2021 Annual report

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Feature article on solar district heating and cooling networks

2021
Annual report

April 2022

The contents of this report do not necessarily reflect the viewpoints or policies of the International Energy Agency or its member countries, the IEA Solar Heating and Cooling Technology Collaboration Programme members or the participating researchers.

Cover: The solar heating plant in Silkeborg, Denmark, is 156,694 m2 and covers 20% of the city's annual heat demand. (source: Silkeborg Forsyning A/S)

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1. Message from the Chair

In 2021, the IEA SHC Technology Collaboration Programme (SHC TCP) members and Task leaders continued to adjust to the pandemic's virtual world. The bright spot has been the opportunity to have engaging virtual meetings of our geographically diverse Executive Committee and Task members. The TCP Executive Committee also followed through on its commitment to start new Tasks and collaborate with emerging economies. In 2021, the TCP welcomed one more of UNIDO's Global Network of Regional Sustainable Energy Centres, SICREEE (8 Central American countries), for a total of six centres and one more in the process of joining.

In June 2021, I was elected as the new Executive Committee Chair. I am looking forward to carrying on the work initiated by my predecessor, Daniel Mugnier, who worked hard to raise the visibility of solar heating and cooling and our TCP at the local, national, and international levels. My first full year as Chair will be a very busy one as we co-organize the first ISES/IEA SHC collaborative EuroSun conference, begin work on our new Strategic Plan, and continue to oversee and initiate new Tasks. I may be new to the SHC TCP, but not to IEA TCPs. I have been the Dutch Alternate Executive Committee Member for the Heat Pumping Technologies TCP since 2018.

A top priority for the TCP will be 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 2021, 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 several IEA publications (Renewable Energy Market Report 2021, IEA Handbook for Emerging Economies), and presenting the SHC TCP at the IEA Tsinghua Dialogue Series on buildings decarbonization pathways: Towards 2060: heat decarbonization in China focus on district heat and renewable heat, Asia Pacific Solar Research Conference 2021, Solar World Congress 2021, and SBE21 Heritage Conference.

I want to thank the very active TCP Vice-Chairs, He Tao (China), Elimar Frank (Switzerland), and Richard Hall (UK), with a special thank you to Elimar Frank for serving as the Scientific Committee Co-Chair of Solar World Congress 2021. 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.

Solar heat's potential is immense. As the IEA reports in *Renewables 2020*, heat is the largest energy end-use, accounting for half of global final energy consumption, significantly more than electricity (20%) and transport (30%). And in 2020, about 50% of total heat consumed was used for industrial processes and another 47% consumed in buildings for space and water heating, which means solar heat is key to combatting climate change and creating sustainable economies worldwide.

In 2022, I look forward to taking solar thermal energy a necessary step forward by placing it firmly on the maps of policy makers, developers and financiers, together with my colleagues around the world. But, most of all, I look forward to meeting all of you in person after two years of communicating virtually.

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 founded in 1977 as one of the first multilateral technology initiatives of the IEA. All our work is supporting our…

Vision

Solar energy technologies will provide more than 50% of low temperature heating and cooling demand for buildings in 2050 and contribute a significant share to the heat supply for the agricultural and industrial sectors. Thus, solar heating and cooling will contribute significantly to lowering CO2 emissions worldwide and reaching the Paris Agreement goal.

Mission

Through multi-disciplinary international collaborative research and knowledge exchange, as well as market and policy recommendations, the SHC TCP will work to increase the deployment rate of solar heating and cooling systems by breaking down the technical and non-technical barriers to increase deployment.

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 2021 were:

- Renovating Historic Buildings Towards Zero Energy (Task 59)
- Integrated Solutions for Daylight and Electric Lighting (Task 61)
- Solar Energy in Industrial Water and Wastewater Management (Task 62)
- Storage Materials within Components and Systems (Task 67)
- Solar Neighborhood Planning (Task 63)
- Solar Heat Processes (Task 64)
- Solar Cooling for the Sunbelt Regions (Task 65)
- Solar Energy Buildings (Task 66)
- Compact Thermal Energy

To support our Task work, the *SHC Solar Academy*, established in 2016, facilitates the dissemination of Task results and supports R&D and implementation of solar heating and cooling projects worldwide. The main activities are webinars (hosted by ISES), videos, national days in conjunction with Executive Committee meetings, and onsite training in member countries.

Our other activities include the SHC Conference, which beginning in 2022, will be jointly organized with ISES as EuroSun conferences and the annual *Solar Heat Worldwide* statistics report.

Members & Membership

The overall management of the SHC TCP rests with the Executive Committee comprised of one representative 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
5 International Solar Energy Society
6 Regional Centre for Renewable Energy and Energy Efficiency
7 SADC Centre for Renewable Energy and Energy Efficiency
8 Centre for Renewable Energy and Energy Efficiency of SICA countries (Joined March 2021)

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

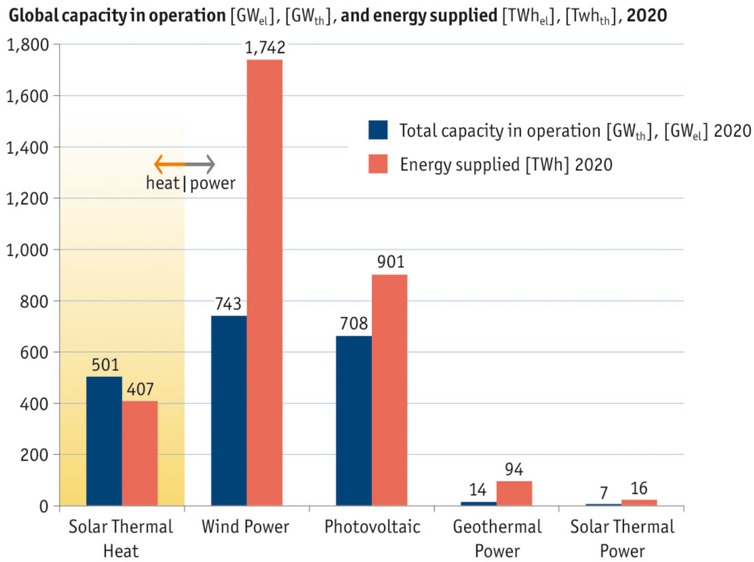
To learn how your government agency or your international industry association, international non-profit organization, or international non-governmental organization can join, please contact the SHC Secretariat, secretariat@iea-shc.org.

3. 2021 Recap

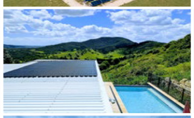
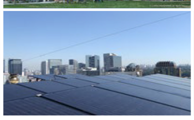
Solar Thermal Outlook

Every year we publish *Solar Heat Worldwide: Markets and Contribution to the Energy Supply*, the only annual global solar thermal statistics report. The 2021 edition reports that in 2020, solar thermal technologies produced 401 GWth – which corresponds to an energy savings equivalent of 43.8 million tons of oil and 141.3 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. Below is a graph showing the **Global Capacity for different renewable energy sources for 2020**.



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.

Three top markets		1	2	3
Solar district heating new additions in **2020**		Germany	Denmark	China
Solar industrial heat new additions in **2020**		China	Mexico	Germany
Swimming pool heating new additions in **2019**		USA	Brazil	Australia
Solar air heating systems total in operation at end of **2019**		Canada	Australia	Japan
Hybrid systems for heat and electricity (PVT) total in operation at the end of **2020**		France	South Korea	China

Photos: SOLID Solar Energy Systems, Solareast Holding Company, SolarWall, PA-ID Process, Sunbather

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.

In 2021, the following Tasks began:

- Task 66 Solar Energy Buildings (*Lead Country: Germany*)
- Task 67 Compact Thermal Energy Storage Materials within Components and Systems (*Lead Country: Austria*)
- Task 68 Efficient Solar District Heating Systems (*Lead Country: Austria. Start date April 2022)*

Completed Tasks

In 2021, the following Tasks ended:

- Task 59 Renovating Historic Buildings Toward Lowest Possible Energy Demand and CO2 Emission (NZEB), *(Lead Country: Italy)*
- Task 61 Integrated Solutions for Daylighting and Electric Lighting *(Lead Country: Germany)*

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 68 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 will partner with ISES to co-organize EuroSun 2022 in Kassel, Germany, on September 25-29.

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 twelve times since 2003 and looks forward to once again honoring those working to advance solar heating and cooling at EuroSun 2022.

SHC Book Series

This collection of books on Task results is published by Wiley-VCH and can be purchased online. There are five books currently in the series: 1) *The Solar Cooling Design Guide: Case Studies of Successful Solar Air Conditioning Design*, 2) *Solution Sets for Net-Zero Energy Buildings: Feedback from 30 Net ZEBs Worldwide Modeling*, 3) *Design and Optimization of Net-Zero Energy Buildings*, 4) *Solar and Heat Pump Systems for Residential Buildings*, and 5) *Polymeric Materials for Solar Applications*.

SHC Collaboration

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

Within the IEA

Energy in Buildings and Communities TCP and the SHC TCP had planned to hold a joint meeting and national day before our Executive Committee Meetings in the Netherlands. Unfortunately, COVID-19 restrictions forced our meetings to go online, so we each held a TCP webinar highlighting our respective work and collaboration activities.

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

SolarPACES TCP is collaborating in Task 62: Solar Energy in Industrial Water and Wastewater Management and jointly managing SHC Task 64/SolarPACES Task IV: Solar Process Heat.

Renewable Energy Working Party held two virtual meetings in 2021. The SHC Chairs, Daniel Mugnier (79th in April) and Tomas Olejniczak (80th in September), and Pamela Murphy, SHC Secretariat, participated for the TCP. Tomas Olejniczak also participated in the TCP Universal Meeting in October 2021.

Buildings Coordination Group held a virtual meeting in February 2021 attended by the SHC German Executive Committee member, Kerstin Krüger.

Outside the IEA

International Solar Energy Society invited the SHC TCP to be the Key Partner of the ISES Solar World Congress 2021. Elimar Frank, the Swiss Alternate Executive Committee member, co-chaired the Scientific Committee.

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 2022.

Solar Industry Associations in Australia, Europe, and North America are collaborating with the SHC TCP to increase awareness of solar thermal's potential and encourage industry to use solar thermal R&D results in new products and services.

UNIDO is supporting the Sponsor membership of five GN-SEC Centres through 2022.

Conferences, *SBE21 Heritage Conference* (Task 59): SHC Chair Daniel Mugnier co-led the session on Renewable energy integration in historic buildings, areas, and landscapes. *APSRC 2021*: Tomas Olejniczak served on the Conference Committee, Kerstin Krüger presented an SHC overview, and Task experts from Tasks 61, 62, 63, 65, and 66 and the proposed Solar Hot Water for 2030 gave session presentations.

2021 MEETINGS	2022 MEETINGS
89th ExCo Meeting Virtual June 15 – 18 *(was to be in the Netherlands)*	**90th ExCo Meeting** Raperswill, Switzerland June 1 – 3
88th ExCo Meeting Virtual November 3 – 5 *(was to be in Slovakia)*	**90th ExCo Meeting** Stellenbosch, South Africa December 5 – 7

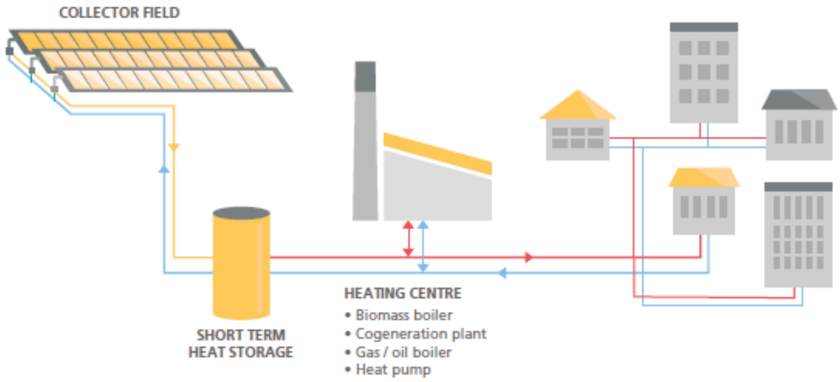
4. Feature Article

Integrating Large SHC Systems into District Heating Networks

Introduction

Renewable sources represent a central component of a sustainable energy supply in the urban environment. Nowadays, traditional supply technologies and infrastructures are experiencing big challenges, which are introducing significant changes in how energy is stored and distributed. In this evolution, new, economically attractive, and technologically innovating possibilities for solar thermal energy are emerging in European towns and beyond. Large solar thermal plants offer a significant potential to reduce the usage of fossil fuels and save CO2 emissions.

In terms of the large market potential and reachable heat generation costs, the competition of large solar thermal plants against conventional and other renewable energy sources is a barrier. If solar thermal district heating and cooling is to seize the opportunity of this increasing market potential, then an optimized integration and design of complex systems, targeted transformation strategies, and new financing models are necessary.



Example of a simple large-scale solar thermal system integration into district heating
Source: IEA SHC Task 55, Solar Heat for Cities brochure.

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.

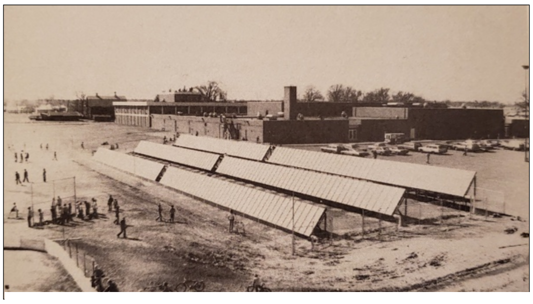
Current Status

First Solar District Heating Installations

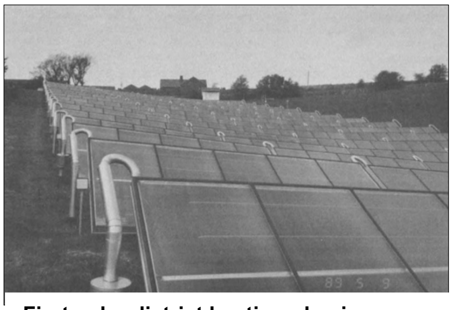
The first large-scale solar heat networks were deployed in the USA and Europe around the 1970s.

In Europe, the first solar heat networks were installed in Sweden. In 1979 and 1980, solar heating plants were connected to newly built residential areas in Ingelstad, outside the city of Växjö, and in Lambohov, outside the city of Linköping.

The first solar heat network in Denmark was put into operation in the spring/summer of 1985 in Vester Nebel. It consisted of 296 m^2 of flat plate collectors installed on the field in front of the district heating substation (straw and oil) and supplied approximately 100 houses with solar heat.



First solar thermal district heating plant at Northview Junior High School (USA) designed and installed by Honeywell in 1974.

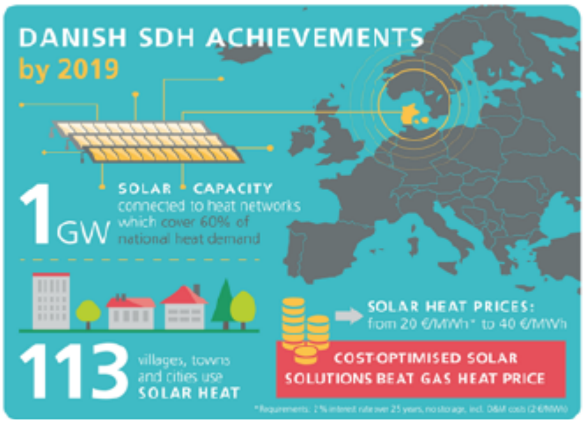


First solar district heating plan in Saltum, Denmark, installed by Saltum Varmevaerk.

Solar District Heating Today

Denmark is the leading solar thermal district heating country and recently set a world record.

Silkeborg: Harnessed solar energy meets 20 % of annual heat demand from 21,000 households.
PHOTO: ARCON-SUNMARK



Denmark's largest solar district heating installation (left).

Danish solar district heating achievements – 1GW by 2019 (right). *Source: IEA SHC Task 55, Solar Heat for Cities brochure.*

Denmark aspires to transition to a low-emission society and an energy system independent of fossil fuels by 2050. Presently, the share of renewable energy in total primary energy consumption is 37%, indicating that fossil fuels still contribute

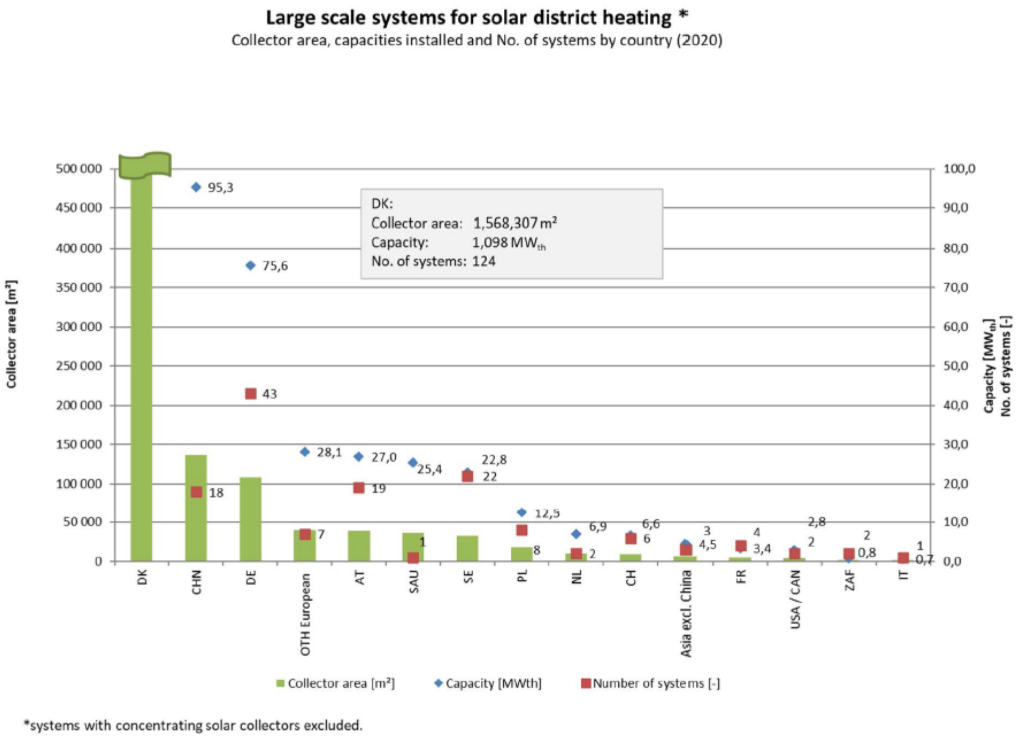
substantially to Danish energy consumption. For the electricity consumption, 61% is supplied by renewable energy, mainly due to large wind power production, delivering 46% of the total electricity demand.

Worldwide, Denmark is an excellent example of a mature and commercial solar district heating market, but other markets are catching up, especially China. In several other countries, smaller niche markets exist, such as in Austria, where 28 systems >500 m² feed into district heating networks, smaller microgrids in urban areas, and local biomass heating networks and supply energy to large residential, commercial, and public buildings. Other countries to note are Germany with 43 large-scale systems (some of these with seasonal storage), Sweden (22 systems), France (17 systems), Poland (14 systems), Greece (13 systems), and Switzerland (10 systems). Although Germany is currently considered a niche market relative to Denmark, accelerated market growth is observable. In some countries (for example, the Netherlands, Poland or UK), new incentive programs for large-scale solar heating are currently coming up. And, Canada's Drake Landing Solar Community, operating since 2007, is proof that solar district heating can maintain very high solar fraction renewable energy systems, over 90%, even in locations like Alberta, Canada, where temperatures range from -33°C to 28.3°C.

Solar District Heating Systems by 2020

By the end of 2020, 262 large-scale solar district heating systems (>350 kWth; 500 m²) with an installed capacity of 1.410 MWth (2.01 million m²) were in operation.

