IEA Solar Heating and Cooling Task 48

Quality assurance and support measures for Solar Cooling

SHC
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Technology and quality assurance for solar thermal cooling systems

Task 48

1 Solar thermal cooling technology and its potential

Solar thermal cooling uses the heat which is generated by collectors from solar irradiation for driving an absorption or adsorption chiller machine. One big advantage of this technology is the timely coincidence of solar irradiation and cooling demand.

In order to have a solar cooling system, which runs efficiently and reliably over the long term, certain quality issues have to be considered during the planning, installation and operation phase. These aspects will be briefly outlined in this brochure.

1.1 Technologies

Currently, absorption chillers are the most common thermally-driven cooling process in solar cooling installations. Common absorption chiller working pairs include ammonia-water and water-lithium bromide, with many sorption chillers available commercially over a range of capacities, but few at capacities of 100 kW_{th} or less. The so-called “single effect” absorption chillers typically need heat with temperatures in the range of 70 to 100°C, and achieve a coefficient of performance (COP) of about 0.7 (Fig. 1). Adsorption chillers are able to work at lower temperature ranges (down to 55°C), however this leads to an inferior COP (nearly 0.6).

1.2 Potential

The IEA Technology Roadmap Solar Heating and Cooling (2012) sees a potential of 1,5 EJ from an installed solar thermal cooling capacity of more than 1,000 GW_{th} for cooling in 2050. This would account for nearly 17% of the worldwide energy use for cooling. Currently the installed capacity is far below 1 GW_{th}.

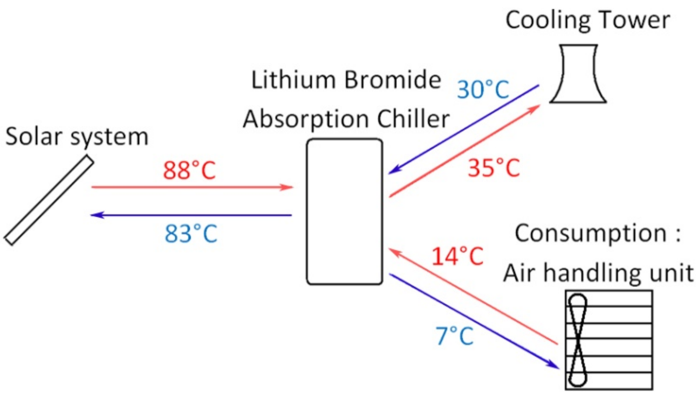

Fig. 1: Schematic principle of solar cooling; temperatures can deviate (Source: SOLID)

2 Quality procedures and best practice of solar thermal cooling systems

2.1 Heat rejection

In previous research projects the heat rejection was identified as the largest consumer of auxiliary electricity in solar cooling systems. In Task 48 a special focus on heat rejection, or recooling, was set (Fig. 2). Even though for quality optimization the whole solar cooling system has to be regarded. An overview of existing and novel concepts for heat rejection devices in solar cooling systems and recommendations on which heat rejection measure should be used under different boundary conditions (climate, system concept, etc.) while achieving the 2 main objectives: 1) investment & operation costs minimization and 2) re-cooling performance and efficiency. For selected components, where it was possible, a performance characterization has been made in partnership with manufacturers. The created publication reports on:

1. A survey of market available heat rejection devices suitable for solar cooling applications; an added value to the survey work has been a categorization of the product.
2. A survey of available standards in Europe, USA and Australia to understand the limitations vs. opportunities of the different technologies.
3. “Real-life” examples/experiences from monitored solar cooling systems. Practical hints have been retrieved.

http://task48.iea-shc.org/publications

Fig. 2: Heat rejection system for a large solar cooling system in desert environment (Source: SOLID)

2.2 Pumps Efficiency and Adaptability

Beside the electricity consumption of the cooling tower, auxiliary power in thermally driven SHC Systems is mainly dominated by pumping effort for heat transmission between the components. Depending on size, a high-efficiency pump, running at its best efficiency point, converts about 50% to

80% of the consumed electricity into useful hydraulic power (Fig. 3). But the deployment of high-efficiency pumps in solar cooling installations does not implicate an efficient pumping automatically. The strong relationship between pump and plant curve demands a proper system design and pump selection.

