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Quality assurance and support measures for solar cooling on system level

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Abstract

Within the IEA SHC Task 48 "Quality assurance and support measures for Solar Cooling" the analysis and evaluation of the systems has been one of the four main focuses. Here the activities are including the lab- and field-based characterization of the systems, the definition and application of performance figures, a guideline for a reliable monitoring procedure including methods for automated error detection and an updated overview on worldwide installed DEC systems including hints and good practice examples. They are furthermore leading to three different easy-to-use tools for solar cooling systems: The LCA tool considers environmental and energetic values for the evaluation, the PISTACHE tool offers a fast pre-sizing of the systems giving support for the planner in advance and finally an Excel tool allows a complete system evaluation using long term monitoring data.

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Keywords: system characterization, desiccant evaporative cooling, LCA, design tool, system monitoring, performance figures

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1. Introduction

While the overall aim of the IEA SHC Task 48 were quality assurance and support measures for solar cooling systems in general, ranging from activities on component level over system level to market support and policy advice this paper is focusing on the consideration of the system level.

It has been the aim to develop tools and deliverables to show the level of quality of solar cooling and heating systems to contribute to the effort of making these systems efficient, reliable and cost competitive. Therefore this subtask had been realized in two steps: first, the development of a procedure to extend the quality characteristics from component level to system level and second, to extend the procedure from characterization of single stationary states to a performance evaluation for whole year operation.

The activities within this subtask had been covering a broad spectrum with the following topics:

- System/Subsystem characterization and performance assessment
- Good practice for DEC design and installation
- Life cycle analysis at system level
- Simplified design tool used as a reference calculation tool: design facilitator
- Self-detection on monitoring procedure
- Quantitative quality and cost competitiveness criteria for system

2. System/Subsystem characterization and performance assessment

This activity comprised at first a review of laboratory test standards suitable for performance analysis of single components such as heat pumps, storages and solar thermal collectors of systems related to the European and US markets. Furthermore, different non-regulated methods have been assessed suitable for whole system characterization, e.g. the Bin-method, the CTSS, and the SCSPT/CCT methods.

The Bin Method is based on the EN 14825 and EN 12309: at present it is well suited for testing single components with boundary conditions that can be decided depending on the location. The component performance is obtained by stationary testing at full and partial load. The integration of the single components performance into a system calculation over a range of different boundary conditions gives the seasonal behavior.

The CTSS method is a combination of performance results from component laboratory tests with a numerical simulation. The components' test validates the numerical models that are used in the system simulation to determine the standardized annual energy use.

The SCSPT/CCT methods finally test the entire system in the lab, including pipelines, actuators and control strategy by emulating the boundary conditions, which the system is subject to. A short test sequence lasting few days is used to extrapolate the annual system performance.

In any of the cases described, the components, actuators and boundary conditions included in the calculations deeply influence the results. To support a general and comparable system evaluation a methodological approach has been adapted considering the system main components, the energy flows among each, the auxiliary units and the system boundaries (dashed line in fig. 1) indicating what elements are considered in the computation and what are disregarded. This work has had a strong link to the certification effort for solar cooling systems, which are handled within the activity of Task 48 on market support measures.