As can be clearly seen in the following figure, Denmark leads this market segment in terms of both the number of systems and the installed area. In addition to Denmark (124 systems) and China (18 systems), a number of other countries are showing an increasing interest in this type of plant, as they offer an excellent opportunity for decarbonizing the heat sector in neighborhoods and entire cities. Several countries, such as Saudi Arabia, Asia (excluding China), Japan, Kyrgyzstan, Russia, USA, Canada, and South Africa, have already started to decarbonize their district heating sector by using large-scale solar thermal systems.



Large-scale systems for solar district heating– capacities and collector area installed and number of systems in 2020 (concentrating systems and PVT collectors add up to 162,784 m²). *Source: IEA SHC report, Solar Heat Worldwide, edition 2021.*

Potential

Solar thermal systems used in residential buildings, hotels, hospitals, and district heating systems and for renewable and storable heat can significantly contribute to rapidly moving closer to a net-zero greenhouse gas emissions economy.

Solar district heating is steadily growing. This can be seen in the number of megawatt-scale systems for district heating and industrial applications. Twenty-three large-scale solar thermal systems with about 228,900 m² (160 MW_{th}) were installed in Europe in 2019. Of these installations, 15 were in Denmark (191,300 m²), including five extensions of existing systems, six in Germany (14,700 m²), one in Latvia (21,700 m²), and one in Austria (1,200 m²). Due to the new systems installed in Denmark, their market grew at a remarkable 170% in 2019.

In recent years, the size of the newly installed collector areas has increased significantly. In 2016, the world's largest SDH (solar district heating) collector area was built in Denmark (157,000 m²), followed by projects in Tibetan regions (22,000 m²) in China with high solar fractions of up to 100% of the space heating demand, and the largest German plant with 14,800 m². It is expected that the trend of large-scale SDH systems will continue in the coming years and that these systems will become increasingly important for the decarbonization of the heat supply.

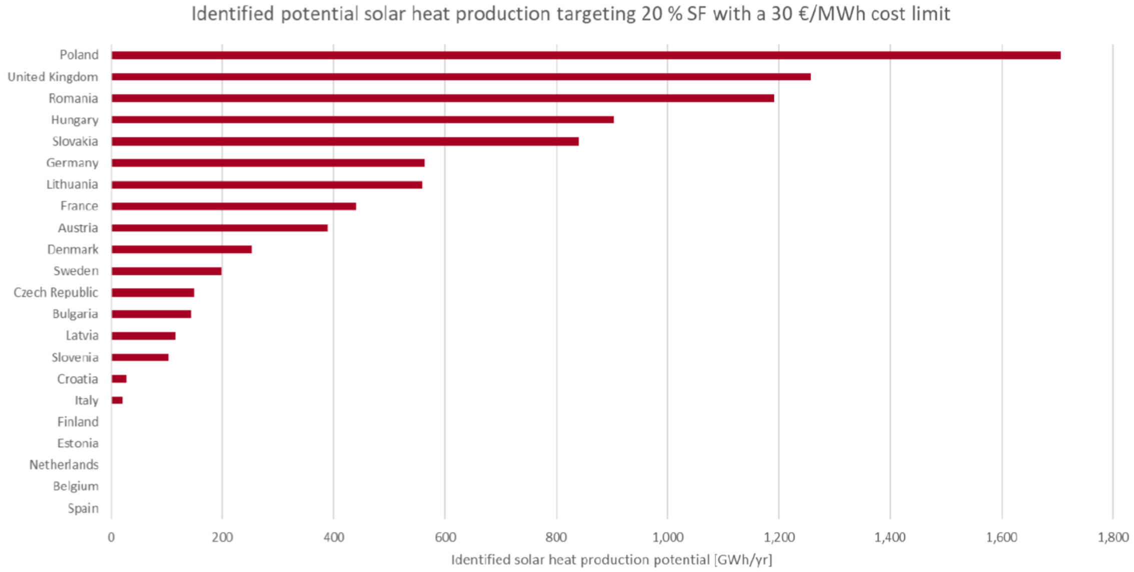
The EU aims to have a net-zero greenhouse gas emissions economy by 2050, as envisioned in the European Commission's 2050 long-term strategy, to meet the EU's commitment under the Paris Agreement. While renewables have made an important contribution in this area, there is still a long way to go, particularly in the heating and cooling sector.

Experts of IEA SHC Task 55 estimated the solar heat potential in Europe, assuming 20% solar fraction and solar heat cost limits between 25 and 60 €/MWh.

The figure below shows the potential solar heat production for a 30 €/MWh cost limit for countries in Europe. Poland has significant potential for solar heat as they have huge district heating networks, which can be supplied by renewable. The biggest challenge for implementing large-scale solar thermal installations is the use of land for anything other than agriculture. Currently, incentive programs for large-scale solar thermal installations are coming up in Poland.

To summarize, the potential analysis indicates that a roll-out of large-scale SDH is possible and economically feasible in most countries. Solar thermal and seasonal storages in intelligent combination with other generating options can improve the feasibility of fully decarbonized DH systems.

Identified potential for solar heat production with a 30€/MWh in Europe.

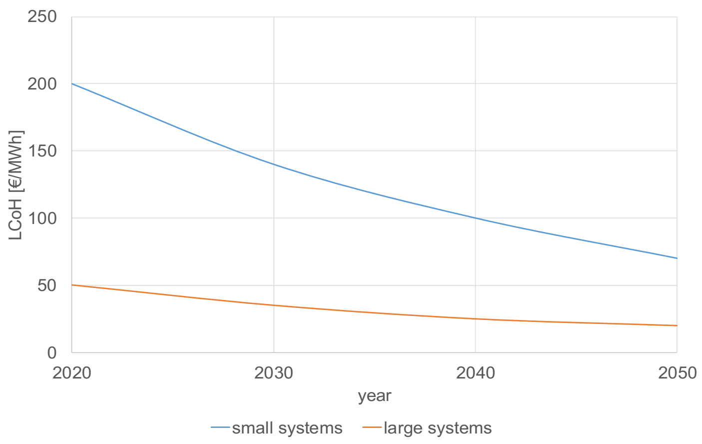


Source: IEA SHC Task 52: Solar Heat and Energy Economics.

Levelized Cost of Heat

The graph below shows the current situation and the cost reductions that could be achieved. The Levelized Cost of Heat (solar thermal) LCoH is in the range of 50 €/MWh for district heating systems located in mid-European climates.

LCoH reduction potential for large systems



The costs of both small and large systems can be significant reduced under the following boundary conditions:

Overheating protection limiting the heat transfer fluid temperature below 100 °C results in lower investment costs in the heat transfer fluid loop and lower maintenance costs.

Performance increase of components and overall systems results in a higher energy yield, thus lowering the LCoH even if the upfront investment for a better performing component and/or system is higher.

Standardization of the components, mechanical and hydraulic interfaces, and the overall systems. Standardization reduces the costs all along the value chain from the production of the components up to the installation of the systems and results in well-installed systems with lower maintenance costs and a longer lifetime, leading to a reduced LCoH.

Long-lasting components and systems will result in significantly reduced operating and maintenance costs.

Actions Needed

To support the rapid decarbonization of district heating, the table below highlights some of the challenges and the actions needed to overcome them.

Challenge	Action needed
Development of system components for solar district heating	• System technology for optimized operation of solar thermal district heating systems with seasonal storage. • Technical concepts and business models for integrating decentralized solar thermal systems into heating grids. • Technical concepts and business models for thermo-electrical smart grids with integrated solar thermal systems. • System design with increased solar thermal fraction in smart heating grids. • Integration of decentralized cooling and air-conditioning systems into solar thermal district heating systems.
Planning and implementation of large solar district heating systems	• Design and 'rule-of-thumb' rules focused on integration points. • Commissioning rules for large-scale systems improved and further tested. • Advanced concepts to support sustainable and healthy land use around cities and industrial areas for solar thermal energy. • Cost reductions in the same order of magnitude seen in the wind and PV industries.
Demonstration of large solar district heating systems	• Feasibility studies on system optimization of large projects. • Development of new low-temperature district heating systems, where temperatures less than 60°C-80°C are promoted as the future choice for decarbonization of heating and cooling. • Demonstration sites with medium and high-temperature collectors. • Explore retrofitting existing higher temperature district heating networks with newly developed vacuum PVT systems. Potential to increase energy yield per m^2 by 30%-50% and significantly enable PVT coupled with heat pumps to play a role in distributed and centralized solutions. • LCA and recycling of solar district heating components. • New materials and technologies for collectors, thermal energy storages, and other components to reduce costs and increase performance and reliability. • Innovative control and monitoring concepts with forced integration of new ICT technologies (e.g., new sensors, advanced self-learning, self-adapting control and monitoring strategies, communication of the solar system components, active building components, connection to the internet (e.g., using weather forecast)) and integration in the Smart Home solution to increase performance, reliability, and reduce costs.
Awareness raising	• Targeted information dissemination at the government level. • Classes and simulation tools for engineering education programs. • Better communication with storage and heat pump industry. • Targeted communication on best practices and SDH cost-effectiveness.
Simulations and validations	• Thermal system modeling and yield prediction for solar district heating. • Define KPIs based on testing and simulation solutions to ensure that the evaluation is reliable, relevant and increases sector confidence. • Develop common notations and KPI's for communicating research and field results so that comparisons are possible between different manufacturers and planner offers.

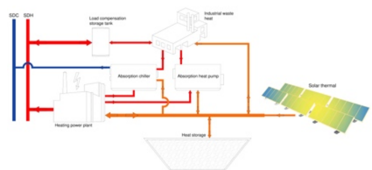
*This article is one of a series of Technology Position Papers published by the IEA SHC for policymakers, https://www.iea-shc.org/publications.

Author: Sabine Putz, SOLID Solar Energy Systems, Austria and Task Manager of IEA SHC Task 55: Towards the Integration of Large-Scale Solar Heating and Cooling Systems into District Heating and Cooling Networks of the Solar Heating and Cooling Technology Collaboration Programme with inputs from Task 55 Experts.

5. Completed Tasks

Task 55 – Towards the Integration of Large SHC Systems into DHC Networks

Sabine Putz
SOLID Solar Energy Systems GmbH
Task Manager for the Republic of Austria



Task Overview

SHC Task 55 elaborated on the technical and economic requirements for the commercial market introduction of solar district heating and cooling systems in a broad range of countries. The Task activities aimed to improve technological and market know-how, as well as to develop tools for the network integration of solar thermal systems and the implementation of other renewable energy technologies for maximum energy coverage. A key element was the direct cooperation of SDH experts with associations, companies, and institutions from the DHC community to bridge the gap between the research fields and organizations.

The Task's work was divided into four subtasks:

- Subtask A: Network Analyses and Integration (Austria)
- Subtask B: Components Testing, System Monitoring, and Quality Assurance (China)
- Subtask C: Design of the Solar Thermal System and of Hybrid Technologies (Denmark)
- Subtask D: Promotion and Economic Aspects of Solar Thermal and Hybrid Technologies (Germany)

Participating Countries

	Research Institutes	Universities	Companies
Austria		2	3
Canada	1		1
China	1	1	
Denmark		1	2
Finland*			1
France	1		1
Germany	3	5	1
Italy	1		1
Spain	1	1	
Sweden			1
United Kingdom			1
Total	**8**	**10**	**12**

**Through IEA DHC TCP*

Task Duration

The Task started September 2016 and ended December 2020. The final reporting was in June 2021.

Collaboration with other IEA TCPs

The District Heating and Cooling including Combined Heat and Power TCP (IEA DHC) officially collaborated with SHC Task 55 on a ***moderate*** level as defined by the IEA SHC. Further collaborations with HPT Annex 47 (Heat pumps in DHC systems), ECES Annex 28 (Energy Conservation through Energy Storage), EBC Annex 60 (Energy in Buildings (new generation tools), EBC Annex 64 (Optimized urban energy systems) took place at different levels of intensity.

Collaboration with Industry

More than 60% of the Task experts were from industry. As most of them were not funded for the Task work their contribution is of particular interest to highlight.

Several SDH installations were built as a result of cooperation that started during the first Task meetings. For example, the installation of a solar district heating plant in Langkazi, Tibet, link. As the SDH market is still a niche market, the strategic business cooperation established amongst the Task Experts over the Task's duration is a very important outcome.

Key Results

Investor Brochure

The investor brochure "Solar Heat for Cities" was published in November 2019 to raise awareness and interest about this technology and facilitate the entry of investors into SDH by answering their key questions. Successful case studies and testimonials that prove the key advantages of using SDH are a core part of the brochure. The brochure contains very useful info charts and general information about large scale SDH as well as several case studies of SDH installations in Denmark, China, Serbia, Austria, France, Latvia, and Germany.

SDH markets are growing in Denmark, Germany, China and new markets are starting like in France, Italy, Poland, Spain etc. To increase the market share of SDH in new and existing markets, communication efforts are necessary. The brochure is available in English and Turkish.

Fact Sheets

Twenty-seven Fact Sheets were published. These documents were written by the most experienced SDH researchers and practitioners from China and Europe collaborating in this four-year Task. They offer valuable insights into SDH research and real-world showcases by providing information on feasibility studies, the monitoring of large solar fields, the design of hybrid technologies, and business models.

Dissemination Activities

Reports, Published Books, Online Tools, etc.

Author(s)/Editor	Title	Report No. Publication Date
Task experts	27 Fact Sheets	https://task55.iea-shc.org/fact-sheets
Bärbel Epp, Marisol Oropeza, editors	Investor brochure, *Solar Heat for Cities*	2019
Danish District Heating Association / PlanEnergi	Solar District Heating: Inspiration and Experiences from Denmark	2018

Journal Articles, Conference Papers, etc.

Author(s)/Editors	Title	Publication/Conference	Bibliographic Reference
Unterberger, V., Muschick, D., Loidl, A., Poms, U. R., Gölles, M., & Horn, M. (2020).	Model-based control of hydraulic heat distribution systems — Theory and application	Journal of Control Engineering Practice, 101, [104464]	https://doi.org/10.1016/j.conengprac.2020.104464
Kaisermayer, V., Muschick, D., Gölles, M., & Horn, M. (2020).	Progressive Hedging for Stochastic Energy Management Systems: The Mixed-Integer Linear Case. Energy Systems	Journal of Control Engineering Practice, Elsevier	https://doi.org/10.1016/j.conengprac.2020.104464
Moser, A. G. C., Muschick, D., Gölles, M., Nageler, P. J., Schranzhofer, H., Mach, T., Hofer, A. (2020).	A MILP-based modular energy management system for urban multi-energy systems: Performance and	Journal of Applied Energy, 261, [114342]	https://doi.org/10.1016/j.apenergy.2019.114342

	sensitivity analysis		
Ochs, Fabian; Dahash, Abdulrahman; Tosatto, Alice and Bianchi Janetti, Michele (2020).	Techno-economic planning and construction of cost-effective large-scale hot water thermal energy storage for renewable district heating systems	Journal of Renewable Energy Elsevier	Renewable Energy, 150, 1165-1177. DOI: 10.1016/j.renene.2019.11.017.
Dahash, Abdulrahman; Ochs, Fabian; Tosatto, Alice and Streicher, Wolfgang. (2020).	Toward efficient numerical modeling and analysis of large-scale thermal energy storage for renewable district heating	Journal of Applied Energy	Applied Energy, 279, 115840. DOI: 10.1016/j.apenergy.2020.115840.
Paolo Leoni, Roman Geyer, Ralf-Roman Schmidt	Developing innovative business models for reducing return temperatures in district heating systems: Approach and first results	Journal of Energy	Vol. 195, 2020, 116963 https://doi.org/10.1016/j.energy.2020.116963
Tschopp, D., Tian, Z., Berberich, M., Fan, J., Perers, B., Furbo, S., 2020:	A review and comparative study of Denmark, China, Germany and Austria.	Journal of Applied Energy, 270, 114997,	doi.org/10.1016/j.apenergy.2020.114997
Tschopp, D., Jensen, A. R., Dragsted, J., Ohnewein, P., Furbo, S.,	Measurement and modeling of diffuse irradiance masking on tilted planes for solar engineering applications	Journal of Applied Energy	
Zlabinger, S., Unterberger, V., Gölles, M., Horn, M., Wernhart, M., & Rieberer, R. (2020).	Development and experimental validation of a linear state-space model absorption heat pumping systems for model-based control strategies	In T. Meyer (Ed.), ISHPC 2021 proceedings – online pre-conference 2020 (pp. 191 -195). Technische Universität Berlin	https://doi.org/10.14279/depositonce-10430.2
Tschopp, Daniel	Review of In situ Test Methods for Solar Thermal Installations		
SOLITES	SDH newsletter; News about SDH market, promotion of the brochure “Solar Heat for Cities”	www.solar-district-heating.eu; April 2020	https://www.solar-district-heating.eu/solar-heat-for-cities-iea-brochure-and-infographics/
Putz, S.	SHC Solar Update newsletter contributions	IEA SHC Solar Update newsletter	June and October 2020
Epp, B.	1 GW - Danish SDH market reaches new milestone	Solarthermalworld.org	https://www.solarthermalworld.org/news/danish-sdh-market-reaches-new-milestone
Newsletter Fernwärme/Kälte	Newsletter Fernwärme/Kälte		
Epp, B.	Success Factors in top SDH countries	June 2020	

Epp, B.	Improved design for giga-size pit heat storage GBP 320 million for low-carbon heat networks	October 2020	

Conferences, Workshops, Seminars, etc.

