SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

2022
Annual report

Feature Article

Integrating Daylighting and Electric Lighting into Non-residential Buildings

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1. Message from the Chair

In 2022, the IEA SHC Technology Collaboration Programme (SHC TCP) members and Task leaders took a strategic look at our TCP and the work we do. Over the course of the year, we discussed how the TCP should navigate the growing and changing solar landscape over the next five years. During ExCo meetings and online collaboration, we charted a path for the TCP guided by our new Strategic Plan 2024-2029 and a new vision and mission to carry us through to 2030.

2022 was a year filled with many firsts and, once again, travel. We held our first ISES/IEA SHC collaborative EuroSun conference in Kassel, Germany. For the first time, the recipient of our Solar Award was from Africa. We presented our first out-of-contest solar award at Solar Decathlon Europe. We participated in the IEA's Future Buildings Forum and Critical Minerals Coordination Group meetings. We held our first in-person meetings since the pandemic in Switzerland and South Africa. And lastly, we initiated four new Tasks. A critical part of all these activities is our continued collaboration with the IEA, other TCPs, and solar organizations.

A top priority for the TCP is to share our work and results in the most comprehensive way. Of course, in doing this, we will continue with our Solar Academy webinars and trainings, and our well-known publications, *Solar Heat Worldwide* published every year, *Solar Update* newsletter published twice a year, *Task Highlights* published every year, *Technology Position Papers*, and new Task reports and online tools. All these modes of communication are supported through our partnership with Solarthermalworld.org, the leading news service in the solar heating and cooling field.

In 2022, our outreach activities beyond our Task work included contributions from me as the Executive Committee Chair and other members – our annual briefing to the IEA Renewable Energy Working Party, review of the IEA's Renewable Energy Market Update 2022, TCP's contribution to the IEA's Technology and Innovation Pathways for Zero-carbon-ready Buildings by 2030, and SHC TCP presentations at ISEC 2022 in Austria and the Asia Pacific Solar Research Conference 2022 in Australia.

I want to thank the very active TCP Vice-Chairs, Lucio Mesquita (Canada), He Tao (China), and Kerstin Krüger (Germany). I would also like to acknowledge the contributions of the Executive Committee members, the Task Managers, and all the Task experts. And for those that 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.

Tomas Olejniczak, *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.

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 2022 were:

Solar Energy in Industrial Water and Wastewater Management (Task 62)	Solar Energy Buildings (Task 66)
Solar Neighborhood Planning (Task 63)	Compact Thermal Energy Storage Materials (Task 67)
Solar Heat Processes (Task 64)	Efficient Solar District Heating Systems (Task 68)
Solar Cooling for the Sunbelt Regions (Task 65)	Solar How Water for 2030 (Task 69)

Members & Membership

The overall management of the SHC TCP rests with the Executive Committee 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 the expenses and the 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.

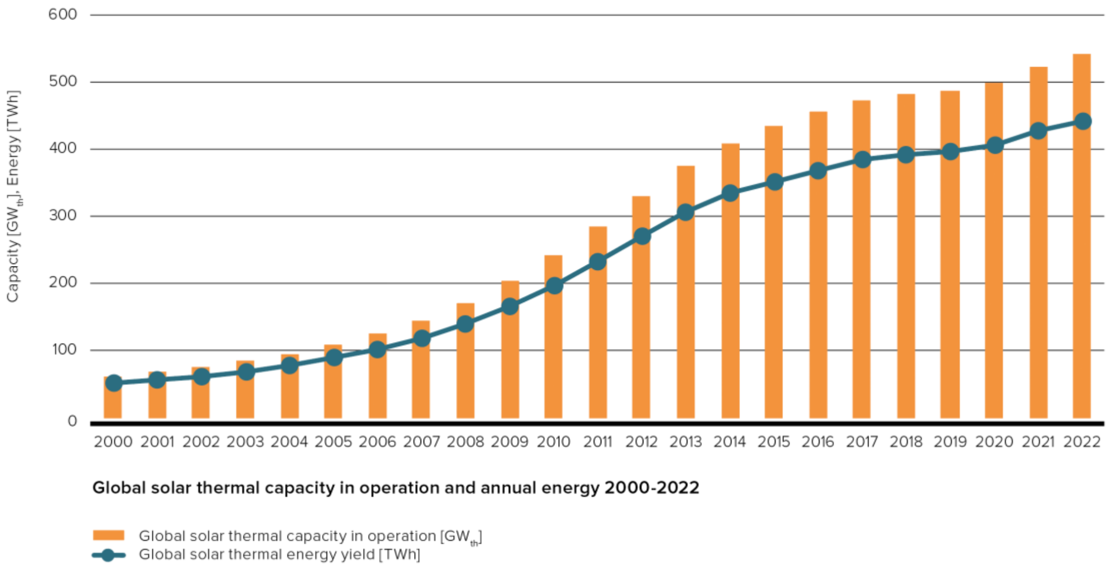
3. 2022 Recap

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 2023 edition reports that in 2022, solar thermal technologies produced 442 TWh – which corresponds to an energy savings equivalent of 47.48 million tons of oil and 153.3 million tons of CO_2.

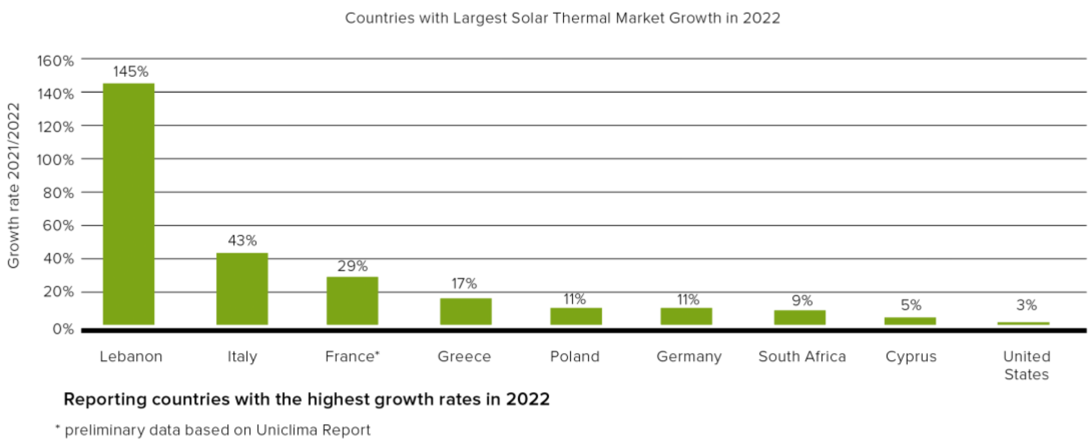
This report is the most comprehensive of its kind and is referenced by many international organizations, including the IEA, REN21 and IRENA, and national governments. The report is free to download at http://www.iea-shc.org/solar-heat-worldwide. A snapshot of the market is shown in the figures below.

Global solar thermal capacity in operation and annual energy 2000 - 2022



Solar thermal heating and cooling systems serve millions of residential, commercial, and industrial clients worldwide with a wide variety of technologies. Below are the top three countries for different market segments.

Top 10 markets in 2022



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 2022:

- Task 68 Efficient Solar District Heating Systems (*Lead Country: Austria)*
- Task 69 Solar Hot Waterfor 2030 (*Lead Countries: Australia and China)*
- 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)*

Completed Tasks

In 2022, the following Task ended:

- Task 62 Solar Energy in Industrial Water and Wastewater Management (Task 62) *(Lead Country: Austria)*

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 70 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 2022, the SHC TCP began its partnership with the International Solar Solar Energy Society (ISES) to co-organize EuroSun 2022 in Kassel, Germany, on September 25-29. The next EuroSun will be in 2024 in the Netherlands.

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 2022 webinars: Global Solar Certificatiin, Solar Heating and Cooling Markets and Industry Trends, Task 65: Solar Cooling for the Sunbelt Regions, and Task 64: Solar Process Heat.

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.

Solar Update Newsletter

Biannual newsletter highlighting Task work and solar thermal programs/activities in our member countries/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 will be asked to consideration collaboration in our newest Tasks, Task 70: Low Carbon High Comfrot Integrated Lighting and Task 71: Life Cycle and Cost Assessment for Heating and Cooling Technologies.

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 and collaborated in Task 62: Solar Energy in Industrial Water and Wastewater Management.

Renewable Energy Working Party held two virtual meetings in 2022. The SHC Chair, Tomas Olejniczak, and SHC Secretariat, Pamela Murphy, participated for the TCP. The TCP also participated in the Critical Minerals TCP Coordination Group December meeting.

Buildings Coordination Group and Future Buildings Forum participated in the planning and attended the Future Buildings Forum.

Critcal Minerals Coordination Group participated in meetings.

Outside the IEA

International Solar Energy Society co-organized EuroSun 2022.

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 2023*.*

UNIDO supported the Sponsor membership of GN-SEC Centres in 2022.

Conferences, TCP presentations at the *EuroSun 2022*, *Asia Pacific Solar Research Conference 2022 and ISEC 2022*.

2022 MEETINGS	2023 MEETINGS
91st ExCo Meeting (hybrid) Raperswill, Switzerland June 1 – 3	**93rd ExCo Meeting** (hybrid) Sophia Antipolis, France June 13 – 16
92nd ExCo Meeting (hybrid) Stellenbosch, South Africa December 5 – 7	**94th ExCo Meeting** TBD November

4. Feature Article

Integrating Daylighting and Electric Lighting into Non-residential Buildings

Introduction

Lighting accounts for 5% of global CO_2 emissions. In addition to its carbon footprint and impact on global warming, as the world transitions to primarily all electricity-based energy systems, lighting is in strong competition with other existing and new consumers (e.g., e-mobility, heat pump systems, etc.) as it consumes 15% of the global electricity consumption (Figure 1). Plus, taxed CO_2 emissions, rising electricity prices, and power shortages are related phenomena requiring more efficient use of lighting. Aside from the direct impact on the consumption of electric lighting, daylighting – when appropriately utilized in trade-off with solar gains – can have a positive impact on managing heating and cooling loads in today's highly engineered buildings. Furthermore, embodied energy for electric and daylighting technologies is playing a growing role on a relative scale and needs to be taken into account. On these bases, to support the sustainability of buildings, it is urgently necessary to widen the design perspective of lighting solutions embracing a more holistic view of its impact on CO_2 emissions, encompassing the whole life cycle (the 'lighting value chain)' also in the context of regional energy markets aspects, interaction with other building trades, etc. This goes far beyond implementing strategies focusing uniquely on LED lamp-driven energy efficiency gains.

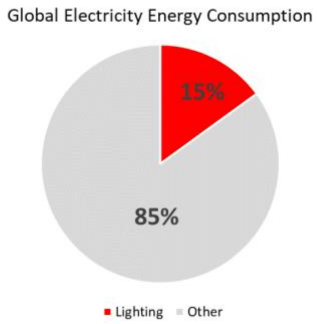


Figure 1. Lighting accounts for 15% of global electricity consumption1

An important innovation in the IEA SHC's recent work on the topic, Task 55: Integrating Large Solar Heating and Cooling Systems into District Heating and Cooling Networks, was the analysis of solar thermal systems supplying heating and cooling networks with high thermal shares. Contrarily to previous studies, in which solar thermal covered low network shares, a holistic approach was necessary for successful large-scale integration. This approach resulted in extensive information material for district heating suppliers, investors, urban planners, and various other stakeholders. It also aimed to evaluate economically optimized transformation strategies for the entire heating net – reduction in grid operating temperatures, development of efficient algorithms for operation optimization and control, integration of seasonal thermal energy storage, and analysis of the impact of decentralized supply on the net hydraulics.

The users and their needs are of paramount relevance: lighting has to be made for the people. Humans receive 80 to 90% of information from their surrounding environment through their eyes. This shows how important the visual environment is for comfort, well-being, and performance. To achieve an optimal lighting scenario, designers must consider personal needs and the environment in which individuals work. Tailor-made solutions, today, should always encompass an appropriate combination of electric lighting and daylight. The interface to new and, possibly, more complex lighting controls (Human-machine interface, HMI) needs to be properly addressed, as they can raise issues of interaction and acceptance. Still, they could finally unleash substantial energy savings.

1 Data Source: UNEP Report, Accelerating the Global Adoption of ENERGY-EFFICIENT LIGHTING, 2017

From a user perspective, it is now understood that lighting solutions have to consider not only the visual but also the non-visual effects (or non-image forming, NIF) of the luminous radiation received by the eye. This renewed design paradigm strengthens the role of daylight as the basis for indoor lighting. However, implementing efficient, comfortable, healthy, and widely acceptable lighting installations is a multi-criteria task.

Current Status

To address user needs and be energy efficient, integrated lighting is driven by architecture and building design practice. It employs technologies from three sectors: the façade industry, electric lighting, and building automation (Figure 2).

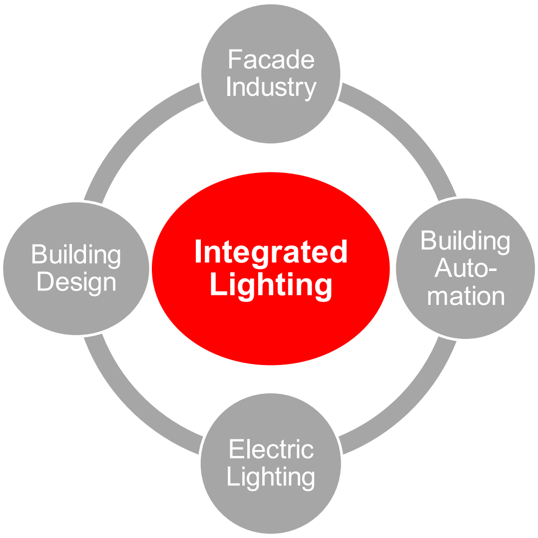


Figure 2. Efficient lighting driven by building design and technologies from three sectors – façade industry, electric lighting, and building automation.

Architecture & building design

Indoor daylight availability strongly depends on architectural parameters like floor plans, façade layout, and neighborhood density. These inherently structural features are established (or given) at the very early stages of design. Building performance is a function of these parameters along the life of the building, so errors made at this stage are difficult to address later. Conversely, systems like electric lighting and other building services have shorter use expectancies and are typically replaced several times over a building's lifespan[2]. **Therefore, building design usually plays the most important role in securing quality daylighting. Clearly, nowadays, this must be contextualized more with the increasing densification of urban settings.**

The proper implementation of daylighting strategies requires specific training of designers. This also encompasses the role of the architect or designer to respond to the client's expectations, the building's technical requirements, and interactions with its urban surroundings. In professional practice, this is often accompanied by guidelines, ordinances, and private partnership agreements, also including sustainability certificates. **To reach an appropriate level of design definition, larger architecture companies often employ automated, parametric software-driven design processes.** This means they are varying under given constraints, for instance, the window size in the façade design to achieve sufficient daylight penetration. In some advanced cases, the arrangement of floor plans or the distribution of lighting over large surfaces (e.g., stadium design) is modified parametrically by **algorithms that can reduce design and simulation time by a factor of 5.** Advanced software tools are starting to indicate untapped energy-saving potentials throughout the design process directly.

New standards like **EN 17037, "Daylight in Buildings,"** now offer guidelines to designers **by introducing new criteria, such as a classification of daylight autonomy, risks of daylight glare, sunlight exposure, and views to the outside**. In practice, this standard can significantly improve daylight quality and daylight-driven energy

2 Typical lifespan of fenestration systems is 30-50 years, whereas electric lighting is now around 10-15 years.

efficiency. Initial experiences in practice show the need for some adaptations while not questioning the general feasibility of the methodology.

Façade technology

The global façade market has grown significantly in the last decades. Today, **around 1.3 billion square meters of glazed facades (the equivalent of the area of the city of London) are built every year.** Innovation in glazing has significantly improved the thermal properties by using new coating techniques and multilayer systems. In recent years, 3-pane glazing systems have become the standard option in many countries despite their reduced visual transmission. Advances in matched coatings for sun protection glazing show **favorable LSG (light-to-solar-gains) close to 2**, therefore offering sun protection while still providing an acceptable ingress of daylight. In terms of solar protection, the 1990s saw the development of diverse advanced (complex) fenestration systems offering simultaneously good shading and daylight potential. From the wide variety of systems developed, only a few have had a lasting impact on the market, partly due to technical drawbacks but mostly linked to economic reasons. Among these, **electrochromic switchable glazing is expecting a boost as its color rendering properties improve, particularly when used at large scales**. For these switchable elements, costs nevertheless are still a multiple of the costs of conventional solutions, which are made up of standard glazing units combined with mechanical glare and or sun protection. The architectural trend of fully glazed facades is generally still prevalent. Another tendency consists in integrating active solar systems (photovoltaic and thermal collectors) directly within the façade. These solutions must be paired with the need to provide sufficient daylight supply in the adjacent indoor spaces. **Daylight provision should not be reduced in conflicts of goals.**

Electric lighting and building automation technology

LED lamp efficiency has come close to the **theoretical maximum of around 230 lm/W**[3], so no further significant improvements are expected (Figure 3).

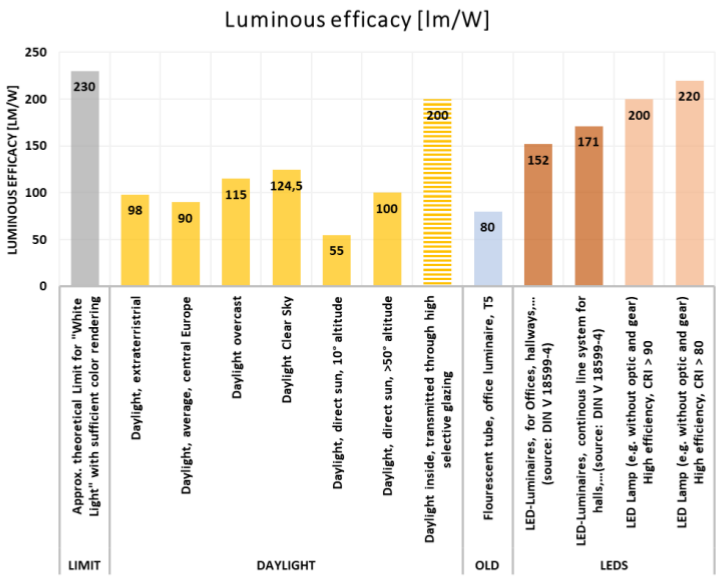


Figure 3. Luminous efficacies: Theoretical limit for white light, selected efficacies of daylight, and LED luminaires and lamps.

In current practice, **luminaire efficacies of a minimum of 150 lm/W should be the benchmark**. Recent advances in LEDs lie in the field of better color rendition with so-called full spectrum LEDs, which offer more balanced luminous emission. From an economic perspective, LED lamps (which cost well under 2€/1000 lm) are no longer the driving factor in selecting lighting solutions. Instead, the fixtures with optics, housing, and control gear determine the final prices of installation. But also, in this case, significant effects of economy of scale are observable for standard

3 Higher efficiencies would lower acceptable color rendering for premises like offices.

fixtures. This goes along with persistently stronger integration of additional features, e.g., sensor and network functionality, as known for other integrated semiconductor products following the principle of “more for less.”

In its now-published strategic vision, *‘Technology and innovation pathways for zero-carbon-ready buildings by 2030,’* the IEA promotes LED implementation as one of the possible fast-working contributions in lowering carbon emission in the built environment (https://www.iea.org/reports/targeting-100-led-lighting-sales-by-2025). Regulations, as in the European Union, taking fluorescent lamps almost entirely out of the market support this transition process.

Daylight-dependent control of electric lighting is a technology that has proven to work efficiently and lead to substantial energy savings. Nevertheless, its actual implementation rate is still low, as in Germany with an estimated 20% of new installations. Façade control technology can now be easily integrated into building management systems. Available functionalities also include cut-off controls for shading systems, which provide a good compromise between solar protection, daylight penetration, and views to the outside. Integrating façade control and occupancy detection technologies into electric lighting control schemes can lead to additional energy savings. Finally, designing control systems to accommodate energy-efficient user behaviors, for example, by introducing energy saving default settings for shading and lighting, can further reduce energy demand.

