SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

2025 HIGHLIGHTS

Task 68 - Efficient Solar District Heating Systems

THE ISSUE

Heat is the largest energy end-use, accounting for 50% of global final energy consumption in 2021 and contributing to 40% of global carbon dioxide (CO_2) emissions. Of the total heat produced, about 46% was consumed in buildings for space and water heating. Regarding the heat supply of buildings, district heating systems play an important role and are well-established in many countries since they typically enable efficient resource utilization. However, most district heating networks in Europe and worldwide still operate with supply temperatures over 80 to 120°C (medium-high temperature), which is still typically produced by caloric power plants. Currently operating solar district heating (SDH) systems are typically installed with flat-plate collectors providing either heat at lower temperatures or lower efficiency in case of higher temperatures. SHC Task 68 is therefore investigating how to increase the efficiency of SDH systems further and support the dissemination of such systems.

OUR WORK

SHC Task 68 provides a high-quality and powerful platform for practitioners and scientists to elaborate on the latest benefits and challenges of SDH systems. It elaborates on options and measures how to further increase the efficiency of solar district heating (SDH) systems when providing the desired temperatures needed by currently operated district heating systems by investigating how:

- To provide the heat most efficiently at the desired temperature level either directly by solar (e.g., combining flat-plate collectors with other solar collectors) or indirectly by solar by combining solar collectors with other technologies (e.g., solar collectors with heat pumps).
- To take the next step in digitalization measures to allow for more efficient data preparation and utilization.
- To make SDH systems more competitive and more appealing by exploring new business models and ways to reduce costs.
- To raise awareness of solar technologies and disseminate the knowledge.

Finally, SHC Task 68 aims to create synergies between the IEA Technology Collaboration Programme on District Heating and Cooling, including Combined Heat and Power (IEA DHC).

Participating Countries

Austria
China
Denmark
Germany
Italy
Netherlands
Spain
Sweden
United Kingdom

Task Period	2022 – 2025
Task Leader	Klaus Lichtenegger, BEST GmbH, Austria
Email	klaus.lichtenegger@best-research.eu
Website	task68.iea-shc.org

KEY RESULTS IN 2025

Insights from a Survey on Simulation Tools Used in SDH

A wide range of simulation and calculation tools is used in SDH applications. The results of a survey conducted, a collection of fact sheets for selected simulation tools created in collaboration with SolarPACES Task IV, and a brief comparison between TRNSYS and PolySun based on an example SDH system are presented in the report RA2.

Key findings of the survey show that, in addition to public tools, internal (non-public) tools are frequently used. Results from 32 survey responses show that TRNSYS is mentioned a total of 7 times, energyPRO 3 times, and internal tools are mentioned 9 times in total. While internal tools are often customised to specific industry or research needs, their lack of accessibility poses a challenge for collaboration and reproducibility in research. These tools are used in different fields of work, with most being used in research and development and engineering. They are also used in different project phases, primarily for preliminary studies, basic analysis and feasibility studies.

For different district heating (DH) applications, different collector technologies are suitable depending on the specific requirements of the system. Concentrating collectors, such as parabolic trough collectors (PTC) and linear Fresnel collectors, can play a key role in DH applications requiring higher temperatures, as they can provide heat more efficiently at elevated temperature levels. To evaluate tool capabilities in this area, the survey specifically asked whether concentrating collectors could be modeled, see Figure 1. Further investigation on the integration and simulation of PTC is ongoing as part of the German research project ProSolNetz (BSW Solar, 2025).