Conference/ Workshop/ Seminar	Activity & Presenter	Date & Location
6th International Conference on Smart Energy Systems	Paolo Leoni, Aurelien Bres, Ilaria Marini, Alessandro Capretti; Lowering the operating temperatures in old-generation district heating systems: first results from the TEMPO demonstration project in Brescia (Italy)	6 - 7 October 2020 Virtual
In T. Meyer (Ed.), ISHPC 2021 proceedings – online pre-conference 2020 (pp. 191 -195). Technische Universität Berlin	Zlabinger, S., Unterberger, V., Gölles, M., Horn, M., Wernhart, M., & Rieberer, R. (2020).; Development and experimental validation of a linear state-space model absorption heat pumping systems for model-based control strategies https://doi.org/10.14279/depositonce-10430.2	August 2020 Virtual
13th International Conference on Solar Energy for Buildings and Industry (EuroSun 2020)	Putz, S. ; Results of IEA SHC TASK 55 "Towards the Integration of Large SHC Systems into DHC Networks	September 1 – 3, 2020 Virtual
13th International Conference on Solar Energy for Buildings and Industry (EuroSun 2020)	Dahash, Abdulrahman; Ochs, Fabian and Tosatto, Alice: Advances in modeling and evaluation of large-scale hot water tanks and pits in renewable-based district heating	September 1 – 3, 2020 Virtual

Task Meetings

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 1	October 19-21, 2016	Graz, Austria	25 participants (8 countries)
Task Meeting 2	March 14-16, 2017	Aalborg, Denmark	33 participants (8 countries)
Task Meeting 3 *In conjunction with ISES SWC/SHC Conference*	October 27-28, 2017	UAE	35 participants (12 countries)
Task Meeting 4 *In conjunction with SDH Conference 2018.*	April 9-10, 2018	Graz, Austria	41 participants (11 countries)

Combined with DHC TCP Annex TS2 workshop.			
Task Meeting 5 *In conjunction with SHC Solar Academy onsite training*	October 29-30, 2018	Lianyungang, China	32 participants (7 countries)
Task Meeting 6	April 8-10, 2019	Zaragoza, Spain	29 participants (11 countries)
Task Meeting 7 *Combined with DH industry workshop*	October 7-9, 2019	Härnösand, Sweden	33 participants (7 countries)
Task Meeting 8	October 13 - 15, 2020	Virtual	51 participants (11 countries)
Technology Transfer Workshop	October 15, 2020	Virtual	62 participants (11 countries)

SHC Task 55 Participants

Country	Name	Institution / Company	Role
AUSTRIA	**Sabine Putz**	**SOLID**	**Task Manager**
AUSTRALIA - observer	Ken Guthrie	Sustainable Energy Transformation Pty Ltd	National Expert
AUSTRIA	Christian Engel	Thermaflex Int Holding	National Expert
AUSTRIA	Christian Fink	AEE INTEC	National Expert
AUSTRIA	Christian Holter	SOLID	National Expert
AUSTRIA	Daniel Tschopp	AEE INTEC	National Expert
AUSTRIA	Daniel Muschick	BIOENERGY 2020+ GmbH	National Expert
AUSTRIA	Fabian Ochs	University of Innsbruck	National Expert
AUSTRIA	Georg Sima	MGR GEORG SIMA E.U.	National Expert
AUSTRIA	Ingo Leusbrock	AEE INTEC	National Expert
AUSTRIA	Moritz Schubert	SOLID	National Expert
AUSTRIA	Markus Gölles	Bioenergy 2020+ GmbH	National Expert
AUSTRIA	Peter Luidolt	SOLID	National Expert
AUSTRIA	Philip Ohnewein	AEE INTEC	National Expert
AUSTRIA	Patrick Reiter	SOLID	National Expert
AUSTRIA	Paolo Leoni	AIT	National Expert
AUSTRIA	Ralf-Roman Schmidt	AIT	Subtask A Leader
AUSTRIA	Viktor Unterberger	Bioenergy 2020+ GmbH	National Expert
AUSTRIA	Werner Doll	SOLID	National Expert
CANADA	James Bererton	Naked Energy	National Expert
CANADA	Lucio Mesquita	CanmetENERGY	National Expert
CHINA	Jianhua Fan	Technical University of Denmark	National Expert
CHINA	Youjin Xu	Tongji university	National Expert
CHINA	Aaron Feng Gao	Arcon-Sunmark Large-scale Solar Systems Integration Co., Ltd,	National Expert
CHINA	Liu Mu	Vicot Solar Technology Co., Ltd	National Expert
CHINA	Qingtai Jiao	Jiangsu Sunrain Solar Energy Co., Ltd	Subtask B Leader

CHINA	Kaichun Li	Jiangsu Sunrain Solar Energy Co., Ltd	National Expert
CHINA	Shai Li	Jiangsu Sunrain Solar Energy Co., Ltd	National Expert
CHINA	Zheng Wei	Yazaki Energy System Corporation	National Expert
DENMARK	Lars Munkoe	Purix	National Expert
DENMARK	Andreas Zourellis	Aalborg CSP	National Expert
DENMARK	Bengt Perers	Technical University of Denmark	National Expert
DENMARK	Christian Kok Nielsen	PlanEnergi	National Expert
DENMARK	Jan Birk	Arcon Sunmark	National Expert
DENMARK	Jes Donneborg	Aalborg CSP	National Expert
DENMARK	Jakob Jensen	Heliac	National Expert
DENMARK	Jan Erik Nilsen	PlanEnergi	Subtask C Leader
DENMARK	Jianhua Fan	Technical University of Denmark	National Expert
DENMARK	Junpeng Huang	Technical University of Denmark	National Expert
DENMARK	Povl Frich	Danish Energy Agency	National Expert
DENMARK	Simon Furbo	Technical University of Denmark	National Expert
DENMARK	Zhiyong Tian	Technical University of Denmark	National Expert
FINLAND	Kaj Pischow	Savo-Solar Oy	National Expert
FINLAND	Morten Hofmeister	Savo-Solar Oy	National Expert
FRANCE	Alexis Gonnelle	New Heat Directeur technique / CTO	National Expert
FRANCE	Cedric Paulus	CEA/INES	National Expert
FRANCE	Nicolas Lamaison	CEA/INES	National Expert
FRANCE	Paul Kaaijk	ADEME	National Expert
FRANCE	Pierre Delmas	New Heat Directeur technique / CTO	National Expert
GERMANY	Axel Gottschalk	Bremerhaven University of Applied Sciences	National Expert
GERMANY	Magdalena Berberich	Solites - Steinbeis Research Institute for Solar and Sustainable Thermal Energy Systems	Subtask D Leader
GERMANY	Dominik Bestenlehner	ITW/TZS University of Stuttgart	National Expert
GERMANY	Detlev Seidler	SOLID	National Expert
GERMANY	Dan Bauer	DLR	National Expert

GERMANY	Dominik Bestenlehner	IGTE University of Stuttgart	National Expert
GERMANY	Bärbel Epp	Solrico	National Expert
GERMANY	Andrej Jentsch	Operating Agent, IEA DHC TCP	National Expert
GERMANY	Karin Rühling	TU Dresden	National Expert
GERMANY	Korbinian Kramer	Fraunhofer ISE	National Expert
GERMANY	Roman Marx	ITW University of Stuttgart	National Expert
GERMANY	Nirendra Lal Shrestha	Technische Universität Chemnitz	National Expert
GERMANY	Norbert Rohde	KBB Kollektorbau Gmbh	National Expert
GERMANY	Stefan Mehnert	ISE	National Expert
GERMANY	Sven Fahr	Fraunhofer ISE	National Expert
GERMANY	Thorsten Urbanek	TU Chemnitz	National Expert
ITALY	Luca Degiorgis	Politecnico di Torino	National Expert
ITALY	Marco Calderoni	Polimi	National Expert
ITALY	Roberto Fedrizzi	Eurac Research	National Expert
ITALY	Marco Scarpellino	TVP Solar	National Expert
NETHERLANDS	Luuk Beurskens	ECN-TNO	National Expert
NETHERLANDS	Ruud Vandenbosch	Ecovat	National Expert
POLAND	Armen Jaworski	Cim-Mes	National Expert
SPAIN	Ana Lazaro	University of Zaragozza	National Expert
SPAIN	Andoni Diazdemendibil	Tecnalia	National Expert
SPAIN	Carol Pascual	Tecnalia	National Expert
SPAIN	Javier Mazo	University of Zaragoza	National Expert
SPAIN	Miguel Lozano	University of Zaragozza	National Expert
SPAIN	Patricio Aguirre Múgica	Tecnalia	National Expert
SPAIN	Luis M. Serra	University of Zaragoza	National Expert
SWEDEN	Joakim Byström	Absolicon Solar Collector AB	National Expert
SWEDEN	Josefine Nilsson	Absolicon Solar Collector AB	National Expert
SWEDEN	Gunnar Lennermo	Energianalys AB	National expert

SWEDEN	Klaus Lorenz	Dalarna University	National Expert
SWEDEN	Peter Kjellgren	Absolicon Solar Collector AB	National Expert
SWITZERLAND	Vittorio Palmieri	TVP Solar	National Expert
UNITED KINGDOM	Eamon Clarke	Kingspan Environmental Ltd.	National Expert
UNITED KINGDOM	Finbarr McCarthy	Kingspan Environmental Ltd.	National Expert
UNITED KINGDOM	Martin Crane	Carbon Alternatives Ltd	National Expert
UNITED KINGDOM	Richard Hall	Energy Transition	ExCo
UNITED KINGDOM	Joshua King	AES Solar	National Expert

Task 59 – Renovating Historic Buildings Towards Zero Energy

Alexandra Troi
EURAC Research
Task Manager for ENEA

Task Overview

Historic buildings represent a large share of the existing building stock. They are the trademark of numerous cities, and they will only survive if maintained as a living space. To preserve this heritage, we need to find conservation compatible energy retrofit approaches and solutions, which allow maintaining the historic and aesthetic values while increasing comfort, lowering energy bills, and minimizing environmental impact.

Standard energy-saving measures are often not compatible with preserving the historic buildings' character, nevertheless, the energy performance can be improved considerably if the right package of solutions for the specific building is identified. Also, the possibilities to use solar energy in historic buildings are more than one might expect.

The Task's work is divided into four subtasks:

- Subtask A: Knowledge Base (Austria)
- Subtask B: Multidisciplinary Planning Process (Sweden)
- Subtask C: Conservation compatible Retrofit Solutions and Strategies (Austria)
- Subtask D: Knowledge transfer and dissemination (United Kingdom)

Participating Countries

	Research Institutes	Universities	Companies
Austria		1	1
Belgium	1	1	1
Denmark	1		
France	1		
Germany	1		
Italy	1	4	
Ireland	1		
Spain	3	1	1
Sweden		1	
Switzerland		1	
Turkey		1	
United Kingdom	1	1	
United States		2	
TOTAL	**10**	**13**	**3**

*Participation through both the SHC TCP and EBC TCP

Collaboration with Other IEA TCPs

The Energy in Buildings and Communities TCP (IEA EBC) officially collaborated with SHC Task 59 as EBC Annex 76 on a ***moderate*** level as defined by the IEA SHC and the IEA PVPS TCP on a ***minimum*** level.

Collaboration with Industry

Stakeholders of Task 59 included more than building owners, architects, and planners but as well craftsmen, builders, public authorities, and policymakers. They all are addressed in different ways in order to gather their input and needs and bring results to their realities.

Task Duration

The Task started in September 2017 and was scheduled to end in February 2021, but due to COVID19 related delays and the final Task conference scheduled for April 14-16, 2021, the end date was moved to April 2021.

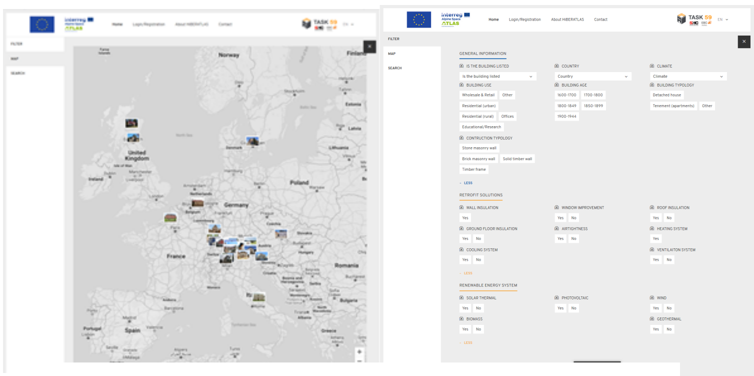
Participating Countries

Austria, Belgium, Denmark, France, Germany, Ireland*, Italy, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States* *(* thru IEA EBC/EBC PVPS)*

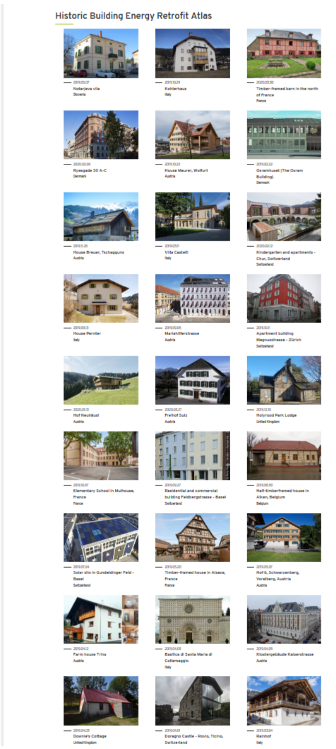
Key Results

HiBERATLAS

The website on best practices, the Historic Building Energy Retrofit Atlas (HiBERATLAS), www.hiberatlas.com, has been an online beta version since October 2019 with the last modifications and changes made in 2021. HiBERATLAS will to continue after SHC Task 59 ends so a major effort was placed on developing a user-friendly backend for adding cases, user management, and the integrated process of gathering IP and privacy forms.



Map and filters in the HiBERATLAS.



HiBERtool

Thanks to the contribution of the Interreg Alpine Space ATLAS project (which is one of the contributing projects for 3 experts, namely Eurac, SUPSI, and University of Innsbruck), the so-called HiBERtool was developed in 2020.

The approach to combine the assessment and documentation of solutions with writing common papers has proven to be very motivating and successful. At this stage, 5 scientific papers are underway:

- Two papers from the walls working groups 1) Conservation-compatible retrofit solutions in historic buildings: an integrated approach and 2) How can scientific literature support decision-making in the renovation of historic buildings? An evidence-based guideline for improving the performance of walls
- One paper from the ventilation working group 1) Integration of energy efficient ventilation systems in historic buildings)
- One paper from the solar working group 1) Solar systems solutions for historic buildings: assessment of

case studies and review of EN-16883:2017 standard
- One paper from the strategy working group 1) Review of energy retrofit decision-support tools in historical contexts, towards the definition of a system for combining conservation-compatible solutions

Each working group has adapted the assessment criteria to their specific category. For the detailed assessment: each working group has promised three detailed assessments.

Fact Sheets

Five Fact Sheets are available online. The topics covered are Simulation Tools for Historic Buildings, Methods for Assessing Heritage Values in Historic Buildings, Life Cycle Analysis – LCA/LCC, Guidelines and Standards, and Certification Protocols.

European standard EN 16883

Significant work was done on the Assessment of the European standard EN 16883 *Conservation of cultural heritage — Guidelines for improving the energy performance of historic buildings.* This work along will feed into a proposal for improving the standard. The analysis was based on three case studies and information from experts from different countries.

Travelling Exhibition

The **Travelling Exhibition** successfully started its journey with "stopovers" in Santiago (Chile), Coburg (Germany), Stirling (United Kingdom), and Salzburg (Austria), and then COVID19 brought the tour to an end. The hope is that it will once again go to events after the pandemic.

Trade Magazine Campaign

The **trade magazine campaign** led by Bärbel Epp submitted articles on Best Practices and the HiBERATLAS adapted for a specific country and in its national language. The broad uptake of the information was supported by active follow up with national contacts.

Article	Country	Date	Journal/Paper
Når Energiforbruget I Historiske Bygninger Skal Reduceres	Denmark	February 20	Energi Forum Danmark
Hvordan Kan Energiforbruget Reduceres I Historiske Bygninger?	Denmark	February 20	Bygge-&Anlægsavisen
Efficienza Energetica Negli Edifici Storici: Le Strategie Per Ridurre I Consumi	Italy	February 20	Info Buildenergia
La Plataforma Hiberatlas Muestra La Rehabilitación De Edificios Históricos	Spain	February 20	Ecoconstrucción
¿Como Reducer El Comsumo Enérgetico En Los Edificios Históricos?	Spain	February 20	SolarNews
Hvordan Kan Energiforbruget Reduceres I Historiske Bygninger?	Denmark	April 20	HVAC Magazinet
Ejemplos De Buenas Prácticas En La Rehabilitación De Edificios Históricos Mediante La Plataforma Hiberatlas	Spain	April 20	Construbile
Online Plattform Für Gelungene Sanierungsobjekte	Austria	May 20	Handwerk+Bau
Come Ridurre I Consumi Energetici Negli Edifici Storici?	Italy	May 20	Rinnovabili.it
Altbau-Sanierungs-Altas	Austria	May 20	Building Times

Wie Lässt Sich Der Energieverbrauch In Historischen Gebäuden Senken?	Austria	Aug 20	Online Magazin Umwelttechn-ik, Energie und Abfallwirtschaft
Hygrothermal Performance of Traditional Buildings	UK	Winter 20	SPAB Magazine
How to Maintain Your Traditional Tenement Flat and Communal Areas	UK	July 20	Scottish Construction Now

Dissemination Activities

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
Akkurt, G.G., Aste, N., Borderon, J., Buda, A., Calzolari, M., Chung, D., Costanzo, V., Del Pero, C., Evola, G., Huerto-Cardenas, H. E., Leonforte, F., Lo Faro, A., Lucchi, E., Marletta, L., Nocera, F., Pracchi, V., Turhan, C.	Dynamic thermal and hygrometric simulation of historical buildings: critical factors and possible solutions	Renewable & Sustainable Energy Reviews	Volume 118, February 2020 https://doi.org/10.1016/j.rser.2019.109509
H.E.Huerto-Cardenas, F.Leonforte, N.Aste, C.Del Pero, G.Evola, V.Costanzo, E.Lucchi	Validation of dynamic hygrothermal simulation models for historical buildings: State of the art, research challenges and recommendations	Building and Environment	Volume 180, August 2020, https://doi.org/10.1016/j.buildenv.2020.107081
SUPSI	BIPV in dialogue with history	BIPV Status Report 2020 "Building Integrated Photovoltaics: A practical handbook for solar buildings' stakeholders". 2020	November 2020
SUPSI	Pacchetto Ambiente: Soluzioni Pratiche e tecniche per RI-construire una società rinnovabile, sostenible e futurible	SUPSI, Becquerel Institute Tutto Green magazin	Ed. n°2-2020 (editor: Edimen SA)
Pelle, M.; Lucchi, E.; Maturi, L.; Astigarraga, A.; Causone, F.	Coloured BIPV technologies: methodological and experimental assessment for architecturally sensitive areas	Energies	13(17) https://www.mdpi.com/1996-1073/13/17/4506
Hao, L.; Herrera-Avellanosa, D.; Del Pero, C.; Troi, A	What Are the Implications of Climate Change for Retrofitted Historic Buildings? A Literature Review	Sustainability	12(18), 7557; https://www.mdpi.com/2071-1050/12/18/7557

E .Lucchi1; C. S. Polo Lopez; G. Franco	A conceptual framework on the integration of solar energy systems in heritage sites and buildings		IOP Conf. Series: Materials Science and Engineering949 (2020) 012113 https://iopscience.iop.org/article/10.1088/1757-899X/949/1/012113/pdf
Rieser, A.; Pfluger, R.; Troi, A.; Herrera-Avellanosa, D.; Thomsen, K.E.; Rose, J.; Arsan, Z.D.; Akkurt, G.G.; Kopeinig, G.; Guyot, G.; Chung, D.	Integration of energy efficient ventilation systems in historic buildings – review and proposal of a systematic intervention approach	Sustainability – Special Issue	*13*(9) 2021 https://www.mdpi.com/2071-1050/13/4/2325
Marincioni, V.; Gori, V.; de Place Hansen, E.J.; Avellanosa, D.; Mauri, S.; Giancola, E.; Egusquiza, A.; Buda, A.; Leonardi, E.; Rieser, A.	How can scientific literature support decision making in the renovation of historic buildings? An evidence-based approach for improving the performance of walls	Sustainability – Special Issue	*13*(9) 2021 https://www.mdpi.com/2071-1050/13/4/2266
Buda, A.; de Place Hansen, E.J.; Rieser, A.; Giancola, E.; Pracchi, V.N.; Mauri, S.; Marincioni, V.; Gori, V.; Fouseki, K.; Polo López, C.S.; Lo Faro, A.; Egusquiza, A.; Haas, F.; Leonardi, E.; Herrera-Avellanosa, D.	Conservation-compatible retrofit solutions in historic buildings: an integrated approach in Task 59 project	Sustainability – Special Issue	13(9) 2021 https://www.mdpi.com/2071-1050/13/5/2927
Polo López, C.S.; Lucchi, E.; Leonardi, E.; Durante, A.; Schmidt, A.; Curtis, R	Risk-benefit assessment scheme for renewable solar solutions in traditional and historic buildings	Sustainability – Special Issue	13(9) 2021 https://www.mdpi.com/2071-1050/13/9/5246
Polo López, C.S.; Troia, F.; Nocera, F.	Photovoltaic BIPV Systems and Architectural Heritage: New Balance between Conservation and Transformation. An Assessment Method for Heritage Values Compatibility and Energy Benefits of Interventions	Sustainability – Special Issue	13(9) 2021 https://www.mdpi.com/2071-1050/13/9/5107/htm
A. Egusquiza, S. Ginestet, J.C. Espada, I. Flores-Abascal, C. Garcia-Gafaro, C. Giraldo-Soto, S. Claude, G. Escadeillas,	Co-creation of local eco-rehabilitation strategies for energy improvement of historic urban areas	Renewable and Sustainable Energy Reviews	Volume 135 https://www.sciencedirect.com/science/article/pii/S1364032120306201
20+ papers		SBE21 Heritage conference proceedings	https://iopscience.iop.org/issue/1755-1315/863/1

