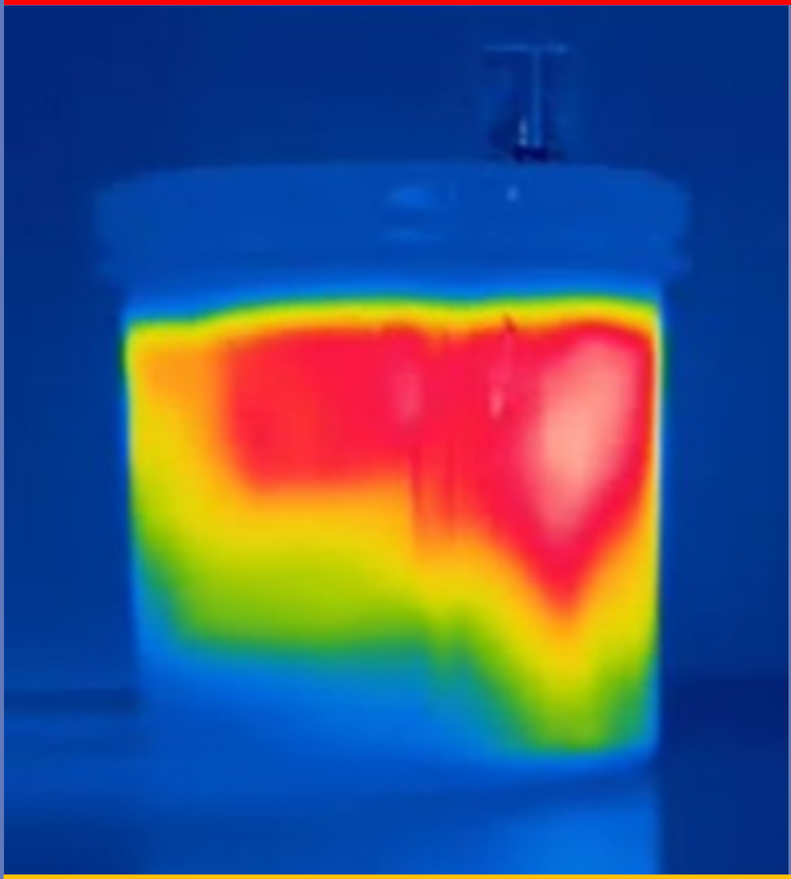
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

2023 Annual report



Feature Article

Compact Thermal Energy Storage

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Cover: PCM crystallization from supercooled phase – temperatures obtained with a thermal camera in a cylinder with PCM solidifying from top to bottom. Photo credit: Technical University of Denmark

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1. Message from the Chair

In 2023, the IEA SHC Technology Collaboration Programme (SHC TCP) members took time to look back at our work over the past five years and look forward to the ever-changing landscape for the solar heating and cooling sector. The SHC TCP also said farewell to Tomas Olejncizak, who passed the baton on to me after guiding the SHC TCP since 2021. I've worn many hats in the SHC TCP, from a Brazilian Executive Committee Meeting observer to a Task Expert to the Canadian Executive Committee member and Vice Chair.

I look forward to using these experiences and my decades of solar thermal research to continue raising the visibility and impact of solar heating and cooling at the local, national, and international levels.

Over the course of the year, the SHC TCP members and invaluable Task Managers have delved deep into how the TCP should navigate the growing and changing solar landscape over the next five years. Our Programme has delivered scientifically sound and comprehensive results throughout the years. Since 1977, the Programme has strived to bring together researchers, engineers, and key stakeholders to advance state-of-the-art solar heating & cooling technologies and daylighting. The TCP has supported the development of new collector technologies, small and large energy storage systems, better and broader standards and certification schemes, and enhanced systems integration, to name just a few accomplishments. However, we need to do even more, and our Programme has identified key areas and actions for strategic development:

Analyze - Provide authoritative and impartial analysis on solar heating and cooling and daylighting technologies, markets, and barriers.

Research - Demonstrate the effectiveness of solar heating and cooling technologies and designs through increased performance, reduced costs, and facilitated market competitiveness in heating and cooling applications.

Connect - Cooperate with stakeholders, including international organizations, local, regional, and national governments, potential users, energy and urban planners, and industry.

Communicate - Raise awareness and understanding of the potential and value of solar heating and cooling systems.

More than ever, we need broader participation and stronger partnerships to deliver results in the key areas listed above. This will be challenging as solar heating and cooling still needs strong policy support in many countries and the focus on electrification, despite the urgent need for decarbonization and the fact that the technology is sustainable, cost-effective, and locally manufactured using common commodity metals.

Solar thermal can and should deliver a strong contribution to our decarbonized future. It's clean, reliable, shovel-ready, and, in many cases, locally manufactured. It is also cost-effective in many instances, particularly in cases where there is a level field with other energy sources.

Policies come and go. Any predictions regarding energy technologies carry a significant uncertainty, as we have seen many times. So, let's focus on what we can do and work together to help fulfill the potential of solar heating and cooling technology on our way to a more sustainable planet!

As the new Chair, I will be building upon the work of Tomas and other past Chairs, the diverse experiences of the ExCo members, and the committed Task Managers and experts as the TCP enters a new 5-year term in 2024. I want to thank the very active TCP Vice-Chairs, He Tao (China), Kerstin Krüger (Germany), and Francisco Ferrera (Spain), and those who keep the TCP running and in the public eye. Thank you to Bärbel Epp for preparing SHC TCP news articles, Randy Martin for maintaining our website, and Pamela Murphy for keeping all the parts of the TCP's work moving forward.

Lucio Mesquita, SHC Executive Committee Chair

2. Solar Heating and Cooling Technology Collaboration Programme

IEA

The International Energy Agency (IEA) is an international organization at the heart of global dialogue on energy, providing authoritative analysis, data, policy recommendations, and real-world solutions to help countries provide secure and sustainable energy for all. Taking an all-fuels, all-technology approach, the IEA advocates policies that enhance energy reliability, affordability, and sustainability. It examines the full spectrum of issues, including renewables, oil, gas, and coal supply and demand, energy efficiency, clean energy technologies, electricity systems and markets, access to energy, demand-side management, and much more. For more information on the IEA, visit http://www.iea.org.

SHC TCP

The Technology Collaboration Programme on Solar Heating and Cooling (SHC TCP) was established in 1977 as one of the first multilateral technology initiatives of the IEA. All our work is supporting our…

Vision

Solar heating and cooling for secure and sustainable energy for all.

Mission

To bring the latest solar heating and cooling research and information to the forefront of the global energy transition.

Our mission assumes a systematic approach to applying solar technologies and designs to whole buildings and industrial and agricultural process heat. Based on this mission, the SHC TCP will carry out and coordinate international R&D work and will continue to cooperate with other IEA Implementing Agreements and the solar industry to expand the solar market. Our activities support market expansion by providing reliable information on solar system performance, design guidelines and tools, data and market approaches, and developing and integrating advanced solar energy technologies and design strategies for the built environment and industrial and agricultural process heat applications.

Our target audiences are the design community, solar manufacturers, and the energy supply and service industries that serve the end-users as well as architects, cities, housing companies, and building owners.

Our scope includes the practical use of sunlight for heating, cooling, and daylighting. The core research areas are technologies for heating, ventilation, and air conditioning for (1) buildings and neighborhoods, (2) industry, and (3) agriculture. The Programme is technology neutral and aims to find the best available solar solution.

The primary activity of the SHC TCP is to develop research projects (Tasks) to study various aspects of solar heating and cooling. Each research Task is managed by a Task Manager selected by the Executive Committee.

The Tasks running in 2023 were:

Solar Neighborhood Planning (Task 63)	Efficient Solar District Heating Systems (Task 68)
Solar Heat Processes (Task 64)	Solar How Water for 2030 (Task 69)
Solar Cooling for the Sunbelt Regions (Task 65)	Low Carbon, High Comfort Integrated Lighting (Task 70)
Solar Energy Buildings (Task 66)	Life Cycle and Cost Assessment for Heating and Cooling Technologies (Task 71)
Compact Thermal Energy Storage Materials (Task 67)	

Members & Membership

The overall management of the SHC TCP rests with the Executive Committee, which is comprised of representatives from each Contracting Party organization and Sponsor organization.

Members

Australia	Contracting Party	**Italy**	Contracting Party
Austria	Contracting Party	**Netherlands**	Contracting Party
Belgium	Contracting Party	**Norway**	Contracting Party
Canada	Contracting Party	**Portugal**	Contracting Party
CCREEE[1]	Sponsor	**RCREEE**[6]	Sponsor
China	Contracting Party	**SACREEE**[7]	Sponsor
Denmark	Contracting Party	**SICREEE**[8]	Sponsor
EACREEE[2]	Sponsor	**Slovakia**	Contracting Party
ECI[3]	Sponsor	**South Africa**	Contracting Party
ECREEE[4]	Sponsor	**Spain**	Contracting Party
European Commission	Contracting Party	**Sweden**	Contracting Party
France	Contracting Party	**Switzerland**	Contracting Party
Germany	Contracting Party	**Turkey**	Contracting Party
ISES[5]	Sponsor	**United Kingdom**	Contracting Party

1 Caribbean Centre for Renewable Energy & Energy Efficiency
2 East African Centre for Renewable Energy and Energy Efficiency
3 European Copper Institute
4 ECOWAS Centre for Renewable Energy and Energy Efficiency (West Africa region)
5 International Solar Energy Society
6 Regional Centre for Renewable Energy and Energy Efficiency (MENA region)
7 SADC Centre for Renewable Energy and Energy Efficiency (Southern Africa region)
8 Centre for Renewable Energy and Energy Efficiency of SICA countries (Central America region)

Benefits of Membership

The SHC TCP is unique in that it provides an international platform focused on solar thermal R&D. The benefits of membership are numerous.

- ***Accelerates*** the pace of technology development through the cross-fertilization of ideas and exchange of approaches and technologies.
- Promotes standardization of terminology, methodology, and codes & standards.
- Enhances national R&D programs through collaborative work.
- Permits national specialization in technology research, development, or deployment while maintaining access to information and results from the broader project.
- Saves time and money by sharing expenses and work among the international team.

How to Join

To learn how your government agency or your international industry association, international non-profit organization, or international non-governmental organization can join, please contact the SHC Secretariat, secretariat@iea-shc.org.

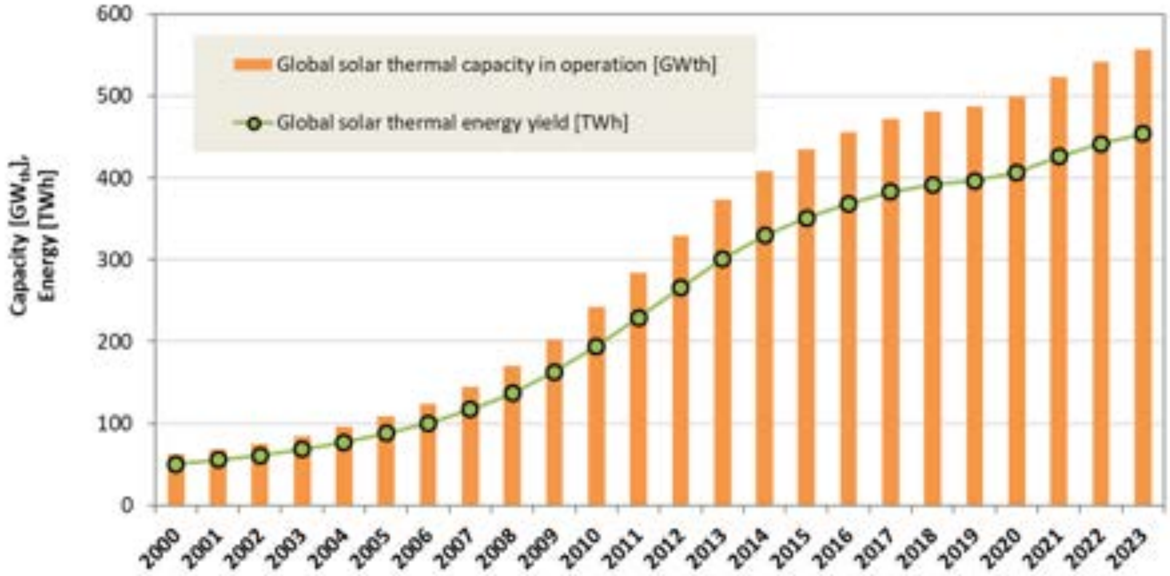
3. 2023 Recap

Solar Thermal Outlook

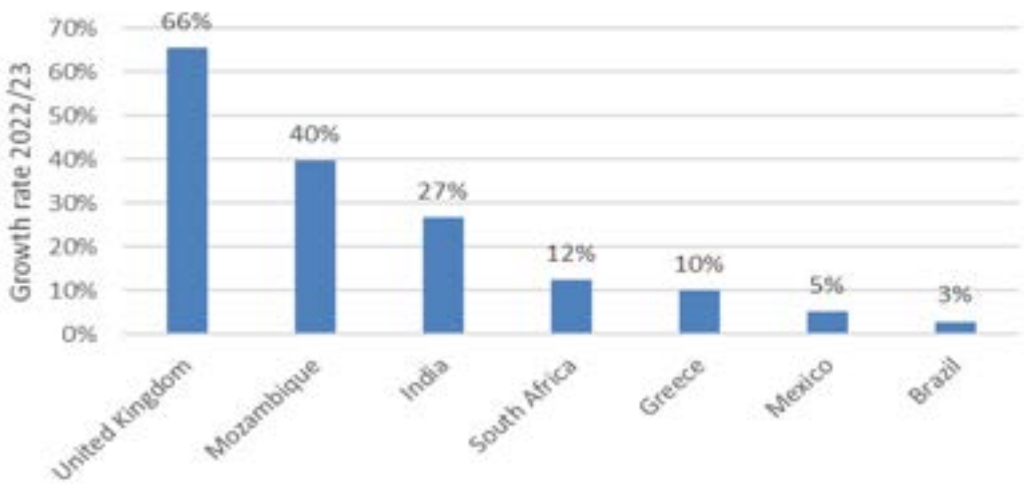
Every year we publish *Solar Heat Worldwide: Markets and Contribution to the Energy Supply*, the only annual global solar thermal statistics report. The 2024 edition reports that in 2023, solar thermal technologies produced 454 TWh – which corresponds to an energy savings equivalent of 48.8 million tons of oil and 157.4 million tons of CO_2.

This annual report is the most comprehensive of its kind and is referenced by many international organizations, including the IEA, REN21, IRENA, and national governments. The report is free to download at http://www.iea-shc.org/solar-heat-worldwide. The figures below show a snapshot of the market.

Global solar thermal capacity and energy yield



Market Leaders in 2023



SHC Tasks

New Tasks

The TCP continues to push forward on cutting-edge topics in solar thermal and the field of solar buildings, architecture, and lighting, all of which support our strategic focus on market deployment and R&D.

Of the eight running Tasks, the following were initiated (started or began Task Definition Phase in 2023):

- Task 70 — Low Carbon High Comfort Integrated Lighting (*Lead Country: Germany)*
- Task 71 — Life Cycle and Cost Assessment for Heating and Cooling Technologies (*Lead Country: Germany)*
- Task Definition Phase — Solar Powered Photo-Reactors (*Lead Country: Austria)*
- Task Definition Phase — Solar Cooling for the Global South (*Lead Country: Germany*

Completed Tasks

Task 64 on Solar Process Heat ended December 2023.

SHC Activities

Each of the activities below serves as a means to inform policy and decision-makers about the possibilities of solar thermal and the achievements of our TCP.

You can learn more about these activities and our work on our website, http://www.iea-shc.org.

Solar Heat Worldwide

This report is a primary source for the annual assessment of solar thermal. The report is the leading data resource due to its global perspective and national data sources. The installed capacity of the 71 documented countries represents 95% of the solar thermal market worldwide.

International Conference on Solar Heating and Cooling for Buildings and Industry

Our international conference provides a platform for experts to gather and discuss the trending topics and learn about the work others are doing in the field of solar heating and cooling. In 2024, the SHC TCP, in partnership with the International Solar Solar Energy Society (ISES), will co-organize EuroSun 2024 in Limassol on August 26-30.

Solar Academy

This activity is another vehicle to share our work and support solar heating and cooling R&D and projects worldwide. It includes 4 webinars every year, onsite training workshops at the request of SHC Executive Committee members, and a video series. In 2023, the webinars were Global Solar Certification Network, Solar Heating and Cooling Markets and Industry Trends, Task 66: Solar Energy Buildings, and Task 67: Thermal Energy Storage plus a Task 69: Solar Hot Water for 2030 organized webinar. And, there was one onsite training on solar cooling in Cape Verde and one online for Turkish professionals.

SHC Solar Award

Our prestigious award recognizes individuals, companies, and institutions that have made significant contributions to the growth of solar thermal. The SHC TCP has presented this award 13 times since 2003. The most recent award was presented to the ORVI social housing project in Namibia at EuroSun 2022. The next award will be presented at EuroSun 2024.

Solar Update Newsletter

Biannual newsletter highlighting Task work and solar thermal programs/activities in our member countries and organizations.

SHC Collaboration

To support our work, the SHC TCP is collaborating with other IEA Technology Collaboration Programmes and solar organizations.

Within the IEA

District Heating and Cooling TCP is collaborating in Task 68: Efficient Solar District Heating Systems.

Energy in Buildings and Communities TCP is collaborating in SHC Task 70/EBC Annex 90: Low Carbon High Comfort Integrated Lighting.

Energy Storage TCP is jointly managing SHC Task 67/ES Task 40: Compact Thermal Energy Storage Materials within Components and Systems.

Heat Pumping Technologies TCP is collaborating in Task 65: Solar Cooling for the Sunbelt Regions and Task 69: Solar Hot Water for 2030.

PVPS TCP is collaborating in Task 69: Solar Hot Water for 2030.

SolarPACES TCP is jointly managing SHC Task 64/SolarPACES Task IV: Solar Process Heat.

Renewable Energy Working Party held two meetings in 2023. The SHC Chair, Tomas Olejniczak, presented the TCP's Annual Briefing at the March meeting, and the new Chair, Lucio Mequita, presented the TCP's request for Extension virtually at the November meeting. The TCP also participated in the TCP Universal Meeting.

Outside the IEA

International Solar Energy Society is co-organizing EuroSun 2024 and hosts our Solar Academy webinar series.

ISO TC 180*,* the SHC TCP, specifically through Tasks, supports the work of ISO TC 180.

Mission Innovation Challenge 7: Affordable Heating and Cooling of Buildings is supporting the work of Task 65: Solar Cooling for the Sunbelt Regions

Solar Heat Europe, the SHC TCP has a close working relationship with this organization and looks forward to new opportunities for collaboration in 2024*.*

UNIDO supports our GN-SEC Centre Sponsor members.

Conferences, TCP presentations at the *Asia Pacific Solar Research Conference,* and *Solar World Congress 2023*.

2023 MEETINGS	2024 MEETINGS
93rd ExCo Meeting (hybrid) Sophia Antipolis, France June 13 – 16	**95th ExCo Meeting** (hybrid) Oslo, Norway June 4 – 7
94th ExCo Meeting Virtual November 6 – 8	**96th ExCo Meeting** (hybrid) Berlin, Germany November 5 – 7

4. Feature Article

Compact Thermal Energy Storage

Introduction

Half of the world's final energy demand is used for heating and cooling purposes. Thermal energy storage systems are needed to match the variability of renewable sources and optimize the performance of thermal systems.

Compact thermal energy storage (CTES) systems make use of either phase change materials (PCM) or thermochemical materials (TCM). They enable the storage of heat or cold in a more compact manner compared to water or other sensible storage technologies. In addition, they enable storage at very stable temperatures (PCM) or with very low heat losses over time (TCM). These qualities both allow for more efficient heating or cooling systems and increased use of renewable sources. TCM, in particular, enables longer storage times, even bridging seasons.

Some important application areas of CTES technologies are:

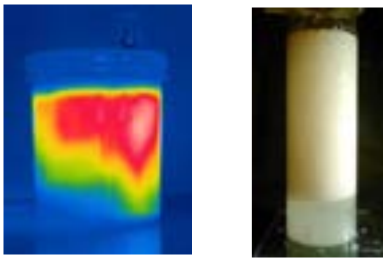
- Sector Coupling: improved efficiency in the operation of networks and coupling different energy sectors by peak-shaving and demand flexibility options.
- Energy efficiency in buildings for both cooling and heating, including domestic hot water.
- Heat recovery in industrial processes: enabling heat transfer between different processes or between subsequent batches of production.
- Cold storage for data centers or other cooling processes and solar-driven cooling.
- Areas in which thermal storage is combined with drying or steam production processes (e.g., the zeolite dishwasher).
- Seasonal thermal storage of solar energy (heat or electricity).

Current Status

A growing number of compact thermal energy storage technologies are on the market. **PCM-based products** are available that guarantee a stable temperature when transporting vulnerable goods or that stabilize indoor temperatures while simultaneously increasing the efficiency of the heating/cooling system[1]. Furthermore, there is a growing market for compact, domestic, PCM-based hot water storage systems[2].

For the time being, there are only a few **TCM-based products** on the market. Nevertheless, one very successful example is the zeolite-assisted dishwasher. This appliance reduces energy demand by 20% by combining the water heating and the drying steps using the sorption process of the zeolite. In addition, several small companies are working on **prototypes or early market products** of compact thermal energy storage, either with zeolites3 or with salt hydrates4. The challenges in further developing these technologies are improving materials and components and reducing the cost of the complete device.

1 https://pluss.co.in/; https://www.pcmproducts.net/; https://phase-energy.com/pcm-products/; https://www.rubitherm.eu/en/
2 https://sunamp.com/how-thermal-batteries-work/
3 https://zeosys-energy.de/
4 https://cellcius.com/en/



PCM crystallization from supercooled phase – temperatures obtained wit a thermal camera (left) in a cylinder with PCM solidifying from top to bottom. Source: Technical University of Denmark

Grains of potassium carbonate in a test set-up. It is a TCM material used for seasonal solar thermal energy storage for domestic applications. (Source: Eindhoven University of Technology, Netherlands)

Different aspects of the technologies have been and are being studied and further developed by a relatively small group of researchers worldwide. The main classes of PCM and TCM have been investigated but are **not yet fully understood** regarding stability, performance increase through materials combination, and cost reduction possibilities. **Components** developed for the charging, storage, and discharging of materials have been **proven** in the laboratory and **demonstration systems**. **Systematic knowledge** of the possibilities to improve component performance already in the design phase is **still lacking** but necessary for cost reduction. Reliable measurement techniques for state-of-charge determination are currently being investigated. And a diverse number of **compact thermal storage systems** have been **demonstrated**, giving valuable insight into the system integration and control requirements while proving the technologies' potential for efficiency increase and better use of renewable sources.

Three prototype modules for a seasonal solar thermal storage system using potassium carbonate as TCM, CREATE project. Source: AEE INTEC, Austria

Liquid-sorption-based heat storage system developed at the Lucerne University of Applied Science. Source: University of Applied Sciences, Lucerne, Switzerland

Zeolite beads in the heat exchanger of the zeolite dishwasher. Source: ZAE Bayern

The Sunamp Plentigrade PCM thermal storage system. Source: Sunamp

Potential

There is a broad application base for PCM/TCM thermal storage technologies in the built environment, industry, and sector coupling.

Estimates of the potential of a limited number of applications are shown below, with the assumption that the total potential is much higher.

Seasonal storage of solar energy

In moderate climate regions, seasonal thermal energy storage of solar energy, coming from solar thermal systems or PV systems, enable a year-round, 100% renewable heating and domestic hot water supply while providing short-term storage. Especially in multifamily or single-family houses in areas without district heating, these systems can play an important role, as they are less dependent on electricity in the heating season. In a first estimate, about 5% of the houses in moderate climate regions could be equipped with these storage systems. This would be in the order of 25 million homes, with an average heat demand of about 15 MWh, leading to 375 TWh of energy savings annually.

Dishwasher potential

An innovative dishwasher has been commercially available since November 2009 and reduces energy consumption compared to a conventional dishwasher from about 1.05kWh to 0.80kWh per washing cycle, or energy savings of about 20%[5]. Worldwide, there are about 450 million dishwashers. If 20% of these are zeolite-equipped with 250 washing cycles per year, the annual electricity savings would be 4.7 TWh.

Distributed power–to–heat

With compact thermal energy storages like the Sunamp system, excess renewable electricity from the grid can be stored locally and used for heating later. With 100 cycles per year, a unit can use 1,500 kWh of additional renewable electricity annually. With 10% of the world's households using such a storage and a rough estimate of 2 billion households, the annual renewable energy uptake by household compact thermal energy storage appliances is 300 TWh.

Data center cooling

Globally, the electricity demand of data centers is estimated to be between 220 and 320 TWh, or around 0.9 to 1.3% of global final electricity demand in 2021[6]. The electricity consumed in data centers is almost completely converted into low-temperature heat – which indicates high cooling demand. The main advantage of PCM is the high storage density in small temperature intervals, which is applied in "free cooling" systems using ambient air as a cooling source and in hydronic cooling systems to maximize the operational flexibility of chillers.

Researchers recently found that data centers in the European electricity system could provide up to 10 GW of demand response capacity by 2030[7].

Thermal comfort in buildings

In the context of global warming, more extreme weather periods are being observed. Thus, maintaining thermal comfort in buildings (domestic and industrial) is becoming increasingly important – both during warm and cold seasons. The global energy demand from air conditioners is expected to triple by 2050[8]. Therefore, compact storage solutions will be increasingly important regarding peak shaving of cooling and heating loads and to ensure demand-side flexibility for maximized utilization of renewable energy via heat pumps and chillers.

Industrial processes

5 https://www.bosch-home.com/de/produkte/geschirrspueler/perfectdry
6 https://www.iea.org/reports/data-centres-and-data-transmission-networks
7 C. Koronen, M. Åhman, and L. J. Nilsson, "Data centres in future European energy systems—energy efficiency, integration and policy," Energy Efficiency, pp. 129–144, 2019.
8 The Future of Cooling. Opportunities for energy efficient air conditioning. Edited by IEA Publications, International Energy Agency (IEA), 2018.

About 90% of the global industrial process heat demand below 400°C is provided by fossil fuels9. CTES systems can supply flexibility to industrial heating systems by re-using heat in batch processes or by enabling the use of low-cost renewable electricity in power-to-heat systems10,11,12. If 15% of the process heat demand can be covered by power-to-compact thermal energy storage systems, approximately 1,600 TWh of fossil fuels could be replaced.

Actions Needed

The potential drivers for a successful implementation of CTES are:

- The need for **distributed thermal storage** enables better utilization of excess renewable energy and accelerates the replacement of fossil fuels by renewables, with no additional grid infrastructure needed.
- **Higher volatility of arbitrage prices** will translate the thermal storage added value to an energy system into monetary value.
- The need for a **diversification of energy supply** and, therefore, an increased security of supply.Lowering the material and component costs.

These potentials can be opened up by addressing the following challenges:

Challenge	Action needed	Action by whom
Added value to the energy system is not monetarized	Include CTES in **total system costs** and compare these to other system configurations with the same performance.	Application/system engineers
	Pass volatility of energy prices on to the operators of CTES storage technology.	Policy makers, electricity companies
Relatively high cost	Long-term market introduction **support program**.	International and national policy makers
Slow progress of technology development and innovation	National and international, long-term and dedicated **R,D&D support programs** for basic CTES materials research. Targeted support to small and highly **innovative CTES companies**. Dedicated **demonstration programs** to monitor and evaluate performance and stepwise improve CTES performance.	International and national policy makers
Low industry involvement	Targeted demonstration and market introduction **support programs** to avoid 'valley of death' in development.	International and national policy makers, and Industry decision makers
Thermal technologies are not seen	Increase **awareness** among decision makers and the broader public on the potential of compact thermal energy storage.	Industry decision makers, R&D community, and Professional organizations

*This article is one of a series of Technology Position Papers published by the IEA SHC for policymakers, https://www.iea-shc.org/publications.

Author: Wim van Helden, AEE INTEC and co-Task Manager of SHC Task 67 / ES Task 40 Compact Thermal Energy Storage Materials within Components within Systems with input from Benjamin Fumey, Univ. of Applied Sciences Lucerne, Switzerland; Gerald Englmair, Technical Univ. of Denmark; Florian Kerscher, Technical Univer Munich, Germany; Ruud Cuypers, TNO, The Netherlands; Dominic Groulx, Dalhousie Univ, Canada; Daniel Lager, Austrian Institute of Technology; Stefania Doppiu, CICenergiGune, Spain; and Christoph Rathgeber, ZAE Bayern, Germany.

9 IRENA (2014), Renewable energy options for the industry sector: global and regional potential until 2030
10 Project envIoTcast PCM storage for die-casting; https://projekte.ffg.at/projekt/3849163
11 Project EDCSproof, PCM storage for industry, 100 – 200 °C; https://www.nefi.at/de/projekt/edcsproof
12 Project HySteps, retrofitting of steam storage with PCM; https://www.ait.ac.at/themen/efficiency-in-industrial-processes-systems/projekte/hysteps

5. Completed Tasks

Task 64 – Solar Process Heat

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SPF Institute for Solar Technology | Eastern Switzerland University of Applied Sciences (OST)
Task Manager for the Swiss Office Fédéral de l'Economie Energétique

Task Overview

The goal of this fully joint Task with the SolarPACES TCP **was** to help solar technologies be (and **be** recognized as) a reliable part of process heat supply systems. Instead of focusing on component development, **the Task** look**ed** at the overall (solar) system at process temperatures from just above ambient temperature to approximately 400°C-500°C. Open research questions **addressed were** the standardization of integration schemes on the process **and supply levels** and the combination with other efficient heat supply technologies such as combined heat and power plants, heat pumps, or power-to-heat. **An essential** aspect **of the work was to examine** the experiences of numerous solar process heat markets **worldwide and** enable market-oriented dissemination of existing and new knowledge.

The Task's key objective **was** to identify, verify, and promote the role of solar heating plants in combination with other heat supply technologies for process heat supply, such as fossil and non-fossil (biomass and biogas) fuel boilers, combined heat and power plants, high-temperature heat pumps, or power-to-heat.

The integration of solar energy in a hybrid energy supply system must be completed with optimized energy storage management**, taking into consideration** different thermal energy storage technologies. Based on this, solar energy can become a reliable part of the future industrial heat supply in industrial systems.

The Task **was** organized into five main activities:

- Subtask A: Integrated Energy Systems *(Lead Country: Germany)*
- Subtask B: Modularization *(Lead Country: Spain)*
- Subtask C: Simulation and Design Tools *(Lead Country: Chile)*
- Subtask D: Standardization / Certification *(Lead Country: Greece)*
- Subtask E: Guideline to Market *(Lead Country: Austria and Germany)*

Participating Countries

	Research Institutes	Universities	Companies	Consultants
Austria	2	1		
Chile	1	1		
China			1	
Denmark		1	2	
France	1		2	
Germany	2	1	1	2
Spain	2	3	2	
Switzerland		1		
Turkey		1		
USA	1			1
Total	**9**	**9**	**8**	**3**

Task Duration

This Task started in January 2020 and ended in December 2023. Final deliverables will be published in 2024.

Collaboration with other IEA TCPs

Task 64 was a fully joint task together with SolarPACES Task IV.

Collaboration with Industry

A high number of companies have been active in Task 64 activities, showing the high interest of industry in the field of solar process heat.

Key Results

The main accomplishments of this Task are highlighted below. More details and specific deliverables can be found on the SHC Task 64 webpage and in the activities of the specific Subtasks:

Subtask A: Integrated energy systems *(Subtask Leader: Dr. Felix Pag, University of Kassel, Germany)*

An analysis of daily heat load profiles for reference applications was completed. Four clusters with different ambient temperature dependencies were defined and incorporated into an Excel tool that allows the practical creation of typical load profiles (see Figure 1).

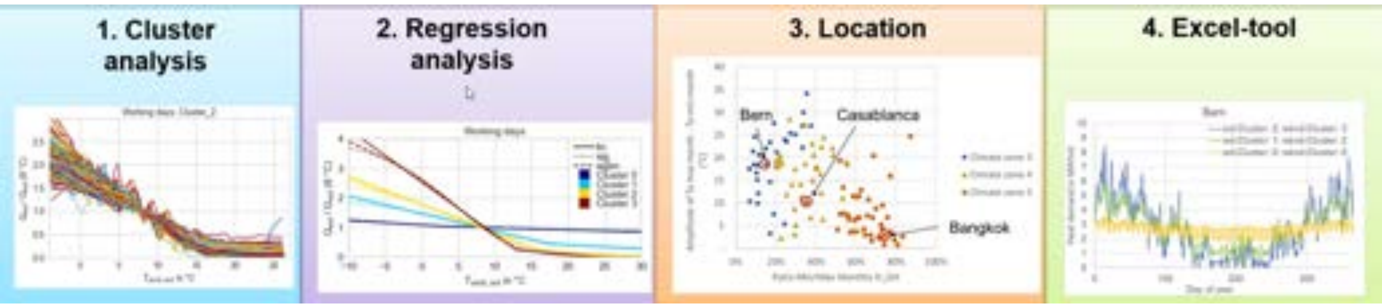


Figure 1: Analysis of heat load profiles.