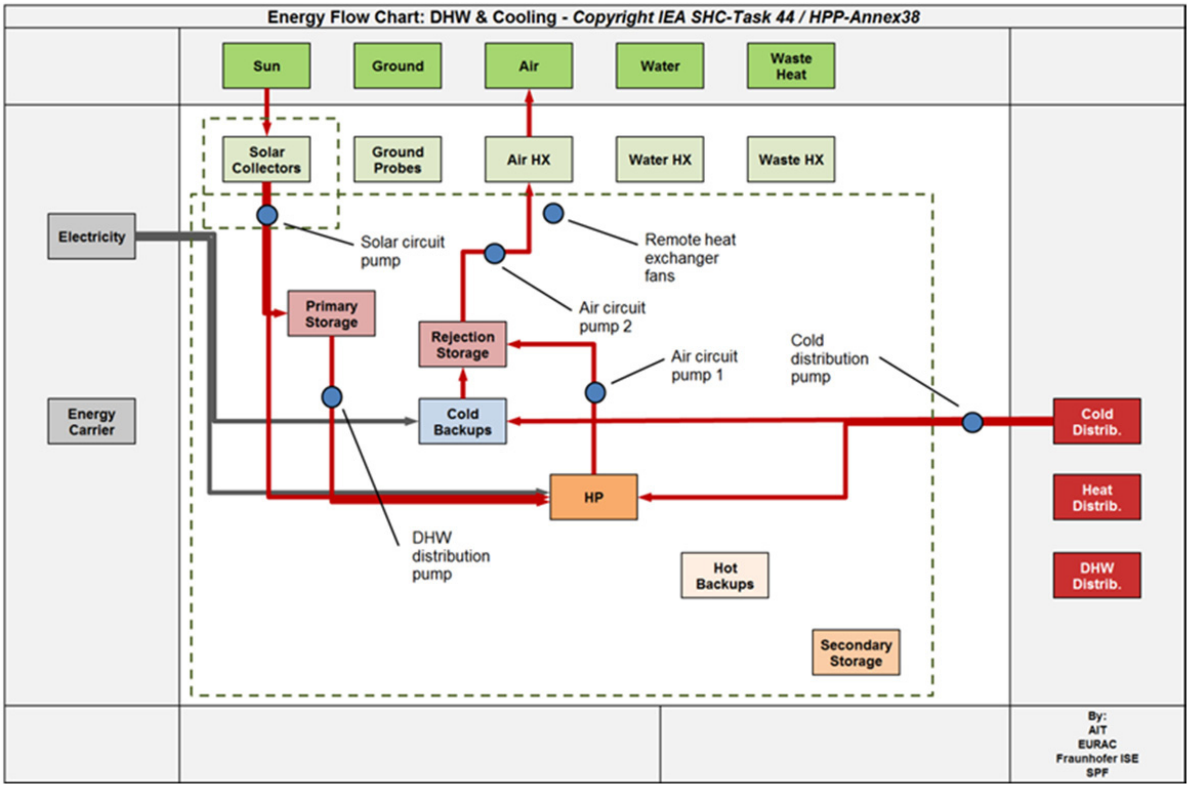


Fig. 1. Example for an energy flow chart of a typical heat pump / solar cooling system, showing the boundaries of different approaches – for components or the whole system [1]

3. Good practice for solar heat driven DEC design and installation

This activity was aiming to produce a technological survey and an update on good practice of solar heat driven desiccant cooling systems (SDEC). The SDEC-technology is not the major focus of the Task but with this activity the current situation of this technology has been reported.

The elaborated report gives an overview on overall 30 worldwide installed SDEC systems (see fig. 2). Beside the description of the used technologies in each system, it gives detailed information of the application and building type and the type of collectors used. If available, the scientific background and a system analysis are provided.

The cooperation and the exchange of international experts on SDEC-systems led to a review of new technical developments in this field ranging from fixed bed systems to double-rotor systems.

To support future installations of SDEC systems a compilation of quality labels and certifications corresponding to the regulations like EUROVENT, ANSI/AHRI, ARI and ASHREA of the different subsystems is provided.

A specific chapter of the report is dedicated to good practice SDEC systems. Here, the three examples: the ENERGYbase SDEC-system in Vienna, Austria, the TAFE SDEC based tri-generation system in Newcastle, Australia and the POLIMI SDEC-system installed in Milan, Italy, are comprehensively described and analyzed. The lessons learnt from the systems are given at the end of each chapter.

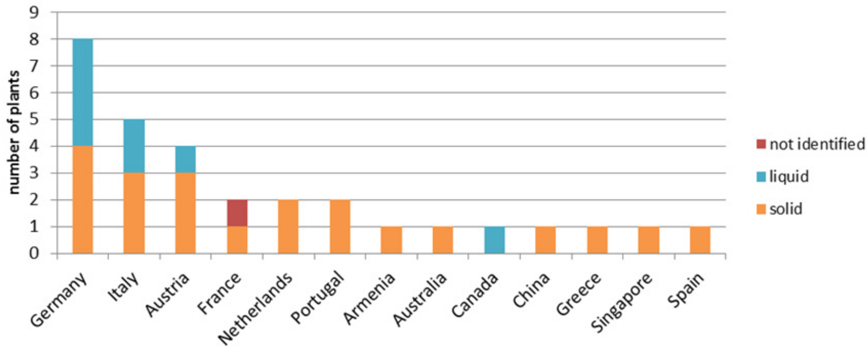


Fig. 2. Overview on the identified systems per country and type of sorption material used [2]