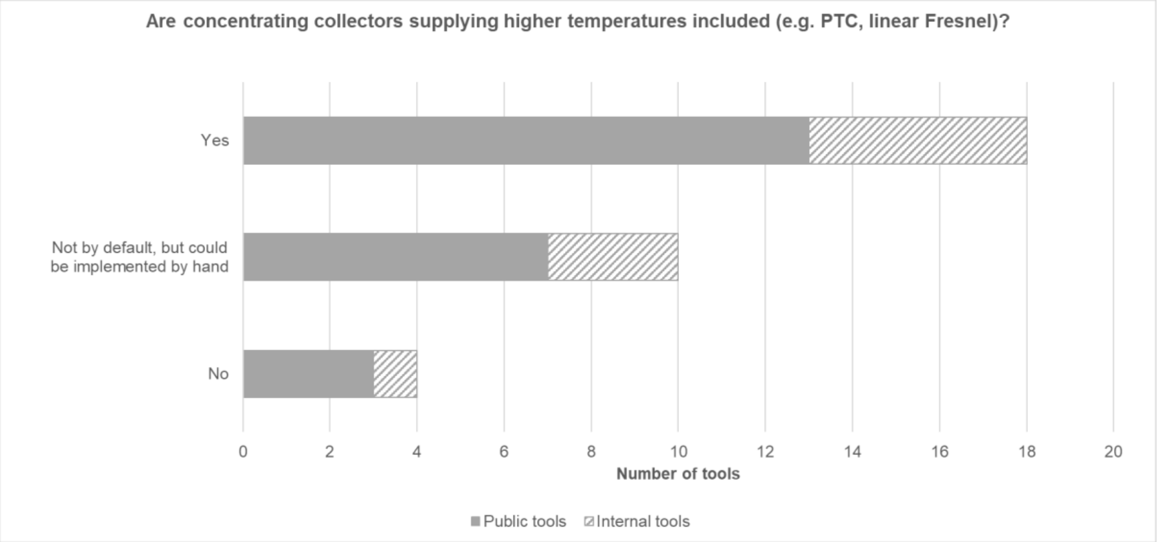


Figure 1 Concentrating collectors in the tools

Based on all the tools mentioned, none of them seem to fulfill all the requirements optimally: simple tools lack accuracy and detailed/accurate tools are complex to setup and use. It seems that, as the level of detail of the simulations increases, the user-friendliness tends to decrease, making it more difficult for new users to work efficiently with highly accurate models.

(Reference: Tamm et. al., Simulation and Calculation Tools for Solar District Heating, IEA SHC Task 68 report RA2, 2025, https://doi.org/10.18777/ieashc-task68-2025-0001)

(Reference: Bundesverband Solarwirtschaft e.V. (BSW Solar), Prozess- und Fernwärme mit konzentrierenden Solarkollektoren [online 14.7.2025], Available from: https://www.solarwirtschaft.de/unsere-themen/csp/prosolnetz/)

Annual Yield Check of Large-Scale Solar Thermal Systems

Large-scale solar thermal systems are increasingly deployed in district heating networks and industrial heat supply, including applications with medium- to high-temperature operation and concentrating collector technologies. While design tools and simulations are well established, a standardized and transparent method to verify whether a solar field delivers its predicted annual yield has long been missing.

Existing standards mainly focus on collector-level performance under laboratory conditions. Field performance checks are available, but they typically address short-term operation (power or daily yield) and are not suited for tracking or concentrating collectors, or for capturing the impact of real operational behaviour over a full year. This gap complicates contractual guarantees, performance verification, and confidence-building among plant owners, operators, and investors.

Within IEA SHC Task 68, Subtask A addressed this challenge by contributing to the development of a simple yet robust method to verify the predicted annual yield of large-scale solar thermal collector fields. Building on established standards such as ISO 9806 and ISO 24194, the work introduces an **Annual Yield Check** (AYC) that:

- Is applicable to **all collector technologies**, including tracking and concentration collectors
- Remains **compatible** with existing certification and performance characterization approaches,
- Uses **measured field data** from real operation,
- Can be implemented with **practical**, market-ready measurement effort.

The method was developed in close interaction with ongoing standardisation activities and directly incorporated into the current revision of **ISO/DIS 24194**, ensuring international relevance and long-term impact. The AYC introduces a transparent procedure to compare the **measured annual heat yield** of a solar field with a **predicted annual yield estimate** derived from:

- Collector performance parameters,
- System-specific heat losses,
- Real operating conditions,
- Explicit performance and safety factors reflecting measurement and process uncertainties.

The method consists of the procedural steps shown in Figure 2.