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
Solar Academy webinar	Alexandra Troi and Daniel Herrera (Eurac), Walter Hüttler (e7), Tor Broström (UU), Pavel Sevela (UIBK)	January 28, 2020	185
Energy Efficiency Seminar 2020	Julien Borderon, CEREMA: Engaging Owners in Energy Renovations: a case study of farmhouse refurbishment in Alsace, France	February 6-7, 2020	~100
Energy Efficiency Seminar 2020	Daniel Herrera, EURAC: Inspiring Good Practices	February 6-7, 2020	~100
Monumento Fair, Salzburg/Austria	Franziska Haas (Eurac), presentation of the Touring Exhibition	March 5-7, 2020	
REHABEND 2020	Aitziber Egusquiza, Josè Luis Izkara, Inaski Prieto: quiskisa3D-GIS Models to support the co.-creation of energy efficient strategies for historic urban environments	September 28 – October 1, 2020	
REHABEND 2020	Daniel Herrera-Avellanosa, Dagmar Exner, Franziska Haas, Alexandra Troi: Dissemination of Best-Practice in energy retrofit of historic buildings. Rainhof, a case study in the Italian Alps	September 28 – October 1, 2020	
REHABEND 2020	Cristina Polo Lopez, Elena Lucchi, Givanna Franco: Acceptance of building-integrated photovoltaics (PiPV) in heritage buildings and landscapes: potential, barriers and assessment criteria	September 28 – October 1, 2020	
Certificate of Advanced Study (CAS) in regenerative materials, ETH Zürich	Seminar on the sustainable retrofit of traditional buildings UCL	October 5, 2020	15 professionals
Hygrothermal Risk Seminar, Edinburgh Architects Association, HERITECH Florence	Seminar on retrofit and hygrothermal risk HES	October 7, 2020	70 professionals
EURAC/SUPSI	A conceptual framework on the integration of solar energy systems in heritage	October 14-16, 2020	40 professionals

	sites and buildings		
Southern Uplands Partnership: Energy Efficiency in Traditional Buildings (Online)	Presentation on traditional building retrofit HES	October 21, 2020	20 professionals
Renovate Europe Webtalk, Vienna	Seminar on Innovative Retrofit Approaches E7	October 27, 2020	35 professionals
Workshop: Responsible Restoration of Old Buildings (Online)	Cerema, EURAC	November 17, 2020	
RIAS Aberdeen CPD: Thermal Upgrades in Traditional Buildings (Online)	Presentation on Traditional building retrofit HES	November 25, 2020	70 professionals
Fabric Monitoring in Traditional Buildings (Online)	HES	November 26, 2020	25 professionals
RIAS Aberdeen CPD: Hygrothermal Matters and HES Case Studies (Online)	Hygrothermal Matters and HES Case Studies HES	February 19, 2020	64 professionals
Energy Renewal of the historic building: a ‘Sustainable Issue’ for debate (Online)	Relationship between conservation and sustainability safeguarding - in a sustainable key - the historical and cultural heritage, to foster the energy retrofit of historic buildings and the integration of renewable energy and solar energy promoting a theoretical-critical debate with stakeholders. SUPSI	December 2, 2020	25 trade & practitioners
Briefing session with Public authorities	La legislazione nazionale e locale per l’integrazione dei sistemi fotovoltaici EURAC	January 21, 2021	20 trade & practitioners
Briefing session with Heritage Authorities	Architettura solare in contesti di pregio: il Progetto BIPV meets history EURAC	February 17, 2021	20 trade & practitioners
SBE21 workshop	Balancing heritage preservation, local RES potential and BIPV technology exploitation EURAC	April 14, 2021	trade & practitioners

Wester Ross UNESCO Biosphere	Community outreach – energy efficiency and sustainability	January 11, 2021	20 public outreach

Task Meetings

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 1	October 23-25, 2017	Edinburgh, UK	17 participants (9countries)
Task Meeting 2	March 1, 2018	Dublin, Ireland	25 participants (10 countries + 10 remote)
Task Meeting 3	October 28-29, 2018	Visby, Sweden	29 participants (11 countries + 1 remote)
Task Meeting 4	April 8-10, 2019	Copenhagen, Denmark	34 participants (14 countries)
Task Meeting 5	October 14-15, 2019	Vienna, Austria	27 participants (10 countries)
Task Meeting 6	April 23-24, 2020	Virtual	40 participants (11 countries)
Task Meeting 7	October 19-21, 2020	Virtual	34 participants

SHC Task 59 Participants

Country	Name	Institution	Role
ITALY	**Alexandra Troi**	**EURAC**	**Task Manager**
AUSTRIA	Walter Hüttler	E-7	Subtask A Leader
AUSTRIA	Rainer Pfluger	UIBK	Subtask C Leader
BELGIUM	Michael de Bouw	BBRI	National Expert
BELGIUM	Samuel Dubois	BBRI	National Expert
BELGIUM	Yves Vanhellemont	BBRI	National Expert
BELGIUM	Sophie Trachte	UCL	National Expert
BELGIUM	Dorothée Stiernon	UCL	National Expert
BELGIUM	Nathalie Vernimme	FHA	National Expert
DENMARK	Jørgen Rose	SBI	National Expert
DENMARK	Kirsten Thomsen	SBI	Subtask D Leader
DENMARK	Ernst Jan de Place	SBI	National Expert
FRANCE	Julien Borderon	CEREMA	National Expert
FRANCE	Julien Burgholzer	CEREMA	National Expert
FRANCE	Elodie Héberié	CEREMA	National Expert
GERMANY	Arnulf Dinkel	Fraunhofer	National Expert
GERMANY	Sebastian Herkel	Fraunhofer	National Expert
GERMANY	Johannes Eisenlohr	Fraunhofer	National Expert
IRELAND	Peter Cox	ICOMOS	National Expert
IRELAND	Leila Budd	ICOMOS	National Expert
ITALY	Elena Lucchi	EURAC	National Expert
ITALY	Lingjun Hao	EURAC	National Expert
ITALY	Daniel Herrera	EURAC	National Expert
ITALY	Franziska Haas	EURAC	National Expert
ITALY	Dagmar Exner	EURAC	National Expert
ITALY	Niccolo Aste	POLIMI	National Expert
ITALY	Claudi Delpero	POLIMI	National Expert
ITALY	Fabrizio Leonforte	POLIMI	National Expert

ITALY	Enrico Deangelis	POLIMI	National Expert
ITALY	Valeria Pracchi	POLIMI	National Expert
ITALY	Alessia Buda	POLIMI	National Expert
ITALY	Harold Enrigue Huerto Cardenas	POLIMI	National Expert
ITALY	Pietromaria Davoli	UNIFE	National Expert
ITALY	Marta Calzolari	UNIFE	National Expert
ITALY	Giovanna Franco	UNIGE	National Expert
ITALY	Luigi Marletta	UNICT	National Expert
ITALY	Giuseppe Margani	UNICT	National Expert
ITALY	Giampiero Evola	UNICT	National Expert
ITALY	Alessandro Lo Faro	UNICT	National Expert
ITALY	Francesco Nocera	UNICT	National Expert
ITALY	Antonio Gagliano	UNICT	National Expert
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SPAIN	Miguel Angel Garcia	CARTIF	National Expert
SPAIN	Sonia Alvarez	CARTIF	National Expert
SPAIN	Emanuela Giancola	CIEMAT	National Expert
SPAIN	Eduardo Garcia	CUPA	National Expert
SPAIN	Aitziber Egusquiza	TECNALIA	National Expert
SPAIN	Ander Romero	TECNALIA	National Expert
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SWEDEN	G. Leijonhufvud	UU	National Expert
SWEDEN	Petra Eriksson	UU	National Expert
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TURKEY	Zeyenep Durmuş Arsan	IYTE	National Expert
UNITED KINGDOM	Carsten Hermann	HES	Subtask D Leader
UNITED KINGDOM	Roger Curtis	HES	National Expert
UNITED KINGDOM	Valentina Marincioni	UCL	National Expert
UNITED KINGDOM	Virginia Gori	UCL	National Expert

UNITED KINGDOM	Hector Altamirano	UCL	National Expert
UNITED STATES	Amanda Webb	CINCINNATI	National Expert
UNITED STATES	Daniel Chung	DREXEL	National Expert

Task 61 – Integrated Solutions for Daylighting and Electric Lighting: From Component to User Centered System Efficiency

Jan de Boer
Fraunhofer Institute for Building Physics IBP
Task Manager for Forschungzentrum Jülich GmbH

Task Overview

The main objective was to foster the integration of daylight and electric lighting solutions to the benefits of higher user satisfaction and at the same time energy savings. This can be subdivided into the following specific objectives.

- Review relation between user perspective (needs/acceptance) and energy in the emerging age of "smart and connected lighting" for a relevant repertory of buildings.
- Consolidate findings in use cases and "personas" reflecting the behavior of typical users.
- Based on a review of specifications concerning lighting quality, non-visual effects as well as ease of design, installation and use, provision of recommendations for energy regulations and building performance certificates.
- Assess and increase robustness of integrated daylight and electric lighting approaches technically, ecologically and economically.
- Demonstrate and verify or reject concepts in lab studies and real use cases based on performance validation protocols.
- Develop integral photometric, user comfort and energy rating models (spectral, hourly) as pre-normative work linked to relevant bodies: CIE, CEN, ISO. Initialize standardization.
- Provide decision and design guidelines incorporating virtual reality sessions. Integrate approaches into wide spread lighting design software.
- Combine competencies: Bring companies from electric lighting and façade together in workshops and specific projects. Hereby support allocation of added value of integrated solutions in the market.

To achieve these objectives, the work focused in four main topics:

1. Subtask A: User perspective and requirements
2. Subtask B: Integration and optimization of day- and electric lighting
3. Subtask C: Design Support for practitioners
4. Subtask D: Lab and Field Study Performance Tracking

Participating Countries

	Research Institutes	**Universities**	**Companies**
Australia	0	1	0
Austria	0	0	2
Belgium	1	1	0
Brazil*	0	1	0
Canada	0	1	0
China	1	1	0
Denmark	2	3	1
Germany	2	1	1
Italy	1	1	0
Japan*	0	1	0
The Netherlands	0	1	1
Norway	0	1	1
Poland*	0	1	0
Slovakia	0	1	0
Sweden	0	1	1
Switzerland	2	2	1
USA*	1	0	1
Total	**10**	**18**	**9**

**thru IEA EBC TCP*

Task Duration

This Task started in January 2018 and ended in June 2021. Final deliverables are published under https://task61.iea-shc.org/publications.

Collaboration with Other IEA TCPs

Within the IEA there was a “maximum” collaboration with the IEA EBC TPC, where the project was listed as Annex 77. The collaboration was later adapted to “moderate”. In the project C.3 on sky models of Subtask C a collaboration was established with IEA PVPS Task 16 “Solar resource for high penetration and large scale applications”.

Collaboration with Outside Organizations/Institutions

The project C.3 also collaborated with the Commission International d’Eclairage (CIE), TC 3-60: Spectral daylight characteristics. The work on the hourly rating method for energy demand of integrated lighting solutions was very closely linked to the standardization body ISO TC 274 “Light & Lighting”.

Collaboration with Industry

Seven companies (one sun shading manufacturer, one software company, five consulting / engineering companies) and one trade association participated actively in Task 61 with own work packages / contributions. Three international companies (two lighting manufacturers, one rooflight company) participated in “level 2” industry collaboration.

Over its duration Task 61 has attracted significant interest from industry. Altogether four industry workshops were organized in conjunction with the task meetings in Lund, Sweden, Lausanne, Switzerland, Beijing, China and Gdansk, Poland. An already fully organized 5th workshop in Aversa, Italy, and associated workshops with the other then following virtual meetings had to be cancelled due to the pandemic situation. In September 2020 a webinar on Task 61 with a Q&A session was given by the five subtask leaders and the operating agent, organized by the solar academy.

With the industry workshops and webinar experts continuously informed about general lighting integration issues and possible solutions. Experts from industry shared their experiences and views in discussions and panels. By this the Task activities with respect to industry and practitioners’ needs were mirrored. The industry workshop and webinar were visited (in person and by live streams) by altogether more than 3000 participants. In addition, numerous contributions in other workshops, conferences and seminars related to the Task.

In a survey, more than 100 experts from practice (building/facility managers and planers) were interviewed about opportunities and barriers in lighting controls in their business. Afterwards they were informed about the evaluation.

Key Results

The main accomplishments of this Task are highlighted below. More details and specific deliverables can be found on the SHC Task 61 webpage and in the activities of the specific Subtasks.

Subtask A: User perspective and requirements

(Barbara Szybinska Matusiak, Norwegian University of Science and Technology NTNU, Norway)

During the last twenty years the knowledge about light and lighting has significantly developed and at the same time the technological development has been immense. Today we are able to get much more electrical lighting with less energy than ever before, but is the light of good quality? We need to develop evaluation methods that take all the qualitative aspects of illumination as well as the energy efficiency into account at the same time and transfer these into practice. Reliable and valid measures of light, as well as valid and reliable measures of user’s reactions are needed.

In this project in a literature review on user lighting requirements more than 100 articles were reviewed and analyzed, covering 4 main categories with investigated 28 sub criteria (selection in brackets):

1. Perception of light (vision development, visual performance, temporal differences, cultural differences);
2. Visual Comfort (glare, flicker, contrast, spacial frequency);
3. Psychological aspects of lighting (view out, perceived quality of interior spaces, privacy, behavioral effects of light);
4. Non-image forming aspects of light (ipRGCs action spectrum, hormones, timing and previous experience, individual differences, mood, SAD and sub-SAD).

By using these four basic aspects with the different criteria on both an image-forming and non-image-forming level the project has provided the means to compare between qualities of electric lighting and daylighting. For the specific case of office work, the findings have been aggregated into an overview table of application related requirements.

The main objective of work in this project was to examine how public buildings (offices, schools, university buildings, hospitals, commercial buildings, industry buildings and libraries) are used regarding lighting, considering both daylight and electric lighting. The work was organized in two main parts. In an extensive literature review, it investigated what can be learned from the already documented use of buildings. Then in the second part of the project, it looked more specifically into the impact of building occupancy on the use of lighting systems. Here the key point is to understand and model when and how spaces are occupied. First occupancy simulation methods are now available, based on statistic models derived from empirical field studies (as from IEA EBC Annex 66). Generally, this approach seems very promising; nevertheless, at the moment it is limited to office buildings only. Therefore, it was worked on a more empirically fundamental level with occupancy registration. The research method used in registration consisted of simultaneous registration of occupancy and use of (day-) lighting with the help of a self-report diary, and light-technical measurements. The registration confirmed a pattern of occupants' behavior found in literature. In general, occupants consider the visual environment at the workplace when they enter or leave the room. It happens mainly at the beginning (adjustment of blinds and switching on the electric light) and at the end of the working day (switching of the light). The use of lighting follows occupancy patterns, and not daylight level outdoors, something that indicates significant potential for energy saving. These empirical data may in the future serve for the further development of the statistical models of occupancy simulation methods.

The consumption of energy for lighting in buildings depends very much on the way people interact with the build environment. In this project the following building types were studied, office, school, university, commercial and industry buildings. Pushed by the pandemic situation in addition to the original workplan also home office situations (students and professionals) were included in the project. For each building type, typical user groups were identified. Then, Personas have been created for each group, altogether 26. As opposed to describing users with numbers and statistics, a single Persona reflects a group and is presented with a narrative. The Persona has a name, a family and living conditions that are representative for the group, also her/his values and interests are not uncommon. The Personas "typical day" includes a time schedule typical for the group. Visual conditions are common for the group, but some specific challenges connected to the visual conditions that may occur in the group are also mentioned. Personas can in the future be used for instance in lighting design for a much more holistic description of the user impact, i.e. requirements and behavior, on lighting installations.

Subtask B: Integration and optimization of day- and electric lighting

(Marc Fontoynont, BUILD – Institut for Byggeri, By og Miljø, Denmark)

A survey in eight countries on the status quo of daylight and electric lighting control systems was performed. Feedback from more than 100 international experts (building / facility managers and planers) was evaluated. The aim of the survey was to identify the perception of the different possibilities of the current lighting control solutions and the expectations about the control systems. Participants of the survey had to rank each question in relation to the perceived importance and the need for improvement. The survey enclosed five general topics: energy, operational aspects, occupant control, occupant comfort and control functionality. The findings suggest that the two main reasons for the implementation of lighting control systems are:

1. The possibility to reduce the electric lighting consumptions and
2. The opportunity to increase the user's well-being and thereby reduce complaints from the users.

Among others, the evaluated feedback suggests, the satisfaction with the lighting conditions in general increases when providing manual override possibilities the users should be able to both increase and dim the light levels or completely turn it off and also to manually control the shading systems. A control system, which is easy for the users to understand intuitive, will most likely increase the chances of an 'optimal' interaction with the system. If the system does not meet the users need or is too complex to use, the possibility that the users will try to override the control systems increases, and this will most likely result in increased energy consumption.

There is a large number of control systems proposed by either lighting manufacturers or motor manufacturers for shading systems. In addition, there are many other solutions proposed by specific manufacturers of Building Management Systems (BMS) or manufacturers of components to be installed in luminaires and switches, as well as in the electric lighting architecture (transformers, gateways to the internet, sensors, etc.).

In the project the principles of controls, which are rather independent of the progress of technology, were documented. Here, by listing and explaining major functions and components of control systems, an overview about the technical possibilities and challenges is given. Different types of daylight and electric lighting control strategies and altogether 16 specific lighting control protocols (wired and wireless) were analyzed, discussed, and documented to create an understanding of the potentials and barriers of existing and to give an outlook on future solutions.

Innovative and integrative lighting solutions are a rapidly developing trend among BMS manufacturers. They are being implemented in various systems from industry-leading firms, however they are met with a challenge of finding the best possible compromise between occupant expectations and optimization of building operation.

This project described the relation between new trends and systems, the challenges associated with them, and the value creation that follows these innovative solutions.

A general discussion has been then specified by examples of 3 innovative systems from leading European brands and experts. The presented solutions are showing different possible directions in the development of new integrated control solutions: a) integration of electric lighting and daylight-blocking blinds b) integration of electric lighting and blinds with the best possible solar gains and glare prevention at the workplaces, and c) innovative approach to implementing a glare prevention and human-centric lighting in the building's lighting system. Each of the three systems is analyzed with its' advantages and challenges.

This project showed that the impact of a good User Interfaces (UI) is not only affecting the usability and comfort for the user but is also a major key to save energy. At least as important for effectiveness to the quality of individual interfaces is consistency in the meaning of individual user interface elements (visual, conceptual, auditory, etc.). The energy management can be hidden and embedded. When the UI is not fully intuitive, it is a key element to train the user in optimizing the system, in an attractive way. Understanding of the operation will allow the occupant to understand and interact in a way, an important contribution to reduce the energy consumption of the building.

Beginning with the basic categories of Lighting Interfaces (analog, digital and hybrid), and going through the several functions to more complex and self-learning solutions, the project gives a basic understanding of lighting and shading control interfaces. With this, it gives an overview of the current trends and solutions on the market for professionals as well as nonprofessionals. Among the most significant trends which have been identified are:

- The ability to customize the UI to the users' needs
- To synchronize with the global building management system
- To propose (or suggest) attractive pre-programmed options
- To develop interfaces which are "educating" the user: making him or her understand the consequence of his (her) choices.
- Use of standard UI elements to facilitate basic user comprehension of the interface

The two areas – control of daylight, and control of electric lighting – are usually treated separately in standards, which raises a question whether it is possible to combine existing knowledge and technology in an attempt of creating a thorough standard or guidelines considering integration of the two areas. Here the project identified key issues to address, like: a) Blocking of the sunlight penetration to reduce glare, overheating, and thermal discomfort, while at the same time increasing energy usage to compensate lighting levels with electric lighting. b) Manual override of the systems according to the user preference in juxtaposition with the automated systems defining the most efficient settings for the building performance. c) Simplification of the operation to create user-friendly (and most importantly: used) systems. The project also reflected additional topics that can be challenging in standardization of integrated lighting controls: security, calculation procedures, and user interfaces.