The number of lighting fixtures equipped with electronics, such as sensors for daylight-dependent lighting control, occupancy detection, and communication components, is increasing. This integration of functionalities is helping to lower costs for more effective use of daylight. Integrative lighting (often referred to as ‘human-centric lighting’), which aims to elicit a human circadian response, is currently driving innovations in lighting technology. A wider implementation of integrative lighting – whereas electric lighting installations can supplement daylight to address non-visual requirements – can be expected as the knowledge advances in this field.

Potential

The energy demand for lighting can drastically be reduced due to the combined effect of more efficient light sources, advances in controls, and raised awareness about the integration of daylighting and electric lighting. As SHC Task 61 / EBC Annex 77 on Integrated Solutions for Daylighting and Electric Lighting has shown, **annual lighting energy use as low as 3-4 kWh/m² for spaces like offices is now possible**. **But this is still far from being the standard in typical projects, where the range of energy demands is often around 10-20 kWh/m².**

Substantial energy-saving potentials can be achieved by replacing the large stock of old installations with state-of-the-art lighting technologies. Nevertheless, replacement decisions based on investment costs can present a significant barrier. Instead, **approaches based on the total cost of ownership** should be adopted. These recognize long-term benefits of effective daylighting use. As a result, replacements of installations with high operating times become highly favorable.

As the focus shifts from pure energy performance optimization to a more holistic view of general resource use efficiency, decarbonization aspects – particularly embodied energy – will come stronger into play. The IEA SHC TCP is planning to address this issue in depth in the new IEA SHC Task on Low Carbon, High Comfort Integrated Lighting.

Products

Whereas in electric lighting, the **transition to LEDs at the lamp level is already largely achieved**, this shift is **yet to be fully realized at the luminaire level**. Potentials for decreasing the embodied energy lie, for instance, in:

- **Modular luminaire architectures** including exchangeable optics, programmable lumen outputs, smart use of 3D printed parts, recyclable components, and
- **Direct integration** of light **into building components** (e.g., allocation as heat sinks for the lamps) and architecture (e.g., with new slim optical systems).

In daylighting technology, the **embodied energy is dominated by façades**.

- **Micro-optics for light redirection** can be obtained for **1/5 of the plastic mass** employed compared to standard solutions.

- New, **electrochromic glazing systems** with **better color rendering** combined, for example, **with vacuum glazing**, are making conventional glare protection and sun shading devices obsolete while allowing much lighter solutions than closed cavity systems.
- At the laboratory level, diverse **lighting control schemes** are being tested to **better integrate daylighting and electric lighting as perceived by the users directly at their workplace**. Nevertheless, the increasing use of sensor hardware and bigger standby losses need to be addressed for controls.

Planning/design

This stage has a long-lasting impact as a decisive lever on the usage phase, which usually dominates the overall lifetime costs and resources used. Numerous inefficiencies are known in lighting design. For example, erroneous design processes result in over-installations. **Trade association's findings are that the majority of installations are not properly designed (or are not designed at all)**. This needs to be significantly improved.

Architectural and design constraints demand answers like offering good (day) light supply in dense urban environments – inside and outside (also understanding the external impacts of façades at an urban level). **Lighting must find its place in a strive for optimal functionality within a limited building envelope surface – daylight vs. active solar vs. facade greening**, difficulties meeting requirements, as in EN 17037 or workplace regulations. 'Daylight mimicking' is a recurrent theme. When electric lighting is the only luminous source available, it relies on the use of variable spectra and intensities following, to a certain degree, the dynamics of daylight. In some cases, this approach can be considered more resource efficient as a whole. Yet, despite soaring energy prices and the high efficiency of LEDs, the feasibility of the approach is still questioned. Potentials need to be better understood under variable boundary conditions throughout the world.

Further alignment with user expectations is of great importance at the design stage – integrative lighting, including visual and non-visual effects, is driving innovation in lighting technology[4]. However, **if not properly integrated with daylight, this comes with the risk of energy rebounds, that is, more delivered lumens and lower luminous efficacies, as shown in SHC Task 61 / EBC Annex 77**. Here, tools and knowledge for designers to implement daylight in integrative lighting schemes are available but need to be put into practice more often. Their application could be increased by widening their scope to include methods for appropriate LCA analysis of lighting and lighting's role in building rating schemes.

Construction/commissioning/usage/end-of-life

These phases can only be as performant as product quality and design processes allow. **Commissioning and maintenance processes need to be improved and become standard practice. Otherwise, efficiency might be jeopardized**. The better a product and architectural solution (e.g., durable, recyclable components), the lower the impact at the end-of-life stage. SHC Task 61 / EBC Annex 77 has shown that (re) commissioning and maintenance (monitoring, validation) are central to achieving good, energy-efficient performance over the usage period. **However, this is far from standard practice, unlike other HVAC trades, where appropriate commissioning and maintenance procedures are long established**.

Digitalization

Cross-cutting for an effective design and technical implementation is digitalization on all levels: 1) next-level design tools (parametric, automated, VR/AR) and robust processes relying, among others, on basic work from previous IEA SHC Tasks (digital façade models, energy rating algorithms) and 2) transfer of design data into the commissioning, predictive maintenance, and grid integration in a seamless data integration. **Digitalization is a critical success factor for low-carbon lighting and goes hand in hand with profitable future business models**.

Actions Needed

To support the implementation of energy efficient, sustainable, and at the same time integrated and integrative lighting solutions, the table below highlights some of the existing challenges, and the actions needed to address

4 Also, in standardization as EN 12464 "Light and lighting - Lighting of work places - Part 1: Indoor work places."

them. **The targeted stakeholders are governments, industry and their trade associations, designers, and building owners.**

Challenge	Action needed
Harvest 'low hanging fruit' in electric lighting	• Replace old lighting installations with **LED** technology. • Request **luminaire efficiencies >150 lm/W**. • Refocus from decisions based on pure investment costs to **total cost of ownership**.

Strengthen the role of daylighting	• **Recognize daylight** – which nowadays can be sufficiently quantified as a substitute for electric lighting – **a "renewable energy source"** – allowing for **inclusion in subsidy programs** as known from other market sectors (PV, wind, etc.).
	• **Use sustainability certificates** to promote daylighting, if not included, or revisit existing certificates and update.
	• Demand **a minimal window to floor area ratio,** e.g., in central Europe between **1/8 and 1/10**.
	• **Revise ordinances** to demand technical and economical advantageous daylighting solutions, such as:
	  - **Daylight-supportive combinations of glazing and sun shading/glare protection** devices
	  - **Light redirecting** fenestration, and
	• Daylight and occupancy sensitive **electric lighting controls** also integrated with facades (i.e., visual comfort driven when occupied, solar gain driven when unoccupied).

Widen the rating perspective of lighting	• Put lighting into the perspective of its **impact on decarbonization**. • **Foster LCA approaches** for rating integrated lighting.
Rethink products	• Make **product architectures5** more **sustainable.** • Push product design based on **micro-optics** for LED luminaires and façades applications. • Support development and implementation of disruptive façade technologies like **electrochromic glazing systems** (or other switchable technologies), ideally **in combination with vacuum glazing,** to drastically lower a façade's embodied energy.
Improve design processes	• Make **planning** of lighting installations **mandatory.** • Foster **employment of new available integrated design and rating tools**, which in part automatically indicates not yet allocated potentials. • Introduce processes **ensuring** certain **daylight quality levels** (e.g., parametric, automated design tools. • Use **design strategies** that prompt **energy efficient behaviors**. • Support the **deployment** of concepts from **new daylighting and electric lighting standard** (e.g., EN 17037 "Daylight in Buildings" and EN 12464 "Lighting of indoor workplaces").
Foster commissioning and maintenance	• Make **commissioning and maintenance** procedures mandatory avoiding rebound effects - as already done in other HVAC trades for years. • Practically integrate lighting into regular **electrical safety check procedures** in commercial buildings.

*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: Jan de Boer, Fraunhofer Institute for Building Physics, Germany and Task Manager of SHC Task 61 / EBC Annex 77 Integrated Solutions for Daylighting and Electric Lighting of the Solar Heating and Cooling Technology Collaboration Programme with input from Barbara Szybinska Matusiak, NTNU, Norway; David Geisler-Moroder, Bartenbach, Austria; and Niko Gentile, Lund University, Sweden

5 Product architecture is the organization (or chunking) of a product's functional elements.

5. Completed Tasks

Task 62 – Towards the Integration of Large SHC Systems into DHC Networks

Christoph Brunner
AEE – Institute for Sustainable Technologies
Task Manager for the Republic of Austria

Task Overview

The change to a sustainable, resource- and energy-efficient industry represents a major challenge in the coming years. The efficient supply of energy, the best possible integration of renewable energy sources and the recovery of resources in the sense of circular economy must go hand in hand. The use of solar process heat represents a large, but so far largely unused, potential in industry. Innovative and concrete solutions are needed for the long-term and successful introduction of solar thermal energy. The integration of solar process heat to supply technologies for waste water treatment represents a new field of application with great technical and economic potential for solar thermal energy. The efficient interaction, the nexus, between solar energy and water opens up new and innovative approaches.

The main objective of IEA SHC Task 62 is to increase the use of solar thermal energy in industry, to develop new collector technologies and to open up industrial and municipal water treatment as a new area of application with high market potential for solar thermal energy. The nexus between solar thermal energy and water treatment enables the development of new and innovative technology combinations and the change to a sustainable, resource- and energy-efficient industry.

The Task's work was divided into four subtasks:

- Subtask A: Thermally driven water separation technologies and recovery of valuable resources (Lead Country: Germany)
- Subtask B: Solar Water Decontamination and Disinfection Systems (Lead Country: Spain)
- Subtask C: System integrations and decision support for end user needs (Lead Country: Australia)

Participating Countries

	Research Institutes	Universities	Companies
Australia	4		
Austria		1	2
Denmark	1	1	
Germany	3	5	2
Italy	3	1	1
Netherlands		3	
Portugal	1	2	1
South Africa	1	1	
Spain	6	4	4
Sweden	1	1	
United Kingdom	1		
Total	**21**	**19**	**10**

Task Duration

The Task started October 2018 and ended September 2022. The final reporting was in November 2022.

Collaboration with other IEA SHC Tasks, IEA TCPs and Outside Organizations

The Task collaborated with IEA SHC Task 64 & IEA SHC Task 68. Exchanged information with the IEA SolarPACES Task VI: Solar Energy and Water Processes and Applications, the Industrial Energy-Related

Technologies and Systems Technology collaboration Programme (IETS TCP) and the SPIRE Association.

Collaboration with Industry

A high number of companies have been active in the Task 62 activities, showing the high interest of industry in the field of solar water management. Industrial involvement especially focused on technology developers related to membrane distillation and water treatment technologies.

In 2022, expert meetings of IEA SHC Task 62 could again be held physically. The 8th Meeting was held in Graz (Austria) within the conference ISEC 2022. AS the conference was a get together of industry and research, also industrial partners with focus in Membrane distillation joined the expert meeting with high interest. The 9th expert meeting (final meeting) was conducted within the EUROSUN conference held in Kassel (Germany). Within the conference participants from IEA SHC Task 62 had the possibility to meet with solar experts from research and industry.

Key Results

Technology Position Paper & Reports

Matrix of different industrial separation demands to be subjected to cutting edge thermal technologies versus availability of different low exergy heat sources

Deliverable A1 targets to elaborate a matrix to show the potential for separation technologies (focus MD) driven by waste heat and/or solarthermal in different industrial sectors. In 2022 the work on the matrix was included into the deliverable. The deliverable includes an overview on industrial wastewater and process fluid treatment, an overview on industrial heat supply as well as an overview on potential industrial applications.

Definition of future R&D demand

Based on the results already gained on defining the future R&D demand, the elaborated list has been finalized in 2022. In general, the deliverable targets to identify technological challenges and hurdles and specification of related R&D demand including basic research, component development, system technology and control strategy.
The definition of the technological future R&D demand is supposed to reflect needs for improvement by the MD manufactures. On the one hand the number of MD module and system suppliers is limited. On the other hand, information on problems and R&D demands from manufacturers is limited. Therefore, the definition of R&D demand is mainly based on the comprehensive experiences of the Task 62 research experts who have long term experience on the design, construction and operation of MD systems in different applications. The following Table 2 provides an overview on the key components of MD systems and associated R&D activities. Further up to date examples from R&D (e.g. recovery of galvanizing liquids, ammonia recovery, etc.) have been summarized in the deliverable. The deliverable is finalized and ready for the review process.

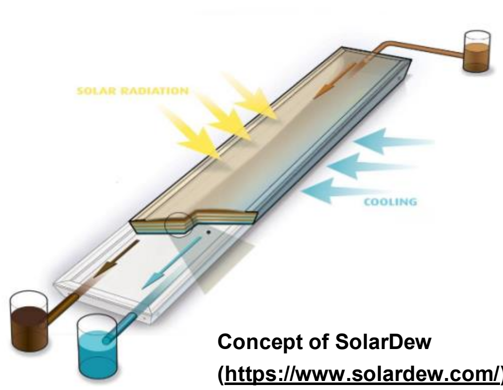
Overview on future R&d demand

Topic	Key properties	R&D activities
Membranes and materials	▪ Long term Hydrophobicity ▪ Scaling and fouling	The maintenance of the long-term hydrophobicity of the membrane is in different aspects associated with scaling and fouling prevention since depositions on the membrane surface or depositions growing into the membrane pores lead to significant changes of the natural properties of the membrane. Current R&D activities e.g. conducted by University of Bremen are focusing on the investigation of scale formations under artificial conditions in a MD lab cell for artificial sea water compositions. Simulation models are developed. These investigations must be continued for other complex wastewater streams to get broader knowledge on critical operation conditions for MD in industrial wastewater treatment and to have adequate design tools available. These experiences must be transferred to pilot scale application and tests must be conducted in real environment to validate the experiments and simulation models. With respect to future applications which will most likely always be in cutting edge conditions (concentration ratios very close and above saturation) hydrophobicity under extreme condition will be a key property to compete with other technologies.

	▪ Temperature resistance ▪ Mechanical reliability	Temperature resistance and mechanical reliability are mainly associated with material properties. The aim is on the one hand to enable a MD operation at higher temperatures to increase the process efficiency and on the other hand to make the MD process more robust against temperature fluctuations and random temperature peaks without complex safety control measures. For Polymer membranes which are often made from PTFE the limiting factor often is the support structure which is typically made from PP (polypropylene) or PE (polyethylene) is the limiting factor. Membrane research shall address the development of membranes with or without support which are entirely temperature resistant up to at least 150°C and have high mechanical strength. New R&D approaches are investigating tubular ceramic membranes for MD. Ceramic combines the advantage of high temperature stability and high mechanical strength which offers new design opportunities
	▪ Flux ▪ Selectivity also for other compounds ▪ Cost reduction	Flux and selectivity are a mainly depending on pore geometries while the change of pore diameter has opposing effects on the optimization. R&D must address the development of membranes with narrow pore diameter distribution and higher fluxes at smaller pore diameter to increase the hydrophobicity and LEP respectively. Future R&D should also address additional functionalization of MD membranes to achieve additional selectivity. Also other production technologies for polymer membranes must be developed to achieve the objectives mentioned above. Cost reduction of MD membranes and in further consequence the modules is an additional important factor to accelerate the market uptake of MD.
Module design	▪ Heat recovery ▪ Thermal efficiency ▪ Flux enhancement e.g. by vacuum ▪ Mechanical strength e.g. under Vacuum	Module design is a key enabling factor to make MD more efficient. Concepts for internal heat recovery exist and need to be further improved. The reduction of temperature polarization by appropriated channel structures and spacer material respectively will enable higher driving forces and more efficient processes. R&D is e.g. addressing MD module design for tubular ceramic membranes where an efficient internal heat recovery is not trivial. The application of vacuum for the removal of none dissolved gasses is another feature for the reduction of the specific thermal energy demand also at low operation temperatures. Therefore, ceramic materials are of huge interest since the design of vacuum assisted modules is much simper due to the mechanical strength of the material but also intelligent designed MD modules with polymer membranes need to be developed in the future which can withstand higher vacuum pressures.
	▪ Cleaning, scaling & fouling protection, maintenance	In addition to advancements in membrane design also modules and module operations must focus on scaling and fouling prevention. The operation of MD in cutting edge conditions has a high R&D demand.
	▪ End of life recycling	Thinking in a circular economy where water and material recovery plays is an important application for MD in the future the MD modules and systems also need to be considered as part of a circular economy. Therefore, a reuse of MD components or their raw material must be part of the design thinking process. Most critical part today are the PTFE membranes which must be substituted.
	▪ Costs	Operation costs are mainly driven by energy costs (heat and electrical) and energy efficiency respectively while investment costs can significantly be reduced in the future due to mass production, low cost polymers and simple system set ups. Costs will be one of the key factors to compete with other technologies.
System design	▪ Heat supply and cooling e.g. ▪ Advanced supply e.g. heat pump	The system integration of MD in industrial environment is quite individual. Neverthe less heating and cooling devices must be investigated and developed as e.g. the integration of heat pumps. Renewable energy supply for industrial processes as PV, wind and solar thermal integration also requires new flexibilities of users for better balances between supply and demand side without additional storage capacities. MD could act as flexible load in such industrial process heat networks. In addition, heat cascades need to be developed which are optimized with respect to best exegetic exploitation efficiencies.
	▪ System control	Digitalization provides huge potentials for the optimization of water treatment processes and overall system efficiency increases. E.g. digital twins could be applied

		for heat management of industrial sides with different suppliers and users. For the MD process, beside efficiency optimization, a digital controller could indicate maintenance intervals based on actual and real time operation parameters.
	▪ Integrated systems (e.g. SolarDew)	For integrated systems where the membrane is integrated into a solar thermal collector as in the SolarDew system R&D is addressing the proof of concept and the long-term reliability under real environmental conditions.

New solar thermal collector concepts for industrial water treatment



Concept of SolarDew (https://www.solardew.com/)

Within 2022 concepts for solar thermal water treatment have been summarized and included in Deliverable A.5. As an example, the concept of Solar Dew can be mentioned. The concept consists of a solar collector combined with the separation technology membrane distillation, which should enable the production of drinking water from virtually any source of polluted, contaminated, or saline water with the help of solar radiation. The main markets are developing countries, emergency relief (e.g., natural disasters), military, etc.

Summary report on lessons learned from demonstration projects and recommendations on best practices

Following lessoned learned could be summarized for creating and finalizing the deliverable:

- Intensive onsite demonstration is essential to make technology ready for the market and detect weaknesses.
- Big difference between specifications of wastewater composition and real wastewater – significant changes in short periods → treatment system fails (reported e.g. by companies operating waste water plants in India)
- Development, construction and implement of complex treatment systems in the framework of public founded projects is often time critical – finally not enough time for operation.
- Conflict of interest in public funded projects between innovation and industrial applicability (TRL to low) – demonstrated technology cannot be implemented on industrial scale directly after the project, funding for follow up R&D is missing.
- New technologies are too expensive even if demonstration was successful – industry does not follow up due to costs.
- Water market is conservative and not very open for innovation.

New solar collectors' concepts/design for hydrogen production and industrial water decontamination and disinfection. Potential link with thermal technologies

Solar reactor concept from AEE INTEC

Within 2022 concepts for hydrogen production and industrial water decontamination and disinfection have been summarized and included in Deliverable B.2. As an example, the concept of AEE INTEC for a Solar reactor can be mentioned. The design of the solar reactor includes a targeted process intensification approach in which a photo-electrochemical cell (PEC) is integrated into a concentrating solar collector tube with optimized rheology. To concentrate the solar irradiation, the solar collector tube is surrounded by a concave trough mirror. The photo-electrochemical process is used to split water into its components by directly using sunlight to produce alternative fuels such as hydrogen. To increase the process efficiency, wastewater is used in test series, since pollutants and waste substances contained in wastewater (e.g. microplastics, pesticides, trace substances) serve as an additional "source" of hydrogen (sacrificial substances). The advantage - at the same time as the fuel is produced, a significant elimination of pollutants and thus purification of the wastewater takes place. By combining this unique process concept with the direct use of solar energy, it is possible to offer the oxidation of the decomposition components sufficient residence time in the reactor with simultaneous intensive energy and mass transfer, and thus good penetration of the radiation into the reaction tubes. The reactor is set up in the technical center of AEE INTEC in Gleisdorf (Austria) and is tested there under real irradiation conditions.