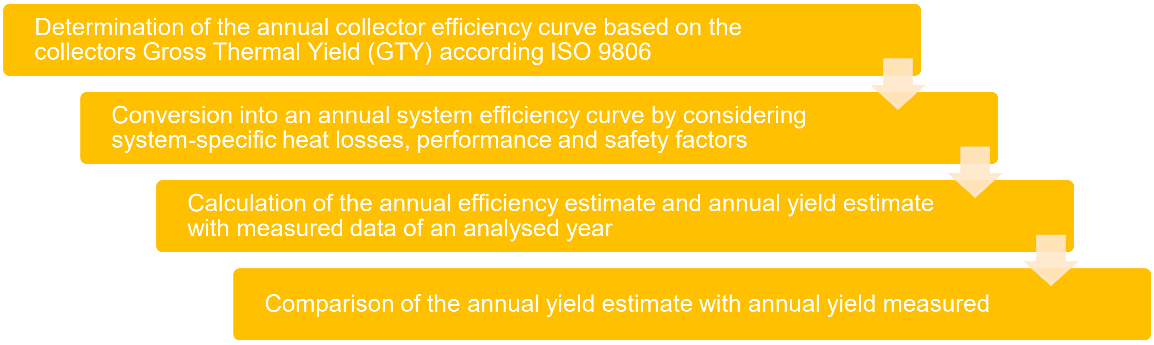


Figure 2 Process steps of the method for checking the annual yield

A key innovation is the formulation of a **technology-neutral approach** based on effective irradiation, allowing the method to be applied consistently to non-concentrating collectors using hemispherical irradiation, and concentrating or tracking collectors by appropriately accounting for direct and diffuse radiation components. This closes an important methodological gap for modern solar district heating and process heat systems. Unlike earlier approaches, the Annual Yield Check:

- Reflects **actual operating behaviour over a full year**, and
- Accounts for system losses, shading, and operational restrictions via defined performance and safety factors.

This enables more realistic and fair performance assessment compared to short-term checks alone.

Guide to ISO 24194 Power Check

How can operators, investors, and funding bodies verify that a solar thermal plant performs as expected? With this 120-page document, over 50 experts from 30 institutions provide a clear answer: How to translate a written method from an ISO standard into real-world, data-based verification, supported by SunPeek, a practical, high-quality open-source solution.

The need for standardized performance verification

Assessing the performance of large-scale solar thermal plants does not end with commissioning. While standards such as ISO 9806 define collector performance based on laboratory testing, a harmonized approach to verify the operational performance of entire collector fields had long been missing. ISO 24194 addresses this gap by introducing the Power Check, the first ISO standard designed to verify the performance of solar thermal collector fields during operation. However, early applications revealed practical challenges: interpretation ambiguities, high data quality requirements, and no transparent reference implementation.

A community-driven practical guide

Within IEA SHC Task 68, over 50 experts from more than 30 institutions across industry, research, and testing laboratories collaborated to develop this guide. It provides a structured explanation of the Power Check methodology, clarifying calculation steps, data requirements, and the treatment of practical issues such as shading, measurement uncertainty, and safety factors. The guide clearly distinguishes between normative requirements and recommended best practices, helping users apply ISO 24194 consistently and traceably. Importantly, the Power Check methodology has been extended to cover a wide range of practically relevant plant configurations and validated using operational data from several real solar thermal plants. It is enriched with informative graphical elements and examples, as shown in Figure 3.

Open-source reference implementation

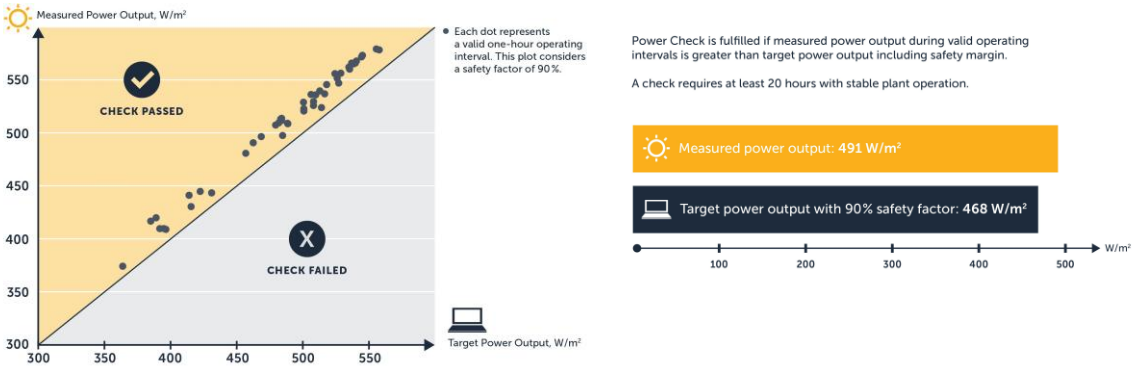
A central piece of software for ISO 24194 is SunPeek, a transparent open-source tool that provides a reference implementation of the Power Check method. SunPeek enables automated data validation, reproducible calculations, and standardized reporting, translating the written standard into a practical tool for scientific and commercial use, based on automated data analysis. By combining methodological clarification with accessible software, the Guide significantly lowers the barriers to applying standardized performance verification.