The next step was to define system design strategies. Three generic concepts for combining solar thermal collectors with a heat pump are parallel installation and serial installation, with one preheating and the other "boosting" to set the temperature.

These generic systems were analyzed for two given applications, one at 80/60 °C and the other at 150/130 °C flow/return temperature. The following conclusions were drawn from that analysis:

- The solar yield suffers only a little if the collectors are operated at higher temperatures (system S2).
- The drawback for the seasonal COP of the heat pump is high if the heat pump has to deliver the high set temperature, so system S2 is preferable to system S1.
- The performance benefit of a serial system probably does not justify the higher installation effort compared to a parallel installation of a heat pump and solar collectors (P).

The design goal is to supply 100% of the industrial heat load from renewables. The design approach is to maximize the solar thermal plant to the limit where surplus heat is produced. With that size of solar thermal system, the heat pump covers the rest of the annual load.

A wide variety of simulations were conducted, and the first conclusions are 1) one of the most important design parameters for the heat pump will be the temperature of the heat source, and 2) the availability of a high-temperature heat source will drastically improve the seasonal COP of the HP thus lowering the LCOH of the whole system. Most other aspects are of minor importance.

Another activity within subtask A was analyzing the available roof area at industrial sites. With an automated GIS approach, an analysis of a large number of companies in Germany was conducted. The analysis showed that, indeed, a large number of roofs are not sufficiently large to meet the above requirements for the solar thermal system. However, the majority of roofs are still large enough.

Subtask B: Modularization *(Subtask Leader: Dr. Diego Alarcón, CIEMAT - Plataforma Solar de Almería, Spain)*

The discussion with industrial partners within Subtask B led to the focus on the Balance of Plant (BoP) of SHIP plants and to:

- Define a generic BoP scheme for each combination of solar field heat transfer medium and process-HTF, including a statement for the limits of validity.
- Identify the main elements (hydraulic equipment and instrumentation) for each BoP scheme.
- Identify the thermal storage options for each BoP scheme.
- Define the key technical parameters for each BoP scheme.

Within the German project MODULUS, such a BoP was designed for thermal oil or water on the solar side and thermal oil, hot air, or steam on the consumer side. A prototype was commissioned at a 2.5 MW pilot plant in Turnhout, Belgium. Operation experience has been gathered since the end of August 2023, and the learnings will be summarized in the report, Integration Schemes and BOPs More Commonly Used in Commercial SHIP Applications.

Another activity within Subtask B was a guideline for instrumentation and performance assessment of solar fields in SHIP plants with line-focus solar concentrators. The purpose of this guideline is to provide the procedures for on-site solar field performance testing in SHIP plants using liquid HTF and line-focus solar concentrators, thus allowing assessment of the solar field performance with the least uncertainty possible based on the best knowledge and engineering practices available in the solar thermal industry, using the ISO/IEC Guide 98-3 Guideline for its calculation. The scope of this guideline includes recommendations for determining solar field performance utilizing short tests performed under quasi-steady-state conditions.

Subtask C: Simulation and Design Tools *(Subtask Leader: Prof. Dr. José Miguel Cardemil, Pontificia Universidad Católica de Chile, Chile)*

The main activities in Subtask C were comparative studies based on four case studies of actual plants and identifying the source of observed differences to system simulations:

Case 1: Copper Mining in Chile (flat plate collector)

Case 2: Paper Mill in France (one axis tracking flat plate collector)

Case 3: Direct steam generation with linear Fresnel collector

Case 4: Dairy in Switzerland (parabolic trough collector).

The simulation tools used were:

- NEWHeat
- CEA (Ship2Fair)
- Polysun
- SAM
- SHIPCAL
- Greenius
- MATLAB (UPV)
- SCILAB
- TRNSYS (in various forms)

The most important sources for differences were:

- control scheme
- HX modeling
- how to deal with the solar position
- internal flows
- thermal capacitance
- modeling of the storage

All results were summarized in deliverable C1, Guideline for Yield Assessment in SHIP Plants. This report summarizes the results obtained by the comparison campaign of the simulation tools used to evaluate SHIP plant yields. Currently, there are a large number of public and private simulation tools available for the study and evaluation of solar technologies; however, there is a lack of standardized methodologies that collect the vast international experience of the scientific community that allow reducing inadvertent errors that can significantly impact the performance and design of the schemes. Added to the above, it was noticed that most project developers employ their in-house developed tools; however, certain tools have been developed to model specific systems and do not perform appropriately for technologies different from the original.

The analysis of simulation results from four cases using different simulation tools and scenarios with induced errors showed significant differences in each control volume studied. The statistical results show that although there are simulation tools that can reproduce statistical distributions similar to the reference, the assumptions and models involved, which are highly nonlinear, propagate errors that can be compensated to a lesser extent by the applied control system and or largely by the energy storage system. Despite this, the energy dispatched towards the energy demand shows overestimates or underestimates, with differences that can reach 41% annually. Furthermore, the complementarity between the analyses has made it possible to identify through Dynamic Time Warping (DTW) that there are differences in terms of the time series dynamics, observing a wide range of values between the maximum and minimum limits found. Within the further progress of Subtask C, the results obtained by each simulation tool and the normalized errors can be used as a reference to demonstrate the impact of each induced error and the simulation differences between simulation tools, but also the limitations of the assumptions to obtain acceptable results with errors less than 10%.

The Subtask C reviewed existing guidelines on monitoring and O&M for SHIP plants, including,

- PROCESOL II (CRES) [2002] Solar Thermal Plants in Industrial Processes - Design and Maintenance Guidelines
- UNEP (UN Env. Prog.) [2015] Technical Study Report On Measuring, Remote Monitoring And Remote Controlling For Solar Thermal Systems
- UNE 206017IN (ES) [Nov-2020] Specific sensors for solar-thermal plants assessment
- ISO 24194 [Apr-2022] Solar energy — Collector fields — Check of performance

The team will complement this existing information with their own experiences in the report, Existing Guidelines and Lessons Learned (to be published).

Subtask E: Guideline to Market *(Subtask Leader: Dr. Peter Nitz, Fraunhofer ISE, Germany and Wolfgang Gruber-Glatzl, AEE INTEC, Austria)*

A collection of available solar process heat-related national and transnational research and funding programs was performed. The main conclusion is that funding schemes and incentives support the realization of SHIP projects but are not sufficient alone.

A position paper on the conversion factor m^2 to kW for statistical survey of projects that use concentrating solar thermal collectors was completed. The paper concludes that it is reasonable to use the same factor of 0.7 for concentrating collectors that is also used for non-concentrating technologies.

A market survey conducted by Solrico and AEE INTEC was published at solarthermalworld.org and included in the IEA SHC Solar Heat Worldwide 2023 report. It shows that in 2022, the total number of installed systems (114) was higher than in past years, but the total installed capacity (30 MWth) was lower. However, for 2023, some large concentrating systems are expected to boost the installed capacity in SHIP.

The database www.ship-plants.info was updated with a new technology and design.

Within Subtask E, a webinar was held to reach the financing world. It started with a comprehensive overview of technologies and examples of solar heat in industrial processes (SHIP). It then showed how financing solutions can be developed using established methods for financing photovoltaic and wind power plants, how capacity utilization can be optimized, and how offtake risks can be managed using the energy cells approach for distributed energy production. The third part of the webinar gave the floor to a financial investor in decarbonization projects to explain how investment projects are evaluated, how long-term financing can be structured on a cash-flow basis, and for smaller projects. A recording is available at https://youtu.be/aFI3AOdKX98?si=mPBh-CAahi3ozumd.

In 2023, a Technology Position Paper on Solar Process Heat was published for policymakers, decisionmakers, and influencers. It presents high-level information as a basis for SHIP uptake and further development.

Dissemination Activities

Reports, Published Books, Online Tools, etc.

Author(s)/Editor	Title	Report No. Publication Date
Felix Pag, Wolfgang Gruber-Glatzl, and Jürgen Fluch. Input from Andreas Häberle, Tobias Hirsch,	Technology Position Paper – Solar Heat for Industrial Processes (SHIP)	https://task64.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task64-Technology-Position-

Diego C. Alarcón-Padilla, JoséMiguel Cardemil, Peter Nitz		Paper-SHIP-2024-01.pdf January 2024
José Miguel Cardemil, Alan Pino, Allan Starke, Ignacio CalderónVásquez, Ian Wolde, Carlos Felbol, Leonardo F.L Lemos, Vinicius Bonini, Ignacio Arias, Cristóbal Sarmiento, Javier Iñigo-Labairu, Jürgen Dersch	Guideline for Yield Asessment in SHIP Plants: Uncertainties Derived from the Simulation Approaches	https://task64.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task64-SubtaskC-D1-STC.pdf October 2023
	Calculation method for the conversion of aperture area into thermal power for tracked concentrating solar thermal systems for statistical purposes	https://task64.iea-shc.org/Data/Sites/1/publications/technical_note_conversion_factor_m2tokW_final_April2023.pdf April 2023
E. Zarza, D. Alarcón with contributions from M. Frasquet, P. Saini	Integration Schemes and BOPs More Commonly Used in Commercial SHIP Applications	https://task64.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task64-SubtaskB-DB1.pdf June 2021
Peter Nitz, Jürgen Fluch	Collection of Available Solar Process Heat Related National and Trans-national Research and Funding Programs	https://task64.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Task64-SolarPACES-TaskIV-D.E1--Collection-of-solar-process-heat-related-research-and-funding-programs.pdf April 2021
F. Pag, M. Jesper, U. Jordan with contributions from W. Gruber-Glatzl, J. Fluch	Reference Applications for Renewable Heat and accompanying Excel tool	https://task64.iea-shc.org/Data/Sites/1/publications/210416_Task64_SubtaskA_D1-1.pdf January 2021

Journal Articles, Conference Papers, etc.

Author(s)/Editors	Title	Publication/Conference	Bibliographic Reference
D. Krüger, B. Epp, T. Hirsch, M. Neises-von Puttkamer	Developments in Solar Heat from Concentrating Solar Systems	SolarPACES Conference	2020
B. Epp	Project sponsors need to offer banks sufficient securities and guarantees	Solarthermalworld.org	2021
M. Jesper, F. Schlosser, F. Pag, T. Gordon Walmsley, B. Schmitt, K. Vajen	Large-scale heat pumps: Uptake and performance modelling of market-available devices	Renewable and Sustainable Energy Reviews	Vol 137, 2021, 110646, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2020.110646

			https://www.sciencedirect.com/science/article/pii/S1364032120309308
B. Epp	Standardised yield assessments for industrial solar heat plants	solarthermalworld.org	https://task64.iea-shc.org/article?NewsID=378 2021
J.M. Cardemil	IEA SHC Task64/SolarPACES Task IV – SubTask C: Assessment of uncertainties in simulation tools	SWC2021	2021
M. Jesper, F. Pag, K. Vajen, U. Jordan	Annual Industrial and Commercial Heat Load Profiles: Modeling Based on k-Means Clustering and Regression Analysis	Energy Conversion and Management, Volume 10, June 2021, 100085	https://doi.org/10.1016/j.ecmx.2021.100085
J. Jensen	Large-Scale SHIP Installations Without Risks & Investments	UNIDO (webinar)	April 19, 2021
J. Jensen	Evaluation of high-temperature solar thermal opportunities in the Netherlands	TNO (advising the Dutch government on subsidy schemes needed to support solar thermal)	May 20, 2021
J. Jensen	Presentation of the market potential for industrial process heat <200C, Heliac solution, and competing solutions for this temperature range	Energistyrelsens fjernvarmegruppe under 'Center for Global Rådgivning	August 27, 2021
J. Jensen	Presentation of the market potential for industrial process heat <200C, Heliac solution, and competing solutions for this temperature range	Dansk Industri (conference: "Sol Over Danmark")	August 31, 2021
J.M. Cardemil, I. Calderón-Vásquez, A. Pino, A. Starke, I. Wolde, C. Felbol, L.F.L. Lemos, V. Bonini, I. Arias, J. Iñigo-Labairu, J. Dersch, R. Escobar	Assessing the Uncertainties of Simulation Approaches for Solar Thermal Systems Coupled to Industrial Processes	Energies 2022, 15, 3333	https://doi.org/10.3390/en15093333
F. Pag	CO2-freie solare Prozesswärme in der Oberflächentechnik,	43. Ulmer Gespräch - Forum für Oberflächentechnik, Ulm	May 5, 2022
M. Jesper, F. Pag, O. Kusyy O., K. Vajen, U. Jordan	Deckungsraten solarer Prozesswärmeanlagen unter Berücksichtigung des Lastprofils und vorhandener Dachflächen	Proc. 32. Symposium Solarthermie, Bad Staffelstein	May 3, 2022

M. Jesper, F. Pag, K. Vajen, U. Jordan	Can Electricity Load Profiles Be Used to Increase the Accuracy of Heat Load Profile Predictions in Industry?,	Proc. International Sustainable Energy Conference, Graz, Austria	April 6, 2022
M. Jesper, F. Pag, O. Kusyy O., K. Vajen, U. Jordan	Solar Fractions for Solar Process Heat Plants Taking into Account Load Profile and Available Roof Area,	Proc. International Sustainable Energy Conference, Graz, Austria	April 6, 2022
M. Jesper, F. Pag, K. Vajen, U. Jordan	Heat Load Profiles in Industry and the Tertiary Sector: Correlation with Electricity Consumption and Ex Post Modeling,	Sustainability, Vol. 14, Iss. 7, p. 4033	doi:10.3390/su14074033 2022
F. Pag	How the available roof area and the heat load profile influence the potential of solar heat in industry?,	Wind and Solar Energy Week, Kassel, Germany	March 24, 2022
M. Jesper, F. Pag, J. Fluch W. Gruber-Glatzl, K. Vajen, U. Jordan	Reference Applications for Renewable Heating Systems in Industry and Commerce,	Solar World Congress, Online	October 25, 2021
M. Jesper, F. Pag, K. Vajen, U. Jordan	Hybrid Solar Thermal and Heat Pump Systems in Industry: Model Based Development of Globally Applicable Design Guidelines	Solar Energy Advances,	https://doi.org/10.1016/j.seja.2023.100034 2023
M. Jesper, F. Pag, K. Vajen, U. Jordan	Auswirkungen der Energiepreisinflation auf die wirtschaftliche Bewertung industrieller Abwärme-Großwärmepumpen	Symposium Solarthermie und innovative Wärmeversorgungssysteme	2023
F. Pag, K. Vajen	Wie können Solarthermie und BHKW für industrielle Anwendungen möglichst effizient kombiniert werden?	Symposium Solarthermie und innovative Wärmeversorgungssysteme	2023
W. Gruber-Glatzl, A. Häberle, P. Nitz, F. Pag, J. Fluch	Solare Prozesswärme als Schlüsseltechnologie der industriellen Dekarbonisierung – Positionspapier IEA SHC Task 64	Symposium Solarthermie und innovative Wärmeversorgungssysteme	2023
Y. Louvet, F. Pag, D. Ritter, C. Schmelzer, K. Vajen	Häufige, aber vermeidbare Fehler bei Planung, Installation und Betrieb solarer Prozesswärmeanlagen	Symposium Solarthermie und innovative Wärmeversorgungssysteme	2023

F. Pag, Y. Louvet	Kombination solarthermischer Anlagen mit KWK-Anlagen im industriellen Prozesswärmebereich	KWK-Jahreskongress	2022
M. Jesper	Großwärmepumpen und Solarthermie in der Oberflächentechnik	12. Südwestfälischer Oberflächentag	2023

Conferences, Workshops, Seminars, etc.

Conference/ Workshop/ Seminar	Activity & Presenter	Date & Location
EuroSun 2022	Keynote by Andreas Häberle	Kassel, September 25-29, 2022 (Germany)

Task Meetings

Two Task Definition Meetings were held in 2019 in Germany and Switzerland, respectively. Over the entire term of the Task, 12 Expert Meetings were held. Due to the Pandemic, the first eight meetings were held online, and only the last four meetings, including a site visit, could be organized as physical meetings.

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 1	March 26, 2020	Virtual	51 participants 18 countries
Task Meeting 2	June 25, 2020	Virtual	52 participants 24 countries
Task Meeting 3	September 22, 2020	Virtual	57 participants 23 countries
Task Meeting 4	December 16, 2020	Virtual	52 participants 23 countries
Task Meeting 5	March 24, 2021	Virtual	60 participants 23 countries
Task Meeting 6	June 29, 2021	Virtual	55 participants 20 countries
Task Meeting 7	September 21, 2021	Virtual	50 participants 20 countries
Task Meeting 8	December 14, 2021	Virtual	46 participants 16 countries
Task Meeting 9	April 5, 2022	Graz, Austria (hybrid)	60 participants 16 countries
Task Meeting 10	November 8-9, 2022	Bordeaux, France (hybrid)	35 participants 12 countries
Task Meeting 11	May 31-June 1, 2023	Copenhagen, Denmark (hybrid)	37 participants 12 countries
Task Meeting 12	November 19-20, 2023		45 participants 12 countries

Task 64 Participants

Country	Name	Institution / Company	Role
SWITZERLAND	**Andreas Häberle**	**SPF**	**SHC TCP Task Manager**
SWITZERLAND	**Tobias Hirsch**	**DLR**	**SolarPACES TCP Task Manager**
AUSTRIA	Winfried Braumann	REENAG	National Expert
AUSTRIA	Jürgen Fluch	FH-Joanneum	National Expert
AUSTRIA	Wolfgang Gruber-Glatzl	AEE INTEC	Subtask E Leader
CANADA	Lucio Mesquita	CanmetENERGY	National Expert
CHILE	Ivan Munoz	Fraunhofer Chile	National Expert
CHILE	José-Miguel Cardemil	PUC	Subtask C Leader
CHINA	Qingtai Jiao	Sunrain	National Expert
DENMARK	Sergio de la Huerga Menéndez	Aalborg CSP A/S	National Expert
DENMARK	Simon Furbo	Technical University of Denmark	National Expert
DENMARK	Jakob Jensen	not with Heliac anymore	National Expert
DENMARK	Weiqiang Kong	Technical University of Denmark	National Expert
DENMARK	Miguel Herrador Moreno	Aalborg CSP A/S	National Expert
DENMARK	Andreas Zourellis	Aalborg CSP A/S	National Expert
FRANCE	Valéry Vuillerme	CEA	National Expert
FRANCE	Alexis Gonelle	newHeat	National Expert
FRANCE	Guillaume Raigné	newHeat	National Expert
GERMANY	Andreas Burger	Industrial Solar GmbH	National Expert
GERMANY	Bärbel Epp	SOLRICO	National Expert
GERMANY	Uli Jakob	Dr. Uli Jakob Energy Research	Task Manager SHC Task 65
GERMANY	Mateo Jesper	University of Kassel	National Expert
GERMANY	Ulrike Jordan	University of Kassel	National Expert
GERMANY	Dirk Krüger	DLR	National Expert
GERMANY	Peter Nitz	Fraunhofer ISE	Subtask E Leader
GERMANY	Felix Pag	University of Kassel	Subtask A Leader

SPAIN	Diego Alarcón	CIEMAT	Subtask B Leader
SPAIN	Antonio Cazorla-Marín	Universitat Politècnica de València	National Expert
SPAIN	Miguel Frasquet	Solatom	National Expert
SPAIN	Mercedes Ibarra Mollá	UNED	National Expert
SPAIN	Alan Pino	University of Seville	National Expert
SPAIN	Klaus Pottler	CSP Services GmbH	National Expert
SPAIN	Fabienne Sallaberry	CENER	National Expert
SWITZERLAND	David Theiler	OST	National Expert
TURKEY	Yelda Erden-Topal	Middle East Technical University (METU)	National Expert
TURKEY	Onur Taylan	Middle East Technical University (METU)	National Expert
UNITED KINGDOM	Alex Mellor	Naked Energy	National Expert
UNITED STATES	Henry K. Vandermark	Solar Wave	National Expert

* Chile, Spain, and the United States participated through the IEA SolarPACES TCP.

6. Ongoing Tasks

Task 63 – Solar Neighborhood Planning

Prof. Maria Wall
Energy and Building Design, Lund University
Task Manager for the Swedish Energy Agency

Task Overview

The main objective of Task 63 is to support key players in achieving solar neighborhoods that support long-term solar access for energy production and for daylighting buildings and outdoor environments, resulting in sustainable and healthy environments. Key players include developers, property owners/associations, architects, urban planners, municipalities, and institutions.

The scope of the Task includes solar energy issues related to:

1. New neighborhood development
2. Existing neighborhood renovation and development

Solar energy aspects include active solar systems (solar thermal and photovoltaics) and passive strategies. Passive solar strategies include passive solar heating and cooling, daylighting, and thermal/visual comfort in indoor and outdoor environments.

The types of support being developed in this Task include strategies for designing new and existing communities with a focus on solar energy, comprising methods to secure sunlight access (right to light). Furthermore, the Task focuses on economic strategies and business models for better passive and active solar energy use. Apart from economic values, solar energy's added or co-benefits are considered. Another objective is to study the workflow of tools needed to support decisions in all planning stages (tool chain). Finally, case studies in each participating country will be a central part to bind close ties to practice and implementation.

To achieve these objectives, work is needed on four main topics:

- Solar planning strategies and concepts for achieving net zero energy/emission neighborhoods.
- Economic strategies, including added values and stakeholder engagement.
- Solar planning tools for new and existing neighborhoods.
- Case studies and stories, to test Task developments in dialogue with key players, implement and disseminate.

Task 63 requires dialogue and cooperation with key players in neighborhood planning in each participating country. These include developers, real estate owners, architects, consultants, urban planners, municipalities, and other institutions. This cooperation gives the possibility to identify barriers and test strategies, methods, and tools to get feedback on development needs. In addition, case studies and lessons learned will be documented to show inspiring examples of solar neighborhoods. Local collaborations within municipalities are an important part that complements the international cooperation within the Task and links Task experts with the practice and implementation in each country.

The Task is organized into four main activities, Subtasks derived from the key areas described above:

- Subtask A: Solar Planning Strategies and Concepts *(Lead Country: Canada)*
- Subtask B: Economic Strategies and Stakeholder Engagement *(Lead Country: Italy)*
- Subtask C: Solar Planning Tools *(Lead Country: Sweden and France)*
- Subtask D: Case Studies *(Lead Country: Norway)*

Subtask A is looking at concepts for solar neighborhood planning in view of achieving high environmental goals (e.g., NZE, NZC) and the role of various strategies to reach them (including planning, design, and technology implementation). Subtask B focuses on strategies - business models and stakeholder engagement - to increase solar energy utilization towards zero-emission neighborhoods. Subtask C works on supportive tools related to active solar energy systems and daylighting within a chain of tools needed for neighborhood planning and design. Subtask D focuses on implementation issues and disseminating case studies with solar planning for existing and new neighborhoods. Subtask D also gives input and serves as a testing platform for Subtasks A, B, and C thus, the case studies are a core activity for the Task work.

Scope

Subtask A: Solar Planning Strategies and Concepts

The main objectives of Subtask A are:

- Review existing concepts and targets that underlie neighborhood design, both new and existing.
- Develop (criteria for) the design of representative archetypes/prototypes in existing and new neighborhoods (e.g., spatial design and building design - types of buildings, mixes of buildings, density, open space -, passive solar design potential, various active solar strategies and technologies, synergies and conflicts with other potential usages - in connection with Subtask B).
- Develop and test planning strategies and concepts for increased solar energy capture and utilization in neighborhoods, with the goal of achieving net zero energy (NZE), low carbon status, or other goals in the era of low-carbon energy transition.
- Recommend strategies and concepts for the conceptual design of new and existing neighborhoods.
- Give a common definition/concept of urban surface usages relating to functions (e.g., energy production, microclimate regulation, surface permeability, etc.) and materials (e.g., solar thermal panels, PV panels, green areas/facades/roofs, water, cool/reflective materials, etc.).

Subtask B: Economic Strategies and Stakeholder Engagement

The main objectives of Subtask B are:

- Analyze the potential integration of the Task outputs for the New Urban Agenda implementation.
- Identify and describe conflicts and synergies of the different and potential usages of urban surfaces, with specific relevance to solar energy harvest.
- Develop a method to propose and assess alternative scenarios for urban surface usage.
- Identify the potential co-benefits related to the hybrid or/and integrated usage of urban surface, apart from solar energy production.
- Recommend suitable activities for stakeholder engagement/nudging strategies and integrate the lessons learned in urban planning practice.
- Identify financial mechanisms and suggest ways to finance the transition from the energy market to added-value services.

Subtask C: Solar Planning Tools

The main objectives of Subtask C are:

- Identify the current solar planning tool workflows and related tools used by key actors for planning solar neighborhoods. This could include tools from all platforms (GIS, CAD, or BIM). Analyze the strengths, weaknesses, and development needs.
- Identify relevant common indicators synthesizing solar energy and daylight performance of neighborhoods, which will be used in a summary dashboard for easy comparison.
- Develop a roadmap for improved workflows and solar planning tools needed in all planning stages (tool chain).

Subtask D: Case Studies

The main objectives of Subtask D are:

- Coordinate and collect case studies across subtask (A, B, and C) topics.
- Serve as a platform for exchanging experiences from practice, including testing strategies and tools and interviewing stakeholders.
- Describe and disseminate case studies and stories of new and existing solar neighborhoods.

Collaboration with Industry

Local collaboration with municipalities and key actors in participating countries.

Task Duration

This Task started in September 2019 and will end in April 2024 (6-month extension).

Participating Countries

Australia, Canada, China, Denmark, France, Norway, Italy, Slovakia, Sweden, Switzerland

Work During 2023

The final Task meeting was held in Padua, Italy, in September 2023.

Task 63 participants in Padua, Italy.

Subtask A: Solar Planning Strategies and Concepts

The work has focused on preparing and writing the last deliverables. The report “Strategies for the Design of New and Existing High Energy Performance Solar Neighborhoods” (Report A1) consists of background and context, neighborhood archetype designs, solar strategies (passive and active), analysis of solar neighborhood archetypes, and finally, a chapter on a (new) decisionmaking tool for solar strategies. Archetypes represent typical neighborhood patterns and commonly applied designs. Archetypes can also be defined as theoretical neighborhoods to test more advanced solar strategies that existing neighborhoods may not allow.

The report introduces a decision-making tool framework for solar strategies, emphasizing both passive and active approaches. The framework covers a comprehensive range of solar strategies and employs an adoption score methodology, assessing factors such as ease of implementation, cost, accessibility, environmental impact, and acceptance. The MS Excel tool is developed through a pilot study involving Task experts, and it classifies and ranks various solar strategies based on defined criteria. The report includes sensitivity analyses for existing and new neighborhoods, demonstrating the impact of varying weights on decision criteria. Practical applications for single and composite objectives in cold and very cold climates are presented, showcasing the prioritization of solar strategies. The tool is presently in development. Linking to this tool, a user guide is developed (Report A2). Both reports (A1 and A2) and the tool will be published in 2024.

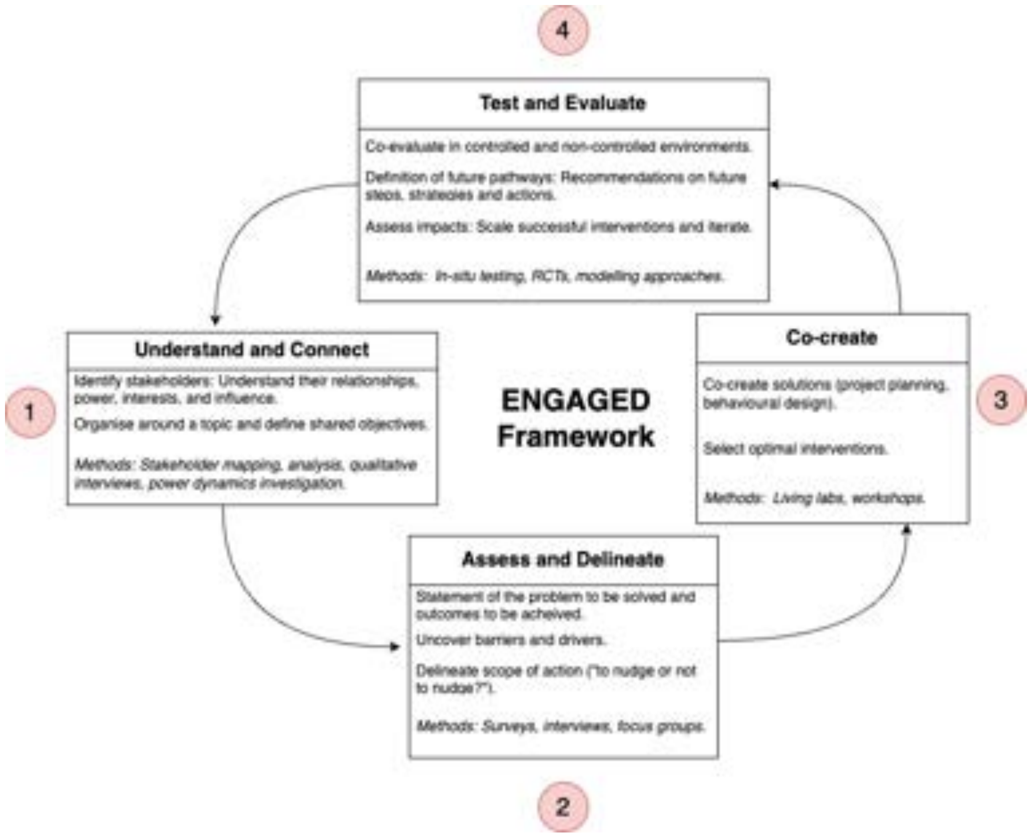
Subtask B: Economic Strategies and Stakeholder Engagement

The second report, “Solar Neighborhood Financing Mechanisms and Business Models” (Report B2), will be published in March 2024. This work identifies financial mechanisms and suggests ways to finance the transition from the energy market to added-value services. The work is coordinated by Eric Wilczynski, Eurac Research. Work included:

- Research on the economics of solar district development
- Identification of financing mechanisms
- Literature review
- Case study review of existing examples of neighborhood/community solar projects
- Categorization of financing mechanisms
- Develop a framework for matching projects with financing mechanisms
- Gather feedback on the categorization and framework of financing mechanisms.

The third report in Subtask B, "An Integrated Framework for Stakeholder and Citizen Engagement in Solar Neighborhoods," will be published in March 2024. This report proposes an integrated framework for stakeholder engagement in solar neighborhoods, informed by practical insights from behavioral science (a practice known as behavioral design). The report bookends a series of three workshops on these topics with Task 63 experts, as well as follow-up discussions in general Task meetings where the topics of stakeholder analysis and behavioral design were discussed and case studies collected. All these activities informed the design of the proposed framework.

The report includes a state-of-the-art stakeholder engagement method in urban planning practice, presents insights from behavioral science, and details how their application can enrich participatory processes, contextualizing these insights to the case of solar neighborhood planning. This discussion culminated in developing a stakeholder ENGAGEment-behavioral Design framework (ENGAGED). This framework is intended to inform engagement processes in solar neighborhood planning and highlight how engagement activities and citizen participation can inform several phases in developing a solar project. A series of solar neighborhood stakeholder engagement case studies are included from Task experts: Australia (Knutsford), Norway (Finnøy and Møllenberg), France (Ferney-Geneva), and Switzerland (Geneva). The work is coordinated by Nicolas Caballero, Eurac Research.



Stages in the stakeholder ENGAGEment-behavioral Design framework (ENGAGED), discussed in Report B3. Source: Nicolas Caballero et al, Eurac Research.

Subtask C: Solar Planning Tools

Work in 2023 focused on the second report (C2), "Opportunities for Improved Workflows and Development Needs of Solar Planning Tools. The report describes the current use of tools in the design process, mapping the solar potential and installed capacity for solar neighborhoods, opportunities and development needs in the use of solar planning tools, and the influence of tools on the design process (example). The target group of this report consists of the users of tools for solar neighborhood planning, relevant stakeholders in the design process, and legislators. This report will be finalized in 2024.

