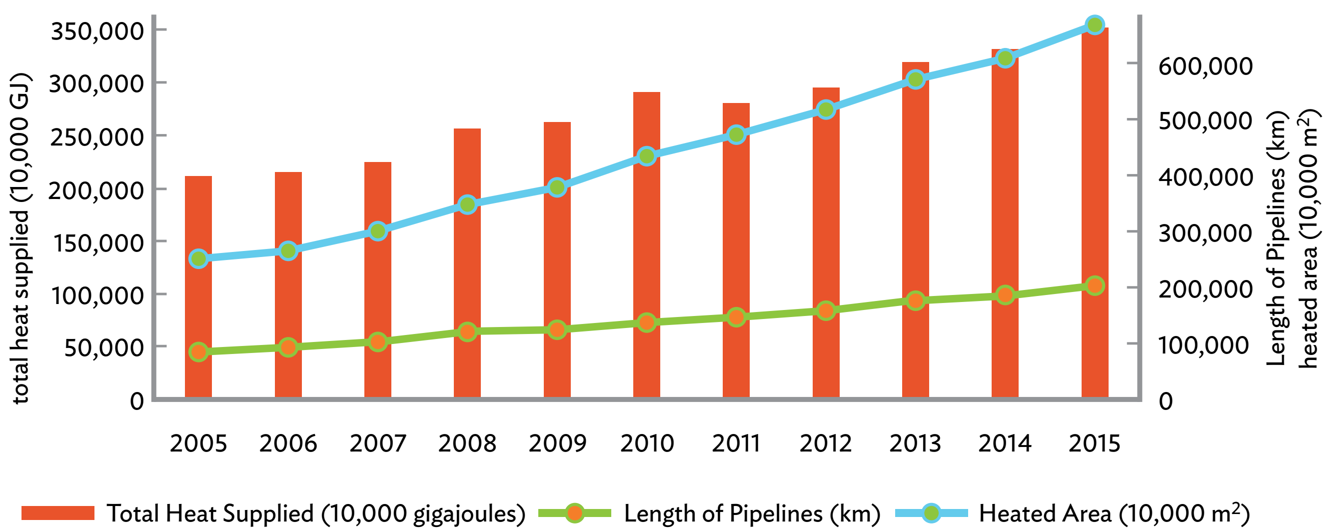
		Baseline Case	Gas Boiler Project	SDH Project
Energy balance				
Gas consumption	Nm^3/year	1,712,000	1,556,000	1,245,200
Heat production, gas engine	MWh/year	2,669	1,742	1,596
Heat production, gas boiler	MWh/year	13,731	14,658	11,334
Heat production, solar thermal	MWh/year			3,524
Total heat production	**MWh/year**	**16,400**	**16,400**	**16,454**
Net electricity production, gas engine	MWh/year	2,044	1,333	1,221
Investment				
6 MWh gas boiler	DKK		2,314,926	2,314,926
Solar thermal plant (including land acquisition, geologic surveys, etc.)	DKK			18,944,180
Engineering and auxiliaries	DKK		383,000	2,050,000
Total	**DKK**	**0**	**2,847,926**	**21,547,106**
Operating expenses	DKK/year	7,654,479	7,360,624	5,828,568
Annual savings	DKK/year		293,855	1,825,910
Simple payback period	Years		9.7	11.8

DKK = Danish krone, MWh = megawatt-hour, Nm^3 = normal cubic meter.
Source: Løgstrup District Heating Company

7. Solar Thermal District Heating Market in the People's Republic of China

The Chinese district heating sector is the world's largest. Installed capacity in 2016 was 529 GWth, of which hot water district heating made up 89%, and steam district heating, 11%. The growth of the market, in terms of annual energy supply (GJ), length of pipelines (km) and heating area (m^2), is shown in Figure 22.

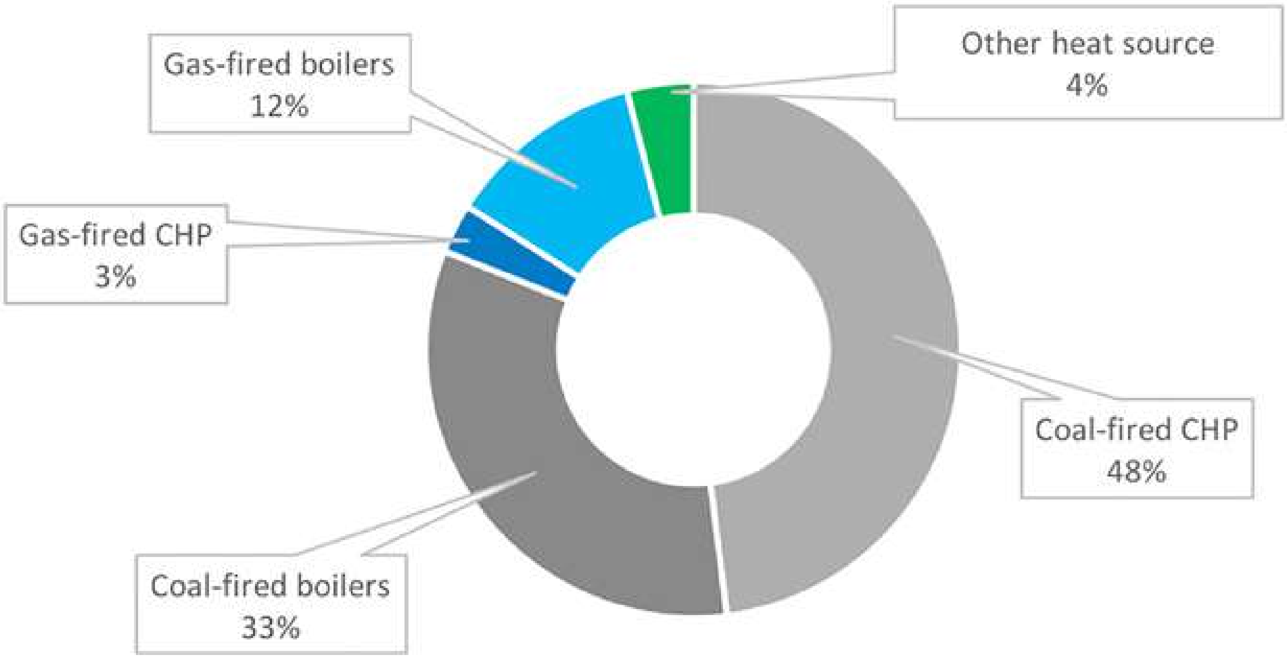
Figure 22: Growth of the District Heating Market in the People's Republic of China, 2005–2015



GJ = gigajoule, km = kilometer, m^2 = square meter.
Source: International Metal Solar Industry Association (IMSIA).

Coal and gas are the two main resources for district heating in the PRC, accounting for 81% and 15% of the district heating total in 2016, respectively. The government plans to increase the share of non-fossil fuels to 15% by 2020 and 20% by 2030—ambitious targets given their current share of less than 4%. The energy structure for district heating in the PRC is shown in Figure 23.