Toward a harmonized framework

Looking ahead, the Guide outlines a harmonized framework for the Power Check method, addressing current methodological limitations to inform future revisions of ISO 24194. This work contributes to the ongoing professionalization and standardization of performance verification in hybrid solar thermal plants.

Further Information

Guide to ISO 24194:2022 Power Check, IEA SHC Task 68, Subtask B, Report RB2, 2025
https://doi.org/10.5281/zenodo.15876487   SunPeek Code   SunPeek Docs   SunPeek Demo



● Each dot represents a valid one-hour operating interval. This plot considers a safety factor of 90 %.

Power Check is fulfilled if measured power output during valid operating intervals is greater than target power output including safety margin.

A check requires at least 20 hours with stable plant operation.

Figure 3 Visualisation of the principle of the power check method for an example plant

Open Data in the Solar Thermal Community: Unlocking Transparency, Reproducibility, and Innovation for Solar District Heating

Digitalization is becoming a key enabler for the next phase of solar thermal deployment, particularly for **large-scale and district heating applications**. Advanced monitoring, fault detection, performance benchmarking, and data-driven control strategies all depend on **high-quality operational data**.

Despite this growing importance of digital aspects, the solar thermal sector still lacks a strong culture of open and accessible data. Measurement data from operating plants are rarely shared publicly, data formats and metadata are often inconsistent, and long-term datasets suitable for benchmarking or algorithm development are scarce. This contrasts with other energy domains, where open data has already accelerated innovation, transparency, and trust. The absence of openly available datasets limits:

- Independent performance assessment and comparison of systems,
- Reproducibility of scientific results,
- Development and validation of digital tools such as AI-based fault detection or predictive control,
- Knowledge transfer from demonstration projects to wider market uptake.

Addressing this gap is particularly important for **solar district heating**, where system complexity and scale make learning from operational experience essential. Within **IEA SHC Task 68**, Subtask B, the experts systematically investigated the **state of open data practices in the solar thermal community**, with a strong focus on large-scale systems and district heating applications. The work combined:

- A structured review of scientific literature,
- An analysis of existing open data repositories and platforms,
- Expert surveys and interviews with researchers, plant operators, and industry representatives.

The objective was not only to assess what data are currently available, but also to identify **barriers, best practices, and concrete opportunities** for improving data openness in a way that is compatible with commercial interests and data protection requirements.
The results were consolidated in a **peer-reviewed journal article** that provides the first comprehensive overview of open data in the solar thermal field. It is available as an open-access document both on https://www.sciencedirect.com/science/article/pii/S2667113125000270 and on the Task 68 homepage.

Key results

Open data remains the exception, not the norm:

The analysis shows that, in contrast to other domains and applications, **open operational datasets in solar thermal are rare**, especially for large-scale systems. Available datasets are often limited to short time periods, lack documentation, or focus on specific research questions rather than long-term system behavior.

Strong fragmentation of data formats and metadata:

Where data are available, they are typically stored in **project-specific formats**, with inconsistent naming conventions, units, and metadata. This significantly limits reusability and comparability across projects and countries.

Clear benefits of open data are widely acknowledged:

Despite these limitations, survey results demonstrate broad agreement among experts that open data can:

- Improve system design and operation,
- Support standardization and performance verification,
- Enable benchmarking and quality assurance,
- Accelerate the development of digital tools, including AI-based methods.

The results of the survey about perception on open data are shown in Figure 4.