Subtask D: Case Studies

The main work in Subtask D during 2023 has been writing the case studies. The case studies present new development areas and existing areas requiring refurbishments, infills, etc. We have about 20 case studies from all 10 participating countries. All case studies will be published online in 2024.

The topics included are (when applicable): overview of the case - the planning process - active solar strategies and energy systems - passive solar strategies (solar access, daylight, etc.) - surface uses - financial mechanisms and stakeholder engagement - interviews and insights from key actors - environmental, social, and other impacts - tools and workflow - tools for informed design support - lessons learned and recommendations, and - final information page.

In parallel, Task experts have been involved locally in the planning of different neighborhoods in cooperation with stakeholders. The collaboration with different local solar neighborhood planning projects gives feedback on our work and provides the Task participants the opportunity to present the results.

The planned public seminars and workshops, in conjunction with Task meetings, were canceled during the pandemic and restarted in 2023. Two public seminars were held during 2023: in Trondheim, Norway, in March and Padua, Italy, in September.

Work Planned For 2024

Since Task 63 ends in 2024, the remaining work is focused on finalizing the deliverables.

Subtask A: Solar Planning Strategies and Concepts

The main activities for Subtask A planned in 2024 are:

- Finalizing Report A1: Strategies for the Design of New and Existing High Energy Performance Solar Neighborhoods.
- Finalizing Report A2: A Tool to Select Solar Strategies For Neighborhoods: A User Guide for Preliminary Decision-Making.
- Finalize and publish the first version of the MS Excel tool online.

Subtask B: Economic Strategies and Stakeholder Engagement

The main activities planned for Subtask B in 2024 are:

- Finalizing Report B2: Solar Neighborhood Financing Mechanisms and Business Models - Economic incentives and business models that promote the diffusion of solar neighborhoods.
- Finalizing Report B3: An Integrated Framework for Stakeholder and Citizen Engagement In Solar Neighborhoods—ENGAGED Framework for Stakeholder Engagement and Behavioral Design.

Subtask C: Solar Planning Tools

The main activities planned for Subtask C in 2024 are:

- Finalizing Report C2: Opportunities for Improved Workflows and Development Needs of Solar Planning Tools.

Subtask D: Case Studies

The main activities planned for Subtask D in 2024 are:

- Finalize all case studies.
- Prepare a webpage and a map for the case studies.
- Publish final case studies online, linked to a map.

Dissemination Activities In 2023

Reports, Published Books

Author / Editor	Title	Bibliographic Reference
Czachura, A.	Solar access indicators for urban planning	Lund University, licentiate thesis. Lund, February 2023. Web: https://portal.research.lu.se/en/publications/solar-access-indicators-for-urban-planning
Campamà Pizarro, R., Krezlik, A., Bernardo, R.	Chapter in book: Simulating energy renovation towards climate neutrality—Digital workflows and tools for life cycle assessment of collective housing in Portugal and Sweden	BOOK: In: Barberio, M., Colella, M., Figliola, A., Battisti, A. (eds) Architecture and Design for Industry 4.0. Lecture Notes in Mechanical Engineering. Springer, Cham. Web: https://doi.org/10.1007/978-3-031-36922-3_39

Journal Articles, Conference Papers, etc.

Author(s) / Editor	Title	Publication / Conference	Bibliographic Reference
Campamà Pizarro, R., Bernardo, R., Wall, M.	Streamlining Building Energy Modelling Using Open Access Databases—A Methodology towards Decarbonisation of Residential Buildings in Sweden.	Sustainability	Sustainability 2023, 15(5), 3887; https://doi.org/10.3390/su15053887
Andreolli F., D'Alpaos C., Kort P.	Does P2P Trading Favor Investments in PV-Battery Systems?	Working paper FEEM	02.2023, Milano, Italy: Fondazione Eni Enrico Mattei https://www.feem.it/publications/does-p2p-trading-favor-investments-in-pv-battery-systems/
Paparella R., Caini M.	Strategie progettuali per la valorizzazione e riqualificazione dell'ex Palazzo del Turismo nel contesto dell'area degli scavi archeologici di Montegrotto Terme	2030 d.C. PROIEZIONI FUTURE PER UNA PROGETTAZIONE SOSTENIBILE	ISBN:978-88-492-4558-5
Giorio M., Bertolazzi A., Paparella R., Savino M.	Edilizia pubblica incompiuta italiana: Il progetto di riuso e ri-funzionalizzazione dell'ex Ospedale Psichiatrico di Laghetto (VI)	2030 d.C. PROIEZIONI FUTURE PER UNA PROGETTAZIONE SOSTENIBILE	ISBN:978-88-492-4558-5 ISBN:978-88-492-4558-5
Manni, M., Nocente, A., Bellmann, M., Lobaccaro, G.	Multi-Stage Validation of a Solar Irradiance Model Chain: An Application at High Latitudes	Sustainability	2023, 15(4), 2938; https://doi.org/10.3390/su15042938
Formolli, M., Kleiven, T., Lobaccaro, G.	Assessing solar energy accessibility at high latitudes: A systematic review of urban spatial domains, metrics, and parameters	Renewable and Sustainable Energy Reviews	Volume 177, May 2023, N. 113231 https://doi.org/10.1016/j.rser.2023.113231

Manni, M., Mohammadreza Aghaei, M., M.M. Sizkouhi, A., R.R. Kumar, R., Stølen, R., Steen-Hansen, A.-E., Di Sabatino, M., Moazami, A., Völler, S., Jelle, B.J., Lobaccaro, G.	Solar Energy in the Built Environment	Book Chapter in Encyclopedia of Sustainable Technologies, 2E (Elsevier)	Reference Module in Earth Systems and Environmental Sciences, 2023. https://doi.org/10.1016/B978-0-323-90386-8.00049-8
Epp, B.	How planners use tools to assess solar potential in neighborhoods	Solarthermalworld. News article written by Bärbel Epp based on material from Jouri Kanters, Lund University, and Martin Thebault, University Savoie Mont-Blanc	January, 2023 https://task63.iea-shc.org/article?NewsID=444 How planners use tools to assess solar potential in neighbourhoods | Solarthermalworld
Epp, B.	Paving the way for solar access in Sweden and Norway	Solarthermalworld. News article written by Bärbel Epp based on material from Jouri Kanters, Lund University, Sweden, and Ida Bryn, Multiconsult, Norway.	March, 2023 https://task63.iea-shc.org/article?NewsID=453 Paving the way for right to solar access | Solarthermalworld
Czachura, A., Gentile, N, Kanters, J, Wall, M	Vertical Sky Component (VSC) and daylight regulation compliance by the EN 17037 and BFS 2011:6 standards	CISBAT 2023 Proceedings	In Journal of Physics Conference Series 2600(11):112018 DOI: 10.1088/1742-6596/2600/11/112018
Campamà Pizarro, R	Solar PV integration in multifamily buildings renovation: an effective strategy towards climate neutrality.	SWC 2023	To be published
Campamà Pizarro, R	Efficient building energy renovation strategies: benchmarking optimization algorithms for enhanced decision-making.	SWC 2023	To be published
Hachem-Vermette, C., Singh, K., Jolly, K., Yadav, S.	Decision making method to prioritize and implement solar strategies on neighborhood level	18th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES), September, 2023.	To be published.
Desthieux G., Gressin A., Ingensand J., Raybaud B.	Solar potential on facades at urban scale: an integrated approach combining solar and digital building modelling (accepted paper, to be published in the Journal of Physics – Conference series)	CISBAT 2023 international conference (Built environment in transition)	2023

Desthieux, Manni, Lobaccaro, Kanters, Croce, Hachem-Vermette	Co-editors of the special issue “Solar Neighborhood Planning: Optimize Solar Energy Use in Cities Through the Digitalization of the Built Environment”	Journal Frontiers in Built Environment - section Sustainable Design and Construction	2023
Hasan, J., E. Zheng, E., Horvat, M.	A least squares regression-based approach in the investigation of the influence of density metrics of 14 distinct Toronto neighbourhoods on the roof and facade solar potential	Frontiers in Built Environment	Published September 2023, DOI: 10.3389/fbuil.2023.1248259
Giorio, M. & Paparella, R.	A methodology to improve energy efficiency and sustainability 2 in urban environments.	Applied Sciences, 2023	https://www.mdpi.com/2076-3417/13/17/9745
Zanchetta, C., Donatiello, M.G., Gabbanoto, A. & Paparella, R.	Digitalization of building systems using IFC to support performance analysis and code checking: standard limits and technological barriers. A case study on fire safety.	Rivista Tema, 09(01), 2023	https://doi.org/10.30682/tema0901l
Giorio, M. & Paparella, R.	Climate Mitigation Strategies: The Use of Cool Pavements	Sustainability 2023, 15(9),7641;	https://dx.doi.org/10.3390/su15097641
Paparella, R., Zanchetta, C., Giorio, M. & Donatiello, M.G.	BIM Based rating of urban and architectural surfaces to refine Solar Potential Analysis	Proceedings 2023 European Conference on Computing in Construction 40th International CIB W78. Heraklion, Crete, Greece, July 10-12, 2023	ISBN: 978-0-701702-73-1. DOI:10.35490/EC3.2023.271
Andreolli F., D’Alpaos, C. & Kort, P.	Does P2P Trading Favor Investments in PV-Battery Systems?	Working paper FEEM 02.2023	https://www.feem.it/publications/doesp2p-trading-favorinvestments-in-pvbattery-systems/
Manni M, Formolli M, Boccalatte A, Croce S, Desthieux G, Hachem-Vermette C, Kanters J, Ménézo C, Snow M, Thebault M, Wall M, Lobaccaro G.	Ten questions concerning planning and design strategies for solar neighborhoods	Journal Building and Environment (2023), Elsevier.	DOI: https://doi.org/10.1016/j.buildenv.2023.110946

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
Lyskonferansen 2023	Helene Solvang, Multiconsult, title “Dagslysplanlegging i fremtidens byrom og bygninger”	2 February 2023, Bergen	~100
pen international seminar: Solar and daylight planning in the built	Task 63 experts and invited presenters. Organized as part of IEA SHC Task 63, and the	10.03.2023 Hybrid event	111 (85 in person and 26 online)

environment	HELIOS project. In total 16 presentations by Norwegian and international experts, 10 posters and four panel sessions.	Trondheim	
Norwegian Solar Cell Conference 2023	Oral presentation “Local Ground Monitoring Network of Solar Irradiance at High Latitude: the NTNU-SINTEF SolarNet”. Presenter: Mattia Manni, NTNU.	23.05.2023 Son, Norway	50 registered
Nordic Symposium on Building Physics - NSB 2023	Oral presentation “Validation of decomposition models for solar irradiance at high latitudes: A preliminary study”. Presenter: Mattia Manni, NTNU.	13.06.2023 Aalborg, Denmark	150 registered
CISBAT 2023	Poster presentation: “Vertical Sky Component (VSC) and daylight regulation compliance by the EN 17037 and BFS 2011:6 standards” by Agnieszka Czachura	13-15 September in Lausanne	
CISBAT 2023	Poster presentation “NTNU-SINTEF SolarNet: A solar irradiation monitoring network at high latitudes”. Presenter: Mattia Manni, NTNU.	13.09.2023 Lausanne, Switzerland	400 registered
SWC 2023	Oral presentation: “Solar PV integration in multifamily buildings renovation: an effective strategy towards climate neutrality“ by Rafael Campamà Pizarro	29 October – 4 November, New Delhi	
SWC 2023	Poster presentation:” Efficient building energy renovation strategies: benchmarking optimization algorithms for enhanced decision-making” by Rafael Campamà Pizarro	29 October – 4 November, New Delhi	
Daylight, sun and energy efficiency as drivers for sustainable urban development	Helene Solvang, daylight, Multiconsult	18 October 2023, Oslo	~200
AMASES 2023 annual conference	Presentation (D’Alpaos C. speaker)	Milan 20-23 September 2023	200
Public international seminar: Future challenges in fostering the energy transitions: sustainable innovation, prosumers’ engagement, and energy communities.	Task 63 experts and invited presenters. Organized as part of IEA SHC Task 63. In total 12 presentations by Italian and international experts.	29.10.2023 Hybrid event Padua	Approx. 40

Seminar: Presenting international work and results from Task 63, and Danish cases	Presenters: Task manager Maria Wall, and the subtask leaders Gabriele Lobaccaro and Jouri Kanters. From Denmark: Ennogie, Bjerg Arkitektur, DEM and Solar City Denmark	29/11/2023, Copenhagen, Denmark	Approx. 40

Dissemination Activities Planned For 2024

Since the Task is ending, no further international/joint activities are planned. However, the national experts plan to hold local seminars to present the results from Task 63.

Task Meetings in 2023

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 8	March 6-10, 2023	Trondheim, Norway	29 (21 onsite, 8-10 online), 8 countries
Public seminar	In conjunction with 8th Task meeting	Trondheim, Norway	In total 111 (85 onsite, 26 online)
Task Meeting 9 (final)	September 26-29, 2023	Padua, Italy	In total 34 (29 onsite, 5 online), 9 countries
Public seminar	In conjunction with the 9th Task meeting	Padua, Italy	Approx. 40

Task 63 Participants

Country	Name	Institution / Company	Role
SWEDEN	**Maria Wall**	**Energy and Building Design, Lund University**	**Task Manager**
AUSTRALIA	Mark Snow	Australian PV Institute (APVI)	National Expert
CANADA	Caroline Hachem-Vermette	University of Calgary	Subtask A Leader + co-leader Subtask D
CANADA	Somil Yadav	Concordia University	National Expert
CANADA	Ricardo D'Almeida	University of Calgary	National Expert
CANADA	Kuljeet Sing Grewal	University of Prince Edward Island	Subtask A Leader + co-leader Subtask D
CANADA	Olivia Alarcon Herrera	University of Calgary	National Expert
CANADA	Ayoyimika Edun	University of Calgary	National Expert
CANADA	Miljana Horvat	Ryerson University, Department of Architectural Science	National Expert
CANADA	Javeriya Hasan	Ryerson University, Department of Architectural Science	National Expert
CANADA	Ursula Eicker	Concordia University	National Expert
CANADA	Andreas Athienitis	Concordia University	National Expert
CANADA	James Bambara	Concordia University	National Expert
CANADA	Azin Sanei	Concordia University	National Expert
CANADA	Mostafa Saad	Concordia University	National Expert
CHINA	Haiyue Lyu	China National Engineering Research Center for Human Settlements, CAG	National Expert
CHINA	Xiuxiu Gao	China National Engineering Research Center for Human Settlements, CAG	National Expert
CHINA	Ying Cao	China National Engineering Research Center for Human Settlements, CAG	National Expert
CHINA	Xi Zhao	China National Engineering Research Center for Human Settlements, CAG	National Expert

CHINA	Xiaotong Zhang	China National Engineering Research Center for Human Settlements, CAG	National Expert
CHINA	Xin Cui	Xi'an Jiaotong University (XJU)	National Expert
CHINA	Wei Chen	Xi'an Jiaotong University (XJU)	National Expert
CHINA	Xiangzhao Meng	Xi'an Jiaotong University (XJU)	National Expert
CHINA	Yang Wang	China Agricultural University in Beijing	National Expert
CHINA	Xiaomeng Chen	China Agricultural University in Beijing	National Expert
DENMARK	Olaf Bruun Jørgensen	Danish Energy Management (DEM)	National Expert
DENMARK	Karin Kappel	Solar City Denmark	National Expert
FRANCE	Christophe Ménézo	University Savoie Mont-Blanc - INES	National Expert
FRANCE	Alessia Boccalatte	University Savoie Mont-Blanc - INES	National Expert
FRANCE	Martin Thebault	University Savoie Mont-Blanc - INES	Subtask C Leader + co-leader Subtask D
FRANCE	Joyce De Sousa	University Savoie Mont-Blanc - INES	National Expert
FRANCE	Stéphanie Giroux	Centre for Energy and Thermal Sciences of Lyon (CETHIL)	National Expert
ITALY	Daniele Vettorato	EURAC Research	Subtask B Leader + co-leader Subtask D
ITALY	Silvia Croce	EURAC Research	Subtask B Leader + co-leader Subtask D
ITALY	Jessica Balest	EURAC Research	National Expert
ITALY	Grazia Giacovelli	EURAC Research	National Expert
ITALY	Eric Wilczynski	EURAC Research	National Expert
ITALY	Nicolas Caballero	EURAC Research	National Expert
ITALY	Rossana Paparella	Civil, Environmental and Architectural Engineering, Padua University	National Expert

ITALY	Mauro Caini	Civil, Environmental and Architectural Engineering, Padua University	National Expert
ITALY	Chiara D'Alpaos	Civil, Environmental and Architectural Engineering, Padua University	National Expert
ITALY	Francesca Andreolli	Civil, Environmental and Architectural Engineering, Padua University	National Expert
ITALY	Fabio Bignucolo	Industrial Engineering, Padua University	National Expert
NORWAY	Gabriele Lobaccaro	NTNU – Norwegian University of Science and Technology	Subtask D Leader
NORWAY	Mattia Manni	NTNU – Norwegian University of Science and Technology	Subtask D Leader
NORWAY	Martina Giorio	NTNU – Norwegian University of Science and Technology	National Expert
NORWAY	Tahmineh Akbarinejad	NTNU – Norwegian University of Science and Technology	National Expert
NORWAY	Johannes Brozovsky	SINTEF	National Expert
NORWAY	Tommy Kleiven	NTNU – Norwegian University of Science and Technology	National Expert
NORWAY	Matteo Formolli	NTNU – Norwegian University of Science and Technology	National Expert
NORWAY	Ida Bryn	Multiconsult	National Expert
NORWAY	Wolfgang Kampel	Multiconsult	National Expert
NORWAY	Tobias Kristiansen	Multiconsult	National Expert
NORWAY	Rein Kristian Raaholdt	Multiconsult	National Expert
SLOVAKIA	Peter Durcansky	University of Zilina	National Expert
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SWEDEN	Rafael Campamà	Energy and Building Design, Lund University	National Expert
SWEDEN	Agnieszka Czachura	Energy and Building Design, Lund University	National Expert

SWEDEN	Marja Lundgren	White Arkitekter AB	National Expert
SWEDEN	Viktor Sjöberg	White Arkitekter AB	National Expert
SWEDEN	Nicholas Baker	White Arkitekter AB	National Expert
SWEDEN	Caroline Cederström	White Arkitekter AB	National Expert
SWEDEN	Alejandro Pacheco Dieguez	White Arkitekter AB	National Expert
SWITZERLAND	Gilles Desthieux	HES-SO/Hepia Geneva	National Expert

Task 65 – Solar Cooling for the Sunbelt Regions

Dr. Uli Jakob
Dr. Jakob energy research GmbH & Co. KG
Task Manager for the German Government (PtJ for BMWi

Task Overview

The key objective of the IEA SHC 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 analyzed 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 basis.

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

- Increase the audience and attention to Solar Cooling solutions by combining MI IC7 and IEA SHC activities and the entire stakeholders.
- Provide a platform for transferring and exchanging know-how and experiences from OECD countries, that 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 levels adapted for the boundary conditions of the Sunbelt (tropical, arid, etc.) that are affordable, safe, and reliable in medium to large scale (2 kW-5,000 kW) capacities.
- Adapt existing technology, economic, and financial analysis tools to assess and compare the 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 the '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.
- Establish a technical and economic database to provide a standardized assessment of demo (or simulated) use cases.
- Accelerate market creation and development through communication and dissemination activities.

The Task's work is divided into four subtasks:

- Subtask A: Adaptation *(Lead Country: Italy)*
- Subtask B: Demonstration *(Lead Country: United States)*
- Subtask C: Assessment and Tools *(Lead Country: Austria)*
- Subtask D: Dissemination *(Lead Country: Germany)*

Scope

Subtask A: Adaptation
The main objectives of Subtask A are:

- Collect technical/climatic boundary conditions for sunbelt regions to better understand the operating conditions for all components of solar cooling systems.
- Adapt and document specific key components for solar cooling and complete systems according to the specific boundaries of sunbelt climates.

  - Sources (PV, ST, PVT)
  - Heat rejection (direct air-cooled, Cooling towers: electricity/water demand, etc.)
  - Heat pumps/chillers (improved heat/mass transfer, multistage concepts, hybrid systems, sorption storage for combined cooling and storage)
  - Storage concepts (cold, hot side, sorption storage)
- Complete systems, including hydraulic concepts, control strategies, etc.
- Identify the technical and economic potential of building and process to optimize solar cooling technology and system adaptation needs.
- Identify ongoing and future related standards and testing methods and initiate the update/extension of testing methods/standardization (norm).

Subtask B: Demonstration
The main objectives of Subtask B are:

- Showcase systems and components through existing projects, new MI IC7 activities, and theoretical investigations through simulations.
- Maximize solar fraction of solar cooling under certain local technical & economic boundaries, including load optimization (building & passive measures).
- Force the work of standardization and solar cooling kits in all capacity ranges and different technologies.
- Document lessons learned (technical & non-technical) and preparation for dissemination activities.

Subtask C: Assessment and Tools
The main objectives of Subtask C are:

- Prepare an overview and possibly update/merge useful tools for design & assessment.
- Establish/adapt assessment method and benchmarking (incl. reference system in different locations).
- Create a common database for technical, environmental, and economic assessment for the participating countries.
- Analyze Subtask B results and benchmark against reference systems and renewable and solar solutions.
- Sensitivity analysis of high influencing parameters on the technical/economic/ environmental assessment.

Subtask D: Dissemination
The main objectives of Subtask D are:

- Communicate best practice demo cases, successful installations, and business models (based on a summary of lessons learned; Subtask B5).
- Accelerate know-how transfer from scientists to industry & know-how carrier to Sunbelt regions.
- Establish a network of scientists/consultants/companies to accelerate new projects in Sunbelt regions.
- Synchronize national / international research & funding programs.
- Develop financing and business models for solar cooling.
- Map necessary R&D as the base for a road map of Solar Cooling in Sunbelt regions.

Collaboration with Other IEA TCPs

The Task is collaborating informally with the IEA Heat Pumping Technologies TCP's Annex 53 on Advanced Cooling/Refrigeration Technologies Development. The Task is also collaborating with the IEA SHC Task 64 on Solar Process Heat and Mission Innovation, Innovation Community (IC7).

Collaboration with Industry

The strong interest and involvement from industry and business are reflected in the number of Task 65 participants from solar thermal collector manufacturers, sorption chiller manufacturers, system suppliers, consultancies, business developers, and ESCOs – overall, in 2022, about 50% of the Task experts are from industry and SMEs.

Task Duration

This Task started in July 2020 and will end in June 2024.

Participating Countries

Australia, Austria, China, Denmark, Egypt*, France, Germany, Italy, Mozambique**, Netherlands, Slovakia, Spain, Sweden, Switzerland, Uganda***, United Kingdom, United States****, Zimbabwe**.

**through RCREEE, **through SACREEE, ***through EACREEE, ****Limited Sponsor*

Work During 2023

Subtask A: Adaptation

Activities planned to achieve the specific objectives and their timeframe were discussed. The following results were achieved in Subtask A in 2023.

A1: Climatic Conditions & Applications

Activity A1 is concluded. A Geographical information system (GIS) software was used to combine geographic data in a way that can determine local reference boundary conditions for solar cooling systems in the Sunbelt regions and use them for evaluation. The developed method can also be used to create information about possible locations and potentials of specific Solar Cooling systems (Figure 1). Using population density and purchasing power data, for example, provides a base for future market potential studies on specific products/technologies. As a result, potential sites can be identified, and economic factors can be considered to identify (future) markets.

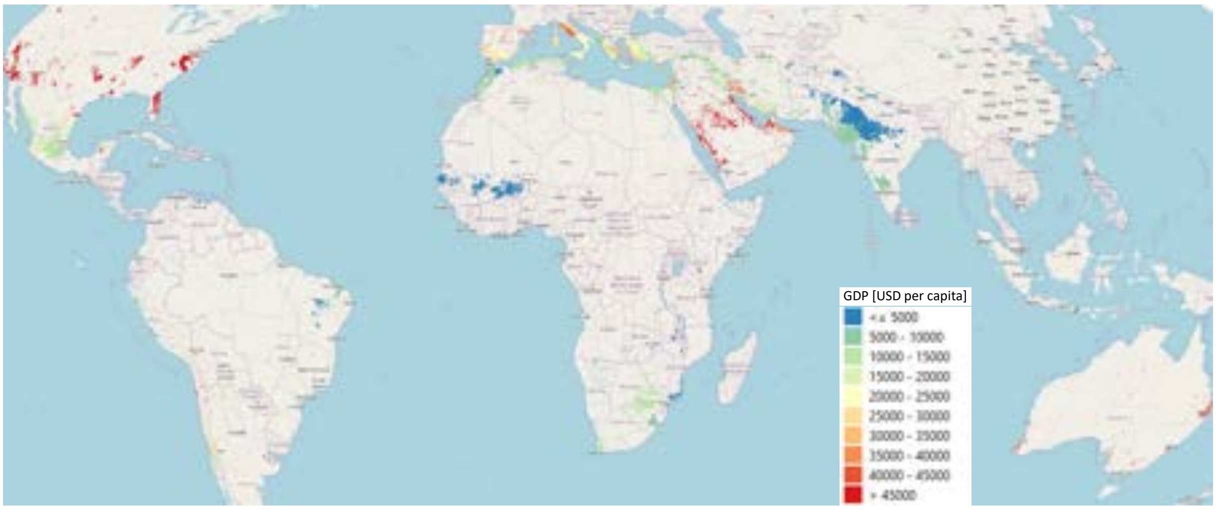

Figure 1: Resulting GDP map of climatization potentials based on population. (ZAE Bayern)

Many results from the ongoing research project “Solar thermal energy system for cooling and process heating in the Sunbelt region – SBC” have been included in this Task. The project is carried out by two partners: Industrial Solar GmbH and the Bavarian Center for Applied Energy Research (ZAE Bayern). It was funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) under project number 03ETW026. As a first example, the developed method was used to determine possible locations and potentials for the SBC system. The developed method is planned to be used further in the Task’s work.

The final report, D-A1, was published in June 2023, DOI: 10.18777/ieashc-task65-2023-0002.

A2/B1: Showcases on system and component level & Adapted components

The joint activity A2/B1 has already been concluded. Activity A2/B1 focused on a survey conducted within the activities of two subtasks: adapted components (A2) and showcases on system and component level (B1). Its main goal was to enhance the understanding of how varying climatic conditions and operating parameters impact the selection of components and to identify the factors that either facilitate or present challenges to widespread application in the region.

Indeed, solar cooling systems designed for countries in the sunbelt region incorporate components specifically adapted to the local climate and environmental conditions. These components are selected to optimize the system's performance and ensure its reliability in high-temperature regions. All the analyzed countries in the Sunbelt region demonstrated a favorable environment, proving the maturity of solar cooling technology (Figure 2).

Figure 2: Representation of projects from across different countries. (IEA SHC Task 65)

The presented results are drawn from 32 projects with over 17.06 MW of thermal cooling across 18 countries representing a variety of weather profiles. Key findings include:

- Most projects are in hot desert regions, hot semi-arid regions, and hot summer Mediterranean climates.
- Nearly 70% of the projects are either implemented or have detailed plans, with 25% being conceptual. Some projects involve experimentation and validation in real-time buildings.
- Solar thermal cooling is the most widely applied technology, with evacuated tube collectors, flat plate collectors, Fresnel collectors, and parabolic trough collectors being popular choices.
- Solar absorption is the predominant solar thermal cooling technique, with some projects using solar adsorption cooling and other technologies like ejector cooling and PV-assisted cooling.
- Hot water storage or heat backup by auxiliary heating is used in 72% of the projects, with heat storage being more common.
- Cold backup is less frequently used than heat backup, with heat storage or auxiliary heating being the common practice.
- Primary applications include public buildings, domestic buildings, and the process industry.

These findings provide valuable insights into utilizing solar cooling technology in different climates, helping stakeholders make informed decisions for their specific projects.

The final report, D-B1/A2, will be published in Spring 2024.

A3: Adapted systems

The objective of Activity A3 is to provide a comprehensive overview of existing solar cooling systems and determine the necessary adaptations required for their layouts, with a specific focus on thermally driven systems, PV solar cooling, DEC, and free cooling. This objective will be accomplished through a systematic literature review, which will be structured into four distinct phases as described below:

- The first phase is the integrative review, which involves gathering relevant sources through comprehensive, focused searches. Both experimental and non-experimental research will be considered, and purposive sampling may be utilized. The search will encompass database searches and an exploration of grey literature.
- The second phase is the selection process, where studies and reports directly related to the identified problem or question will be included. This includes empirical and theoretical reports employing diverse study methodologies.

- In the third phase, appraisal, two quality criteria instruments will be developed for each type of source. The scores obtained from these instruments will serve as criteria for inclusion/exclusion or as variables in the data analysis stage.
- The fourth and final phase is synthesis, which involves conducting a narrative synthesis for qualitative and quantitative studies. Data will be extracted to capture study characteristics and concepts. The synthesis will be presented as a table, diagram, or model to effectively portray the results. Extracted data will be compared item by item, and similar data will be categorized and grouped.

In the initial step, the literature review on solar cooling systems adapted to Sunbelt regions encompassed systems of all sizes. The review focused on selected keywords related to Solar PV and solar thermal cooling, specific climatic boundaries (hot dry/hot humid climates), system components and performance, hydraulic and system design, system optimization (economic, efficiency, primary energy), control strategies, and heat rejection. A separate literature review was conducted specifically on low-temperature district heating networks as heat rejection systems compatible with the Sunbelt regions. The next step focused on literature preprocessing and cleaning to identify cross-references between literature data/abstracts/keywords/full texts (Figure 3).

Figure 3: Literature pre-processing and cleaning for about 628 abstracts analysed. (IEA SHC Task 65)

A4: Building and process optimization potential

The Activity A4 has been completed. The report encompasses two main parts:

- Study on the Relevance of Urban Heat Islands (UHI): This part focuses on investigating the impact of Urban Heat Islands (UHIs) and leverages key findings from the Intergovernmental Panel on Climate Change's Sixth Assessment Report (AR6). The AR6 Synthesis Report synthesizes the latest scientific knowledge on climate change and its consequences. It underscores that human activities, especially fossil fuel consumption, are the primary drivers of global warming. Urgent greenhouse gas emissions reduction is necessary to mitigate climate change's severe consequences for ecosystems, human health, and economic stability. The report highlights the importance of achieving net-zero emissions and implementing adaptation measures to protect vulnerable populations and ecosystems. It also stresses the need for international cooperation and transformative actions across various sectors to achieve climate goals. Activity A4 studied the impact of UHI, including increased temperatures, CDD (cooling degree days), and cooling energy demand (Figure 4). Mitigation strategies included passive cool pavements, green roofs/walls, water bodies, urban green spaces, and high-reflecting roofs.

- Study on Building Adaptation & Optimization: This part focused on the potential of energy-efficient buildings and processes in Sunbelt regions, including new constructions and existing buildings. The subtask activities involved studying other projects, collaborating with the IEA EBC (Buildings and Communities Programme), and related workshops involving individuals from Sunbelt countries. A specific focus was the integration of solar cooling into retrofitted HVAC systems, addressing challenges related to refrigerants and cold distribution. The study also explored cold delivery systems to reduce drafts and enhance thermal comfort in buildings. The research program "POI ENERGIA 2014e2020" under the EU Horizon 2020 was the funding source for this project. It assessed the energy performance of buildings in the Italian regions of Campania, Puglia, Calabria, and Sicilia, aiming to reduce energy consumption while enhancing building quality.

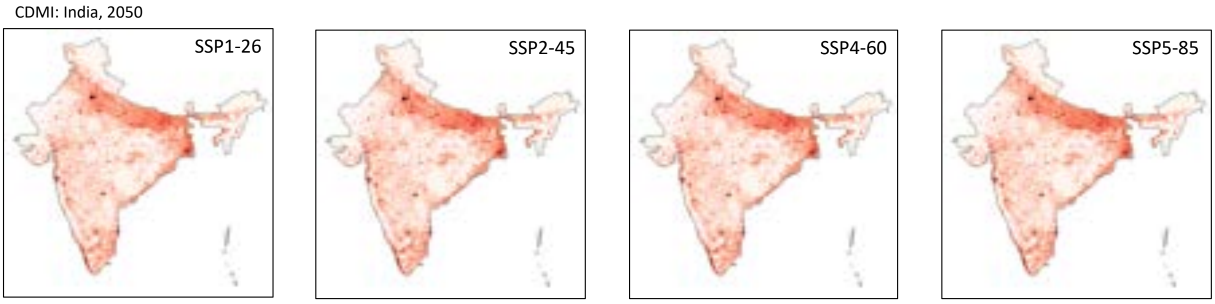

Figure 4: Cooling Demand Market Index (CDMI) results for India by 2050, taking into account the development of the population and GDP (from SSP1 Sustainability to SSP5 Fossil-fueled development) as well as Cooling Degree Days. (CDD) (JER/Strobel 2023)

In the context of cooling energy demand for buildings, factors like site conditions, building characteristics, cooling system performance, heat gains, and occupant behavior influence energy consumption. The study specifically focuses on Sunbelt region countries, and diverse results are reported in the literature due to these varying factors. It involves presenting relevant studies to assess cooling system consumption with and without solar support and quantify potential energy savings. To evaluate the integration of solar cooling systems in buildings and develop optimized plant-building systems, numerous parameters beyond building design must be considered. A thorough literature review was conducted, and the collected data were analyzed and presented to address these aspects.