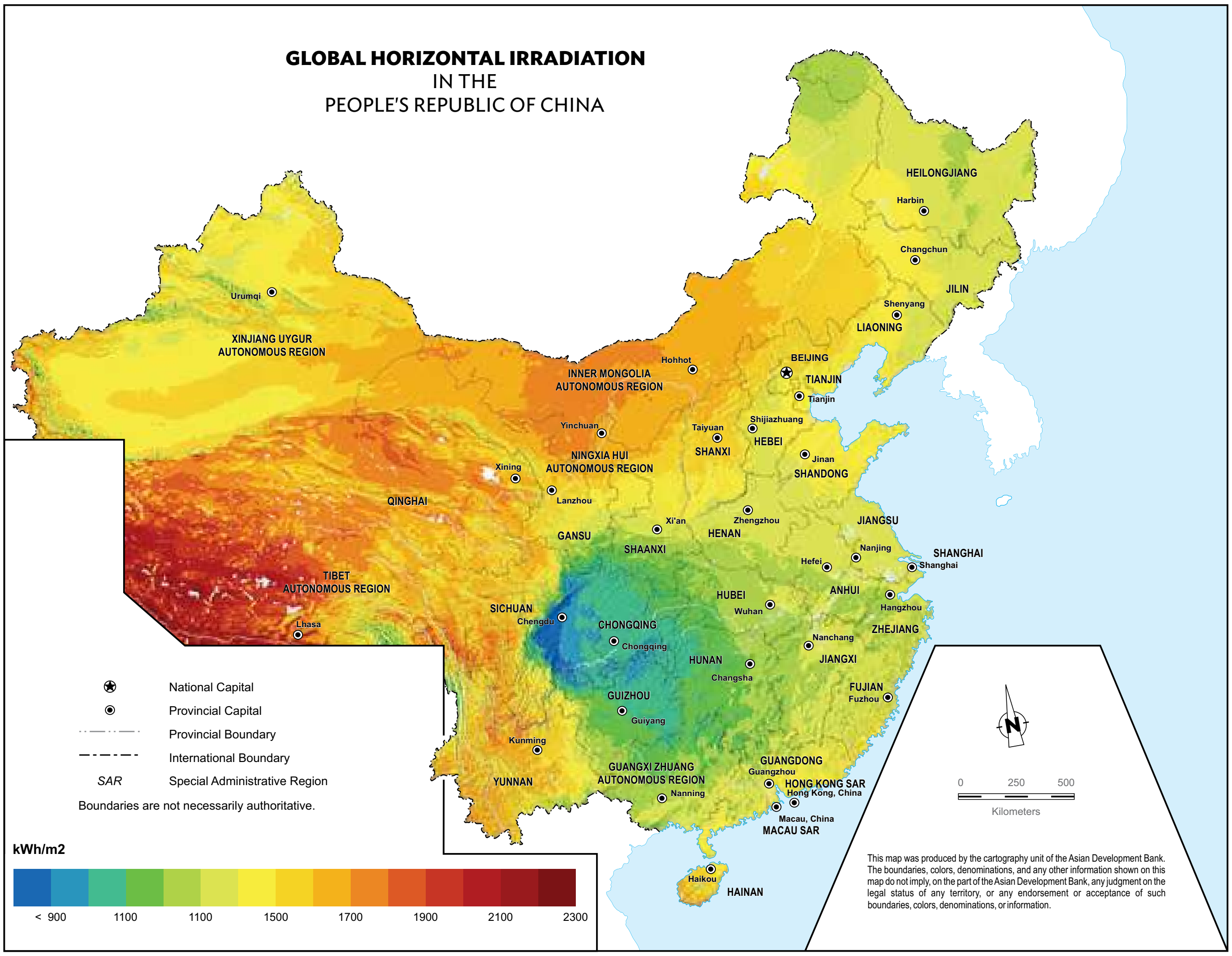
Figure 23: Energy Structure of District Heating in the PRC



CHP = combined heat and power, PRC = People's Republic of China.
Source: International Metal Solar Industry Association (IMSIA).

Average horizontal solar irradiation in the PRC is shown in Figure 24. It can be seen from the figure that large parts of northern PRC are rich in solar resources. The Tibet Autonomous Region has the most solar resources, followed by Xinjiang, Qinghai, Inner Mongolia, and Gansu. Compared with central and northern Europe, the other provinces in northern PRC are relatively rich in solar resources as well.

Figure 24: Average Horizontal Solar Irradiation in the PRC



km = kilometer, kWh/m^2 = kilowatt-hour per square meter.
Source: Solargis. https://solargis.com/

The PRC is the world's top economy in solar thermal installation, in terms of capacity (GWth) as well as collector area (m^2). At the end of 2015, the installed solar collector area in the PRC reached a total of 442.1 million m^2, corresponding to 309 GWth. The country holds 71% of the global market in both installed solar heating capacity and collector area.

Flat-plate collectors made up 25 GWth of the PRC's installed solar heating capacity and 35.6 million m^2 of its installed solar collector area at the end of 2015. Vacuum tube collectors accounted for 284 GWth and 406.6 million m^2, corresponding to 92% of installed capacity and of installed collector area.

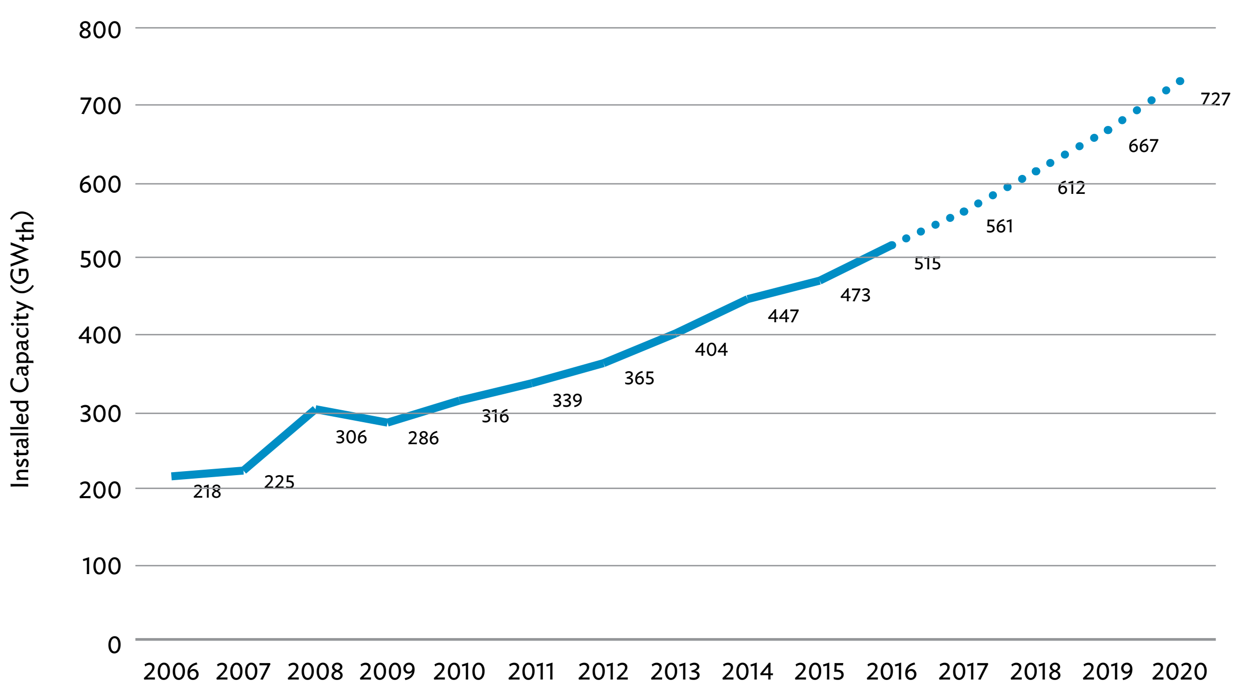
SDH projects make up only a fraction of the solar heating projects in the PRC. The installed solar heating collector area for these projects in the PRC ranges from 30,000 m^2 to 155,000 m^2, depending on the data source. The SDH projects listed in Chapter 9 (Table 7) cover about 30,000 m^2 of installed solar collector area. With an average heat capacity factor of about 0.7 kWth/m^2 for its solar heating collectors, the PRC has installed SDH capacity of 20–110 MWth.

Market Potential for Solar Thermal District Heating in the PRC

In recent years, the country's hot water district heating sector has grown by an average of 10% in pipeline length, 9% in installed capacity, and 7% in annual heat supply.

Figure 25 traces the growth in installed hot water district heating capacity (GWth) from 2006 to 2015. The data for 2016–2020 are based on an assumed capacity growth of 9% over the 5-year period.

