Solar Cooling for the Sunbelt Regions – a new IEA SHC Task

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Abstract

In 2016, air-conditioning accounted for nearly 20% of the total electricity demand in buildings worldwide and is growing faster than any other energy consumption in buildings. The lion's share of the projected growth in energy use for space cooling comes from emerging economies. This Solar Cooling initiative in cooperation with SHC TCP and MI IC7 is focusing on innovations for affordable, safe and reliable Solar Cooling systems for the Sunbelt regions. The innovation is the adaptation of existing concepts/technologies to the Sunbelt regions using solar energy, either solar thermal or solar PV.

The importance of the topic is reflected by the high number of interested entities and their feedback to the workplan and its specific content. Although the IEA SHC Task 65 started in July 2020 several ongoing R&D and demo projects of can be put forward in connection to different activities. This paper introduces the IEA SHC Task 65 and its main content, highlights the ongoing research projects and aims to attract a larger audience to get part of the initiative.

Keywords: Solar thermal cooling, PV cooling, sunbelt regions, IEA SHC Task 65, MI IC7

1. Introduction

Global energy demand is growing, although its growth rate is less than in the past. Nevertheless, by 2040 an increase of 30% is projected by OECD (2017). Nowadays air-conditioning accounts for nearly 20% of the total electricity demand in buildings worldwide and is growing faster than any other consumption in buildings (OECD/IEA 2018). The undisputed rationales for the increase are global economic and population growth and thus rising standards of living. Growth in the demand of cooling is especially driven by countries with high temperatures. Three emerging countries (India, China, Indonesia) contribute to more than half of the annual growth rates. Additionally, the efficiency of the air-conditioners varies considerably. The most common systems run at half of the available efficiency (OECD/IEA 2018). If measures are not taken to counteract this increase, the space cooling demand could triple by 2050. With the increase in demand the increase in the cost of electricity and summer brownouts can be considered, which have been attributed to the large number of conventional air conditioning systems running on electricity. As the number of traditional vapor compression chillers grow so do greenhouse gas emissions, both from direct leakage of high GWP refrigerant, such as HFCs, and from indirect emissions related to fossil fuel derived electricity consumption.

Solar air-conditioning is intuitively a good combination, because the demand for air-conditioning correlates quite well with the availability of the sun. The hotter and sunnier the day, the more air-conditioning is required. Interest in solar air-conditioning has grown steadily over the last years. A survey has estimated the number of worldwide installations at nearly 1,350 systems (Mugnier and Jakob 2015). Solar air-conditioning can be achieved by either driving a vapor compression air-conditioner with electricity produced by solar photovoltaic cells or by driving a thermal chiller with solar thermal heat. The knowhow capitalized in OECD countries (Europe, US, Australia, etc.) on solar cooling technology (both thermal and PV) is already very great, but very few efforts have been made to adapt and transfer this knowhow to Sunbelt countries such as Africa, MENA, Asian countries, which are all dynamic emerging economies They are also part of the global increase in demand for air conditioning (AC), where solar cooling could play an important role, as these are all highly irradiated regions of the world. Therefore, the

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present Task 65 is aiming to develop innovations for affordable, safe and reliable cooling systems for the sunbelt regions worldwide (sunny and hot climates, between the 20th and 40th degrees of latitude in the northern and southern hemisphere). It should cover the small to large size segment of cooling and air conditioning (between 2 kW_c and 5,000 kW_c). The implementation/adaptation of components and systems for the different boundary conditions is forced by cooperation with industry and with support of target countries like UAE, India, etc. through Mission Innovation (MI) Innovation Challenge “Affordable Heating and Cooling of Buildings” (IC7).

2. Sunbelt regions

The Sunbelt countries can be grouped in sunny, hot-arid or hot- humid climates between the 20th and 40th degrees of latitude in the northern and southern hemisphere. According to the climate classification of Köppen-Geiger (Geiger 1954) the range is between Group A (tropical climates), Group B (dry climates) and Group C (temperate climates). A world map which shows the countries inside or touching the Sunbelt on the northern and southern hemisphere is shown in Figure 1. Overall 84 countries can be accounted to the Sunbelt. Table 1 lists all these countries.