The final report, D-A4, was published in September 2023, DOI: 10.18777/ieashc-task65-2023-0003.

A5: Building and process optimization potential

Activity A5 aimed at standardizing definitions to define a widely shared “language” for solar cooling. Furthermore, Activity A5 will investigate the current status of standardization and regulation on solar heating and cooling in the Sunbelt countries. The primary focus of this activity is twofold:

1. Standardization and Definition of KPIs: The goal is to establish standardized definitions to create a common language for solar cooling. Key Performance Indicators (KPIs) play a crucial role in evaluating and comparing different solutions and technologies in the field. The diversity of solar cooling systems and components and their relatively low level of adoption in today's energy systems make it essential to create a precise and comprehensive set of KPIs. A decision-making process has been designed to select appropriate KPIs, and seven base KPIs have been identified, which will be further extended to cover materials, components, and systems.

2. Study of Existing Standards and Regulations: Activity A5 examines the current status of standardization and regulation regarding solar heating and cooling in Sunbelt countries. Various countries and international organizations have developed standards covering performance testing, system design, equipment specifications, safety requirements, and installation practices for solar heating and cooling systems. Notable organizations in this context include the International Organization for Standardization (ISO), the European Committee for Standardization (CEN), the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and others.

The identified Australian Standard AS5389 on solar heating and cooling systems is considered the most suitable for solar cooling in the Sunbelt region. It provides a comprehensive framework covering the design, installation, commissioning, operation, maintenance, and replacement of solar heating and cooling systems for buildings, active and passive, direct and indirect systems, and closed-loop and open-loop systems, among others. The standard also includes performance requirements for various components, system performance monitoring and evaluation, installation and commissioning guidelines, operation and maintenance procedures, and compliance standards.

However, AS5389 does not specifically address solar cooling systems in the Sunbelt region. To adapt it, potential modifications are identified:

- Design Considerations: Additional design considerations include using reflective materials to reduce heat gain and incorporating passive cooling strategies to complement active solar cooling systems.
- Cooling Load Calculation: Guidelines on calculating the cooling load for Sunbelt region buildings to ensure appropriately sized solar cooling systems.
- Solar Collector Selection: Guidance on selecting solar collectors designed to withstand high solar radiation and operate at high temperatures.
- Thermal Energy Storage: Recommendations on designing and selecting thermal energy storage systems optimized for high temperatures and high-efficiency cooling technologies.
- System Performance: Guidance on monitoring and evaluating the performance of solar cooling systems in the Sunbelt region, including defining key performance indicators (KPIs) for benchmarking.

These adaptations aim to tailor the existing standard to the Sunbelt region's specific solar cooling system needs and challenges.

Activities planned to achieve the specific objectives and their timeframe were discussed. The following results were achieved in Subtask B in 2023.

B1/A2: Showcases on system and component level & Adapted components
Activity B1 was merged with Activity A2 into one deliverable and includes results from the 32 collected solar cooling projects noted above.

B2: Design guidelines
The Activity B2 has been completed. The report focuses on design guidelines for solar cooling systems. This activity aimed to compile a summary of case studies that demonstrate novel and updated system concepts for solar cooling applications based on practical or theoretical cases. The method employed involves collecting information through questionnaires and analyzing the case studies in the report. Three distinct case studies, each with a unique scope and attributes, are elaborated upon. The summary is as follows:

- Industrial Cooling Potential: Industrial cooling holds significant promise for solar cooling applications. These systems can achieve a high solar fraction, leading to a considerable reduction in CO_2 emissions compared to conventional electricity-driven chillers.
- Solar PV and Vapor Compression Chillers: The integration of Solar PV with vapor compression chillers is examined as an emerging solution for decarbonizing cooling systems. A comparative analysis involving different load and weather profiles suggests that solar PV cooling (Figure 5) can result in a lower levelized cost of cooling compared to solar thermal. The study underscores the significance of thermal storage and the effectiveness of lower temperatures in solar thermal collectors for cost competitiveness.
- Hybrid Electrical and Thermal Chillers: This study is based on the HyCool project. The focus is on combining electrical and thermal chillers. Both simulation and real-world outcomes demonstrate a significant decrease in electricity consumption when utilizing the topping cycle of the absorption chiller. Progress in policies and economies of scale is expected to boost the cost-effectiveness of these innovative methods.

In conclusion, these case studies underscore the transformative potential of cooling solutions. As technology advances and policies evolve, adopting such systems will be pivotal in shaping a greener, more energy-efficient cooling future.

The final report, D-B2, was published in December 2023, DOI: 10.18777/ieashc-task65-2023-0006.

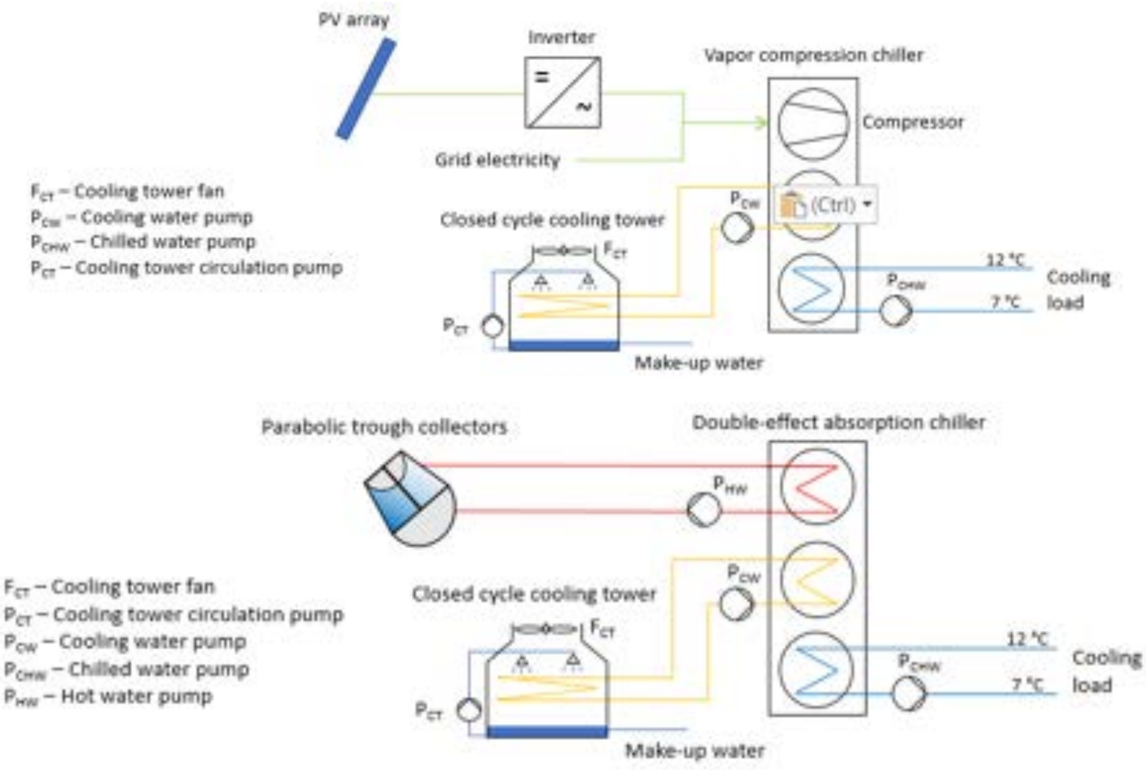

Figure 5: Most important components in the PV cooling system (top) and in the ST part of the cooling system (bottom). (IEA SHC Task 65)

B3: Key Performance Indicators

Activity B3 was merged with Activity C3 into one Deliverable. Details of the current progress can be found under Subtask C below.

B4: Standardization / solar cooling kits

Activity B4's objective is to compile an overview of standardizations and certifications of solar cooling equipment in all capacity ranges and different technologies. It has also compiled an overview of renewable energy standards. The inventory of renewable energy standards includes the International Standards, Australian National Standards AS5389:2019, and European Standards. These standards provide guidelines and specifications for the design, installation, and performance evaluation of solar cooling systems and related components.

B5: Lessons Learned (technical and non-technical)

The activity (B5) has been completed. The main focus of this activity was to gather reliable data; gain insights from research, experience, and observations; analyze the information to understand the stakeholder's challenges, needs, and desires; and integrate input from previous Task 48 and Task 53:

- Activity B5 involved identifying and documenting lessons learned, both technical and non-technical, to create a summary for dissemination in Subtask D. The primary objective was to collect trustworthy data and gain valuable insights from various stakeholders. A survey was conducted to gather information on stakeholder's requirements, expectations, and specific circumstances that may prompt the utilization of solar cooling. The survey's primary objective was to identify crucial factors influencing the adoption of solar cooling technologies across different applications and regions. The gathered information was then analyzed to understand better the stakeholders' challenges, needs, and desires.

- The results obtained from the questionnaire showed that solar cooling technologies are highly valued and important, but their market transformation requires collaboration across various sectors. Engaging with stakeholders, including government agencies, industry players, research institutions, and consumers, is crucial for creating a supportive ecosystem for solar cooling. GIS software aids in effective planning and deployment, while technical training programs build capacity and expertise in the industry. Demonstrating the technical and economic viability of solar cooling and reducing reliance on the electrical grid can promote adoption. A multi-faceted strategy involving awareness-raising, market acceptance, and accelerated penetration can make solar cooling a sustainable solution for cooling needs. This approach contributes to climate change mitigation, economic growth, and energy security.

The final report, D-B5, was published in October 2023, DOI: 10.18777/ieashc-task65-2023-0005.

Subtask C: Assessment and Tools

Activities planned to achieve the specific objectives and their timeframe were discussed. The following results were achieved in Subtask C in 2023.

C1: Design tools and models
The Activity C1 has been completed. The report includes the results of three review methods:

- A systematic literature review:
  A total of 1,216 documents (757 journal articles, 418 proceeding papers, 98 review articles, and 12 book chapters) were identified due to the search in WoS.
- Interviews/questionnaire of Task 65 experts:
  The initial data gathered provides a general idea of which components are being used and which software is being implemented by the task participants.
- Interactive results of subtask and task expert meetings:
  Mentimeter was used in the 3rd Expert Meeting to complement the interviews/ questionnaire of Task 65 experts and cross-check the results in an interactive way and further discussions.

The final report, D-C1, was published in October 2023, DOI: 10.18777/ieashc-task65-2023-0004.

C2: Database for technical and economic assessment
The elaboration of the database and collection of technical (e.g., standard reference systems, etc.) and economic data (energy prices for electricity, natural gas, etc.) for different components (Investment, maintenance, lifetime, etc.) and the different sunbelt countries (based on subtask B demo cases) has been started and is the bases for the following assessments of the various solar cooling concepts.

The structure is ready and shows the current values of SHC Task 53. An update for different projects and locations can be arranged as soon as those projects are ready to deliver the data accordingly. The new database includes future scenarios for technical and economic boundaries (e.g., efficiency of conventional chillers, energy prices) to provide the base and a solid framework for sensitivity analyses and future scenarios.

Furthermore, a learning curve model for cost developments will be set up with available data to predict future system costs for solar cooling. The database elaboration also includes reviewing existing useful information on IEA knowledge (e.g., SHC Task 54 and others).

C3: Assessment mechanism
Joint Activity C3/B3 has determined that although the key performance indicator (KPI) definition exists, there is no standard, and often, a mix of non-comparable KPIs is used to express the quality of systems. This is not only confusing for end-users/operators/policymakers but also misleading the discussion among experts.

The first step is the collection of existing technical and economic KPIs among completed and current IEA SHC Tasks and other sources. Next, through discussions in Activity B3 and C3, work to simplify the key messages and KPIs. The result is the development of a design tool that is now in the validation phase.

From a methodology point of view, the first input by the R&D project “SunBeltChiller,” which developed and delivered a design tool for the optimal sizing of the system, is being elaborated. In this design tool, the typical project data like cooling load, climatic and price conditions, and so forth are fed into the calculation and KPI results like solar fraction, primary energy savings, and especially economic figures like Levelized cost of cooling (LCoC) for the optimum systems are generated (Figure 6). The results are being compared to reference systems, namely a standard compression chiller fed exclusively from the electrical grid and an optimized PV-driven compression chiller system with storages (thermal and/or electrical).

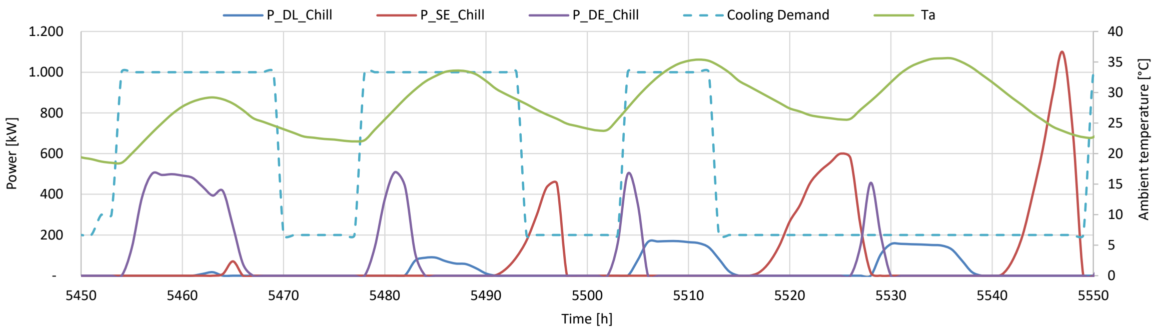

Figure 6: Typical time-resolved indicative load and power levels of the SunBeltChiller system. (ZAE Bayern)

C4: Benchmarking and sensitivity analysis

Activity C4 focuses on technical, economic, and financial assessment of received simulated/measured results on standardized tasks and specific local boundary conditions of the demonstration plants of Subtask B. The results will be compared and benchmarked against conventional and other renewables cooling solutions. One important aim is to study promising locations and applications for the "SunBeltChiller" (SBC) using the GIS method (Activity A1), the design tool mentioned above, and the assessment tool. Within the research project, the SBC was evaluated using a comparative study between SBC and DE chiller (each equipped with a dry re-cooler), and the economic and ecological advantages were assessed.

Both investigated systems using concentrated solar collectors (Fresnel collectors) as a heat source to cover the heat requirements of the process and the chillers. As an application example, an industrial process located at Windhoek, Namibia, was considered. To map the energy requirement, load curves (Figure 7) for process heating (at 160°C), process cooling (at 6°C), and electricity were assumed to reflect a typical production cycle (two shifts during the week, rest day on Sunday). Both solar cooling systems have identical installed collector peak power sizes and nominal cooling capacity. Additionally, the SBC has a hot water and cold water storage.

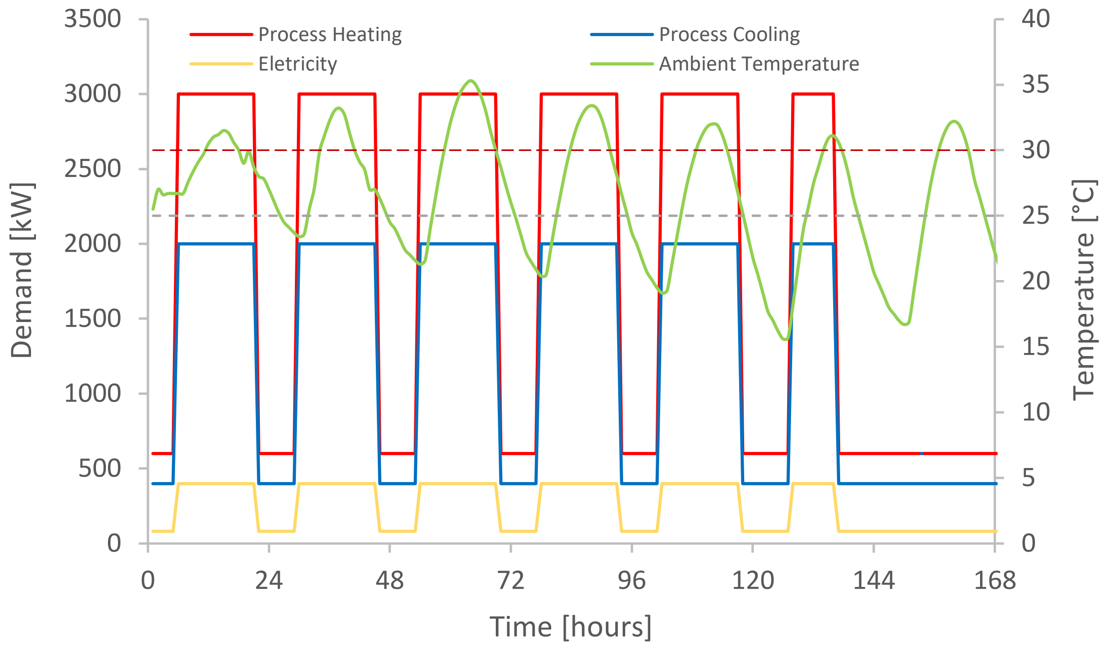

Figure 7: Plot of energy requirements of the considered industrial application and ambient temperature located at Windhoek, Namibia, for an exemplary week. (ZAE Bayern)

Both systems are reaching a high solar heating coverage of nearly 50%. However, the DE-Chiller can provide a solar cooling coverage of only 16% due to the limitation of a dry cooling tower operating at high ambient temperatures. The SBC, on the other hand, achieves a solar cooling coverage of 41%, thus enabling a significant reduction in CO2 emissions of 221 tons per year.

LCBA questions raised and answered in this analysis:

- What are the economic and financial implications of the additional investment for the SBC?
- How do the additional electricity savings calculated at 150 EUR/MWh impact the SBC business case?
- What would be the effect of an assumed carbon pricing at 90 EUR/t CO_2?
- Does the project cash flow (CF) support debt service for a 70% loan at a 5% interest rate?

The life-cycle costs and benefits of the SBC business case are modeled over a 20-year project cycle, using the standard Double-Effect solution as a reference case (baseline). The net-CF accounts for revenues from electricity savings and all life-cycle cost (CAPEX, fix and variable OPEX, and 5% re-investment budgets in year 13). Based on the additional SBC investment cost of 1 million EUR, the project-CF reveals a cumulative net surplus of 325 T.EUR after 20 years. Its internal rate of return (IRR) stands at 2.9%, and a dynamic payback period of 15.4 years would require very low expectations on the investor's side. If carbon pricing @90 EUR/t CO_2 is included, the cumulative net surplus increases to 725 T.EUR with an IRR of 5.9% and a payback of 11.4 years, as depicted in Figure 7. Regarding financing, the debt service for the 700 T.EUR loan can be covered from the net savings. After the 10-year loan repayment, the net surpluses accrue to the equity investor and amount to a surplus of 532 T.EUR with an IRR of the equity CF of 6.5%.

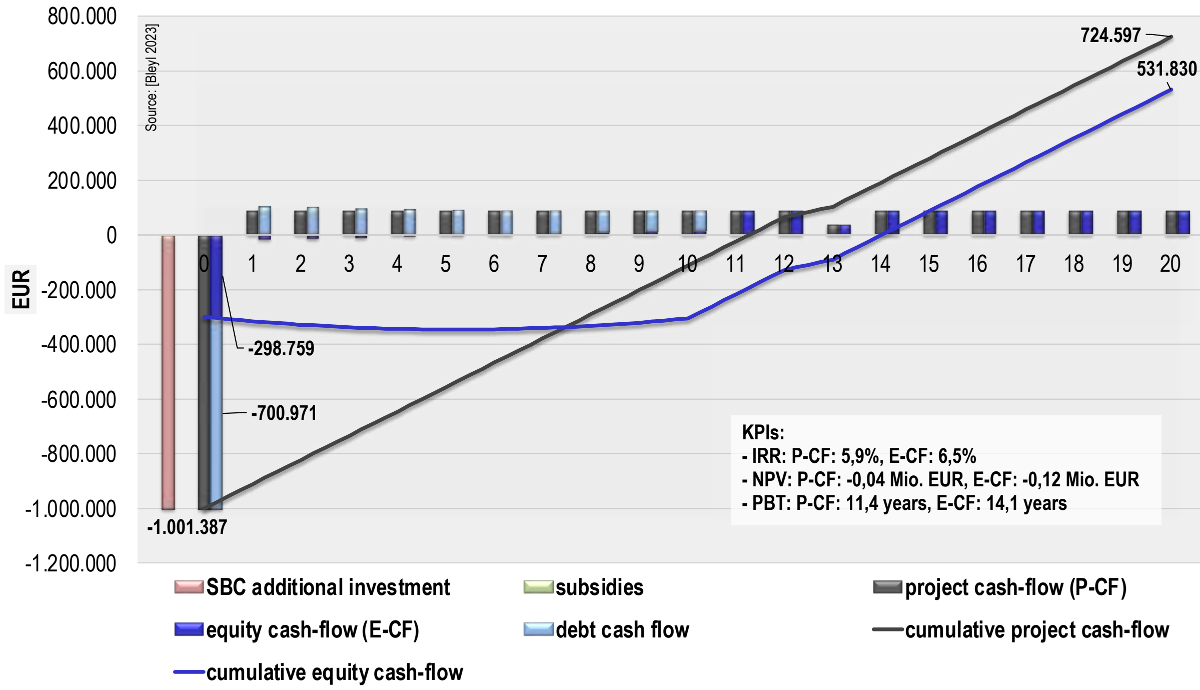

Figure 8: Investment, project, and equity cash flows (annual and cumulative) including carbon pricing at 90 EUR/t CO_2. (Energetic Solutions)

In conclusion, the SBC is one of only a few solar thermal cooling systems equipped with a dry re-cooling tower that can reach significant solar cooling coverage and CO2 emissions savings despite high ambient temperatures. CO_2 savings are almost three times higher than a similar solar cooling system with a DE chiller.

Economically, the SBC investment still requires a long-term business case. Feasibility is greatly increased by a remuneration for avoided CO_{2e} emissions (and other 'Multiple Benefits' of reduced fossil fuel consumption). It is also interesting to note that the SBC payback period is just six months longer than a standard DE solution (compared to a conventional compression chiller + natural gas heating solution). In any case, the availability of long-term and reasonably cheap (WACC ≤ 6.5%) financing options is a key pre-requisite (as for many renewable, decarbonized supply options).

Subtask D: Dissemination

Activities planned to achieve the specific objectives and their timeframe were discussed. The following results were achieved in Subtask D in 2023.

D1: Website/publications

Task 65 homepage is in operation and continuously updated. Two National Workshops (China and Austria) and two Industry Workshop (part of the 2nd and 6th Task Meetings, respectively) were successfully organized and informed stakeholders about the Task work.

Several publications have been published about Task 65 and the experts' work related to the different activities: EuroSun 2020, FotoVolt 10/2021, SWC 2021, APSRC 2021, ISEC 2022, EuroSun 2022, APSRC 2022, s@ccess 2023, ICR 2023, SWC 2023, and APSRC 2023.

D2: Financial models for solar cooling

The work in Activity D2b is ongoing. A list of the most relevant business and financing models that could be used for solar cooling systems has been compiled. A clear distinction has to be made between business models and third-party financing – these terms are often mixed up. Third-party financing (TPF) can be part of a business model, but the latter goes well beyond financing. Some examples of ESCO (energy service company) models have existed in the solar thermal sector for a long time. Scottsdale's Desert Mountain High School in Arizona, USA, was one of the first clients to profit from a cooling energy supply contract. In 2014, SOLID from Austria financed and installed a 3.4 MW cooling system and signed a 20-year cooling energy supply contract with the school (Figure 9).

Figure 9: Solar roof for Scottsdale's Desert Mountain High School in Arizona, USA. (SOLID, 2014)

Another example is a special purpose vehicle, where a separate legal company is established, which plans, builds, finances, and operates the energy production units and signs all the relevant documents such as EPC contracts, O&M agreements, or loan contracts. The first solar thermal specialists have successfully used this model - for example, NewHeat in France. The company created an SPV already in 2018 to finance and operate a package of solar industrial and district heat projects. Solar fields from the Netherlands also founded an SPV recently for the 37 MW district heating plant under construction in Groningen. Given the special situation in some sunbelt countries with weaker economies, another model can be recommended: the utility-based on-bill repayment model. On-bill repayment is widely used in the United States for energy-saving measures or heating upgrades in the residential sector. The asset, including the re-financing agreement, can be sold with the house if the owners have to move.

D3: Guidelines/roadmaps for Sunbelt countries

Work has been started on compiling new guidelines for solar cooling roadmaps, focusing on Sunbelt countries' specific constraints and opportunities based on the adaptation of the 2015 IEA SHC Task 48 guidelines. Furthermore, a list of recommendations for policy options will be published to develop the solar cooling industry and establish markets in the Sunbelt countries. The aim is to compile a position paper/white paper for policymakers.

D5: Workshops
The third SHC Solar Academy Training course was organized and successfully held on October 10th and 11th, 2023, for SOLTRAIN / ECREEE onsite in Praia, Cape Verde. A total of 27 West African participants took part.

Moreover, a two-day Solar Academy & TTMD online training was held on December 13th-14th, 2023. The Solar Academy's online training was a success in presenting Task 65, the upcoming Task with a focus on emerging economies and Solar Cooling, in detail to selected TTMD members and other international participants. Among the 15 participants were architects, mechanical engineers, design engineers, a SHIP supplier, scientists, and Ph.D. students.

D6: Stakeholder engagement
A first round of identifying potential stakeholders in sunbelt countries has been completed. 45 individuals have been contacted as potential stakeholders in March 2022. 19 positive replies have been received in return. A questionnaire was sent out to these 19 individuals in May 2022 to collect details about the individual challenges and motivations these stakeholders have regarding solar cooling in their countries. Five positive answers were received by June 2022 from that second round of contact. There is now an ongoing process of individually contacting stakeholders in one-to-one meetings or collective workshops. They shall further be encouraged and assisted in initiating the first solar cooling projects in their respective countries.

Work Planned For 2024

Subtask A: Adaptation

The main activities planned for Subtask A in 2024 are:

- Evaluate the economic potential of adaption to certain climates and applications, especially when they can be simplified on component and system levels.
- Finally, map the technical and economic potential for solar cooling of building/process optimization under different climates and national standards.

Subtask B: Demonstration

The main activities planned for Subtask B in 2024 are:

- Finally, document the work of standardization and solar cooling kits in all capacity ranges and different technologies.

Subtask C: Assessment and Tools

The main activities planned for Subtask C in 2024 are:

- Finally, the LCCBA framework will be documented 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.
- Decision support in various phases of a project cycle, from initial project ideas, comparison of technology options, detailed investment grade calculation, and optimization of the operation phase, based on case studies and use cases from subtasks A and B.
- Pre-assess the 'bankability' of solar cooling investments with financial KPIs.
- Analyze and report on the demonstration plant's technical and economic performance (KPIs) and select best practice examples from Subtask B.

Subtask D: Dissemination

The main activities planned for Subtask D in 2024 are:

- Expand and deepen communication with stakeholders.
- Further dissemination of the Task results on a national and international level.
- Provide efficient communication tools such as guidelines/roadmaps/books.
- Continue to collect and structure evidence for policymakers of the Sunbelt countries.

Dissemination Activities In 2023

Reports, Published Books

None at this time.

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
Bärbel Epp	Business and financing models – a clear distinction	solarthermalworld.org	February 2023
Uli Jakob, Daniel Neyer, Salvatore Vasta, Richard Gurtner	Solar Cooling for the Sunbelt regions - first results of Task 65 Activity A1 Climatic conditions and applications	4th International Conference on Solar Technologies & Hybrid Mini Grids to improve energy access, Palma de Mallorca / Spain	April 2023
Michael Strobel, Uli Jakob, Wolfgang Streicher, Daniel Neyer	Spatial Distribution of Future Demand for Space Cooling Applications and Potential of Solar Thermal Cooling Systems	Sustainability 2023	15 (12), p. 9486. DOI:10.3390/su15129486, June 2023
Paul Kohlenbach, Uli Jakob, P. Munzinger, A. Werntges	The Potential of Photovoltaic Green Cooling with Natural Refrigerants	ICR 2023, 26th International Congress of Refrigeration Paris / France	August 2023
Marina Bonomolo, Uli Jakob, Daniel Neyer, Michael Strobel, Salvatore Vasta	Integration of solar cooling systems in buildings in Sunbelt region: an overview.	Buildings 2023	13 (9), p. 2169. DOI: 10.3390/buildings13092169, August 2023
Uli Jakob, Daniel Neyer, Salvatore Vasta, Wolfgang Weiss, Paul Kohlenbach	Solar Cooling for the Sunbelt regions – Results from task 65 activities	ISES SWC 2023 conference, New Delhi / India	October 2023
Michael Strobel, Uli Jakob, Manuel Ostheimer, Daniel Neyer	Solar Heating and cooling solutions in energy efficient buildings in Nepal	ISES SWC 2023 conference, New Delhi / India	November 2023
Uli Jakob, Michael Strobel	Investigation of a solar cooling and process heat system in hot climates for steam, heat and cold supply in industry	ISES SWC 2023 conference, New Delhi / India	November 2023
Lu Aye, Nayrana Daborer-Prado, Daniel Neyer, Uli Jakob	Third Update on Activity C2 Design Tools and Models, Task 65 Solar Cooling Sunbelt Regions	Asia-Pacific Solar research Conference 2023, Melbourne / Australia	December 2023

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
4th International Conference on Solar Technologies & Hybrid Mini Grids to improve energy access	Solar Cooling for the Sunbelt regions - first results of Task 65 Activity A1 Climatic conditions and applications. Daniel Neyer, Neyer	April 26-28, 2023, Palma de Mallorca, Spain	136

	Brainworks / UIBK		
Coffee talk – Solar Heat Europe	Cooling down with the sun. Uli Jakob, JER	May 9, 2023, Virtual	5
ICR 2023, 26th International Congress of Refrigeration	The Potential of Photovoltaic Green Cooling with Natural Refrigerants. Paul Kohlenbach, BHT	August 21-25, Paris, France	1,000
ISES SWC 2023 conference	Keynote: Solar cooling technologies for emerging markets. Uli Jakob, JER	Oct. 30-Nov. 4, 2023, New Delhi, India	300
ISES SWC 2023 conference	Solar Heating and cooling solutions in energy efficient. Michael Strobel, UIBK/JER	Oct. 30-Nov. 4, 2023, New Delhi, India	300
ISES SWC 2023 conference	Investigation of a solar cooling and process heat system in hot climates for steam, heat and cold supply in industry. Michael Strobel, UIBK/JER	Oct. 30-Nov. 4, 2023, New Delhi, India	300
Asia-Pacific Solar Research Conference APSRC 2023	Third Update on Activity C1 Design Tools and Models, Task 65 Solar Cooling Sunbelt Regions. Lu Aye, Uni Melbourne	December 5-7, Melbourne, Australia	n/a

Dissemination Activities Planned For 2024

A third Austrian national workshop is planned in conjunction with the ISEC 2024 conference in Graz, Austria.

Contributions at the ISEC 2024, EuroSun 2024, and national conferences.

