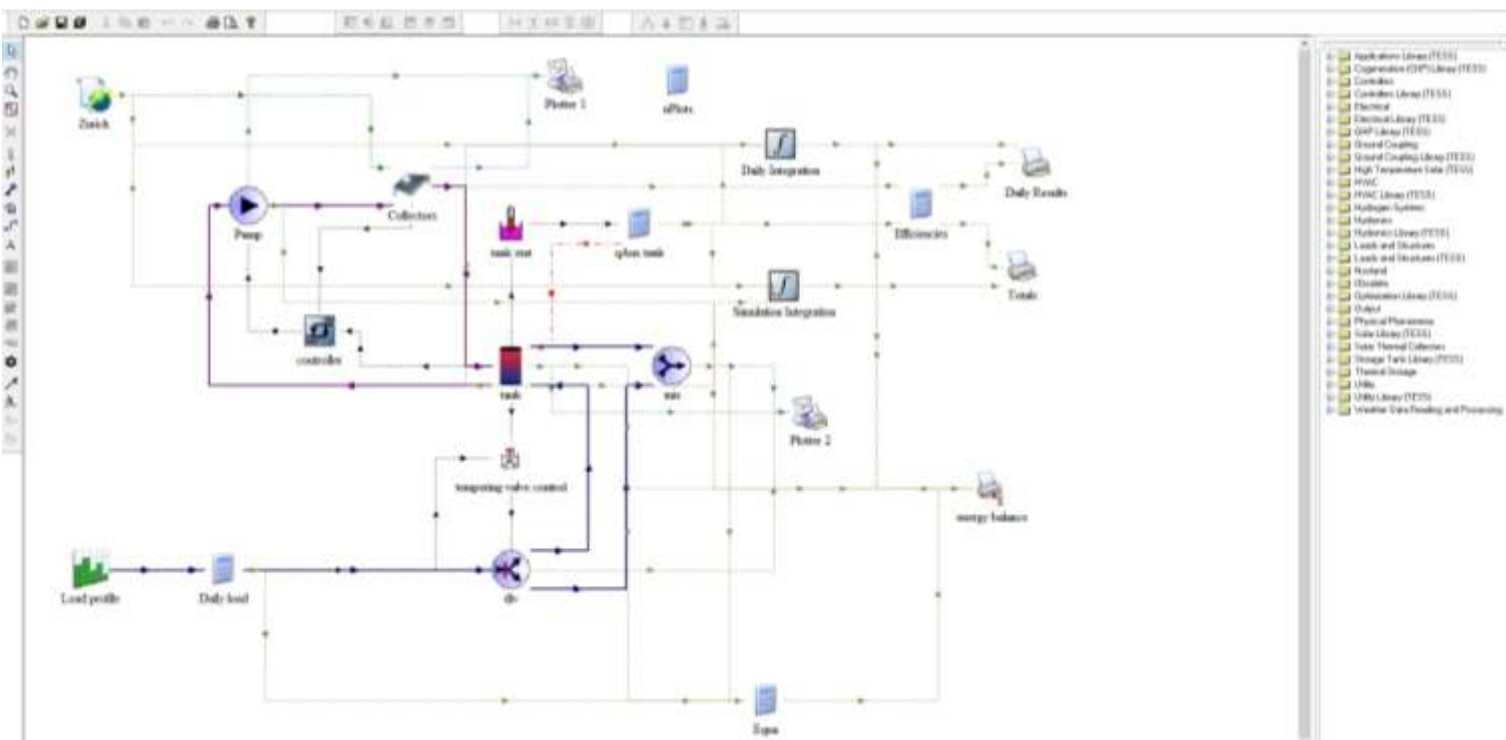
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Simulation and Calculation Tools for Solar District Heating

An Overview of the Tools Used by Experts



IEA SHC TASK 68| Efficient Solar District Heating Systems – Considering higher temperatures and digitalization measures

Technology Collaboration Programme
by iea

Simulation and Calculation Tools for Solar District Heating

This is a report from SHC Task 68: Efficient Solar District Heating Systems and work performed in Subtask A: Concepts for Efficiently Providing Solar Heat at Medium-High Temperature Level

Authors: Silas Tamm, Magdalena Berberich (Solites), Stefano Pauletta (HEIG-VD, HES-SO)

Co-Authors: Nikola Botzov, Miguel Frasquet, Geoffroy Gauthier, Leif Holm, Javier Inigo Labairu, Julian Jensen, Klaus Lichtenegger, Maria Moser, Florian Reusch, Johannes Werner

Date: July 7, 2025

Report number: RA2 DOI: 10.18777/ieashc-task68-2025-0001

Solar Heating and Cooling Technology Collaboration Programme (IEA SHC)

The Solar Heating and Cooling Technology Collaboration Programme began its work in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency.

Our mission is: *To bring the latest solar heating and cooling research and information to the forefront of the global energy transition.*

IEA SHC members carry out cooperative research, development, demonstrations, and exchanges of information through Tasks (projects) on solar heating and cooling components and systems and their application to advance the deployment and research and development activities in the field of solar heating and cooling.

Our focus areas, with the associated Tasks in parenthesis, include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54, 69)
- Solar Cooling (Tasks 25, 38, 48, 53, 65)
- Solar Heat for Industrial and Agricultural Processes (Tasks 29, 33, 49, 62, 64, 72)
- Solar District Heating (Tasks 7, 45, 55, 68)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63, 66)
- Solar Thermal & PV (Tasks 16, 35, 60, 73)
- Daylighting/Lighting (Tasks 21, 31, 50, 61, 70)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, Test Methods and LCA/LCoH (Tasks 14, 24, 34, 43, 57, 71)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42, 58, 67)

In addition to our Task work, other activities of the IEA SHC include our:

- SHC Solar Academy
- *Solar Heat Worldwide*, annual statistics report
- SHC International Conference

Our members

Australia	France	SACREEE (UNIDO GN-SEC)
Austria	Germany	SICREEE (UNIDO GN-SEC)
Belgium	ICIMOD/REEECH (UNIDO GN-SEC)	Solar Heat Europe
Canada	International Solar Energy Society	Slovakia
CCREEE	Italy	South Africa
China	Netherlands	Spain
Denmark	Norway	Sweden
EACREEE (UNIDO GN-SEC)	Poland	Switzerland
ECREEE (UNIDO GN-SEC)	Portugal	Türkiye
European Commission	RCREEE (UNIDO GN-SEC)	United Kingdom

For more information on the IEA SHC work, including many free publications, please visit www.iea-shc.org.

Contents

1 Executive Summary

This report provides a comprehensive analysis of simulation and calculation tools used in solar district heating (SDH) applications by evaluating a survey on simulation tools and compiling factsheets for selected tools that are well represented among researchers and engineers.

The results of the survey show that, in addition to public tools, internal (non-public) tools are frequently used. 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.

In terms of technical capabilities, the tools vary in their level of detail and accuracy, with most offering a moderate level of complexity, detail and accuracy. Most tools can model concentrating collectors, either directly or through manual implementation, while heat storage modelling also differs significantly between tools, ranging from simple capacity calculations to multiple segments stratified storage models.

Most tools are rated as moderately user-friendly, but several require improvements in their Graphical User Interface (GUI). Learning methods primarily rely on hands-on experience and mentoring, rather than structured training materials. Licensing models vary, with an equal distribution of one-time fees, recurring license costs, and free tools, while many internal tools fall into the "Other" category due to customised pricing structures.

These findings emphasise the need for greater transparency, improved usability, and increased accessibility of tools to enhance collaboration, innovation, and efficiency in SDH simulating and calculating.

Factsheets of software used by experts in the field have been included, to compare features, as perceived by their users. The factsheets provide the main characteristics of each software, as well as useful information such as pricing, known users, relevant publications, etc. The factsheets were created in a collaboration with SolarPACES Task IV: Solar Heat Integration in Industrial Processes (SHIP). SolarPACES Task IV created factsheets for SHIP applications and will update the list of simulation tools and their descriptions when important changes are required.

A brief comparison between TRNSYS and PolySun for the modelling of direct solar heating is presented, using an example case with available measurements (used as a reference for both). The main findings will be shared to illustrate the compromise between user-friendliness and modelling accuracy.

2 Introduction

The transition to sustainable energy systems requires efficient tools for the analysis, planning, and optimisation of SDH applications. Therefore, advanced SDH tools are important for the market to ensure efficient integration of solar thermal technologies and other components such as heat pumps and thermal energy storages into district heating systems.

To accurately model and optimise SDH systems, the simulation tools must include detailed models at the component level, e.g., different collector types or technologies. At the system level, these tools must allow for the combination of multiple components to create realistic and flexible system simulations. Sensitivity analysis based on these models help to determine optimal system design parameters, thereby improving efficiency and supporting market introduction.

The aim of this report is to analyse and compare existing SDH simulation and calculation tools and evaluate their capabilities, ease of use and accessibility. This was done through the evaluation of a self-conducted survey about SDH tools, as well as standardised factsheets for selected tools which are currently widely used in the market and a detailed simulation comparison of TRNSYS and PolySun. Therefore, this report provides an overview of suitable simulation tools for efficient SDH systems, helping inexperienced users choose the most suitable tool for their applications.

3 Survey on SDH Simulation and Calculation Tools

3.1 Survey methodology

IEA SHC Task 68, Subtask A3, conducted a survey using Microsoft Forms to collect information on simulation and calculation tools for SDH applications. This survey was distributed among the Subtask A3 working group and their colleagues, partners, and contractors from the German research project ProSolNetz, as well as the heat sector group of the German Research Network (DFN). In total, 32 responses were received, with an average completion time of approximately 30 minutes. Each response corresponds to a single simulation tool, as participants were instructed to complete one survey per tool. The survey was open from November 28, 2024, to February 4, 2025.

3.2 General questions in the survey

The survey covered various aspects of simulation and calculation tools for SDH applications. Participants provided details about field of work and the project phase in which the tool was used. The survey also addressed level of detail, specific applications, the representation of concentrating collectors operating at higher temperatures and thermal storages in the tools. The learning process associated with each tool and the user-friendliness was also explored. Additionally, respondents provided information on costs and licensing models. Other questions are about the simulation period, time step size, and overall simulation duration. The survey also examined possible extensions, additional applications, and programming capabilities. At the end, participants were asked to highlight the advantages and disadvantages of their respective tools, discuss any special features, and share further comments. The survey comprised 36 questions in total.

3.3 Evaluation of the survey results

The following sections present the results of the survey. Public tools are displayed in solid colors, while internal tools are shown with gray stripes. The findings are based on the responses provided by tool users and have not been scientifically verified. Therefore, the accuracy of the results cannot be guaranteed, and individual responses may be subjective or influenced by personal experience. Information such as license costs may change in the future.

Furthermore, no representative conclusions can be drawn for individual tools, as the number of responses for each tool varies. To enhance transparency, each figure includes the original survey question as it was presented in the tool survey, ensuring clarity on the context in which the data was collected.