4. Life cycle analysis at system level

LCA at system level cannot be performed without the knowledge of the components. Therefore the presented final report [3] is considering the whole chain which leads finally to the system. A simplified and easy to use but comprehensive method tool, based on Excel, has been prepared using a database of different thermal components (chillers, collectors, heat storages, …) as well as PV-system components (photovoltaic panels, inverter, storages, …).

The tool is developed with the following characteristics:

- easy-to-use: it can be used both by LCA practitioners and non-professional users;
- easy to update: it can easily be expanded with the life cycle data of new components or updated with new life cycle data for the existing components;
- applicable to different geographic contexts and devoted to perform parametric analyses for SHC systems.

Figure 3 shows the main menu of the tool.

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

LCA METHOD TOOL

Task 48

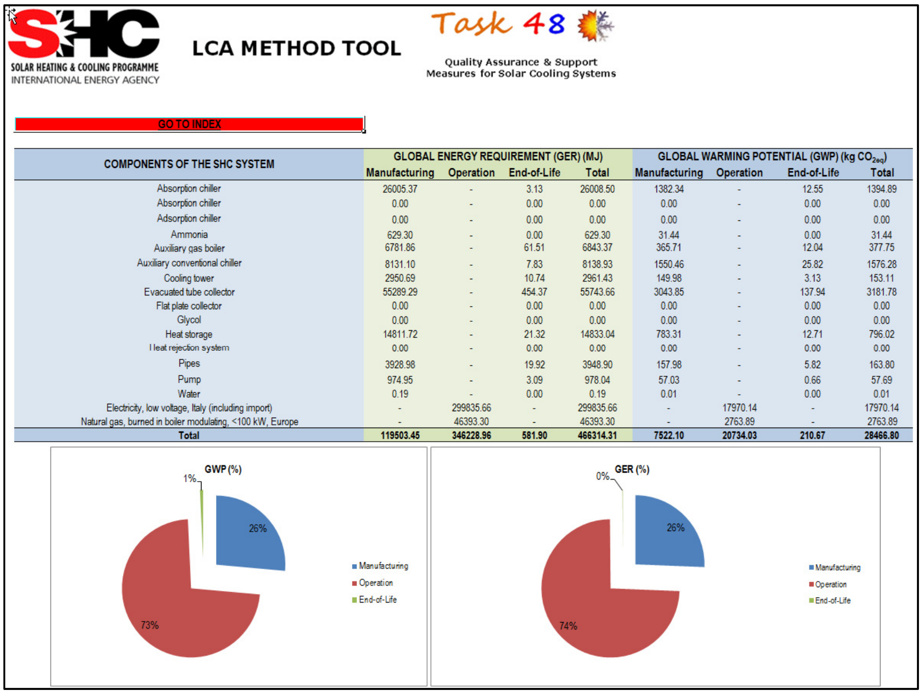
Quality Assurance & Support Measures for Solar Cooling Systems

Worksheet number	Description	Go to the worksheet
1	SHC system	Click here
2	Conventional system	Click here
3	Specific impacts SHC system	Click here
4	Specific impacts conventional system	Click here
5	Total impacts SHC system	Click here
6	Total impacts conventional system	Click here
7	Impacts comparison	Click here
8	Payback indices	Click here