Task Meetings in 2023 and Planned for 2024

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 6 + Industry Workshop	March 23-24, 2023	Uni Innsbruck, Austria Hybrid	35 participants (9 countries)
Task Meeting 7	October 24-25, 2023	Virtual	22 participants (7 countries)
Task Meeting 8	March 6-7, 2024	CNR-ITAE, Messina, Italy, Hybrid	

Task 65 Participants

Country	Name	Institution / Company	Role
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AUSTRIA	Herbert B. Bremstaller	Ecotherm	National Expert
AUSTRIA	Antoni Castells	Ecotherm	National Expert
AUSTRIA	Akshay Kumbhar	Ecotherm	National Expert
AUSTRIA	Jan Bleyl	Energetic Solutions	National Expert
AUSTRIA	Mathias Blaser	ENGIE Kältetechnik	National Expert
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AUSTRIA	Hannes Poier	SOLID Solar Energy Systems	National Expert
AUSTRIA	Manuel Ostheimer	University of Innsbruck	National Expert
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CHINA	Yanjun Dai	Shanghai Jiao Tong University	National Expert
CHINA	Yao Zhao	Shanghai Jiao Tong University	National Expert
CHINA	Ma Tao	Shanghai Jiao Tong University	National Expert
DENMARK	Lars Munkoe	Purix	National Expert
EACREEE	Tom Fred Ishugah	Makerere University, Uganda	National Expert
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GERMANY	Raplh Herrmann	Fahrenheit	National Expert
GERMANY	Gerrit Füldner	Fraunhofer ISE	National Expert
GERMANY	Mathias Safarik	ILK Dresden	National Expert
GERMANY	Michael Strobel	JER	National Expert
GERMANY	Benjamin Huber	JER	National Expert
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GERMANY	Frank Molter	SolarNext	National Expert
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GERMANY	Manuel Riepl	ZAE Bayern	National Expert
GERMANY	Richard Gurtner	ZAE Bayern	National Expert
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ITALY	Francesca Martorana	CNR ITAE	National Expert
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ITALY	Marco Pellegrini	UNIBO	National Expert
ITALY	Cesare Saccani	UNIBO	National Expert

ITALY	Alessandro Guzzini	UNIBO	National Expert
ITALY	Marco Beccali	UNIPA	National Expert
ITALY	Marina Bonomolo	UNIPA	National Expert
ITALY	Ben Alex Baby	UNIPA	National Expert
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NETHERLANDS	Henk de Beijer	ARES / SolabCool	National Expert
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RCREEE	Mahmoud N. Abdelmoez	Assiut University, Egypt	National Expert
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SACREEE	Samson Mhlanga	National University of Science and Technology, Zimbabwe	National Expert
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SPAIN	Manuel Lucas	Miguel Hernandez University	National Expert
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SPAIN	Joan Carles Bruno	CREVER	National Expert
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SPAIN	Victor Fabregat	Regenera	National Expert
SPAIN	Francisco David Gallego Martinez	Regenera	National Expert
SWEDEN	Puneet Saini	Absolicon	National Expert
SWITZERLAND	Guglielmo Cioni	TVP	National Expert

UNITED KINGDOM	Alex Mellor	Naked Energy	National Expert
UNITED KINGDOM	Mitchell Van Oosten	Naked Energy	National Expert
UNITED KINGDOM	Bob Critoph	University Warwick	National Expert
UNITED KINGDOM	Stan Shire	University Warwick	National Expert
UNITED KINGDOM	Jake Locke	University Warwick	National Expert
USA	Wolfgang Weiss	ergSol	Subtask B leader
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Task 66 – Solar Energy Buildings

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Task Manager for the German Government (PtJ for BMWi)

Task Overview

Task 66 focuses on developing economic and ecologic feasible solar energy supply concepts with high solar fractions for new and existing buildings and communities. The targeted solar thermal and solar electrical fractions depend significantly on the climate zone.

For **moderate climate zones** such as central Europe, northern China, and the northern USA, the following solar fractions should be achieved:

- 85% of the heat demand
- 100% of the cooling demand and
- 60% of the electricity requirements for households and e-mobility

For **sunny climate zones** such as southern Europe, southern China, southern USA, Australia, and Mexico, the following solar fractions should be achieved:

- 100% of the heat demand
- 85% of the cooling demand and
- 80% of the electricity requirements for households and e-mobility

The main objective of Task 66 is the development of economically and ecologically achievable solar energy supply concepts for heat and electricity with high solar fractions for new and existing buildings and communities.

The Task addresses single-family buildings, multi-story residential buildings, and building blocks or distinguished parts of a city, named communities, for both new buildings and the comprehensive refurbishment of existing buildings.

In the context of this Task, the separation between (single) buildings and building blocks or communities is based on if the buildings are connected to a thermal grid or not. This separation is based on the thought that all buildings will be connected to an electricity grid in general. Hence, regarding the interexchange ability of energy between different buildings, the only difference is the aspect of whether the buildings are connected to a thermal grid or not.

The Task's work is divided into four subtasks:

- Subtask A: Boundary Conditions, KPIs, Definitions and Dissemination *(Lead Country: Germany)*
- Subtask BC: New and Existing Buildings and Building Blocks/Communities *(Lead Country: Denmark, Co-lead Country: China)*
- Subtask D: Current and Future Technologies and Components *(Lead Country: Austria)*

Scope

Subtask A: Boundary Conditions, KPIs, Definitions and Dissemination
The main objectives of Subtask A are:

- Define the framework conditions and system boundaries as well as screening for legal framework conditions and definition of reference buildings (single and multi-family houses) or districts; Define the involved stakeholders (energy suppliers, housing developers, urban planning, etc.); Discuss and define different scenarios regarding overall energy system developments; Determination of specific KPIs;
- Address aspects of scalability and assignability, user and stakeholder engagement, business and statement models, financing;
- Summarize and prepare the results; disseminate measures.

Subtask BC: New and existing buildings and building blocks/communities

The main objectives of Subtask B/C are:

- Investigation of economic and ecologic energy supply concepts with high solar fractions for new and existing buildings and communities, based on the technologies determined in subtask D. If applicable, further development of individual technology elements.
- Exploit the new degrees of freedom and possibilities by linking individual technologies from the technology portfolio from a perspective that looks at the entire energy system, such as sector coupling, SRI indicators (Smart Readiness Indicator), self-consumption levels, and grid load rejection potential (overall grid infrastructures), etc. Consider available surface and the area- efficiency of individual technologies. Define integrated and grid-interacting energy supply concepts for heat, cold, domestic electricity demand, and e-mobility. Consider aspects of increased user involvement.
- Modeling, simulation, and determination of KPIs defined in subtask A and optimization procedures.
- Evaluate using the technical, economic, and environmental KPIs and optimization procedures.

Subtask D: Current and future technologies and components

The main objectives of Subtask D are:

- Define current and future technologies in a technology portfolio, such as solar thermal (conventional collector technologies, medium-temperature collectors, charge boost sorption collectors, other specific new developments), PVT hybrid collectors, PV, micro heat pumps, different thermal and electrical energy storage technologies (e.g., activation of thermal masses, water storage with vacuum insulation, sorption storage, ice storage, stationary and mobile battery storage, etc.), heat and cold supply systems, water heaters and other technologies for heat, cold and power generation (biomass, green gas, cogeneration, etc.).
- Initiate the development of significantly new and improved technical solutions.
- Conduct techno-economic assessment of newly developed solutions.

Collaboration with Other IEA TCPs

The Task is collaborating with the IEA PVPS (Photovoltaic Power Systems Programme) and IEA EBC (Energy in Buildings and Communities Programme).

Collaboration with Industry

Five industry workshops have been organized to date. In total, around 235 persons have participated in these workshops. The share of representatives from industry is around one-third and comprises participants from solar thermal collector manufacturers, system suppliers, building companies, HAVC companies, consultancies, business developers, and governmental institutions.

Regarding the task itself, industry interest and involvement are reflected by the fact that approximately 25 % of the participants represent the non-academic sector.

Task Duration

This Task started in July 2021 and will end in September 2024 (3-month extension).

Participating Countries

Countries that have expressed interest in participating include Australia, Austria, Belgium, China, Denmark, Germany, Mexico*, Portugal, Slovakia, Switzerland, United Kingdom, United States*

**Through the PVPS TCP.*

Work During 2023

Subtask A: Boundary Conditions, KPIs, Definitions and Dissemination

Activities performed:

- The final list with KPIs for the technical, energetical, economic, ecological, and sociological evaluation of Solar Energy Buildings (Deliverable D.A2) was prepared and presented during the 5th task meeting.
- Deliverable D.A4, “Final definition of reference buildings/cases,” was elaborated. This deliverable serves as a basis for comparing different energy supply concepts, elaborating reasonable energy supply concepts for typical buildings, building blocks, and/or communities, and validating and calibrating simulation models based on representative examples.

- At the 6th task meeting, aspects related to the specific target groups, the format, and the number of pages for the deliverables D.A6 "Solar Energy Buildings promotion document for investors" and D.A7 "Policy-oriented guidelines for the promotion of Solar Energy Buildings" were discussed. Furthermore, the first drafts of the content of both deliverables were elaborated.
- The idea of preparing a final task video was discussed. This would be an additional deliverable not mentioned in the original work plan.
- A Solar Academy Webinar on Solar Energy Buildings was organized and carried out on September 19th and 21st, 2023, with 222 participants. The recording is available via the following link: https://www.youtube.com/watch?v=Ym1eQW3OWx8.

Subtask BC: New and existing buildings and building blocks/communities

Activities performed:

- As a result of the merger of Subtasks B and C to Subtask BC, the work plan and deliverables were adapted.
- Based on an analysis of around 150 solar energy buildings, regional specific technology trends for realizing solar energy buildings were identified.
- A comprehensive survey related to planning, project development, performance, and financial and environmental aspects of Solar Energy Buildings was elaborated and performed. More than 300 answers from 13 different countries were received and evaluated.
- A “Solar Energy Buildings Around the World” publication related to some of the results achieved within Subtask BC of Task 66 was published in “Solar Update” Vol 78, December 2023.

Subtask D: Current and future technologies and components

Activities performed:

- The deliverable D1, "Description of available technology portfolio," was updated and finalized. The deliverable provides an overview of 126 case studies using various technology options and the available technology portfolio, considering existing and emerging technologies with the potential to be successfully used in Solar Energy Buildings. In addition, 25 case studies provided by Task 66 participants are included, showing a large variety of building uses (residential, commercial, public, mixed-use), different building sizes, new construction and renovation projects, and actual R&D approaches.
- The deliverable D2 related to the description of promising future technologies was elaborated as a final draft and discussed during the 6th meeting of Task 66 in October 2023
- It was discussed and decided that the deliverable D.D3, “Summary of new technologies and components identified within the Task,” will be based on a Fact Sheet collection.Work Planned for 2023.

Follow-up Task

The potential of Solar Energy Buildings for reducing the building sector's CO2 emissions is huge. As it is evident that not all open questions related to the concept and technology of Solar Energy Buildings can be answered by Task 66, the idea of a follow-up Task was discussed during the 6th task meeting in October 2023 in Graz, Austria. The discussion concluded that a Task entitled Smart Solar Energy Buildings or Green Solar Buildings would be useful. The initiative to establish a follow-up Task will continue in 2024.

Dissemination Activities In 2023

Reports, Published Books

Author(s)	Title	Bibliographic Reference
Elsabet Nielsen et. al.	Solar Energy Buildings around the world	Solar Update” Vol 78, December 2023 https://pubs.iea-shc.org/Data/Sites/1/publications/2023-12-Solar-Energy-Buildings-Around-the-World.pdf

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication /	Bibliographic Reference

Conference			
Bärbel Epp	Demo projects of high-solar-fraction buildings carefully analyzed	solarthermalworld.org,	October 2023
Thomas Ramschak; Michael Gumhalter	Internationale Ko-operation: Innovative Technologien und Strategien für Solar Energy Buildings	Nachhaltige Technologien AEE INTEC	March 2023
Harald Drück et. al.	Wie klimaneutral ist die Solarthermie	Solarthermie-Jahrbuch	2023

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
Task 66 Industry Workshop No. 3	Several persons	February 7th, 2023 Online	47 participants 10 countries
Task 66 Industry Workshop No. 4	Several persons	October 9th, 2023 Graz, Austria	18 participants 7 countries
Joint Workshop with ECBS Annex 83	Several persons	October 10th, 2023 Graz, Austria	23 participants 5 countries

Dissemination Activities Planned For 2024

Event	Date and Location	# of Participants (# of Countries)
Industry Workshop No 5	February 6th, 2024, online	
Final Task Workshop	August 2024, Limassol, Cyprus	

Task Meetings in 2023 and Planned for 2024

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 5	February 6, 2023	Virtual meeting	25 participants (9 countries)
Task Meeting 6	October 9-10, 2023	Graz, Austria	17 participants (6 countries)
Task Meeting 7	February 5, 2024	Virtual meeting	21 participants (8 countries)
Task Meeting 8	August 24, 2024	Limissal, Cyprus In conjunction with EuroSun 2024	

Task 66 Participants 2023

Country	Name	Institution / Company	Role
GERMANY	**Harald Drück**	**IGTE, University of Stuttgart**	**Task Manager**
AUSTRALIA	Gavin Chengyang	RMIT University Melbourne Australia	National Expert
AUSTRALIA	Rebecca Yang	RMIT University Melbourne Australia	National Expert
AUSTRIA	Dr. Fabian Ochs	University of Innsbruck	National Expert
AUSTRIA	Thomas Ramschak	AEE INTEC	Subtask D Leader
CHINA	Wenbo Cai	China Academy of Building Research, Beijing, China	National Expert
CHINA	Luo Yongqiang	Huazhong University of Science and Technology	National Expert
CHINA	Xinyu Zhang	China Academy of Building Research, Beijing	Subtask B Leader
CHINA	Tian Zhiyong	Huazhong University of Science and Technology	National Expert
DENMARK	Elsabet Nomonde Nielsen	DTU	National Expert
DENMARK	Simon Furbo	DTU	National Expert
GERMANY	Dominik Bestenlehner	IGTE, University of Stutgart	National Expert
GERMANY	Franziska Bocklmann	siz energieplus / dp-quadrat, Germany	National Expert
GERMANY	Yong Chen	IRENA	National Expert
GERMANY	Tillmann Gauer	Technische Universität Kaiserslautern	National Expert
GERMANY	Paul Kastner	Institut für Solarenergieforschung GmbH, Emmerthal, Germany	National Expert
GERMANY	Henner Kerskes	IGTE University of Stuttgart	National Expert
GERMANY	Florian Lichtblau	Lichtblau Architekten BDA	National Expert
GERMANY	Stefanie Lott	IGTE, University of Stuttgart	National Expert
GERMANY	Gerhard Mengedoht	Technische Hochschule Ulm (THU)	National Expert

GERMANY	Dr. Christoph Müller	hc-solar innovative solar solutions	National Expert
GERMANY	Lukas Oppelt	TU Bergakademie Freiberg	National Expert
GERMANY	Markus Peter	siz energieplus / dp-quadrat, Germany	National Expert
GERMANY	Claudia Scholl-Haaf	IGTE, University of Stuttgart	National Expert
GERMANY	Micha Schäfer	IGTE, University of Stuttgart	National Expert
GERMANY	Frank Späte	Ostbayrische Technische Hochschule OTH	National Expert
PORTUGAL	Jorge Facao	LNEG, Portugal	Subtask D
SLOVAKIA	Prof. Dr. Roman Rabenseifer	Slovak University of Technology in Bratislava	National Expert
SWITZERLAND	Dr. sc. ETH Luca Baldini	EMPA	National Expert
UNITED KINGDOM	Richard Lewis	Swansea University	National Expert

Task 67 – Compact Thermal Energy Storage Materials within Components within Systems

Dr. Wim van Helden
AEE – Institute for Sustainable Technologies
Task Manager for The Republic of Austria

Task Overview

The purpose of Task 67 is to push forward the compact thermal energy storage (CTES) technology developments to accelerate the market introduction of these technologies through the international collaboration of experts from materials research, components development and system integration, and industry and research organizations.

The main objectives of the Task are to 1) better understand the factors that influence the storage density and the performance degradation of CTES materials, 2) characterize these materials in a reliable and reproducible manner, 3) develop methods to determine the State of Charge of a CTES effectively, and 3) increase the knowledge base on how to design optimized heat exchangers and reactors for CTES technologies.

The Task is organized into five subtasks**:**

- Subtask A: Material Characterization and Database *(Lead Country: Austria)*
- Subtask B: CTES Material Improvement *(Lead Country: Spain)*
- Subtask C: State of Charge – SoC Determination (*Lead Countries: Denmark (PCM) and Canada (TCM))*
- Subtask D: Stability of PCM and TCM (*Lead Country: Germany)*
- Subtask E: Effective Component Performance with Innovative Materials *(Lead Countries: Spain (PCM) and Switzerland (TCM))*

Scope

CTES technologies are the subject of the Task. These technologies are based on the classes of phase change materials (PCM) and thermochemical materials (TCM). Materials from these classes will be studied, improved, characterized, and tested in components. The main components for these technologies are heat exchangers and reactors, which are also studied and further improved in the Task. The temperatures of the heat that the thermal storage will supply are determined by the areas of application and range from 0°C to 20°C for cooling purposes, from 40°C to 95°C for buildings, between 60°C and 130°C in DHC networks, and 80°C to more than 500°C for industry and vehicles. Due to the underlying physical and chemical processes, the charging and discharging temperatures, especially with TCM, can have very different values, with charging temperatures determined mainly by the applied heat source.

Subtask A: Material Characterization and Database
The subtask's main objective is to develop and validate several standardized measurement procedures for CTES materials and further expand and maintain the materials and knowledge databases.

Subtask B: CTES Material Improvement
The subtask's main objective is to identify proper strategies that allow for tuning the reactivity of CTES materials, thus improving their properties and final performances.

Subtask C: State of Charge – SoC Determination
The subtask's main objective is to develop techniques with which the SoC of a CTES can be determined in a reliable and cost-efficient way.

Subtask D: Stability of PCM and TCM
The subtask's main objective is to arrive at PCM and TCM with predictable and improved stability.

Subtask E: Effective Component Performance with Innovative Materials
The subtask's main objective is to improve material-component interaction for optimal system performance.

Collaboration with Other IEA TCPs

Task 67 is a fully joint Task with the IEA Energy Storage (ES) TCP Task 40. The Task Manager for the ES Task 40 part is Andreas Hauer, ZAE Bayern, Germany.

Collaboration with Industry

Three industries are participating in the Task: Sunamp (United Kingdom), Engineer (Portugal), and Rubitherm Technologies (Germany).

Task Duration

This Task started in October 2021 and will end in September 2024.

Participating Countries

Austria, Canada, China, Denmark, France, Germany, Italy, Netherlands, Norway, Portugal, Slovenia, Spain, Switzerland, United Kingdom, United States

Work During 2023

Several round-robin tests on PCM and TCM were conducted and evaluated in Subtask A. These results were discussed to derive possible improvements to the applied measurement procedures. The current material database (thermalmaterials.org) was reviewed, and based on the experts' feedback, a requirements document was developed for further development of the database.

A.1 Round robin tests

In A.1.1: Thermal conductivity and thermal diffusivity of liquids, solids, and packed beds, a PCM (paraffin wax CAS 8002-74-2; melting temperature 53°C - 58°C) was examined by 12 institutes using a wide variety of measurement methods compared the results. These included the “Laser Flash”, “Transient Plane Source”, and the “Hot Wire” method. Building on these results, the methods for uncertainty assessment were also discussed. With the measurement protocol and evaluation methods developed, good comparability of the data across all procedures could be achieved.

In A.1.2: Specific heat capacity of powdery materials, six institutes measured and evaluated a TCM (SrBr2) using different DSC methods (see Figure 1).

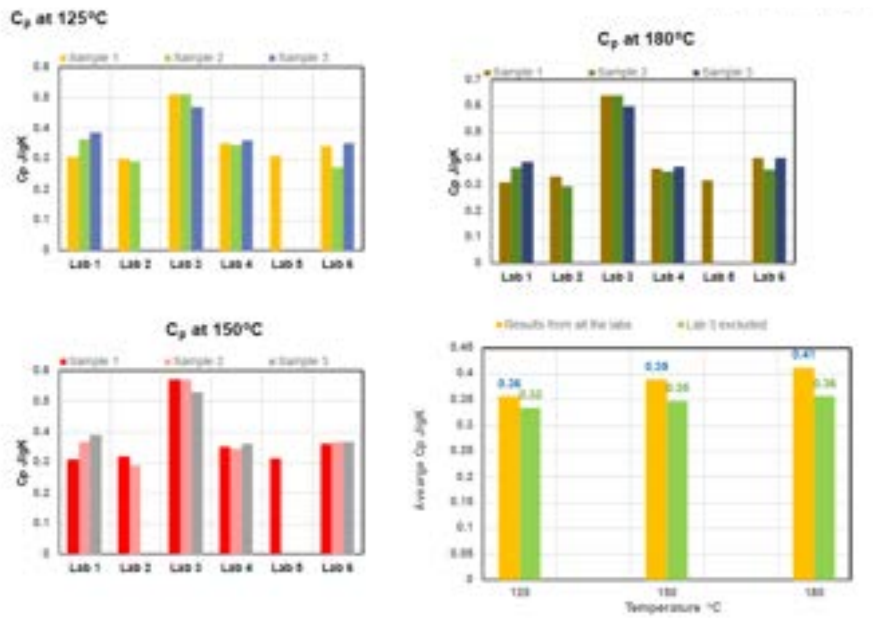
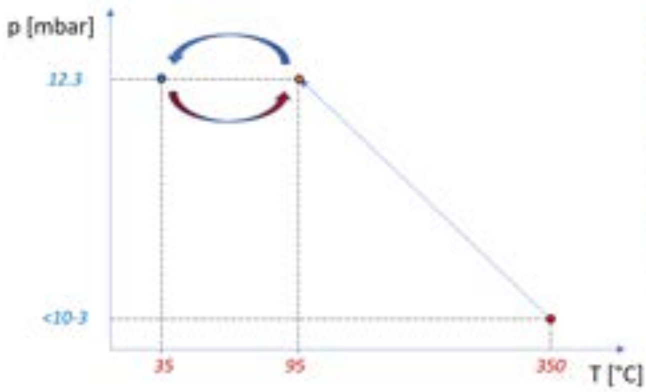


Figure 1: Six institutes measured and evaluated the specific heat capacity of powdery materials, a TCM (SrBr2), using different DSC methods.

The deviations from Laboratory 3 are currently under discussion. The procedure used shows good comparability of the measurement results; further tests with another TCM material are already planned.

In A.1.3: Enthalpy change due to sorption/chemical reaction, the measuring method for a zeolite 13X material was defined (see Figure 2).



Phase	Temperature [°C]	Pressure [mbar]	Duration
Desorption	350 °C	< 10-3	> 6 h
Equilibrium	95 °C	12.3	Until stabilization
Adsorption	95->35 °C	12.3	Until stabilization
Desorption	35->95 °C	12.3	Until stabilization

Figure 2: Enthalpy change due to sorption/chemical reaction, the measuring method for a zeolite 13X material was

Although only a few results have been received, six institutes have expressed interest. The measurement results will be compared at the next expert meeting in Q2/2024.

In A.1.4 Thermal expansion, density and viscosity determination, the density measurements were carried out on a paraffin wax CAS 8002-74-2 (melting temperature 53°C – 58°C) and compared. There was excellent agreement in the liquid range but deviations in the solid state. To limit the spread, measurement instructions about the buoyancy method were forwarded to all participants.

Five institutes measured the viscosity of a reference standard and the paraffin wax CAS 8002-74-2 in the liquid range. The paraffin's dynamic viscosity data at 70°C show an average of $\eta = 4.712$ mPa·s with an expanded measurement uncertainty U(k=2) = 0.079 mPa·s (which corresponds to approx. 3%). In a further experiment, the data will now also be recorded from T = 60 °C - 85 °C.

A.2 Database

Activity A.2 will continue to be supported by ISE and AIT to promote the database's further development. Ten institutes have agreed to provide their feedback on the current database. In particular, the restructuring of the current database and website “thermalmaterials.org” was discussed. A detailed survey and several online meetings were conducted to discuss the new database concept, design, content, and user management.

These discussions defined a “Software Requirement Specification” that is currently being discussed with various web developer companies.

Subtask B: CTES Material Improvement

A report related to the various methods to improve energy densities and tune the working temperatures of TCMs and PCMs was published (see Figure 3). It was also decided to prepare an extract of the report to share with a broader audience.

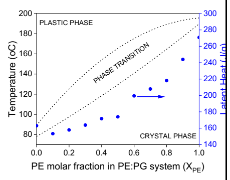
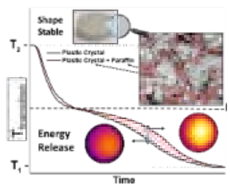
PCMs	Materials	Transition	Improving strategies	Expected results
	Novel ternary mixtures of salt hydrates, salts, and water (-70 -120 °C) Organic PCMs Fatty acids, Esters, Paraffins, Salt hydrates, natural oils (15-20 °C) Plastic Crystals (40-200 °C), Ionic Plastic Crystals (20-120 °C)	solid-liquid solid-solid	 New formulations 	- Theoretical prediction and experimental determination - New solid-liquid and solid-solid systems design with tailored temperatures and latent heat. - Mitigation of subcooling - Polymorphism suppression
	S-L and S-S PCM Hybrid PCM-TCM concept: S-L and S-S PCM as a TCM (salt hydrates) matrix	Combined composites		- Latent heat enhancement - Shape stabilization - Solving compatibility issues

Figure 3: An example of improving strategies for PCMs.

Began work on two reports on PCMs and TCMs composites to be delivered at the end of the Task. These reports will report on the work carried out by the materials experts in Subtask B and include some key literature work. Task participants discussed how to quantify and how the improvement of the materials impacts the TES system. To answer these questions, it was decided to follow two different approaches for TCMs and PCMs. In the case of TCMs, a joint document on “materials into system” will be prepared. At the same time, for PCMs, it was decided to prepare a map of materials, including all the work done concerning the use of carbon-based materials to improve PCMs properties. The key parameters collected will be used in a numerical model (for a certain system configuration) to build Ragone plots (specific power versus specific energy). This could be a first step to defining the state-of-the-art related to the types of materials that could be applied to other materials and properties in the following steps. The final goal is to have a clear picture of the degree of development reached up to now and define guidelines for materials improvements when considering specific applications.

Subtask C: State of Charge – SoC Determination

Most of the three Subtask C activities were completed in 2023. This includes 1) an inventory of promising material properties and related measurement techniques for both PCM and TCM SoC thermal energy storage systems, 2) a collection of experimental and numerical proof of concepts, including tested measurement techniques and sensor technologies, and 3) a description of application requirements. Results illustrating the state-of-the-art state-of-charge (SoC) determination of either PCM or TCM CTESs are now being summarized in the Subtask report currently being developed.

The following preliminary conclusions were presented during the SHC Solar Academy webinar in November 2023. For PCM CTES, the combination of bulk temperature and heat flux measurement is the most common measurement approach used in the laboratory set-ups of the 25 participant studies examined, and the reported novel techniques are potentially less complex in their application (once developed). For TCM CTES, adsorbate content of sorption material and mass of reactants in closed vessels measurement is the most common measurement approach used in the laboratory set-ups of 17 of the participant studies, and the reported novel techniques are non-intrusive and are important for large and high-temperature solutions.

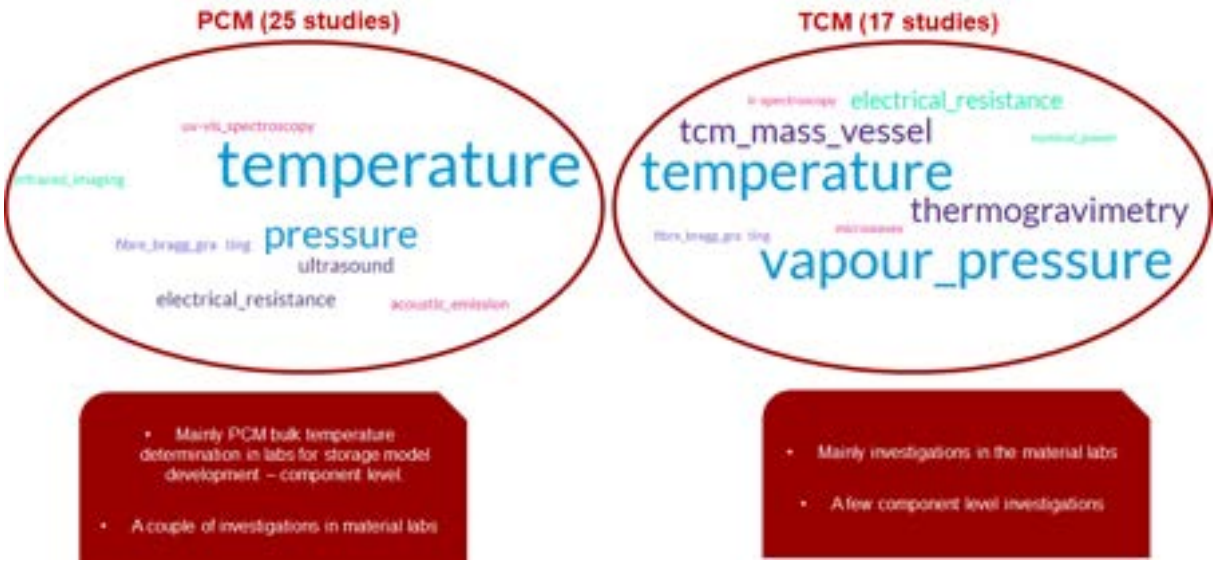


Figure 4: Subtask C: State of Charge determination measurements techniques applied by Task experts (weighted)

Subtask D: Stability of PCM and TCM

In 2023, mapping degradation of PCM and TCM with the approach developed by Ángel Serrano of *CIC energiGUNE* was the focus of Subtask D. This approach connects the degradation mechanisms (e.g., phase separation, corrosion, polymorphism) with their effect on the performance on CTES material level (e.g., change in transition enthalpy or thermal conductivity) and CTES system (e.g., change in power or capacity). The degradation mechanisms are specified by their dependence on application conditions, called degradation factors (e.g., time, heating/cooling rate, and atmosphere). The following figure illustrates this approach for organic plastic crystals – a material class used as solid-solid PCM.

Organic Plastic Crystals

Degradation Factors: Temperature	Thermal cycling	Atmosphere	Pressure	External agents (lct, capsule, HTF...)	Mechanical Stress	Degradation Mechanism	Effect on Material: (A) Thermal conductivity decrease	(B) Transition temperature displacement	(C) Enthalpy decrease	(D) Mass loss	(E) Shape variation
	X					*Phase segregation*	1	2	1	0	0
X	X		X			*Sublimation*	0	2	2	2	0
		X		X		*Water uptake*	1	1	2	0	2
X	X				X	*Shape-stability failure*	0	0	0	2	2
	X		X			*Hysteresis*	0	2	0	0	0

Effect on TES system

TES configuration/App	Fixed packed bed based on solid-solid PCM			
Power	Efficiency	TES Capacity	Service Life	
A+B	A+B+C	C+D	D+E	

Figure 5: Mapping degradation of PCM and TCM; this chart illustrates this approach for organic plastic crystals – a material class used as solid-solid PCM.

Subtask E: Effective Component Performance with Innovative Materials

The overall goals of Subtask E are 1) to make it possible to compare different components and 2) to assess how the use of different CTES materials affects the performance of a storage unit.

2023 Performance charaterization of PCM TES components

The different aproaches were applied to several configurations of PCM components to assess the capability of characterize and enable comparision between the components.

A set of performance parameters is foreseen to be required.

2023 Experimental characterization of PCM TES components

Based on the existing methodologies for PCM TES components characterization followed by the subtask participants, a draft of guidelines for experimental characterization was proposed.

2023 PCM properties and component performance interaction

Two participants have contributed with experimental results on performance of the same component with different PCM to assess the PCM-component performance interaction.

Work Planned For 2024

Subtask A: Material Characterisation and Database

A.1 Round robin tests

In activity A.1.1: Thermal conductivity and thermal diffusivity of liquids, solids and packed beds, an additional round-robin test is planned. From the first round-robin test of the PCM, data are still needed to determine the actual uncertainty of the participating institutions' results. This missing data should be prepared until the next expert meeting in Lucerne. Additionally, a measurement procedure for thermal conductivity/thermal diffusivity measurements of a Zeolite 13X is being developed.

In activity A.1.2: Specific heat capacity of powdery materials, ongoing activities include measuring the specific heat capacity of the hydrated $SrBr_2.6H_2O$ and the anhydrous Zeolite 13X. The measurement procedures for both round robins are drafted, and the first results should be ready for the next expert meeting.

In A.1.3: Enthalpy change due to sorption/chemical reaction, only a few results for the Zeolite 13X have been received, and six institutes have expressed their interest. A comparison of the obtained measurement results is planned at the next expert meeting in April.

In activity A.1.4 Thermal expansion, density and viscosity determination, the viscosity measurement on the paraffin wax CAS 8002-74-2 PCM will also be recorded from T = 60°C - 85°C.

A.2 Database

The “Software Requirement Specification” – SRS document developed in the former period will continue to be discussed with web developer companies. The current “https://thermalmaterials.org/” website and database must be transferred to another provider, and the new features, defined in the SRS, must be implemented by a professional web developer company. Discussions and negotiations are currently underway.