Technological, economic, and political barriers for up-scaling new decontamination and disinfection systems for industrial water and wastewater management and reuse

In this methodological approach, a literature review was conducted. The aim was to identify and collect barriers from literature. The insights gained there were incorporated into the development of a questionnaire at the international level of IEA SHC Task 62 for data collection. This was distributed to a pool of experts at the international level to identify techno-economic and policy challenges as well as necessary measures to address these challenges, taking into account the water-energy nexus, and to improve water resilience in the industry. Furthermore, as part of the 6th Expert Meeting of the IEA SHC Task 62, a survey was created using MURAL (https://www.mural.co/). MURAL offers the possibility of a digital collaboration to visualize discussion topics in the form of a brainstorming.

The results on technological, economic and political barriers are summarized below. As far as **technological-economic barriers** are concerned, the studies agree with the opinion of the IEA Task 62 experts that **costs are the main bottleneck** for the adoption of new technologies. Efficient planning would save costs by choosing the right technologies. In addition to cost, the **lack of infrastructure** for water reuse, the **lack of maturity** of certain technologies, the **lack of knowledge** of operation and maintenance personnel, and the lack of knowledge of the purpose of the recycled water are also barriers to commercial use. Finally, **political barriers are also related to social barri**ers, with **awareness and social acceptance** of both the existing problem and the reuse of water being most important. The **lack of government regulations** also prevents the introduction of new technologies, as wastewater producing companies invest in achieving the prescribed quality standards and not beyond what is required by law.

Overview on technological and economic barriers

<table>
<tr><th>Technological barriers</th><th>Economic barriers</th></tr>
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<tr><td>

Lack of know-how
Optimized energy supply (incl. storage management)
Lack of space availability for solar installation when combining solar and wastewater treatment
Reservations towards new technologies in industry
Low interest in treatment technologies; present only in a few sectors that have concrete treatment problems

</td><td>

Operating costs (€/m^3 fresh water cheaper than recycled water).
Low degree of maturity with high investment costs - in total too high a risk
Regulatory and economic incentives too low
Costs and time required

</td></tr>
</table>

Overview on political barriers

Political barriers

- Legislation
- Regulations for water management
- Fresh water too cheap in many countries
- Government regulations lacking
- Tax adjustments for transportation costs and recycling costs

Dissemination Activities

Reports, Published Books, Online Tools, etc.

Author(s)/Editor	Title	Report No. Publication Date
Malato S., Oller I., Polo I., Fernández-Ibañez P.	Solar Detoxification and Disinfection of Water. In: Meyers R.A. (eds) Encyclopedia of Sustainability Science and Technology.	Springer, New York, NY. https://doi.org/10.1007/978-1-4939-2493-6_686-3

Journal Articles, Conference Papers, etc.

Author(s)/Editors	Title	Publication/Conference	Bibliographic Reference
M. Duke	Guidelines for wastewater treatment technologies in preparation	Solarthermalworld.org	https://solarthermalworld.org/news/guidelines-for-wastewater-treatment-technologies-in-preparation/
S.Meitz, C. Brunner, B. Muster-Slawitsch	Solar energy in industrial water and waste water management	Nachhaltige technologien	journal number 04/2022
Elena Guillen Burrieza, Eva Moritz, Maria Hobisch, Bettina Muster-Slawitsch	Recovery of ammonia from centrate water in urban waste water treatment plants via direct contact membrane distillation: Process performance in long-term pilot-scale operation	Journal of Membrane Science	https://www.sciencedirect.com/science/article/abs/pii/S0376738822009061?via%3Dihub

AEE INTEC, Christoph Brunner	Gold recovery in PCB industry (Project ReWaCem, MD-Gold)	Local news Austria	https://steiermark.orf.at/stories/3156726/
AEE INTEC	Austrian State Award for Ammonia recovery and usage in fuel cell (Project Ammonia-to-Power)	News	https://www.acr.ac.at/news/aee-intec-mit-umwelt-staatspreis-ausgezeichnet/
Submitted by Baerbel Epp	Online workshop about solar-powered industrial water management + Information on Deliverable B.1.	Press Release	https://www.solarthermalworld.org/news/online-workshop-about-solar-powered-industrial-water-management
J. Koschikowski	Using solar energy to recover acids and metals from wastewater	Press Release	https://task62.iea-shc.org/article?NewsID=345
Samira Nahim-Granados, Ana Belén Martínez-Piernas, Gracia Rivas-Ibáñez, Patricia Plaza-Bolaños, Isabel Oller, SixtoMalato, José Antonio Sánchez Pérez, Ana Agüera, María Inmaculada Polo-López	Solar processes and ozonation for fresh-cut wastewater reclamation and reuse: Assessment of chemical, microbiological, and chlorosis risks of raw-eaten crops	Water Research	Volume 203, 15 September 2021, 117532 https://doi.org/10.1016/j.watres.2021.117532
Azahara Martínez-García, Isabel Oller, Martin Vincent, Viviana Rubiolo, Jacent K. Asiimwe, Charles Muyanja, Kevin G. McGuigan, Pilar Fernández-Ibáñez, María Inmaculada Polo-López	Meeting daily drinking water needs for communities in Sub-Saharan Africa using solar reactors for harvested rainwater	Chemical Engineering Journal	Chemical Engineering Journal 428 (2022) 132494. https://doi.org/10.1016/j.cej.2021.132494
L. T. Nyamutswa, B. Hanson, D. Navaratna, S. F. Collins, K. G. Linden and M. C. Duke	Sunlight-Transmitting Photocatalytic Membrane for Reduced Maintenance Water Treatment	ACS ES&T Water	1(9): 2001-2011
L. T. Nyamutswa, S. F. Collins, D. Navaratna and M. C. Duke	Concept Demonstration and Future Developments of Sunlight Transmitting Nanophotocatalyst Coated Substrates for Sustainable Low Pressure Water Filtration	Water Desalination: Current Status and New Developments. Editor Y. Cohen, World Scientific Publishing Company:	In press
L. T. Nyamutswa, S. F. Collins, D. Navaratna and M. C. Duke	Light Transmitting Substrates for Convenient Solar Illumination of Nanophotocatalyst Coatings on Membranes for Low Pressure Water Filtration	Materials and Energy	17: 459-489
B. Muster-Slawitsch, N.	Membrane distillation for	Journal of Water Process	44: 102285

Dow, D. Desai, D. Pinches, C. Brunner and M. Duke	concentration of protein-rich wastewater from meat processing.	Engineering	
Fabrício Eduardo Bortot Coelho, Dennis Deemter, Victor M. Candelario, Vittorio Boffa, Sixto Malato, Giuliana Magnacca	Development of a photocatalytic zirconia-titania ultrafiltration membrane with anti-fouling and self-cleaning properties	Journal of Environmental Chemical Engineering	9: 106671
Elisabeth Cuervo Lumbaque, Renata M. Cardoso, Adriano de Araújo Gomes, Sixto Malato, Jose A. Sanchez Perez, Carla Sirtori	Removal of pharmaceuticals in hospital wastewater by solar photo-Fenton with Fe^{3+}-EDDS using a pilot raceway pond reactor: Transformation products and in silico toxicity assessment	Microchemical Journal	164: 106014
Ilaria Berruti, Samira Nahim-Granados, María Jesús Abeledo-Lameiro, Isabel Oller, María Inmaculada Polo-López	UV-C Peroxymonosulfate Activation for Wastewater Regeneration: Simultaneous Inactivation of Pathogens and Degradation of Contaminants of Emerging Concern	Molecules	26: 4890

Conferences, Workshops, Seminars, etc.

Conference/ Workshop/ Seminar	Activity & Presenter	Date & Location
ISEC 2022	Persentation on “More than just water -Waste water and sewage as a valuablre source”	Graz; April 5-7, 2022 (Austria)
ISEC 2022	Presentation by Mikel Duke: Industrial Water Treatment Technologies Driven by Renewable or Waste Energy Sources	Graz; April 5-7, 2022 (Austria)
ISEC 2022	Poster by Sarah Meitz: NEXUS ENERGY & WATER: SOLAR ENERGY IN INDUSTRIAL WATER AND WASTEWATER MANAGEMENT WITHIN THE IEA SHC TASK 62	Graz; April 5-7, 2022 (Austria)
Solarthermie Symposium	Presentation by Sarah Meitz: NEXUS Energie & Wasser: Solarenergie im industriellen Wasser- und Abwassermanagement im Rahmen des IEA SHC Task 62	Bad Staffelstein, May 3-5, 2022 (Germany)

EuroSun	Presentation by Sarah Meitz: Nexus Energy and Water: Integration Concepts for Solar Energy in Industrial Water and Waste Water Management	Kassel, September 25-29, 2022 (Germany)
EuroSun	Presentation by Mikel Duke: Solar Thermal and Photon Technology Selection Guidelines and Application Examples for Industrial Water Treatment: Updates from IEA Task 62 Subtask C	Kassel, September 25-29, 2022 (Germany)
EuroSun	Presentation by Alba Ruiz Aguirre: Pilot-Scale Photocatalytic Hydrogen Production, Decontamination and Disinfection Using TiO2 Mixed With Metal-Cocatalysts Under Natural Radiation	Kassel, September 25-29, 2022 (Germany)
Conference: Holistic approaches for water and resource efficiency in process industry	Energy Footprint of Water Treatment	March 25-26
IEA SHC Solar Academy: Webinar on Task 62: Solar Energy in Industrial Water & Wastewater Management	Christoph Brunner and Isabel Oller	March 23 & 25
ICheaP 15, The 15th International Conference on Chemical and Process Engineering	Poster	May 23-26, 2021 Naples, Italy
PHOTOPUR (FEDER EC funded project) Online Symposium	Water-Energy-Food nexus in industrial and urban wastewater recovery (Keynote)	December 9-10, 2021
ODAKTR Seminar Series (SOLARTWINS H2020 project)	Water-Energy-Food nexus in industrial and urban wastewater recovery (Keynote)	February 26, 2021
SECAT 2021	Poster presentation	October 18-21, 2021 Valencia, Spain
Asia Pacific Solar Research Conference	Oral presentation by Prof. Mikel Duke	December 16-17, 2022 UNSW and online

Task Meetings

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 1	October 1-2, 2018	Graz, Austria	11 participants 7 countries/sponsors

Task Meeting 2	March 18-19, 2019	Almería, Spain	33 participants 7 countries/sponsors
Task Meeting 3	October 8-9, 2019	Freiburg, Germany	24 participants 8 countries/sponsors
Task Meeting 4	April 21-22, 2020	Online Meeting	44 participants 14 countries/sponsors
Task Meeting 5	November 26- 27, 2020	Online Meeting	43 participants 10 countries/sponsors
Task Meeting 6	May 19, 2021	Virtual	28 participants 12 countries
Task Meeting 7	October 6-7, 2021	Virtual	27 participants 9 countries
Task Meeting 8	05.04.2022	Graz (Austria) & Online	23 participants 8 countries/sponsors
Task Meeting 9	September 28-29, 2022	Kassel (Germany) & Online	9 participants 5 countries/sponsors

Task 62 Participants

Country	Name	Institution / Company	Role
AUSTRIA	**Christoph Brunner**	**AEE INTEC**	**Task Manager**
AUSTRALIA	Mikel Duke	Victoria University	Subtask C Leader
AUSTRALIA	Cagil Ozansoy	Victoria University	National Expert
AUSTRALIA	Wei Yang	Victoria University	National Expert
AUSTRALIA	Xiwang Zhang	Monash University	National Expert
AUSTRALIA	Yunchul Woo	University of Technology Sidney	National Expert
AUSTRALIA	Gabriele Sartori	Project Manager APEC Project EWG 13 2017A; Director FutureCarbon Australia; Director EUAA	National Expert
AUSTRALIA	Anthony Fane	UNSW	National Expert
AUSTRIA	Bettina Muster-Slawitsch	AEE INTEC	National Expert
AUSTRIA	Elena Guillen	AEE INTEC	National Expert
AUSTRIA	Sarah Meitz	AEE INTEC	National Expert
AUSTRIA	Hendrik Müller-Holst	Evonik	National Expert
GERMANY	Joachim Koschikowski	Fraunhofer-Institute for Solar Energy Systems ISE	Subtask A Leader
GERMANY	Christian Sattler	DLR	National Expert
GERMANY	Dirk Krüger	DLR	National Expert
GERMANY	Matthias Kozariszczuk	VDEh-Betriebsforschungsinstitut GmbH	National Expert
GERMANY	Ewa Borowska	KIT	National Expert
GERMANY	Florencia Saravia	KIT	National Expert
GERMANY	Heike Glade	Universität Bremen	National Expert
GERMANY	Rebecca Schwantes	Solar Spring	National Expert
GERMANY	Wolfgang Heinzl	Wolf07	National Expert
GREECE	Konstantinos Plakas	Centre for Reseach and Technology-Hellas (CERTH)	National Expert
ITALY	Mariachiara Benedetto	Industrie De Nora S.p.A.	National Expert
ITALY	Daniela Fontani	CNR-INO	National Expert

ITALY	Frederica Prioetto	Università degli studi di Palermo	
ITALY	Paola Sansoni	CNR-INO	National Expert
ITALY	Fabrizio Vicari	Università degli studi di Palermo	National Expert
ITALY	Luigi Rizzo	Department of Civil Engineering; University of Salerno	National Expert
ITALY	Giacomo Pierucci	Dipartimento di Ingegneria Industriale dell'Università degli Studi di Firenze	National Expert
MALAYSIA	Ahmad Fauzi Ismail	Advanced membrane Technology Research Centre, Universiti Teknologi Malaysia	National Expert
MALAYSIA	Pei Sean Goh	Advanced membrane Technology Research Centre, Universiti Teknologi Malaysia	National Expert
MALAYSIA	Mohd Hafiz Ohman	Advanced membrane Technology Research Centre, Universiti Teknologi Malaysia	National Expert
NETHERLANDS	Alexander van der Kleij	SolarDew	National Expert
NETHERLANDS	Bart Nelemans	Aquastil	National Expert
PORTUGAL	Marta Carvalho	Aguas de Portugal	National Expert
PORTUGAL	Ana Magalhães	INEGI	National Expert
PORTUGAL	Ricardo Barbosa	INEGI	National Expert
PORTUGAL	António Manuel Pedro Martins	Águas do Algarve, S.A	National Expert
PORTUGAL	Luís Paulo Mestre Henriques	Águas do Algarve, S.A	National Expert
PORTUGAL	Tiago Osório	University of Évora	National Expert
PORTUGAL	Maria João Carvalho	LNEG	National Expert
SPAIN	Isabel Oller Alberola	CIEMAT PSA	Subtask B Leader
SPAIN	Junkal Landaburu	IMDEA Water	National Expert
SPAIN	Fernando Fresno	IMDEA Energy Institute	National Expert
SPAIN	Javier Marugán Aguado	Department of Chemical and Environmental Technology	National Expert

		Universidad Rey Juan	
SPAIN	Antonio Arqués	Campus de Alcoy de la Universitat Politecnica de Valencia	National Expert
SPAIN	Jose Ignacio Ajona	Seenso Renoval, S.L.	National Expert
SPAIN	Diego Alarcón-Padilla	CIEMAT PSA	National Expert
SPAIN	Lourdes Gonzalez	CIEMAT PSA	National Expert
SPAIN	Guillermo Zaragoza	CIEMAT PSA	National Expert
SPAIN	Sara Dominguez	APRIA Systems	National Expert
SPAIN	Javier Pinedo	APRIA Systems	National Expert
SPAIN	Manuel Pérez García	University of Almería	National Expert
SPAIN	Sandra Contreras Iglesias	Universitat Rovira i Virgili - Departament d'Enginyeria Química - ETSEQ	National Expert
SWEDEN	Joakim Byström	Solar Collector AB Absolicon Solar Collector AB	National Expert
SWEDEN	Stavros Papadokonstantakis	Chalmers University of Technology; Division of Energy Technology, Department of Space, Earth and Environment (SEE)	National Expert
UK	Harjit Singh	Brunel University London	National Expert

6. Ongoing Tasks

Task 63 – Solar Neighborhood Planning

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 to achieve 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 a 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 in 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 is focusing on strategies - business models and stakeholder engagement - to increase the 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 dissemination of case studies with solar planning of existing and new neighborhoods. Subtask D also gives input and serves as a testing platform for Subtask 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, in view 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, permeability of surface, 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 usages.
- Identify the potential co-benefits related to the hybrid or/and integrated usage of urban surface, apart from the solar energy production.
- Recommend suitable activities for stakeholder engagement/nudging strategies, and integrate the lessons learnt in the urban planning practice.
- Identify financial mechanisms and suggest ways to finance the transition, moving from 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 synthetizing solar energy and daylight performance of neighborhoods to 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 exchange of experiences from practice, including testing strategies and tools and interview 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 is in planning.

Task Duration

This Task started in September 2019 and will end in October 2023.

Participating Countries

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

Work During 2022

Subtask A: Solar Planning Strategies and Concepts

The second of two planned Ph.D. courses ("Fall Schools") was held during September 2022. The main objective was to introduce and discuss various solar strategies, and methods employed to assess and evaluate these solar strategies and concepts. The Fall School constituted of 4 days and final presentations. All sessions were carried online. The students worked in groups, on a project that allowed them to explore the integration of various solar technologies and strategies and to analyse them from various perspectives. The lectures were compiled into a booklet and put online on the Task 63 website.

The work to identify solar strategies based on archetypes continued. The neighborhood archetypes are employed to analyse various solar strategies and concepts. The 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 neighbourhoods may not allow. Recent work included to discuss different ways to compile and present the work on solar strategies. Workshops were held to discuss different ways of decision-making processes of solar strategies implementation, to support informed decisions. The first approach proposes steps including the identification of solar strategies and implementation of archetype scenarios, followed by recommendations for new and existing communities. The second approach focused on the development of a decision-making process for selecting solar strategies (i.e., PV, solar thermal, passive design, etc.) based on objectives/requirements to achieve solar neighborhoods (i.e., daylight, passive heating/cooling, solar access, energy consumption and generation, energy storage, net-zero energy, etc.). Such a decision-making process could be supported by introducing relative values on each factor and weighing them. The work on analyses of archetypes will be documented and used as part of the Deliverables D.A2 Design and analysis of archetypes and D.A3 Strategies for the design of new and existing high energy performance solar communities. Cooperation between Subtask A and Subtask B is ongoing; archetypes developed in Subtask A will be used in Subtask B to analyse financial mechanisms. Probably Subtask A and B will work together for the final deliverables. The final documentation and recommendations are scheduled to be online at the end of the Task.

Subtask B: Economic Strategies and Stakeholder Engagement

The main work focused on finalizing the first report (D.B1): *Surface Uses in Solar Neighborhoods. Definition of the most suitable surface uses to prevent conflicts and create synergies.* The core of the report describes urban surfaces definition and classification (surface uses in solar neighborhoods), conflicts, and synergies among surface uses (multiple benefits provided by surface uses). Furthermore, the most relevant solutions for each cluster were analysed, and the suitability of urban surfaces to integrate these solutions was discussed, together with their contribution to the climate resilience and sustainability objectives. The report is available online (published in September 2022).

Work to develop a method to propose and assess alternative scenarios for urban surface usages is ongoing and will be tested in 2023, in cooperation with Subtask A. The main focus is to find out how a flowchart for decision making could be developed. Discussions across subtasks are ongoing, to find suitable ways to present results.

Work on the second report; on economic incentives and business models, including added values, is ongoing. This activity aims at identifying financial mechanisms and suggest ways to finance the transition, moving from energy market to added value services. There was a delay for this part due to a change of the expert leading this work. Ongoing activities include the identification of:

- Typical financing mechanisms (e.g. bank financing, equity-based financing, etc.)
- Innovative financing mechanisms (e.g. PPA, P2P, VPP, etc.)
- Technological enablers, e.g. BIPV, thermal insulation, building Energy Management Systems (EMS).

As part of the third report in Subtask B, work on stakeholder analysis and behavioural economic strategies is ongoing. Three workshops were defined. The aim of these workshops was to introduce strategies for stakeholder analysis and concepts from behavioural science in the context of urban planning, and highlight their relevance:

- Workshop 1, held in March 2022, aimed to introduce stakeholder analysis approaches and work on an exercise on stakeholder identification. The final goal was to discuss, together with experts, what stakeholders are important to consider when designing solar neighborhoods, and the benefits and limits of taking this approach. The case study of NTNU Campus (Norway) was used as example for identifying stakeholders and their role.