Key
= Input data
= Information data
= Output data

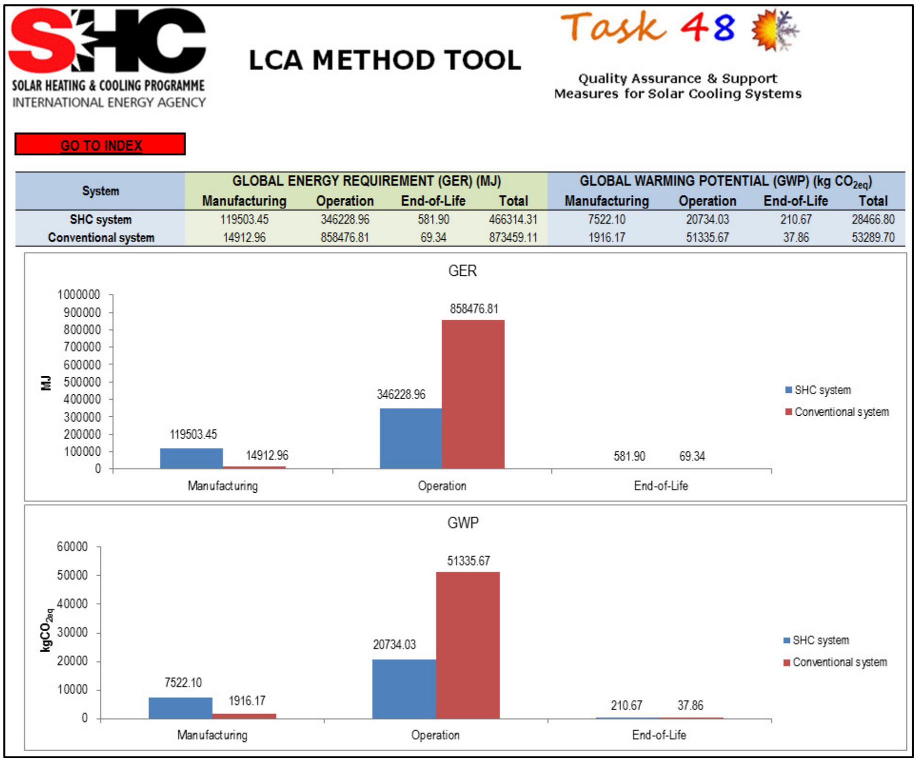
Fig. 3. Main menu of the LCA tool

The data base also embeds the impacts of electricity use in 25 different countries. This allows additionally a comparison of both technological approaches. In addition, as a tool for pre design purpose, the results are referred to the total impact for each component/energy source, the impact for the manufacturing and end-of life steps of each component of the system and for the operation step, the total impact for each life-cycle step (manufacturing, operation, and end-of-life), and the total impact for the life cycle of the system (Fig. 4 and Fig. 5).



COMPONENTS OF THE SHC SYSTEM	GLOBAL ENERGY REQUIREMENT (GER) (MJ)				GLOBAL WARMING POTENTIAL (GWP) (kg CO_{2eq})			
	Manufacturing	Operation	End-of-Life	Total	Manufacturing	Operation	End-of-Life	Total
Absorption chiller	26005.37	-	3.13	26008.50	1382.34	-	12.55	1394.89
Absorption chiller	0.00	-	0.00	0.00	0.00	-	0.00	0.00
Adsorption chiller	0.00	-	0.00	0.00	0.00	-	0.00	0.00
Ammonia	629.30	-	0.00	629.30	31.44	-	0.00	31.44
Auxiliary gas boiler	6781.86	-	61.51	6843.37	365.71	-	12.04	377.75
Auxiliary conventional chiller	8131.10	-	7.83	8138.93	1550.46	-	25.82	1576.28
Cooling tower	2950.69	-	10.74	2961.43	149.98	-	3.13	153.11
Evacuated tube collector	55289.29	-	454.37	55743.66	3043.85	-	137.94	3181.78
Flat plate collector	0.00	-	0.00	0.00	0.00	-	0.00	0.00
Glycol	0.00	-	0.00	0.00	0.00	-	0.00	0.00
Heat storage	14811.72	-	21.32	14833.04	783.31	-	12.71	796.02
Heat rejection system	0.00	-	0.00	0.00	0.00	-	0.00	0.00
Pipes	3928.98	-	19.92	3948.90	157.98	-	5.82	163.80
Pump	974.95	-	3.09	978.04	57.03	-	0.66	57.69
Water	0.19	-	0.00	0.19	0.01	-	0.00	0.01
Electricity, low voltage, Italy (including import)	-	299835.66	-	299835.66	-	17970.14	-	17970.14
Natural gas, burned in boiler modulating, <100 kW, Europe	-	46393.30	-	46393.30	-	2763.89	-	2763.89
Total	**119503.45**	**346228.96**	**581.90**	**466314.31**	**7522.10**	**20734.03**	**210.67**	**28466.80**