Tab. 1: List of countries inside or touching the Sunbelt

Afghanistan	Dominican Republic	Madagascar	Saudi Arabia
Albania	Egypt	Mali	South Africa South Korea
Algeria	Eritrea	Malta	Spain
Argentina	Greece	Mauritania	Swaziland
Armenia	Guatemala	Mexico	Syria
Australia	Haiti	Morocco	Taiwan
Azerbaijan	India	Mozambique	Tajikistan
Bahrain	Iran	Namibia	Thailand
Bangladesh	Iraq	Nepal	The Bahamas
Belize	Israel	New Caledonia	Tunisia
Belize	Italy	New Zealand	Turkey
Bolivia	Jamaica	Niger	Turkmenistan
Botswana	Japan	North Korea	United Arab Emirates
Brazil	Jordan	North Sudan	United States of America
Bhutan	Jordan, West	Oman	Uruguay
Burma	Kuwait	Pakistan	Uzbekistan
Chad	Kyrgyzstan	Paraguay	Vanuatu
Chile	Laos	Philippines	Vietnam
China	Lebanon	Portugal	Western Sahara
Cuba	Lesotho	Puerto Rico	Yemen
Cyprus	Libya	Qatar	Zimbabwe

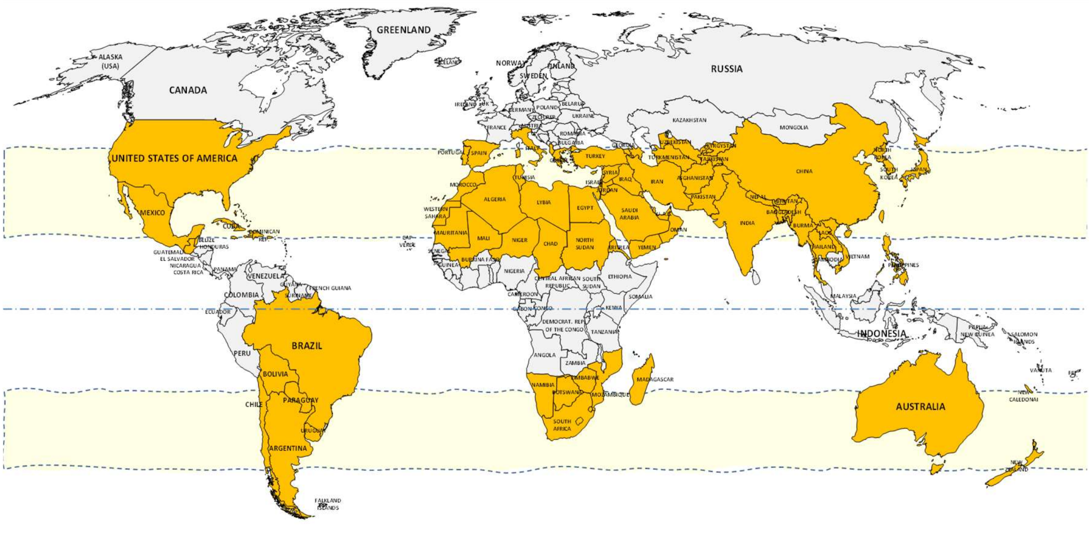

Fig. 1: Countries inside or touching the Sunbelt on northern and southern hemisphere

3. History of previous IEA SHC Tasks on Solar Cooling

Solar thermal/photovoltaic driven heating and cooling systems are belonging to the IEA SHC Strategic Plan Key Technologies (IEA SHC 2009, 2014, 2018), because they have the potential to cover much of the rising demand for air-conditioning by solar energy. The R&D projects of the recent decades, as well as the IEA Solar Heating and Cooling program tasks show the major technical and economic burden. The overall target of all these tasks and the solar heating and cooling program is to encourage a strong and sustainable market.

Initial work is completed in **IEA SHC Task 25** (Henning 1999) dealing with improvement of market conditions, promotion of primary energy and electricity peak reduction and the identification of promising technologies for solar (thermal) air conditioning.

Building on these results, **IEA SHC Task 38** (Henning 2006) is sub-divided into small and large-scale systems. On the one hand, market surveys are conducted to point out the availability and performance of components (Reinholdt et al. 2010) but also the modelling of these components is conducted in detail (Beccali et al. 2003; Bongs et al. 2010; Bourdoukan et al. 2009; Marletta et al. 2010). On the other hand, an initial comprehensive monitoring procedure (Napolitano et al. 2010) is established, existing systems are analysed accordingly (Thür et al. 2010; Jaehnig and Thür 2011) and main learnings are summarized (Preisler et al. 2011). A comprehensive life cycle assessment of solar cooling systems is applied to four case studies (Beccali et al. 2010) outlining not only the detailed energetic and environmental advantages of the solar applications, but also a database of main components for further investigation. In general, the lack of (technical and economic) performance at component and especially at system level (electrical performance, system losses, etc.) are documented in detail.