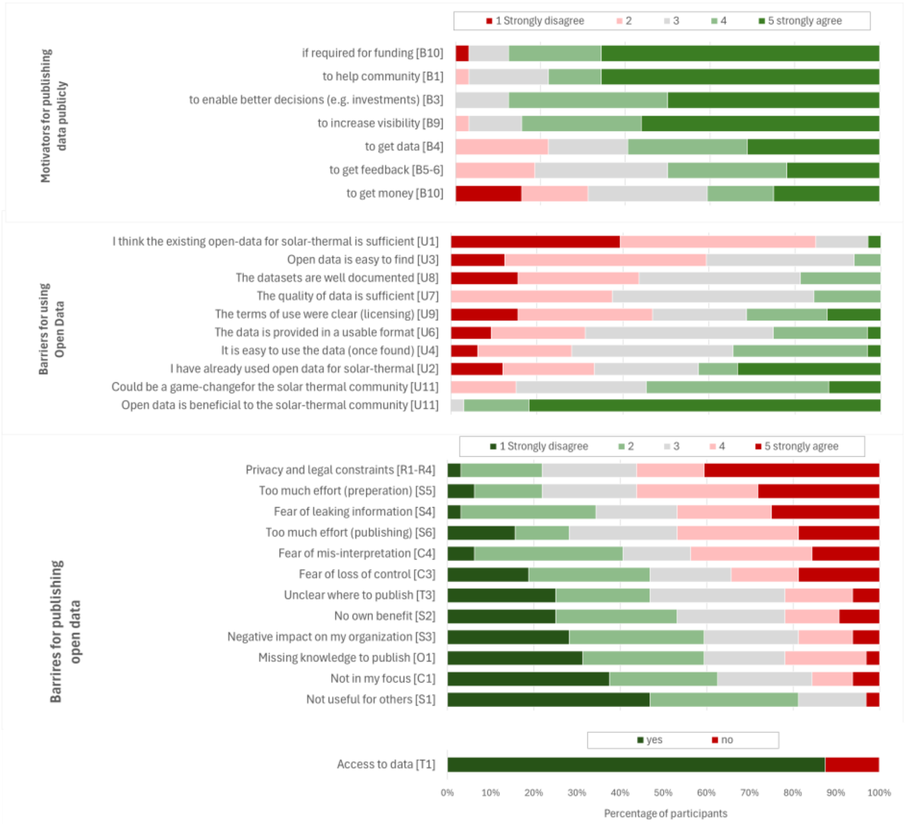


Figure 4: Results of the survey about the perception on open data. The bar chart on the right shows the percentage of participants picking the corresponding answer for the statements listed on the left. The results are sorted with statements receiving higher agreement on top.

Identified barriers are mostly non-technical

The main obstacles to data sharing are not technical, but institutional and organizational:

- Concerns about data ownership and commercial sensitivity,
- Lack of incentives for plant operators to publish data,
- Additional effort required for data cleaning, documentation, and hosting.

A structured overview of relevant open datasets

As a concrete outcome, Task 68 compiled a **structured overview of existing open datasets** relevant to solar thermal research and practice, including measurement data, weather data, and auxiliary datasets. This overview provides an entry point for researchers and practitioners seeking reference data for analysis, model validation, or tool development.

Impact and relevance

By systematically analyzing open data practices, this work **lays the foundation for a more transparent and data-driven solar thermal sector**. It highlights that improved data availability is not an abstract academic goal, but a practical prerequisite for:

- Reliable performance assessment,
- Efficient operation and maintenance,
- Scalable digitalization of solar district heating systems.

The findings directly support other outcomes of Task 68, such as AI-based fault detection and monitoring approaches, Standardized performance verification methods (e.g. ISO 24194), advanced control and optimization strategies.

Business Models and Funding Schemes for Solar District Heating

The business case of large solar thermal depends strongly on the configuration at stake: directly providing heat to an end-user (a large building or an industry) or indirectly providing heat to many end-users through a solar district heating (SDH) network or through a SDH network with seasonal heat storage and a heat pump. In all these system layouts solar thermal heat is competing with conventional heat supply (end-user prices, or more directly on the level of energy and supply costs), which may require additional support for the solar option, depending on the local climate and technical configuration. As solar thermal is a renewable technology without direct CO_2-emission, countries may decide to apply generic or specific support measures, of which following policies have been distinguished:

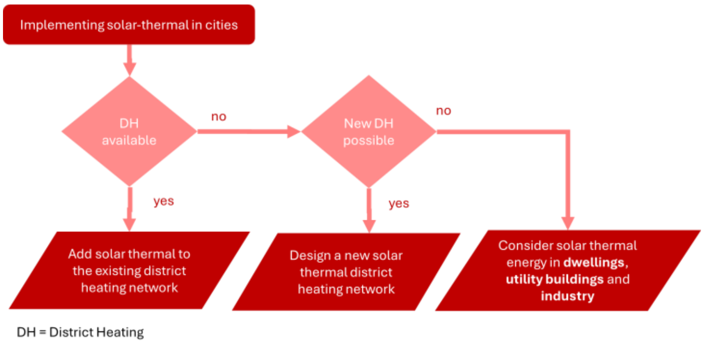
- **Direct policies and instruments** are used to support the deployment of renewable energy heating and cooling fuels, appliances, and products. Distinguished are push policies (for SDH these push policies are applicable: building codes (including district heating), mandates, replacement strategies, blending mandates (a share of renewable heat in a DH network), pull policies that are relevant for SDH are regulatory and pricing policies, tradable certificates, instruments for self-consumption and measures to support voluntary programmes, and fiscal & financial measures for SDH could be tax incentives, subsidies, grants and loans.
- **Integrating policies** for SDH may be referencing to system flexibility (in combination with thermal storage), increasing the renewable share of district heating networks, and incite sector coupling.
- Next, **enabling policies** relevant for SDH may be policies levelling the playing field, ensuring reliability, targets, affordable financing, training and education, labour policies, innovation, and urban and health policies.
- Finally, a number of policies both are integrating and enabling. Of these **mixed policies**, SDH may have advantages from streamlined permitting procedures, participative and awareness programmes and integrated resource management.