3.3.1 Tools which have been mentioned in the survey

Figure 1 shows all the tools that were specified in the survey. It is noticeable that a large proportion of the tools are internal tools. Internal tools also include public software that uses in-house models that are not publicly available and are only used internally. The online links of the public tools are listed in the references chapter, see chapter 8.

Another striking aspect is that TRNSYS appears a total of 7 times. This indicates that TRNSYS is widely used within the group that conducted the survey.

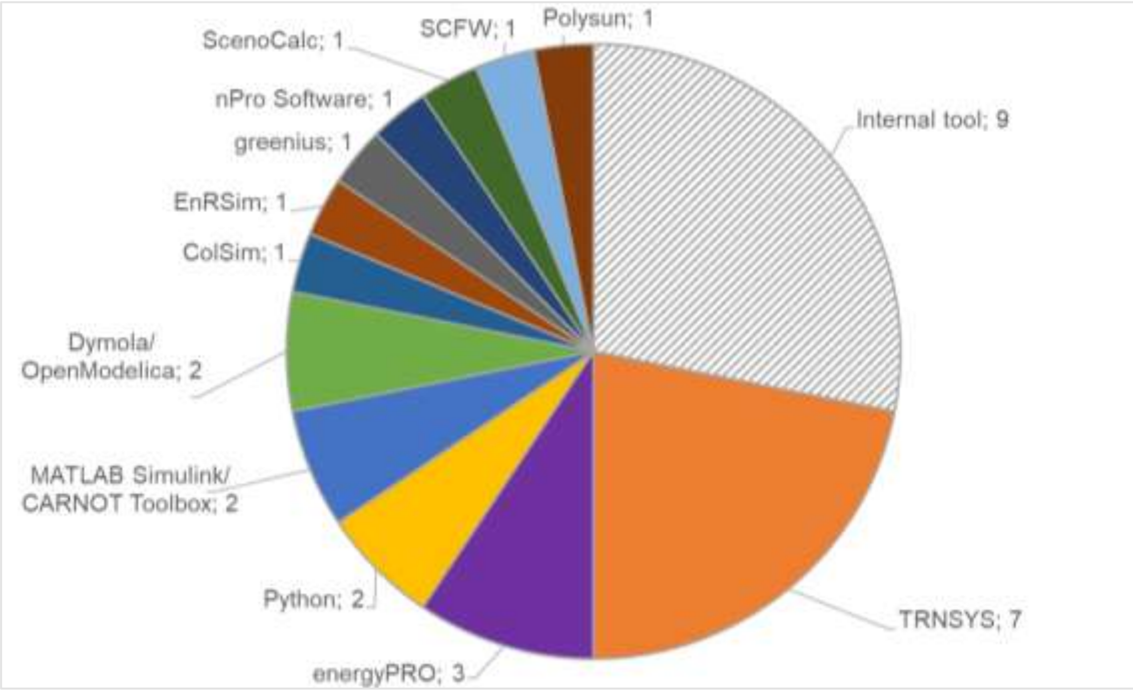


Figure 1 Overview of tools for which the survey was completed

3.3.2 Fields of work of tool users

Figure 2 illustrates the fields of work in which the survey respondents are active. It is evident that 23 of the tool users work in research and development. This can be attributed to the fact that, as previously mentioned, the survey was primarily distributed among various research groups. Additionally, 20 respondents are working in the engineering sector. In project development and sales, as well as in energy management, internal tool users account for at least 50 %. In academic teaching, however, only public tools are used. This is because educational institutions often benefit from discounted licenses, which makes publicly available tools more accessible and widely used in this context.

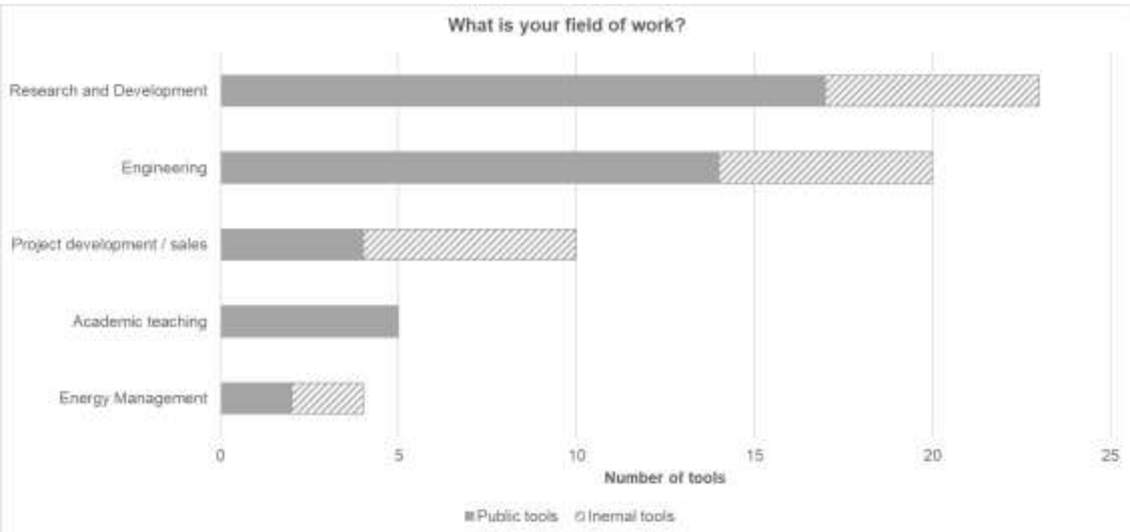


Figure 2 Field of work of tool users (multiple answers allowed)

3.3.3 Project phase of tool use

The next question examined is in which project phase are tools applied, see Figure 3. Multiple responses were possible in this case as well. The largest share is accounted in the preliminary study/ basic analysis, with 30 tools. Additionally, 24 out of 32 tools were used for feasibility studies. The number of tools used in research is similarly high to those previously reported for research and development, indicating a strong presence of tools in this field of work.

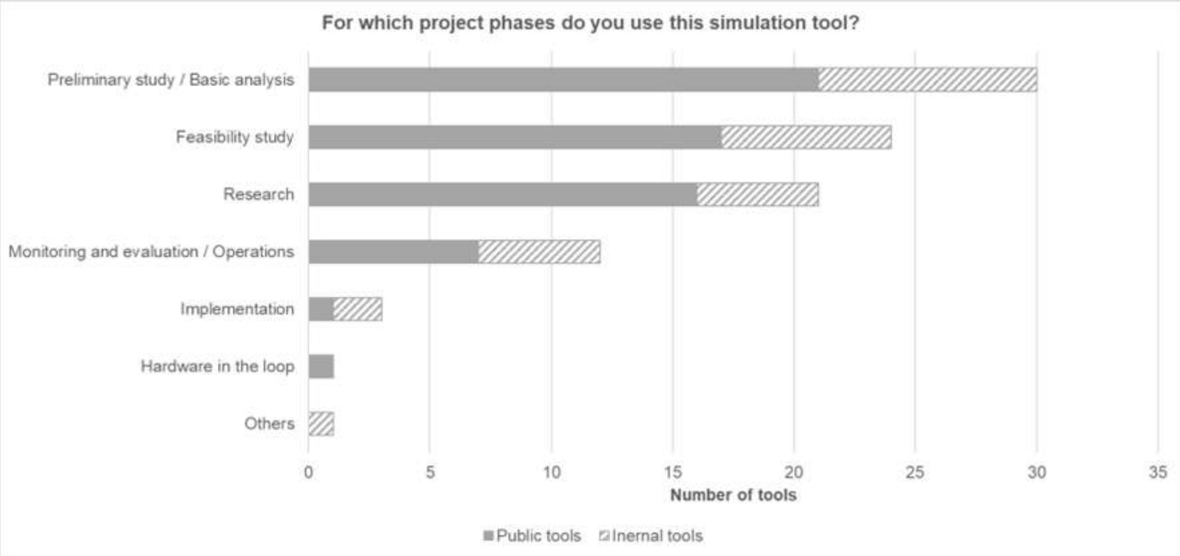


Figure 3 Project phase of tool use (multiple answers allowed)

3.3.4 Level of detail

On a scale from 1 to 5, users could indicate the level of detail by the tool they use, see Figure 4. A rating of 1 was defined as very basic (e.g., energy flows, steady-state conditions, mass & energy balance), while a rating of 5 was defined as very detailed (e.g., CFD simulations, pressure calculations). None of the public tools were rated as very basic or very detailed. Instead, most public tools were classified as quite detailed and were rated between 3 and 4. This distribution aligns well with the requirements, as most tools are primarily used for preliminary studies and basic analysis, where a moderate level of detail is generally sufficient.

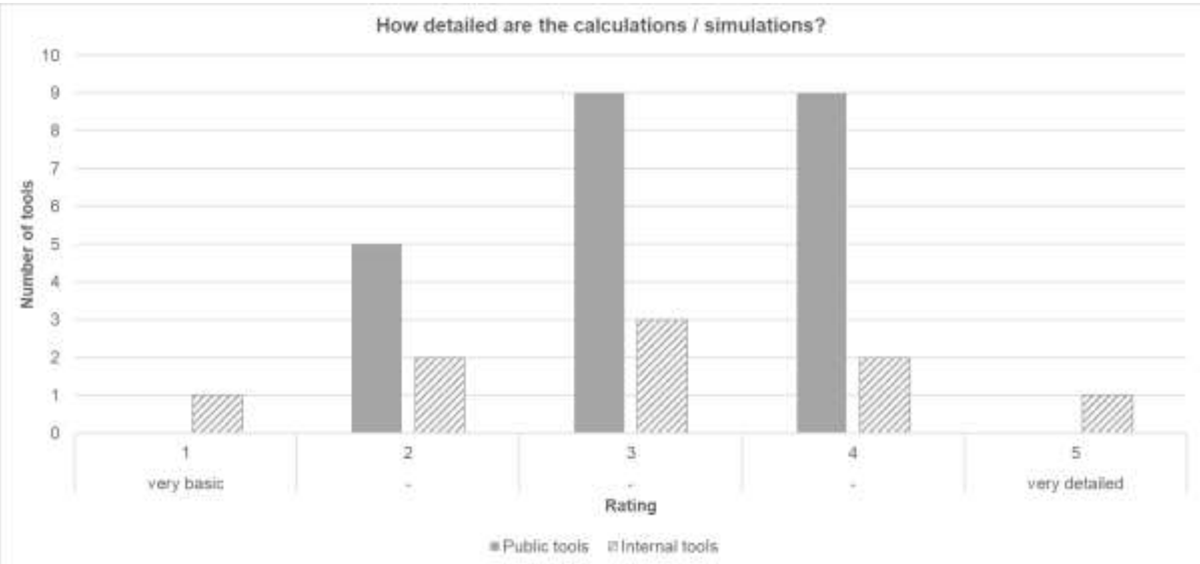


Figure 4 Rating for level of detail of simulation / calculation tool

3.3.5 Specific applications covered by the tools

Figure 5 shows the specific applications that each tool can simulate and calculate. All tools can model solar thermal collectors, as the survey focuses exclusively on SDH applications.