This activity focused on pump efficiency and adaptability to part load conditions in order to minimize the electricity consumption in the hydraulic circuits to obtain a high seasonal energy efficiency ratio in solar cooling systems.

Fig. 3: Heat rejection pump at the world's most powerful solar cooling installation in USA (Source: SOLID)

2.3 Simplified design tool used as a reference calculation tool (design facilitator)

The development of the PISTACHE (Presizing tool for solar cooling, heating and domestic hot water production systems) software tool called design facilitator for the fast pre-design was based on the work jointly done in France by TECSOL and CEA INES.

The PISTACHE software is a tool to pre-size and evaluate the performances of solar installation for cooling, heating and domestic hot water preparation, with or without energy back-up system.

The tool aims to realize easy and quick calculation of solar installation for cooling, heating and DHW production. It helps the user to pre-size the installation and provides energy balance and annual performance indicators. It shall help to support planners in the process of evaluation and feasibility studies of similar projects and then improve the quality of the predesign phase of a solar cooling project.

2.4 Financing: energy service companies

One hurdle for potential users of solar cooling systems is the high upfront cost of the installation and payback times of often 5-10 or more years. One solution to overcome this are energy service companies (ESCo) which are specialized on the installation, financing and operation and maintenance of energy systems. This is a well-established solution for many renewable and non-renewable energy systems. The ESCo finances and owns the solar cooling system and the user of the generated cold only pays for the energy which he consumes (Fig. 4). As the ESCo company has good expertise in purchasing and operation of energy systems, a high level of quality can be reached.

So far the ESCo principle was only applied for very large solar thermal cooling applications with cooling powers beyond 1.5 Megawatt.
Namely these are the solar cooling systems at United World College in Singapore and at Desert Mountain High School in Scottsdale, USA.

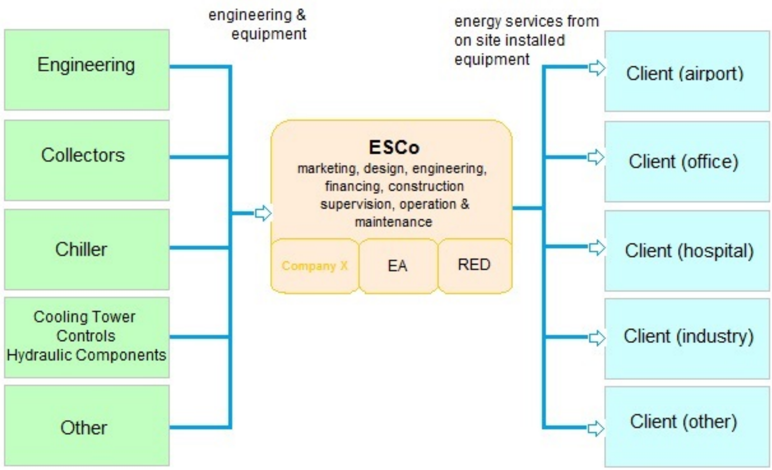

Fig. 4: Main ESCo system components, working schemes and theoretical processes

2.5 Selection and standardisation of best practice solutions through the edification of a Best Practice Book

From the past and present experience with small, medium and large size solar air-conditioning systems, a reduced and documented set of system design schemes and control schemes have been selected as real best practices, which exhibit favourable system operation in terms of optimised performance and reliability. Three case study configurations have been selected and used to define and standardise the engineering criteria, which lead to target reliability, efficiency and cost competitiveness. High attention has been drawn to the standardisation of the system design schemes and defining the constraints of applicability of these standardised designs. In order to give support to planners and installers a selection of proven system designs including hydraulic schemes have been detailed in the form of design guidelines for heating, cooling and ventilation of commercial buildings, leading to a Best Practice Book which will be published by some Task 48 experts after the end of the Task in 2016. These best practices will include as well monitoring feedbacks and lessons learnt from the three cases (a small-scale single-effect ammonia/water absorption chiller system, a medium-scale water/lithium bromide absorption chiller system and a double-effect absorption chiller system).