Perceived from the policy effectiveness perspective, providing (temporary) support for solar thermal district heating may be more attractive than the support for end users (for example in terms of realisation speed or government expenses per avoided CO_2-emission, the policy efficiency). Report RC1 lists example policies for solar heat in the Netherlands, Austria, Germany, Spain, Switzerland and Denmark, documented as inspiration for policy makers all around the world.

Also, in the RC1 report four examples of business models for large solar thermal projects are presented: a SDH plant in Groningen, the Netherlands, a concentrating solar thermal (CST) plant in Brandenburg, Germany, a CST plant in North Rhine-Westphalia, Germany (both in pre-feasibility stage) and SDH plants in Ørum and Aulum, Danmark. The cases show that multiple options exist for solar thermal district heat.

Checklist for Solar Thermal District Heating

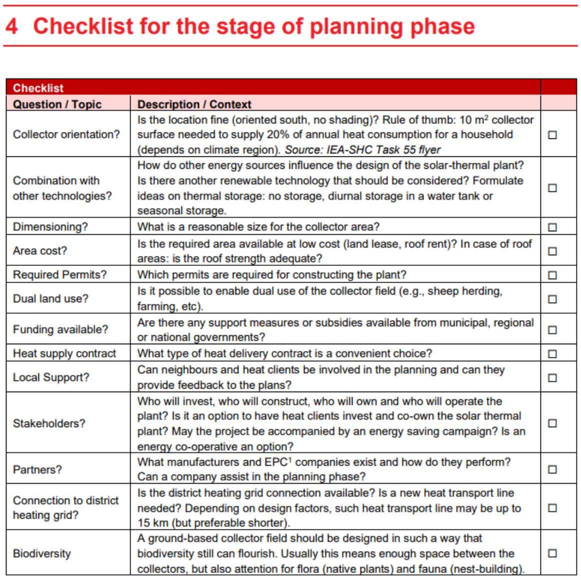
The flow chart below gives a basic approach to start considering solar thermal energy. The first question is whether a district heating system is already available, which could be a starting point for adding a new solar thermal source. An alternative option is to design a new district heating network, in which solar thermal is an integral part of the design. If both options are not possible, stand-alone installations are still worthwhile to consider.



Good standards in designing, constructing, and operating solar-thermal plants are key to create cost-efficient solutions and maximize the usable energy output over their long lifetime. Providing consistent high quality system performance will also increase the image and utilization of the solar-thermal technology.

Report RC2 aims to help plant designers and operators by providing checklists with critical aspects and questions for each stage of a solar-thermal plant's lifetime (from project idea to decommissioning). The report is aimed at different actors for each phase, from project developers to plant operators. Six lifetime stages of a solar thermal plant highlight important aspects and decisions in each phase. Moreover, different actors are addressed in each step:

For each stage, checklists present structured questions and considerations that highlight essential technical, economic, regulatory, environmental and organisational issues. As an example, the checklist for the planning phase is shown below.