A key aspect of many SDH systems is thermal storage, which plays a crucial role in combination with solar thermal energy. Among the 23 public tools, 20 tools include thermal storage models, while among the 9 internal tools, 8 tools can simulate or calculate thermal storage. This reflects the importance of storage systems in SDH applications. In addition to solar thermal collectors and thermal storage, a significant number of tools also consider other energy systems, such as heat pumps and sector coupling (19 public tools and 6 internal tools). Furthermore, 12 public tools are capable of simulating heating networks and heat distribution, which is essential for SDH simulations. However, simulation and calculation of building heating is not supported by any of the internal tools. This functionality is only available in 7 public tools. The others include, among others, electricity (PV, wind and batteries) and hydrogen applications.

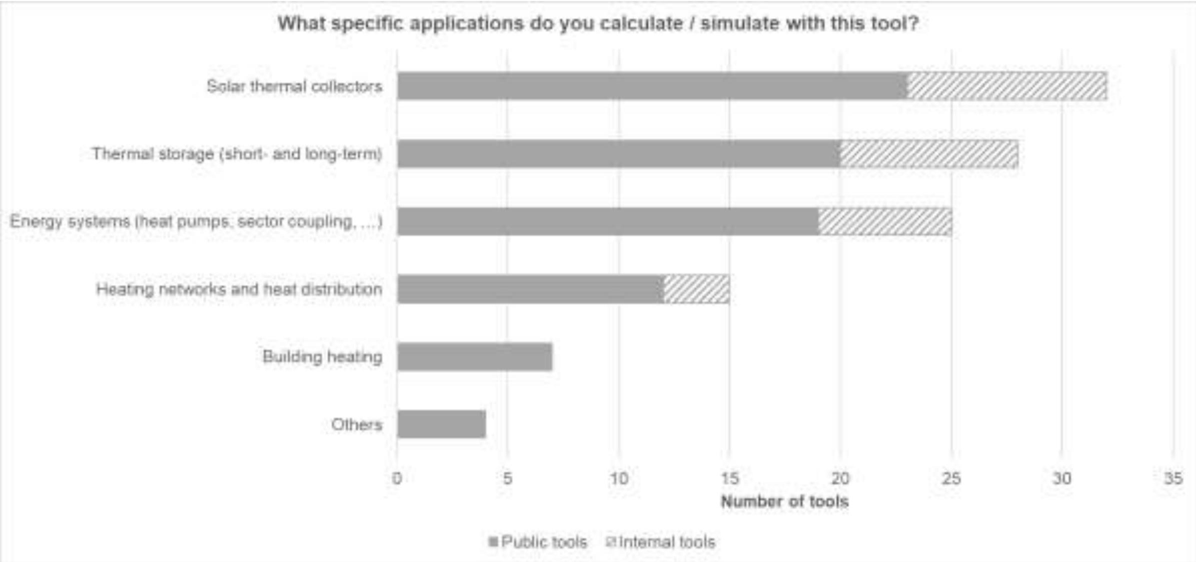


Figure 5 Specific applications covered by the tools (multiple answers allowed)

3.3.6 Representation of concentrating collectors

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 6. The results show that 13 public tools and 5 internal tools support the simulation or calculation of concentrating collectors. Additionally, 7 public tools and 3 internal tools allow manual implementation of concentrating collectors. Only 3 public tools and 1 internal tool have no possibility to model concentrating collectors.

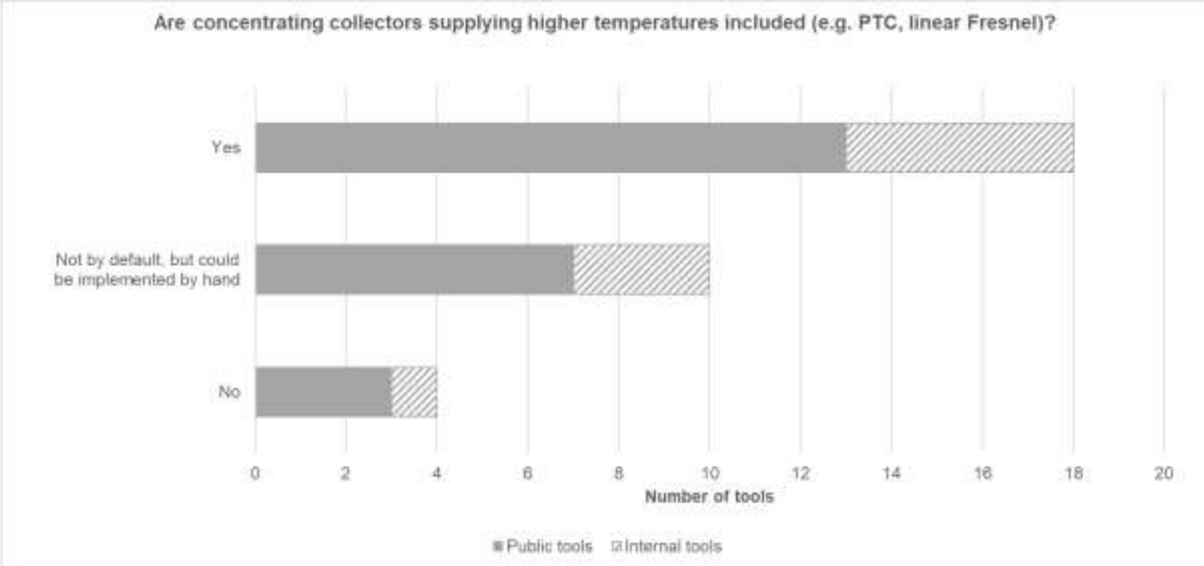


Figure 6 Concentrating collectors in the tools

3.3.7 Thermal storage modelling

As discussed in chapter 3.3.5, most tools include thermal storage systems. This section examines how storage is modeled within the tools, see Figure 7. Among the available modeling approaches, the calculation of multiple segments stratified storage models is the most detailed method. This approach is implemented in 13 public tools and 6 out of 9 internal tools. Additionally, 13 tools (10 public and 3 internal) consider only the temperature level for storage modeling. Another approach, which models simple storage capacity without consideration of temperatures, is implemented by 4 public tools and 1 internal tool.

These results indicate that a significant number of SDH tools offer a detailed thermal storage representation, which is particularly important for accurately simulating SDH systems.

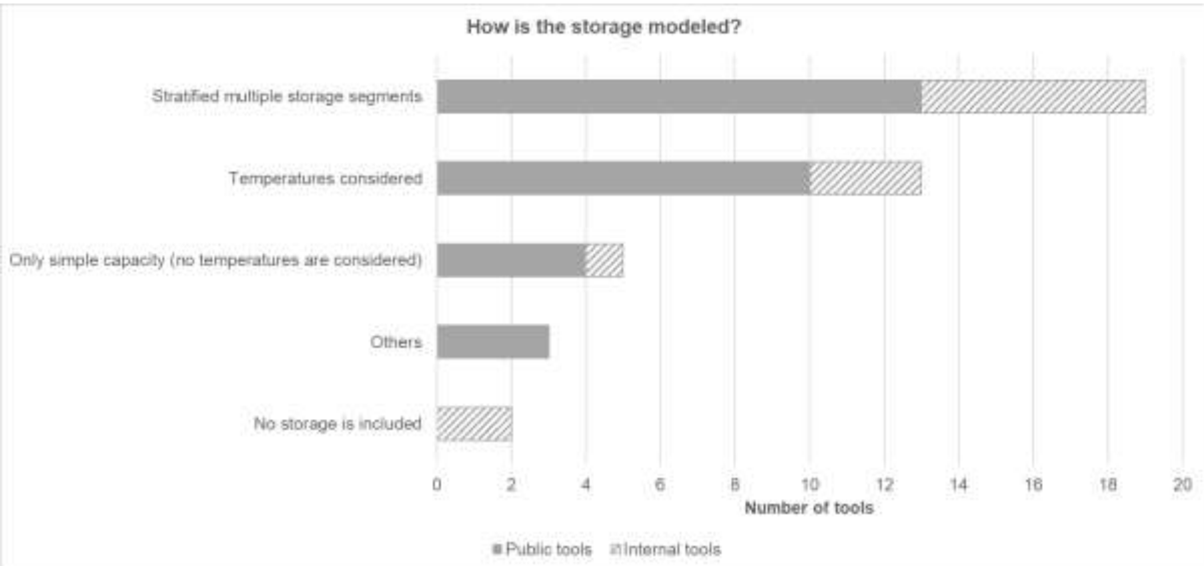


Figure 7 Thermal storage modelling of the tools (multiple answers allowed)

3.3.8 Learning methods and time required to master the tools

In addition to the technical details of the tools, it is essential to understand the most effective ways to learn how to use them, see Figure 8. The most frequently mentioned method is through hands-on practice and experimentation, which was selected as the most effective approach for 21 public tools and 4 internal tools. The second most common response is learning with the help of an experienced mentor or colleague (17 public and 6 internal tools). Other learning methods were mentioned significantly less frequently.

These results highlight the importance of practical experience and the support of colleagues in mastering the tools, suggesting that the other learning methods mentioned may not be sufficient for effective learning.

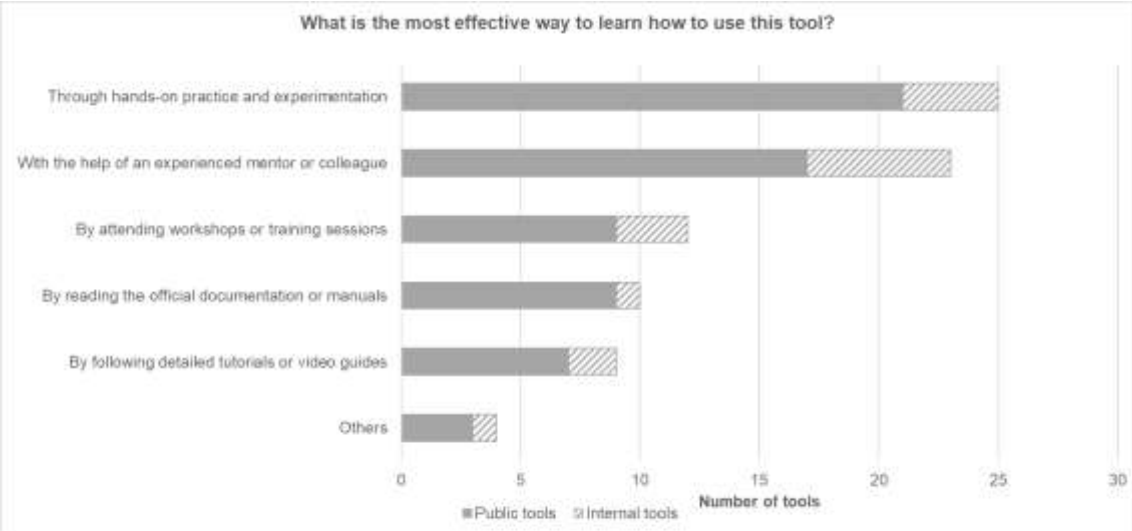


Figure 8 Most effective way to learn the tool (multiple answers allowed)

Beyond the learning methods, the survey also examined how long it typically takes until the tools can be used effectively, see Figure 9. For 3 public tools, users stated that they could become experienced in less than a day. However, for most public tools, the estimated learning time falls within 1 to 7 days and 1 to 4 weeks, with 6 public tools in each of these categories.