Subtask B: CTES Material Improvement

The work planned in 2024 includes preparing the two reports related to PCMs and TCMs composites for improved thermophysical properties. Moreover, two documents related to “materials into system,” possibly addressing guidelines for material improvements, will be prepared for PCMs and TCMs.

Subtask C: State of Charge – SoC Determination

The first results of tests with novel methods for the SOC determination in sorption materials will be presented and discussed. Further work will be done on the third Subtask C activity, “Description of application requirements,” dealing with system control requirements.

Subtask D: Stability of PCM and TCM

The next step in Subtask D is to collect further input from the Task experts to discuss a possibly required revision of the degradation mapping table. Additional examples of TCM degradation studies are needed. With more examples collected, drafting the report of Subtask D will be started.

Subtask E: Effective Component Performance with Innovative Materials

Further work is needed to construct a set of KPIs for TCM and gather input for the component performance testing methods used.

For PCM, planned activities are to finalize the guidelines for PCM components characterization and to work on the final report with the conclusions from the work on performance characterization and PCM properties-component interaction.

Dissemination Activities In 2023

Reports, Published Books

Author(s) / Editor	Title	Report No.
W. van Helden, W., Fumey, B., Englmair, G., Kerscher, F., Cuypers, R., Groulx, D., Lager, D., Doppiu, S., Rathgeber, C.	Technology Position Paper: Compact Thermal Energy Storage	Technology Position Paper: Compact Thermal Energy Storage. International Energy Agency, SHC TCP.
A. Hubman, J. Volavšek, T. Urbič, N. Zabukovec Logar, F. Merzel	Water–aluminum interaction as driving force of Linde Type A aluminophosphate hydration	https://dirros.openscience.si/IzpisGradiva.php?id=16888, DOI: 10.3390/nano13172387.
Andreas König-Haagen; Moritz Faden; Gonzalo Diarce.	A CFD results-based reduced-order model for latent heat thermal energy storage systems with macro-encapsulated PCM	Journal of Energy Storage. 73, Elsevier Ltd, 2023.
L. Quant, G. Diarce, L. Bouzas, A. García-Romero	A comprehensive study of the phase segregation of a urea-based phase change material tested under thermal cycling conditions	Journal of Energy Storage. 60, 2023.
A. König-Haagen et al	Analysis of the discharging process of latent heat thermal energy storage units by means of normalized power parameters	Journal of Energy Storage. 72, Elsevier Ltd, 2023.
A. König-Haagen, G. Diarce	Comparison of Corrected and Uncorrected Enthalpy Methods for Solving Conduction-Driven Solid/Liquid Phase Change Problems.	Energies. 16, 2023.

A. König-Haagen; G.Diarce.	Prediction of the discharging time of a latent heat thermal energy storage system with a UA approach.	Journal of Energy Storage. 73, Elsevier Ltd, 2023.
M. Navarro, G. Diarce, A. Lázaro, A. Rojo	Comparative study on bubbling and shearing techniques for the crystallization of xylitol in TES systems	Results in Engineering. 17, 2023.
G. Englmair	Case 1: DTU optimerer faseskiftende materialers høje energitæthed til kompakt og decentral energilagring. In Status Styrker Synergier: DaCES Rapport om Energilagring i Danmark 2023 (pp. 15).	DaCES – Dansk Center for Energilagring (website)

Journal Articles, Conference Papers, etc.

Author(s) / Editor	Title	Publication / Conference	Bibliographic Reference
O. Galteland, M. Gouis, J. Salgado-Beceiro and A. Evault	Fourteen months operation of a 200 kWh latent heat storage pilot	2023 8th International Conference on Smart and Sustainable Technologies - SpliTech	IEEE, pg. 1-5
Jorge Salgado Beceiro, Ragnhild Sæterli, Magnus Rotan, Jan Hendrik Cloete, Margaux Gouis and Alexis Sevault	Thermochemical Energy Storage: an approach to integration pathways	2023 8th International Conference on Smart and Sustainable Technologies - SpliTech	IEEE, pgp. 1-4
Fride Vullum-Bruer, Magnus Rotan, Jorge Salgado-Beceiro, Olai Brevik Mykland, Ragnhild Saeterlie, Alexis Sevault, José Lara Cruz, Jawad Rabbi, Jean-Pierre Bedecarrats	Exploring supercooling phenomena through extensive experimental method design	Eurotherm Seminar #116 - Innovative Solutions For Thermal Energy Storage Deployment	May 2023
Jorge Salgado-Beceiro and Alexis Sevault	Experimental investigation of phase change material integrated in a gasketed-plate heat exchanger	Eurotherm Seminar #116 - Innovative Solutions For Thermal Energy Storage Deployment	May 2023
Edurne Erkizia, Christina Strunz, Jean-Luc Dauvergne, Guido Goracci, Ignacio Peralta, Ángel Serrano, Amaya Ortega, Beatriz Alonso, Francesca Zanoni, Michael Düngfelder, Jorge S. Dolado, Juan Jose Gaitero, Christoph Mankel &	Cement Based Materials with PCM and Reduced Graphene Oxide for Thermal Insulation for Buildings	SynerCrete 2023	https://doi.org/10.1007/978-3-031-33211-1_113

Eduardus Koenders			
Ángel Serrano, Sergio Santos, Jean-Luc Dauvergne, Juan Miguel López del Amo, Mikel Durán, Maria Taeño, Stefania Doppiu, Elena Palomo Del Barrio	Effect of processing on thermal properties of pentaglycerine-based solid-solid phase change materials	Materials Today Energy	https://doi.org/10.1016/j.mtener.2023.101472
Taeño, M.; Adnan, A.; Luengo, C.; Serrano, Á.; Dauvergne, J.-L.; Crocomo, P.; Huerta, A.; Doppiu, S.; Palomo del Barrio, E.	Improved Thermophysical and Mechanical Properties in LiNaSO4 Composites for Thermal Energy Storage	Nanomaterials	https://doi.org/10.3390/nano14010078
Jorge L. Lopez-Morales, Jonatan Perez-Arce, Angel Serrano, Jean-Luc Dauvergne, Nerea Casado, Aginmariya Kottarathil, Elena Palomo Del Barrio, Eduardo J. Garcia-Suarez	Protic dialkylammonium-based ionic liquids as promising solid-solid phase change materials for thermal energy storage: Synthesis and thermo-physical characterization	Journal of Energy Storage	https://doi.org/10.1016/j.est.2023.108379
Artem Nikulin, Yaroslav Grosu, Jean-Luc Dauvergne, Asier Ortuondo, Elena Palomo del Barrio	Physical dealloying for two-phase heat transfer applications: Pool boiling case	International Communications in Heat and Mass Transfer	https://doi.org/10.1016/j.icheatmasstransfer.2023.106913
Duran, M., Nikulin, A., Serrano, A., Dauvergne, J. L., Grosu, Y., Labidi, J., & Del Barrio, E. P.	Jet-Injection In Situ Production of PVDF/PCM Composite Fibers for Thermal Management	ACS omega	https://doi.org/10.1021/acsomega.3c02318
König-Haagen, A.*, Höhlein, S., Lazaro, A., Delgado, M., Diarce, G., Groulx, D., Herbinger, F., Patil, A., Englmair, Wang, G., Abdi, A., Chiu, J.N.W., Xu, T., Rathgeber, C., Pöllinger, S., Gschwander, S., Gamisch, S.	Analysis of the discharging process of latent heat thermal energy storage units by means of normalized power parameters	Journal of energy storage	Journal Of Energy Storage, 2023, V. 72, 108428.
Azad, M., Groulx, D*, Donaldson, A.	Solidification of phase change materials in horizontal annuli	Journal of Energy Storage	Journal Of Energy Storage, 2023, V. 57, 106308
D'oliveira, E.J.*, Costa, T., Zabiegaj, D., Azimov, U., Groulx, D., Costa Pereira, S.C.	Experimental investigation on the thermal performance of low-temperature om55/gnps/span80 nanocomposites	Heat Powered Cycles Conference 2023	Heat Powered Cycles Conference 2023, Edinburgh, UK, 2023, 15 pg.
Callaghan, R.L., D'oliveira, E.J., Groulx, D.*, Costa Pereira, S.C.	Characterization of a small-scale pcm-heat exchanger: impact of pcm selection	17th International Heat Transfer Conference	17th International Heat Transfer Conference, Cape Town, South Africa, 10 pg.

Callaghan, R.L.*, Groulx, D.	Experimental characterization of a pcm-heat exchanger: impact of pcm properties on comparison metrics	Experimental characterization of a pcm-heat exchanger: impact of pcm properties on comparison metrics	Eurotherm Seminar: Innovative Solutions For Thermal Energy Storage Deployment, Lleida (Spain), 2023 4 pg.
Thonon M., Fraisse G., Zalewski L., Pailha M.	Simultaneous charging and discharging processes in latent heat thermal energy storage: A review.	Thermal Science and Engineering Progress	47 (2024) 102299. Accepted 20/11/2023, https://doi.org/10.1016/j.tsep.2023.102299
Wenye Lin, Stefan Gschwander, Wenji Song, Ziping Feng, Mohammed M. Farid	Preparation, characterisation and property modification of a calcium chloride hexahydrate phase change material slurry with additives for thermal energy transportation	International Journal of Refrigeration	International Journal of Refrigerantion, vol.160, pp. 312-328. DOI: https://doi.org/10.1016/j.ijrefrig.2024.02.010
E. Legotin, G. Issayan, B. Zettl, M. Brandstetter, C. Rankl, F. Winter	Near-infrared sensor for in-line state-of-charge determination of zeolite-based heat storages	NIR 2023, Innsbruck, Austria, 21st International Conference on Near Infrared Spectroscopy	https://doi.org/10.1177/09603360231165217
Kieskamp, B., Mahmoudi, A., Shahi, M	Reaction kinetics of the hydration of potassium carbonate including the influence of metastability	Eurotherm Seminar #116	https://doi.org/10.21001/eurotherm.seminar.116. 2023
Kieskamp, B., Mahmoudi, A., Shahi, M	A novel multi-reactor system for thermochemical heat storage through detailed modeling of K2CO3 particles	Journal of Energy Storage	https://doi.org/10.1016/j.est.2023.110028
Aastha, A., Mahmoudi, A., Shahi, M	Volume variation in a thermochemical material- An experimental study	Eurotherm Seminar #116	https://doi.org/10.21001/eurotherm.seminar.116. 2023
Aastha, A., Mahmoudi, Donkers, P. A. J., Brem, G.A., Shahi, M	Microstructural changes in thermochemical heat storage material over cycles: Insights from micro-X-ray computed tomography	Renewable Energy	https://doi.org/10.1016/j.renene.2024.120045
Aastha, A., Mahmoudi, A., Jorge Martinez-Garcia & Philipp Schuetz, Shahi, M	Characterizing Changes in Salt Hydrates using Micro X-Ray Computed Tomography for Improved Cyclability in Thermochemical Materials	ICT'24 conference	https://www.fh-ooe.at/ict2024/abstractbooklet/
Werner, Jakob Smith, Jakob Stöger, Berthold Artner, Werner	Characterization of Ca-Dicarboxylate Salt Hydrates as Thermochemical Energy Storage Materials	Journal Article	Werner, J., et al. Crystals, 2023. **13**, DOI:

Werner, Andreas Weinberger, Peter			10.3390/cryst13101518.
Smith, Jakob Werner, Andreas Weinberger, Peter	Dehydration performance of a novel solid solution library of mixed Tutton salts as thermochemical heat storage materials	Journal Article	Journal of Energy Storage. 2024. 78, DOI: 10.1016/j.est.2023.110003
Sebastian Gamisch, Moritz Kick, Franziska Klünder, Julius Weiss, Eric Laurenz, Thomas Haussmann	Thermal Storage: From Low-to-High-Temperature Systems	Journal Energy Technology	Energy Technology 2023, 2300544, https://doi.org/10.1002/ente.202300544
Kieskamp, B., Mahmoudi, A., Shahi, M	Reaction kinetics of the hydration of potassium carbonate including the influence of metastability	Eurotherm Seminar #116	https://doi.org/10.21001/eurotherm.seminar.116.2023
Kieskamp, B., Mahmoudi, A., Shahi, M	A novel multi-reactor system for thermochemical heat storage through detailed modeling of K2CO3 particles	Journal of Energy Storage	https://doi.org/10.1016/j.est.2023.110028
Aastha, A., Mahmoudi, A., Shahi, M	Volume variation in a thermochemical material- An experimental study	Eurotherm Seminar #116	https://doi.org/10.21001/eurotherm.seminar.116
Aastha, A., Mahmoudi, Donkers, P. A. J., Brem, G.A., Shahi, M	Microstructural changes in thermochemical heat storage material over cycles: Insights from micro-X-ray computed tomography	Renewable Energy	https://doi.org/10.1016/j.renene.2024.120045
Aastha, A., Mahmoudi, A., Jorge Martinez-Garcia & Philipp Schuetz, Shahi, M	Characterizing Changes in Salt Hydrates using Micro X-Ray Computed Tomography for Improved Cyclability in Thermochemical Materials	ICT'24 conference	https://www.fh-ooe.at/ict2024/abstractbooklet/
Werner, Jakob Smith, Jakob Stöger, Berthold Artner, Werner Werner, Andreas Weinberger, Peter	Characterization of Ca-Dicarboxylate Salt Hydrates as Thermochemical Energy Storage Materials	Journal Article	Werner, J., et al. Crystals, 2023. **13**, DOI: 10.3390/cryst13101518
Smith, Jakob Werner, Andreas Weinberger, Peter	Dehydration performance of a novel solid solution library of mixed Tutton salts as thermochemical heat storage materials	Journal Article	Smith, J., et al. Journal of Energy Storage. 2024. 78, DOI: 10.1016/j.est.2023.110003

Sebastian Gamisch, Moritz Kick, Franziska Klünder, Julius Weiss, Eric Laurenz, Thomas Haussmann	Thermal Storage: From Low-to-High-Temperature Systems	Journal Energy Technology	Energy Technology 2023, 2300544, https://doi.org/10.1002/ente.202300544
Andreas König-Haagen, Stephan Höhlein. Ana Lazaro, Monica Delgado, Gonzalo Diarce, Dominic Groulx, Florent Herbinger , Ajinkya Patil, Gerald Englmair, Gang Wang, Amir Abdi, Justin N.W. Chiu, Tianhao Xu, Christoph Rathgeber, Simon Pöllinger, Stefan Gschwander, Sebastian Gamisch	Analysis of the discharging process of latent heat thermal energy storage units by means of normalized power parameters	Journal of Energy Storage	Journal of Energy Storage 72 (2023) 108428, DOI: https://doi.org/10.1016/j.est.2023.108428
Čebulj, Daša, Mal, Suzana, Ristić, Alenka, Zabukovec Logar, Nataša	Synthesis of Al-doped hierarchical silicate for sorption thermal battery	29th Annual Meeting of the Slovenian Chemical Society, 13.-15. september 2023, Portorož, Portorose, Slovenija	
Smith, Jakob, Werner, Jakob, Kapsamer, Frieda Maria, Ristić, Alenka, Werner, Andreas, Weinberger, Peter	Exploring the synergies of gamma alumina and sulfate salt hydrates in thermochemical energy storage.	29th Annual Meeting of the Slovenian Chemical Society, 13.-15. september 2023, Portorož, Portorose, Slovenija	.
Marčec, Jan, Djinović, Petar, Zabukovec Logar, Nataša, Ristić, Alenka	Transition metal modified microporous materials for thermal battery	FEZA 2023: 9th Conference of the Federation of the European Zeolite Associations, Portorž-Portorose Slovenija, 2-6 July 2023	https://feza2023.org/en/
Marčec, Jan, Zabukovec Logar, Nataša, Ristić, Alenka	Towards green synthesis of ZIF-90 for thermal battery application	5th European Conference on Metal Organic Frameworks and Porous Polymers), Granada, Spain 24-27 September 2023	https://www.euromof2023.com/images/site/Abstract_EUROMOF2023.pdf
Byrne, Ciara Susan, Vodlan, Katja, Golobič, Amalija, Zabukovec Logar, Nataša	Noval synthesis methods of ZIF-71 and ZIF-93 for sorption based applications	34. Deutsche Zeolith-Tagung : 21-23 February 2023, Universität Wien, Österreich	
Byrne, Ciara Susan, Vodlan, Katja, Lacomi, Paul, Golobič, Amalija, Zabukovec Logar, Nataša	Green synthesis methods of ZIF-71 and ZIF-93 for thermal battery applications	5th European Conference on Metal Organic Frameworks and Porous Polymers (EuroMOF2023): Granada, 24-27 September 2023	
Vodlan, Katja, Byrne, Ciara Susan, Golobič, Amalija, Zabukovec Logar, Nataša	Green synthesis of ZIF-71 and ZIF-93 with preliminary evaluation for heat storage applications	29th Annual Meeting of the Slovenian Chemical Society, 13.-15. september 2023, Portorož, Portorose, Slovenija	
Mlakar, Urška, Ristić,	Experimental system for	Eurotherm Seminar #116 :	https://repositori.udl.c

Alenka, Stritih, Uroš.	testing adsorption heat storage materials	Innovative solutions for thermal energy storage deployment : 24-26 May 2023, Lleida, Spain	at/items/29285fea-468a-4225-abe3-97d7010136a7
Miguel Navarro, Gonzalo Diarce, Ana Lázaro, Ander Rojo, Mónica Delgado	Comparative study on bubbling and shearing techniques for the crystallization of xylitol in TES systems	Results in Engineering	Results in Engineering 17 (2023) 100909, DOI: https://doi.org/10.1016/j.rineng.2023.100909
Andreas König-Haagen et al.	Analysis of the discharging process of latent heat thermal energy storage units by means of normalized power parameters	Journal of Energy Storage	Journal of Energy Storage 72, Part C (2023) 108428, DOI: https://doi.org/10.1016/j.est.2023.108428
Andreas König-Haagen, Gonzalo Diarce ENEDI Research Group, Department of Energy Engineering, Faculty of Engineering of Bilbao, University of the Basque Country UPV/EHU, Bilbao, Spain	Prediction of the discharging time of a latent heat thermal energy storage system with a UA approach	Journal of Energy Storage	Journal of Energy Storage 73 (2023): 108849
Pablo Moreno; Gonzalo Diarce; Olatz Irulegi; Alba Arias; Iñaki Gomez-Arriaran.	Study of an underground cistern as a thermal storage with HVACR system via heat pump assisted by PV: the case of the IWER building in Pamplona.	EESAP 14 - 14th International Conference on Energy Efficiency and Sustainability in Architecture and Urbanism	
Pablo Moreno; Gonzalo Diarce; Olatz Irulegi; Alba Arias.	Analysis of an existing cistern as thermal storage at the rehabilitation of the IWER building in Pamplona and assessment of the solar assisted HVACR production control	CNIT 13 - 13th National and 4th International Conference in Engineering Thermodynamics	
Lourdes Bouzas; Ana Garcia-Romero; Pello Larrinaga; Gonzalo Diarce.	Experimental Assessment of a Plate-Based LHTES: Comparison Between Compressed Expanded Graphite Plates Infiltrated with a PCM, and Bulk PCM Plates Macroencapsulated n Aluminum	CNIT 13 - 13th National and 4th International Conference in Engineering Thermodynamics	
Eukene Garcia; Gonzalo Diarce.	On the use of TGA for the study of degradation of thermal energy storage materials:analysis of the influence of evaporation	CNIT 13 - 13th National and 4th International Conference in Engineering Thermodynamics	
Eukene Garcia; Gonzalo Diarce.	On the use of TGA for the study of degradation of	Medicta 2023, Oporto	

	thermal energy storage materials: analysis of the influence of evaporation and mass sample		
A. Crespo, A. Frazzica, C. Fernández, A. de Gracia	Optimizing the discharge process of a seasonal sorption storage system by means of design and control approach	Journal Publication	Journal of Energy Storage, Volume 60, April 2023, 106652, DOI: 10.1016/j.est.2023.106652
G. Airò Farulla, V. Palomba, D. Aloisio, G. Brunaccini, M. Ferraro, A. Frazzica, F. Sergi	Optimal design of lithium ion battery thermal management systems based on phase change material at high current and high environmental temperature	Journal Publication	Thermal Science and Engineering Progress, Volume 42, 1 July 2023, 101862. DOI: 10.1016/j.tsep.2023.101862
G. Airò Farulla, V. Brancato, V. Palomba, Y. Zhang, G.E. Dino, A. Frazzica	Experiments and Modeling of Solid–Solid Phase Change Material-Loaded Plaster to Enhance Building Energy Efficiency	Journal Publication	Energies, Volume 16, March 2023 2384. DOI: 10.3390/en16052384
A. Frazzica, V. Palomba, A. Freni	Development and Experimental Characterization of an Innovative Tank-in-Tank Hybrid Sensible–Latent Thermal Energy Storage System	Journal Publication	Energies, Volume 16, February 2023 1875, DOI: 10.3390/en16041875
Talebi, Elija; Morgenstern, Leander; Würth, Manuel; Kerscher, Florian; Spliethoff, Hartmut	Effect of particle size distribution on heat transfer in bubbling fluidized beds applied in thermochemical energy storage	Journal Publication	Fuel 344, 2023
Morgenstern, L.; Talebi, E.; Kerscher, F.; Spliethoff, H.	Experimental investigation of CaO/Ca(OH)2 for thermochemical energy storage – commissioning of a 0.5 kWh experimental setup	Journal Publication	Fuel 345, 2023
Morgenstern, L.; Ohmstedt, S.; Kerscher, F.; Spliethoff, H.	Particle Properties of CaO/Ca(OH)2 Throughout Cyclisation in a Fluidized Bed for Thermochemical Energy Storage – Consequences for Fluidization	Conference Proceedings	Heat Powered Cycles Conference 2023, 2023, pg. 520 - 528
Benjamin Fumeya, Robert Weber, Luca Baldini	Heat transfer constraints and performance mapping of a closed liquid sorption heat storage process	Publication	Applied Energy 335 (2023) 120755
Zhu, Y., Englmair, G., Huang, H., Dragsted, J., Yuan, Y., Fan, J., & Furbo,	Numerical investigations of a latent thermal energy storage for data center	Applied Thermal Engineering	Applied Thermal Engineering, 236 Part B, Article 121598. https://doi.or

S.	cooling.		g/10.1016/j.applthermaleng.2023.121598
Filonenko, K., Dominkovic, D. F., Jensen, A. U., & Englmair, G.	Investigation of cold storage integration in a Danish data center.	Building Simulation Conference Proceedings	In Building Simulation Conference Proceedings (Vol. 18, pp. 2875 - 2878). International Building Performance Simulation Association, DOI: https://doi.org/10.26868/25222708.2023.1560
König-Haagen, A., Höhlein, S., Lázaro, A., Delgado, M., Diarce, G., Groulx, D., Herbinger, F., Patil, A., Englmair, G., Wang, G., Abdi, A., Chiu, J. N. W., Xu, T., Rathgeber, C., Pöllinger, S., Gschwander, S., & Gamisch, S.	Analysis of the discharging process of latent heat thermal energy storage units by means of normalized power parameters.	Journal of Energy Storage	Journal of Energy Storage, 72, Article 108428, DOI: https://doi.org/10.1016/j.est.2023.108428
Dannemand, M., Englmair, G., Kong, W., & Furbo, S.	Experimental investigations of multiple heat storage units utilizing supercooling of sodium acetate trihydrate: Stability in application size units.	Journal of Energy Storage	Journal of Energy Storage, 86, Article 111194, DOI: https://doi.org/10.1016/j.est.2024.111194
Simonsen, Galina; Ravotti, Rebecca; O'Neill, Poppy; Stamatiou, Anastasia	Biobased phase change materials in energy storage and thermal management technologies.	Renewable and sustainable energy reviews, 184, 2023, 113546	
Martinez Garcia, Jorge; Gwerder, Damian; Guarda, Dario; Fenk, Benjamin; Stamatiou, Anastasia; Worlitschek, Jörg; Schütz, Philipp	Study of the solidification behaviour of calcium chloride hexahydrate by in-situ X-ray computed tomography.	Research and Review Journal of Nondestructive testing, 1(1), 2023, 1-6	
Martinez Garcia, Jorge; Gwerder, Damian; Wahli, Fabian; Guarda, Dario; Fenk, Benjamin; Stamatiou, Anastasia; Worlitschek, Jörg; Schütz, Philipp	Volumetric quantification of melting and solidification of phase change materials by in-situ X-ray computed tomography.	Journal of energy storage, 61, 2023, 106726	
Anastasia Stamatiou, Jorge Martinez-Garcia, Rebecca Ravotti, Poppy O'Neill, Benjamin Fenk, Dario Guarda, Simone Mancin, Damian Gwerder, Ludger J. Fischer, Jörg Worlitschek, Philipp Schuetz	Using in-situ X-ray computed tomography to study the crystallization of salt hydrates.	Proceedings of the Eurotherm Seminar "Innovative solutions for thermal energy storage deployment" 2023	

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# Attendees
Thermal Energy Storage Workshop 2023	Organized by Jorge Salgado-Beceiro and Ragnhild Sæterli (SINTEF Energy Research)	November 30 – December 1, 2023 Trondheim, Norway	100+
Eurotherm Seminar #116	Development of protective coatings for lithium/sodium sulfate salts intended for high-temperature thermal energy storage, Ángel Serrano (CIC energiGUNE)	May 2023 Lleida, Spain	
13CNIT	Oral presentation: Bayón R, Rabasco P. Study of different fatty acids as PCM for latent storage: dependence of thermal degradation with molecular structure	November 29 – December 1, 2023 Castellón de la Plana, Spain	
Eurotherm Seminar #116	Oral presentation Mina Shahi	May 2023 Lleida	~30
Exner Lectures 2023	Presentation. “Crystals and gases unite to save energy” Smith, Jakob	May 2023 Vienna, Austria	~100
Exner Lectures 2023	Poster presentation. “From waste to resource: investigating calcium dicarboxylate hydrates as thermochemical energy torage materials for waste heat storage” Werner, Jakob	Exner Lectures 2023	~100
36th Workshop on Novel Materials and Superconductors	Poster: Novel Materials and Superconductors Smith, Jakob	February 2023 Schladming, Austria	~50
36th Workshop on Novel Materials and Superconductors	Poster: “Synthesis and characterization of novel calcium salt dicarboxylate hydrates as thermochemical energy storage materials” Werner, Jakob	February 2023 Schladming, Austria	~50
6th EuChemS Inorganic Chemistry Conference	Poster: Exploring the Synergies of Gamma Alumina and Tutton Salt Hydrates in Thermochemical Energy Storage	September 2023 Vienna, Austria	~500
6th EuChemS Inorganic Chemistry Conference	Poster: “Solving energy challenges through chemical bonds: calcium dicarboxylate hydrates as thermochemical energy storage materials” Werner, Jakob	September 3 – 7, 2023 Vienna, Austria	~500

Zbornik povzetkov Slovenski kemijski dnevi 2023	Exploring the synergies of gamma alumina and sulfate salt hydrates in thermochemical energy storage	September 2023 Portorož, Slovenia	~200
International Renewable Energy Storage Conference IRES 2023	Presentation “Comparison Of Ageing At Elevated Temperature And Cycling Experiments Of HD-PE: A Degradation Study”, Franziska Klünder	Aachen, Germany	
Lecture at a foreign university EIRES Lunch lecture at Eindhoven Institute for Renewable Energy Systems	Invited lecture: Recent advances in materials for sorption-based thermal batteries Dr. Alenka Ristić and prof. dr. Nataša Z. Logar	May 2023 EIRES, The Netherlands	50
6th EuChemS Inorganic Chemistry Conference	Invited keynote lecture: Development of advanced materials for adsorption thermal battery, Dr. Alenka Ristić	September 2023 Vienna, Austrina	400
ECOS, The 36th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems	Oral Presentation. Design and evaluation of a stirred tank for its use as a thermal energy storage system using xylitol. Miguel Navarro	June 202 Gran Canaria, Spain	
International Conference on Polygeneration- ICP 2023	Oral Presentation. Use of a low cost phase change material emulsion in de-centralized thermal energy storage for district heating network enlargement, José María Marín	July 2023 Kuta, Indonesia	
International Conference on Polygeneration- ICP 2023	Oral Presentation: Study on crystallization of sugar-alcohols. Comparison between xylitol, erythritol and its mixtures. Miguel Navarro	July 2023 Kuta, Indonesia	
XIII National and y IV International Conference on Engineering Thermodynamics (13Cnit)	Poster: Experimental setup to test heat exchanger using PCM slurries as heat transfer fluids. Ana Lázaro	November 2023 Castellón, Spain	
XIII National and y IV International Conference on Engineering Thermodynamics (13Cnit)	Oral Presentation: Validation of a CFD model for the simulation of a stirred tank containing a PCM emulsion. Ana Lázaro	November 2023 Castellón, Spain	
XIII National and y IV International Conference on Engineering Thermodynamics (13Cnit)	Oral Presentation: Nucleation modelling of xylitol in a stirred tank. Miguel Navarro	November 2023 Castellón, Spain	
IEA SHC Task 67 - 5th Task Meeting	T67T40 Viscosity RRT progress. Miguel Navarro	September 2023 Lyon, France	

IEA SHC Task 67 - 4th Task Meeting	T67T40 Viscosity RRT progress. Mónica Delgado	April 2023 Halifax, Canada	
IEA SHC Webinar	Task67/Task40 Compact thermal energy storage materials within components within systems. Wim van Helden	21 November, 2023 Online	
Heat Powered Cycles Conference 2023	Presentation: Leander Morgenstern	September 2023	~ 120
Fluidization XVII 2023	Presentation: Leander Morgenstern	May 2023	~ 100
Fluidization XVII 2023	Presentation: Elija Talebi	May 2023	~ 100
Eurotherm Seminar #116 Advances in Thermal Energy Storage	Presentation: Daniel Lager, Evaluation of thermochemical materials for thermal energy storage applications using TGA-DSC and existing material databases	May 2023 Lleida, Spain	>100
Sorption Friends 3	Presentation: Benjamin Fumey. Mission Innovation Heating and Cooling – Sorption Heat Pump Systems	May 2023 Taormina, Italy	50
PhD “Winter School of ScAIEM” on “Sustainable Energy Transition – Technology and Management Perspecitves”	Guest Lecture: G. Englmair on “Thermal Energy Storage”	March 2023 Stockholm, Sweden	30
IEA Energy Storage Task 41 – 2nd expert meeting on “Economics of Energy Storage”	Presentation: G. Englmair, PCM cold storage for flexible server room cooling – Cool-Data project	May 2023 Linz, Austria	25
Presentation to the Thermal Storage group at DaCES – Danish Center for Energy Storage.	Presentation: G. Englmair, Compact Thermal Energy Storage	Online Denmark	20
SHC Solar Academy Webinar on IEA SHC Task 67 “Compact Thermal Energy Storage”	Presentation: G. Englmair, State of Charge Determination Utilizing Material Response in Compact Thermal Energy Storage	Online hosted by IEA SHC TCP	~120
Conference on “Advanced Energy Storage”	Presentation: G. Englmair, Compact Thermal Energy Storage – Status, perspectives and research example (Cool-Data)	November 2023 Aarhus, Denmark	75
11th Swiss Thermal Energy Storage Symposium	Presentation: G. Englmair, Cool-Data: PCM Cold Storage for Server Room Cooling; Participation in penal debate	January 2024 Lucerene, Switzerland	100
Slovenian Chemistry days	Oral Presentation: The polymorphism of phase-change	September 2023	1

	materials: new discoveries and approaches, Rebecca Ravotti	Portoroz, Slovenia	
European Conference on Non-Destructive Testing (ECNDT)	Oral Presentation: Study of the solidification behaviour of phase change materials by in-situ X-ray computed tomography, Jorge Martinez Garcia	July 2023 Lisbon, Portugal	1
Eurotherm Seminar 2023	Oral Presentation: Using in-situ X-ray computed tomography to study the crystallization of salt hydrates, Anastasia Stamatiou	May 2023 Lleida, Spain	2

Dissemination Activities Planned For 2024

Hold a Summer School at the HSLU in Lucerne, Switzerland, from 2-6 September 2024.