4 Checklist for the stage of planning phase

Checklist		
Question / Topic	**Description / Context**	
Collector orientation?	Is the location fine (oriented south, no shading)? Rule of thumb: 10 m^2 collector surface needed to supply 20% of annual heat consumption for a household (depends on climate region). *Source: IEA-SHC Task 55 flyer*	☐
Combination with other technologies?	How do other energy sources influence the design of the solar-thermal plant? Is there another renewable technology that should be considered? Formulate ideas on thermal storage: no storage, diurnal storage in a water tank or seasonal storage.	☐
Dimensioning?	What is a reasonable size for the collector area?	☐
Area cost?	Is the required area available at low cost (land lease, roof rent)? In case of roof areas: is the roof strength adequate?	☐
Required Permits?	Which permits are required for constructing the plant?	☐
Dual land use?	Is it possible to enable dual use of the collector field (e.g., sheep herding, farming, etc).	☐
Funding available?	Are there any support measures or subsidies available from municipal, regional or national governments?	☐
Heat supply contract	What type of heat delivery contract is a convenient choice?	☐
Local Support?	Can neighbours and heat clients be involved in the planning and can they provide feedback to the plans?	☐
Stakeholders?	Who will invest, who will construct, who will own and who will operate the plant? Is it an option to have heat clients invest and co-own the solar thermal plant? May the project be accompanied by an energy saving campaign? Is an energy co-operative an option?	☐
Partners?	What manufacturers and EPC[1] companies exist and how do they perform? Can a company assist in the planning phase?	☐
Connection to district heating grid?	Is the district heating grid connection available? Is a new heat transport line needed? Depending on design factors, such heat transport line may be up to 15 km (but preferable shorter).	☐
Biodiversity	A ground-based collector field should be designed in such a way that biodiversity still can flourish. Usually this means enough space between the collectors, but also attention for flora (native plants) and fauna (nest-building).	☐

Solar District Heating Cost Reduction Mechanisms

An expert-based analysis of cost reduction mechanisms (CRMs) for Solar District Heating (SDH) systems quantifies future reductions in capital expenditures (CAPEX), operational expenditures (OPEX), and the resulting Levelised Cost of Heat (LCoH), by considering the impact from technological development, scientific development, and yield improvements across different project phases. The analysis has been documented in Report RC3.

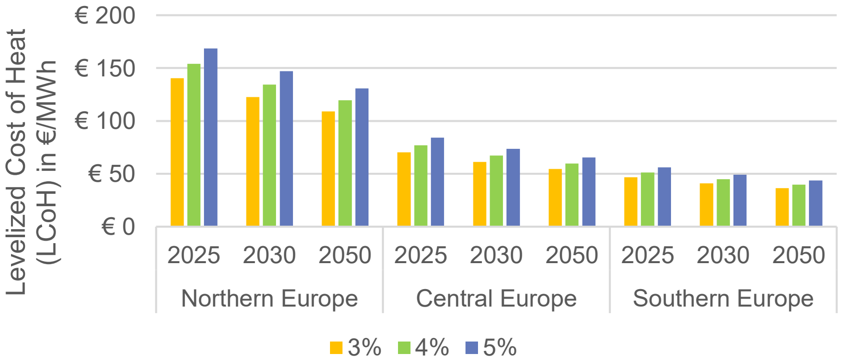
The target audience consists of decision makers, city planners, energy modellers, local, regional and national governments and technology specialists, which may benefit in making robust plans, projections and energy transition policies with SDH incorporated. It may help energy modelers in determining the competitiveness of solar thermal and to see the effect of policy measures.

Results of the analysis show that the largest potential future cost reductions are expected to be realised during the construction phase, which includes the CAPEX costs, primarily through prefabrication, smart procurement, and process standardization. The planning and preparation phases also offer notable opportunities for cost reduction, especially through financing optimization, economies of scale, and design standardization.

By 2030, average CAPEX might decrease by 6.5% and OPEX by 7.7%, with further reductions expected by 2050: 10.9% and 9.3%, respectively (compared to 2025). These potential cost savings, combined with potential yield improvements of up to 14.9%, would contribute to a significant reduction in solar thermal LCoH across Europe. For this estimate European solar collectors have been used as a reference, with discount rates of 4%, and an assumed lifetime 25 years. The expert inputs furthermore show that the cost reduction potential is to be unlocked by a combination of deployment of solar thermal and research-based cost reduction measures.

Summary of all study results. Percentages in parentheses refer to the difference compared to base year 2025. The Levelised Cost of Heat (LCoH) values refer to a discount rate of 4% (in [square brackets] the values using discount rates of 3% and 5%). Assumed lifetime is 25 years. All monetary data are in euros of the year 2024 (€2024)

Metric	2025 (base year)	2030	2050
CAPEX [€/m²]	€416/m²	€389/m² (-6.5%)	€370/m² (-10.9%)
OPEX [€/m²/year]	€4.19/m²/year	€3.87/m²/year (-7.7%)	€3.80/m²/year (-9.3%)
LCoH [€/MWh]			
Northern Europe	€154 [€140 - €169]	€134 (-13%) [€122 - €147]	€119 (-22%) [€109 - €131]
Central Europe	€77 [€70 - €84]	€67 (-13%) [€61 - €74]	€60 (-22%) [€54 - €65]
Southern Europe	€51 [€47 - €56]	€45 (-13%) [€41 - €49]	€40 (-22%) [€36 - €44]
Yield increase (vs. 2025)	-	+7%	+15%



Levelised Cost of Heat (LCoH) for three different regions in Europe, with varying discount rates (3% to 5%) and a time horizon of 25 years. All bars use the average values of the CAPEX and OPEX estimates, and the yield increases by 7% in 2030 and 15% in 2050. Costs are expressed in €2024.