These findings show that while some tools are relatively easy to learn, many require moderate time investment before they can be used effectively.

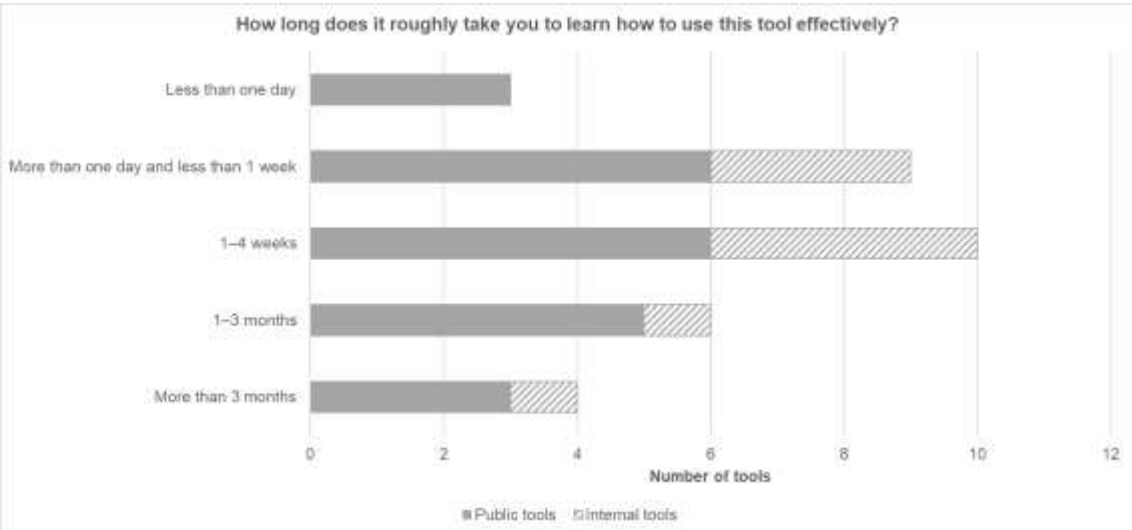


Figure 9 Time required to master the tool

3.3.9 User-friendliness

Figure 10 shows the user-friendliness of the tools. Users rated the user-friendliness on a scale from 1 to 5, where 1 represents "very difficult" and 5 represents "very user-friendly". The distribution of responses follows a bell-shaped curve, with most tools have been rated as 3 (10 public and 4 internal tools), while ratings of 1 and 5 were given less frequently.

This pattern indicates that most tools offer a moderate level of usability. However, some tools show a clear need for improvement, particularly in terms of their graphical user interface (GUI), as user-friendliness issues were frequently mentioned in the survey in additional comments and suggestions for improvement.

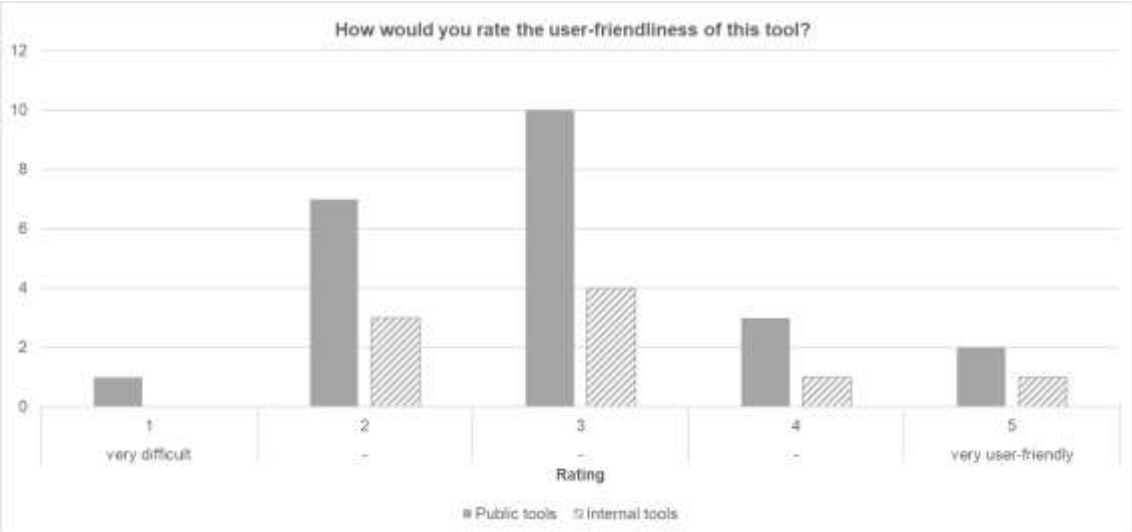


Figure 10 Rating for user-friendliness

3.3.10 License scheme and costs

Tools used in the market often follow different licensing models. As shown in Figure 11, one time license costs, recurring license costs, and free tools appear with similar frequency in the survey. The high proportion of tools categorized as "Others" is primarily due to internal tools being classified under this category. This is because the survey did not initially differentiate between public and internal tools. Additionally, the "Others" category was chosen when individual public tool libraries had different pricing structures or when a distinction was made between academic and non-academic use.

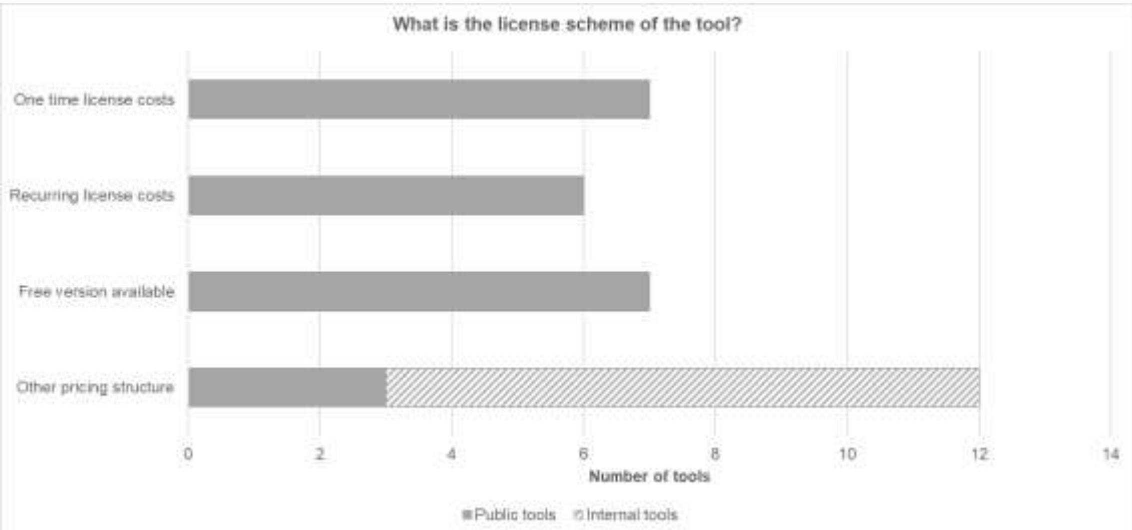


Figure 11 License scheme of tools

Table 1 includes the cost data provided in the survey. If a cost structure was mentioned without specific prices, it has been omitted for clarity. Only entries explicitly reported in the survey are listed. The unit of the license cost indicates the licensing model, with recurring costs referring to the annual price. The costs apply to a standard single-user license. Internal tools are not included, and each tool is listed only once in this table. Prices were also completed with further research in case there were deviations within prices for a single tool or if only approximate values were provided in the survey.

Table 1 License costs of tool

Name of tool	License costs (standard single-user)
EnRSim	Free version available
greenius	
Python	
ScenoCalc	
SCFW	
nPro Software	891 €/year
MATLAB Simulink/ CARNOT Toolbox	938 €/year MATLAB/Simulink, CARNOT is free of charge
energyPRO	2.080 €/year
Dymola/ OpenModelica	~ 5.000 €/year Dymola, OpenModelica is free of charge
PolySun	4.199 €
TRNSYS	4.800 €

3.3.11 Special features of the tools

Another question in the survey asked whether the tool has special features that other tools do not have. If this question was answered with "Yes," respondents were asked to provide a description of these special features, which are presented in the Table 2. Entries with no response or unclear, meaningless answers have not been included.

Table 2 Special features of the tools

Name of tool	Special features that other tools do not have
ColSim	Allows for dynamic assessment, includes various alternative hybridization sources besides solar thermal collectors, such as heat pumps, PV, wind, battery storage, exothermal chemical processes, and can provide heat to power blocks, heat networks, industrial processes according to specific demand curves on a high temporal resolution.
energyPRO	Simple GUI to easily understand what's going on. Formula editor for Time Series combined with user defined units to model freely.
	Sector and market coupling with all other heat and power types; multi use business cases; optimizer tool included, very flexible and user friendly.
greenius	It is difficult to find other reliable tools in the market for concentrating solar systems.
MATLAB Simulink/ CARNOT Toolbox	It is fully customizable and extendable; it has its own validation procedures to ensure the results are consistent on a specific computer configuration
	Allows usage of different Toolboxes within the MATLAB Simulink Environment (e.g. machine learning) and has also the possibility to model everything customized (control, hydraulics,)
nPro Software	Full integration with other generation technologies: boiler, chp, heat pump, hydrogen, waste heat, chiller; regeneration of borehole fields; combination of solar thermal calculation and borehole field sizing; techno-economic design optimization; full integration with deep district heating simulation/sizing; economic analysis (VDI 2067)
PolySun	Manufacturer catalogue-based component selection
Python	Creating your own components Combining Pressure/Flow distribution in the grid with a dynamic pipe model (temperature wave propagation) Direct interface to data analysis package

SCFW	Easy to use with results validated against TRNSYS simulations. The calculations are based on ScenoCalc and Solar Keymark certificates can be recalculated for validity.
TRNSYS	Creating own components
	Lots of TRNSYS types available for a wide range of applications
	Flexible open-source approach, implementation of third-party or self-written models possible

3.3.12 Suggested improvements for SDH tools

The survey responses indicated missing features or modules in each tool. In the case of energyPRO, it was stated that the optimization is missing. For greenius, it was mentioned that an explanatory video on how to use the tool is not available. For nPro Software, it was stated that the integration of BEW funding (German funding program for efficient DH networks) is not fully included. For SCFW, the interaction of several collector fields, a tracking system and an English version for international use are not available. In the case of TRNSYS, it was noted that hydraulic modelling is not covered.