Subtask C: Design Support for practitioners

(David Geisler-Moroder, Bartenbach GmbH, Austria)

Practitioners are using a wide variety of different workflows, methods, and tools in the planning of integrated solutions for daylighting, electric lighting, and lighting controls. Lighting design projects cover a wide variety of applications with different requirements, as well as project types and sizes. For this project, Task participants reviewed applied workflows in practical applications. They did this using a three-step process. First, three buildings using integrated lighting solutions were selected and analyzed. The state-of-the-art building projects are in Austria, Germany, and China. Second, based on these design projects, typical workflows for the planning process were collected and discussed. And third, as all described workflows utilize software tools to support the planning and design processes, an overview of the possibilities, strengths, weaknesses, and barriers of the state-of-the-art in lighting simulations was prepared. This analysis includes a tabulated comparison of the key features of relevant and widely used software tools.

The project focused on summarizing the current state of the art in the field of characterization of daylighting and shading systems by bidirectional scattering distribution functions (BSDFs), performing quality assurance and paving the way for future standardization of BTDF assessment and digital processing methods.

Procedures for:

1. measuring angle-dependent transmittance and reflectance properties of daylighting and shading systems, and then
2. generating bidirectional scattering distribution functions (BSDF) from the measured data for use as input to simulation tools

are proposed and were documented in a white paper. The white paper is intended to stimulate discussion and critical review of these procedures internally within the IEA task and then also externally by research and industry with the end objective of releasing harmonized procedures to be considered by international standards organizations.

Based hereupon various methods for generating BSDF data sets for shading and daylighting systems as applied by different laboratories are documented and compared. Worldwide, several institutes provide the service of measuring and simulating BSDF data for such fenestration systems. The aim here was to highlight the pros and cons of the different approaches and to provide an overview of used measurement instruments and simulation software tools.

Finally, a round robin test among the project participants was performed. The objective was to assess the comparability of BSDF data sets generated by the various laboratories for the same shading or daylighting system as well as – for practical use in daylighting design even more important – the comparability of daylight performance metric evaluations based on these data. One outdoor venetian blind system and one interior textile roller blind were selected representing widely used shading and glare protection systems. The overall result of the comparison shows that there is good agreement between the BSDF data sets provided by the different laboratories.

The project dealt with the current state of the art in the field of spectral measurements and models of daylight. It generated overviews of:

1. daylight sites conducting spectral (radiance, irradiance) measurements
2. spectral sky models
3. simulation software supporting spectral calculations

The first part of the project focused on two measurement approaches, spatially resolved (radiance) and global (irradiance) spectral measurements. Measurement activities at different locations were analyzed, described, and compared. Next, the existing data-driven and analytical models were reviewed. Based on this a simplified model for practical applications was proposed. Material properties in the built environment, comprising glazing and opaque materials were described regarding their spectral behavior. Furthermore, three simulation platforms LARK, ALFA, and RADIANCE that support spectral calculations were analyzed. The last project part developed design guidelines comprised of: spectral daylight potential diagrams (SDPD) displaying the orientation dependent spectral characteristics of daylight on the façade, and urban aesthetics studying the aesthetics of changing sky conditions for urban environments of various materiality.

An hourly based evaluation and rating method for the energy demand of integrated lighting solutions has been developed. The approach is based on a clear segregation of emulating reality, i.e. daylight & room, electric lighting & room and occupancy behavior on the one hand side and description of sensors, actors and (network) functionality on the other side, where the latter is kept in accordance with standard building automation and control system (BACS) description semantics. The approach allows an integrated workflow for lighting design and commissioning of lighting installations, while avoiding double modelling / specifications in the future.

The work on the generic method here in project C.4 has been jointly performed with ISO/TC 274/JWG 1 in revising the ISO 10916 “Calculation of the impact of daylight utilization on the net and final energy demand for lighting”. It will be included as a new method in the standard. It here has reached the status of a positively voted Committee Draft and will now - after inclusion of received and already negotiated comments - be circulate as a Draft International Standard (DIS) until 31st December 2021. In the Joint Working Group (JWG) a software for testing and application of the method in common use cases has been implemented.

Subtask D: Lab and Field Study Performance Tracking

(Niko Gentile, Lund University, Sweden and Werner Osterhaus, Aarhus University, Denmark)

Measures for the reduction of electric energy loads for lighting have predominantly focussed on increasing the efficiency of lighting systems. This efficiency has now reached levels unthinkable a few decades ago. However, a focus on mere efficiency is physically limiting, and does not necessarily ensure that the anticipated energy savings actually materialize. There are technical and non-technical reasons because of which effective integration of lighting solutions and their controls, and thus a reduction in energy use, does not happen.

This literature review aims to assess the energy saving potential of integrated daylight and electric lighting design and controls, especially with respect to user preferences and behavior. It does so by collecting available scientific knowledge and experience on daylighting, electric lighting, and related control systems, as well as on effective strategies for their integration.

Based on this knowledge, the review suggests design processes, innovative design strategies and design solutions which – if implemented appropriately – could improve user comfort, health, well-being, and productivity, while saving energy as well as the operation and maintenance of lighting systems. The review highlights also regulatory, technical, and design challenges hindering energy savings.

Potential energy savings are reported from the retrieved studies. However, these savings derived from separate studies are dependent on their specific contexts, which lowers the ecological validity of the findings. Studies on strategies based on behavioral interventions, like information, feedback, and social norms, did not report energy saving performance. This is an interesting conclusion, since the papers indicate high potentials that deserve further exploration. Quantifying potential savings is fundamental to fostering large scale adoption of user-driven strategies, since this would allow at least a rough estimation of returns for the investors. However, such quantification requires that studies are designed with an inter-disciplinary approach.

The literature also shows that strategies, where there is more communication between façade and lighting designers, are more successful in integrated design, which calls for more communication between stakeholders in future building processes.

In the project tools for post-occupancy evaluation (POE) to evaluate indoor lighting of commissioned projects ('case studies') under a common framework were developed. POE includes technical environmental assessment (TEA) and observer-based environmental assessment (OBEA). The framework proposed evaluates four key aspects for case study analysis:

1. Energy use (electrical lighting systems),
2. Visual effects (Indoor lighting environment /photometry)
3. Non-visual effects (circadian potential), and
4. The user (subjective/surveys and observations)

The results target industry professionals, building designers, lighting designers, building managers, researchers and/or owners wishing to evaluate projects where lighting is supplied by a combination of electrical lighting, daylighting systems (e.g., fenestrations) and assisted technologies (e.g., smart sensors). The framework makes available methods and procedures related to the evaluation of integrated lighting performance in residential and non-residential buildings and its impact on users, and it summarizes and categorize methods and procedures in an accessible and industry-oriented language. Work is based on methods and procedures used by participating experts in IEA SHC Task 61 for monitoring twenty-five worldwide-integrated daylighting and electric lighting case studies (rf. D3/D4). Since integrated lighting projects are different in type and scopes, the methods and procedures included in the framework do not follow a rigid protocol. Practitioners should use the framework to define the scope of POE monitoring in terms of the aims of the project, context, and resources available. The project thus provides a toolbox for planning and executing the monitoring of their integrated lighting projects.

25 case studies, at 22 sites in 12 countries covering different climatic zones on 5 continents, implementing the integration of daylighting and electric lighting were monitored with respect to energy use for lighting, visual performance, non-visual performance, and users' satisfaction following the monitoring protocol developed in project D2. The monitoring is largely based on field measurements, but it is also complemented with simulations and calculations where needed. The case studies were described, the monitoring and calculation results evaluated, and specific lessons learned gleaned.

The project elaborated the lessons learned from the 25 worldwide cases. Special focus in this cross-sectional analysis was put on the impact on energy efficiency, opportunities, and challenges of integrative lighting solutions (here circadian potentials, risk for energy rebounds), daylighting and view out, impact or user interaction with the lighting system, the importance of monitoring and verification - and subsequently recommissioning - for successful lighting projects.

Dissemination Activities

Reports, Published Books & Online Tools

Author(s)/Editor	Title	Report Number Publication Date	Target Audience
Cláudia Naves David Amorim, David Geisler-Moroder, Thorbjörn Laike, Justyna Martyniuk-Pęczek, Barbara Szybinska Matusiak, Wilfried Pohl, Natalia Sokół	Literature review of user needs, toward user requirements	Technical Report A1	Researchers, Designers / consultants
Barbara Szybinska Matusiak, Sergio Sibilio, Justyna Martyniuk-Pęczek, Cláudia Naves David Amorim, Marzieh Nazari, Marie Boucher, Michelangelo Scorpio, Natalia	Subtask A: User Perspective and Requirements	Technical Report A2	Researchers, Designers / consultants

Sokół, Giovanni Ciampi, Yasuko Koga, Thorbjörn Laike			
Barbara Szybinska Matusiak, Justyna Martyniuk-Pęczek, Sergio Sibilio, Cláudia Naves David Amorim, Michelangelo Scorpio, Giovanni Ciampi, Marzieh Nazari, Natalia Sokół, Julia Kurek, Marta Waczyńska, Natalia Giraldo Vasquez, Julia Resende Kanno	Subtask A: Personas	Technical Report A3	Researchers, Designers / consultants
Bruno Bueno Unzeta, Jan de Boer, Ruben Delvaeye, Bertrand Deroisy, Marc Fontoynont, David Geisler-Moroder, Niko Gentile, Tao Luo, Daniel Neves Pimenta, Per Reinhold, Michelangelo Scorpio, Sergio Sibilio, Natalia Sokól, Anne Sophie Louise Stoffer, Robert Weitlaner	Survey on opportunities and barriers in lighting controls	Technical Report B1	Owners / Investors, Authorities, Designers / consultants, Industry
Bruno Bueno Unzeta, Jan de Boer, Ruben Delvaeye, Bertrand Deroisy, Marc Fontoynont, Daniel Neves Pimenta, Per Reinhold, Anne Sophie Louise Stoffer, Robert Weitlaner	Integration and Optimization of Daylight and Electric Lighting	Technical Report B2	Owners / Investors, Authorities, Designers / consultants, Industry
Bruno Bueno Unzeta, Jan de Boer, Ruben Delvaeye, Nikodem Derengowski, Bertrand Deroisy, Marc Fontoynont, Daniel Neves Pimenta, Per Reinhold, Anne Sophie Louise Stoffer, Robert Weitlaner	Review of new systems and trends	Technical Report B3	Designers / consultants, Industry, Researchers
Editor: Marc Fontoynont Additional: Bruno Bueno Unzeta, Jan de Boer, Ruben Delvaeye, Nikodem Dernegowski, Bertrand Deroisy, Marc Fontoynont, Bruce Norman, Daniel Neves Pimenta	User Interfaces	Technical Report B4	Industry, Designers / consultants
Jan de Boer, Nikodem Derengowski, Marc Fontoynont, Daniel Neves Pimenta, Per Reinhold, Robert Weitlaner	Standardisation issues related to lighting and daylighting control systems	Technical Report B5	Authorities, Industry, Researchers
Bruno Bueno Unzeta, David Geisler-Moroder, Ulf Greiner Mai, Markus Hegi, Chris Jackson, John Alstan Jakubiec, Fabian Jarrin, Jérôme H. Kaempf, Yasuko Koga, Marios Liaros, Tao Luo, Biljana Obradovic, Bernard Paule, Harris Poirazis, Dave Speer, Zhen Tian, Taoning Wang,	Workflows and software for the design of integrated lighting solutions	Technical Report C1	Designers / consultants

Daniel Witzel			
Bruno Bueno Unzeta, Bertrand Deroisy, David Geisler-Moroder, Lars Oliver Grobe, Eleanor S. Lee, Taoning Wang, Gregory J. Ward, Helen Rose Wilson	BSDF generation procedures for daylighting systems	Technical Report C2_1	Designers / consultants, Industry, Researchers
Peter Apian-Bennewitz, Jan de Boer, Bruno Bueno Unzeta, Bertrand Deroisy, Yuan Fang, David Geisler-Moroder, Lars Oliver Grobe, Jacob C. Jonsson, Eleanor S. Lee, Zhen Tian, Taoning Wang, Gregory J. Ward, Helen Rose Wilson, Yujie Wu	Analysis and evaluation of BSDF characterization of daylighting systems	Technical Report C2_2	Designers / consultants, Industry, Researchers
Aicha Diakite-Kortlever, Priji Balakrishnan, Stanislav Darula, David Geisler-Moroder, John Alstan Jakubiec, Martine Knoop, Tao Luo, Gunther Seckmeyer, Mario Tobar, Taoning Wang, Gregory J. Ward, Jan Wienold	Spectral sky models for advanced daylight simulations	Technical Report C3	Designers / consultants, Researchers
Jan de Boer, Yuan Fang, David Geisler-Moroder, Daniel Witzel	Hourly Rating Method for the Energy Demand of Integrated Lighting Solutions	Technical Report C4	Authorities, Designers / consultants, Industry, Researchers
Editors: Niko Gentile, Werner Osterhaus Additional: Sergio Altomonte, Cláudia Naves David Amorim, Giovanni Ciampi, Veronica Garcia-Hansen, Myrta Gkaintatzi Masouti, Eleanor Lee, Biljana Obdradovic, Kieu Pham, Michelangelo Scorpio, Sergio Siblio	Literature review: Energy saving potential of user-centred integrated lighting solutions	Technical Report D1	All stakeholders involved in integrated lighting
Cláudia Naves David Amorim, Veronica Garcia-Hansen, Niko Gentile, Werner Osterhaus, Kieu Pham	Evaluating integrated lighting projects	Technical Report D2	Designers / consultants, Industry, Researchers
Editors: Niko Gentile, Werner Osterhaus	Integrating daylighting and lighting in practice	Technical Report D3D4	All stakeholders involved in integrated lighting
Jan de Boer, Barbara Matusiak, Marc Fontoynont, David Geisler Moroder, Werner Osterhaus, Niko Gentile	IEA SHC Task 61 / EBC Annex 77 Information Brochure	Brochure	Industry
Jan de Boer, Barbara Matusiak, Marc Fontoynont, David Geisler Moroder, Werner Osterhaus, Niko Gentile	IEA SHC Task 61 / EBC Annex 77 1st Newsletter	Task Newsletter	Academia, practitioners Industry, authorities

Elif Ceren Yilmaz, Rawan Abdulhaq	Assessment of the circadian stimulus potential of an integrative lighting system in an office area		Academia, architects, lighting and façade designers
Mia West Jensen	(Il)luminance Mapping for Assessment of Circadian Lighting in Office Spaces by use of the Raspberry Pi System		Academia, architects, engineers, lighting measuring professionals
T.F. Baumann	Determination of daylight provision and spectral composition of lighting in indoor environments from practical measurements of the luminance distribution		Academia, architects, engineers, lighting measuring professional
Filibert Dobos	Development of a light measurement method: assessing lighting and human light exposure using a RaspberryPi camera and dosimeters in a short-term care facility		Academia, architects, engineers, lighting measuring professionals
K.G. Nielsen	Investigating Non-Visual Effects of Lighting in Health and Elderly Care Facilities: Comparing Simulations and Measurements		Academia, architects, engineers, lighting measuring professionals
Ayana Dantas de Medeiros, Cláudia Naves David Amorim (supervisor)	A arquitetura de Severiano Mario Porto na cidade de Boa Vista: um olhar com enfoque bioclimático (The architecture of Severiano Mario Porto in the city of Boa Vista: a bioclimatic approach)		Academia, architects
Giuseppina Iuliano, Sergio Sibilio	Dynamic glazing: on-site measurement and modelling. A case study for an Electric Driven Window		Academia, architects, lighting and façade designers
Roberta Laffi	Innovative systems and technologies for lighting design		Academia, architects, lighting and façade designers
Lars Oliver Grobe	Data-driven modelling of daylight redirecting fenestration at variable directional resolution		Academia, architects, lighting and façade designers, industry
Eleanor S. Lee, Anothai Thanachareonkit, D. Charlie	High-Performance Integrated Window and		Academia, architects, lighting

Curcija, Gregory J. Ward, Taoning Wang, David Geisler-Moroder, Christoph Gehbauer, John Breshears, Luís L. Fernandes, Stephen E. Selkowitz, Robert Hart, Christian Kohler, David Blum, Jinqing Peng, Howdy Gou	Façade Solutions for California		and façade designers, industry
Yuan Fang, Jan de Boer	Simple online tool implementing the generic method of C.4	Tool	Authorities, Designers / consultants, Industry, Researchers
Daniel Witzel	DIALux EVO release with hourly rating method for integrated lighting solutions	Tool	Authorities, Designers / consultants, Industry, Researchers

Journal Articles, Conference Papers, etc.

Author(s)/Editor	Title	Publication / Conference	Bibliographic Reference
Eleanor S. Lee, David Geisler-Moroder, Gregory J. Ward	Modeling the direct sun component in buildings using matrix algebraic approaches: Methods and validation	Solar Energy Journal	No. 160 (2018) pp. 380 – 395
Lars Oliver Grobe	Characterization and data-driven modeling of a retro-reflective coating in Radiance.	Energy and Buildings Journal	Volume 162, 2018, pp. 121 – 133
Julien Nembrini, Jérôme H. Kaempf, Michael Papinutto, Denis Lalanne	A smart luminaire in an office environment: Impact on light distribution, user interactions and comfort	Journal of Physics	Conference Series, 1343 (2019), 012164
Justina Martyniuk-Pęczek, Natalia Sokół	Oświetlenie efektywne biologicznie? Spotkanie ekspertów w ramach programu badawczego Międzynarodowej Agencji Energetycznej na PG	Pismo PG	No. 9, 2019, pp. 28 – 29
Stephen Wasilewski, Lars Oliver Grobe, Jan Wienold, Marilyne Andersen	A critical literature review of spatio-temporal simulation methods for daylight glare assessment.	Journal of Sustainable Design & Applied Research	Vol. 7: Issue 1, 2019, Article 4
Lars Oliver Grobe	Photon-mapping in climate-based daylight modelling with high-resolution BSDFs.	Energy and Buildings Journal	Photon-mapping in climate-based daylight modelling with high-resolution BSDFs.
Lars Oliver Grobe	Photon mapping in image-based visual comfort assessments with BSDF	Journal of Building Performance Simulation	Photon mapping in image-based visual comfort assessments with BSDF models of

	models of high resolution.		high resolution.
Lars Oliver Grobe	Photon mapping to accelerate daylight simulation with high-resolution, data-driven fenestration models	Journal of Physics	Conference Series, CISBAT 2019, Volume 1343, 2019
Michelangelo Scorpio, Giovanni Ciampi, Antonio Rosatoa, Luigi Maffei, Massimiliano Masullo, Manuela Almeida, Sergio Sibilio	Electric-driven windows for historical buildings retrofit: Energy and visual sensitivity analysis for different control logics	Journal of Building Engineering	Volume 31, 2020, 101398, ISSN 2352-7102
Michelangelo Scorpio, Roberta Laffi, Massimiliano Masullo, Giovanni Ciampi, Antonio Rosato, Luigi Maffei, Sergio Sibilio	Virtual reality for smart urban lighting design: applications and opportunities	Energies Journal	Virtual reality for smart urban lighting design: applications and opportunities
Giovanni Ciampi, Michelangelo Scorpio, Yorgos Spanodimitriou, Antonio Rosato, Sergio Sibilio	Thermal Model Validation of an Electric-Driven Smart Window through Experimental Data and Evaluation of the Impact on a Case Study	Building and Environment Journal	2020
Barbara Szybinska Matusiak, David Geisler-Moroder	IEA SHC Task 61 / EBC Annex 77: Integrated Solutions for Daylight and Electric Lighting: From Component to User Centered System Efficiency	IEA SHXC Solar Update Newsletter	2020
Aicha Diakite-Kortlever, Martine Knoop	Forecast accuracy of existing luminance-related spectral sky models and their practical implications for the assessment of the non-image-forming effectiveness of daylight	Lighting Research and Technology Journal	2021
Gregory J. Ward, Taoning Wang, David Geisler-Moroder, Eleanor S. Lee, Lars Oliver Grobe, Jan Wienold, Jacob C. Jonsson	Modeling specular transmission of complex fenestration systems with data-driven BSDFs	Building and Environment Journal	Volume 196, 2021
Elif Ceren Yilmaz, Rawan Abdulhaq	Assessment of the circadian stimulus potential of an integrative lighting system in an office area	MSc Thesis	June 2020
Mia West Jensen	(Il)luminance Mapping for Assessment of Circadian Lighting in Office Spaces by use of the Raspberry Pi System	MSc Thesis	June 2019
T.F. Baumann	Determination of daylight	MSc Thesis	January 2020

	provision and spectral composition of lighting in indoor environments from practical measurements of the luminance distribution		
Filibert Dobos	Development of a light measurement method: assessing lighting and human light exposure using a RaspberryPi camera and dosimeters in a short-term care facility	MSc Thesis	February 2020
K.G. Nielsen	Investigating Non-Visual Effects of Lighting in Health and Elderly Care Facilities: Comparing Simulations and Measurements	MSc Thesis	June 2020
Ayana Dantas de Medeiros, Cláudia Naves David Amorim (supervisor)	A arquitetura de Severiano Mario Porto na cidade de Boa Vista: um olhar com enfoque bioclimático (The architecture of Severiano Mario Porto in the city of Boa Vista: a bioclimatic approach)	MSc Thesis	January 2020
Giuseppina Iuliano, Sergio Sibilio	Dynamic glazing: on-site measurement and modelling. A case study for an Electric Driven Window	MSc Thesis	January 2019
Roberta Laffi	Innovative systems and technologies for lighting design		ongoing
Lars Oliver Grobe	Data-driven modelling of daylight redirecting fenestration at variable directional resolution		2019
Eleanor S. Lee, Anothai Thanachareonkit, D. Charlie Curcija, Gregory J. Ward, Taoning Wang, David Geisler-Moroder, Christoph Gehbauer, John Breshears, Luís L. Fernandes, Stephen E. Selkowitz, Robert Hart, Christian Kohler, David Blum, Jinqing Peng, Howdy Gou	High-Performance Integrated Window and Façade Solutions for California		2020