Figure 25: Installed Hot Water District Heating Capacity in the PRC, 2006–2020



GW_{th} = gigawatt-thermal.
Source: Consultant's compilation and projections.

Based on the forecast growth of the district heating market, Table 5 presents scenarios for the potential SDH capacity of the PRC in 2018–2020. The scenarios assume that clean energy will constitute 5%–20% of district heating supply in the PRC, and that 5%–20% of the clean energy will be SDH.

Table 5: Potential Solar District Heating Capacity of the PRC at Different Penetration Levels, 2018–2020

	Share of Clean District Heating											
SDH Share	**5%**			**10%**			**15%**			**20%**		
	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
5%	1.5	1.7	1.8	3.1	3.3	3.6	4.6	5	5.5	6.1	6.7	7.3
10%	3.1	3.3	3.6	6.1	6.7	7.3	9.2	10	10.9	12.2	13.3	14.5
15%	4.6	5.0	5.5	9.2	10	10.9	13.8	15	16.4	18.4	20	21.8
20%	6.1	6.7	7.3	12.2	13.3	14.5	18.4	20	21.8	24.5	26.7	29.1

GW = gigawatt, PRC = People's Republic of China, SDH = solar district heating.
Source: Consultant's compilation and projections.

Considering that the PRC has less than 0.1 GW of installed SDH capacity at present, its SDH potential is huge. Under the most conservative scenarios listed above, the SDH market in the PRC could become 20 times as large in the coming years. If developed SDH projects are assumed to have an average solar capacity of 10 MW, 150–200 projects can reasonably be expected.

Feasible District Heating Schemes

In the PRC, the district heating supply is mainly used for comfort heating, and is limited to the local heating season period in each municipality. As solar resources are most plentiful in summer, seasonal storage is a precondition for the feasibility of SDH projects.

Solar thermal technology, a production technology with relatively high capital cost but low operating cost, is best suited to base load utilization with many full-load hours. In Europe, 20%–50% of annual energy supply typically comes from solar thermal in SDH systems, complemented with production facilities for which the capital cost is relatively low but operating cost is high. This same concept would be appropriate to the PRC. SDH in combination with heat pumps, preferably driven by wind power, would make up a highly efficient and environment-friendly district heating scheme.

Traditional district heating systems in the PRC often operate with a supply temperature of up to 120°C–130°C. Integrating new district heating systems with a lower supply temperature would increase efficiency. Smaller areas in counties and elsewhere, for example, use temperature levels more similar to those of secondary heating networks or fourth-generation district heating systems (40°C–50°C).

Traditional systems with centralized HOBs or CHP could integrate solar thermal plants as well. Land availability and cost issues are often raised in relation to SDH. To deal with such issues in densely populated areas, long transmission lines could be used to transmit heat from remote production sites. It should be remembered that the cost of land for SDH is very low, compared with the cost of land for biomass power generation with its associated opportunity cost, especially if the energy generated over the life of the project is taken into account.

A number of characteristics determine the feasibility of SDH schemes:

i. cheap land
ii. solar collector plant (covering typically 20%–50% of annual energy demand)
iii. complementary renewable heat and power generation (for peak production and increased temperatures)
iv. seasonal thermal energy storage
v. rich solar resources

Priority Provinces

The areas in the PRC that are most suitable for SDH systems development are those with relatively abundant solar resources, a long heating season, and cheap land that is readily available. Lack of infrastructure for gas and coal supply would further increase the incentives for SDH. Provinces with these characteristics are parts of the Tibet Autonomous Region, Xinjiang, Qinghai, the Inner Mongolia Autonomous Region, and Gansu.

8. Legislation and Policies in Support of Solar Thermal Energy Use in the PRC

In its 13th Five-Year Plan (2010–2016), the PRC set a minimum target of 15% for nonfossil energy's share of overall primary energy consumption by 2020, while pledging to invest CNY2,500 billion ($364 billion in August 2017) in the renewable energy sector. Financial support for urban clean heating in the "2 + 26" cities in the Jing-Jin-Ji region was the first manifestation of its resolve. Beijing and Tianjin would each receive CNY1 billion ($149.62 million) yearly; provincial-level capital cities, i.e., Shijiazhuang, Taiyuan, Jinan, and Zhengzhou, CNY7 billion ($1.05 billion); and prefecture-level cities, e.g., Tangshan, Baoding, Langfang, Zibo, Kaifeng, and Jincheng, CNY5 billion ($748.12 million).

The 13th Renewable Energy Development Five-Year Plan (2016–2020) sets guidelines for solar energy development, such as, "Speed up the application of all kinds of medium- to high-temperature solar thermal technologies in the industrial sector to satisfy the demand for domestic hot water, space heating, steam heating and cooling, etc., in the appropriate areas; promote cross-seasonal solar thermal energy storage projects for heating."

The National Energy Administration has further clarified the goal of solar energy deployment in its 13th Solar Energy Development Five-Year Plan (2016–2020), released on 8 December 2016.

The plan includes targets of 110 gigawatts (GW) of installed solar power (105 GW of solar photovoltaic power and 5 GW of concentrated solar power) and 800 million m^2 of installed solar collector area (560 GW). Annual investment of CNY100 billion ($14.96 billion) in solar heating is expected. By the end of 2020, installed solar collector area for the use of the general public should have reached 200 million m^2, and for industrial and agricultural use, 150 million m^2. The plan set the following main tasks for solar heating and cooling:

Further Promote the Use of Solar Hot Water

In areas where solar energy resources are suitable for use, solar water heating projects for public buildings, affordable housing, and tenement housing in large and medium-sized cities should be intensively promoted from the time the buildings are planned and designed to the time they are built, rebuilt and restored, or expanded.

Promote Solar Heating and Cooling Technology According to Local Conditions

In northeastern and northern PRC, as well as other areas where there is centralized heating, the integration of solar energy with conventional energy, for use in centralized or distributed heating, should be actively promoted. In areas without centralized heating, such as eastern and central PRC, and the Yangtze and Pearl river deltas, combining renewable energy in the form of solar energy, geothermal energy, or biomass with locally available renewable energy resources would increase generating efficiency while reducing environmental impact and improving environmental sustainability. Given suitable conditions, the use of solar district heating systems should be encouraged in medium-sized and small towns and in residential and public buildings, and triple power supply systems should be built for domestic hot water and space heating and cooling. The solar energy development plan foresees more than 200 large regional heating stations in the appropriate areas by 2020, and a total heating area or more than 4 million m^2. Heating demonstration projects would be serving more than 3 million families in rural areas nationwide.