Present Task papers at conferences, including:

- Eurotherm 2024 – 9th European Thermal Sciences Conference, Lake Bled, Slovenia)
- 16th IAE EST CP International Conference on Energy Storage, Lyon, France)
- 14th IIR Conference on Phase-Change Materials and Slurries for Refrigeration and Air Conditioning-PCM 2024, Paris, France
- Eurosun2024,26-29/08 Limassol, Cyprus
- 37th Workshop on Chemistry and Physics of Novel Materials, February 2024
- ISEC 2024, 3rd International Sustainable Energy Conference, April 2024

Scientific papers

- Journal of Thermal Analysis and Calorimetry
- Journal of Energy Storage or International Journal of Heat and Mass Transfer
- Journal of Materials Chemistry

Task Meetings in 2023 and Planned for 2024

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 4	April 24-26, 2023	Halifax, Canada	30 (11 countries)
Task Meeting 5	September 25-27, 2023	Lyon, France	29 + 6 virtual (11 countries)
Task Meeting 6	April 22-24, 2024	Lucerne, Switzerland	

Task 67 Participants

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Task 68 – Efficient Solar District Heating Systems

Dr. Viktor Unterberger
BEST GmbH
Task Manager for The Republic of Austria

Task Overview

Solar technologies offer an efficient option for using CO2-free technologies for local/district heating systems. Therefore, the SHC TCP work on solar district heating systems is continuing in this new Task. Task 68 is providing a platform for research and industry to work together on the opportunities, challenges, and benefits of solar district heating.

The Task is organized into four subtasks:

- Subtask A: Concepts for Efficiently Providing Solar Heat at Medium-high Temperature Level *(Lead Country: Germany)*
- Subtask B: Subtask B: Data Preparation & Utilization *(Lead Country: Austria)*
- Subtask C: Business Models *(Lead Country: Netherlands)*
- Subtask D: Use Cases and Dissemination *(Lead Country: Sweden)*

Scope

Subtask A: Concepts for Efficiently Providing Solar Heat at Medium-high Temperature Level
The main objective of Subtask A is to develop concepts, models and performance measures **to** efficiently provide solar heat by SDH systems, with a special focus on medium-high temperature heat. Specific objectives of Subtask A are:

- Requirements and concepts for planning and designing SDH systems, with a special focus on medium-high temperature heat.
- Configuration/scaling of systems
- Modeling of different technologies on component and system level
- Performance and efficiency definitions
- Testing methods and standardization

Subtask B: Data Preparation & Utilization
The main objective of Subtask B is to increase the efficiency of SDH by taking **the** next step regarding digitalization aspects**,** especially regarding data preparation and utilization. Specific objectives of Subtask B are**:**

- Automated gathering, storing and distribution of data
- Validation of data
- Analysis/monitoring/detection techniques
- Advanced control strategies for plants/systems
- Open data approaches

Subtask C: Business Models
The main objective of Subtask C is to evaluate and identify new business models as well as find ways to make SDH systems more **business-appealing** (e.g.**,** by reducing costs). Specific objectives of Subtask C are**:**

- Investigate current risks and barriers for the success of SDH systems
- Investigate the requirements and needs of district heating grids to integrate solar heat
- Investigate and propagate possible financing and investment schemes for SDH systems
- Ways and possibilities of cost reduction for SDH systems regarding CAPEX and OPEX
- Investigate how energy policy can act as an enabling factor for SDH systems aiming at a medium-term subsidy-free situation.

Subtask D: Use Cases and Dissemination
The main objective of Subtask D is to gather data and insights from real installations and to disseminate the knowledge to industry and **the** public. Specific objectives of Subtask D are**:**

- Description of installations

- Summary of demo applications
- Policy-oriented document for the promotion of efficient temperature SDH systems, especially focusing on medium-high temperatures
- Country reports regarding SDH systems to derive a holistic view of the global situation
- Industry workshops

Collaboration with other IEA TCPs

IEA DHC Annex TS5, *Integrating Renewables*. The level of cooperation will start at a low level and possibly increase after further discussion. Future plans include holding meetings close to the ISEC 2024 and EUROSUN 2024 conferences. In addition, the Task Manager continued a technical and organizational exchange on synergies between the two Tasks.

IEA Bioenergy Task 44. A joint workshop was held in Graz, Austria in January 2023. SHC Task 68 how solar and biomass can work together in Mengsberg, Germany. The outcome was a best practice example, https://task44.ieabioenergy.com/wp-content/uploads/sites/12/2023/12/Task-44-Best-Practice_Mengsberg_Germany_with-SHC68.pdf

Collaboration with Industry

The cooperation rate with industry is high, about 50% among the Task participants. Currently, it is dominated by manufacturers of collectors and solar-based systems. Efforts are underway to better integrate utilities and companies from the field of digitalization into the Task.

Task Duration

This Task started on April 2022 and will end March 2025.

Participating Countries

Austria, China, Denmark, Germany, Italy, Netherlands, Spain, Sweden, Switzerland, Turkey, United Kingdom

Work During 2023

Subtask A: Concepts for Efficiently Providing Solar Heat at Medium-high Temperature Level

Work on the first deliverable, Subtask A: Comparison of different collector technologies was intensified. A template for information collection, including costs, was finalized.

Furthermore, a comprehensive list of collector manufacturers from around the world was created to share the template with. Task participants were assigned manufacturers to contact and request specific information.

Figure 2: Example of how the template information will be transformed into data sheets.

The template input will be transformed into appealing factsheets for the different collector manufacturers to show the different available and mature technologies, see Figure 1.

Subtask B: Data Preparation and Utilization

The open source software was presented, which can provide performance checks and advanced monitoring functionalities for large-scale solar thermal plants and determine if a plant performs as it should. The implemented procedures are the performance Check (ISO 24194:2022) and D-CAT (Dynamic Collector Array Test). The software is open source and can be accessed over a public Git lab repository.

The first Subtask B1 report was finalized. The report provides checklists and recommendations on how to get accessible and reliable data. With the following scope:

- Focus on proven solutions currently in use and showing examples.
- Description of at an overview level. Level where details can be found in cited literature
- Main target group: designers and operators
- Side Target group: researchers

Figure 3: Subtask B - Exemplarily insights regarding the first report RB1

A workshop was held to draft a joint scientific paper in the context of open data. A short recap of the typical storyline for the paper was given and three possible concrete storylines (A, B, C) were discussed. As an example, the structure of storyline A is given below:

- Introduction
  - Open data
  - Open data in solar thermal
  - Research gap
- Possible applications for OD in solar thermal
  - Extensive literature study (which are the ones currently used)
  - Elaboration application possibilities regarding the lifetime of solar thermal plants (Design, Planning, Construction, Operation, Maintenance, Description)
  - Categorization
  - Evaluate the most important application possibilities by a survey among the participants
- Concrete barriers and recommendations for OD
- Conclusion and outlook

Subtask C: Business Models

Based on the author teams formed in 2022, the work was continued regarding the first two reports with the focus on t report RC1 (*Overview of financing and investment schemes and possible new business models*). The overall goals of the report are:

- Focus mainly on the situation of the year 2022, perhaps 2023.
- Meant to give inspiration to policy makers (not an encyclopedia of policy measures)
- Not quantity but quality: a few nice policy examples
- Optional: interviews with the designers of solar thermal policy in various countries
- Input from collector manufacturers and project developers is highly appreciated
- Link to RED III (Renewable Energy Directive)

Furthermore, it was discussed with the technology providers how it could be possible to include the costs in the report RC3 (Measures and possibilities to reduce the costs of SDH systems) where respective data should be gathered together with Subtask A. A first draft regarding Report RC1 was created describing the situation in Germany, Austria and the Netherlands.

Finally, the report RC2 (*Standards and quality criteria for planners and designers of SDH systems*) was introduced and a first discussion was started about what should be the concrete goal of the report. The idea for the report was to make a checklist as shown in the following figure, in order to check if important design aspects had been considering by the system designer.

Stage	Checks
Planning phase	• Is the location fine (oriented south, no shading)? • Is the required area available at low cost (land lease, roof rent)? • Who will invest, who will own and who will operate the plant?
Project preparation	• Make a detailed yield [MWh/year] calculation • Make a detailed calculation for the cost of heat [€/MWh] • User interface: what will the user see and what are control options?
Construction phase	• Will there be inconvenience for the neighbours?
Operation	• Is maintenance guaranteed? • What is the expected lifetime?
Decommissioning	• Anticipate to next generation solar thermal: cheaper, more performant

Figure 4: Example of a checklist for RC2 at the different stages of a solar thermal project and its necessary checks.

Subtask D: Use Cases and Dissemination

The first report on efficient SDH installations in operation or being built was started. And, several industry workshops were held, with the last one in October.

Figure 5: Subtask D - Photos from the industry workshop organized in Harnösand, Sweden.

Together with the industry workshop, a live 1 hour webinar was streamed and recorded for the first time, to view click here.

Work Planned For 2023

Subtask A: Concepts For Efficiently Providing Solar Heat at Medium-high Temperature Level

- Collect all the feedback from the different collector manufactures
- Finish the first deliverable RA1
- Draft a respective news article about the outcomes of RA1
- Start the work on the other reports which are due to March 2025
- Further work on how synergies can be used with IEA DHC TS 5 or other TCPs
- Evaluate whether the work in the subtask can lead to a scientific paper or a joint project

Subtask B: Data Preparation and Utilization

- Starting the work on the remaining reports
- Continue the successful work on RB2
- Draft the report RB3 regarding control strategies
- Continue the work on writing a joint paper addressing the issues of RB4
- Evaluate whether the work in the subtask can lead to another scientific paper or a joint project

Subtask C: Business Models

- Finalize Report RC1 - regarding financing and investment schemes as well as new business models.
- Start and draft report RC2
- Prepare the other reports in order to finish them 2025
- Evaluate whether the work in the subtask can lead to a scientific paper or a joint project

Subtask D: Use Cases and Dissemination

- To Provide an Overview of efficient SDH systems which should be updated throughout the task
- Finalize the first Report RD1
- Work and improve the dissemination website run by Absolicon with the latest Task results
- Carry out further Industry workshops as it has been done 2023
- Publish a news article
- Evaluate whether the work in the subtask can lead to a scientific paper or a joint project

Dissemination Activities In 2023

Reports, Published Books

None at this time.

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
Lukas Feierl, Viktor Unterberger, Claudio Rossi, Bernhard Gerardts, Manuel Gaetani,	Fault detective: Automatic fault-detection for solar thermal systems based on artificial intelligence	https://www.sciencedirect.com/science/article/pii/S2667113123000013	Solar Energy Advances, Volume 3, 2023, 100033, ISSN 2667-1131, https://doi.org/10.1016/j.seja.2023.100033
Daniel Tschopp, Philip Ohnewein, Roman Stelzer, Lukas Feierl, Marnoch Hamilton-Jones, Maria Moser, Christian Holter	One year of high-precision operational data including measurement uncertainties from a large-scale solar thermal collector array with flat plate collectors in Graz, Austria	https://www.sciencedirect.com/science/article/pii/S2667113123000013	Data in Brief, Volume 48, 2023, 109224, ISSN 2352-3409, https://doi.org/10.1016/j.dib.2023.109224

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
Cross-TCP (SHC, DHC, Bioenergy) industry workshop	Presentation of Task 68: opportunities offered by seasonal storages and large-scale solar thermal systems	January 18, 2023 Graz, Austria	~ 50
Webinar of Euroheat & Power	Keynote on behalf of Task 68 based on the SDH info package	March 23, 2023	Webinar of Euroheat & Power
Webinar of Energy Cities / Convenant of Mayors – "Solar Heating: how can cities decarbonize their district heating system – Session 1"		May 17, 2023 online	54 online (100 registered)
Euroheat & Power Congress	Keynote dedicated to Solar District Heating	May 23, 2023 Turin, Italy	~100
Webinar of Energy Cities / Convenant of Mayors – "Solar Heating: how can cities decarbonize their district heating system - Session 2"	The Task 68 experts Magdalena Berberich (SOLITES), Luuk Beurskens (TNO), Geoffroy Gauthier (PLANENERGI)	online	~100
Power Plant Technology Colloquium	Presentation of solar district heating by Bärbel Epp	October 11, 2023 Dresden, Germany	95
Webinar on Solar District Heating	Task 68 experts Joakom Byström (Absolicon), Viktor Unterberger (BEST)	October 10, 2023 Härnösand, Sweden	40 (70 views of the recorded video)

Dissemination Activities Planned For 2024

- Future joint TCP Workshops with DHC TS5 or other TCPs, such as Energy Storage or Bioenergy
- Draft scientific paper

Task Meetings in 2023 and Planned for 2024

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 3	May 31 – June 2, 2023	Copenhagen, Denmark *(with SHC Task 64)*	50 participants
Task Meeting 4	October 9-11, 2023	Härnösand, Sweden	44 participants
Task Meeting 5	April 9-10, 2024	Graz, Austria	
Task Meeting 6	August 2024	Limassol, Cyprus *EuroSun 2024*	

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*Finland participates through the DHC TCP.

Task 69 – Solar Water Heating for 2030

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Task Overview

Hot water demand is continuously growing globally, and many IEA SHC member countries have 2030 commitments/targets to achieve a higher solar fraction of their economies. At present, ~16% of residential energy consumption in IEA countries goes to water heating (according to 2018 IEA data). However, the solar share of this is low—only 2.1% of space and water heat demand was met by solar thermal in 2018, and this mainly come**s** from evacuated tube systems installed in China (according to a recent IEA Report). This same report states, "to be in line with the Sustainable Development Scenario (SDS), the share of clean energy technologies needs to exceed 50% of new heating equipment sales by 2030." Thus, the general scope of this Task is to investigate the best way for solar hot water configurations to fill this gap. The Task will focus on the development path and best practices for two technologies expected to play the biggest role in the solar hot water market in 2030: solar thermal thermosyphon and solar photovoltaic (PV) derived hot water heating systems.

Key Objectives

The Task will define the market status, core technical issues for development, and the training**/standards needed** for two cost-effective and reliable solar water heater technologies (*thermosyphon and* PV solar hot water heating systems). The Task will rely heavily on international knowledge among participants from the different IEA SHC member country regions to consider differences in economic development, solar resources, regulations, and other factors (i.e., GN SEC vs. Europe). A key part of the scope is to investigate 'smart' systems for thermosyphons and 'integrated' systems for PV-driven systems, including **overcoming** barriers to further deployment (e.g., harmoni**z**ation) in different climates and markets. As such, the Task will identify opportunities to improve the performance, cost, and reliability of solar water heaters, aiming to accelerate the rollout of best practices for these technologies.

The Task is organized into four subtasks:

- Subtask A: State-of-the-art and Operating Environments in Different Regions *(Lead Country: Austria)*
- Subtask B: Thermosyphon Hot Water Systems *(Lead Country: China)*
- Subtask C: Solar Photovoltaic Hot Water Systems *(Lead Countries: Australia and United Kingdom)*
- Subtask D: Training and Standards *(Lead Country: Denmark)*

Scope

Subtask A: State-of-the-art and Operating Environments in Different Regions
Analyzing global solar hot water installation data, including operating environment, trends, best practices, regulations, and major technical and non-technical barriers to adoption.

Subtask B: Thermosyphon Hot Water Systems
Investigating how thermosyphons can be modernized via new technologies, system durability and reliability, and the potential of new technologies to save energy and reduce GHG emissions compared to conventional systems.

Subtask C: Solar Photovoltaic Hot Water Systems
Evaluating environmental, social, and economic implications of increased deployment of solar PV diverter and PV2Heat technologies.

Subtask D: Training and Standards (Lead Country: China)
Using Task results to recommend improvements and revisions to current and new standards for PV SHWs and to prepare training materials on SHW principles, sizing, and installation.

Collaboration with Other IEA TCPs

Task 69 is collaborating with the Photovoltaic Power Systems Programme (PVPS) and the Heat Pumping Technologies (HPT) TCPs.

Collaboration with Industry

The following companies have devoted experts to Task 69:

- Rheem Pty Ltd. (Australia)
- Apricus (Australia)
- Reclaim Energy Pty Ltd. (Australia)
- Sunspin Pty Ltd. (Australia)
- Exemplary Energy (Australia)
- Sustainable Energy Transformation Pty Ltd. (Australia)
- GreenoneTEC (Austria)
- Solareast Holdings Co. (China)
- Haier (China)
- Pleion SpA (Italy)
- Inventasolar (Norway)

Task Duration

This Task started in July 2022 and will end in June 2025.

Participating Countries

Australia, Austria, Canada, China, Denmark, Germany, Italy, Norway, South Africa, Switzerland, United Kingom, GN SECs: EACREEE, SACREEE, RCREEE

Work During 2023

Overall Task Progress

2023 is the halfway mark of this three-year Task. On 4 December, we had our Task Meeting #3 in Melbourne, Australia, Hybrid organized. During this meeting, we had productive technical discussions (one deep-dive presentation for each subtask). Task 69 also conducted two training seminars on the topic of Key considerations for adoption of PV hot water heaters; one was on 5 December in collaboration with the ASIA-PACIFIC SOLAR RESEARCH CONFERENCE in Melbourne, Australia, and the other was the broadcasted webinar live Q/A Session on 11 December. Two trilingual surveys are underway (English, Chinese & Spanish). Soltrain+ thermosyphon vs. PV2Heat testbed in Namibia was almost ready. The Thermosyphon testbed is ongoing at CABR. Solarshift PV electric water heaters testing was done in Albion Park, NSW, Australia. Solar hot water heater standards were reviewed.

Also, as noted below, each Subtask has made significant progress according to the Work Plan.

Subtask A: State-of-the-art and Operating Environments in Different Regions

Subtask A had the following accomplishments in 2023:

1) Survey with STB
    - Questions on production data, target markets, and costs, business models and innovations
    - 29 questions + option to provide data on flagship thermosyphon models
    - Language available in English, Spanish, and Chinese
    - 54 answers from manufacturers of thermosyphon systems by the end of 2023
2) Side-by-side Comparison Study
    - Side-by-side comparison of solar hot water technologies: a) Indirect thermosyphon system with a flat plate collector, b) Indirect thermosyphon system with evacuated heat pipe collector, c) PV-to-Heat (PV2Heat) system
    - Monitoring phase: Spring 2024 to Spring 2025
    - Location: Namibia University of Science and Technology
    - Data from the comparison test bed and insights from the SOLTRAIN project (665 demo systems over 12 years) will be shared with the Task.

- Current Status: Detailed planning phase / First components being shipped/installed.
3) Creation of template for Best Practice Examples

Subtask B: Thermosyphon hot water systems

Subtask B had the following accomplishments in 2023:

1) Survey with STA
   - Questions on Trends of thermosyphons, new models, and their benefits.
   - Through Chinese WeChat, a questionnaire was sent to 12 manufacturers, accounting for most of the Chinese thermosyphon system market.
   - All 12 Chinese manufacturers answered the questions (in Chinese).
   - Linuo Ritter International Co., Ltd provided an introduction to their intelligent controller for Thermosyphon systems.
2) GHG reduction testing in China
   - A GHG reduction test bed for thermosyphon systems finished in China.
   - CABR and Solareast in China are conducting GHG reduction performance analysis and testing of different hot water systems.
   - A method to predict long-term carbon reduction of thermosyphon systems has been introduced by combining the international standard ISO 9459-2 and the Chinese standard GB/T 18708-2002.
   - The test bed results were used to verify the method.
   - Initial results were available and being transferred into English.
3) Creation of reports on failure modes and effects & durability and reliability improving research.
4) Two news articles were prepared for Solar Thermal World for STB:
   - "Life cycle assessment of novel all-polymeric solar thermal collector systems for hot water" https://solarthermalworld.org/news/carbon-footprint-assessment-of-various-types-of-solar-water-heater/
   - "Tests of Solar Water Heater in China Aim at Improving Standards" https://solarthermalworld.org/news/tests-of-solar-water-heaters-in-china-aim-at-improving-standards/

Subtask C: Solar Photovoltaic Hot Water Systems

Subtask C had the following accomplishments in 2023:

1) Joint Leader was confirmed, Tony Day (UK-New!) & Dean Clift (AU).
2) Survey – Preliminary results (40 now).
3) Technical presentation at APRSC on 'Key considerations for the adoption of PV Water Heaters."
4) **3** Journal Papers were accepted in 2023!
   - Clift et al. "Assessment of advanced demand response value streams for water heaters in renewable-rich electricity markets" Energy, 267, 2023. https://doi.org/10.1016/j.energy.2022.126577.
   - Clift et al., "Maximising the benefit of variable speed heat-pump water heater with rooftop PV and intelligent battery charging," Solar Energy, 112049, 2023. https://doi.org/10.1016/j.solener.2023.112049
   - Clift et al. "Peer-to-peer energy trading for demand response of residential smart electric storage water heaters" Applied Energy, In press, 2023.
5) SolarShift case study + technical analysis underway

Subtask D: Training and standards

Subtask D had the following accomplishments in 2023:

1) A new DTU expert joined the leadership team, Elsabet Nielsen, who has experience in previous SHC Tasks.
2) Deliverable D.1 is under preparation and will be submitted in January/February 2024.
3) Coordinated with STC to facilitate a Solar Academy training as Deliverable D.2. The training session was held as a special session at the 10th Asia Pacific Solar Research Conference on December 5, 2023, at RMIT University, Melbourne, Australia. There were around 40-50 participants in the session. A 2nd online session was organized for the western hemisphere on December 11, 2023. There were 10 participants.
4) At Task Meeting #3, a technical discussion was held on the global Standards. DTU gave a presentation on 'Standards for solar water heaters.'

Work Planned For 2024

Subtask A: State-of-the-art and Operating Environments in Different Regions

According to the Work Plan, subtask A will commence all three of the planned activities, which are as follows:

- Report on most dominant solar water heating systems and state-of-the-art reviews for thermosyphon and PV2Heat technologies, analysis of market regions and potential for solar water heating (A1)
- Documentation of success stories and market barriers in relevant regions (A2)
- Report on emerging products and research trends for SHW (A3)

Note: A1 & A2 are due in February and December 2024, and A3 is due in 2025.

Subtask B: Thermosyphon hot water systems

According to the Work Plan, subtask B will have commenced all four of the planned activities by the end of 2024, which are as follows:

- Report of thermosyphon system potential (B1)
- Survey of failure modes and effects and suggestions (B2)
- Report on durability and reliability improving research and technical results (B3)
- Report on energy-saving & GHG reduction methods along with current and future trends (B4)

Note: B1 was completed in 2023, B2 & B3 are due to be completed by January 2024, and B4 is due in 2025.

Subtask C: Solar Photovoltaic Hot Water Systems

According to the Work Plan, several of the subtask C Activities are scheduled to commence or be completed in 2024, which are as follows:

- Expert Network, Expert Questionnaire / Interviews and Case Studies (C1)
- Systematic International Literature + Market Review (C2)
- Technology / Policy Brief (C3)
- Reference Models / Solar Heat Worldwide Chapter (C4)

Note: C1 was done in 2023, while C2 & C3 are due to complete by January 2024.

Subtask D: Training and standards

According to the Work Plan, three of the Subtask D Activities are scheduled to commence in 2024, which are as follows:

- Report on ‘Solar Hot Water Standards and Certifications – Pathways to 2030’ (D1)
- Facilitate Training (D2)
- Needs Assessment Report (Training for Solar Energy Practitioners) (D3)

Note: D1 & D3 are due for completion in January and December 2024, respectively. Training will be done in 2024, according to D2.

Dissemination Activities In 2023

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
Harald Kicker, Bärbel Epp (editor)	Life cycle assessment of novel all-polymeric solar thermal collector systems for hot water	Solar Thermal World	https://solarthermalworld.org/news/carbon-footprint-assessment-of-various-types-of-solar-water-heater/

Li Bojia, Bärbel Epp (editor)	Tests of Solar Water Heater in China Aim at Improving Standards	Solar Thermal World	https://solarthermalworld.org/news/tests-of-solar-water-heaters-in-china-aim-at-improving-standards/
Dean Holland Clift (STC lead), Cameron Stanley, Kazi N Hassan, Gary Rosengarten	Assessment of advanced demand response value streams for water heaters in renewable-rich electricity markets	Energy, 267, 126577, 2023.	https://doi.org/10.1016/j.energy.2022.126577
Dean Holland Clift (STC lead), J Leerson, Kazi N Hasan, Gary Rosengarten	Maximising the benefit of variable speed heat-pump water heater with rooftop PV and intelligent battery charging	Solar Energy, 265, 112049, 2023	https://doi.org/10.1016/j.solener.2023.112049
Dean Holland Clift (STC lead), Kazi N. Hasan, Gary Rosengarten	Peer-to-peer energy trading for demand response of residential smart electric storage water heaters	Applied Energy, 353, 122182, 2024	https://doi.org/10.1016/j.apenergy.2023.122182

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees	If Task Hosted: Organized with, # participants
Asia Pacific Solar Research Conference	training seminar on the topic of Key considerations for adoption of PV hot water heaters	5 December, Melbourne, Australia	50	Hosted by APSRC
Asia Pacific Solar Research Conference	Solar Academy seminar: Key considerations for adoption of PV hot water heaters	11 December Online	10	Hosted by UNSW
4th International Conference on Solar Technologies & Hybrid Mini Grids to improve energy access	Presentation by Monika Spörk-Dür: SOLTRAIN+ and SHC Task 69: New International Initiatives to Promote Solar Energy in SADC Countries and Globally	26 April 2023, Palma de Mallorca, Spain	30	

Dissemination Activities Planned For 2024

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication/Conference	Bibliographic Reference

Joseph Shigwedha, Fenni Shidhikai, Helvi Ileka, Daniel Tschopp, Rudi Moschik, Penti Paulus	Monitoring and evaluation of thermosyphon and PV Hot Water systems under the same operating conditions in a side-by-side experimental setup	ISEC (International Sustainable Energy Conference) 2024	
Harald Kicker, Gernot Wallner, Daniel Tschopp, Rudi Moschik, Wolfgang Gruber-Glatzl, Fenni Shidhikai, Helvi Ileka, Joseph Shigwedha	Life Cycle Assessment of thermosyphon and PV Hot Water systems under the same operating conditions in a side-by-side experimental setup: Initial results and data comparison with existing installations	ISEC (International Sustainable Energy Conference) 2024	
Li Bojia, Bian Mengmeng, Jiao Qingtai	Energy-saving & GHG reduction performance evaluation on thermosyphon systems		

Task Meetings in 2023 and Planned for 2024

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 2	April 26, 2023	Spain (hybrid) (in conjunctions with S-@ccess 2023)	55 (8 in person)
Task Meeting 3	December 4, 2023	Australia (hybrid) (in conjunctions with APSRC 2023)	50
Task Meeting 4	April 9-12, 2024	Austria (hybrid) (in conjunctions with ISEC 2024)	
Task Meeting 5	November 2024	Beijing China (hybrid)	

Task 69 Participants

Country	Name	Institution / Company	Role
AUSTRALIA	Robert Taylor	University of New South Wales	Co-Task Manager
CHINA	He Tao	China Academy of Building Research (CABR)	Co-Task Manager
AUSTRALIA	Saeed Tehrani	Apricus	National Expert
AUSTRALIA	David Ferrari	Exemplary Energy (Australia)	National Expert
AUSTRALIA	Harry Suehrcke	Sunspin	National Expert
AUSTRALIA	Osama Bany Mousa	University of New South Wales	National Expert
AUSTRALIA	Ken Guthrie	SE Transformation	National Expert
AUSTRALIA	Lu Aye	University of Melbourne	National Expert
AUSTRALIA	Zheng Wang	Deakin University	National Expert
AUSTRALIA	Doug Smith	PVT Lab	National Expert
AUSTRALIA	Baran Yildiz	University of New South Wales	National Expert
AUSTRALIA	GRAHAM MORRISON	University of New South Wales	National Expert
AUSTRALIA	Jose Bilbao	University of New South Wales	National Expert
AUSTRALIA	Dean Clift	RMIT/Rheem	Subtask C co-Leader
AUSTRALIA	Alistair Sproul	University of New South Wales	National Expert
AUSTRALIA	Ned Ekins-Daukes	University of New South Wales	National Expert
AUSTRIA	Christoph Rohringer	AEE INTEC	National Expert
AUSTRIA	Daniel Tschopp	AEE INTEC	Subtask A Leader
AUSTRIA	Harald Poscharnig	GREENoneTEC Solarindustrie GmbH	National Expert
AUSTRIA	Harald KICKER	University of Linz	National Expert
AUSTRIA	Gernot Wallner	University of Linz	National Expert
AUSTRIA	Veronika Hierzer	AEE INTEC	National Expert
CANADA	Christopher McNevin	NRCAN	National Expert

CANADA	Stephen Harrison	Queen's University	National Expert
CHINA	Bojia LI	China Academy of Building Research (CABR)	Subtask B Leader
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CHINA	Yan Li	Ocean University of China	National Expert
CHINA	Xianping Liu	Hunan University of Science and Technology	National Expert
CHINA	Qingtai Jiao	Solareast	National Expert
CHINA	Ma Guangbai	CNAS test center	National Expert
CHINA	Lianggong Ma	Dalian University of Technology	National Expert
CHINA	Zhenhua Quan	Beijing University of Technology	National Expert
CHINA	Wu Yunqimuge	-	National Expert
CHINA	Jili Zhang	Dalian University of Technology	National Expert
CHINA	Han Yuan	Ocean University of China	National Expert
CHINA	Ning MEI	Ocean University of China	National Expert
CHINA	Peng Wang	Dalian University of Technology	National Expert
CHINA	Lincheng WANG	*Beijing University of Technology*	National Expert
CHINA	Yan LI	Ocean University of China	National Expert
CHINA	Han Yuan	Ocean University of China	National Expert
CHINA	Yubo Yang	*Beijing University of Technology*	National Expert
CHINA	Bin Liu	Haier	National Expert
CHINA	Zhenzhen Fan	Linuo-Ritter International	National Expert
DENMARK	Jianhua Fan	Technical University of Denmark	Subtask D Leader
DENMARK	Elsabet Nielsen	Technical University of Denmark	National Expert
DENMARK	Ivan Katic	Teknologisk Institute	National Expert

EACREEE	Goddy Muhumuza	GN SEC	National Expert
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GERMANY	Stephan Fischer	University of Stuttgart	National Expert
GERMANY	Korbinian Kramer	Fraunhofer ISE	National Expert
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ITALY	Zeno Benciolini	Pleion SpA	National Expert
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RCREEE	Khalid Salmi	RCREEE	National Expert
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SACREEE	Kudakwashe (Kuda) Ndhlukula	SACREEE	National Expert
SACREEE	Fenni Shidhika	Namibia University of Science and Technology-Namibia Energy Institute	National Expert
SACREEE	Helvi Ileka	Namibia University of Science and Technology-Namibia Energy Institute	National Expert
SACREEE	Tawanda Hove	University of Zimbabwe	National Expert
SACREEE	Reis Chirinze	Eduardo Mondlane University, Mozambique	National Expert
SACREEE	Selma Festus	GN SEC	National Expert
SACREEE	Blessed Sarema	National University of Science and Technology	National Expert
SACREEE	Kevin Nwaigwe	Clean Energy Research Centre, University of Botswana	National Expert
SACREEE	Anadola Tsiu	Precise Technical Solutions, Lesotho	National Expert
SACREEE	Kornelia Iipinge	SACREEE	National Expert
SACREEE	Eugenia Masvikeni	SACREEE	National Expert
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SACREEE	Wally Weber	Blackdot Energy	National Expert

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SWEDEN	Diogo Cabral	University of Gävle	National Expert
SWEDEN	Björn O. Karlsson	University of Gävle	National Expert
SWEDEN	Siddhi Bagde	-	National Expert
SWITZERLAND	Andreas Häberle	OST Switzerland	National Expert
SWITZERLAND	Michel Haller	SPF Institute for Solar Technology - Eastern Switzerland University of Applied Sciences (OST)	National Expert
UNITED KINGDOM	George Bennett	UK Department for Business, Energy & Industrial Strateg	Subtask C co-Leader
UNITED KINGDOM	Dr Chris Horne	MyEnergi	National Expert
UNITED KINGDOM	Tom Oldfield	Mixergy Ltd -Oxford UK	National Expert
UNITED KINGDOM	Andrew Ireland	MyEnergi	National Expert

Task 70 – Low Carbon, High Comfort Integrated Lighting

Dr. Jan de Boer
Fraunhofer Institute for Building Physics
Task Manager for the German Government (PtJ for BMWi)

Task Overview

The overall objective of the activity is to identify and support implementing the potentials of lighting (electric, façade: daylighting & passive solar) in the decarbonization on a global perspective while aligning the new integrative understanding of humans' light needs with digitized lighting on a building and a building related urban scale. This can be subdivided into the following specific objectives.

- Actively support broadening the view on lighting solutions in the context of decarbonization. Help bridge the gap between a component view (manufacturer's focus) and design-oriented system approaches. Support the transition from a relatively pure energy-focused view to a life cycle assessment (LCA) perspective. On this basis, identify key impact factors and develop the most effective strategies and roadmaps while including regional specifics.