Fig. 4: Example of the results (screenshot): overview on component related values



System	GLOBAL ENERGY REQUIREMENT (GER) (MJ)				GLOBAL WARMING POTENTIAL (GWP) (kg CO_{2eq})			
	Manufacturing	Operation	End-of-Life	Total	Manufacturing	Operation	End-of-Life	Total
SHC system	119503.45	346228.96	581.90	466314.31	7522.10	20734.03	210.67	28466.80
Conventional system	14912.96	858476.81	69.34	873459.11	1916.17	51335.67	37.86	53289.70

Fig. 5. Example of the results (screenshot): comparison between SHC system and conventional system

Finally the application of the LCA has been tested and reported on four self-explaining case studies. The considered SHC systems having either hot and a cold-backup are compared with a conventional system: whether grid-connected, assisted by a grid-connected PV system or assisted by a stand-alone PV system. The LCA tool as well as the examples are available on the Task 48 website for the public.

5. Simplified design tool used as a reference calculation tool: “Design facilitator”

The PISTACHE tool [4] is a simple to use pre-sizing and evaluation tool for solar cooling, heating and domestic hot water systems. It is available on the websites of the Task 48 and of the company TECSOL. The software-tool calculates energy balances and performance indicators based on input data for a pre-selected hydraulic scheme. The user has to provide local information of the planned installation like meteorological data of the site, cooling and heating loads as well as the domestic hot water demand of the building. An automatically provided short interpretation of the annual energy results gives fast support for the investor and planner. It provides as well monthly and annual energy balance of a pre-defined configuration. Some automatic pre-sizing functions can help him to select the main component characteristics. It can be used at an early stage of a solar cooling project, for feasibility study as well as to plan the performance of a realized installation.

6. Self-detection on monitoring procedures

To avoid mistakes in the monitoring and evaluation of systems an updated guideline has been elaborated [5]. It is based on experiences of the former work within the IEA SHC Task 38. The guide provides background information and gives hints to detect possible errors. Starting at a general system definition and the characterization of typical system errors, the document is going more and more into detail: errors are classified, typical systematic errors, sensor errors and control problems are considered and described. With the description of typical errors of the different fault categories and additionally the discussion of methods and equipment for their detection the guideline provides support for an effective error identification and prevention. Practical examples of faults and its reason are presented, if available. In the second part of the report some of existing error detection systems and methods are presented: e.g., the concept of METHODIQA is based on online analysis of operation data and the calculation of specific benchmarks. These values are evaluated using intelligent algorithms to identify malfunctions or unfavorable operating conditions. Another described self-detection system uses a MATLAB routine to compare performance indicators which are derived from the system monitoring and online simulation. In general, automated fault detection uses more and more self-learning procedures which help to reduce significantly the external evaluation effort of the system operator.

7. Quantitative quality and cost competitiveness criteria for systems

This activity has been, among others one of the activities with the most side effects and the most interaction to others respectively. The main problem to be solved at the beginning has been the definition of common accepted performance figures and calculation methods [6]. This led to a close link to activities for system characterization, rating and benchmarking. Beside the general performance figures, additional indicators has been defined and described. This led to a comprehensive overview of the nomenclature required for the description of solar heating and cooling systems. Its ranging from typical energy flows between the components, considering the electricity values to different back-up solutions. For a specific evaluation and also for a comparison of the systems specific efficiency and primary energy conversion factors for five countries and also general Task 48 potential future Standard-values are listed. Beside this theoretical basis, a comprehensive Excel tool for the technical and economic system evaluation has been elaborated including the flow chart of the defined system. It gives an overview on the energy balance and calculates the Task 48 key figures. The tool has been tested with 10 best practice SHC-plants and is available for download at the website of the Task 48. Comprehensive results of the evaluation of the ten examples can be found in [7] or Task 48 Subtask C2 report.

Acknowledgements

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