Thus, the follow up **IEA SHC Task 48** (Mugnier 2011) focuses on quality at component and system level, as well as on market support measures. Different components such as pumps (Helm et al. 2015), collectors (Calderoni 2015), chillers (Melograno et al. 2015) and heat rejection units (Fedrizzi et al. 2014) are analysed and their influence at system level is illustrated. Followed by methods of system characterization (Menegon and Fedrizzi 2015) and assessment criteria for technical and economic performance (Neyer et al. 2015) best practice solutions are identified (Selke and Frein 2015) and design guidelines (Mugnier et al. 2017b) are documented accordingly. Promising system efficiency and economic competitive solutions are found, and policy advice is formulated to further stimulate the market. Beside the solar thermal system solutions, PV driven solutions are entering the R&D of solar cooling.

The latest **IEA SHC Task 53** (Mugnier 2014) on new generation solar heating and cooling focuses on both, solar thermal and photovoltaic supported systems, best practice solutions and on performance, benchmarking and assessment. A comprehensive overview of commercially available existing but also new products is given by Mugnier et al. (2017a). Ongoing not yet published work focuses on new system configurations, storage concepts, life cycle analysis (LCA) and techno-ecological comparisons as well as the technical and economical assessment (Neyer et al. 2016) of the new systems.

4. Objectives of new IEA SHC Task 65

The key objective of this Task 65 is to adapt, verify and promote solar cooling as an affordable and reliable solution in the rising cooling demand across Sunbelt countries. The (existing) technologies need to be adapted to the specific boundaries and analysed and optimized in terms of investment and operating cost and their environmental impact (e.g. solar fraction) as well as compared and benchmarked on a unified level against reference technologies on a life cycle cost bases.

Solar cooling should become a reliable part of the future cooling supply in Sunbelt regions. After completion of the Task 65 the following should be achieved:

- Increase the audience and attention on solar cooling solutions through the combination of MI IC7 and IEA SHC activities and the entire stakeholders.
- Provide a platform for the transfer and exchange of know-how and experiences from OECD countries, already having long experiences in solar cooling, towards Sunbelt countries (e.g. Africa, MENA, Asia, …) and vice versa.

- Support the development of solar cooling technologies on component and system level adapted for the boundary conditions of Sunbelt (tropical, arid, etc.) that are affordable, safe and reliable in the medium to large scale (2 kW-5,000 kW) capacities
- Adapt existing technology, economic and financial analyses tools to assess and compare economic and financial viability of different cooling options with a life-cycle cost-benefit analyses (LCCBA) model.
- Apply the LCCBA framework to assess case studies and use cases from subtasks A and B to draw conclusions and recommendations for solar cooling technology and market development and policy design.
- Pre-assess 'bankability' of solar cooling investments with financial KPIs.
- Find boundary conditions (technical/economic) under which solar cooling is competitive against fossil driven systems and different renewable solutions.
- Establishing of a technical and economic data base to provide a standardized assessment of demo (or simulated) use-cases.
- Accelerate the market creation and development through communication and dissemination activities.

5. Task Structure

The Subtask structure is oriented to welcome MI IC7 projects and identified action areas and to support the market creation in Sunbelt regions. The structure is open for all technologies/ components of solar cooling, creating a path from idea to action in the promising market. Existing/new technologies need to be adapted to the boundary conditions of the Sunbelt regions, innovation on system level and demonstration cases create best practice examples, which are analysed with a uniformed method and database adding up to the necessary pool of knowledge to push outreaching dissemination activities (Figure 2).