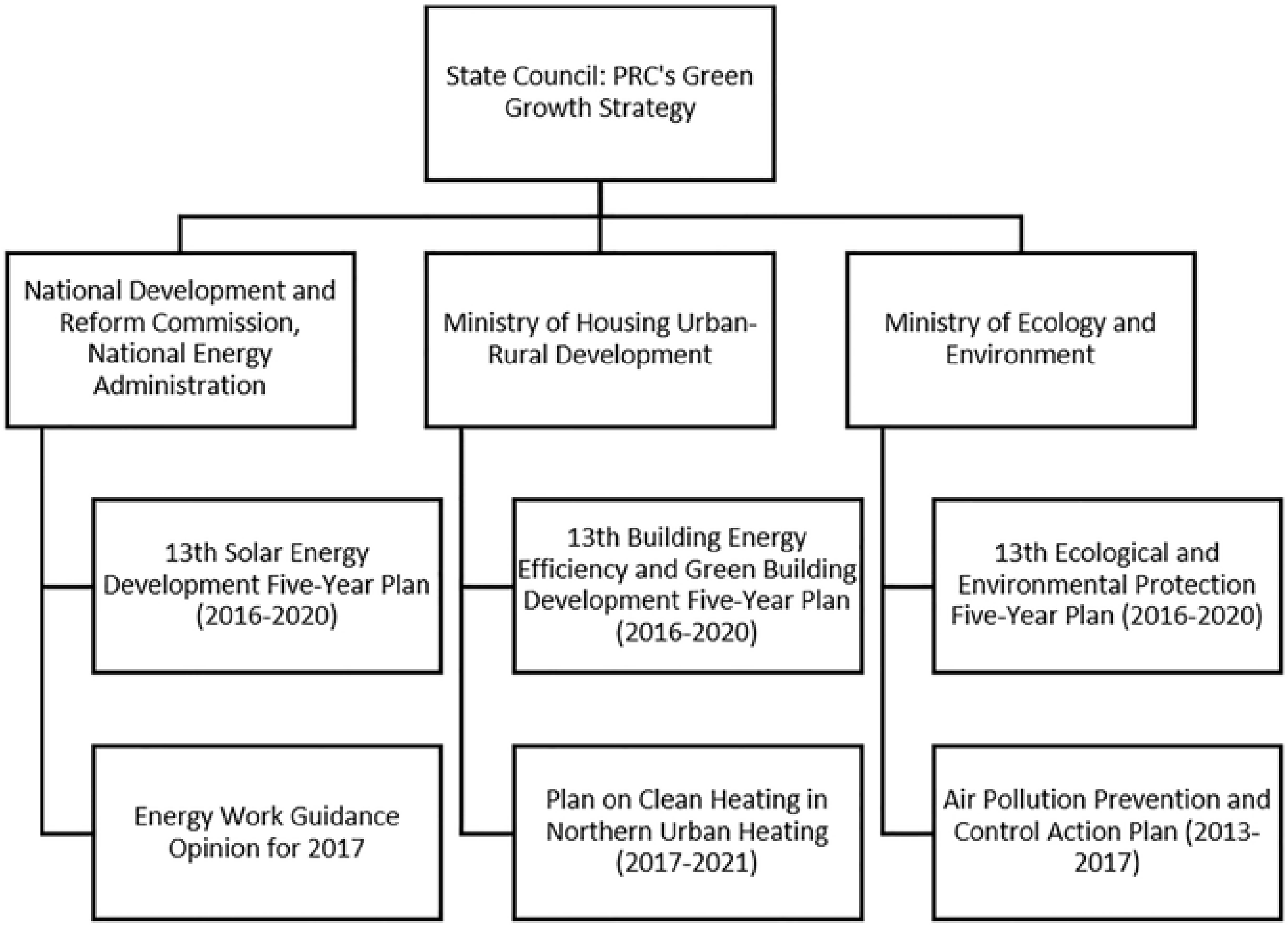
Promote Solar Heating in Industrial and Agricultural Areas

In new industrial areas (economic development zones) and reconstructed traditional industrial areas, solar heating should be combined with conventional heating to promote clean energy generation by industries, reduce carbon emissions, and save energy. Solar heating should be a basic energy source of conventional power systems in the printing and dyeing, ceramics, food processing, agricultural greenhouse, farming, and other industries where heat demand is large and solar thermal systems can be applied. Together with new energy demonstration cities, new renewable energy industrial parks, and green energy demonstration counties (districts), a number of industrial and agricultural projects using solar heating, with a total collector area of 20 million m^2, should be built.

National policies influence local policies. The 13th Renewable Energy Development Five-Year Plan (2016–2020) of Hebei province, for example, advocates the speedy and innovative development of renewable energy to replace coal burning, with an expected total heating area of 160 million m^2 by 2020. Technologies such as solar thermal collectors, solar heating, ground-source heating, hot dry rock heating, cross-seasonal solar thermal energy storage, and biomass heating are suggested. Beijing municipality has announced that it will provide 50% financial support for fixed asset investments in TES facilities integrated with air-source heat pump systems, ground-source heat pump systems, or centralized solar heating projects. Tianjin municipality has also issued technical guidelines for the regulation of solar water heating, air-source and ground-source heat pump systems, and coal–gas boiler systems.

The structure of policies that favor clean heating in the PRC is outlined in Figure 26 and set out in greater detail in Table 6.

Figure 26: Policies Favoring Clean Heating in the PRC



PRC = People's Republic of China.
Source: International Metal Solar Industry Association (IMSIA).

Table 6: Clean Heating Targets Set by Government Departments in the People's Republic of China

Regulations and Plans	Indices and Targets
13th Solar Energy Development Five-Year Plan (2016–2020)	Non-fossil energy will account for 15% of primary energy consumption by 2020, and 20% by 2030. By 2020, there will be more than 200 solar district heating stations in suitable areas, and more than 4 million m^2 of collector area in total. Together with the planned creation of a "new countryside," more than 3 million solar water heating demonstration projects will be promoted in rural areas nationwide.
13th Renewable Energy Development Five-Year Plan (2016–2020)	Non-fossil energy will make up 15% of primary energy consumption by 2020, and 20% by 2030.
13th Energy Development Five-Year Plan (2016–2020)	By 2020, renewable energy alternatives will account for about 1.5 tons tce in heating and civilian fuels. Solar thermal energy use (for heating and hot water supply) will have reached 96 million tce (800 million m^2).
13th Building Energy Efficiency and Green Building Development Five-Year Plan (2016–2020)	By 2020, the supply capacity of non-fossil energy will have increased to 750 million tce, and non-fossil energy consumption will compose more than 15% of primary energy consumption.
Policy Recommendations to Promote Renewable Heating Technologies	By 2020, renewable energy alternatives will have replaced more than 6% of conventional energy consumption in civil buildings. Buildings will have more than 2 billion m^2 of new solar thermal application area.
Air Pollution Prevention and Control Action Plan (2013–2017)	By 2017, the proportion of non-fossil energy consumption in primary energy consumption will have increased to 13%.

m^2 = square meter, tce = metric tons of coal equivalent.
Source: International Metal Solar Industry Association (IMSIA).

9. Case Studies

Not many solar thermal projects implemented in the PRC could be regarded as SDH systems. The solar thermal district heating project of the Hebei University of Economics and Business in Shijiazhuang is a large-scale project, even by global standards, and is the largest SDH project in the PRC. Table 7 is a list of SDH projects implemented in the PRC. The gap in heating area between the largest project and the second largest is evident.

Table 7: Solar District Heating Projects Implemented in the PRC

Project	Heating Area (m^2)	Solar Collector Type (m^2)	Solar Collector Area (m^2)	Storage Volume (m^3)	Storage Period	Investment in Solar System (CNY million)
Hebei University of Economics and Business, Shijiazhuang, Hebei Province	480,000	All-glass vacuum tube collector	11,600	20,292 (228 x 89)	Seasonal	40
Shigatse Railway Station, Rikaze, Tibet Autonomous Region	9,991	Heat pipe vacuum tube collector	2,000	2,500	Seasonal	N/A
Hongsipu Railway Station, Ningxia	2,287	All-glass vacuum tube collector	320	10	Daily	N/A
Lhasa Railway Station, Lhasa, Tibet Autonomous Region	19,504	Heat pipe vacuum tube collector	6,720	1,000	Daily	N/A
Naqu Logistics Center, Naqu, Tibet Autonomous Region	33,000	Heat pipe vacuum tube collector	7,616	770	Daily	N/A

m^2 = square meter, m^3 = cubic meter, N/A = not available.
Source: Consultant's compilation.

Interviews (see sample results in Appendix 1) revealed that the PRC has a large number of projects in the pipeline, and that many are expected to be implemented in the coming years. The main challenges at the moment pertain to the complexity of technology integration into district heating systems and the need to develop concepts that are both technically and financially feasible. The two projects presented in more detail below give insights into a potentially challenging project (in Beijing Da'anshan District) as well as a project that could be quite feasible (in Wangjiapu Village, Kangzhuang Town, Beijing Yanqing District).