- Workshop 2, held in August 2022, discussed the application of behavioural design in urban planning practices. The aim was to introduce concepts of behavioural science and how to practically think of potential behavioural problems when designing techno-centric interventions.

A third workshop will be held in Spring 2023, to discuss how strategies of stakeholder engagement can be combined with behavioral design to have a more successful, cooperative approach to project implementation. The results of the workshops will be used for the development of deliverable B3.

Subtask C: Solar Planning Tools

Work in 2022 mainly focused on finalizing the first report (D.C1): *Identification of existing tools and workflows for solar neighborhood planning*, published online in June 2022. In this report, data was gathered on the current state-of-the-art of tools for solar neighborhoods through a literature review, an analysis of National Common Indicators, and Workflow Stories (a model describing a specific design and / or planning project showcasing how tools were used during this process). All nine Task 63 countries contributed to the report; Australia, Canada, China, Denmark, France, Italy, Norway, Sweden and Switzerland.

The second part in Subtask C will be a "roadmap for improved workflows". Based on the results from workshops, two aspects and need of information stood out from discussions about such a roadmap:

1. Need of more information about the use of data sciences approaches in a holistic way. To that aim, it was decided to assess the available data and their uses around the world, through the collection of Solar Data Sheets, focused on solar maps.
2. The "state of the art" process when studying solar neighborhoods and related solar strategies is not sufficiently clarified. Therefore, it was decided to further investigate different planning processes. A template was developed to be used by different experts / countries to document planning processes.

This work will contribute to the development of the second and final deliverable in Subtask C.

Subtask D: Case Studies

The main work in Subtask D during 2022 has been on further detailing the template to describe the Task 63 case studies, and for the experts to continue to fill in the template for their case studies. The case studies could be for new development areas or existing areas requiring refurbishments, infills, etc. Presently we have 23 confirmed case studies from all nine participating countries, and two potential cases.

The topics included (when applicable) are on: 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 are locally involved in the planning of different neighborhoods in cooperation with local stakeholders. The cooperation with different local solar neighborhood planning projects will give feedback on our work and provide the Task participants the opportunity to present the results.

The planned public seminars and workshops in conjunction with Task meetings have been postponed due to the pandemic. The first public seminar in conjunction with a Task meeting was held in September 2022. The presentations were compiled into a booklet, available on the Task 63 website. The next public seminar (hybrid) will be held in Trondheim, in March 2023.

Work Planned For 2023

Subtask A: Solar planning strategies and concepts

The main activities for Subtask A planned in 2023 are:

- Simulation and analysis of the archetypes, developing of a decision-making tool/method regarding solar strategies.
- Report on neighborhood archetypes: design and analysis.
- Compile recommendations for designing solar neighborhoods for existing and new applications.

Subtask B: Economic strategies and stakeholder engagement

The main activities planned for Subtask B in 2023 are:

- Develop and test the method for urban surface uses on archetypes (link to Subtask A).
- Develop a framework to assess multiple benefits and financial benefits.
- Report on economic incentives and business models, including added values, to promote the diffusion of solar neighborhoods.
- Develop a framework for stakeholder engagement, and test.
- Report on strategies for stakeholder engagement and citizen involvement in solar neighborhoods.

Subtask C: Solar planning tools

The main activities planned for Subtask C in 2023 are:

- Finalize the work on data sciences and solar maps, and on planning processes.
- Develop a roadmap for improved workflows and development needs of solar planning tools.

Subtask D: Case studies

The main activities planned for Subtask D in 2023 are:

- Prepare all case studies, described using the case study template.
- Prepare final case studies online.
- Hold public seminar in conjunction with the Task 63 meeting in March in Trondheim, Norway.

Dissemination Activities In 2022

Reports, Published Books

Author / Editor	Title	Bibliographic Reference
Paparella R., Zanchetta C.	IL BIM TRA MODELLO E DOCUMENTO	Società Editrice Esculapio, Bologna, 2022 ISBN 978-88-9385- 270-8
Brozovsky, Johannes	The Climate Dimension in the Design of Resilient Urban Neighborhoods in Norway	Doctoral thesis (05, 2022)

Journal Articles, Conference Papers, etc.

Author(s) / Editor	Title	Publication / Conference	Bibliographic Reference
Formolli, M., Croce, S., Vettorato, D., Paparella, R., Scognamiglio, A., Mainini, A.G., Lobaccaro, G.	Solar Energy in Urban Planning: Lesson Learned and Recommendations from Six Italian Case Studies	Applied Sciences	2022, 12(6), 2950; http://dx.doi.org/10.3390/app12062950

Bragolusi, P., D'Alpaos, C. (corresponding author)	The valuation of buildings energy retrofitting: A multiple-criteria approach to reconcile cost-benefit trade-offs and energy savings	Applied Energy	Vol. 310, art number 118431, year 2022
Andreolli, F., D'Alpaos, C. (corresponding author), Moretto, M.	Valuing investments in domestic PV-Battery Systems under uncertainty	Energy Economics	Vol. 106,art number 105721, year 2022
Hasan, J., and Horvat M.	An Investigation on the Influence of Neighbourhood Morphology on Outdoor Thermal Comfort in Toronto's Public Spaces	A paper accepted to the 5th International Conference on Building Energy and Environment	COBEE 2022, Montreal, Canada
Czachura A, Kanters J, Gentile N, Wall M.	Solar Performance Metrics in Urban Planning: A Review and Taxonomy.	Buildings	Build 2022;12. https://doi.org/10.3390/buildings12040393.
Manni, M., Nocente, A., Stenerud, K., Skeie, Bellmann, M., Lobaccaro, G.	A Comparative Study on Solar Radiation Datasets for Photovoltaic Energy Prediction at High Latitudes	EuroSun 2022	Conference Proceedings
Jouttijärvi, S., Lobaccaro, G., Kamppinen, A., Miettunen, K.	Benefits of bifacial solar cells combined with low voltage power grids at high latitudes	Renewable and Sustainable Energy Reviews	Volume 161June 2022 Article number 112354 https://doi.org/10.1016/j.rser.2022.112354
Formolli, M., Kleiven, T., Lobaccaro, G.	Solar Accessibility at the Neighborhood Scale: A Multi-Domain Analysis to Assess the Impact of Urban Densification in Nordic Built Environments	Solar Energy Advances	Volume 2, 2022, 100023 https://doi.org/10.1016/j.seja.2022.100023
Thebault M., Desthieux G., Castello R., Berrah L.	Large-scale evaluation of the suitability of buildings for photovoltaic integration: Case study in Greater Geneva	Applied Energy	2022 https://doi.org/10.1016/j.apenergy.2022.119127
Shristi Bhusal, Supervisor: Dr. Miljana Horvat	Investigating the Effect of Neighbourhood Morphology on Outdoor Thermal Comfort in Public Spaces of Six Canadian Cities	Master Research Project (MRP) at Toronto Metropolitan University	Completed August 2022. Will be posted at university digital commons in few weeks
Yangchao Li, Supervisor: Dr. Miljana Horvat	Optimization of Neighborhood Form for Maximizing PV Production and Potential for Transformation into a Net-Zero Energy Neighborhood	Master Research Project (MRP) at Toronto Metropolitan University	Completed August 2022. Will be posted at university digital commons in few weeks
Czachura A, Gentile N, Kanters J, Wall M.	Identifying potential indicators of neighbourhood solar access in urban planning	Buildings	Buildings. 2022, 12. http://doi.org/10.3390/buildings12101575
Brozovsky, J.; Radivojevic, J.;	Assessing the impact of urban microclimate on building energy demand by coupling CFD and	Journal of Building Engineering	55, 2022, 104681. DOI: 10.1016/j.jobe.2022.

Simonsen, A.	building performance simulation.		104681
Paparella R. Paparella R.; Caini M.	Sustainable Design of Temporary Buildings in Emergency Situations	Sustainability	2022, 14(13), 8010; (Basel,Switzerland), MDPI, ISSN: 2071-1050 https://dx.doi.org/10.3390/su14138010
Hachem-Vermette, C.	Role of solar energy in achieving net zero energy neighborhoods	Solar Energy Advances	Volume 2, 2022, 100018, https://doi.org/10.1016/j.seja.2022.100018
Hachem-Vermette, C., Singh, K.	Energy systems and energy sharing in traditional and sustainable archetypes of urban developments	Journal of Sustainability	2022, 14(3):1356. DOI: 10.3390/su14031356
Singh, K., Hachem-Vermette, C.	Novel approach of urban energy simulations using EnergyPlus and programming language	Energy and Buildings	Volume 263, 15 May 2022, 112040. https://doi.org/10.1016/j.enbuild.2022.112040

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
COST Action CA16235 PEARL PV workshop entitled "Photovoltaic Systems in the Built Environment"	Oral presentation by Gabriele Lobaccaro, entitled “Solar Energy in Nordic Built Environments: Opportunities, Challenges and Barriers”	Januray 19, 2022 Digital event	20
Toronto 2030 District: Building Mounted Solar Project	J. Hasan presented the solar potential assessment for select Toronto neighbourhoods in the ‘Toronto 2030 District’.	February 18, 2022 Toronto, Canada	
COST Action CA16235 PEARL PV - PV in the built environment (WG4)	Oral presentation by G. Lobaccaro, entitled “Solar Energy in Urban Environment: Opportunities, Challenges and Barriers”	March 15, 2022 Hybrid event	40
Sustainable Practices course at the Department of Architectural Science, Ryerson, Toronto, Canada	J. Hasan presented a lecture on Solar Buildings: Solar Energy and Architecture	March 25, 2022 Toronto, Canada	
SHC ExCo Meeting	Oral presentation by G. Desthieux, of the research activities related to Solar Task 63	June 1, 2022 Rapperswil, Switzerland	100
APVI SHC knowledge	Mark Snow. Update on Task 63	Virtual meeting	14

sharing meeting	progress	July 22, 2022	
5th International Conference on Building Energy and Environment (COBEE 2022)	J. Hasan presented on the topic of "An Investigation on the Influence of Neighbourhood Morphology on Outdoor Thermal Comfort in Toronto's Public Spaces".	July 27, 2022 Montreal, Canada	
EvEuCoP workshop	Oral presentation by C. D'Alpaos, title "Do redistributive effects of incentives to buildings energy retrofitting hamper fuel poverty reduction in public housing?"	July 6, 2022 Coimbra, Portugal - online	200
MIT A+B	Oral presentation by C. D'Alpaos, title "Impact of P2P trading on the decision to invest in domestic PV-Battery Systems"	July 5-8, 2022 MIT Cambridge, USA - online	1100
Seminar on Solar neighborhoods: strategies and application case studies	Task 63 experts and invited presenters. Organized as part of IEA SHC Task 63	September 23, 2022 Calgary, Canada	Approx. 40 persons onsite, plus more than 45 online

Dissemination Activities Planned For 2023

Due to the pandemic, seminars and workshops in conjunction with Task meetings will be determined on a case by case basis. A public (hybrid) seminar is planned in conjunction with the next Task 63 meeting in Trondheim, Norway (March 2023).

Task Meetings in 2022 and Planned for 2023

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 6	March 28-31, 2022	Virtual	40 registrations 9 countries
Task Meeting 7	September 19-23, 2022	Calgary, Canada	29 (20 onsite, 9 online) 9 countries
2nd Fall School	September 2022 (partly in conjunction with 7th Task meeting	Virtual / Calgary, Canada	14 registered
Public seminar	In conjunction with 7th Task meeting	Calgary, Canada (hybrid)	Approx. 90 onsite + online
Task Meeting 8	March 7-10, 2023	Trondheim, Norway	
Public seminar	In conjunction with 8th Task meeting	Trondheim, Norway	
Task Meeting 9	TBD	TBD	

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	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
FRANCE	Benjamin Govehovitch	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	Martina Giorio	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	Johannes Brozovsky	NTNU – Norwegian University of Science and Technology	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	Arnkell J. Petersen	Multiconsult	National Expert
NORWAY	Wolfgang Kampel	Multiconsult	National Expert
NORWAY	Tobias Kristiansen	Multiconsult	National Expert
NORWAY	Rein Kristian Raaholdt	Multiconsult	National Expert
SWEDEN	Jouri Kanters	Energy and Building Design, Lund University	Subtask C Leader + co-leader Subtask D
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 64 – Solar Process Heat

Andreas Häberle
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 is to help solar technologies be (and recognized as) a reliable part of process heat supply systems. Instead of focusing on component development, we will look at the overall (solar) system at process temperatures from just above ambient temperature to approximately 400°C-500°C. Open research questions are 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. As a very important aspect, the experiences of numerous solar process heat markets worldwide will be brought together to enable market-oriented dissemination of existing and new knowledge.

The Task's key objective is 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 under consideration of 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 is organized into four main activities (Subtasks) derived from the above-described key areas:

- 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)*

Scope

Subtask A: Integrated Energy Systems
The main objective of Subtask A is to develop innovative hydraulic schemes for future process heat supply. These schemes will deploy different regenerative or highly efficient heating technologies to maximize the savings of final energy and greenhouse gas emissions compared to monovalent regenerative heating systems.

Specific objectives of Subtask A are to:

- Define reference applications for further research in the whole Task.
- Adapt hydraulic schemes, operational modes, and dimensioning rules of renewable heating technologies when combined with integrated energy systems.
- Assess the benefits of integrated energy concepts regarding overall synergies and economically achievable greenhouse gas emission savings.

Subtask B: Modularization
Since the advantages of using modularized components/packages are evident and widely admitted by the entities involved in the design and implementation of SHIP applications, the specific objective of Subtask B is the definition of modularized and "normalized" components/packages for these applications (e.g., components/packages for the balance of plant, solar field, interfaces, and hydraulic circuit). The legal requirements currently imposed on some industrial equipment (boilers, heat exchangers, etc.) will be considered when proposing normalized components/systems.

Subtask C: Simulation and Design Tools
The main objective of Subtask C is to develop simulations and monitoring tools for assessing the potential benefits of integrating Solar Heat into industrial processes with known uncertain sources, taking into consideration economic,

social and environmental issues. In addition, Subtask C will devote significant efforts to assessing monitoring strategies that improve actual systems' performance.

Subtask D: Standardization / Certification
The main objective of Subtask D is to investigate the standardization and certification area regarding the technology of solar process heat, to support the existing ongoing relevant standardization and certification activities, and to suggest and develop new innovative standardization procedures and certification aspects considering the relevant technological developments and legislative requirements.

Subtask E: Guideline to Market
Subtask E is to draft guidelines for a market approach more likely to succeed among industrial end-users. Closing the circle of strategies tackling technical and non-technical barriers to market penetration, in this subtask Solar Process Heat is to be delivered to industrial end-users as a simple, reliable, innovative, affordable, and profitable technological solution for the decarbonization of heating (and cooling) supply to industry.

Collaboration with Other IEA TCPs

This is a fully joint Task with the SolarPACES Task IV: Solar Heat Integration in Industrial Processes.

Collaboration with Industry

Twenty companies from 11 countries participated in at least one of the Task meetings in 2022.

Task Duration

This Task started on January 2020 and will end December 2023.

Participating Countries

Australia, Austria, Belgium, Brazil, Canada, Chile, China, Denmark, France, Germany, Greece, Italy, Mexico, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States

Work During 2022

Subtask A: Integrated energy systems

The team of Subtask A continued its work on system design for solar heating plants and heat pumps in industrial applications.

The design goal is to supply 100% of the individual 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 the ST system, the heat pump covers the rest of the annual load.

A large variety of simulations was conducted, and the first conclusions are that one of the most important design parameters will be the heat source temperature for the heat pump. The availability of a high-temperature heat source will drastically improve the seasonal COP of the HP and thus lower the LCOH of the whole system. Most other aspects are of minor importance.

Another activity within subtask A is the analysis of available roof area at industrial sites. Using an automated GIS approach, an analysis of a large number of companies in Germany was conducted. It showed that the majority of roofs are large enough to meet the above requirements for the ST system.

Subtask B: Modularization

The hypothesis of activity B1 was to identify a small number of integration schemes that can be viewed as generic "standards." However, the discussion with industrial partners within the subtask revealed very different approaches. The focus of that activity was therefore agreed to look at the Balance of Plant (BoP) of SHIP plants and to:

1. 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.
2. Identify the main elements (hydraulic equipment and instrumentation) for each BoP scheme.
3. Identify the thermal storage options for each BoP scheme.

4. Define the key technical parameters for each BoP scheme.

Deliverable B1 includes two generic BoP schemes. We decided to publish it and possibly amend it later with more schemes as they become available.

A lucky coincidence is that the German national project "Modulus" covers exactly the above-described focus and its results will be contributed to Subtask B in the coming year.

Subtask C: Simulation and Design Tools *(Lead Country: Chile)*

The activities in Subtask C are to execute comparative studies based on four case studies of actual plants and identify 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).

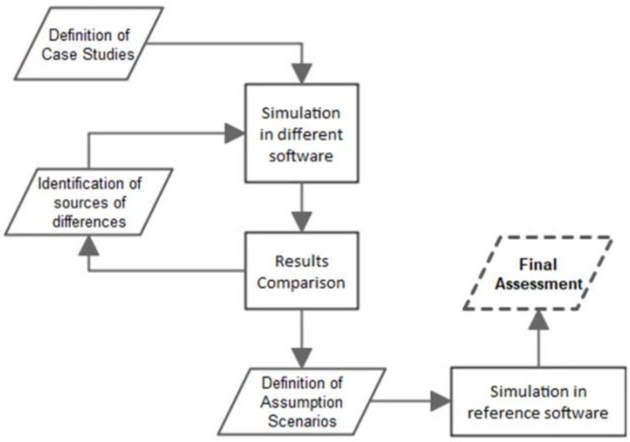
The simulation tools used were:

- 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

Figure 2. Flow chart for the case



All results were summarized in deliverable C1. This report shows a summary of the results obtained by the comparison campaign of the simulation tools used to evaluate SHIP plants 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 allows 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 for Cases A, B, C, and D obtained with different simulation tools and scenarios with induced errors studied show 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 mainly by the energy storage system. Despite the above, the energy dispatched towards the energy demand shows overestimates or underestimates with differences that can reach 41 % at an annual level. Furthermore, the complementarity between the analyses has made it possible to identify through the Dynamic Time Warping (DTW) that there are differences in terms of the dynamics of the time series, observing a wide range of values between the maximum and minimum limits found. Within the further progress of Subtask C of IEA-SHC Task 64, 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%.

Subtask D: Standardization / Certification

Unfortunately, the Subtask Leader had to cancel her contributions completely before reports were finalized due to a lack of resources. The Task experts could not identify a replacement Subtask Leader or find a solution to shift Subtask D work to other Subtasks, so the decision was made to cancel this Subtask.

Subtask E: Guideline to Market

Within activity E2, "Competitiveness indicators," the team of Subtask E is working on identifying the most relevant parameters for project assessment, split into the different project development phases pre-feasibility, detailed engineering and implementation.

An activity close to finalization is a position paper on the conversion factor m^2 to kW for statistical survey of projects that use concentrating solar thermal collectors. 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.

Work Planned For 2023

Subtask A: Integrated energy systems

Complete the final two deliverables:

D.A2 General integration concepts and achievable renewable fraction of integrated energy systems

D.A3 Dimensioning and integration guideline for integrated energy systems

Subtask B: Modularization

Coordinate with the Project MODULUS and complete the final deliverable:

D.B2 System/component modularization for SHIP applications that will focus on the Balance of Plant (BoP).

Subtask C: Simulation and Design Tools

Complete the final deliverable:

D.C2 Guidelines for implementing simulation tools for assessing and monitoring the performance of SHIP systems

Subtask E: Guideline to Market

Complete the final two deliverables:

D.E2 Update on technology costs, statistics and cost reduction trends, including suitable energy cost evolution perspectives and promoting the use of LCOH as benchmark for the comparison of innovative heating/cooling production systems

D.E3 New trends on financing schemes and business models to SHIP and collection of available SHIP financing possibilities

Finalize the position paper on the conversion factor $m^2 \rightarrow$ kW for concentrating collectors in market statistics.

Complete the Technology Position Paper on SHIP.

Dissemination Activities In 2022

Reports, Published Books

None at this time.