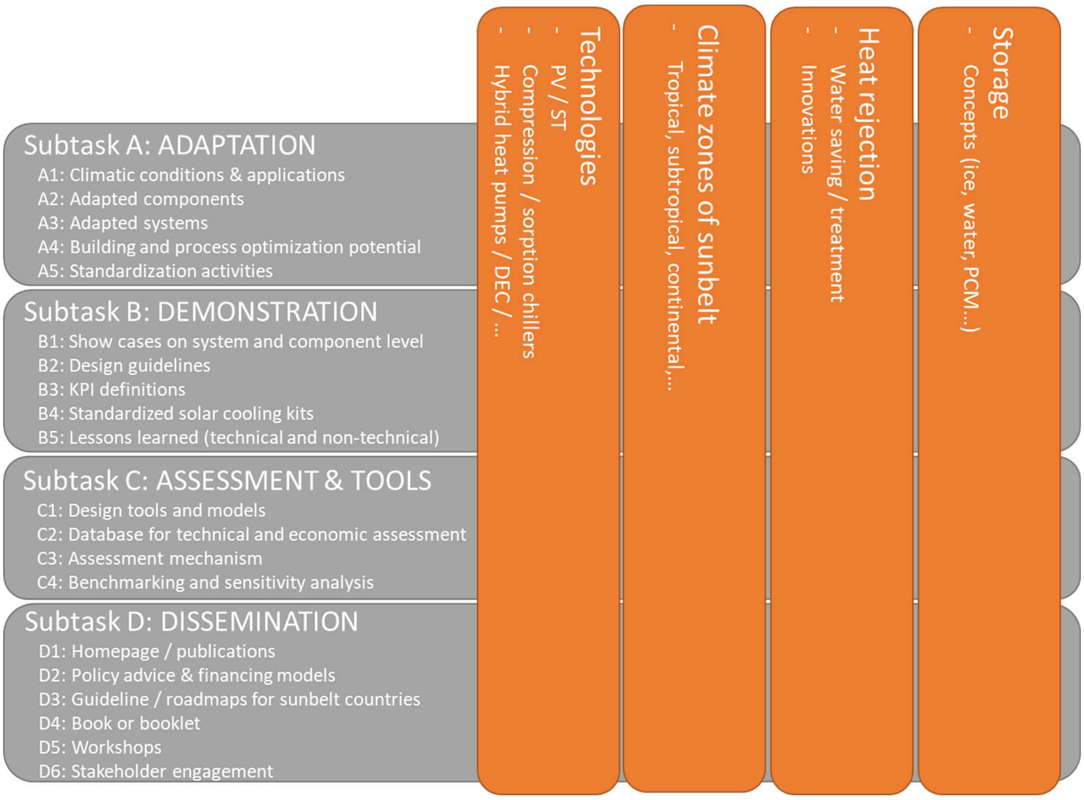

Fig. 2: IEA SHC Task 65 Subtask structure

5.1 Specific objectives of Subtask A

- Deliver a base for market studies for certain components and solar cooling systems
- Document the commercially available equipment compatible with PV electricity supply as well as solar thermal cooling equipment
- Get to know R&D entities / manufacturer working on solar cooling components and systems and their expected technology development, especially according to the key point of climatic adaptation efforts
- Document and show different possibilities of storages on hot / cold side or any other state
- Evaluate the economic potential of adaption to certain climates and application, especially when they can be simplified on component and system level
- Map the technical and economic potential for solar cooling of building / process optimization under different climates and national standards

5.2 Specific objectives of Subtask B

- Update and transfer procedures for measuring the performance of the solar cooling systems and to communicate existing monitoring procedure for field tests or demo projects
- Define and select technical and economic key performance factors for the different stakeholders in the entire project phases
- Documentation of the demonstration plant and their achieved technical and economic KPIs
- Analyse potential technical issues on monitored systems and create lessons learned for the specific climactic conditions
- Report selected pest practise examples of solar cooling in sunbelt countries

5.3 Specific objectives of Subtask C

- Collection of supporting decision tools for technical, economic and financial analyses with different levels of detail from simple pre-study tools to sophisticated dynamic simulation models
- Adapt existing technology, economic and financial analyses tools to assess and compare economic and financial viability of different cooling options with a life-cycle cost-benefit analyses (LCCBA) model
- Apply LCCBA framework to assess case studies and use cases from subtask A and B to draw conclusions and recommendations for solar cooling technology and market development and policy design
- Decision support in various phases of a project cycle from initial project ideas, comparison of technology options to detailed investment grade calculation up to optimization of the operation phase based on case studies and use cases from subtasks A and B
- Analyse the economic and environmental potentials of innovative technical concepts across the sunbelt boundary conditions
- Pre-assess ‘bankability’ of solar cooling investments with financial KPIs
- Analyse and report the technical and economic performance of demonstration plant and selected best practise example of Subtask B.

5.4 Specific objectives of Subtask D

- Establish communication structure with stakeholders
- Disseminate the task results on national and international level
- Provide efficient communication tools such as brochures/guidelines/Roadmaps/Book
- Collect and structure evidence for policymakers of the sunbelt countries
- Stimulate innovation through the communication of shortcomings

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