Table 3 presents suggestions for improving SDH simulation tools, based on survey responses. The feedback covers both technical enhancements and usability improvements.

Several tools require expanded technical capabilities, such as better hydraulic modeling, enhanced seasonal storage simulation, and integration of techno-economic analyses. Additionally, some responses highlight the need for improved usability, including easier access, default values for quick estimations, and more intuitive graphical user interfaces (GUIs). Other suggestions focus on enhanced automation, such as automatic component connections and open-source model libraries.

These results indicate that both technical depth and user experience are critical factors in improving SDH tools.

Table 3 Suggestions for improving the tool

Name of tool	Suggestions for improving the simulation tool for solar thermal and heating network applications?
ColSim	A hydraulic solver is not included and beyond the scope of the tool. The hydraulics are based on a plug-flow model that allows modelling process heat systems to large solar thermal power plants, but heating networks have other requirements. Here a further extension could be considered. On the other hand, an interface to existing heating network tools can be provided.
energyPRO	easy access, default values for quick estimations
	Adding the possibility to simulate seasonal storage more easily would be great
	Comparison study of modeled and real measured data
EnRSim	Upgrade user-friendliness
greenius	Implementation of a system that combines solar energy, heat pump and seasonal storage.
MATLAB Simulink/ CARNOT Toolbox	Adding techno-economic analyses
PolySun	Being able to input irradiance values at 1min, 15 min sampling // inter-row shadowing module doesn't consider partial shading of collectors
Python	Bundling of models in a dedicated open-source library
TRNSYS	Some automatic connection of components would be handy (when connecting weather data to a solar collector, all the outputs of the weather component/type would be automatically connected to the relevant inputs of the solar collector component/type) to set up models more efficiently and avoid mistakes. Some reference setups (parameters) for each component would also be very practical, and the possibility to import a specific type of solar collector characteristics (optical coefficients, capacity, etc.)
	GUI could be improved

4 Factsheets of selected SDH Simulation Tools

In this section SDH tools will be described by factsheets, which have been completed and reviewed by contributors of IEA SHC Task 68 and SolarPACES. Each factsheet consists of two tables providing general information and a technical overview. These tools are widely used within the process of researching and planning of SDH systems. As the survey described in the previous chapters is not representative, the tools have been selected according to the experience of the Task 68 group from their various projects:

- energyPRO, see chapter 4.1
- greenius, see chapter 4.2
- PolySun, see chapter 4.3
- TRNSYS, see chapter 4.4

In addition to the mentioned tools, there are others like Modelica/Dymola and Python, which are not presented here but are used in the industry. Since there is little experience with these tools within the IEA SHC Task 68, no factsheets were created for them.

4.1 Factsheet for energyPRO

General information	
Name and version of tool	**energyPRO version 5 (5.0.354)**
Submodels/ library considered	Most available modules can be relevant, depending on what the tool is used for: Accounts, Design (mandatory, main module), Finance, Interface, Operation, Region, Language (desired extra user interface and report language, available for English, Danish and German). By default, energyPRO is available in one given language, and licenses to other languages can be bought
Developed by/ Author/ provider	EMD International A/S
Web link for more information	https://www.emd-international.com/energypro/
Creation date of factsheet	12/03/2025
Primary usage related to solar applications	• Engineering • Project development / sales • Research & Development • Energy Management (in the planning phase, not in the operation phase) • Production plant size optimisation
List of users/ companies actively using this tool for solar applications	PlanEnergi, EMD International, Bobach Solutions, Aalborg CSP, Artelia, Rambøll, COWI, NIRAS, IREES, Fraunhofer Institute (ISI, IEG)
Software language of source code, graphical user interface	energyPRO has its own graphical user interface and uses either an analytic or a Mixed Integer Linear Programming (MILP) solver to run simulations. The MILP method runs by default on the open-source solver HiGHS, written in C++, but can also run on other solvers, such as CBC (also open-source and written in C++), CPLEX or Gurobi (both available under commercial license and written in C). See EMD's website for more information
Operating system requirements	A multi-core CPU running at 2 GHz or more on each core is recommended. Windows 11 / 10 / 8.1 / 8 / 7. Min. RAM 4GB
Relevant publications	https://www.sciencedirect.com/science/article/abs/pii/S0360544224029517 E. Popovski *et al.*, The role of solar district heat in the energy transition of the German heating sector, Energy (2024)
Cost/ price structure/ license scheme	Yearly license for each module, the design module costs 2'080 €/user/year, all extra modules cost 480 €/user/year, except the language modules which are at 360 €/user/year. All extra user licenses are discounted at 50%. A demo version can be used to open and run existing models (no editing possible). Special prices are also available for University, Educational (classroom training) and Student licenses. University and Educational licenses cannot be used for commercial activities.

Technical overview	
Project phase/ main purpose	• Preliminary study/basic analysis • Feasibility Study • Research (on system level, not on detailed component level)
Level of detail. Programming skills necessary?	Models are focused on system level-contribution of heating and cooling units, with some level of details for the single components, but not down to the detailed physics properties (thermal capacity and conductivity of materials and fluids, stratification, etc.). No specific programming skills are necessary to use the program, but knowledge about techno-economics of the main components is (heat loss coefficient for a tank, solar thermal collector efficiency, operational costs, etc.), and external time-series sometimes need to be generated (with Excel for example).
Level of user friendliness	Quite user friendly (components can be connected graphically, and the program will calculate accordingly)
Most effective way to learn how to use the tool	• By following detailed tutorials or video guides • Through hands-on practice and experimentation • With the help of an experienced mentor or colleague
Effort required to understand and effectively use the tool	Less than one month of dedicated work is sufficient to use the tool in an efficient way (but not exactly enough to master all the details/possibilities offered by the tool, such as workarounds, personalization, etc.)
Specific applications in the tool	• Solar thermal collectors • Energy supply systems (heat pumps, sector coupling, …) • Thermal storage (mainly short-term, advanced workarounds possible to model long-term as well) • Heating networks and heat distribution
Advantages	• Easy and fast setup of integrated energy systems (including both electricity and heating, several heat and electricity production units, as well as fuel sources) • Gives the opportunity to test a wide variety of energy system arrangements (multi-source heating and power systems) • Optimises the operation based on the lowest integrated system costs (no need to make advanced control systems to make the system work)
Disadvantages	• Not a high level of details (cannot be used for plant design, only for overall sizing of the main components)
Special features	• Production unit size optimisation • Variation of multiple parameters and multiple iterations through an XML spreadsheet
Tool is not designed for	• Detailed design of solar thermal plants • Optimisation of hydraulic networks • Temperature optimisation within the energy system
Included collector models (concentrated / non-concentrated; technologies)	• Flat-plate solar collectors • Evacuated tube solar collectors
Included storages How are storages calculated?	Short-term thermal energy storages are included (above-ground TTES). Those can be separated between thermal storage, cold storage and process heat storage. Other storages (such as batteries, ev-vehicles or pumped hydro storage) are available for electrical energy storage (not directly relevant for thermal energy). They are modelled as an available capacity, based on maximum and minimum temperatures, a given volume, and a utilisation factor (the model doesn't calculate the temperature inside the storage depending on inlet water temperature, thermal losses, etc.), with a given overall heat-loss coefficient. It is possible to make a temperature-dependent function for the thermal losses, dependent on storage and ambient air temperatures, using formulas that can be calibrated from real-life examples or other (more detailed) modelling tools, but to make the storage work properly as a long-term storage requires additional advanced workarounds.

Possible time steps and time period of simulation, simulation duration for 1 year	• Simulation resolution can be chosen between 1 and 60 minutes • Simulations can be carried out for 1 year in DESIGN module, for multiple years in FINANCE and ACCOUNTS modules, and for shorter periods in OPERATION module • Simulation duration depends greatly on the complexity of the model and processing power and memory of the machine
Other tools/ extensions which are applicable with this tool (co-simulations)	• No other tools are usually used together with energyPRO, except an XML spreadsheet for parameter variations in the INTERFACE module
Remote execution of simulations	Using the INTERFACE module, it is possible to execute remote simulations. This is achieved either by using XML spreadsheet or Python scripts to generate xml files that would launch energyPRO (installed on a server for instance)
Simulation results	• Ready to use result figures available • Export in spreadsheet format available • Flexible GUI to investigate the results (e.g. by zooming in into timeseries results)
Author of factsheet Reviewed by	Geoffroy Gauthier (PlanEnergi) Nikola Botzov (PlanEnergi), Leif Holm Tambjerg (EMD International)

4.2 Factsheet for greenius

General information	
Name and version of tool	**greenius 4.12.0.3**
Submodels/ library considered	
Developed by/ Author/ provider	DLR
Web link for more information	http://freegreenius.dlr.de
Creation date of factsheet	04.03.2025
Primary usage related to solar applications	• Engineering • Research and Development • Academic teaching
List of users/ companies actively using this tool for solar applications	Protarget, Solarlite, Dornier Power and Heat, Fichtner, Solatom, Solites.
Software language of source code, graphical user interface	Delphi, RAD Studio
Operating system requirements	Windows XP, 7 or later
Relevant publications	• Dersch, J.; Inigo Labairu, J; Hirsch, T. (2024) *greenius – A free Software Tool for Simulating Electricity and Heat Generation Systems with Concentrating and Non-Concentrating Solar Collectors*. Kölner Sonnenkolloquium 2024. https://elib.dlr.de/204967/ • Inigo Labairu, J.; Dersch, J.; Schomaker, L. (2022) *Integration of CSP and PV Power Plants: Investigations about Synergies by Close Coupling.* Energies. Multidisciplinary Digital Publishing Institute (MDPI). doi: 10.3390/en15197103. ISSN 1996-1073.
Cost/ price structure/ license scheme	Free of charge

Technical overview	
Project phase/ main purpose	• Research • Preliminary study / Basic analysis • Feasibility study • Technology comparisons