Beijing Da'anshan District Solar District Heating Project

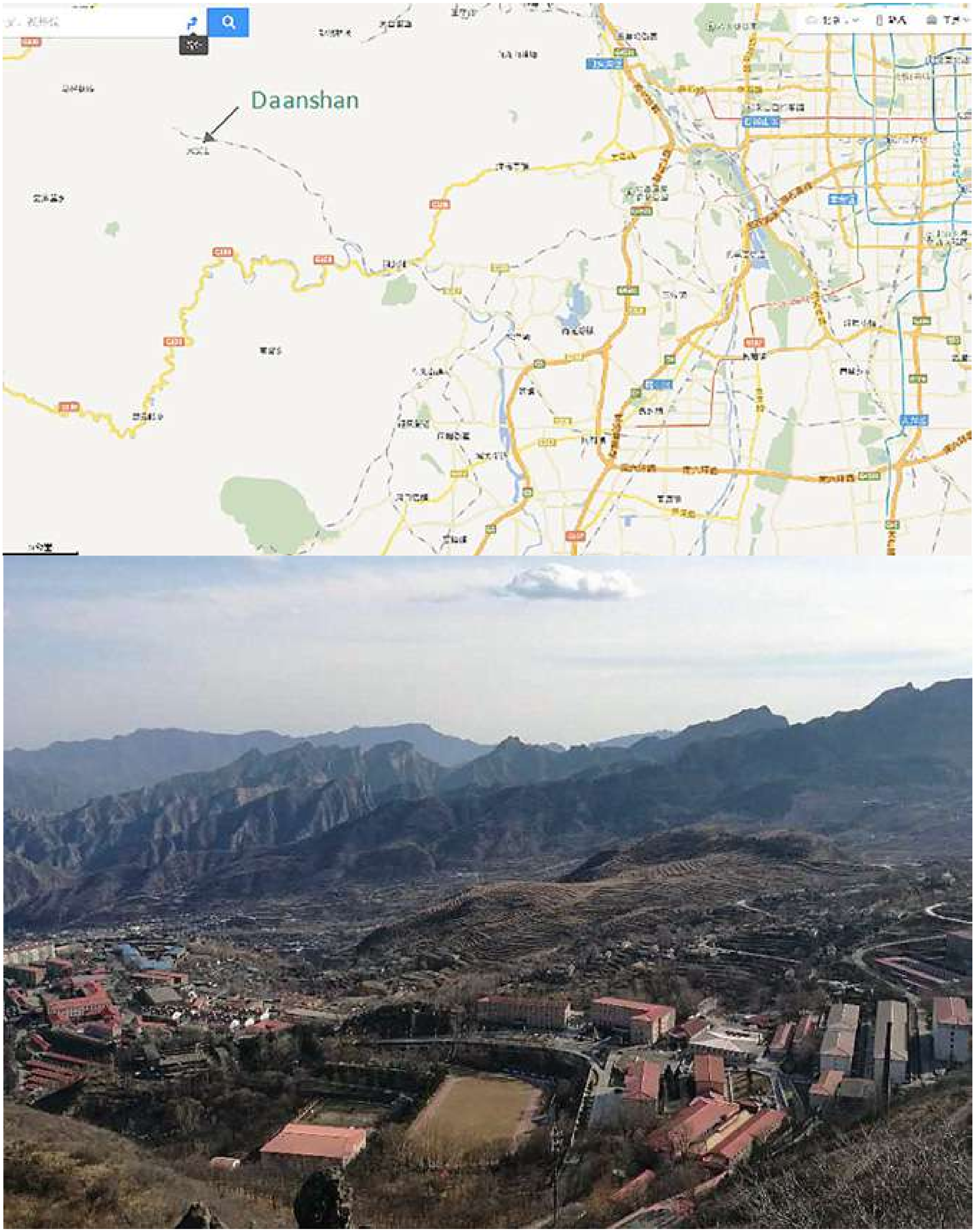
The project entered the feasibility study phase in 2017. It would supply low-carbon district heating in a relatively remote mountainous area west of Beijing, which has historically endured considerable local pollution from inefficient coal HOBs. The project owner is the Beijing District Heating Group. Table 8 gives key information about the project.

Table 8: Key Information about the Beijing Da'anshan Solar District Heating Project

Type of buildings		Residential and office
Type of consumption (comfort heating/DHW)		Space heating and DHW
Heating area		119,000 m^2
Annual heating consumption		8,350 MWh
Peak load		5 MW
SDH Concept	Solar collectors	Vacuum tubes 10,834 m^2 8,800 MWh
	Additional heat source	Solar thermal–based heat pump 5 MWth
	Storage	PTES 80,000 m^3
	District heating system	65°C/45°C
Investment cost		CNY126 million
Heat production cost		CNY450/MWh (excluding financial costs and depreciation)

DHW = domestic hot water, m^2 = square meter, m^3 = cubic meter, MWh = megawatt-hour, MWth = megawatt-thermal, PTES = pit thermal energy storage, SDH = solar district heating, C = Celsius, CNY = Chinese yuan.
Source: Consultant's compilation.

Figure 27: Map and Overview of the Beijing Da'anshan Solar District Heating Project



Source: Consultant's compilation.

Because of the immaturity of the project, it is difficult to give a final assessment of its feasibility. However, the key figures listed in Table 8 indicate low financial feasibility, compared with other technologies. Local conditions in the mountainous area are also challenging in regard to the installation of solar collectors.

Solar District Heating Project in Wangjiapu Village, Kangzhuang Town, Beijing Yanqing District

The project started construction in 2017 and will be in partial operation during the 2017/2018 heating season. It is expected to be completed in 2018. The leading contractor for the project is Tianpu Solar, which is also providing the flat panels to the project. Key information about the project is given in Table 9.

Table 9: Key Information about the Solar District Heating Project in Wangjiapu Village, Kangzhuang Town, Beijing Yanqing District

Type of buildings		Single-family houses
Type of consumption		Space heating
Heating area		19,000 m^2
Annual heating consumption		N/A
Peak load		1.9 MW
SDH Concept	Solar collectors	Flat panel 2,400 m^2 1.68 MW 8,935 GJ
	Additional heat source	Heat pumps 0.42 MW 1,814 GJ
	Storage	BTES 500 wells, 100 m depth 1.48 MW and 7,148 GJ
	District heating system	Fan coil 45°C/40°C
Investment cost		CNY20 million
Heat production cost		CNY166/MWh (excluding financial costs and depreciation)

BTES = borehole thermal energy storage, GJ = gigajoule, m = meter, m^2 = square meter, MW = megawatt, MWh = megawatt-hour, MWth = megawatt-thermal, N/A = not available, SDH = solar district heating, CNY = Chinese yuan.
Source: Consultant's compilation.

Figure 28: Map and Overview of the Solar District Heating Project in Wangjiapu Village, Kangzhuang Town, Beijing Yanqing District

Source: Consultant's compilation. Map Data: Google Earth; Annotations: Consultant.

The relative immaturity of the project makes a final assessment of its feasibility difficult. But the project plan and initial studies indicate that it could become one of the most feasible projects in the PRC. The technologies applied, the geographic conditions, and the design follow the principles identified during this study for a successful project. The project is still smaller in scale than many international SDH projects. However, it is advisable to have a feasible and well-planned small-scale project that can serve as a model for larger-scale projects in the future.

10. Conclusions and Recommendations

SDH is feasible in the PRC, given the right system design and suitable locations. The most appropriate solar collector technologies for SDH will depend somewhat on local conditions, but flat-panel collectors are expected to be the most suitable in general. Highly efficient solar collectors, including both flat panels and vacuum tube collectors, are available in the Chinese market. The final choice of technology could be decided in the course of feasibility studies during project development.

The market potential is huge. A conservative estimate suggests that 150–200 projects could be implemented in the coming years. The PRC could overtake Denmark as the economy with the most number of SDH projects implemented. While the country has policies that indirectly support SDH, more specific policies and incentive models would be needed to promote SDH systems development. Intensified project development would in turn support the intended increase in the use of renewable energy in the Chinese district heating sector.