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
Cardemil, J.M.; Calderón-Vásquez, I.; Pino, A.; Starke, A.; Wolde, I.; Felbol, C.; Lemos, L.F.L.; Bonini, V.; Arias, I.; Iñigo-Labairu, J.; Dersch, J.; Escobar, R.	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
Pag F., Jesper M., Kusyy O., Vajen K., Jordan U.	Deckungsraten solarer Prozesswärmeanlagen unter Berücksichtigung des Lastprofils und vorhandener Dachflächen	Proc. 32. Symposium Solarthermie, Bad Staffelstein	May 3, 2022
Jesper M., Pag F., Vajen K., Jordan U.	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
Pag F., Jesper M., Kusyy O., Vajen K., Jordan U.:	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
Jesper M., Pag F., Vajen K., Jordan U.	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
Pag F.	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
Jesper M., Pag F., Vajen K., Jordan U.	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

Conferences, Workshops, Seminars

None at this time.

Dissemination Activities Planned For 2023

Contributions to Solar World Congress 2023, SolarPACES and national conferences.

Participation in the Solar Heat Europe (SHE) Task Force on industrial process heat.

Task Meetings in 2022 and Planned for 2023

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 9	April 5, 2022	Graz, Austria + online	60 participants 16 countries
Task Meeting 10	November 8-9, 2022	Bordeaux, France + online	35 participants 12 countries
Task Meeting 11	May 31 – June 1, 2023	Copenhagen, Denmark + online	37 participants 12 countries
Task Meeting 12	November 2023	TBD	

Task 64 Participants

Country	Name	Institution / Company	Role
SWITZERLAND	**Andreas Häberle**	**SPF**	**SHC TCP Task Manager**
SWITZERLAND	**Andreas Häberle**	**OST**	**ES TCP Task Manager**
AUSTRIA	Jana Fuchsberger	AEE INTEC	
AUSTRIA	Wolfgang Gruber-Glatzl	AEE INTEC	Subtask E Leader
AUSTRIA	Jürgen Fluch	FH-Joanneum	
AUSTRIA	Simon Moser	JKU	
AUSTRIA	Winfried Braumann	REENAG	
CHILE	Maria Cerda	Fraunhofer Chile	
CHILE	Ivan Munoz	Fraunhofer Chile	
CHILE	José-Miguel Cardemil	PUC	Subtask CLeader
CHINA	Qingtai Jiao	Sunrain	
DENMARK	Andreas Zourellis	Aalborg CSP	
DENMARK	Elsabet Nielsen	DTU	
DENMARK	Jakob Jensen	Heliac	
DENMARK	Simon Furbo	Technical University of Denmark	
DENMARK	Weiqiang Kong	Technical University of Denmark	
FRANCE	Valéry Vuillerme	CEA	
FRANCE	Alexis Gonelle	newHeat	
GERMANY	Tobias Hirsch	DLR	Task Manager SolarPACES Task IV
GERMANY	Dirk Krüger	DLR	
GERMANY	Uli Jakob	Dr. Uli Jakob Energy Research	Task Manager SHC Task 65
GERMANY	Peter Nitz	Fraunhofer ISE	Subtask E Leader
GERMANY	Andreas Burger	Industrial Solar GmbH	
GERMANY	Irapua Ribeiro	Industrial Solar GmbH	
GERMANY	Stefan Abrecht	Solar-Experience GmbH	
GERMANY	Mateo Jesper	Uni Kassel	

GERMANY	Ulrike Jordan	Uni Kassel	
GERMANY	Felix Pag	Uni Kassel	Subtask A Leader
ITALY	Marco D'Aurea	ENEA	
ITALY	Alessandro Guzzini	University of Bologna	
MEXICO	Mario Nájera Trejo	CIMAV	
MEXICO	Naghelli Ortega Avila	CIMAV	
SPAIN	Diego Alarcón	CIEMAT	Subtask B Leader
SPAIN	Loreto Valenzuela	CIEMAT	
SPAIN	Aitana Sáez	Circe	
SPAIN	Klaus Pottler	CSP Services	
SPAIN	Miguel Frasquet	Solatom	
SPAIN	Mercedes Ibarra Mollá	UNED	
SPAIN	Juan Diego Gil	University of Almería	
SPAIN	Manuel Pérez	University of Almería	
SPAIN	Alan Pino	University of Seville	
SPAIN	Antonio Cazorla-Marín	UPV	
SPAIN	Marco David	UPV	
SWITZERLAND	David Theiler	OST	
SWITZERLAND	Dimitrios Papageorgiou	TVP	
TURKEY	İbrahim Halil Yılmaz	Adana University	
TURKEY	Onur Taylan	METU	
TURKEY	Derek Baker	Middle East Technical University	

Task 65 – Solar Cooling for the Sunbelt Regions

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 2022

Subtask A: Adaptation

Activities planned to achieve the specific objectives and their timeframe were discussed. The following results were achieved in Subtask A in 2022.

A1: Climatic Conditions & Applications
Activity A1 is concluded. A Geographic information system (GIS) software was used to combine geographic data in a way that local reference boundary conditions for solar cooling systems in the Sunbelt regions can be determined and used for evaluation. The developed method can also be used to create information about possible locations and potentials of specific Solar Cooling systems. In addition, using, for example, population density and purchasing power data, a base for future market potential studies on certain products/technologies can be provided. As a result, potential sites can be identified, as well as economic factors to identify (future) markets.

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. The developed method was used to determine possible locations and potentials for the SBC system as a first example. It is planned to use the developed method in the further course of the task work.

A2/B1: Showcases on system and component level & Adapted components
The first survey results were conducted within the activities of two Task 65 activities: Adapted components (A2) and showcase of the system and favorable environment to prove the maturity of solar cooling technology. Insights drawn from this study could benefit a range of stakeholders: private users, public entities, 'hard to abate industrial sectors', policymakers, etc.

Moreover, the outcome of this study, and in general the expected results of Task 65, will facilitate tracing the pathway to decarbonization goals and contribute towards energy transition in the region. With the certainty of different case studies presented, energy professionals can make a more informed decision in choosing components and system adaptions suitable for varying climatic conditions.

The first presented results are drawn from 32 projects across 18 countries representing a range of 10 weather profiles such as the tropical wet and dry (Aw), hot desert (BWh), hot semi-arid (BSh), hot summer-Mediterranean (Csa), Warm-summer Mediterranean (Csb), Humid subtropic (Cfa), Monsoon-influenced humid subtropical (Cwa), Hot summer humid continental climate zones. The 32 projects studied are over 17.1 MW of thermal cooling projects, which are summarized as follows:

- Most of the projects reported are from BWh (Hot desert) (23%), and BSh (Hot semi-arid) & Csa (Hot summer-Mediterranean) (both 20%) climate regions.
- Almost 70% of the projects studied are implemented or detailed, with 25 % being concepts. 6% of the projects are experimentations and validated using real-time buildings.
- ST cooling is by far the most applied solar cooling technology over solar electric cooling. Out of which, 30% of cases studied use evacuated tube collectors, Flat plate collectors (17%), Fresnel collectors (17%), Parabolic trough collectors (10%) and PV panels (10%). These are some of the most preferred options.
- Of the available ST cooling techniques, 71% of them use solar absorption, whereas 19% use solar adsorption cooling and other technologies such as Ejector cooling, PV assisted cooling (3% each)
- Hot water storage or heat backup by auxiliary heating was used in 72% of the projects, with heat storage being more popular over heat backup.
- Cold backup was comparatively less in use, with 53% when compared to heat backup. To account for the intermittency of solar radiation, heat storage or auxiliary heating is observed to be the common practice.

- The major application was on public buildings (34%) with an average working span of 8hr/day, while others were used on domestic buildings (25%) and for the process industry (9%) and food processing sectors, among others.

A3: Adapted systems
The objective of Activity A3 is to summarise existing solar cooling systems and identify necessary adaptations to existing layouts. To this aim, Activity A3 focuses on Thermally driven systems, PV solar cooling and DEC and Free-cooling. Therefore, a systematic literature review structured in four different phases is conducted:

1. Integrative review
   - Sources and search
   - Comprehensive but with a specific focus
   - Experimental and non-experimental research
   - Purposive Sampling may be employed
   - Database searching, along with grey literature searching
2. Selection
   - Selected as related to an identified problem or question
   - Inclusion of empirical and theoretical reports and diverse study methodologies
3. Appraisal
   - Two quality criteria instruments should be developed for each type of source, and scores should be used as criteria for inclusion/exclusion or as a variable in the data analysis stage
4. Synthesis
   - Narrative synthesis for qualitative and quantitative studies
   - Data extracted for study characteristics and concept
   - Synthesis in the form of a table, diagram, or model to portray results
   - Extracted data are compared item by item
   - Similar data are categorized and grouped

The current literature review on solar cooling systems adapted to Sunbelt regions used 220 references and the main keywords: Solar cooling, Solar cooling adaption, Solar cooling climate, Solar cooling system design and Solar cooling control. Furthermore, a literature review was conducted on low-temperature district heating networks as heat rejection systems compatible with the Sunbelt regions.

A4: Building and process optimization potential
The current status of works related to activity A4 is as follows and, in particular, can be divided into two main parts. The first part aims to study the potential of energy-efficient buildings and processes in sunbelt regions for new and existing buildings. To do this, the subtask activities will be related to studies of other projects and, in particular, will be connected to IEA EBC (Buildings and Communities Programme) through projects that include building optimization and through the workshop with related and active Persons of EBC in sunbelt countries.

Another topic discussed under this topic is the integration of solar cooling in retrofitted HVAC systems. Depending on the existing conventional HVAC system, the integration can be challenging regarding refrigerants and cold distribution. Cold delivery systems are also of interest in decreasing the draft of air-based systems and increasing thermal comfort in buildings. The best technical solutions for the situation will be elaborated from technical and economic points of view.

A5: Building and process optimization potential
Activity A5 aims to standardize definitions to define a widely shared “language” for solar cooling. The first activity is about the definition of KPIs. To this aim, ITAE shared an ongoing activity on KPIs for thermal applications, focusing on adsorption systems and adsorbent materials. As a starting point, useful and interesting results have been achieved. KPIs will be classified at three levels: materials, components and systems. KPIs are widely recognized as an effective way to evaluate and compare different solutions and technologies within a certain field. Looking at the field of Solar Cooling, a “common language” is in some cases still missing; thus, precision and a grand vision in KPIs definition are missing as well. This is because of the vast range of different systems types and components (thermal, PV, chillers, storage, etc.) and because of the relatively low level of technology penetration in today’s energy systems, especially compared to other heating and cooling techniques. To solve this problem, Activity A5 designed a decision-making process to select appropriate KPIs.

Subtask B: Demonstration

Activities planned to achieve the specific objectives and their timeframe were discussed. The following results were achieved in Subtask B in 2022.

B1/A2: Show cases on system and component level & Adapted components
Activity B1 was merged with Activity A2 into one Deliverable. Therefore, the current results of the 32 collected solar cooling projects are reported.

B2: Design guidelines
A collection of design and system integration guidelines for the specific boundary conditions on solar cooling projects was performed. Responses to a questionnaire were received from several participants on multiple projects. The key focus was put on the following:

- Hybrid cooling system (Solar Thermal + HP + PV/PVT + Boiler, etc.)
- Systems with high solar fractions
- Standard modular packages for solar cooling solutions

B3: Key Performance Indicators
Although the key performance indicator definition is already often proceeded, there is still no standard. Within the solar cooling community, a mix of non-comparable KPIs is often used to express the quality of a system. This is not only confusing for end-users / operators/policymakers but also misleading the discussion among the experts. Thus, the focus is first on collecting existing technical and economic KPIs among completed and ongoing IEA SHC Tasks and other sources.

The approach of collecting necessary information via an online survey did not provide results. Internal discussions will take place to decide on alternatives, such as focusing on academic work already summarized in previous Task 63 or approaching project partners outside of Task 65. Moreover, Activity B3 will be merged with Activity C3.

B4: Standardization/solar cooling kits
The objective is the collection of standardization and solar cooling kits in all capacity ranges and different technologies. Research has been started on the following topics:

- Background on renewable energy standards: Understanding of the status of standards, test procedures and good practices for solar cooling equipment and assessing the needs and gaps for standardization of such technologies
- Specific standards for solar cooling (inputs from partners/organizations)
- Technologies covered by Australian Standards include solar desiccant cooling systems, solar air space heating systems, solar water space heating systems, building ventilation systems and evaporative cooling systems.

B5: Lessons Learned (technical and non-technical)
In Activity B5, the goal is to collect technical and non-technical lessons learned from several realized projects. Therefore, the activity has started identifying lessons learned from previous SHC Task 48 and Task 53 and discussed areas for achieving optimal resource efficiency. A Questionnaire was designed to get more details on:

- Stakeholder's needs and expectations
- Specific situations that could trigger the use of the product/service/process/strategy they want to or have to solve
- Goal: Develop key messages for solar cooling applications, creating scenarios that describe solutions for various stakeholders

The responses showed interest from different stakeholders: Universities (3), Energy Solution Provider (1) and Renewable Energy Research and Promotion Centers from the following countries/regions; South & East Africa, West India and South/East Europe.

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 2022.

C1: Design tools and models
The research based on a systematic literature review has been completed in Activity C1 with the following results. A total of 1,216 documents (757 journal articles, 418 proceeding papers, 98 review articles, and 12 book chapters) were identified as a result of the search in WoS. It is apparent that 'design tools' for solar cooling systems have not been the main focus investigated in the solar cooling knowledge domain. A query search string ("solar cooling") ("design") AND ("software") in the topic field produce 38 documents. Solar cooling system components are generally categorized into four processes: solar energy collection, cooling, distribution, and optional storage. Software tools are applied for estimating design parameters (by sizing tools) and predicting operational performance parameters (by simulation tools).

Moreover, a set of questionnaires was developed and distributed among the Task 65 experts. The initial data was gathered to provide a general idea of which components are being used and which software is being implemented. Based on the information provided by the task experts, the following software is currently being implemented in their applications/research for different design stages:

- Solar collector (Meteonorm + Excel Tool, Matlab, TRNSYS)
- Cooling technology (Matlab, EES, Excel Tool, TRNSYS, EnergyPlus)
- Storage (Matlab, EES, Excel Tool, TRNSYS)

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 prepared 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 the future outcome of system costs for solar cooling. The database elaboration also includes a review of existing useful information (e.g., SHC Task 54 and others).

C3: Assessment mechanism
This activity is working closely with Activity B3, the review of existing tools (other IEA SHC Task, …) and methods for technical (SPF, PER, fsav, etc.) and economic (LCC/CAPEX/OPEX, LCOH/LCOE, LCCBA, etc.) provides the bases to select the necessary KPIs for different project phases and stakeholders. A selection of one tool/platform will be forced to be used by this Task; the core activities are the adaption of methods and integration of the database (C2). The focus is to provide the corresponding methods for the analyses and creation of assessments for certain stakeholders.

Inputs on method adaptation and KPIs were collected in expert meetings, workshops and bilateral meetings/interviews. Moreover, Activity C3 will be merged with Activity B3.

Subtask D: Dissemination

Activities planned to achieve the specific objectives and their timeframe were discussed. The following results were achieved in Subtask D in 2022.

D1: Website/publications
Task 65 homepage is in operation and continuously updated.

Several publications about Task 65 were published, e.g., at EuroSun 2020, FotoVolt 10/2021, SWC 2021, APSRC 2021, ISEC 2022, EuroSun 2022 and APSRC 2022.

D2: Financial models for solar cooling
This work started with collecting and compiling information on established business models and the benefits of solar cooling applications. The next step is to develop new financing schemes suitable for solar cooling considering the

LCOE/LCC results of Subtask C and other alternative data sources. In parallel, work is underway on a document on the costs and benefits of solar cooling applications.

D3: Guidelines/roadmaps for Sunbelt countries
Work has been started on compiling new guidelines for solar cooling roadmaps, focusing on the specific constraints and opportunities in Sunbelt countries 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 industry of solar cooling and establish markets in the Sunbelt countries. The aim is to compile a position paper/white paper for policymakers.

D5: Workshops
The SHC Solar Academy Webinar Solar Cooling for the Sunbelt Regions – Task 65 was held on October 25 and 27, 2022, with the support of ISES. A total of 155 and 42 participants, respectively, took part. Speakers were Task 65 experts Daniel Neyer, Tobias Schmetzer and Uli Jakob, moderated by Bärbel Epp.

D6: Stakeholder engagement
A first round of identifying potential stakeholders in sunbelt countries has been completed. Forty-five individuals were contacted as potential stakeholders in March 2022. Nineteen 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 have been received 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 2023

Subtask A: Adaptation

The main activities planned for Subtask A in 2023 are:

- Finally, document the commercially available equipment compatible with PV electricity supply and solar thermal cooling equipment.
- Get to know R&D entities/manufacturers working on solar cooling components and systems and their expected technology development, especially according to the key point of climatic adaptation efforts.
- Document and show storage possibilities on the hot/cold side or other states.
- Evaluate the economic potential of adaption to certain climates and applications, especially when they can be simplified on component and system levels.
- 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 2023 are:

- Finally, reporting transfer procedures for measuring the solar cooling system's performance and communicating existing monitoring procedures for field tests or demo projects.
-
- Define and select key technical and economic performance factors for the stakeholders in the project phases.
- Document the demonstration plant and its achieved technical and economic key performance indicators.
- Analyze potential technical issues on monitored systems and create lessons learned for specific climatic conditions.
- Report selected best practice examples of solar cooling in sunbelt countries.

Subtask C: Assessment and Tools

The main activities planned for Subtask C in 2023 are:

- Continue to adapt existing technology, economic, and financial analysis tools to assess and compare different cooling options' economic and financial viability 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, market development, and policy design.
- Decision support in various phases of a project cycle, from initial project ideas and comparison of technology options to detailed investment grade calculation up to optimization of the operation phase based on case studies and use cases from subtasks A and B.
- Start to analyze the economic and environmental potentials of innovative technical concepts across the sunbelt boundary conditions.
- Pre-assess the 'bankability' of solar cooling investments with financial KPIs.
- Analyze and report demonstration plants' technical and economic performance and select best practice examples of Subtask B.

Subtask D: Dissemination

The main activities planned for Subtask D in 2023 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/book.
- Continue to collect and structure evidence for policymakers of the Sunbelt countries.

Dissemination Activities In 2022

Reports, Published Books

The first reports from several activities will be published in 2023.

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
Daniel Neyer, Uli Jakob	Solar Cooling for the Sunbelt regions IEA SHC Task 65	ISEC 2022 conference	April 2022
Uli Jakob, Paul Kohlenbach, Monika Weiss, Wolfgang Weiss	Integration of Solar-Assisted Cooling and Freezing into a Micro-Brewery Process Using a Hybrid Vapour-Compression/Sorption System	15th IIR Gustav Lorentzen Conference on Natural Refrigerants, Trondheim / Norway	June 2022
Paul Kohlenbach, Uli Jakob, P. Munzinger, A. Werntges	How To Cool A Warming World? – The Potential of Photovoltaic Green Cooling with Natural Refrigerants in Sunbelt Countries	EUROSUN 2022 conference, Kassel / Germany	September 2022
Bärbel Epp	Future potential of solar cooling	solarthermalworld.org	October 2022
Lu Aye, Nayrana Daborer-Prado, Daniel Neyer, Uli Jakob	Second Update on Activity C1 Design Tools and Models, Task 65 Solar Cooling Sunbelt Regions	Asia-Pacific Solar Research Conference 2022	December 2022

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
IEA-HPT Annex 53, 6th Expert meeting	Solar Cooling for the Sunbelt regions – Update. Uli Jakob, JER	February 2 Virtual	11
ISEC 2022 conference	Solar Cooling for the Sunbelt regions IEA SHC Task 65. Daniel Neyer, Neyer Brainworks / UIBK	April 22, 5-7 Graz, Austria	350
Web Forum Solarthermie 2022, Bauzentrum München	Solare Kühlung und Klimatisierung – Technologie und Entwicklungen. Manuel Riepl, ZAE Bayern	May 11 Virtual	50
15th IIR Gustav Lorentzen Conference on Natural Refrigerants	Integration of Solar-Assisted Cooling and Freezing into a Micro-Brewery Process Using a Hybrid Vapour Compression/ Sorption System. Uli Jakob, JER	June 13-15 Trondheim, Norway	100
EUROSUN 2022 conference	Keynote: The future of solar cooling. Uli Jakob, JER	September 26-28 Kassel, Germany	120
EUROSUN 2022 conference	Adapted Components and Show Cases on Solar Cooling Systems in Sunbelt Region Countries. Ben Alex Baby, Uni Palermo	September 26-28 Kassel, Germany	120
EUROSUN 2022 conference	How To Cool A Warming World? – The Potential of Photovoltaic Green Cooling with Natural Refrigerants in Sunbelt Countries. Paul Kohlenbach, SOLEM Consulting / BHT	September 26-28 Kassel, Germany	40

Dissemination Activities Planned For 2023

A fourth public workshop is planned in conjunction with one of the Task meetings in 2023. Moreover, the second industry workshop will be implemented as a hybrid event during the Task Meeting in March 2023 in Innsbruck, Austria, which will be held again in collaboration with the HPT Annex 53 experts.