Level of detail. Programming skills necessary?	Medium level of detail. Energy balance. No necessary programming skills.
Level of user friendliness	The user-friendliness level is medium. The program is easy to use but requires getting used to, especially when saving project and component files.
Most effective way to learn how to use the tool	• Through hands-on practice and experimentation • By attending workshops or training sessions • With the help of an experienced mentor or colleague • Tutorials and documentation are available
Effort required to understand and effectively use the tool	Less than one month
Specific applications in the tool	• Solar thermal collectors (concentrating and non-concentrating) • Solar tower • Hybrid systems PV-CSP (with electric heater or heat pump) • PV-BESS • Thermal storage • Heat or electricity production
Advantages	• Very fast calculation (a few seconds for an annual calculation) • Entire projects can be saved and later reloaded, archived, or shared with other users • Tools for evaluating results are included • Input of load curves is possible • User-defined operating strategies are possible • User interfaces for parameter manipulation and analysis of the results
Disadvantages	• Based on energy balances, matching of temperatures and mass flows between the components of a system (SF, TES, PB), is not checked. • No option for the user to design new plant concepts • Possible difficulty for the user in creating characteristic maps (PB, tower) in ASCII format • Only entire year or multi-year calculations are possible, no shorter time periods • No integrated parameter variation, but possible with a Python tool • No stratified storage • Relying on external libraries for steam
Special features	• Integration of third-party meteorological data and performance maps generated with other software tools • Users may save individual datasets as well as whole projects in ASCII format
Tool is not designed for	• Detailed calculation of heat balance diagrams for power blocks • Design of plant piping and hydraulics • Up-to-date database for installation costs or meteorological data
Included collector models (concentrated / non-concentrated; technologies)	• Concentrating and non-concentrating solar collectors are included as files that can be loaded. The user can add new ones. • Future integration with SolarKeymark collector database.
Included storage How are storages calculated?	• Short-term and long-term • Single tank, two-tank molten salt, concrete, and electric storage • No stratified storage • Simple capacity and energy balance
Possible time steps and time of simulation, simulation duration for 1 year	Based on hourly (or 30, 15, 10 min) performance simulation of a typical year. The simulation takes a few seconds.
Other tools/ extensions which are applicable with this tool (co-simulations)	It can be linked to Python for running simulations and parameter variations.
Remote execution of simulations	Not possible.
Simulation results	• Ready to use result figures available • Export in spreadsheet format available • Flexible GUI to investigate the results (e.g. by zooming in into the time-series results)
Author of factsheet Reviewed by	Javier Inigo Labairu (DLR) Johannes Werner (Protarget), Miguel Frasquet (Solatom)

4.3 Factsheet for PolySun

General information	
Name and version of tool	**PolySun Designer**
Submodels/ library considered	Solar Keymark and SRCC certification-based collector catalogue for tube collectors, CPC collectors, flat-plate collectors, unglazed collectors, concentrating collectors IEC and UL certification-based catalogue of PVT and PV modules.
Developed by/ Author/ provider	• S. Mathez and U. Frei, SPF (1994 – 2007 SFOE Project N. 13449) • Velasolaris AG (2006 onward)
Web link for more information	• https://www.aramis.admin.ch/Grunddaten/?ProjectID=4078 • https://www.velasolaris.com/
Creation date of factsheet	27.02.2025
Primary usage related to solar applications	• Engineering. • Project development / sales. • Project Planning. • Academic teaching. • Applied R&D.
List of users/ companies actively using this tool for solar applications	• *Academia / Teaching*: SPF/OST, HEIG-VD, HSLU, ETH, FHNW, ZHAW, TU Dresden, Dalarma University. • *Planning / Engineering*: Huber Energietechnik AG, SOCOL France. • *Manufacturers*: Viessmann, TVP Solar, TESVOLT, ENBW, MEIER TOBLER, BAYWA R.E.
Software language of source code, graphical user interface	JAVA, integrated GUI.
Operating system requirements	• Windows 10 and Windows 11 (64-bit recommended). • MacOS 10.15 (Catalina) or later. • Limited support for Linux.
Relevant publications	• Ruesch, F., & Haller, M. (2017). Potential and limitations of using low-Temperature district heating and cooling networks for direct cooling of buildings. *Energy Procedia*, *122*. https://doi.org/10.1016/j.egypro.2017.07.443. • Allegrini, J., Orehounig, K., Mavromatidis, G., Ruesch, F., Dorer, V., & Evins, R. (2015). A review of modelling approaches and tools for the simulation of district-scale energy systems. In *Renewable and Sustainable Energy Reviews* (Vol. 52). https://doi.org/10.1016/j.rser.2015.07.123. • Duret, A., et al.: Dynamic Simulation and Life Cycle Analysis of a 784 m^2 solar thermal plant with evacuated flat plate colletors coupled to a district heating heating network THERMAL SCIENCE: Year 2024, Vol. 28, No. 5B, pp. 4369-4379. • Sotnikov, A., Nielsen, C. K., Bales, C., Dalenbäck, J. O., Andersen, M., & Psimopoulos, E. (2017). Simulations of a Solar-Assisted Block Heating System. *ISES Solar World Congress 2017 - IEA SHC International Conference on Solar Heating and Cooling for Buildings and Industry 2017, Proceedings*, 373–383. https://doi.org/10.18086/swc.2017.06.13.
Cost/ price structure/ license scheme	• Free 30-day trial license for each version. • Periodical Licencing fee (Designer Version 4899 CHF / y; Student Designer version: 70 CHF / 6 months).

Technical overview	
Project phase/ main purpose	• Preliminary study / Basic analysis. • Feasibility study. • Detailed planning / Design. • Hardware in the loop (with Matlab / Simulink / Python add-on).
Level of detail. Programming skills necessary?	• No programming skills needed to work with the GUI. • For the use of programmable controllers and advanced features some basic programming knowledge is required in C, MATLAB or Python.

Level of user friendliness	High level of user friendliness, but debugging models is difficult.
Most effective way to learn how to use the tool	• Through hands-on practice and experimentation. • By reading the official documentation or manuals. • Online tutorial videos. • Attending Velasolaris paid seminars.
Effort required to understand and effectively use the tool	• More than one month
Specific applications in the tool	• Solar thermal & PVT collectors. • PV modules, inverters, grid and electricity users (electric car stations and household) for sector coupling. • Energy systems (air source and water source heat pumps, cogeneration groups, biomass or gas boilers). • Thermal storage (water tank). • Building heating & DHW production.
Advantages	• Comprehensive, easy to use graphical interface. • Fast simulation time, usually < 1 min. • Integration with Meteonorm for meteo data. • Extensive catalogue of predefined simulation schemes. • Creation of own catalogue entries (components and profiles). • Possibility of automated comparison of different concepts/scenarios.
Disadvantages	• It can deliver results even if the model is wrong or controllers have not been properly parametrized, causing the debug to be difficult. • Shadowing modeling outputs wrong results. • Accurate on 1h timesteps only, as at inferior sampling, results present implausible values. • No access to code, therefore limited debugging and no possibility to adapt numerical models of components. • Irradiance values can be included only at hourly steps if from external files. • No uniform data download makes automated result processing difficult. • Automated parameter studies are limited in extent, in some cases to catalogue entries only.
Special features	• Customizable reports. • Customizable pre-compiled system templates.
Tool is not designed for	• Personnel not skilled in thermohydraulic.
Included collector models (concentrated / non-concentrated; technologies)	• Every collector model which has been tested for Solar Keymark, SRCC or IEC; concentrating or non-concentrating collectors.
Includes storage How is storage calculated?	• Customizable storage entries based on water-based tanks or proprietary models (e.g., eTank, ice storage) • Calculated as a stratified 12 segments storage • It is not possible to insert a start temperature for the storage, but this can be corrected by adjusting pre-simulation time.
Possible time steps and time period of simulation, simulation duration for 1 year	• Variable timestep simulation model (1s - 12min). • Result output in 15-minute time steps (not accurate) or 1 hour time steps. • Period of 1 year; long pre-simulation/initialization possible but no result outputs for pre-simulation.
Other tools/ extensions which are applicable with this tool (co-simulations)	• MATLAB, Simulink and python addons.
Remote execution of simulations	• Remote execution through Java API.

Simulation results	• Ready to use result figures available. • Different levels of summary results. • Export in spreadsheet format is not directly available, but tables can be copied to Excel with some formatting issues possible. • Flexible GUI to investigate the results (e.g. by zooming in into time series graphical). • Ready to use reporting at different levels of detail. • Report templates by manufacturers.
Author of factsheet Reviewed by	Stefano Pauletta (HEIG-VD) Maria Moser (SOLID), Florian Reusch (OST-SPF)

4.4 Factsheet for TRNSYS

General information	
Name and version of tool	**TRNSYS v18**
Submodels/ library considered	Large variety of submodels for different technologies available. Some of these are included in the standard TRNSYS library: • Type 832 (dynamic collector model) • Type 1357 (TESS: Concentrating Collector) • Type 340 (stratified fluid storage tank) • Type 1301 (TESS: ground coupling for buried inverted truncated conical storage Tank) • Type 1535 (TESS: inverted truncated conical storage tank) • Type 927 (TESS: normalised water-to-water heat pump)
Developed by/ Author/ provider	Thermal Energy System Specialists (TESS), Transsolar Software Engineering
Web link for more information	https://www.trnsys.com/
Creation date of factsheet	20.02.2025
Primary usage related to solar applications	• Engineering • Research and Development
List of users/ companies actively using this tool for solar applications	Solites, Fraunhofer ISE, PlanEnergi, Uni Kassel, HEIG-VG, ISFH
Software language of source code, graphical user interface	Fortran, TRNSYS Simulation Studio
Operating system requirements	Windows 7 or later, 16 GB RAM is recommended
Relevant publications	• Sunstore 3 and Sunstore 4 (solar district heating in Dronninglund and in Marstal) • IEA ES Task 39 Subtask C, Deliverable C1: Numerical models list - Overview and collection of model fact sheets • Z. Tian, B. Perers, S. Furbo, J. Fan, Analysis and validation of a quasi-dynamic model for a solar collector field with flat plate collectors and parabolic trough collectors in series for district heating, Energy 142 (2018) 130–138, https://doi.org/10.1016/j.energy.2017.09.135
Cost/ price structure/ license scheme	• Free demo/test version with limited functionality available. • One time license scheme: Costs depend on number of licenses. One commercial license costs 4800 €. 10 licenses cost 9600 €. For educational use 10 licenses cost 2400 €. • Costs for additional libraries possible (TESS-library)