Conferences, Workshops, Seminars

Conference / Workshop / Seminar	Activity & Presenter	Date & Location	# of Attendees
IEA SHC 61 / EBC 77 1st Industry Workshop	10 presentations from the industry and task experts	18. March 2018; Lund, Sweden	41
Smart Energy Systems Week Austria 2018	Presentation, David Geisler-Moroder	14. – 18. May 2018; Vienna, Austria	
IEA SHC Seminar, National Day Sweden	Presentation, Jan de Boer	19.6.2018, Stockholm Sweden	50
17th International Radiance Workshop 2018	Presentation, Eleanor S. Lee	3. – 5. September 2018; Loughborough, UK	
17th International Radiance Workshop 2018	Presentation, David Geisler-Moroder	3. – 5. September 2018; Loughborough, UK	
17th International Radiance Workshop 2018	Presentation, Priji Balakrishnan and John Alstan Jakubiec	3. – 5. September 2018; Loughborough, UK	
17th International Radiance Workshop 2018	Presentation, Jan Wienold and Aicha Diakite-Kortlever	3. – 5. September 2018; Loughborough, UK	
IEA SHC 61 / EBC 77 2nd Industry Workshop	10 presentations from the industry and task experts	5. September 2018; Lausanne, Switzerland	35
Advanced Building Skins 2018	Presentation, David Geisler-Moroder	1. – 2. October 2018, Bern, Switzerland	
IBPC2018 Conference	Presentation, Giovanni Ciampi and Michelangelo Scorpio	23. – 26. September 2018, Syracuse, USA	300+
IBPC2018 Conference	Presentation, Giovanni Ciampi and Michelangelo Scorpio	23. – 26. September 2018, Syracuse, USA	300+
IEA SHC 61 / EBC 77 3rd Industry Workshop	Conference >10 presentations from the industry external researchers and task experts	27. March 2019; Beijing, China	150 at CABR, 2586 online
Workshop IEA SHC Research Co-Operation	Presentation, Jan de Boer, David Geisler-Moroder	5. June 2019	50
29th Quadrennial Session of the CIE	Presentation, Niko Gentile	16. – 20. June 2019, Washington D.C., USA	100
18th International Radiance Workshop 2019	Tutorial, David Geisler-Moroder	21. – 23. August 2019, New York, USA	
18th International Radiance Workshop 2019	Presentation, David Geisler-Moroder	21. – 23. August 2019, New York, USA	

IEA SHC 61 / EBC 77 4th Industry Workshop	10 presentations from the industry and task experts	16. September 2019; Gdansk, Poland	45
SDEWES Conference, 2019	Presentation, Antonio Rosato	1. – 6. October 2019, Dubrovnik, Croatia	570
8th VELUX Daylight Symposium	Presentation, Aicha Diakite-Kortlever	9. October 2019, Paris, France	
8th VELUX Daylight Symposium	Presentation, David Geisler-Moroder, Jan de Boer	9. October 2019, Paris, France	
Advanced Building Skins 2019	Presentation, David Geisler-Moroder	28. – 29. October 2019, Bern, Switzerland	
EELYS Lighting Researchers meeting, Stockholm, Sweden	Presentation, Harris Poirazis	5. December 2018	20
29th Quadrennial Session of the CIE	Presentation, Niko Gentile	16. – 20. June 2019, Washington D.C., USA	600
Professional Lighting Design Convention (PLDC) 2019	Presentation, Werner Osterhaus	24. – 26. October 2019, Rotterdam, The Netherlands	1800
ISES Solar World Congress 2019	Presentation, Jonas Manuel Gremmelspacher (on behalf of Niko Gentile and Werner Osterhaus)	2. – 4. November 2019, Santiago, Chile	50
ISES Solar World Congress 2019	Presentation, Jonas Manuel Gremmelspacher (on behalf of Rafael Campama Pizarro)	2. – 4. November 2019, Santiago, Chile	50
Environmental Psychology Scandinavian area meeting 2020	Presentation, Niko Gentile	8. November 2019	40
Workshop at Inter IKEA systems, Helsingborg, Sweden	Presentation, Rafael Campama Pizarro and Niko Gentile	19. November 2019	40
EELYS Lighting Researchers meeting, Gothenburg, Sweden	Presentation, Niko Gentile	2. December 2019	20
CIE Australia Lighting Research Conference 2020	Presentation, Veronica Garcia-Hansen	11. February 2020	30
24º Congresso de Iniciação Científica da Universidade de Brasília e 15º Congresso de Iniciação Científica do Distrito Federal (Scientific initiation Congress of University of Brasilia and Federal District)	Presentation, Elisa de Souza and Cláudia Naves David Amorim	August 2018	40

24º Congresso de Iniciação Científica da Universidade de Brasília e 15º do Distrito Federal	Presentation, Alessandra Zamboni and Cláudia Naves David Amorim	August 2018	40
25º Congresso de Iniciação Científica da Universidade de Brasília e 16º Congresso de Iniciação Científica do Distrito Federal	Presentation, Ana Clara Santos and Cláudia Naves David Amorim	August 2019	50
25º Congresso de Iniciação Científica da Universidade de Brasília e 16º do Distrito Federal	Presentation, Gabriela Baliza and Cláudia Naves David Amorim	August 2019	50
25º Congresso de Iniciação Científica da Universidade de Brasília e 16º do Distrito Federal	Presentation, Alexandre Guerra and Cláudia Naves David Amorim	August 2019	50
PLEA 2020	Myrta Gkaintatzi-Masouti	1. – 3. September 2020, A Coruna, Spain	
LICHT 2020	Myrta Gkaintatzi-Masouti	Unknown date, Bamberg	
Facade Tectonics 2020 World Congress. Los Angeles, United States	Luca Papaiz, Lars Oliver Grobe, Giuseppe De Michele	August 2020	
Architecture, Technology and Innovation 2020: Smart buildings, smart cities. Izmir, Turkey; 2020	Lars Oliver Grobe	August 2020	
www.bauinformation.com	David Geisler-Moroder	June 2020	100
IEA Solar Academy. Seminar on Task 61	Jan de Boer, Barbara Matusiak, Marc Fontoynont, David Geisler Moroder, Werner Osterhaus, Niko Gentile	24. – 25. September 2020	225
Light Symposium Wismar	Jan de Boer	March 2021, online	300
LICHT2021	David Geisler-Moroder, Wilfried Pohl	March 2021, online	
IEA SHC Seminar, National Day Netherlands	Presentation, Jan de Boer	8. June 2021, online	50
Brasilian Congress of Metrology	Niko Gentile	18. October 2021	
Velux Symposium	Natalia Giraldo Vasquez	16. November 2021	

Task Meetings

To develop the Task, the following Task Definition Workshops were held:

1. Stuttgart, Germany October 2016
2. Copenhagen, Denmark March 2017

Over the entire term of the Task a total of ten Experts Meetings were held and four included an additional workshop, symposium or other event.

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 1	February 28-March 2, 2018	Lund, Sweden	29 participants (18 countries)
Industry Workshop 1	February 28, 2018	Lund, Sweden	41 participants
Task Meeting 2	September 5-7, 2018	Lausanne/Switzerland	33 participants (14 countries)
Industry Workshop 2	September 5, 2018	Lausanne/Switzerland	35 participants
Task Meeting 3	March 28-19, 2019	Beijing/China	19 participants (17 countries)
Industry Workshop 3	March 27, 2019	Beijing/China	150 in person at CABR, 2,586 online
Task Meeting 4	September 16-18, 2019	Gdansk / Poland	30 participants (8 countries)
Industry Workshop 4	September 16, 2019	Gdansk / Poland	45 participants
Task Meeting 5	March 16-18, 2020	Virtual	53 participants
Task Meeting 6	September 23-25, 2020	Virtual	40 participants
Task Meeting 7	November 23-24, 2020	Virtual	45 participants
Task Meeting 8	March 18, 2021	Virtual	35 participants
Task Meeting 9	May 10-12, 2021	Virtual	40 participants
Task Meeting 10	October 4-5, 2021	Virtual	35 participants

SHC Task 61 Participants

Country	Name	Institution / Company	Role
GERMANY	**Jan de Boer**	**Fraunhofer Institute for Building Physics IBP**	**Task Manager**
AUSTRALIA	Veronica Garcia-Hansen	Queensland University of Technology	National Expert
AUSTRALIA	Kieu Pham	Queensland University of Technology	National Expert
AUSTRIA	David Geisler-Moroder	Bartenbach GmbH	Subtask C Leader
AUSTRIA	Robert Weitlaner	HELLA Sonnen- und Wetterschutztechnik GmbH	National Expert
BELGIUM	Ruben Delvaeye	Belgian Building Research Institute (BBRI)	National Expert
BELGIUM	Arnaud Deneyer	Belgian Building Research Institute (BBRI)	National Expert
BELGIUM	Bertrand Deroisy	Belgian Building Research Institute (BBRI)	National Expert
BELGIUM	Sergio Altomonte	Belgian Building Research Institute (BBRI)	National Expert
BELGIUM	Marshal Maskarenj	Université Catholique de Louvain	National Expert
BRAZIL	Prof. Cláudia Naves David Amorim	University of Brasilia	National Expert
BRAZIL	Ayana Dantas de Medeiros	University of Brasilia	National Expert
BRAZIL	Julia Rezende Kanno	University of Brasilia	National Expert
CANADA	John Alstan Jakubiec	University of Toronto	National Expert
CHINA	Tao Luo	China Academy of Building Research	National Expert
CHINA	Zhen Tian	Soochow University	National Expert
DENMARK	Marc Fontoynont	BUILD – Institut for Byggeri, By og Miljø	Subtask B Leader
DENMARK	Werner Osterhaus	Aarhus University	Subtask D Leader
DENMARK	Kathrine Gert Nielsen	Aarhus University	National Expert
DENMARK	Nikodem Derengowski	BUILD – Institut for Byggeri, By og Miljø	National Expert
DENMARK	Kasper Fromberg Støttrup	BUILD – Institut for	National Expert

		Byggeri, By og Miljø	
DENMARK	Anne Sophie Louise Stoffer	BUILD – Institut for Byggeri, By og Miljø	National Expert
DENMARK	Per Reinholdt	Dansk Center for Lys (Danish Lighting Center)	National Expert
DENMARK	Natalia Giraldo Vasquez	DTU Civil Engineering	National Expert
DENMARK	Mandana Sarey Khanie	Technical University of Denmark DTU	National Expert
DENMARK	Jens Christoffersen	VELUX A/S	National Expert
GERMANY	Dieter Polle	DIAL GmbH	National Expert
GERMANY	Daniel Witzel	DIAL GmbH	National Expert
GERMANY	Simon Wössner	Fraunhofer Institute for Building Physics IBP	National Expert
GERMANY	Daniel Neves Pimenta	Fraunhofer Institute for Building Physics IBP	National Expert
GERMANY	Bruno Bueno Unzeta	Fraunhofer Institute for Solar Energy Systems ISE	National Expert
GERMANY	Aicha Diakite-Kortlever	Technische Universität Berlin	National Expert
ITALY	Michele Zinzi	ENEA-DTE-SEN	National Expert
ITALY	Giovanni Ciampi	University of Campania	National Expert
ITALY	Michelangelo Scorpio	University of Campania	National Expert
ITALY	Prof. Sergio Sibilio	University of Campania	National Expert
JAPAN	Yasuko Koga	Kyushu University	National Expert
NETHERLANDS	Rajendra Dangol	Eindhoven University of Technology	National Expert
NETHERLANDS	Alexander P.L. Rosemann	Eindhoven University of Technology	National Expert
NETHERLANDS	Peter Fuhrmann	Signify Netherlands B.V.	National Expert
NORWAY	Barbara Szybinska Matusiak	Norwegian University of Science and Technology NTNU	Subtask A Leader
NORWAY	Biljana Obradovic	Norconsult AS	National Expert
NORWAY	Marzieh Nazari	Norwegian University of Science and Technology NTNU	National Expert
POLAND	Justyna Martyniuk-Pęczek	Gdansk University of	National Expert

		Technology	
POLAND	Natalia Sokół	Gdansk University of Technology	National Expert
POLAND	Marta Waczyńska	Gdansk University of Technology	National Expert
POLAND	Julia Kurek	Gdansk University of Technology	National Expert
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SWEDEN	Harris Poirazis	Inform Design AB	National Expert
SWEDEN	Thorbjörn Laike	Lund University	National Expert
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SWITZERLAND	Yujie Wu	École Polytechnique Fédérale de Lausanne (EPFL)	National Expert
SWITZERLAND	Bernard Paule	Estia SA	National Expert
SWITZERLAND	Jérôme H. Kaempf	Idiap Research Institute	National Expert
SWITZERLAND	Lars Oliver Grobe	Lucerne University of Applied Sciences and Arts	National Expert
SWITZERLAND	Julien Nembrini	Université de Fribourg	National Expert
USA	Eleanor S. Lee	Lawrence Berkeley National Laboratory	National Expert
USA	Gregory J. Ward	Anyhere Software	National Expert

6. Ongoing Tasks

Task 62 – Solar Energy in Industrial Water and Wastewater Management

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 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 wastewater treatment represents a new field of application with excellent 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 is divided into three 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)*

Scope

The scope of work covers all low-temperature solar radiation technologies supplying either thermal or photon primary energy for fluid separation and water treatment in regard to industrial applications and sewage plants, either in the context of municipal water treatment/purification or development cooperation.

Subtask A: Thermally Driven Water Separation Technologies and Recovery of Valuable Resources
The main objective of Subtask A is to foster the development and promotion of new energy-efficient solar-driven separation technologies for industrial wastewater and process fluid treatment via:

- Identification of separation technologies that show high potential for solar thermal heat supply (e.g., membrane distillation, pervaporation, vacuum evaporation, rectification, etc.).
- Identification of suitable fields of application (e.g., industrial sectors, production processes, geographical sites; synergistic use of solar and industrial excess heat, etc.).
- Assessment of advantages and disadvantages of these technologies for different industrial applications and the interaction with solar thermal technologies and other renewable energy technologies.
- Comparison (technical and economic) of these emerging technologies with state-of-the-art separation technologies (e.g., ultrafiltration, reverse osmosis, etc.).

Subtask B: Solar Water Decontamination and Disinfection Systems
The main objective of this subtask is the elaboration of emerging process technologies with increased efficiency which can render process technologies much more efficient due to the integration of solar radiation, as it also may affect the quality of the conversion process under study. The most prominent example is wastewater treatment. But also, many chemical processes could benefit from the direct use of solar radiation.

The definition of new solar collectors' concepts for reducing manufacture costs though maintaining high efficiency in the collection of UV photons for better performance of chemical oxidation reactions according to the specific operational requirements should be tackled in close collaboration with technology providers companies.

Specific objectives:

- To provide an in-depth analysis of the energy reduction potential associated with the application of solar based processes to the industrial water management system. (Electrical consumption associated with UV lamps will also be considered).
- To address research questions, such as fluid dynamics and reactor design, to optimize the purification results, as well energy consumption.
- To promote collaborative initiatives for assessment of technical and economic feasibility of specific water decontamination and disinfection problems.
- To identify treatment processes of other water-based streams (e.g., in the bio-based and agro-food industries) that could potentially benefit from direct solar/UV radiation.
- To initiate the development of new collector technologies.
- To promote tools and services in this area to accelerate market penetration.

Subtask C: System Integrations and Decision Support for End-User Needs

The main objective of subtask C is to develop a guideline for decision support, designed purposefully for end users/technology adopters, who wish to achieve a certain practical outcome. The work within this Subtask and the development of the guideline will build on the results of IEA SHC Task 49/IV where among others an integration guideline for solar heat into industrial processes was developed. The guideline of this Task will refer to water process solutions, with examples, that principally harness solar thermal energy. The end user may be an industry such as a manufacturer or foods producer or water utility operating a wastewater treatment plant. Solar thermal energy will be a key focus, but will also consider excess industrial heat where possible, due to its abundance and ability to minimize the use of more expensive solar collectors to improve technology cost viability. The practical outcomes of interest will be assessed in the project in consultation with industry experts, which could include needing to deal with matters such as removing contaminants from wastewater before environmental/sewer disposal or reuse. The proposed technologies may achieve this by contaminant destruction (e.g., organic mineralization), isolation/purification for potential sale as a valuable product or by reducing its volume to enable more convenient disposal. In keeping a narrow focus on solar driven technologies, acknowledgment of other technologies will be included respecting their benefits such as maturity and/or efficiency. Technologies investigated in more detail will be an important feature in the proposed guidelines produced in this subtask.

Where possible, the SHIP Database, which was also developed within Task 49/IV, will be utilized or potentially built on present working examples of processes that are using a solar driven process to meet a treatment need or produce a valuable product. A key feature of the work will be to connect the process need to a technology solution; for example, removal of carbon (biological oxygen demand) from wastewater using solar thermal reactor. Selection criteria can include options better suited to where the industry is located, such as in an urban region serviced by a sewer system that is charged for use by a utility which will have different treatment process requirements compared to one in a remote/isolated region where the environmental discharge occurs.

Aspects to be weighed up include technology maturity/readiness, range (e.g., types of solar thermal collectors), reliability or operation continuity (e.g., 24/7 for municipal water treatment or 5-day operation with peaking/variable flows/compositions). Companies providing technology solutions will be contacted to provide information on their products and working examples.

The output will be a publication (print and/or online database) containing a decision-making framework for selecting solar thermal technologies to achieve a desired outcome. The target audience includes industry (plant operators), consultants, governments/councils, and potentially farm operators or house owners. The aim is to show viable and innovative solutions to particular needs in treating wastewater or capturing valuable products.