Contributions at the 4th International Conference on Solar Technologies & Hybrid Mini Grids to improve energy access, Solar World Congress 2023 and national conferences.

Task Meetings in 2022 and Planned for 2023

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 4	March 23, 2022	Virtual	25 participants (8 countries)
Task Meeting 5	September 29, 2022	University Kassel, Germany	21 participants (11 countries)
Task Meeting 6	March 23-24, 2023	University Innsbruck, Austria, Hybrid	
Industry Workshop	March 24, 2023	University Innsbruck, Austria, Hybrid	
Task Meeting 7	4th quarter 2023	Messina, Italy	
Public Workshop	4th quarter 2023	Messina, Italy	

Task 65 Participants

Country	Name	Institution / Company	Role
GERMANY	**Uli Jakob**	**JER / Green Chiller**	**Task Manager**
AUSTRALIA	Lu Aye	University of Melbourne	National Expert
AUSTRIA	Alexander Friedrich	3F Solar	National Expert
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
AUSTRIA	Harald Dehner	FH OÖ / ASIC	National Expert
AUSTRIA	Nayrana Daborer-Prado	FH OÖ / ASIC	National Expert
AUSTRIA	Alois Resch	FH OÖ / ASIC	National Expert
AUSTRIA	Christian Kloibhofer	Gasokol	National Expert
AUSTRIA	Daniel Neyer	Neyer Brainworks	Subtask C Leader
AUSTRIA	Günter Neyer	Neyer Brainworks	National Expert
AUSTRIA	Christian Holter	SOLID Solar Energy Systems	National Expert
AUSTRIA	Hannes Poier	SOLID Solar Energy Systems	National Expert
AUSTRIA	Manuel Ostheimer	University of Innsbruck	National Expert
CHINA	Wei Wu	Hong Kong City University	National Expert
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
EGYPT	Admed Hamza H. Ali	Assiut University	National Expert
EGYPT	Mahmoud N. Abdelmoez	Assiut University	National Expert
EGYPT	Mohammed B. Effat	Assiut University	National Expert
EGYPT	Tamer A. Rehim	Nile Valley Engineering	National Expert

EGYPT	Laila Elgenedi	Nile Valley Engineering	National Expert
FRANCE	Amin Altamirano	Conservatoire National des Arts et Métiers	National Expert
FRANCE	Nolwenn Le Pierres	University of Savoie, Mont Blanc	National Expert
FRANCE	Benoit Stutz	University of Savoie, Mont Blanc	National Expert
GERMANY	Klaus Ramming	AGO	National Expert
GERMANY	Paul Kohlenbach	Berlin Hochschule für Technik	Subtask D Leader
GERMANY	Julia Römer	Coolar	National Expert
GERMANY	Roland Kühn	Coolar	National Expert
GERMANY	Christian Kemmerzehl	EAW	National Expert
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
GERMANY	Siddharth Dutta	protarget	National Expert
GERMANY	Frank Molter	SolarNext	National Expert
GERMANY	Mathias Safarik	TU Dresden	National Expert
GERMANY	Ernst Müller	Uni Kassel	National Expert
GERMANY	Manuel Riepl	ZAE Bayern	National Expert
GERMANY	Richard Gurtner	ZAE Bayern	National Expert
GERMANY	Andreas Maußner	ZAE Bayern	National Expert
GERMANY	Tobias Schmetzer	ZAE Bayern	National Expert
ITALY	Salvatore Vasta	CNR ITAE	Subtask A leader
ITALY	Alessio Sapienza	CNR ITAE	National Expert
ITALY	Francesca Martorana	CNR ITAE	National Expert
ITALY	Roberto Fedrizzi	EURAC	National Expert
ITALY	Amir Jodeiri Khoshbaf	EURAC	National Expert
ITALY	Pietro Finocchiaro	Solarinvent	National Expert

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
MOZAMBIQUE	Boaventura Cuamba	Eduardo University	National Expert
NETHERLANDS	Henk de Beijer	SolabCool	National Expert
SLOVAKIA	Michal Masaryk	Technical University Bratislava	National Expert
SPAIN	Pedro G. Vicente	Miguel Hernandez University	National Expert
SPAIN	Manuel Lucas	Miguel Hernandez University	National Expert
SPAIN	Francisco Javier Aquilar	Miguel Hernandez University	National Expert
SPAIN	Alberto Coronas	University Rovira I Virgili-CREVER	National Expert
SPAIN	Joan Carles Bruno	CREVER	National Expert
SPAIN	Juan Prieto	CREVER	National Expert
SPAIN	Dereje S. Ayou	CREVER	National Expert
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
UGANDA	Tom Fred Ishugah	Makerere University	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

Task 66 – Solar Energy Buildings

Harald Drück
Institute for Building Energetics, Thermotechnology and Energy Storage (IGTE), University of Stuttgart
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 B: Thermal stand-alone buildings and building blocks (Lead Country: China)
- Subtask C: Thermal grid-connected buildings and building blocks (Lead Country: Denmark)
- 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, system boundaries, and 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.
- Determine specific KPIs.
- Address aspects of scalability and assignability, user and stakeholder engagement, business and statement models, and financing.
- Summarize and prepare the results and disseminate measures.

Subtask B: Thermal stand-alone buildings and building blocks
The main objectives of Subtask B are:

- Determine economic and ecologic energy supply concepts with high solar fractions for new and existing buildings.
- Define potential 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.). If applicable, then further develop 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), and self-consumption levels. Consider available surface and the area- efficiency of individual technologies. Define integrated energy supply concepts for heat, cold, domestic electricity demand, and e-mobility. Develop intelligent control concepts (data-based and predictive). Consider aspects of increased user involvement.
- Model, simulate, and determine the levelized cost of energy. Evaluate using the technical, economic, and environmental KPIs and optimization procedures.

Subtask C: Thermal grid-connected buildings and building blocks
The main objectives of Subtask C are:

- Elaborate economic and ecologic energy supply concepts with high solar fractions for the existing building stock and new building blocks or communities, respectively.
- Define potential 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.). If applicable, further develop 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 potentials (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. Develop intelligent control concepts (data-based and predictive). Consider aspects of increased user involvement.
- Model, simulate, and determine the levelized cost of energy. 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 improved technical solutions.
- Conduct techno-economic assessment of newly developed solutions.

Collaboration with Other IEA TCPs

The Task is aiming to collaborate with the IEA PVPS.

Collaboration with Industry

The strong level of collaboration with industry is reflected by approximately 25% of the Task participants representing the non-academic sector. For the planned industry workshops, it is expected that around 50% of the participants will represent solar thermal collector manufacturers, system suppliers, building companies, HAVC companies, consultancies, business developers, and governmental institutions.

Task Duration

This Task started in July 2021 and will end in June 2024.

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 2022

No information provided.

Work Planned for 2023

No information provided.

Dissemination Activities In 2022

Reports, Published Books

None at this time.

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
Stephanie Banse	Analysing 126 solar energy buildings across Europe	solarthermalworld.org, December 2022	
Stephanie Banse	Optimised PVT and heat pump combinations for heating and cooling of buildings	solarthermalworld.org, October 2022	
Harald Drück, Dominik Bestenlehner	Definitions for Climate Neutrality and their Relevance for the Assessment of Solar Energy bd Hti	EuroSun 2022 conference, Sept. 22 - 29, 2022, Kassel Germany	
Dominik Bestenlehner, Harald Drück	Theoretical investigations for electric heating concepts for residential buildings	EuroSun 2022 conference, Sept. 22 - 29, 2022, Kassel Germany	
Elsabet Nielsen, Simon Furbo	Solar energy buildings with high degree of independence of energy supply from grids	EuroSun 2022 conference, Sept. 22 - 29, 2022, Kassel Germany	
Thomas Ramschak et. al.	Participation potentials for energy active facades in future flexibility markets	EuroSun 2022 conference, Sept. 22 - 29, 2022, Kassel Germany	

Jens Ullmann, Harald Drück, Bernd Hafner	Development of a commbined model predictive and adaptive control strategy for the operation of a cold district heating network	EuroSun 2022 conference, Sept. 22 - 29, 2022, Kassel Germany	
Stefanie Lott, Stephan, Fischer, Harald Drück, Bernd Hafner	Quasi-Dynamic Testing of Thermal Sun-Air-Collectors and Numerical Simulations of a Cold Ditit Hti	EuroSun 2022 conference, Sept. 22 - 29, 2022, Kassel Germany	
Harald Drück & Dominik Bestenlehner	Die Definition von Klimaneutralität und ihre Relevanz für die Solarthermie	Symposium Sola-rthermie und inno-vative Wärme-systeme, 03.–05. Mai 2022, Bad Staffelstein	
Elena Engelniederhammer & Bärbel Epp	How to get renewable energy to buildings in dense urban areas	solarthermalworld.org, April 2022	

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
Task 66 Industry Workshop		Virtual	56 participants
Task 66 Industry Workshop		Kassel, Germnay	31 participants

Dissemination Activities Planned For 2023

Event	*Date and Location*	# of Participants (# of Countries)
Industry Workshop No 3	February 7, 2023, virtual	
Industry Workshop No 4	October 9, 2023, Graz, Austria	

Task Meetings in 2022 and Planned for 2023

Meeting	Date	Location	# of Participants (# of Countries)
Experts Meeting 3	March 23-24, 2022	Virtual meeting	29 participants (12countries)
Experts Meeting 4	September 29-30, 2022	Kassel, Germany	17 participants (7 countries)
Experts Meeting 5	February 6, 2023	Virtual meeting	
Experts Meeting 6	October 9-10, 2023	Graz, Austria	

Task 66 Participants as of 2022

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
MEXICO*	Carlos Espino	Centro de Investigación en Materiales Avanzados, S.C., (CIMAV Durango)	National Expert
MEXICIO*	Naghelli Ortega Avila	Centro de Investigación en Materiales Avanzados, S.C. (CIMAV Durango)	National Expert
MEXICO*	Norma Rodríguez Muñoz	Centro de Investigación en Materiales Avanzados, S.C. (CIMAV Durango)	National Expert
MEXICO*	M.C. Mario Nájera Trejo	Centro de Investigación en Materiales Avanzados, S.C. (CIMAV Durango)	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

*Mexico participation through the PVPS TCP.

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

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 effectively determine the State of Charge of a CTES, and 3) increase the knowledge base on how to design optimized heat exchangers and reactors for CTES technologies.

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.

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

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

Work During 2022

Subtask A: Material Characterization and Database

Overall, 39 institutions from 15 countries participate in four round-robin test groups:

1. Thermal conductivity and thermal diffusivity of liquids, solids, and packed beds
2. Specific heat capacity of powdery materials
3. Enthalpy change due to sorption or chemical reaction
4. Thermal expansion, density, and viscosity determination

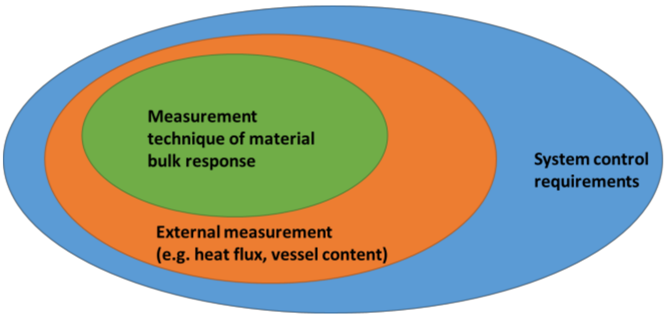
Every round-robin test has a person responsible for the actual progress. In 2022 several online meetings besides the biannual expert meetings took place to harmonize the measurement procedure and materials to be tested. At the time of this report, the round-robin tests are in the state of the actual measurements. Preliminary results from three institutes on the round-robin test on density were already obtained and discussed at the experts meeting in Kassel.

Subtask B: CTES Material Improvement

An overview was made of the different methods to tune material properties like energy density, charge/ discharge temperature, heat transfer and mass transfer. Experts presented their work on the materials developments: cycling stability of high energy density composite materials, synthesizing esters as PCM, plastic crystals as solid-solid PCM, using nano-particles to enhance the behavior of heat transfer fluids and PCM, using phase-diagrams to determine the optimal salt-hydrate mixture PCM.

A schematic overview was composed for CTES material characteristics with related properties on the material level and related KPIs on the component level. It was discussed if and how such a classification can be applied to prepare material improvement learning curves showing the evolution of research over the past years and Tasks.

Subtask C: State of Charge – SoC Determination



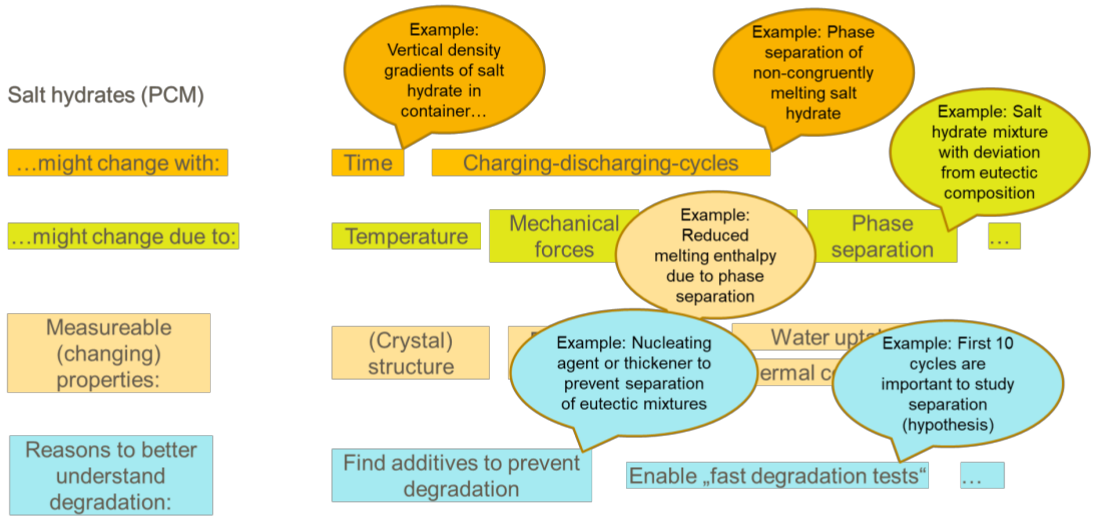
In this Subtask, two activities are running. First, to work on an inventory of promising material properties and related measurement techniques. The inventory will be based on a collection of methods for PCM and TCM thermal energy storage units, which have been developed by the participating organization or published in literature. Second, to work on a collection of experimental and numerical proof of concepts, including tested measurement techniques and sensor technologies.

To discuss and sort the collected SoC determination examples, a three-level schematic was developed and further refined during the 3rd experts meeting; see the figure above. Measurements on the material level (green circle) are usually calibrated with external measurements on the component level (orange circle). System control requirements are application specific and define, for example, the necessary SoC determination uncertainty, SoC determination frequency, and the communication between SoC measurement (device) and storage system integration.

Subtask D: Stability of PCM and TCM

Work started on listing the relevant degradation mechanisms for different material classes. For this, a template was made; see the figure below, where the template was filled in for salt hydrates to be used as PCM.

In the first discussion round, suggestions were made to refine further and improve the template.



Subtask E: Effective Component Performance with Innovative Materials

The Overall goals of Subtask E are: i) to make it possible to compare different components. ii) to assess how the use of different CTES materials affects the performance of a storage unit.

Different alternatives proposed by participants are being explored.

The $\dot{Q}_{mean}^{norm}$ / $\dot{C}_{mean}^{norm}$ (time weighted and energy weighted) proposed by the University of Basque Country and the University of Zaragoza in collaboration with the subtask participants has been applied for experimental results from more than 8 participants, and the open questions were identified and being discussed in the group. Stopping criteria were proposed, and they are also under discussion.

The University of Basque Country proposed the normalized UA for predicting the discharging time of LHTESS with different mass flow and materials properties. The predicting discharging time is compared to the discharging time obtained from the simulation using a numerical model.

An update of the approach of ZAE Bayern to evaluate charging/discharging power curves of PCM thermal energy storage units was presented and discussed. This method calculates charging/discharging curves with constant power output based on constant volume flow experiments. The underlying motivation addresses two questions: "How long can the PCM storage deliver constant power? How much energy can be delivered at constant power until power drops under a certain threshold value?" Based on two experimentally examined PCM storage units, the energy charged/discharged in constant volume flow experiments is equal to or less than the energy charged/discharged at constant power operation. Thus, considering the usable energy content determined in constant volume flow experiments might serve as a rough and conservative estimation for the usable energy content at constant power operation. This conclusion is to be backed up with more experimental results.

The three sections method proposed by Fraunhofer to assess the power performance of LHTESS was presented. The results shown are promising, and the next step is applying the methodology for different LHTESS concepts.

Work Planned For 2023

Subtask A: Material Characterisation and Database

Round-robin tests will be performed for the four properties indicated above. First, results should be discussed and further actions defined. The material database *www.thermalmaterials.org* is to be tested, in particular, the handling of the uploaded measurement data will be examined. In addition, the data content of the database will be extended by uploading measurement data from the group of participants.

Subtask B: CTES Material Improvement

A publication will be written about the current methods for performance improvement techniques for TCM and PCM. The inventory process will be continued, and application examples will be further studied.**Subtask C:**

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

Planned activities are to update the contributor table and complete CTES material stability mapping templates for CTES materials or material classes under investigation by the Task experts.

Subtask E: Effective Component Performance with Innovative Materials

Further work on constructing a set of KPIs for TCM and gathering input for component performance testing methods used.

For PCM, further work will be done on the inventory of existing performance characterization methods in literature, previous (IEA) work, and standards. The discussion on how to improve the current approach or develop alternatives will be continued, with the underlying question of whether it is possible to have a common approach for the different component designs.

Dissemination Activities In 2022

Reports, Published Books

Journal Articles, Conference Papers, etc.