A Study of Best-Practice Solar District Heating installations

While the number of commissioned solar district heating (SDH) installations continues to grow globally, a prominent knowledge gap regarding solar/DH implementation, solar field design parameters, heat production potential, documented measurement data and site evaluations is currently present at many heat providers. With the pragmatic approach and mindset of many heat providers today, these parameters arguable serves as some of the more important factors for promoting SDH. Thus, to accelerate the dissemination of knowledge and use of large-scale solar-assisted DH, Subtask D: Use Cases and Dissemination was initiated by the Task 68 project group.

The subtask aimed to provide an easy-to-read and understandable overview over commissioned SDH installations with different design, synergies and collector types to demonstrate and prove the overall performance of solar-assisted DH to the public and industry. The study involved the completion of a survey questionnaire sent to DH utilities and site managers in addition to phone interviews or mail contact. Report RD1 includes a technical and economical overview, measurement data (as shown in Figure 5) as well as site-related drivers and challenges (as shown in Table 1) for representative installations.

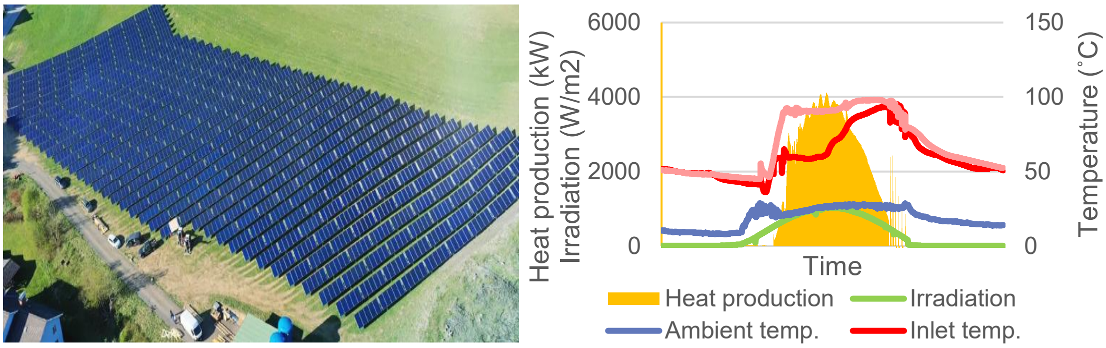


Figure 5. Overview and measurement data from the SDH installation in Mürzzuschlag, Austria. Source: SOLID Solar Energy Systems

Table 1. Reported drivers and challenges for SDH installations in Europe.

Drivers	**Challenges**
Necessity for demo/pilot installations	Capital cost
Heat storage co-construction synergy	High DH supply temperature
Fuel diversity	Lobbying of competing technologies
Sustainability trademark	Industrial uncertainty for emerging technologies
Revision enhancement	Decreased boiler efficiency
Reduced noise pollution	Deficit of production data from operational installations
Technical readiness	Necessity of high-end control systems
Low maintenance	

Key findings emphasise on the necessity for thermal energy storage (TES) synergies at higher latitudes and adequate subsidies/funding prior the realisation of each project. SDH is proven to be effective in increasing the use of renewables in DH production while the feasibility of each system largely depends on substituted fuels and heat sources. DH utilities throughout Europe place an increased emphasis on reduced GHG emissions and inexhaustible heat production, where in some cases, solar thermal (ST) has been regarded as the only competitive alternative to a reduced heat price. In smaller DH systems, DH providers report a 100% solar coverage during summer. In addition, utilities and site managers emphasise on the reliability of ST technology and mention reduced GHG emissions and fuel price dependencies as important drivers for stakeholders. The study shows a common case prior the construction of collector fields is the abolishment of existing heat production technologies or the release of large land areas. These circumstances are proven to work as natural incentives for ST integration in addition to environmental agendas at the DH supplier. Consequently, the most prominent obstacles prior implementation of ST in DH are reported to be capital cost and land availability.