Technical overview	
Project phase/ main purpose	• Preliminary studies • Feasibility studies • Detailed planning/ design • Monitoring and evaluation / operations / optimisation
Level of detail. Programming skills necessary?	TRNSYS simulations are usually quite detailed. For advanced applications programming skills are necessary.
Level of user friendliness	Not very user friendly due to the high complexity of the program, rating based on 7 answers of survey related to TRNSYS: 2.4 (1 is “very difficult to use” to 5 is “very user-friendly”). However, the developers can be reached quickly in the form of a user forum or in direct communication and experience has shown that they answer questions of all kinds in the shortest possible time.
Most effective way to learn how to use the tool	• Through hands-on practice and experimentation • With the help of an experienced mentor or colleague • Tutorials and documentation are available
Effort required to understand and effectively use the tool	More than one month
Specific applications in the tool	• Solar thermal collectors • Energy supply systems (heat pumps, sector coupling, …) • Thermal storage (short- and long-term) • Heating networks and heat distribution • Building heating
Advantages	• Many validated types are available • Fast calculation times for an entire heat generation system with accurate results • Possibility to simulate various kinds of a thermal system
Disadvantages	• Long training period • Not very user friendly • Graphical user interface looks old • Expert knowledge required for modelling • Pressure and phase change processes cannot be calculated
Special features	• Create own TRNSYS types • Detailed mapping of the energetic behavior of buildings with TRNbuild • Access to a large number of validated types, through commercial providers or scientific publications • High customizability in terms of system interconnection, time resolution and output management • Possibility to run parametric studies with TRNEdit
Tool is not designed for	• Less-experienced users. • Quick and rough simulations.
Included collector models (concentrated / non-concentrated; technologies)	Non concentrated and concentrated collectors are included. One can simulate various TRNSYS types for all kinds of collector types like flat plates and evacuated tubes (i.e. Type 832, Type 1350) or parabolic troughs and linear Fresnel, etc. (i.e. Type 1351 to 1358)
Includes storages How are storages calculated?	• Short- and long term technologies are included (TTES above and integrated in the underground, PTES, ATES, BTES, buffer storage). • Storages are calculated in stratified multiple storage segments and temperatures considered. Temperature spread in the ground around the storage can also be simulated.
Possible time steps and time period of simulation, simulation duration for 1 year	• Time step: can be seconds, minutes or hours • Simulation period: can be chosen at will (months, a year or several years). • Simulation duration: depends on the complexity of the model and the time step. System with solar collectors, a buffer tank and auxiliary heating requires a few minutes for one year simulation. With additional large thermal storage and calculated ground temperatures, the simulation takes around 30 to 60 minutes.

Other tools/ extensions which are applicable with this tool (co-simulations)	Can be linked to Python, Fortran and C++ scripts and co-simulations can be done.
Remote execution of simulations	It is possible to run TRNSYS remotely using the TRNSYS executable and any given input file (file with the extension ".dck" which contains the text that states all the parameters and connections of a TRNSYS model, without the graphical display, and which is read by the TRNSYS kernel to run a simulation). This method is directly used/facilitated by programs such as TRNEdit (which can help run several simulations while varying one or several parameters) or GenOpt/TrnOpt (also a program that will vary parameters, but will also read a given output from the simulation and give the possibility to optimise this output using various optimisation strategies). It is also possible to run TRNSYS models on a server by running the executable and providing it with the desired input file
Simulation results	Simulation results are printed in text files for post processing (i.e. in Excel or Python).
Author of factsheet Reviewed by	Silas Tamm (Solites) Julian Jensen (ISFH), Geoffroy Gauthier (PlanEnergi)

5 Simulation Comparison between TRNSYS and PolySun

As part of the SOLARCADII project, funded by the Swiss Federal Office of Energy (SFOE) through its P+D program, a solar thermal plant connected to the urban district heating of Geneva, in Switzerland, has been monitored by the HEIG-VD (Haute École d'Ingénierie et de Gestion du Canton de Vaud; School of Business and Engineering, Vaud) during several years. Two numerical models of the plant performance have been developed in TRNSYS and PolySun, including the solar thermal collector field, a heat exchanger connected to the DH system, as well as the control and regulation system. Both models were validated against real-world measurements using identical input parameters. After validation, simulations were performed to compare the impact on performance of several optimisation measures (Duret et al, 2024).

5.1 PolySun model

Figure 12 shows the PolySun model which implements the components according to the SOLARCADII plant.

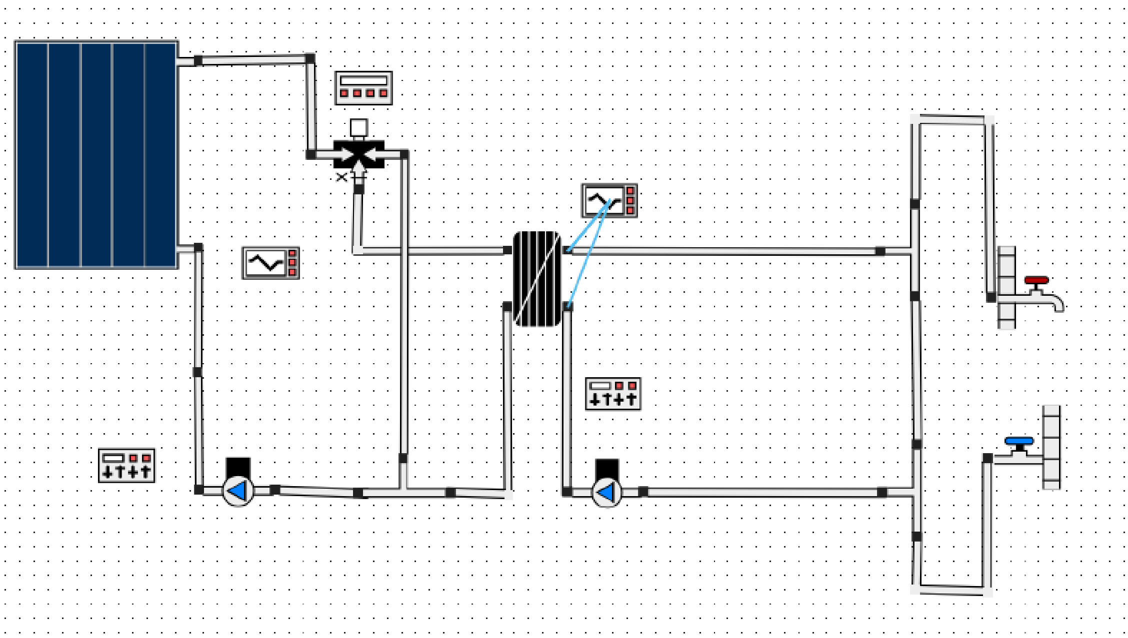


Figure 12 PolySun model for SOLARCADII

The solar field model replicates the SOLARCADII plant's configuration in orientation, tilt, and layout. Since the MT-Power V4 collector data in the PolySun catalog didn't match the Solar Keymark certificate, a custom model has been created. Insulated piping, including the Tichelmann loop, is included to quantify heat losses. A three-way valve controls the solar field production, opening at the target temperature (~80 °C) and closing with a hysteresis. The heat exchanger considered in the model, featuring an overall heat exchange of 150 kW/K, is based on real plant data, while a heat meter block records the solar thermal energy injected into the DH network. The DH system is modelled using measurement data of the temperature and flowrates at the plant inlet, with the SOLARCADII plant connected with a return-return plant topology.

5.2 TRNSYS model

The TRNSYS model includes all elements of the PolySun model with some improvements. These improvements include the consideration of irradiation at time steps shorter than one hour, as well as the consideration of distant, near, and reciprocal shading effects.

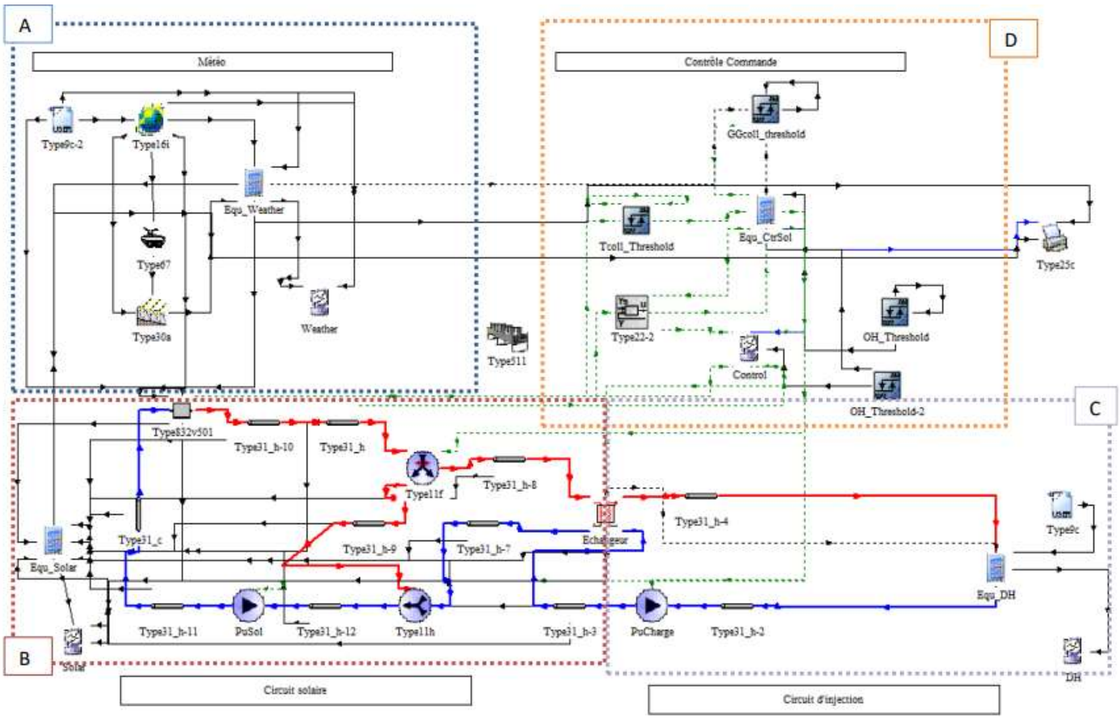


Figure 13 TRNSYS model for the SOLARCADII split into 4 modules (weather, control, solar and injection)

It is divided into four "modules," each grouping multiple components:

Weather (Block A): This block generates weather data (irradiance, temperature, and wind) based on plant measurements and performs shading calculations.

Solar Circuit (Block B): It includes the aggregated solar thermal collector model (Type 832), as well as the forward and return pipes, pump, preheating valve, and the hot side of the heat exchanger.

Injection Circuit (Block C): This module contains the cold side of the heat exchanger, the injection pump, and the connection to the DH network, implemented via an equation block.

Control/Command (Block D): Here, control signals for pumps and valves are processed. On/Off signals are generated using a hysteresis controller (Type 2), while continuous signals come from an ideal closed-loop controller model (Type 22).

5.3 Simulation results

The two numerical models described above have been used to simulate the performance of the SOLARCADII plant during one year of operation, between the beginning of June 2021 and end of May 2022. The results were compared to experimental measurements by focusing on a series of key performance indicators (KPIs).

The comparison has been performed with data featuring short sampling intervals (i.e., less than 60 min) to assess the plant’s dynamic performance (see Figure 14). To compare the respective productivity estimations, on the other hand, longer intervals have been adopted, i.e. on a daily, monthly, or yearly basis. The dynamic comparison is meant to focus on the solar field’s response to rapid input and environmental changes, assessing the model’s ability to replicate the plant response to highly variable real-time conditions. Key temperatures, flow rates, and control system actions (pumps, valves) are analysed to validate the model’s suitability to simulate dynamic conditions and to be adopted for the optimization of the plant control strategy (Duret et al, 2024).