A review of SDH development scenarios suggests that a solar collector plant should be combined with seasonal storage and complementary production facilities, and that a 20%–50% share for solar energy in annual heat supply for SDH should be typical.

The following summary of strengths, weaknesses, opportunities, and threats (SWOT analysis) provides an overview of the business environment for SDH in the PRC.

Strengths

i. low (or no) greenhouse gas emissions
ii. improved environmental efficiency
iii. long life span of over 25 years, leading to lower maintenance cost and better management
iv. financial competitiveness (given the right preconditions) compared with coal-fired CHP, natural gas, and biomass

Weaknesses

i. high initial costs (front-loaded investments)
ii. technical feasibility only in areas with available land
iii. lack of incentives and regulations
iv. need for well-structured and coordinated planning, design, and project implementation

Opportunities

i. huge market growth potential
ii. greater environmental awareness among the general public and within government
iii. possibility of benefiting from policies for increasing renewable energy in district heating sector
iv. success stories

Threats

i. lack of enforced policies for integrating renewable energy
ii. lack of financing for projects in rural areas
iii. unsatisfactory feasibility studies
iv. inexperienced project planners, designers, and implementers

Most solar thermal projects in the PRC are intended for individual households and often use inexpensive but low-quality solar collector technologies. Project failures have created dissatisfied end users and regrettably influenced public perceptions of SDH. But SDH, if correctly planned, designed, implemented, and operated, provides the benefits of district heating—high efficiency, supply reliability, and comfort—as well as environmental benefits.

In developing new SDH systems, priority should be given to areas with abundant solar resources and available land, preferably smaller communities where the temperature level does not have to be too high for distribution reasons.

The following measures are suggested for the further promotion of SDH in the PRC:

i. Increase awareness of SDH benefits, strengths, and opportunities.
ii. Develop a feasibility evaluation tool for SDH projects.
iii. Produce a best-practice handbook for SDH in the PRC, covering the entire project value chain.
iv. Identify an SDH pilot project to provide an example of international district heating best practice.

Appendix 1 – Sample Interview Results

Interview No. 1

Interviewee	**Han Jiangong** General Manager, Sanpu Solar
Interviewers	Mikael Jakobsson Li Shaofang
Questions	**Answers (interpreted/shortened on the basis of discussions)**
1. How is SDH defined in the PRC?	There is no standard definition for SDH.
2. Is SDH feasible in the PRC (compared with other RE, and considering suitable regions and rural vs. urban, new vs. old DHS comparisons)?	It is hard to say at this time whether or not SDH is commercially feasible. In some areas with good solar resource and good financing, it is worthwhile to study and implement SDH pilot projects. Look at the PV sector. Twenty years ago, nobody in the PRC expected that sector to develop so successfully. But now, PV is almost commercially feasible.
3. What are the main challenges for SDH in the PRC?	Land resource and price, technical integration, and component cost are the main limitations. Public awareness of SDH benefits should be enhanced. Marketing should be stepped up, with reasonable timelines. The quality of some solar collectors is not acceptable.
4. What are the main advantages for SDH in the PRC?	We have strong production capacity for solar collectors.
5. Which is the most feasible solar thermal collector technology in the PRC (in technical and financial terms)?	Both glass tube collectors and flat-panel collectors can be used for SDH. Flat-panel collectors may be more suitable in terms of reliability, proven technology, and integration with large systems. Other technologies, such as high-temperature collectors, are also available, but need more study before application.
6. What is the most feasible solar thermal concept in the PRC (in combination with TES, HP, HOB)?	SDH should be combined with energy supply facilities such as TES, HP, HOB. Studies should be done to identify which of these is the most appropriate complementary energy source.
Other comments from the interviewee	Pay attention to R&D and strengthen marketing; integrate other energy sources with solar energy; take a step-by-step approach to promoting SDH; introduce advanced technology; and create awareness among customers, financing agencies, etc. Solar district heating is the future of the solar thermal sector.

DHS = district heating system, HOB = heat-only boiler, HP = heat pump, PRC = People's Republic of China, PV = photovoltaic, R&D = research and development, RE = renewable energy, SDH = solar district heating, TES = thermal energy storage.

Interview No. 2

Interviewee	**He Zinian** Professor, Beijing Institute of Solar Energy
Interviewers	Mikael Jakobsson Li Shaofang
Questions	**Answers (interpreted/shortened on the basis of discussions)**
1. How is SDH defined in the PRC?	There is no standard definition for SDH, only for solar heating (heating system integrated with solar panels).
2. Is SDH feasible in the PRC (compared with other RE, and considering suitable regions and rural vs. urban, new vs. old DHS comparisons)?	Each kind of energy resource has its own features and suitable applications. I do not see solar energy as better or worse than other forms of renewable energy. Its use will be based on local conditions. It will be feasible in some cases, and not feasible in others. Generally, solar heating is more suitable for villages, small towns, and suburban areas of big cities in northern PRC.
3. What are the main challenges for SDH in the PRC?	Policy and technology barriers are the main challenges. Government should issue policies to promote solar heating, and make it easier to acquire land and financing resources for solar heating projects. Technically, we do not have enough solar heating experience. We will learn from Denmark and other countries that have well-developed solar heating systems.
4. What are the main advantages for SDH in the PRC?	Our solar collector production capacity, the biggest in the world, gives us a solid foundation for solar heating.
5. Which is the most feasible solar thermal collector technology in the PRC (in technical and financial terms)?	Each kind of collector has its own features and suitable applications. It's hard to say which is the most feasible.
6. What is the most feasible solar thermal concept in the PRC (in combination with TES, HP, HOB)?	Solar heating systems with seasonal storage tanks look promising.
Other comments from the interviewee	Compared with Denmark and other countries with a well-developed solar heating sector, the PRC has major solar heating potential. In Denmark and other countries, solar collectors used for heating account for a 20%–30% share of all solar collectors used in the countries. However, in the PRC, the share is only 2%–3%; the other solar collectors are used for domestic hot water. We should increase public consultation to improve awareness of the benefits of solar heating, and promote its wider use.

DHS = district heating system, HOB = heat-only boiler, HP = heat pump, PRC = People's Republic of China, PV = photovoltaic, R&D = research and development, RE = renewable energy, SDH = solar district heating, TES = thermal energy storage.

Interview No. 3

Interviewee	**Zheng Ruicheng** Senior consultant, China Academy of Building Research
Interviewers	Mikael Jakobsson Li Shaofang
Questions	**Answers (interpreted/shortened on the basis of discussions)**
1. How is SDH defined in the PRC?	It is a heating system using one solar collector array and covering many customers.
2. Is SDH feasible in the PRC (compared with other RE, and considering suitable regions and rural vs. urban, new vs. old DHS comparisons)?	It is feasible. We used to build a lot of solar domestic hot water systems. Now it is time to build solar heating systems. The solar domestic hot water business is slowing down, and the government is promoting clean energy heating, especially in villages and small towns in northwest and southeast PRC.
3. What are the main challenges for SDH in the PRC?	Management, including project implementation management and operation management, is the main barrier. The main causes of failure of solar projects are poor project preparation and poor operation management, especially in villages.
4. What are the main advantages for SDH in the PRC?	We have a well-developed solar collector manufacturing industry, and a lot of experience with domestic hot water projects.
5. Which is the most feasible solar thermal collector technology in the PRC (in technical and financial terms)?	All kinds of solar collectors can be used. Now flat panels are more in use.
6. What is the most feasible solar thermal concept in the PRC (in combination with TES, HP, HOB)?	Solar collector combined with HP is more feasible. Seasonal storage tank is also feasible.
Other comments from the interviewee	

DHS = district heating system, HOB = heat-only boiler, HP = heat pump, PRC = People's Republic of China, PV = photovoltaic, R&D = research and development, RE = renewable energy, SDH = solar district heating, TES = thermal energy storage.