Author(s) / Editor	Title	Publication / Conference	Bibliographic Reference
João Pássaro; A. Rebola; L. Coelho and J. Conde	Numeric study of geothermal borehole heat exchanger enhancement via phase change material macro encapsulation,	International Journal of Thermofluids, 2022-11	DOI: 10.1016/j.ijft.2022.100245, Part of ISSN: 2666-2027 (Q1)
João Pássaro, A. Rebola, L. Coelho, J. Conde, G.A. Evangelakis, C. Prouskas, D.G. Papageorgiou, A. Zisopoulou and I.E. Lagaris	Effect of fins and nanoparticles in the discharge performance of PCM thermal storage system with a multi pass finned tube heat exchange	Applied Thermal Engineering, 2022-07	DOI: 10.1016/j.applthermaleng.2022.118569, Part of ISSN: 1359-4311 (Q1)

Carlos Simão; Joao Murta Pina; João Pedro Oliveira; Luis Coelho; João Pássaro; Diogo Ferreira, Fernando Reboredo; Tiago Jorge and Pedro Figueiredo	A Case Study for Decentralized Heat Storage Solutions in the Agroindustry Sector Using Phase Change Materials	AgriEngineering, 2022-02	DOI: 10.3390/agriengineering4010018
Luis Coelho; Maria K. Koukou; George Dogkas; John Konstantaras; Michail Gr. Vrachopoulos; A. Rebola; Anastasia Benou; Ioannis Choropanitis; Constantine Karytsas; Constantinos Sourkounis and Zenon Chrysanthou	Latent Thermal Energy Storage Application in a Residential Building at a Mediterranean Climate	Energies, 2022-01	DOI: 10.3390/en15031008 (Q2)
Toifane, H.; Tittelein, P.; Cherif, Y.; Zalewski, L.; Leuck	Thermophysical Characterization of a Thermoregulating Interior Coating Containing a Bio-Sourced Phase Change Material	Applied Sciences 2022 12, 3827	doi:10.3390/app12083827
Ibrahim, R.A.; Tittelein, P.; Lassue, S.; Chehade, F.H.; Zalewski, L.	New Supply-Air Solar Wall with Thermal Storage Designed to Preheat Fresh Air: Development of a Numerical Model Adapted to Building Energy Simulation	Applied Sciences 2022 12, 3986	doi:10.3390/app12083986
Calabrese L., Palamara D., Piperopoulos E., Mastronardo E., Milone C., Proverbio E.	Deviceful LiCl salt hydrate confinement into a macroporous silicone foam for low-temperature heat storage application	Journal of Science: Advanced Materials and Devices	7, 2022, 100463
Mastronardo E., Mazza E.L., Palamara D., Piperopoulos E., Iannazzo D., Proverbio E., Milone C.	Organic Salt Hydrate as a Novel Paradigm for Thermal Energy Storage	Energies	15, 2022, 4339
Carrillo A.J., Bayon A., Coronado J.M., Mastronardo E.	Editorial: Recent Advances in Solar-Driven Thermochemical Fuel Production and Thermal Energy Storage	Frontiers in Energy Research	10, 2022, 885894
Mastronardo E., Piperopoulos E., Palamara D., Frazzica A., Calabrese L.	Morphological Observation of LiCl Deliquescence in PDMS-Based Composite Foams	Applied Sciences (Switzerland)	12, 2022, 1510
Calabrese L., Hernández L., Mondragón R., Cabeza L.F.	Macro-porous permeability aspects of MgSO4 salt hydrate foams for energy storage applications	Journal of Applied Polymer Science	139, 2022, 51924
Boquera L., Pons D., Fernández A.I., Cabeza L.F.	Characterization of supplementary cementitious materials and fibers to be implemented in high temperature concretes for thermal energy storage (TES) application	Publication	10.3390/en14165190
Gunasekara S.N., Barreneche C., Inés Fernández A., Calderón A., Ravotti R., Ristić A., Weinberger P., Ömur	Thermal energy storage materials (Tesms)—what does it take to make them fly?	Publication	10.3390/cryst11111276

Paksoy H., Koçak B., Rathgeber C., Chiu J.N., Stamatiou A.			
Koçak B., Fernandez A.I., Paksoy H.	Long-term stability of sensible thermal energy storage materials developed from demolition wastes interacting with hot heat transfer fluid	Publication	10.1002/er.7193
Svobodova-Sedlackova A., Barreneche C., Gamallo P., Fernández A.I.	Novel sampling procedure and statistical analysis for the thermal characterization of ionic nanofluids	Publication	10.1016/j.molliq.2021.118316
Majó M., Calderón A., Salgado-Pizarro R., Svodobova-Sedlackova A., Barreneche C., Chimenos J.M., Fernández A.I.	Assessment of Solid Wastes and By-Products as Solid Particle Materials for Concentrated Solar Power Plants	Publication	10.1002/solr.202100884
Svobodova-Sedlackova A., Huete-Hernández S., Calderón A., Barreneche C., Gamallo P., Fernandez A.I.	Effect of Nanoparticles on the Thermal Stability and Reaction Kinetics in Ionic Nanofluids	Publication	10.3390/nano12101777
Salgado-Pizarro R., Calderón A., Svobodova-Sedlackova A., Fernández A.I., Barreneche C.	The relevance of thermochemical energy storage in the last two decades: The analysis of research evolution	Publication	10.1016/j.est.2022.104377
Prieto C., Ruiz-Cabañas F.J., Madina V., Fernández A.I., Cabeza L.F.	Corrosion performance of alloy 800H and alloy 625 for potential use as molten salts solar receiver materials in concentrating solar power tower plants	Publication	10.1016/j.est.2022.105824
García-Plaza J., Díaz-Heras M., Mondragón R., Hernández L., Calderón A., Barreneche C., Canales-Vázquez J., Fernández A.I., Almendros-Ibáñez J.A.	Experimental study of different coatings on silica sand in a directly irradiated fluidised bed: Thermal behaviour and cycling analysis	Publication	10.1016/j.applthermaleng.2022.119169
Salgado-Pizarro R., Martín M., Svobodova-Sedlackova A., Calderón A., Haurie L., Fernández A.I., Barreneche C.	Manufacturing of nano-enhanced shape stabilized phase change materials with montmorillonite by Banbury oval rotor mixer for buildings applications	Publication	10.1016/j.est.2022.105289
Diarce, G., Rojo, A., Quant, L., Bouzas, L., García-Romero, A.	Thermal endurance of xylitol as a phase change material for thermal energy storage applications	Journal of Energy Storage	Journal of Energy Storage , 55, Part C art. no. 105717. Elsevier, 2022.
M. Navarro, Diarce, G., Lázaro, A. Rojo, A., Delgado, M.	Comparative study on bubbling and shearing techniques for the crystallization of xylitol in TES systems	Results in Engineering	Vol 17, March 2023, art no. 100909. Elsevier 2023
Laura Quant, Gonzalo Diarce, Lourdes Bouzas, Ana García-Romero,	A comprehensive study of the phase segregation of a urea-based phase change material	Journal of Energy Storage	Volume 60, 2023, art no. 106621

	tested under thermal cycling conditions,		
König-Haagen A., Diarce G	Comparison of Corrected and Uncorrected Enthalpy Methods for Solving Conduction-Driven Solid/Liquid Phase Change Problems	Energies	Vol 16 (1), art. no. 449,
Jafarian M.; Delgado M.; Omid M.; Khanali M.; Mokhtari M.; Lázaro Fernández, A.	Enhancing thermophysical properties of phase change material via alumina and copper nanoparticles	International Journal of Energy Research	10.1002/er.7594

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# Attendees	# Countries, Industry, Government, Research
ISEC 2022	Poster Wim van Helden	April 2022	~ 350	
VI IMPRES Symposium	Oral presentation Mikel Durán	Barcelona, Spain October 2022		
VI IMPRES Symposium	Oral presentation Sergio Santos	Barcelona, Spain October 2022		
E-MRS Fall meeting	Oral presentation Maria Taeño	September 2022		
Eurosun 2022	Oral presentation Ángel Serrano	Kassel, Germany September 2022		
Eurosun 2022	Poster presentation Stefania Doppiu	Kassel, Germany, September 2022		
Charactérisation Thermophysique d'un Enduit Intérieur Thermo Régulant Contenant Un Matériau a Changement de Phase Biosourcé	Presentation TOIFANE H.; Tittelein, P.; Zalewski, L.; Cherif, Y.; Leuck	Paris, France June 2022	~ 150	
Modélisation Par Approche MFN d'une Façade Solaire Pariétodynamique Destinée Au Préchauffage d'air Neuf : Problème de Détermination Des Coefficients d'échange Convectif	Presentation ABOU IBRAHIM R.; Tittelein, P.; LASSUE, S.; Hage chehade, F.; Zalewski, L.	June 2022 Paris, France	~ 150	
Etude Expérimentale d'un Échangeur-Stockeur Avec Matériaux à Changement de Phase Pour La Production Solaire d'eau Chaude Sanitaire	Poster Thonon, M. ; François, E.; Leconte, A.; Zalewski, L.; Fraisse, G.; Pailha, M.	June/July 2022 Albi, France	~ 100	

IMPRES 2022	Presentation Elpida Piperopoulos	October 2022		
IMPRES 2022	Presentation Candida Milone	October 2022		
IMPRES 2022	Presentation Luigi Calabrese	October 2022		
IMPRES 2022	Presentation Emanuela Mastronardo	October 2022		

Dissemination Activities Planned For 2023

A publication on the materials improvement methods is planned.

Task Meetings in 2022 and Planned for 2023

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 2	April 4-5, 2022	Graz, Austria	38 (13 countries)
Task Meeting 3	September 29-30, 2022	Kassel, Germany	41 (12 countries)
Task Meeting 4	April 24-26, 2023	Halifax, Canada	
Task Meeting 5	September 25-27, 2023	Lyon, France	

Task 67 Participants

Country	Name	Institution / Company	Role
GERMANY	**Wim van Helden**	**AEE INTEC**	**SHC Co-Task Manager**
GERMANY	**Andreas Hauer**	**ZAE Bayern**	**ES Co-Task Manager**
AUSTRIA	Samuel Knabl	AEE INTEC	National Expert
AUSTRIA	Daniel Lager	AIT Austrian Institute of Technology GmbH	Subtask A Leader
AUSTRIA	Peter Weinberger	TU Vienna	National Expert
AUSTRIA	Bernhard Zettl	University of Applied Sciences Upper Austria	National Expert
AUSTRIA	Gayaney Issayan	University of Applied Sciences Upper Austria	National Expert
AUSTRALIA	Kemal Hooman	University of Queensland	National Expert
CANADA	Dylan Brady	CanmetENERGY	National Expert
CANADA	Lia Kouchachvili	CanmetENERGY	National Expert
CANADA	Reda Djebbar	CanmetENERGY	Subtask C Leader
CANADA	Dominic Groulx	Dalhousie University	National Expert
CANADA	Majid Bahrami	Simon Fraser University	National Expert
CANADA	Handan Tezel	University of Ottawa	National Expert
CHINA	Yang Xiaohu	Xian Jiaotong University	National Expert
GERMANY	Anthony Rawson	DLR	National Expert
GERMANY	Nuria Navarrete Argiles	DLR	National Expert
GERMANY	Veronika Stahl	DLR	National Expert
GERMANY	Franziska Klünder	Fraunhofer ISE	National Expert
GERMANY	Sebastian Gamisch	Fraunhofer ISE	National Expert
GERMANY	Stefan Gschwander	Fraunhofer ISE	National Expert
GERMANY	Andrea Gutierrez	German Aerospace Center	National Expert
GERMANY	Maike Johnson	German Aerospace Center	National Expert
GERMANY	Konstantina Damianos	Rubitherm Technologies GmbH	National Expert
GERMANY	Thomas Herzog	TH Wildau	National Expert

GERMANY	Micha Schaefer	University of Stuttgart	National Expert
GERMANY	Christoph Rathgeber	ZAE Bayern	Subtask D Leader
GERMANY	Michael Brütting	ZAE Bayern	National Expert
GERMANY	Florian Kerscher	Technische Universität München	National Expert
GERMANY	Leander Morgenstern	Technische Universität München	National Expert
DENMARK	Alessandro Maccarini	Aalborg University	National Expert
DENMARK	Alireza Afshari	Aalborg University	National Expert
DENMARK	Evdoxia Paroutoglu	Aalborg University	National Expert
DENMARK	Anastasiia Karabanova	DTU	National Expert
DENMARK	Gerald Englmair	DTU	Subtask C Leader
DENMARK	Jianhua Fan	DTU	National Expert
DENMARK	Simon Furbo	DTU	National Expert
FRANCE	Gregory Largiller	CEA	National Expert
FRANCE	Jérôme Soto	CNRS, University of Nantes	National Expert
FRANCE	Lingai Luo	CNRS, University of Nantes	National Expert
FRANCE	Frederic Kuznik	INSA-Lyon	National Expert
FRANCE	Kevyn Johannes	INSA-Lyon	National Expert
FRANCE	Erwin Franquet	LaTEP-ENSGTI - University of Pau	National Expert
FRANCE	Laurent Zalewski	Université d'Artois	National Expert
FRANCE	Jean-Pierre Bedecarrats	University of Pau, LaTep	National Expert
FRANCE	José Laracruz	University of Pau, LaTep	National Expert
FRANCE	Nathalie Mazet	University of Perpignan	National Expert
FRANCE	Nolwenn Le Pierrès	University Savoie Mont Blanc	National Expert
ITALY	Andrea Frazzica	CNR	National Expert
ITALY	Vincenzo Brancato	CNR	National Expert
ITALY	Raffaele Liberatore	ENEA	National Expert

ITALY	Bianca Gumina	University of Messina, Department of Engineering	National Expert
ITALY	Candida Milone	University of Messina, Department of Engineering	National Expert
ITALY	Elpida Piperopoulos	University of Messina, Department of Engineering	National Expert
ITALY	Emanuela Mastronardo	University of Messina, Department of Engineering	National Expert
ITALY	Emanuele La Mazza	University of Messina, Department of Engineering	National Expert
ITALY	Fabrizio Alvaro	University of Messina, Department of Engineering	National Expert
ITALY	Luigi Calabrese	University of Messina, Department of Engineering	National Expert
ITALY	Davide Palamara	University of Messina	National Expert
NETHERLANDS	Henk Huinink	Eindhoven University of Technology	National Expert
NETHERLANDS	Natalia Mazur	Eindhoven University of Technology	National Expert
NETHERLANDS	Ruud Cuypers	TNO	National Expert
NORWAY	Alexis Sevault	Sintef	National Expert
NORWAY	Frida Vullum-Bruer	Sintef	National Expert
NORWAY	Galina Simonsen	Sintef	National Expert
NORWAY	Ragnhild Saeterli	Sintef	National Expert
POLAND	Pawel Oclon	Krakau University of Technology	National Expert
PORTUGAL	Alfredo Oliveira	Engineer	National Expert
PORTUGAL	Luis Coelho	Polytechnic Institute of Setubal	National Expert
PORTUGAL	José Costa	University of Coimbra	National Expert
SLOVENIA	Alenka Ristic	NIC	National Expert
SPAIN	Angel Serrano	CIC EnergiGune	National Expert

SPAIN	Eduardo Garcia-Suarez	CIC EnergiGune	National Expert
SPAIN	Elena Palomo del Barrio	CIC EnergiGune	National Expert
SPAIN	Jean-Luc Dauvergne	CIC EnergiGune	National Expert
SPAIN	Stefania Doppiu	CIC EnergiGune	Subtask B Leader
SPAIN	Elisa Alonso	CIEMAT	National Expert
SPAIN	Oscar Seco Calvo	CIEMAT	National Expert
SPAIN	Rocio Bayón	CIEMAT	National Expert
SPAIN	Ana Lazaro	Universidad Zaragoza	Subtask E Leader
SPAIN	Aran Sole	Universitat de Lleida	National Expert
SPAIN	Emiliano Borri	Universitat de Lleida	National Expert
SPAIN	Luisa Cabeza	Universitat de Lleida	National Expert
SPAIN	Camila Barreneche	University of Barcelona	National Expert
SPAIN	Ines Fernandez	University of Barcelona	National Expert
SPAIN	Gabriel Zsembinszki	University of Lleida	National Expert
SPAIN	Andreas König-Haagen	University of the Basque Country	Subtask E Leader
SPAIN	Gonzalo Diarce	University of the Basque Country	National Expert
SWEDEN	Amir Abdi	KTH Royal Institute of Technology	National Expert
SWEDEN	Saman Gunasekara	KTH Royal Institute of Technology	National Expert
SWEDEN	Tianhao Xu	KTH Royal Institute of Technology	National Expert
SWITZERLAND	Benjamin Fumey	EMPA	Subtask E Leader
SWITZERLAND	Xavier Daguenet-Frick	Institute for Solar Technology	National Expert
SWITZERLAND	Anastasia Stamatiou	Lucerne University of Applied Sciences and Arts	National Expert
SWITZERLAND	Rebecca Ravotti	Lucerne University of Applied Sciences and Arts	National Expert
SWITZERLAND	Paul Gantenbein	SPF Institut für Solartechnik	National Expert
UNITED KINGDOM	Yulong Ding	Birmingham University	National Expert

UNITED KINGDOM	Phil Eames	Loughborough University	National Expert
UNITED KINGDOM	Lukas Bergmann	Sunamp	National Expert
UNITED KINGDOM	Jon Elvins	Swansea University	National Expert
UNITED KINGDOM	Sara Walsh	Swansea University	National Expert
UNITED KINGDOM	Bob Critoph	University of Warwick	National Expert
UNITED STATES	Wale Odukomaiya	NREL	National Expert

Task 67 – Efficient Solar District Heating Systems

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

It is intended to cooperate with the IEA DHC Annex TS5, *Integrating Renewables*. The level of cooperation will start at a low level and possibly increase after further discussion. A joint Task Meeting is planned for 2023.

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 2022

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 started by designing a template to use to collect information from collector manufacturers, which will be included in the Task's first report. An excerpt of the template is shown in Figure 1.

IEA SHC Task 68 – Subtask A Concepts – Template A1 1

Version 1, 10.11.2022

Manufacturer	
Name	
Location	
Year of foundation	
Website	
Collector main features	
Model	
Technology	
Used materials	
Receiver environment	
Specific weight [kg/m²]	
Thermal power [W/m²] for the following conditions: Gb = 850 [W/m²]; Gd = 150 [W/m²]; v_{wind} = 1.3 [m/s]; Tm-Ta = 0 [K]	
Tracking type (single or two axes)	
Tracking precision [°]	
Power consumption of the tracking [kWh_e/m²a]	

Figure 2: Subtask A template used to gather information from collector manufacturers.

The participants also decided to use standard definitions for several key technical terms in the Task. For example, *"medium-high temperature heat"* means supply temperatures in the range of 80-120°C. And a news article in solarthermalworld.org was published covering the latest solar district heating developments in Germany and the Netherlands.

Subtask B: Data Preparation and Utilization

Task participants identified running projects that are relevant to the Subtask's work. Many institutions work on SDH digitalization topics and could support this work. For example, in Austria alone, about ten projects could potentially contribute to the subtask. Experts also discussed a draft of the first report, their inputs are in blue in Figure 2.

Draft structure RB1: Efficient gathering, storing, distributing and validation of data

Sensor Technology

Consider On-device / remote Satellite image resources ((https://solcast.com/?gclid=CjwKCAiAvK2bBhB8EiwAZUbP1ETe_oJLKfRYulFS2xu3d-i42IoO-p8lon4XCO3ot3FHf9LI1Mb_nxoCpQgQAvD_BwE) / Forecast data

- Recommended Sensor Types
- Uncertainties of the sensor types are important
- How to install it in order to reduce measurement errors
- Recommended Measurements

Data Acquisition

- Data Logging
  - Where to do the data logging ? ➔ on-site / in the cloud (e.g. PLC/ Database /) ➔ looking for best-practices here
  - If you need redundancy in the data ?
  - Jensen/ ISFH: Do we have to take care of the data size? Or is the approach: We measure everything we can and in the worst caste produce a lot of "data trash".
    - Feierl / SOLID: 1 Min. interval ➔ typically enough to understand most of the processes, since they are quite slow. Also der is a ISO Draft for the performance check which needs the 1 Min. ➔ it depends on the applications. Regarding data trash ➔ more annoying if you could have logged the data but you didn't do it ➔ Lukas perspective better log more data then needed

Figure 3: Excerpt of the session discussing the structure of the first report of Subtask B. Text in blue refers to input from the meeting participants.

Based on the feedback received, a short survey to identify concrete topics for Subtask B (Data Utilization) will be disseminated. In addition, the first open-access publication was published in the *Journal Solar Energy Advances* titled "Fault Detective: Automatic Fault-Detection for Solar Thermal Systems based on Artificial Intelligence." This publication presents the work on a fully data-driven fault detection algorithm applied to three different solar thermal systems with a focus on long-term performance using data from more than a year. An article on this work was also published in the December 2022 SHC Solar Update newsletter.

Subtask C: Business Models

An author team was formed to manage two upcoming deliverables. At the second Task Meeting, participants focused on *cost reduction*, and experts led by the Chinese collector manufacturer Sunrain provided important insight into the analysis of costs and options to reduce them.

Finally, Excel sheets were drafted to collect information on costs from manufacturers, see Figure 3.

			2023			2030			2050		
			< 1 MW	1 - 10 MW	> 10 MW	< 1 MW	1 - 10 MW	> 10 MW	< 1 MW	1 - 10 MW	> 10 MW
Investment costs total	Concentrating solar	[EUR/m2]	a ··· b	c ··· d	e ··· f						
	Vacuum tubes	[EUR/m2]	g ··· h	i ··· j	k ··· l						
	Flat plate high efficient	[EUR/m2]	m ··· n	o ··· p	q ··· r						
	Flat plate standard	[EUR/m2]	s ··· t	u ··· v	w ··· x						
... of which collector	Concentrating solar	[EUR/m2]									
	Vacuum tubes	[EUR/m2]									
	Flat plate high efficient	[EUR/m2]									
	Flat plate standard	[EUR/m2]									
... of which balance of plant	Concentrating solar	[EUR/m2]									
	Vacuum tubes	[EUR/m2]									
	Flat plate high efficient	[EUR/m2]									
	Flat plate standard	[EUR/m2]									
... of which installation costs	Concentrating solar	[EUR/m2]									
	Vacuum tubes	[EUR/m2]									
	Flat plate high efficient	[EUR/m2]									
	Flat plate standard	[EUR/m2]									
Fixed O&M costs	Concentrating solar	[EUR/m2/year]									
	Vacuum tubes	[EUR/m2/year]									
	Flat plate high efficient	[EUR/m2/year]									
	Flat plate standard	[EUR/m2/year]									
Variable O&M costs	Concentrating solar	[EUR/kWh]									
	Vacuum tubes	[EUR/kWh]									
	Flat plate high efficient	[EUR/kWh]									
	Flat plate standard	[EUR/kWh]									

Figure 4: Excerpt of the Excel sheet to efficiently collect information from manufacturers and system providers.