- Contextualize this with the fast-developing digitization of buildings/lighting installations on the technology, design, and operational side. Add to selected open points in the digital chain like better design processes.

- Align this with the still growing understanding of user needs; here especially build upon results from earlier tasks (e.g., Task 61).

- Integrate competencies: Bring the different involved players (electric lighting, façade, industry, controls) that have not been connected to low-carbon solutions together in workshops and specific projects. Create added value by transferring into standardization, regulations, and building certificates.

- Foster the broad implementation of low-carbon solutions, especially in developing countries, by promoting tailored “Low Tech – High Impact solutions” through demonstrations, design guidelines, and workshops.

Scope

The scope of the Task is on general lighting systems for indoor environments and the interrelation of buildings (their facades) with urban settings. The focus is laid on lighting appliances in non-domestic buildings. Technically, the Task deals with integrating:

- daylight utilization by enhanced facade technologies and other architectural solutions,
- electric lighting schemes addressing technology and design strategies in the context of progressing digitalization, and
- lighting control systems and strategies with special emphasis on visual and non-visual user needs and the interface of day- and electric lighting.

This is under the constraint of low carbon emission to fulfill the lighting services in an LCA / circular economy context. The task targets building designers and consultants, industry (façade, electric lighting, and software companies), owners (investors), and authorities by providing strategic, technical, and economic information and with network activities helping these stakeholders overcome barriers in identifying and then pursuing and implementing low carbon lighting concepts and installations. Thus, a focus mainly on energy efficiency will be widened.

The Task is divided into four Subtasks:

- Subtask A: Low Carbon Lighting and Passive Solar: Scenarios, Strategies, Roadmaps *(Lead Country: China)*
- Subtask B: Visual and non-visual User Requirements *(Lead Country: United Kingdom)*
- Subtask C: Digitized lighting solutions (Technology & Design Tools / Process) *(Lead Country: Austria)*

- Subtask D: Application and Case Studies *(Lead Country: Sweden)*

Collaboration with Other IEA TCPs

Collaboration with IEA EBC was approved at the moderate SHC level at the 93rd EBC Executive Committee Meeting in June 2023. The EBC TCP refers to the Task as EBC Annex 90. Collaboration with ISO (ISO TC 274) and CIE planned.

Collaboration with Industry

Eight companies are participating in the task activities, and the big design and consulting companies AECOM and ARUP are considering joining. Two industry workshops were held.

Task Duration

The Task started in January 2023 and will end in June 2026.

Participating Countries

Australia, Austria, Belgium, Brazil, Canada, China, Denmark, Germany, Italy, Japan, Netherlands Norway, Poland, South Africa, Spain, Sweden, Switzerland, Türkiye, United States, United Kingdom.

* Participating through the EBC TCP: Brazil, Japan, Sweden, and US. Poland in process of joining SHC TCP.

Work During 2023

Subtask A: Low Carbon Lighting and Passive Solar: Scenarios, Strategies, Roadmaps

Status quo: Overview of Data, Methods, and Regulations

A survey was designed to assess the status of LCA in participating countries with respect to lighting. The survey is structured into general electric lighting and façades. Among others, input is requested on general market integration of LCA approaches, used databases, methods, and regulations. The survey was tested in China and Germany and then rolled out to all participating countries. Twelve countries have responded so far (Austria, Belgium, Brazil, China, Denmark, Germany, Greece, Japan, Norway, South Africa, Spain, and Türkiye), and the others are still invited to do so. A first evaluation of databases and cross-sectional evaluations on, e.g., carbon pricing of electricity, has been performed. The survey evaluation is planned to be finished by the end of the year. Earlier, detailed interviews with stakeholders were not deemed necessary, as the level of detail of the information obtained from the survey was sufficient.

Catalogues of Scenarios

The idea of scenarios was presented, discussed, and further elaborated. Based on this, the relevant state-of-the-art and promising future scenarios will be collected and detailed for electric lighting and facades. An outlook on how this catalog will be incorporated into a simple evaluation procedure and decision tool (A.3 and A.4) was given. This will be based on separating EPDs on the product side (taken from manufacturers' information) and operational carbon from lighting energy calculations. The activity integrates with and relies on the other Subtask. This was addressed in joint Subtask meetings.

Subtask B: Visual and non-visual User Requirements

The scope of B.1 was slightly corrected concerning the focus on the conflict (or balance) line between view access and glare protection. The development of a measurement protocol for view studies and a literature review on view and glare were initiated.

A collection of studies, initiatives, etc. on “view preferences/descriptors” was initiated to provide a starting point. The use of VR for view assessment and which characteristics describe views (e.g., how color and reflection play a role) were discussed. The organization of a set of “View workshops” for the 4th quarter of 2024 was discussed.

Different contributions of experts working in the field of “view out of the window and urban morphology” were made and discussed. Suggestions for first consolidations of knowledge proposed: Perform a literature review on urban morphology and view. Perform a sensitivity analysis of urban morphology parameters on view quality perception.

Subtask C: Digitized Lighting Solutions (Technology & Design Tools / Process)

A joint review will be done for C1 and C2 as both the literature review (academic) and the market review (published information & interviews) should be seen holistically as a technology overview covering systems and controls. Reports from the previous SHC projects, Task 50 and Task 61, will be used as a starting point for the reviews, especially for IOT & Controls. Existing information from these previous SHC lighting Tasks will be updated. The collection of EPDs will be adding relevant LCA aspects to the reviews.

A BIM and lighting survey is being prepared and will be evaluated in early 2024.

A survey on VR in lighting research and practice was designed and open until December 2023.

ISO Standardization project on BSDF: A new standardization effort on BSDF data generation and processing (based on Task 61 white paper and report) was proposed to ISO TC 274 "Light and Lighting" at their JWG 1 meeting in July 2023 and perceived positively. The next step is to set up a new ISO work item to start the standardization process. In support, a publication in Lighting Research and Technology, "Towards an international standard for generating BSDF data for daylight applications," was prepared in November.

Subtask D: Application and Case Studies

Catalogue of Case Studies
Criteria for inclusion of case studies were finalized: Inclusion criteria: field study, laboratory study, living labs, and virtual reality. Focus on non-residential stock, but residential can be added. An overview of the current available case studies was provided. About 30-40% of case studies focus on daylighting/lighting components; the remaining are buildings. Typologies require different approaches for assessments. More than 40 case studies are listed.

Evaluation Procedure
"High quality" and "Low Carbon" will be assessed. The "High quality" discussion is on hold now, with the focus on LCA. The activity will closely be connected to Subtask A as input on evaluation LCA aspects is necessary. A current joint MSc thesis at Lund University with IREC, Spain, can serve as a basis for further procedure development. The goal is to have a simple visualization of the carbon impact of different solutions, expressed, e.g., in KgCO2e/lm.

Impact of Densification on Visual Comfort
Activities started with a literature review and case studies on an urban scale are being searched for the key elements "densification" and "daylight."

Promotion of Highly Efficient Solutions for Sunbelt Regions
All task experts were asked to contribute to this activity. Workshops with sunbelt regions will focus on need analysis instead of promoting our activities. The workshop will focus on specific topics of relevance, e.g., (day)lighting for educational spaces, and low-budget retrofitting.

Work Planned for 2024

Subtask A: Low Carbon Lighting and Passive Solar: Scenarios, Strategies, Roadmaps

A.1.2	Working document "Status quo of data, methods, and regulations"	6/2024
A.2.2	Working document "Definition and Catalogue of Scenarios"	9/2024
A.3.1	Draft architecture of framework	6/2024

Subtask B: Visual and Non-visual User Requirements

B.1.1	Study the impact of eye physiology finished	6/2024
B.1.2	Study the impact of colored daylight finished	9/2024
B.2.2	Study of view preferences depending on activities finished	06/2024
B.3.1	Study of view content quality in different urban configurations with greenery included finished	12/2024
B.4.1	Literature study, internal draft finished	06/2024
B.4.2	Interviewers with experts finished	12/2024

B.5.1 Overview of accessible measurement and assessment methods 06/2024

B.5.2 Results from lab and/or field measurement 12/2024

Subtask C: Digitized Lighting Solutions (Technology & Design Tools / Process)

C.1.1 Analysis of digitalization needs completed 03/2024
C.1.2 Summary of activities related to critical path needs completed 12/2024

C.2.1 IOT state-of-the-art, potentials and barriers documented 12/2024

C.3.1 BIM workflows analyzed and end-to-end parameter workflow specified 12/2024

C.4.1 State-of-the-art lighting simulation methods for non-visual quality criteria for integrative lighting solutions summarized 06/2024

C.4.2 Potentials of VR for lighting design investigated and documented 12/2024

Subtask D: Application and Case Studies

D.2.1 Approved whole life cycle approach methodology 12/2023->6/2024

D.2.2 Approved criteria for assessing visual and non-visual environment 12/2023->6/2024

D.3.1 Experience and data from early case studies (internal document) 06/2024

D.4.1 Format for reporting case studies 02/2024

D.4.2 Reporting of early case studies in the final format 06/2024

D.5.1 Report on minimum requirements for energy and daylight in existing standards 02/2024

D.6.1 1st Web workshop by 4-5 task experts and XXREEE representatives 06/2024

D.6.2 2nd Web workshop by 4-5 task experts and XXREEE representatives 11/2024

Dissemination Activities In 2023

Reports, Published Books

Author / Editor	*Title*	*Bibliographic Reference*
de Boer, J. et. al.	LED Guideline for the Promotion of Lighting Retrofitting	SHC website

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
Geisler Moroder, D. et. al.	Towards an international standard for generating BSDF data for daylight applications	Lighting Research and Technology	Submission November 2023

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees	If Task Hosted: Organized with, # participants
1st Industry Workshop of IEA SHC Task 70	Presentations by Jan de Boer, Victor Ferreiram, Barbara Szybinska Matusiak, David Geisler-Moroder, Niko Gentile, Luca Papaiz	April 17, 2023 Caserta, Italy	55	
2nd Industry Workshop of IEA-SHC Task 70 / EBC Annex 90	Presentations by Jan de Boer, Luo Tao, Barbara Matusiak, Mandana Sarey Khanie, David Geisler-Moroder, Adam Bladowski, Michelangelo Scorpio, Niko Gentile, Anna Pellegrino, Valerio RM Lo Verso	October 2, 2023 London, UK	50	
All Energy Australia	Presentations by Ken Guthrie, Prof Lu Aye, Dean Clift, Veronica Garcia Hansen, Mikel Duke	October 25-26, 2023 Melbourne, Australia		

Dissemination Activities Planned For 2024

3rd industry workshop in Berkeley, USA, in April. Another workshop in the 4th quarter.

Task Meetings in 2023 and Planned for 2024

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 1 Plus 1st Industry Workshop	April 17-19, 2023	Caserta, Italy	49 (17)
Task Meeting 2 Plus 2nd Industry Workshop	October 3-5, 2023	London, United Kingdom	45 (16)
Task Meeting 3 Plus 3rd Industry Workshop	April 8-10, 2024	Berkeley, U.S.A.	

Task 70 I EBC Annex 90 Participants

Country	Name	Institution / Company	Role
GERMANY	**Jan de Boer**	**Fraunhofer IBP**	**Task Manager**
AUSTRALIA	Veronica Garcia-Hansen	Queensland University of Technology	National Expert
AUSTRALIA	Francisca Rodriguez	Queensland University of Technology	National Expert
AUSTRIA	Maximilian Dick	Bartenbach GmbH	National Expert
AUSTRIA	Martin Hauer	Bartenbach GmbH	National Expert
AUSTRIA	Johannes Weninger	Bartenbach GmbH	National Expert
AUSTRIA	Christian Knoflach	Bartenbach GmbH	National Expert
AUSTRIA	Maximilian Obleitner	Bartenbach GmbH	National Expert
AUSTRIA	David Geisler-Moroder	Universität Innsbruck	Subtask C Leader
BELGIUM	Marshal Maskarenj	Université Catholique de Louvain	National Expert
BELGIUM	Sergio Altomonte	Université Catholique de Louvain	National Expert
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BRAZIL	Cláudia Naves David Amorim	University of Brasilia	National Expert
BRAZIL	Joao Francisco Walter Costa	University of Brasilia	National Expert
CANADA	J. Alstan Jakubiec	University of Toronto	National Expert
CHINA	Tao LUO	China Academy of Building Research	National Expert
CHINA	Gao YACHUN	China Academy of Building Research	National Expert
CHINA	Peng XUE	Beijing University of Technology	National Expert
CHINA	Biao YANG	Harbin Institute of Technology	National Expert
CHINA	Zhen TIAN	Soochow University	National Expert
DENMARK	Jens Christoffersen	VELUX A/S	National Expert
DENMARK	Ricardo Rupp	VELUX A/S	National Expert
DENMARK	Alireza Afshari	BUILD	National Expert

DENMARK	Morteza Hosseini	BUILD	National Expert
DENMARK	Endrit Hoxha	BUILD	National Expert
DENMARK	Mahmood Khatibi	BUILD	National Expert
DENMARK	Anne Sophie Louise Stoffer	BUILD	National Expert
DENMARK	Georgios Triantafyllidis	BUILD	National Expert
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GERMANY	Bruno Bueno	Fraunhofer ISE	National Expert
GERMANY	Christoph Maurer	Fraunhofer ISE	National Expert
GERMANY	Aicha Diakite-Kortlever		National Expert
GERMANY	Werner Osterhaus		National Expert
~~GREECE~~	~~Lampros Doulos~~	~~Hellenic Open University~~	~~National Expert~~
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ITALY	Anna Devitofrancesco	ITC-CNR	National Expert
ITALY	Ludovico Danza	ITC-CNR	National Expert
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UNITED STATES	Clotilde Pierson	Oregon State University	National Expert

* Participating through the EBC TCP: Brazil, Japan, Sweden, and the US. Poland is in the process of joining SHC TCP.

Task 71 – Life Cycle and Cost Assessment for Heating and Cooling Technologies

Dr. Karl-Anders Weiss
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Task Manager for the German Government (PtJ for BMWi)

Task Overview

SHC Task 71 addresses the challenge of finding ecological and economical solutions for homeowners and manufacturers by developing a transparent methodology to compare various heating and cooling options over time, enabling a fair evaluation of technologies.

The work includes Integrating Ecological (LCA) and Economic (LCOH) assessments of different heating and cooling technologies for the building sector with a comprehensive review of regulations.

The results will make it possible to compare the technologies from an environmental and economic point of view and can be used as input for regulations and standards.

Scope

The Task work is divided into five subtasks:

- Subtask A: Cooperation with SHC Tasks and Related Tasks from other IEA TCPS *(Lead Country: Germany)*
- Subtask B: Methodology Adoption *(Lead Country: Switzerland)*
- Subtask C: Data of Different Technologies and Components *(Lead Country: Norway)*
- Subtask D. Reference Systems and Their Requirements, Scenarios, and Optimization *(Lead Country: Germany)*
- Subtask E: Dissemination, Networking, and Policy Involvement *(Lead Country: Denmark)*

Collaboration with Other IEA TCPs

Task 71 has contacted the programs for collaboration purposes. See Subtask A below.

Collaboration with Industry

The Task participants are universities, research institutes, and solar energy companies. The institutes have close cooperation with industry partners in the solar energy field. In this way, information on marketed products and systems will be available for the task, and the industry can benefit from the results.

Task Duration

The Task started in January 2023 and will end in December 2025.

Participating Countries

Australia, China, Denmark, France, Germany, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland United Kingdom

Work During 2023

Subtask A: Cooperation with Ongoing or Upcoming SHC Tasks and Related Tasks from Other IEA TCPS

Subtask A has successfully established key connections with other IEA TCPs and within SHC (View “Collaboration with other SHC Tasks, IEA Programmes, Outside Organizations/Institutions “). Many bilateral meetings took place during the last month, during which the upcoming cooperations were discussed. The main driving factor for establishing these contacts was the “Task 71 Network Meeting” on September 25th. Aside from identifying possible ways of cooperation, the non-Task members have also requested regular information about the ongoings of Task

71. A semi-internal newsletter will serve that purpose. Table 1 shows the Key Accounts to which we already established a connection and defined the upcoming cooperations. The Key Account is the person responsible for linking Task 71 and the other Task/Annex/TCP programs.

Table 1: Cooperation with other Task/Annex/TCP programs.

IEA Program	Task/Annex	Key Accounts
PVPS	Task 12	Matthias Stucki, Réne Itten (ZHAW)
DHC	Program Manager for DHC	Andrej Jentsch
EBC	Annex 83	Francesco Guarino
EBC	Annex 72	Christoph Rohringer
HPT	Annex 62 Planned Annex 65	Marek Miara (Fraunhofer ISE) Karl-Anders Weiß
ES	Task 39 Task 41	Christoph Rohringer Carina Seidnitzer-Gallien
IETS	Task XXI	Carina Seidnitzer-Gallien, Simon Moser
SolarPaces	Task IV	Tobias Hirsch
H2	Christophe Dumas (and colleagues)	Renewable H2
SHC	Task 65	Daniel Neyer
	Task 67	Wim van Helden
	Task 68	Luuk Beurskens
	Task 69	Daniel Tschopp

Activity 2 of Subtask A generated an extensive overview of EU regulations and eco-labels. This template aims to uniformize, harmonize, and facilitate the collection. During the kick-off, it was decided that all countries participating in Task 71 should also be considered in D.A.1. For this purpose, the Activity Lead, Dr. Silvia Guillen Lambea, was defined, who in turn defined contact persons for the different countries. In addition, corresponding regulations from many individual countries will be “collected” and added to the overview. The deliverable “D A.1: Summary of existing regulations” will focus on this overview of the different countries participating in the Task.

Subtask B: Methodology Adaptation

There has been progress in the activities B1 to B3 of Subtask B. For B1, proposals were prepared for general recommendations on the LCA approach applied following methodology guidelines with the consensus to use the conventional process-based LCA developed by SETAC and standardized in the ISO standards 14040 and 14044. Furthermore, it was proposed to divide the product system into foreground and background processes with the foreground processes, including the processes that decision-makers or product owners can influence directly, and with the background processes as the remaining processes of the particular product system.

In addition, it was proposed that input-output-based LCA methods or hybrid methods combining input-output-based LCA and process-based are excluded from IEA SHC Task 71.

1 kWh of useful heat delivered by the heating system under analysis was proposed as the functional unit for the LCA and LCoH calculations, and this suggestion received agreement within the task for both LCA and LCoH calculations. However, further specifications might be needed to properly reflect the function of the heating system under study.

In B2, there was a process for defining the overarching general product system under study and the system boundaries, including the full life cycle of the heating systems from raw material extraction until deconstruction and disposal, including the production of collectors, the balance of system components, different applications, and the use phase. A graphical representation of this overarching generic product system is shown in Figure 1.

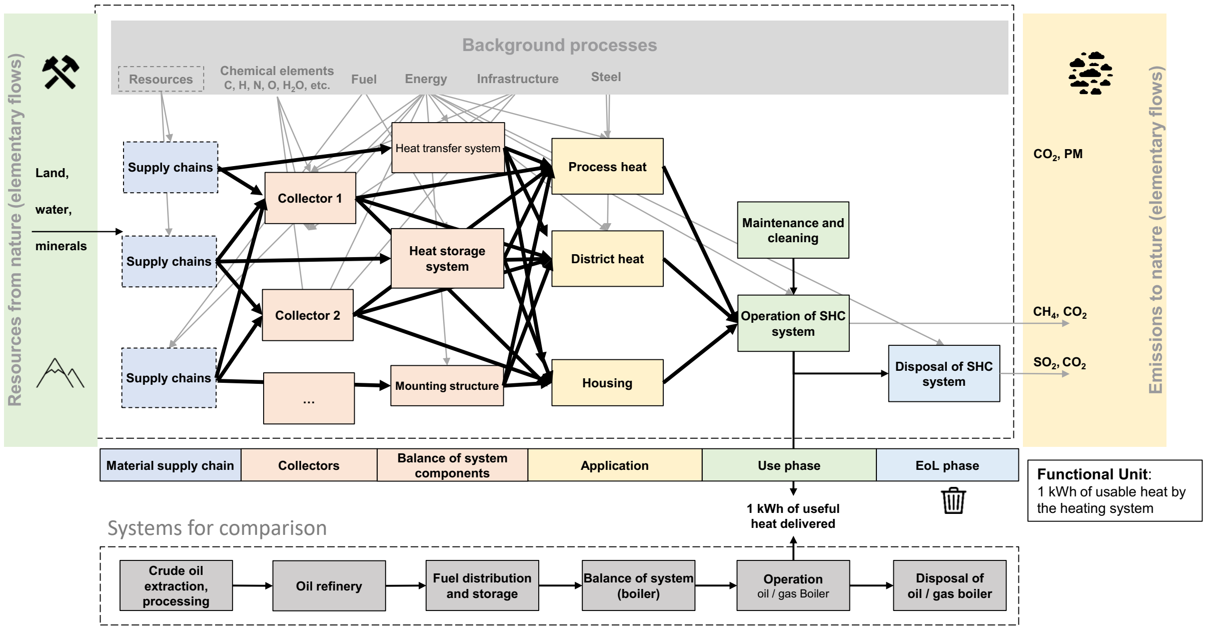

Figure 1: Draft for the graphical representation of the overarching generic product system for LCA and LCoH calculations covering the entire life cycle with the functional units of 1 kWh of useful heat delivered by the heating system.

Furthermore, 16 midpoint indicators for Life Cycle Impact Assessment have been proposed. However, there was no final agreement on the list of additional relevant LCIA methods to consider. The list of suggested midpoint indicators for Life Cycle Impact Assessment agrees with the recommendations in the IEA PVPS Methodology Guidelines and recommendations by the European Commission. The list of suggested midpoint indicators for Life Cycle Impact Assessment is shown in Table 2.

Table 2: List of suggested midpoint indicators for Life Cycle Impact Assessment

Impact category	Indicator	Unit	Recommended default LCIA method	Robust-ness
Indicators required according to the PEF guide and PEFCR				
Climate change	Radiative forcing as Global Warming Potential (GWP100)	kg $CO_{2\ eq}$	Baseline model of 100 years of the IPCC (based on IPCC 2013)	I
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11 $_{eq}$	Steady-state ODPs 1999 as in WMO assessment	I
Human toxicity, cancer	Comparative Toxic Unit for humans (CTU_h)	CTU_h	USEtox model (Rosenbaum et al. 2008)	III
Human toxicity, non- cancer	Comparative Toxic Unit for humans (CTU_h)	CTU_h	USEtox model (Rosenbaum et al. 2008)	III
Particulate matter	Impact on human health	disease incidence	UNEP recommended model (Fantke et al. 2016)	I

Impact category	Indicator	Unit	Recommended default LCIA method	Robust-ness
Ionising radiation, human health	Human exposure efficiency relative to U^{235}	kBq U^{235}	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al. 2000)	II
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg $NMVOC_{eq}$	LOTOS-EUROS model (Van Zelm et al. 2008) as implemented in ReCiPe	II
Acidification	Accumulated Exceedance (AE)	mol $H+_{eq}$	Accumulated Exceedance (Posch et al. 2008; Seppälä et al. 2006)	II
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N_{eq}	Accumulated Exceedance (Posch et al. 2008; Seppälä et al. 2006)	II
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P_{eq}	EUTREND model (Struijs et al. 2009) as implemented in ReCiPe	II
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N_{eq}	EUTREND model (Struijs et al. 2009) as implemented in ReCiPe	II
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTU_e)	CTU_e	USEtox model (Rosenbaum et al. 2008)	III
Land use	PEFCR indicator/method replaced by biodiversity loss indicator, see additional indicators below			
Water use	User deprivation potential (deprivation-weighted water consumption)	m^3 world $_{eq}$	Available WAter REmaining (AWARE) (Boulay et al. 2017)	III
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb_{eq}	CML 2002 (Guinée et al. 2001) and (van Oers et al. 2002)	III
Resource use, fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ	CML 2002 (Guinée et al. 2001) and (van Oers et al. 2002)	III
Additional indicators				
Land use	Biodiversity loss	PDF years	Chaudhary et al. 2015; Chaudhary et al. 2016; Chaudhary & Brooks 2018	n.i.
Cumulative energy demand, renewable	Gross energy content of renewable primary energy resources	MJ oil eq.	Frischknecht et al. 2015d	n.i.
Cumulative energy demand, non-renewable	Gross energy content of non-renewable primary energy resources	MJ oil eq.	Frischknecht et al. 2015d	n.i.

For interpreting the results, discussions on performance indicators like energy payback time (EPBT) and impact mitigation potentials have been held, but there was no consensus on how these indicators should be applied.

In activity B3, the discussion about the economic assessment was aligned with the ecological assessment regarding system boundaries and functional units. Furthermore, a nomenclature has been proposed for the LCoH calculations to clearly distinguish between different forms of energy and system parts, including the specification of the system boundary. However, further alignment in nomenclature and terminology will be required, especially between the LCA and LCoH terminology.

There was no progress in activity B4, but this is to be expected since it focuses on integrating LCA and LCoH calculations.

Subtask C: Data of Different Technologies and Components

In 2023, we worked in Subtask C on an overview, in which national experts could provide input and cost data on which technologies, systems, components, etc.; see Table 3 showing the status in December 2023. In parallel, a data collection sheet was prepared and distributed to the national experts.

Table 3: Overview, which LCA input data are provided by which country experts (status 12/2023).

Status 08.12.2023	Technologies									Systems				Others				
	Bioenergy	Fuels	Heat pump	Heat storage	Solar collectors	Thermal cooling techn.	PTES	PV	PVT	Buildings & renewables	District heating	SH & waste recovery	SHIP	Technology infrastructure	CO2 emissions	Materials	Data sources, data bases	Comments
Australia																		tbc
Austria					x	x	x				x						x	waiting for funding
China			(1)	x							x				x			(1) air source heat pump
Denmark									x									
France						(2)						x						(2) absorption chiller
Germany									x	x			x	x		x	x	
Italy					(3)	(4)		x										(3) air collectors (4) desiccant evaporative cooling + absorption cooling; system focus
Netherlands																		tbc
Norway					x													polymeric collectors
Portugal	x				x													
Spain	x	(6)	(5)															(5) mechanical heat pump (6) gass
Sweden					x													concentrating collectors
Switzerland					x												x	SPF tbc
UK									x									"pipe PVT"
Other TCPs			x			x												tbc

PTES: Pit thermal energy storages
SHIP: Solar heat f. industrial processes

Subtask D: Reference Systems and Their Requirements, Scenarios, and Optimization

The following generic heat demand and supply systems have been selected:

Table 4: Generic heat demand.

Country	Single family house	Multifamily house	District heating	Industrial process
Australia	-	-	-	-
Austria	X	X	X	X
China	X	X	X	X
Denmark	X	-	-	-
France	-	-	-	-
Germany	X	X	X	X
Italy	-	-	-	-
Netherland	-	-	-	-
Norway	X	X	-	-
Portugal	X	X	X	X
Spain	X	X	X	X
Sweden	-	-	-	-
Switzerland	X	X	-	X
United Kingdom	-	-	-	-

Table 5: Generic supply system.

Country	Gas	Heat pump	Solar Gas Combi	PVT + HP	PV heating	District heating system	Direct el. Heating	Solar thermal Heating
Australia	-	-	-	-	-	-	-	-
Austria	-	X	-	X	X	-	-	-
China	X	X	-	-	X	-	-	X
Denmark	-	-	-	X	-	-	-	-
France	-	-	-	-	-	-	-	-
Germany	X	X	X	X	X	X	-	-
Italy	-	-	-	-	-	-	-	-
Netherland	-	-	-	-	-	-	-	-
Norway	-	X	X	-	-	X	X	-
Portugal	X	X	-	X	-	-	-	-
Spain	X	X	-	X	-	X	-	-
Sweden	-	-	-	-	-	-	-	-
Switzerland	-	X	X	X	-	-	-	-
United Kingdom	-	-	-	-	-	-	-	-

For the demand side, the buildings (single-family and multifamily houses, both existing and new buildings) have been defined for Germany, including the heating and hot water demand. Templates were drafted for buildings, district heating, and industrial processes to document the heating and cooling loads in a standardized way.

For the heat supply, the following generic systems have been defined to cover the load of the defined buildings.

1. Gas heating system (existing single-family Germany)
2. Solar thermal combi system (gas) (existing single-family house Germany)
3. Air-water heat pump system (newly built single-family house in Germany)
4. Air-water heat pump system plus solar thermal (newly built single-family house Germany)

Subtask E: Dissemination, Networking, and Policy Involvement

Task 71 information material, such as a brochure, poster, and presentation to third parties, has been prepared.

Also, a LinkedIn group, ‘IEA SHC Task Life Cycle Assessment and Levelized Cost of Heat,’ has been created. Posts will be weekly with news from the task and outreach for participation from industry and policymakers.

Participation in the first workshop in Freiburg, Germany, with the responsibility of the discussion.

Work Planned For 2024

Subtask A: Cooperation with Ongoing or Upcoming SHC Tasks and Related Tasks from Other IEA TCPS

Several important measures need to be fulfilled as part of our further procedure. First, the countries' regulations must be completed to fulfill the deliverable D.A.1. Properly collecting these requirements is essential to ensure that we have a good basis for the upcoming white paper.

In addition, the next network meeting will be used as an opportunity to expand communication activities. An effective way to do this is to intensify the use of newsletters to keep everyone involved regularly informed of the latest developments. Improved networking and increased cooperation can increase the network's efficiency.

In addition, a draft for a scientific white paper should be prepared and published since the milestone "*M A.3 Draft for a white paper is ready*" should be completed by the end of 2024.

Subtask B: Methodology Adaptation

Activities B1 to B3 continue in 2024. The next milestone is the first draft of the methodology guideline based on these activities by the end of Q2 2024.

In addition, activity B4 will start in Q3 2024.

Subtask C: Data of Different Technologies and Components

As the preparation work is done, we will push forward the collection of input data in 2024, which was committed by the national experts. We plan to reach out to other experts and companies to ensure that Subtask D covers the amount and quality of technology data as needed. Data will be evaluated together with Subtasks A, B, and D and organized in a suitable database.

Subtask D: Reference Systems and Their Requirements, Scenarios, and Optimization

The work plan for 2024 includes:

1. Delivery of at least one generic demand and supply system for the countries Australia, France, Italy, Netherlands, Sweden, and the United Kingdom
2. Finalizing the draft templates for the supply demand
3. Development of a standardized template for the documentation of the supply systems
4. Definition of all not yet defined generic load and supply systems listed in the tables above

5. Documentation of all generic load and supply systems is listed in the table above.

Subtask E: Dissemination, Networking, and Policy Involvement

The work plan for 2024 includes:

- The second hybrid workshop of Task 71 will be held at DTU in Denmark on October 8, 2024. The focus will be on decision-makers and policy-makers involved in LCA and LCoH.
- Online expert meetings relevant to the other subtasks will be facilitated.
- Newsletters will be prepared.
- News from the task will be posted on LinkedIn.

Dissemination Activities In 2023

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees	If Task Hosted: Organized with, # participants
How to determine ecological and economical heating and cooling solutions for a sustainable future	Physical and online workshop: **Welcome**, Karl-Anders Weiß, Fraunhofer Institute **The demand side of German PV and heating industry,** Yakup Kaya, Vonovia and Michel Böhm, GdW **Task 71**, Karl-Anders Weiß, Fraunhofer Institute, Stephan Fischer, IGTE, University of Stuttgart and René Itten, Zurich University of Applied Sciences **The supply side of the German PV and heating industry**, Ulrich Leibfried, Consolar, Martin Mense, Bosch and Martin Bentele, DEPI German Pellet Institute **Solutions/realistic datasets – discussion**, Janne Dragsted, Technical University of Denmark	October 18, Fraunhofer Institute, Freiburg, Germany	35	

Dissemination Activities Planned For 2024

Hybrid workshop at Technical University of Denmark, Kgs. Lyngby, Denmark, October 8, 2024

Task newsletters will be prepared.

Task Meetings in 2023 and Planned for 2024

Meeting	Date	Location	# of Participants (# of Countries)
Task meeting 1 – Kick-off meeting	March 22-23, 2023	Online	20-25
Task meeting 2	October 18-20, 2023	Freiburg, Germany	14 participants 7 countries
Task meeting 3	April 18-19, 2024	Online	
Task meeting 4	October 8-8, 2024	Kgs. Lyngby, Denmark	

Task 71 Participants

Country	Name	Institution / Company	Role
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FRANCE	Valery Vuillerme	CEA	National Expert
FRANCE	Francoise Burgun	CEA	National Expert
FRANCE	Pierre Garcia	newheat	National Expert
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GERMANY	Harald Druück	IGTE University of Stuttgart	National Expert
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