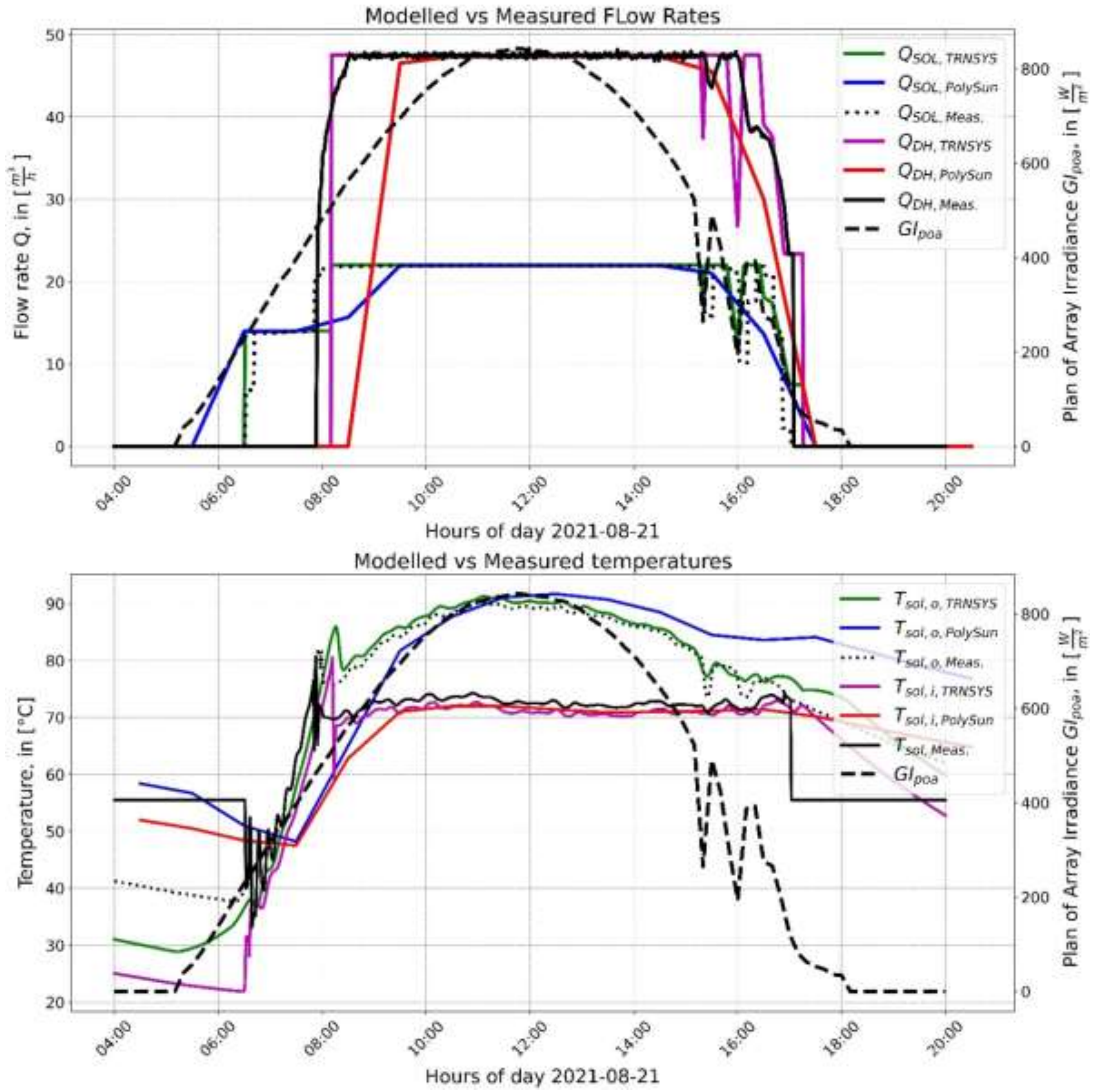


Figure 14 Qualitative comparison of the SolarCADII simulation results under TRNSYS and PolySun against the measurement data for the 21 August of 2021 at minimum sampling rate (1 data per minute for TRNSYS, 1 data per hour for PolySun).

At longer intervals, the comparison quantified the models' ability to predict thermal performance over extended periods of time (see Figure 15). To this purpose, heat production and selected KPIs (e.g., average efficiency of the field) were assessed to determine each models' accuracy for productivity estimations.

The comparison between both models' results and the measurement data acquired between June 2021 and May 2022 on the SOLARCADII, allowed validating both modeling tools for productivity estimations on timeframes of days, months or a year. On the other hand, due to the possibility to input hourly values only from user-provided weather files, at time-steps under 1 h PolySun cannot be considered accurate, while TRNSYS increases its computational accuracy when allowed progressing by smaller time-steps. This suggests that validation or optimization of the plant operational control strategy is better investigated with a TRNSYS model. On the other hand, the user-friendliness in modeling different circuits with the option to easily include (e.g.) several types of energy generation technologies and consumers, makes PolySun ideal as a tool for project feasibility studies performed in the context of business development and the planning phases of construction projects. The use of extensive catalogues for every component feature, as derived from the test certificate of official measurements, provides furthermore a source of readily available information which is difficult to compile for a more detailed model under TRNSYS.

In definitive, while both modelling environments are reasonably in accordance with measurement data when estimated on timeframes larger than a day, TRNSYS offers a better accuracy and the possibility to run in-depth analysis at lower time intervals, while PolySun offers the possibility of rapidly evaluating variants based on features derived from market components (Duret et al, 2024).

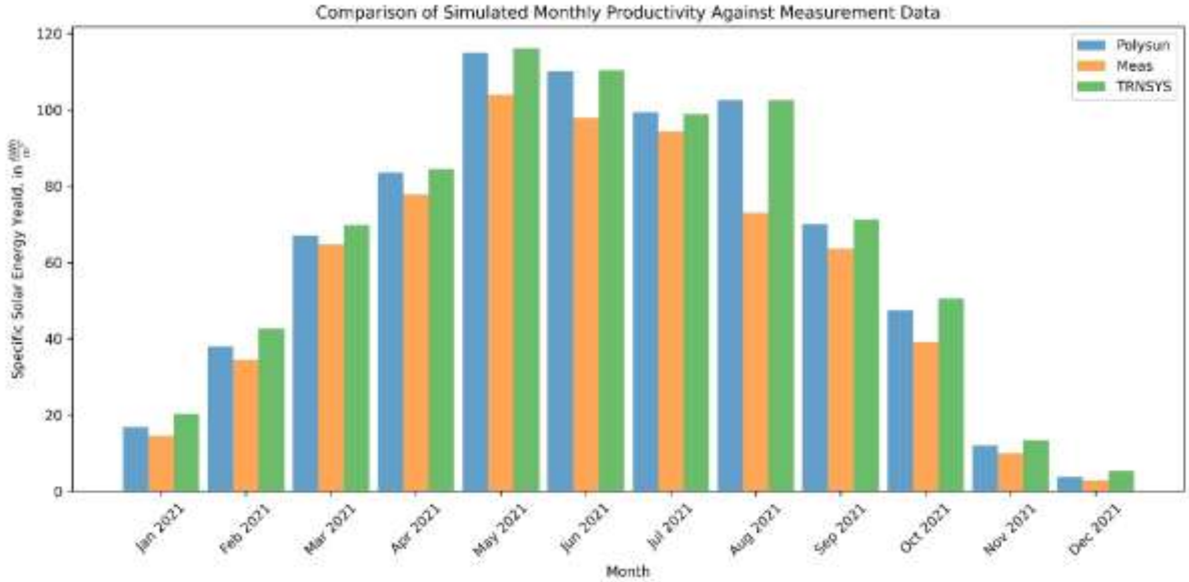


Figure 15: Qualitative comparison of the monthly specific solar yield between simulations under PolySun and TRNSYS and measurement data (Meas).

6 Conclusion

The analysis of the SDH tool survey indicates that most respondents either work with their own in-house tools or use a simulation/calculation tools that are not well represented in the group where the survey was shared.

The generation of higher temperatures with solar energy is becoming increasingly important. Report RA1 outlines the technologies relevant for this purpose (S. Tamm, M. Berberich, 2024). It is crucial that tools are capable of simulating and calculating such applications. The same applies to thermal storage, which is an essential component of SDH systems.

In addition, many tools are still in need of improvement, as certain functions are missing and should be implemented to better suit the needs of users. 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. This is not necessarily an issue, as users who need to get into detailed calculations usually also have the necessary experience to handle the more advanced tools. At the same time, this means that users with less expertise would then be limited to using less accurate tools, which could probably be remedied.

7 Outlook

Many institutions rely on their own internal tools. As the importance of SDH continues to grow, simulation studies are important to support the development of SDH systems. The ability to carry out extensive parameter studies in particular means that optimizations can be carried out during the planning process regarding component selection and system control. While various tools are described, their accuracy can only be estimated through a comparison of test cases, eventually using measurement data as a reference, neither of which have been carried out.

In the future, improvements to these tools could be aimed at better addressing the increasing demand for SDH simulations. The improvements can aim to make the simulations more accessible and accurate while ensuring that the results are plausible. This would contribute to more reliable planning and optimization of SDH systems and ultimately support their wider implementation.

8 References

Duret, A., et al.: Dynamic Simulation and Life Cycle Analysis of a 784 m2 solar thermal plant with evacuated flat plate collectors coupled to a district heating network THERMAL SCIENCE: Year 2024, Vol. 28, No. 5B, pp. 4369-4379.

Tamm S., Berberich, M. (eds.; 2024; version 1.1): Solar Collector Technologies for District Heating, Report RA.1 of IEA SHC Task68, available on https://task68.iea-shc.org/publications

ColSim, 2025, available from https://colsim.org/

Dymola, 2025, available from https://www.3ds.com/de/products/catia/dymola

Greenius, 2025, available from https://www.dlr.de/de/sf/forschung-und-transfer/forschungsdienstleistungen/simulation-und-wirtschaftlichkeitsbewertung/greenius-2

EnergyPRO, 2025, available from https://www.emd-international.com/energypro/

EnRSim, 2025, available from https://enrsim.ines-solaire.org/

MATLAB, 2025, available from https://de.mathworks.com/products/matlab.html

nPro Software, 2025, available from https://www.npro.energy/main/en/district-energy-systems/energy-system-design-tools

OpenModelica, 2025, available from https://openmodelica.org/

PolySun, 2025, available from https://www.velasolaris.com/

Python, 2025, available from https://www.python.org/

ScenoCalc, 2025, available from http://www.estif.org/solarkeymarknew/component/content/article/13-public-area/163-scenocalc

SCFW, 2025, available from https://www.scfw.de/

Simulink, 2025, available from https://de.mathworks.com/products/simulink.html

TRNSYS, 2025, available from https://www.trnsys.com/