Interview No. 4

Interviewee	**Li Renxing** General Manager, Tianpu Solar Energy Industry lrx@tianpu.com, +8613911373299
Interviewers	Mikael Jakobsson Li Shaofang
Questions	**Answers (interpreted/shortened on the basis of discussions)**
1. How is SDH defined in the PRC?	There is no standard definition for SDH.
2. Is SDH feasible in the PRC (compared with other RE, and considering suitable regions and rural vs. urban, new vs. old DHS comparisons)?	It is feasible in areas with good policy support and solar resource.
3. What are the main challenges for SDH in the PRC?	Policy support for SDH is insufficient. The solar thermal sector does not get enough attention from government.
4. What are the main advantages for SDH in the PRC?	Solar products are available. Solar resource is good. Clean energy heating is attracting attention more and more.
5. Which is the most feasible solar thermal collector technology in the PRC (in technical and financial terms)?	The flat-panel collector is the most suitable.
6. What is the most feasible solar thermal concept in the PRC (in combination with TES, HP, HOB)?	This depends on local conditions. Seasonal storage is a good option.
Other comments from the interviewee	

DHS = district heating system, HOB = heat-only boiler, HP = heat pump, PRC = People's Republic of China, PV = photovoltaic, R&D = research and development, RE = renewable energy, SDH = solar district heating, TES = thermal energy storage.

Appendix 2 – Published Papers and Articles on Solar Thermal Power, 1986–2016

Year	Solar Heating Status	Solar Thermal Collector Technology	TES	Technical and Financial Analysis	Environmental Impact and Benefits	Operation and Management	Introduction of International Practice	Control	Total
1986									0
1987									0
1988									0
1989									0
1990				1					1
1991		1							1
1992									0
1993		1							1
1994									0
1995									0
1996									0
1997		1							1
1998		3						1	4
1999		2		1					3
2000		4		3				2	9
2001	1	16		5			1	1	24
2002	1	9		2				2	14
2003	5	24		7				2	38
2004	5	20		8	1			7	41
2005	4	18	3	9	1	1	1	6	43
2006	9	40	1	17	1		1	17	86
2007	13	43	3	27	1	1	1	15	104
2008	17	43	1	23			4	23	111
2009	12	57	4	32		1	2	25	133
2010	25	75	5	40	2	2	1	22	172
2011	20	80	3	26	3	1	1	23	157
2012	20	79	6	43	3	2	2	28	183
2013	26	84	8	36		2	5	24	185
2014	25	86	4	39	2	1	2	39	198
2015	27	86	1	37	3	2	2	26	184
2016	10	66	2	27	1			27	133
Total	**220**	**838**	**41**	**383**	**18**	**13**	**23**	**290**	**1,826**

TES = thermal energy storage.
Source: Wanfang Data Search Engine.

Appendix 3 – Projects Implemented in Denmark, 1988–2016

Plant	Start of Operations	Owner	Location	Solar Collector Area (m^2)	Capacity (kW)	Type of Solar Collector	Type of TES
Silkeborg	2016	Silkeborg Forsyning A/S	Silkeborg	156,694	110,000	FPC	
Vojens	2012 - extension in 2014	Vojens Fjernvarme	Vojens	70,000	49,000	FPC	WTES
Gram	2009	Gram Fjernvarme	Gram	44,836	31,385	FPC	None
Dronninglund	2014	Dronninglund Fjernvarme	Dronninglund	37,573	26,300	FPC	WTES
Marstal	1996	Marstal Fjernvarme	Marstal	33,300	23,300	FPC	WTES
Ringkøbing	2010 - extension in 2014	Ringkøbing Fjernvarmevaerk	Ringkøbing	30,000	21,000	FPC	None
Brönderslev	2016	Brønderslev Forsyning	Brönderslev	26,929	19,000	PTC	
Toftlund	2013	Toftlund Fjernvarme	Toftlund	26,000	18,200	FPC	WTES
Aalestrup	2016	Aalestrup-Nørager Energi a.m.b.a.	Aalestrup	24,129	16,900	FPC	
Helsinge	2012 - extension in 2014	Helsinge Fjernvarme	Helsinge	22,831	16,000	FPC	None
Hjallerup	2015	Hjallerup Fjerrnvarme	Hjallerup	21,546	15,082	FPC	None
Vildbjerg	2014	Vildbjerg Tekniske Værker	Vildbjerg	21,244	14,900	FPC	
Hadsund	2015	Hadsunds Bys fjernvarmevaerk	Hadsund	20,513	14,360	FPC	None
Nykøbing Sjælland	2014	Nykøbing Sj. Varmevaerk	Nykøbing Sjælland	20,084	14,000	FPC	
Öster Toreby	2016	Öster Toreby Varmevaerk	Öster Toreby	20,000	14,000	FPC	
Gråsten	2012	Gråsten Fjernvarme	Gråsten	19,017	13,312	FPC	None
Braedstrup	2007	Braedstrup Fjernvarme	Braedstrup	18,612	13,027	FPC	BTES
Tarm	2013	Tarm Varmevaerk	Tarm	18,585	13,010	FPC	None
Aulum	2015	Aulum Fjernvarme a.m.b.a.	Aulum	16,015	11,200	FPC	None
Tørring	2009	Törring Kraftvarmevaerk	Tørring	15,800	11,000	FPC	None
Løgstør	2014	Løgstør Fjernvarmevaerk	Løgstør	15,500	10,900	FPC	
Farsö	2016	Farsö Varmevaerk	Farsö	15,400	10,800	FPC	
Løgumkloster 1	2015	Løgumkloster Fjernvarme	Løgumkloster	15,276	10,700	FPC	None
Jetsmark	2015	Jetsmark Energivaerk	Jetsmark	15,183	10,630	FPC	None
Jelling	2016	Jelling Vaermevaerk	Jelling	15,000	10,500	FPC	
Nyköping Mors	2016	Nykøbing Mors Fjernvarmeværk	Nyköping Mors	15,000	10,500	FPC	
Tommerup	2016	Tömmerup Bys Fjernvarmefor	Tommerup	15,000	10,500	FPC	
Oksbøl	2010	Oksbøl Varmeværk	Oksbøl	14,745	10,000	FPC	None
Stege	2016	Stege Fjernvarrme	Stege	14,500	10,150	FPC	
Hundested	**2015**	**Hundested Varmevaerk**	**Hundested**	**14,465**	**10,120**	**FPC**	**None**

TES = thermal energy storage.

Continued from page 52.