2.6 Life Cycle Assessment (LCA)

A user-friendly LCA method tool was developed, useful to calculate the energy and environmental impacts and the payback time indices of different SHC systems (Fig. 5) and to compare SHC systems and conventional ones. Furthermore the LCA database of life cycle inventories for components of SHC systems now includes also solar PV components (photovoltaic panels, inverter, storage, etc.). This gives the possibility to perform analysis on conventional systems which use renewable electricity with or without connection with the grid.

Fig. 5: components of a 10 kW absorption chiller machine (Source: PINK)

2.7 Related Best Practice Brochure

The Task 48 Subtask D2 activity is aimed to produce a Best Practice Brochure presenting a selected number of worldwide best practice examples of solar cooling installations. Input from other activities like C3 and the Task 48 participants have been explored to use it for this activity.

In total 12 selected solar cooling projects are presented in the brochure, which represents different applications like office buildings (6), school/institute buildings (4), commercial buildings (1) and residential buildings (1). The projects are located in North America (1), Europe (4) and mostly in South-East Asia (7). The cooled floor spaces of these buildings range between 240 m² up to 11,000 m². The annual electrical COP_{el} are between 6 and 25, which is an average value of about 12.9. The specific installed system costs are 7,300 EUR/kW for small-scale systems and in average 1,900 EUR/kW for large-scale systems as shown in the Fig. 6.

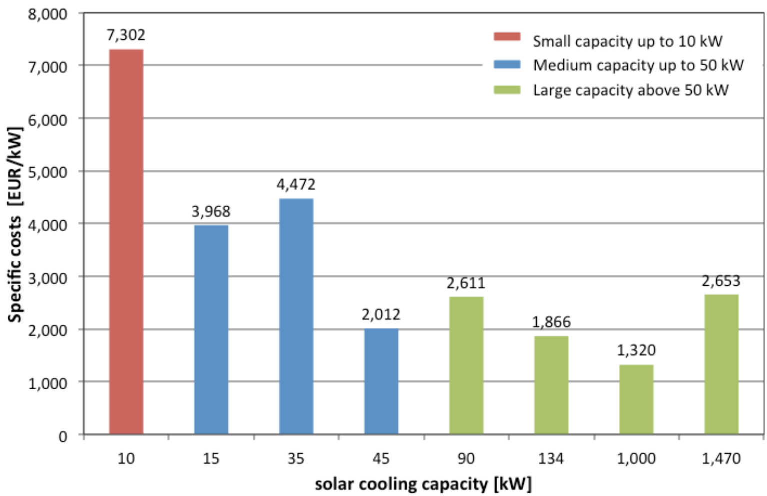

Fig 6: Specific costs of installed solar cooling systems (Source: Green Chiller)

IEA Solar Heating and Cooling Program

The Solar Heating and Cooling Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency. Its mission is *"to enhance collective knowledge and application of solar heating and cooling through international collaboration to reach the goal set in the vision of solar thermal energy meeting 50% of low temperature heating and cooling demand by 2050.*

The member countries of the Programme collaborate on projects (referred to as "Tasks") in the field of research, development, demonstration (RD&D), and test methods for solar thermal energy and solar buildings.

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The content of this brochure "Technology and quality assurance for solar thermal cooling systems" summarizes the key results of the IEA SHC Task 48 (http://task48.iea-shc.org/).

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