Collaboration with Other Organizations

- SPIRE Association
- WSSTP – European Technology Platform for Water

Collaboration with Industry

Ammonia separation via Membrane Distillation

AEE INTEC has successfully operated a Membrane Distillation (MD) pilot plant (14 m^2) to remove ammonia and produce a fertilizer during a 24/7 operation at the municipal wastewater treatment plant of Gleisdorf (Austria). The results were produced jointly with the Austrian flagship project Thermaflex (https://thermaflex.greenenergylab.at/) and within the IEA IETS Task 17. SolarSpring, together with Fraunhofer ISE, University of Stuttgart, and

Abwasserzweckverband Breisgauer Bucht, successfully finalized a research project towards ammonia recovery from wastewater by Osmotic Membrane Distillation (OMD). The Project was funded by Deutsch Bundesstiftung Umwelt. A demonstration system was designed, constructed, and operated in a municipal wastewater treatment plant near Freiburg, Germany, and a full Life Cycle Assessment and economic evaluation were conducted. From the economic analysis carried out, it is evident that the OMD technology can also be economically sustainable if there is a corresponding demand for the ammonium sulfate product produced and corresponding prices can be achieved as a result. In reality, this will depend on the respective wastewater treatment plant for which the application is intended and the local supply and demand situation for fertilizers. It is expected that about 47 ct/kg ammonia sulfate would be necessary to fully cover the costs.

Task Duration

This Task started in October 2018 and will end in September 2022.

Participating Countries

Australia, Austria, Denmark, France, Germany, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom

Work During 2021

Subtask A: Thermally driven water separation technologies and recovery of valuable resources

Deliverable A1: Matrix of different industrial separation demands to be subjected to cutting edge thermal technologies versus availability of different low exergy heat sources

This deliverable elaborates on a matrix showing the potential for separation technologies (focus MD) driven by waste heat and/or solar thermal in different industrial sectors. In 2021, the work on the matrix designed to define the different criteria for the selection of technologies (focus MD) in context with the availability of low exergy heat sources was finalized. Exemplary industries considered in the matrix are shown in Table 1. The main purpose of the matrix is to investigate already existing waste stream treatment technologies, gaps, and potentials for new cutting-edge technologies in complex and diverse industrial processes. Synergies can be identified for similar processes but very different industrial sectors. For example, H2SO4 recovery is of interest for the pickling industry as well as in the mining industry. This will enable a technology transition between industries. With regard to the utilization of thermal waste energy to improve the energy footprint of a factory, the matrix will allow the identification of suitable thermal water treatment processes and their technical specifications. Reference technologies will be identified to compare them with new technologies, e.g., MD versus vacuum evaporator for brine concentration.

Table 1. Exemplary industries taken into account for the matrix

Sea / Brackish water desalination	Drinking water production
Electronic devices Production	Ultra Pure Water Production
Mining Industry	H_2SO_4 Concentration
	Gold Mining
	lithium recovery
Steal and Metal Industry	Galvanizing Industry, HCL Concentration
Food Industry	Juice concentration (orange, apple, general fruit
	Cheese manufacture waste treatment
	Concentration of Saline Dairy Effluent
Shale Gas Industry	Shale Gas
Biomass Industry	Anaerobic membrane bioreactor
Textile Industry	Washing water - dye
Pulp & Paper Industry	Bleaching water
Municipal waste water treatment	Ammonia Recovery
Semi Conductor Industry	PV Production
Plating Industry	printed circuit-board Industry
Food Waste Fermentation	Bioethanol

Based on the selected industries, the matrix was designed around the following criteria to review the integration possibilities for membrane distillation:

- Deployment criteria for new technologies like costs, legislation, environmental regulations, etc.
- Feasibility/effectiveness of recovery of valuable resources
- Waste heat availability in industry
- Solar thermal accessibility
- Fouling/wetting issues
- Competitiveness with other technologies
- Readiness level (laboratory, pilot, demonstration)

Deliverable A2: Definition of future R&D demand

This deliverable will identify the technological challenges, hurdles, and specifications of related R&D demand, including basic research, component development, system technology, and control strategy. In 2021, key components of MD systems and associated R&D activities (see Table 2) were elaborated on by the Task 62 experts. Since this collection procedure is a dynamic and ongoing activity, input will be collected and further developed in 2022.

The three major parts to be addressed through R&D are the membrane as a core component, the module design, and the general system design of the overall heating and cooling circuits, including control aspects. It is very clear that the development of MD technology must always be conducted for particular and specific applications and that the optimal membrane or the optimal module design depends very much on the particular operational conditions. For example, the heat recovery of a MD module may be highly important for a solar thermal energy supply in order to keep the investment cost for the solar system, which is typically the economic bottleneck, as low as possible. While in the industrial context, where an abundant amount of waste heat may be available, heat recovery is not important, but low-cost MD modules may be an attractive solution. Membrane fouling resistance and maintenance of hydrophobicity may be the dominating optimization criteria for applications in organic wastewater, while flux is the most important criteria for applications in pure salt solutions. The following table provides an overview of the different research topics associated with MD and actual work conducted. This table does not claim completeness because several research groups, mainly companies, do not disclose their actual research focus to protect their knowledge for competitive reasons.

Table 2. Overview on future R&D demand

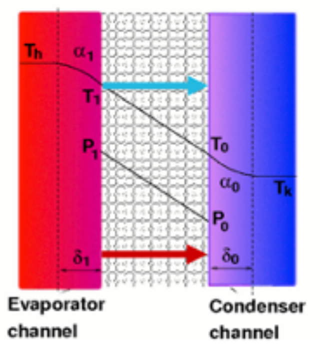
Topic	Key properties	R&D activities
Membranes and materials	▪ Long term Hydrophobicity ▪ Scaling and fouling	The maintenance of the long-term hydrophobicity of the membrane is in different aspects associated with scaling and fouling prevention since depositions on the membrane surface or depositions growing into the membrane pores lead to significant changes in the natural properties of the membrane. Current R&D activities, e.g., conducted by the University of Bremen, focus on investigating scale formations under artificial conditions in a MD lab cell for artificial seawater 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 the natural 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 conditions 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. On the one hand, the aim is 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 that are often made from PTFE, the limiting factor is often the support structure typically made from PP (polypropylene), or PE (polyethylene) is the limiting factor. Therefore, membrane research shall address the development of membranes with or without support that 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 mainly depend on pore geometries, while the change of pore diameter has opposing effects on the optimization. Therefore, 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 are an important factor for accelerating 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. Reducing temperature polarization through appropriated channel structures and spacer material will enable higher driving forces and more efficient processes. R&D is, e.g., addressing MD module design for tubular ceramic membranes where efficient internal heat recovery is not trivial. The application of vacuum to remove non-dissolved gasses is another feature for reducing specific thermal energy demand at low operating temperatures. Therefore, ceramic materials are of enormous interest since the design of vacuum-assisted modules is much simpler due to the mechanical strength of the material, but also intelligently designed MD modules with polymer membranes need to be developed in the future to withstand higher vacuum pressures.
	▪ Cleaning, scaling & fouling protection, maintenance	In addition to advancements in membrane design, 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	In a circular economy where water and material recovery will be an important application for MD in the future, the MD modules and systems also need to be considered part of a circular economy. Therefore, the reuse of MD components or their raw material must be part of the design thinking process. The most critical part today is 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 setups. 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 the industrial environment is quite individual. Nevertheless, heating and cooling devices must be investigated and developed, e.g., the integration of heat pumps. Renewable energy supply for industrial processes such 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 and optimized with respect to the best exegetic exploitation efficiencies.
	▪ System control	Digitalization provides vast potential for optimizing water treatment processes and overall system efficiency increases. For example, digital twins could be applied for heat management of industrial sides with different suppliers and users. Besides efficiency optimization, a digital controller could indicate maintenance intervals based on actual and real-time operation parameters for the MD process.
	▪ 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.

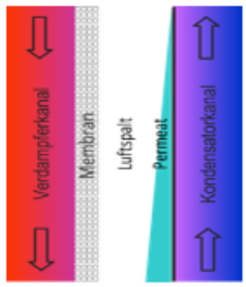
Deliverable A3: Specification of System design and key performance indicators as basis for comparative studies

Different MD module designs exist, which mainly consider the shape of the membrane (flat sheet or hollow fiber), die Module configuration (flat sheet spiral wound or flat sheet plate and frame), and the internal channel configuration, which mainly consider the internal heat recovery function. Direct Contact (DC) MD is the simplest configuration where the hydrophobic membrane separates the Feed channel from the distillate channel, which is the condenser channel at the same time. The distillate is cooled outside the module and acts as a coolant and carrier for the new distillate at the same time. In Permeate Gap (PG) and Air Gap (AG) configurations, in addition to the membrane, there is also a non-permeable foil embedded, which forms a separated condenser channel that can be operated with salty feed water as coolant. The distillate is collected in a channel between the membrane and the foil. While in PGMD, this channel is filled with liquid distillate, in AGMD, this channel is filled with air and liquid water is only formed on the surface of the condenser foil. The air gap provides high thermal isolation and reduces the sensible heat losses between the evaporator and condenser channel but induces an additional diffusion resistance for the water vapor passing the membrane. As preparation for the comparative studies, a questionnaire was created and distributed among research groups and industry to learn which MD configurations for which applications and which simulation tools exist and dominate. The most relevant MD configurations are the Direct Contact (DCMD) and the Air Gap (AGMD) configuration. Therefore, it was decided to focus the first simulation contest on these configurations.

Direct Contact MD



Air Gap MD



The following table shows the geometrical and physical specifications set for the parameterization of the MD module models. We consider three different module sizes where *Module 1* represents a typical test cell dimension and *Modules 2* and *3* represent real scale modules with moderate and intensive internal heat recovery functions. The three different module dimensions will be investigated as DCMD and AGMD configuration, each with the different indicated variations of membrane geometries and operation conditions.

Table 3. Simulation parameter defined

Channel geometry variation DCMD / AGMD	Module 1	Module 2	Module 3
Feed / Permeate Channel length	**0,25m**	**5m**	**10m**
Feed / Permeate channel hight	**0,15m**	**0.5m**	**0,5m**
Feed / Permeate Channel thickness	2mm	2mm	2mm
Nusselt number	6	6	6
Channel with for AGMD	1mm	1mm	1mm

Membrane parameter variation DCMD / AGMD	PTFE	PTFE	PTFE
Membrane thickness	50 µm	50 µm	50 µm
Nominal Membrane pore diameter	**0,1µm**	**0,2µm**	**0,4µm**
Membrane porosity	80%	80%	80%
Support type	scrim	scrim	scrim
Support thickness	200 µm	200 µm	200 µm
Support porosity	70%	70%	70%
Support orientation	Facing condenser	Facing condenser	Facing condenser

Condenser sheet AGMD only	Polymer	Polymer	Polymer
Foil thickness	150 µm	150 µm	150 µm
Heat conductivity λ	0.24W/mK	0.24W/mK	0.24W/mK

The following tables define the feed water compositions and the operating conditions in terms of salinities, mass flows, and temperatures.

Operation conditions salinity	Composition 1	Composition 2	Composition 3
Feed water	Pure Water **0 g/kg**	Water-NaCl **35g/kg**	Water-NaCl **210g/kg**
Permeate	Pure Water 0 g/kg	Pure Water 0 g/kg	Pure Water 0 g/kg

Operation conditions mass flow	Mass flow 1	Mass flow 1	Mass flow 1
Mass flow inlet feed	**200 kg/h**	**400 kg/h**	**600 kg/h**
Mass flow inlet Condenser	**200 kg/h**	**400 kg/h**	**600 kg/h**

Operation conditions temperature	Temperature Set 1	Temperature Set 2	Temperature Set 3
Evaporator inlet	**40°C**	**60°C**	**80°C**
Condenser inlet	20°C	20°C	20°C

The key performance indicators (KPIs), which need to be calculated for model comparison, are shown in the following table. A matrix will be prepared to report the results that consider the different module configurations, material characteristics, and operation conditions. In total, 486 simulation results are expected.

Table 4. KPIs for result comparison

Key Performance indicators
Flux [kg/m² h]
Temperature condenser out [°C]
Temperature evaporator out [°C]
Thermal efficiency [%]
Calculated specific thermal energy demand [kWh_{th}/m^3]
Estimated electrical energy demand [kWh_{el}/m^3]

Based on the defined simulation parameter, the simulation calculations will be initiated in early 2022. The questionnaire results show that very different simulation tools and platforms are used, which are typically designed according to the particular interest of the research groups. Some tools are more designed to investigate module configurations in an entire system context (e.g., Fraunhofer ISE), while others are more designed for scaling and fouling studies (e.g., KIT and Uni Bremen). The complexity of different model approaches is very different, starting from simple excel tools via semiempirical models to fully physical equation-based models with a high degree of parameter variability.

Subtask B: Solar Water Decontamination and Disinfection Systems

Deliverable B1: Report on solar-based technologies applied to industrial water decontamination and disinfection (real and research cases). Potential applications on industrial new sectors

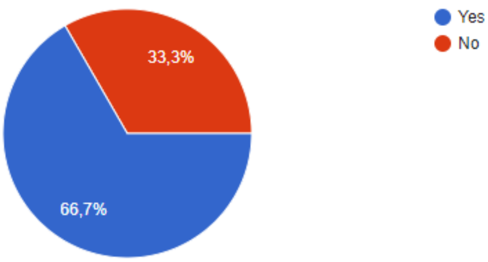
Deliverable B1 includes existing solar-based technologies for industrial wastewater recovery initiatives, mainly in the food and beverages industries. It is important to take into account that details on technology development and performance have been almost impossible to obtain from their own industries. Therefore, the core of information was obtained from the companies' websites. Nevertheless, the picture of near-future objectives and challenges adopted by many industries to reduce their water footprint is equally important.

Deliverable B4: Technological, economic, and political barriers for up-scaling new decontamination and disinfection systems for industrial water and wastewater management and reuse

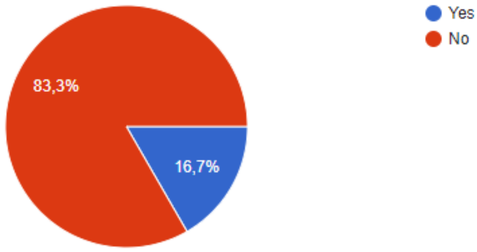
In 2021, the Subtask B team conducted an internal survey to ask the Subtask participants about their experiences, specifically on barriers they consider or have faced with technologies going to market. The possibility of applying technologies to achieve required water quality for specific reusing purposes within their own industrial process is a key focus and considered for this study. The survey was combined with an interactive Task workshop.

Table 5. Overview of survey results

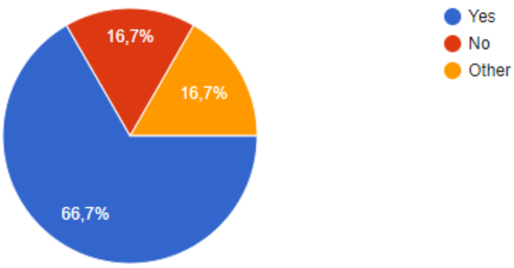
Is your company/institution following any strategy on raw materials (water) sustainability?



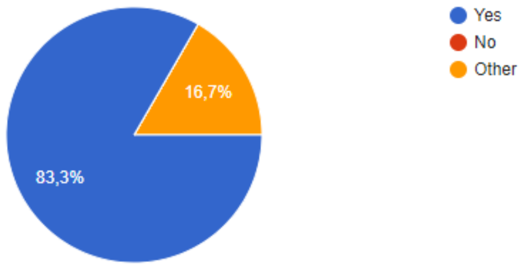
Is there any wastewater treatment technology implemented in your company/institution? If Yes, Which technology?



Do you consider feasible the application of renewable energies in your industrial process and/or wastewater treatment process?



In your country, does the government invest and/or promote renewable energies?



Could you please identify at least two economic barriers for market implementation of new/integrated advanced treatment technologies for industrial wastewater reuse?

Could you please identify at least two political barriers for market implementation of new/integrated advanced treatment technologies for industrial wastewater reuse?

The results show that expert's opinion on **technological barriers** for the market implementation of new/integrated technologies in the treatment of industrial wastewater clearly states cost-related issues as the main barrier. Traditionally advanced oxidation technologies for the remediation of specifically persistent industrial wastewater are characterized for their elevated costs. Such treatments include ozonation, high doses of UV, electrocatalysis, wet oxidation, reverse osmosis, etc. The main **economic barrier** identified by IEA SHC Task 62 experts for implementing new technologies for industrial wastewater treatment is based on the investment. Independently from public investment instruments already available, not only at European or national levels, there is a strong and important lack of investment of the private sector in the development and implementation of such new and/or integrated technologies. Political and legal aspects must always be considered in the introduction of new technologies into a specific market. In the case of industrial wastewater treatment, experts have established the most important **political barriers** in the "conflict of interest" and "legislation." It is clear that new regulations and legislation focused on forcing more stringent water quality parameters, not only before discharging to the sewerage but even more when wastewater recycling is used for activities such as crop irrigation or even in some industrial processes, are necessary. In addition, in the specific case of industrial wastewater, there is always a part related to the conflict of interests that could arise when implementing a sustainable circular economy vision. Nevertheless, it must be considered that time by time, industry is more conscious and focused on trying to reduce its water footprint.

Deliverable B4 will be finished and submitted by December 2021 and contains not only the expert members considerations related to technological, economic, and political barriers that must be overcome nowadays for the implementation of water and wastewater decontamination and disinfection technologies in industry but also a deep assessment of the key bibliography dealing with these issues are being carried out and further discussed.

Subtask C: System integrations and decision support for end user needs

Deliverable C2: Report on how water-energy nexus concept is actually being applied in the industry

Deliverable C2, the first draft has received preliminary feedback. This draft includes examples of industry-led solar water treatment system applications. However, the review identified the importance of including an overview of water treatment technologies and the potential to integrate them with solar in the report. Examples of where industry has adopted solar water treatment and the purpose of the selection were identified.

The three identified industry-led cases were evaluated based on the drivers that led to their implementation and included:

1. Lack of availability of fresh water and abundance of an impaired water source.
2. Direct demonstration of value from system output (including the water itself, agricultural output).
3. Fit for purpose technology complexity.
4. Assurance/control of the quantity and quality of the water supplied.
5. For large-scale systems, heat supply was also required.
6. Best technology option where solar availability is the first factor while other selection factors include relative simplicity and scalability.

The need for more cases identified during the report review process led to the proposal of another six examples, which are currently being evaluated for inclusion in the report.

Deliverable C3: Report on draft version of guidelines/decision-making tool
Work has commenced on Deliverable C3, and feedback from the 7th Expert meeting was useful in understanding the arrangement of the decision support tool being developed at AEE INTEC. Within this work, a workshop was held during the last Expert meeting regarding the status quo on decision-making tools (solar thermal, water treatment), boundary conditions needed for the decision-making process and the tool, input parameters, and output parameters and KPIs needed.

With the recruitment of two interns to assist with Subtask C, the focus can now be on developing a structure and draft of the guidelines report. Again, using IEA SHC Task 49 as an example, the proposed headings consist of:

1. Water treatment in industry (typical plants, water qualities, location, regulations) – extending from the end user's starting point mentioned in the previous update.
2. Assessment methodology for solar integration (building on Task 49).
3. Opportunities for solar water treatment projects (location for treatment opportunity).
4. Classification of solar water treatment concepts (e.g., oxidation, disinfection, desalination).
5. Solar water treatment process concepts (solar utilization and treatment process).
6. Solar water treatment examples.

Inputs to the guidelines framework will include the outcomes of the November 2020 industry workshop. The 37 delegates from the water industry, academia, and technology suppliers came up with the following important points to consider when adopting a solar technology for water treatment and will be included in the report:

- Business cases are essential.
- The role of regulations is important.
- Cost and reliability are important selection criteria. Others include resource recovery, emissions reduction, and community benefits.
- Risks and responsibilities, financing, skills, etc., need to be shared.

Work Planned For 2022

Subtask A: Thermally Driven Water Separation Technologies And Recovery Of Valuable Resources

The main activities planned for Subtask A in 2022 are:

- Deliverable A2: Definition of future R&D demand; Status: finalize Deliverable with inputs from IEA SHC Task 62 Experts
- Deliverable A4: Summary of results from comparative simulation calculation; Status: initiate the simulation studies among institutes and companies; a kick-off workshop and working meeting are planned to run the simulations and guarantee a good exchange.