Subtask D: Use Cases and Dissemination

This subtask includes the results of the work of the SHC TCP communication activity on promoting solar district heating among multiplier organizations. Task participants provided feedback on the PPT presentation and discussed open technical issues, for example, how to deal with storages compared to other technologies.

Participants developed a special website to serve as a platform to promote the results of Task 68 in an appealing, hands-on, and easy-to-understand format for less technical target groups. The website describes the necessity of solar thermal district heating systems and how they can help to decarbonize cities. Example cities, selected from the EU manifest, show what 20% decarbonization of a city's heat demand using solar looks like. For each city, the size of the solar thermal field is shown in relation to the city district so people can better understand the scope of such projects and that it is feasible to build near or close to their city. A Task website is under development, which will include Task deliverables, videos, and roadmaps about the goals to decarbonize cities. Website visitors will be able to leave a comment, proposition, or question, and the Subtask D manager will redirect emails to professionals in charge of the specific topic. Figure 4 shows a screenshot of the draft website homepage, which will be updated throughout the Task.

Figure 4: Screenshot of the new website for disseminating the Task results in an appealing, easily understandable way.

Work Planned For 2023

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

For the year 2023, it is planned to:

- Collect the input from the Task experts on the first deliverable (see Excel sheet in Figure 2)
- Complete a report on the comparison of different collector manufacturers
- Prepare a news article
- Begin work on other Task reports
- Evaluate how the Subtask can use synergies with IEA DHC TS 5
- Evaluate whether the work in the subtask can lead to a scientific paper or a joint project

Subtask B: Data Preparation and Utilization

- Survey Task experts to gather input for the report on efficient gathering/storing/distributing of data and validation techniques
- Begin work on other Task reports
- Evaluate whether the work in the subtask can lead to a scientific paper or a joint project

Subtask C: Business Models

- Collect input from the Task experts on the draft Excel (see Excel sheet in Figure 4)
- Draft report on financing, investment schemes, and new business models
- Publish a news article on cost reduction potential (already published February 2023, see https://solarthermalworld.org/news/iea-shc-investigates-cost-reduction-potential-of-solar-district-heating/)
- Begin work on other Task reports
- Evaluate whether the work in the subtask can lead to a scientific paper or a joint project

Subtask D: Use Cases and Dissemination

- Provide an overview of efficient SDH systems to be updated throughout the Task
- Start the concrete work on reports
- Work and improve the dissemination website run by Absolicon with the latest Task results
- Organize an Industry Workshop
- Hold a joint meeting with the IEA DHC Annex TS5
- Publish a news article
- Evaluate whether the work in the subtask can lead to a scientific paper or a joint project

Dissemination Activities In 2022

Reports, Published Books

None at this time.

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
L. Feierl, V. Unterberger, C. Rossi, B. Gerardts and M. Gaetani	Journal Paper: *Fault detective: Automatic fault-detection for solar thermal systems based on artificial intelligence*	Solar Energy Advances,	Volume 3, 100033, ISSN 2667-1131
Bärbel Epp, Viktor Unterberger	Improving the efficiency of SDH	https://solarthermalworld.org	25.03.2021 Link: https://solarthermalworld.org/news/improving-sdh-efficiency/
Bärbel Epp, Joakim Byström, Bengt Söderbergh, Viktor Unterberger	Support joint marketing efforts for solar district heating	https://solarthermalworld.org	07.02.2022 Link: https://solarthermalworld.org/news/support-joint-

			marketing-efforts-for-solar-district-heating/
Viktor Unterberger	Solar goes Digital: Wie Solarwärme selbstlernende Algorithmen nutzt" (in English: Solar goes Digital: How solar heating uses self-learning algorithms)	https://www.solarwaerme.at/	11.05.2022 Webinar, Link: https://www.youtube.com/watch?v=AL01tNZiNz4
Bärbel Epp, Alejandro Diego Rosell	Heat pumps: Competition or complement in district heating?	https://solarthermalworld.org	13.09.2022 Link: https://solarthermalworld.org/news/heat-pumps-competition-or-complement-in-district-heating/
Absolicon + Task 68 Community	https://solardistrictheating.eu	01.11.2022	Non-researchers, general public

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees	If Task Hosted: Organized with, # participants
Cross SHC task workshop between Task 62, 64 and 68	Keynote regarding Task 68	April 2022 Graz Austria	~ 60	
ISEC 2022	Poster Automatic Fault Detection for Solar-Thermal Systems	April 2022 Graz Austria	350	

ISEC 2022	Poster IEA SHC Task 68 Efficient Solar District Heating Systems Efficient Solar District Heating Systems	April 2022 Graz Austria	350	
Swiss National Research Day	Presentation of the Task and participation panel discussion	June .2022	~100	
Austrian IEA Networking Event	Presentation of the Task	September 2022	~50	
Working group Meeting regarding Subtask D	Working meeting and presentation of task website	September 2022	~40	
IEA DHC ExCO Meeting	Presentation of the Task and interlinks between SHC and DHC	November 2022	~30	
IEA HPT Annex 56	Discussion and presentation of digitalization aspects between the two tasks/annexes	November 2022	~40	

Dissemination Activities Planned For 2023

- IEA Cross-TCP Workshop at the CEBC in Graz, Austria in January 2023
- Joint Task Meeting with TS 5
- Draft scientific paper
- Two Task Meetings
- Several Working Group meetings online

Task Meetings in 2022 and Planned for 2023

Meeting	Date	Location	# of Participants (# of Countries)
Experts Meeting 1	April 4-5, 2022	Graz, Austria	55 (14)
Working Group Meeting on Subtask D	September 25, 2022	Kassel, Germany	~40 (6)
Experts Meeting 2	November 9-10, 2022	Online	51 (16)
Expert Meeting 3	Spring 2023	Not defined yet	-
Expert Meeting 4	Autumn 2023	Sweden	-

Task 68 Participants

Country	Name	Institution / Company	Role
AUSTRIA	**Dr. Viktor Unterberger**	**BEST - Bioenergy and Sustainable Technologies GmbH**	**Task Manager**
AUSTRIA	Ing.in Sabine Putz	SOLID Solar Energy Systems GmbH	Subtask B Leader
AUSTRIA	Dr. Markus Gölles	BEST – Bioenergy and Sustainable Technologies GmbH	National Expert
AUSTRIA	Dr. Daniel Muschick	BEST – Bioenergy and Sustainable Technologies GmbH	National Expert
AUSTRIA	DI Christoph Rohringer	AEE INTEC - Institut für Nachhaltige Technologien	National Expert
AUSTRIA	DI Daniel Tschopp	AEE INTEC - Institut für Nachhaltige Technologien	National Expert
AUSTRIA	DI Philip Ohnewein	AEE INTEC - Institut für Nachhaltige Technologien	National Expert
AUSTRIA	Jonathan Cazco	AEE INTEC - Institut für Nachhaltige Technologien	National Expert
AUSTRIA	DI Thomas Natiesta	AIT - Austrian Institute of Technology GmbH	Subtask A Leader
AUSTRIA	Dr. Ralf-Roman Schmidt	AIT - Austrian Institute of Technology GmbH	National Expert
AUSTRIA	Dr. Sebastian Schramm	GREENoneTEC Solarindustrie GmbH	National Expert
AUSTRIA	DI Lukas Feierl	SOLID Solar Energy Systems GmbH	National Expert
AUSTRIA	Christian Holter	SOLID Solar Energy Systems GmbH	National Expert
AUSTRIA	Ass. Prof. Dr.-Ing. Fabian Ochs	UIBK - Universität Innsbruck Institut für Konstruktion und Materialwissenschaften	National Expert
AUSTRIA	DI Alice Tosatto	UIBK - Universität Innsbruck Institut für Konstruktion und Materialwissenschaften	National Expert
CHINA	Li Bojia	China Academy of Building Research	National Expert
CHINA	Jiao Qingtai	Sunrain Solar	National Expert

CHINA	Wandong Zheng	Tianjin University	National Expert
DENMARK	Andreas Zourellis	Aalborg CSP A/S	National Expert
DENMARK	Jianhua Fan	Department of Civil and Mechanic Engineering, Technical University of Denmark	National Expert
DENMARK	Jakob Jensen	Heliac A/S	National Expert
DENMARK	Geoffroy Gauthier	PlanEnergi	National Expert
FINNLAND	Kaj Bishop	Savo Solar	National Expert
FRANCE	Nicolas Lamaison	INES - cea tech	National Expert
FRANCE	Francoise Burgun	CEA	National Expert
GERMANY	Magdalena Berberich	Solites – Steinbeis Research Institute	Subtask A Leader
GERMANY	Stefan Mehnert	Frauenhofer ISE	National Expert
GERMANY	Dominik Bestenlehner	IGTE – University of Stuttgart	National Expert
GERMANY	Dirk Krüger	Institute of Solar Research German Aerospace Center Deutsches Zentrum für Luft- und Raumfahrt (DLR)	National Expert
GERMANY	Julian Jensen	ISFH (Institute for Solar Energy Research in Hamelin)	National Expert
GERMANY	Yuvaraj Sathiyadev Pandian	Solarlite CSP Technology GmbH	National Expert
GERMANY	Dirk Mangold	Solites – Steinbeis Research Institute	National Expert
GERMANY	Bärbel Epp	SOLRICO	National Expert
GERMANY	Thorsten Urbaneck	Technische Universität Chemnitz	National Expert
GERMANY	Karin Rühling	TU Dresden	National Expert
GERMANY	Christian Stadler	VIESSMANN	National Expert
GERMANY	Andreas Burger	Industrial Solar GmbH	National Expert
GERMANY	Paulina Majewska	Industrial Solar GmbH	National Expert

GERMANY	Joachim Krüger	Industrieverband Deutsche CSP	National Expert
GERMANY	Bert Schieble	Institute for Solar Energy Research Hamelin (ISFH)	National Expert
GERMANY	Julian Schumann	Institute for Solar Energy Research Hamelin (ISFH)	National Expert
GERMANY	Janybek Orozaliev	Kassel University	National Expert
GERMANY	Stefan Abrecht	Solar-Experience GmbH	National Expert
GERMANY	Jan Kelch	Uni Kassel	National Expert
ISRAEL	Lior Eshed	Tigi Solar	National Expert
ISRAEL	Filiba Eytan	Tigi Solar	National Expert
ISRAEL	Zvika Klier	Tigi Solar	National Expert
ITALY	Maurizio Repetto	Politecnico di Torino	National Expert
ITALY	Ivan Mariuzzo	Politecnico di Torino	National Expert
NETHERLANDS	Luuk Beurskens	TNO	Subtask C Leader
SPAIN	Eduardo Antonio Pina	GITSE-I3A, University of Zaragoza (Spain); IPESE, École Polytechnique Fédérale de Lausanne (Switzerland)	National Expert
SPAIN	Luis M. Serra	University of Zaragoza	National Expert
SPAIN	Ana Lazaro	University of Zaragoza	National Expert
SWEDEN	Benjamin Ahlgren	Absolicon	National Expert
SWEDEN	Joakim Byström	ABSOLICON	Subtask D Leader
SWEDEN	Daniel Bergqvist	Absolicon	National Expert
SWEDEN	Bengt Söderbergh	Absolicon	National Expert
SWEDEN	Max Bonnier Eklund	Absolicon	National Expert
SWEDEN	Gunnar Lennermo	Energianalys AB	National Expert
SWITZERLAND	Alexis Duret	Laboratory for Solar Energetics and Building Phyics (LESBAT), School of Engineering and Management Vaud	National Expert
SWITZERLAND	Xavier Jobard	Laboratory for Solar Energetics and Building Phyics (LESBAT), School of Engineering and Management Vaud	National Expert

SWITZERLAND	Florian Ruesch	OST – Ostschweizer Fachhochschule, SPF Institut für Solartechnik	National Expert
SWITZERLAND	Dimitris Papageorgiou	TVP Solar SA	National Expert
SWITZERLAND	Guglielmo Cioni	TVP Solar SA	National Expert
SWITZERLAND	Florent Saunier	TVP Solar SA	National Expert
UNITED KINGDOM	Alex Mellor	Naked Energy	National Expert
UNITED KINGDOM	William R H Orchard	Orchard Partners London Ltd	National Expert

7. SHC TCP Contacts

***These were the members as of December 2022**. Please check www.iea-shc.org for current members & contact information.*

Executive Committee Members

AUSTRALIA	**Mr. Ken Guthrie** Sustainable Energy Transformation Pty Ltd ken.guthrie@setransformation.com.au	***Alternate* – Dr. Stephen White** CSIRO Stephen.d.white@csiro.au
AUSTRIA	**Mr. Werner Weiss** AEE INTEC w.weiss@aee.at	***Alternate* – Mrs. Sabine Mitter** BMK Sabine.mitter@bmk.gv.at
BELGIUM	**Prof. Sergio Altomonte** Architecture et Climat Université Catholique de Louvain sergio.altomonte@uclouvain.be	
CANADA	**Dr. Lucio Mesquita** Natural Resources Canada Lucio.mesquita@canada.ca	
CCREEE (Sponsor)	**Dr. Gary Jackson** CCREEE gary@ccreee.org	
CHINA	**Prof. He Tao** *(Vice Chair)* China Academy of Building Research iac@vip.sina.com	***Alternate* – Dr. Xinyu Zhang** China Academy of Building Research zxyhit@163.com
DENMARK	**Mrs. Carina Haubjerg** Danish Energy Agency carha@ens.dk	***Alternate* – Mr. Leo Holm** PlanEnergi lh@planenergi.dk
EACREEE (Sponsor)	**Canon Goddy Muhumuza** EACREEE f.ishugah@eacreee.org	
ECOWAS/ECREEE (Sponsor)	**Mr. Guei Kouhie** ECREEE g.muhumuza@ecreee.org	***Alternate* – Mr. Julien Bulgo** ECREEE jbulgo@ecreee.org
EUROPEAN COMMISSION	**Mrs. Szilvia Bozsoki** European Commission – ENER C2 Szilvia.BOZSOKI@ec.europa.eu	***Alternate* – Mr. Piero De Bonis** European Commission - RTD D1 Piero.de-bonis@ec.europe.eu
EUROPEAN COPPER INSTITUTE (Sponsor)	**Mr. Robert Pintér** ECI robert.pinter@copperalliance.eu	
FRANCE	**Mr. Paul Kaaijk** ADEME paul.kaaijk@ADEME.fr	***Alternate* – Dr. Daniel Mugnier** PLANAIR daniel.mugnier@planair.fr

GERMANY	**Ms. Kerstin Krüger** *(Vice Chair)* Forschungszentrum Jülich GmbH k.krueger@fz-juelich.de	**Dr. Daniela Rolf** Forschungszentrum Jülich GmbH drolf@fz-juelich.de
ISES (Sponsor)	**Dr. Klaus Vajen** ISES President vajen@uni-kassel.de	***Alternate* – Ms. Jennifer McIntosh** International Solar Energy Society (ISES) mcintosh@ises.org
ITALY	**Dr. Maria-Anna Segreto** ENEA mariaanna.segreto@enea.it	***Alternate* – Dr. Alessandra Scognamiglio** ENEA Alessandra.scognamiglio@enea.it
NETHERLANDS	**Mr. Tomas Olejniczak** *(Chair)* Netherlands Enterprise Agency (RVO) tomas.olejniczak@rvo.nl	***Alternate* – Mr. Lex Bosselaar** Netherlands Enterprise Agency (RVO) Lex.bosselaar@rvo.nl
NORWAY	**Ms. Trine Kopstad Berentsen** Norwegian Solar Energy Cluster trine@solenergiklyngen.no	***Alternate* – Dr. Michaela Meir** Inaventa Solar michaela@inaventasolar.com
PORTUGAL	**Mr. Jorge Facãco** LNEG jorge.facao@lneg.pt	***Alternate* – João Cardoso** LNEG joao.cardoso@lneg.pt
RCREEE (Sponsor)	**TBD** RCREEE ashraf.kraidy@rcreee.org	***Alternate* – Dr. Maged K. Mahmoud** RCREEE maged.mahmoud@rcreee.org
SACREEE (Sponsor)	**Mr. Kudakwashe Ndhlukula** SACREEE kuda.ndhlukula@sacreee.org	***Alternate* – Mr. Readlay Makaliki** SACREEE readlay.makaliki@sacreee.org
SICREEE (Sponsor)	**Ms. María Eugenia Salaverria** SICREEE maria.salaverria@sicreee.org	***Alternate* – Ms. Alexandra Arias** SICREEE alexandra.arias@sicreee.org
SLOVAKIA	**Dr. Eduard Jambor** SIEA eduard.jambor@siea.gov.sk	
SOUTH AFRICA	**Dr. Karen Surridge** SANEDI karenst@sanedi.org.za	***Alternate* – Mr. Barry Bredenkamp** SANEDI barryb@sanedi.org.za
SPAIN	**Dr. Rita Valenzuela** CIEMAT r.valenzuela@ciemat.es	***Alternate* – Dr. Franciso Ferrera Cobos** **CIEMAT – PSA** fferrera@psa.es
SWEDEN	**Ms. Kajsa Paludan** Swedish Energy Agency kajsa.paludan@swedishenergyagency.se	
SWITZERLAND	**Mr. Andreas Eckmanns** Federal Office of Energy andreas.eckmanns@bfe.admin.ch	***Alternate* – Dr. Stephan Mathez** Solar Campus GmbH Stephan.a.mathez@solarcampus.ch
TURKEY	**Dr. Bulent Yesilata** Ankara Yildirim Beyazit University	***Alternate* – Dr. Kemal Gani Bayraktar**

	byesilata@yahoo.com	TTMD kgbayraktar@outlook.com
UNITED KINGDOM	**Mr. George Bennett** Department of Business, Energy & Industrial Strategy (BEIS) george.bennett@beis.gov.uk	

Operating Agents

Task 61 – Integrated Solutions for Daylight and Electric Lighting	**Dr. Jan de Boer** Fraunhofer Institute of Building Physics GERMANY jdb@ibp.fraunhofer.de
Task 62 – Solar Energy in Industrial Water and Wastewater Management	**Mr. Christoph Brunner** AEE INTEC AUSTRIA c.brunner@aee.at
Task 63 – Solar Neighborhood Planning	**Dr. Maria Wall** Lund University SWEDEN maria.wall@ebd.lth.se
Task 64 – Solar Process Heat	**Dr. Andreas Häberle** Eastern Switzerland University of Applied Sciences (OST) SWITZERLAND Andreas.haeberle@ost.ch
Task 65 – Solar Cooling for the Sunbelt Regions	**Dr. Uli Jakob** Dr. Jakob energy research GMbH & Co. GERMANY Uli.jakob@drjakobenergyresearch.de
Task 66 – Solar Energy Buildings	**Dr. Harald Drück** University of Stuttgart GERMANY Harald.drueck@igte.uni-stuttgart.de
Task 67 – Compact Thermal Energy Storage Materials within Components within Systems	**Dr. Wim van Helden** AEE INTEC AUSTRIA w.vanhelden@aee.at
Task 68 – Efficient Solar District Heating Systems	**Dr. Viktor Unterberger** BEST viktor.unterberger@best-research.eu
Task 69 – Solar Hot Water for 2030	**Prof. Robert Taylor** University of New South Wales – Sydney robert.taylor@unsw.edu.au

TCP Support

SHC Secretariat	**Ms. Pamela Murphy** secretariat@iea-shc.org
IEA Secretariat	**Mr. Kazuhiro Kurumi** Kazuhiro.KURUMI@iea.org
Webmaster	**Mr. Randy Martin** randy@rlmartin.com