Plant	Start of Operations	Owner	Location	Solar Collector Area (m^2)	Capacity (kW)	Type of Solar Collector	Type of TES
Östervang	2015	Östervang Sjaelland	Östervang	14,112	9,880	FPC	None
Padborg	2016	Padborg Fjernvarme	Padborg	13,900	9,700	FPC	
Jægerspris	2010	Jægerspris Fjernvarme	Jægerspris	13,300	9,310	FPC	None
Vrå	2015	Vrå Varmeværk a.m.b.a.	Vrå	12,600	8,800	FPC	
Sydlangeland 1	2013	Sydlangeland Fjernvarme	Sydlangeland	12,512	8,758	FPC	None
Holsted	2016	Holsted Varmeværk	Holsted	12,500	8,750	FPC	
Grenaa	2014	Grenaa Varmeværk	Grenaa	12,096	8,500	FPC	
Veggerløse	2011	Sydfalster Fjernvarme	Veggerløse	12,075	8,500	FPC	None
Hvidebaek	2013	Hvidebaek Varmevaerk	Hvidebaek	12,000	8,400	FPC	None
Egtved	2016	Egtved Varmevaerk	Egtved	12,000	8,400	FPC	
Lökken	2016	Lökken Varmevaerk	Lökken	12,000	8,400	FPC	
Sæby	2011	Sæby Fjernvarme	Sæby	11,921	8,300	FPC	None
Svebølle-Viskinge	2011 - extension in 2014	Svebølle-Viskinge Fjernvarme	Svebølle-Viskinge	11,024	7,700	FPC	None
Hedensted	2016	Hedensted Fjernvarme	Hedensted	11,000	7,700	FPC	
Fugleberg	2016	Fuglebjerg Fjernvarme	Fugleberg	10,584	7,400	FPC	
Taars	2015	Taars Varmeværk a.m.b.a.	Taars	10,011	7,000	FPC	None
Jyderup	2016	Jyderup Varmevaerk	Jyderup	10,000	7,000	FPC	
Broager	2009	Broager Fjernvarme	Broager	9,988	6,992	FPC	None
Hvide Sande	2014	Hvide Sande Fjernvarme a.m.b.a.	Hvide Sande	9,576	6,700	FPC	
Christiansfeld	2013	Christianfeld Varmevaerk	Christianfeld	9,300	6,510	FPC	None
Langå	2015	Langå Varrmevaerk	Langå	8,505	5,950	FPC	None
Frederiks	2013	Frederiks Varmevaerk	Frederiks	8,438	5,907	FPC	None
Strandby	2008	Strandby Varmevaerk	Strandby	8,012	5,608	FPC	None
Vejby-Tisvilde	2012	Vejby-Tisvilde Fjernvarme	Vejby-Tisvilde	8,000	5,600	FPC	None
Karup	2013	Karup Varmeværk	Karup	8,000	5,600	FPC	None
Bredsten-Balle	2016	Bredsten-Balle Kraftvarmevaerk	Bredsten-Balle	7,800	5,500	FPC	
Soenderborg/Vollerup	2008	Soenderborg Fjernvarme	Soenderborg/ Vollerup	7,681	5,400	FPC	None
Gørding	2012	Gørding Varmevaerk	Gørding	7,400	5,200	Unknown	None
Skørping	2012	Skørping Fjernvarme	Skørping	7,300	5,110	FPC	None
Ærøskøping	1998	Ærøskøping Fjernvarme	Ærøskøping	7,090	5,000	FPC	None
Trustrup-Lyngby	2016	Trustrup Lyngby Varrmevaerk	Trustrup-Lyngby	7,000	4,900	FPC	
Løgstrup	2016	Løgstrup Varmevaerk	Løgstrup	7,000	4,900	FPC	
Snedsted (THY)	2015	Snedsted Varmevaerk	Snedsted	6,500	4,550	FPC	None
Haslev	2016	Haslev Fjernvarme	Haslev	6,400	45,00	FPC	
Ejstrupholm	2011	Ejstrupholm Fjernvarme	Ejstrupholm	6,243	4,400	FPC	None
Kværndrup	2015	Kvaerndrup Fjernvarme	Kværndrup	6,242	4,370	FPC	None
Hammershöj	2016	Hammershöj Fjernvarmeværk	Hammershöj	6,000	4,200	FPC	
Örum	2016	Örum Varrmevaerk	Örum	6,000	4,200	FPC	

TES = thermal energy storage.

Continued from page 53.

Plant	Start of Operations	Owner	Location	Solar Collector Area (m^2)	Capacity (kW)	Type of Solar Collector	Type of TES
Als (Hadsund)	2016	Als Fjernvarmeværk	Als	6,000	4,200	FPC	
Hejnsvig	2010	Hejnsvig Varmeværk	Hejnsvig	5,763	4,000	FPC	None
Aasa	2014	Asaa Fjernvarme a.m.b.a.	Aasa	5,650	4,000	FPC	
Veddum-Skelund-Visborg	2016	Veddum-Skelund-Visborg Kraftvarmevaerk	Veddum-Skelund-Visborg	5,500	3,850	FPC	
Tistrup	2010	Tistrup Varmeværk	Tistrup	5,400	3,780	FPC	None
Skårup (Sydfyn)	2016	Skårup Fjernavrme	Skårup	5,400	3,800	FPC	
Ulsted	2006	Ulsted Varmevaerk	Ulsted	5,012	3,500	FPC	None
Ørnhøj-Grønbjerg	2012	Ørnhøj-Grønbjerg Kraftvarmevaerk	Ørnhøj-Grønbjerg	5,000	3,500	FPC	None
Mou	2013	Mou Kraftvarme	Mou	4,737	3,316	FPC	None
Söllested	2016	Lolland Varme A/S	Söllested	4,700	3,300	FPC	
Jerslev	2015	Jerslev Kraftvarmevaerk	Jerslev	4,612	3,230	FPC	None
Tim	2013	Ringkøbing Fjernvarmevaerk	Ringkøbing	4,235	2,965	FPC	None
Haderup	2015	Haderup Kraftvarmeværk	Haderup	4,234	3,000	FPC	
Feldborg	2012	Felborg Kraftvarme	Feldborg	4,000	2,800	FPC	None
Tversted	2013	Tversted Kraftvarmeværk	Tversted	4,000	2,800	FPC	None
Gedser	2016	REFA Gedser Fjernvarme A/S	Gedser	4,000	2,800	FPC	
Sandved-Tornemark	2013	Sandved-Tornemark Kraftvarmeværk	Sandved-Tornemark	3,893	2,725	FPC	None
Rise	2001	Rise Fjernvarme	Rise	3,750	2,503	FPC	WTES
Skuldelev	2015	Skuldelev Energiselskab a.m.b.a.	Skuldelev	3,600	2,500	FPC	
Gjerlev	2014	Gjerlev Varmeværk a.m.b.a.	Gjerlev	3,500	2,500	FPC	
Sig	2013	Sig Fjernvarme	Sig	3,479	2,435	FPC	None
Öster Hurup	2015	Öster Hurup Varmevaerk	Öster Hurup	3,223	2,260	FPC	None
Ry	1988	Ry Fjernvarme A/S	Ry	3,040	2,128	FPC	None
Hilleroed/Ulleroed	2007	Hilleroed Fjernvarmevaerk	Hilleroed/Ulleroed	3,007	2,105	FPC	None
Insenvad	2014	Ikast El- og Varmeværk a.m.b.a.	Insenvad	3,000	2,100	FPC	
Høje Taastrup	2015	Høje Taastrup Fjernvarme	Høje Taastrup	3,000	2,100	FPC	
Flauenskjold	2014	Flauenskjold Fjernvarme	Flauenskjold	2,975	2,100	FPC	
Skovlund	2012	Skovlund Varmevaerk	Skovlund	2,970	2,100	FPC	None
Voerså	2016	Voerså Kraftvarmeværk a.m.b.a.	Voerså	2,873	2,000	FPC	
Kölkaer	2016	Energimidt	Kölkaer	2,800	1,960	FPC	
Havdrup	2016	Solröd Fjernvarme	Havdrup	2,569	1,800	FPC	
Nordby	2002	Samsø Energiselskab	Nordby	2,500	1,750	FPC	None
Gl Rye	2014	Rye Kraftvarmeværk a.m.b.a.	Gl Rye	2,400	1,700	FPC	
Dianalund	2011	Filadelfia	Dianalund	2,000	1,400	FPC	None
Ejsing	2016	Ejsing Fjernvarme	Ejsing	1,800	1,260	FPC	
Hørsholm	2012	Velux	Hørsholm	1,275	893	FPC	None
Tubberupvænge	1991	Herlev kom. Boligselskab	Tubberupvænge	1,030	721	FPC	WTES
Saltum	1988	Saltum Fjernvarme A/S	Saltum	1,005	704	FPC	None

TES = thermal energy storage.

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Solar District Heating in the People's Republic of China

Status and Development Potential

This publication explores the significant potential of solar district heating to accelerate the integration of renewable energy into heating systems in the People's Republic of China. This will be important in promoting low-carbon cities and reducing urban air pollution. The study highlights that solar district heating (SDH) can provide high efficiency and reliability as well as environmental benefits. It finds that SDH has considerable market potential in the PRC and proposes practical ways forward. The study will also be of interest to other Asian countries that face similar challenges.

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