Subtask B: Solar Water Decontamination and Disinfection Systems

The main activities planned for Subtask B in 2022 are:

- Deliverable B2: Report on existing solar-based technologies applied to industrial water decontamination and disinfection (real and research cases). Potential applications on industrial new sectors. Status: submitted and reviewed. An update of this deliverable will be published considering the information included in deliverable B3.
- Deliverable B3: Roadmap for technology implementation for defined applications and industries. Status: the first draft will be elaborated as soon as information from deliverable C2 is available.
- Deliverable B4: Technological, economic, and political barriers for up-scaling new decontamination and disinfection systems for industrial water and wastewater management and reuse. Status: First complete draft will be submitted for review at the end of December 2021.
- Deliverable B5: Report on legal thresholds for accomplishing water quality required depending on the final application. Status: structure and required bibliography already stated for this deliverable. New European regulation for water reuse will be deeply included and analyzed. A deep revision of national regulations will also be covered.
- Deliverable B6: Marketplace/Fair. Status: structure defined.

Subtask C: System Integration and Decision Support for End User Needs

The main activities planned for Subtask C in 2022 are:

- Deliverable C2: Report on how the water-energy nexus concept is being applied in industry. Status: the first draft is completed, expected completion end of January 2022.
- Deliverable C3: Report on draft version of guidelines/decision-making tool. Status: Structure will be ready for review end of January 2022 and draft report ready end of March 2022.

Dissemination Activities In 2021

Reports, Published Books

Author / Editor	Title	Bibliographic Reference
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)	Title	Publication / Conference	Bibliographic Reference
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 Desalination: Current Status and New Developments. Editor Y. Cohen, World Scientific Publishing Company:	In press

	Water Filtration		
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. Dow, D. Desai, D. Pinches, C. Brunner and M. Duke	Membrane distillation for concentration of protein-rich wastewater from meat processing.	Journal of Water Process Engineering	44: 102285
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

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
Conference: Holistic approaches for water and resource efficiency in process industry	Energy Footprint of Water Treatment	March 25-26	~70
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 Naples, Italy	

PHOTOPUR (FEDER EC funded project) Online Symposium	Water-Energy-Food nexus in industrial and urban wastewater recovery (Keynote)	December 9-10	
ODAKTR Seminar Series (SOLARTWINS H2020 project)	Water-Energy-Food nexus in industrial and urban wastewater recovery (Keynote)	February 26	
SECAT 2021	Poster presentation	October 18-21 Valencia, Spain	>200
Asia Pacific Solar Research Conference	Oral presentation by Prof. Mikel Duke	December 16-17 UNSW and online	

Dissemination Activities Planned For 2022

32nd Symposium Solarthermie und Innovative Wärmesysteme 2022, May 2022.

ISEC 2022 abstract submission by Mikel Duke "Industrial water treatment technologies driven by renewable or waste energy sources." Planned talk on Task 62, Subtask C work.

Industry workshop sponsored by APVI and ARENA in Melbourne, Australia. Tentatively August 2022.

Active participation in EuroSun 2022, September 25-29, Kassel, Germany.

Poster and oral communications, 39th IAHR (International Association for Hydro-Environment. Engineering and Research) World Congress, June 19-24, 2022, Granda, Spain.

Poster and oral communications, 12th Micropol & Ecohazard Conference in Santiago de Compostela, Spain.

Keynote, poster, and oral communications, 11th European Conference on Solar Chemistry and Photocatalysis: Environmental Applications, June 6-10, 2022, Torino, Italy.

Task Meetings in 2021 and Planned for 2022

Meeting	Date	Location	# of Participants (# of Countries)
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	April 5, 2022	Graz, Austria	

SHC 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	Xiwang Zhang	Monash University	National Expert
AUSTRALIA	Yunchul Woo	University of Technology Sidney	National Expert
AUSTRALIA	Gabriele Sartori	APEC Project EWG 13 2017A; Future Carbon Australia; 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
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ITALY	Luigi Rizzo	University of Salerno	National Expert

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Task 63 – Solar Neighborhood Planning

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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 will require 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 learnt 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 *(Lead Country: Italy)*

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 *(Lead Country: Sweden and France)*

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 *(Lead Country: joint by subtask A-C leaders and OA)*

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

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

Work During 2021

Subtask A: Solar Planning Strategies and Concepts

The first activity was defining design options and analyzing solar neighborhoods in participating countries to identify key influencing factors in reaching NZE or low carbon neighborhoods. A matrix was used to collect information about typical neighborhoods from different countries. The main criteria were extracted and are used to develop neighborhood archetypes for simulations and analysis of solar planning strategies and concepts for neighborhoods.

The first report (D.A1), "Incorporation of Solar Design Strategies in Neighborhoods' Planning: Review of existing and new practices," was finalized. It is an internal Task report. The material will be used in the continued studies, publications, and final presentations. Six participating countries contributed to this report, Canada, Denmark, Italy, Norway, Sweden, and Switzerland.

The first of two planned Ph.D. courses ("Fall Schools") was held during September-October 2021 to study developed neighborhood archetypes. This first Fall School was virtual due to the pandemic and enrolled 14 students from different countries and institutions, and nine instructors (mostly from the Task) were involved. The goal of the course was to enhance the knowledge of Ph.D. and advanced master students in simulating and analyzing the performance of neighborhoods. Such knowledge can facilitate the design and implementation of solar strategies in urban areas. In fact, neighborhood simulation aimed at optimizing energy efficiency and solar access and understanding the impact of various technologies is becoming increasingly significant to develop sustainable and resilient cities. However, the process of simulating urban areas is challenging and involves several degrees of complexity.

Further, a template was developed to collect information about solar strategies, their implementation, and main results. The template recommends using information collected in the matrix (developed previously) to give background about the case studies. In addition, the template includes a section to describe the archetype, information about different solar strategies and concepts that experts will analyze, and the methods that will be implemented in the analysis of solar strategies (e.g., simulations employing various simulation tools). The criteria of performance are also highlighted in the template (e.g., solar potential, energy consumption, etc.), and the main results of the strategies and recommendations on their implementation and benefits. 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 designing new and existing high energy performance solar communities.

Subtask B: Economic Strategies and Stakeholder Engagement

The main work focused on the first report (D.B1): Surface uses in solar neighborhoods. 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), and how to define the suitable uses for urban surfaces (methodologies and tools). The final report is scheduled for February 2022.

A method to define urban surface uses is presently in development and will be tested in 2022.

Work is also ongoing on identifying potential co-benefits related to the hybrid or/and integrated use of urban surface, apart from the solar energy production. An analysis of literature and selected case studies of innovative financial models and trends continued until the end of 2021. In addition, a survey on multiple benefits was developed to identify which stakeholders contribute the most to unlock and achieve multiple benefits. The survey targets four main stakeholder groups: Academy/Research, Business/Industry, Public Bodies/Governance, and Citizens/Users.

Another objective is to recommend suitable activities for stakeholder engagement and "nudging" strategies and to integrate the lessons learned in the urban planning practice. A literature review of stakeholder engagement and citizen involvement in solar neighborhoods was finalized. The definition of a framework was proposed to integrate the traditional stakeholder analysis and engagement approaches with behavioral economics. This will take the form of discussions and presentations in planned workshops that will be organized during 2022 and 2023.

Subtask C: Solar Planning Tools

Work has mainly focused on the first report (D.C1): Identification of existing tools and workflows for solar neighborhood planning. This report, which has been drafted, includes an overview of tools based on a literature review, common national indicators, workflow stories, and a benchmark study. The final additions will be made by the participating countries by the end of 2021.

The common indicators demonstrate a wide range of different metrics used for active and passive solar energy. The workflow stories are a way to obtain data and knowledge from external actors like companies regarding the use of tools for solar neighborhood planning. A benchmark study is carried out to compare the solar irradiation modeling of a neighborhood using different software. This study mainly focuses on the modeling of irradiation on façades. This report will be finalized in 2022.

The planning of the second deliverable started (D.C2): Roadmap for improved workflows and development needs of solar planning tools. One early proposal was to describe 1) state-of-the-art of workflows, 2) visions, and 3) milestones. A Subtask C workshop is planned early in 2022 to brainstorm the roadmap development.

Subtask D: Case Studies

The main work in Subtask D during 2021 has been on developing and finalizing the template to describe the Task 63 case studies in relation to the topics of each Subtask A/B/C. The case studies could be for new development areas or existing areas requiring refurbishments, infills, etc. The template will ensure that we work on and get all the information needed. The final template has started to be used to describe the first case studies.

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. Selected case studies will be presented according to the developed template and published on the SHC website. Approximately 24 cases are so far to be documented and studied.

The planned public seminars and workshops in conjunction with Task meetings have so far been postponed due to the pandemic. The first one is now scheduled for 2022.

Work Planned For 2022

Subtask A: Solar planning strategies and concepts

The main activities for Subtask A planned in 2022 are:

- Simulation and analysis of the defined archetypes.
- Plan and carry out the second "fall school" for advanced Ph.D. students and master students in Calgary, Canada. In conjunction with the Task 63 meeting in September/October 2022.
- First draft of the report (D.A2) on neighborhood archetypes: design and analysis, until the end of 2022.
- 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 2022 are:

- Finalize, apply, and test the method for urban surface uses on archetypes (link to Subtask A).
- Finalize the report (D.B1) on surface uses of neighborhoods, focused on how to define most suitable uses, prevent conflicts, and create synergies.
- Develop a framework to assess multiple benefits of hybrid and integrated strategies for urban surface usage.
- Prepare first draft of the report (D.B2) on economic incentives and business models, including added values, to promote the diffusion of solar neighborhoods (end of 2022).
- Develop a framework for stakeholder engagement.
- Test framework for stakeholder engagement in case studies.

Subtask C: Solar planning tools

The main activities planned for Subtask C in 2022 are:

- Finalize the report (D.C1) on the identification of existing tools and workflows for solar neighborhood planning.
- Finalize the identification of how to improve workflows and identify missing parts in workflows.
- Prepare first draft on a roadmap for improved workflows and development needs of solar planning tools.

Subtask D: Case studies

The main activities planned for Subtask D in 2022 are:

- Identify (if any) missing case studies needed for the work in Subtask A, B, and C.
- Prepare first drafts of all (so far identified) case studies, described using the case study template.
- Prepare final case study/studies online (may be delayed due to the pandemic).
- Hold public seminar in conjunction with the Task 63 meeting in March in Trondheim, Norway.

Dissemination Activities In 2021

Reports, Published Books

Author / Editor	Title	Bibliographic Reference
Benjamin Govehovitch	Implémentation d'une méthodologie intégrée de l'évaluation du potentiel photovoltaïque à l'échelle de la ville – Cas des façades verticals (Implementation of an integrated methodology assessing photovoltaic potential at the city scale - Cases of vertical facades)	Ph.D. thesis, University Claude Bernard Lyon 1 (2021)
Silvia Croce	Urban surface use optimization for energy production, energy efficiency, and microclimate management	Ph.D. thesis, University of Padova / Eurac (2021)
Editors: Caroline Hachem - Vermette, Kuljeet Singh, Rafael Compama Pizzaro, Maria Wall	Incorporation of Solar Design Strategies in Neighbourhoods' Planning. Review of existing and new practices	Restricted document (D.A1), only internal for Task 63 participants (2021).

Journal Articles, Conference Papers, etc.

Author(s) / Editor	Title	Publication / Conference	Bibliographic Reference
D'Alpaos C., Bragolusi P.	The Market Price Premium for Residential PV Plants	New Metropolitan Perspectives. NMP 2020. Smart Innovation, Systems and Technologies	2021, vol. 178, pp. 1208-1216. Bevilacqua C., Calabrò F., Della Spina L. (eds). Springer, Cham
Epp, B.	Surface synergies and conflicts in smart cities	News article written by Bärbel Epp based on material from Silvia Croce, Eurac Research	Dec 2020. https://task63.iea-shc.org/article?NewsID=341
Epp, B.	Workflow stories describe use of solar neighborhood planning tools	News article written by Bärbel Epp based on material from Jouri Kanters, Lund University and Martin Thebault, the University Savoie Mont-	July 2021. https://task63.iea-shc.org/article?NewsID=367

		Blanc – INES	
Epp, B.	Tackling the complexity of urban-level energy simulations	News article written by Bärbel Epp based on material from Caroline Hachem-Vermette, University of Calgary	Nov.2021. https://task63.iea-shc.org/article?NewsID=377
De Luca, F., Naboni, E., Lobaccaro, G.	Tall buildings cluster form rationalization in a Nordic climate by factoring in indoor-outdoor comfort and energy	Energy and Buildings	Volume 238, 2021, 110831, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2021.110831
D'Alpaos C., Andreolli F.	Renewable Energy Communities: The Challenge for New Policy and Regulatory Frameworks Design	New Metropolitan Perspectives. NMP 2020. Smart Innovation, Systems and Technologies	2021, vol. 178, pp. 500-509. Bevilacqua C., Calabrò F., Della Spina L. (eds). Springer, Cham
D'Alpaos C.	Do policy incentives to buildings energy retrofit encourage homeowners' free-rider behavior?	Appraisal and Valuation - Green Energy and Technology	2021, pp. 105-116 Morano P., Oppio A., Rosato P., Sdino L., Tajani F. (eds). Springer, Cham.
Thebault, M., Gaillard, L.	Optimization of the integration of photovoltaic systems on buildings for self-consumption–Case study in France	City and Environment Interactions	2021
Rezaei, A., Samadzadegan, B., Rasoulian, H., Ranjbar, S., Samareh Abolhassani, S., Sanei, A., & Eicker, U.	A New Modeling Approach for Low-Carbon District Energy System Planning	Energies	2021, 14(5), 1383.
Bambara, J., Athienitis, A.K., Eicker, U.	Residential Densification for Positive Energy Districts	Front. Sustain. Cities	2021, 3, 3. https://doi.org/10.3389/frsc.2021.630973
Hasan, J., and Fung, AS.	Building Integrated Photovoltaic/Thermal (BIPV/T) Air Based System and its Potential Application in Canada	Published in eSim2021, June 15th – 16th, Vancouver, Canada.	Link to conference proceedings: https://www.conftool.com/esim2020/index.php?page=browseSessions&presentations=show&search=hasan
Brozovsky, J.; Corio, S.; Gaitani, N.; Gustavsen, A.	Evaluation of Sustainable Strategies and Design Solutions at High-Latitude Urban Settlements to Enhance Outdoor Thermal Comfort	Energy and Buildings	244 (12), 2021, 111037, DOI: 10.1016/j.enbuild.2021.111037
Hasan, J., Horvat M. Riddell, C., Wang, R.	The impact of roof morphology on solar potential: making Toronto suburbs solar ready	CISBAT 2021, Sept 8th – 10th, Lausanne, Switzerland.	Conference proceedings are not yet available.

Kanters, J., Gentile, N. & Bernardo, R.	Planning for solar access in Sweden: routines, metrics, and tools	Urban, Planning and Transport Research	https://www.tandfonline.com/doi/full/10.1080/21650020.2021.1944293
Czachura, A., Wall, M., Kanters, J., Gentile, N.	Climate Representativeness of Simulation Weather Files	SWC 2021	Proceedings not yet available
Formolli, M., Kleiven, T., Lobaccaro, G.	Solar accessibility at neighborhood scale: an analysis to assess the impact of densification in nordic built environment	Solar World Congress (SWC) 2021	Proceedings not yet available
Brozovsky, J.; Simonsen, A.; Gaitani, N.	Validation of a CFD model for the evaluation of urban microclimate at high latitudes: A case study in Trondheim, Norway	Building and Environment	205, 2021, 108175, DOI: 10.1016/j.buildenv.2021.108175
De Luca, F., Naboni, E., Lobaccaro, G.	Tall buildings cluster form rationalization in a Nordic climate by factoring in indoor-outdoor comfort and energy,	Energy and Buildings	Volume 238, 2021, 110831, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2021.110831
Bertolazzi, A. (Corresponding), Foutsitzoglou, A., D'Agnolo, E., Croatto, G., Paparella, R., Turrini, U.	Methodological features and guidelines for the refurbishment of Mediterranean hotels. The case study of Halkidiki peninsula.	Sustainable Mediterranean Construction, ISSN: 2420-8213	Naples: Luciano, Editor
Croce, S. (Corresponding), D'Agnolo, E., Caini, M., Paparella, R.	The use of cool pavements for the regeneration of industrial districts.	Sustainability, ISSN: 2071-1050	2021, 13, 6322, Editor MDPI AG; http://dx.doi.org/10.3390/su13116322
Hasan, J., Fung, A. and Horvat, M.	A Comparative Evaluation on the Case for the Implementation of Building Integrated Photovoltaic/Thermal (BIPV/T) Air Based Systems on a Typical Mid-rise Commercial Building in Canadian Cities	Journal of Building Engineering	Available online as of Sept. 2021 at https://doi.org/10.1016/j.jobe.2021.103325
Thebault, M., Gaillard, L.	Optimization of the integration of photovoltaic systems on buildings for self-consumption - Case study in France	City and Environment Interactions	2021
Govehovitch, B., Thebault, M., Bouty, K., Giroux-Julien, S., Peyrol, E., Guillot, V., Ménézo, C., Desthieux, G.	Numerical Validation of the Radiative Model for the Solar Cadaster Developed for Greater Geneva	Applied Science	2021
Bambara, J., Athienitis, A.K., Eicker, U.	Residential Densification for Positive Energy Districts	Front. Sustain. Cities	2021, 3, 3. https://doi.org/10.3389/frsc.2021.630973

Rezaei, A., Samadzadegan, B., Rasoulian, H., Ranjbar, S., Samareh Abolhassani, S., Sanei, A., & Eicker, U.	A New Modeling Approach for Low-Carbon District Energy System Planning	Energies	2021, 14(5), 1383.
Samadzadegan, B., Samareh Abolhassani, S., Dabirian, S., Ranjbar, S., Rasoulian, H., Sanei, A., & Eicker, U.	Novel Energy System Design Workflow for Zero-Carbon Energy District Development.	Frontiers in Sustainable Cities	2021, 3.

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
Webinar Large PV plants in the open land. Challenges for energy planning, policy and legislation, municipalities, and neighborhoods	Organizing the event in cooperation with Arkitektforeningen, and Danske Landskabsarkitekter	March 8	288 virtual
SOLAR ENERGY Webinar- Building integrated PV (Organized by SINTEF)	Oral presentation "Solar Energy in Urban Environment: Opportunities, Challenges and Barriers" by Gabriele Lobaccaro NTNU, Norway	February 23 (Webinar) https://www.sintef.no/en/events/archive/2021/solar-energy-webinar-building-integrated-pv/	120
Guest lecture at Xi'an Jiaotong-Liverpool University in Suzhou, China	Oral presentation entitled "Solar Energy in Urban Environment: Opportunities, Challenges and Barriers" by Gabriele Lobaccaro NTNU, Norway	September 13	12 virtual
JNES 2021	Oral presentation "Benchmark study of simulation tools to model the solar irradiation on building facades) by M. Thebault, France	August 25-27 Odeillo, France	100
Building Simulation 2021	Oral presentation "Large-scale multicriteria sorting for the integration of photovoltaic systems in the urban environment" by C. Ménézo, France	September 8-10 Bruges, France	thousands

Dissemination Activities Planned For 2022

Due to the pandemic, seminars, and workshops in conjunction with Task meetings will be determined on a case-by-case basis.

Task Meetings in 2021 and Planned for 2022

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 4	March 22-25, 2021	Virtual	44 registrations (9 countries + 1 sponsor)
Task Meeting 5	September 20-23, 2021	Virtual	35 registrations (9countries)
1st Fall School	September 30 - October 2, 2021	Virtual	14 Task 63 Ph.D. students + other students. Canada, Sweden, Norway, France, Italy
Task Meeting 6	March 28-31, 2022	Trondheim, Norway	
Public seminar	In conjunction with 6th Task meeting	Trondheim, Norway	
Task Meeting 7	September/October 2022	Calgary, Canada	
2nd Fall School	September/October 2022	Calgary, Canada	

SHC Task 63 Participants

Country	Name	Institution / Company	Role
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CANADA	Ricardo D'Almeida	University of Calgary	National Expert
CANADA	Kuljeet Sing Grewal	University of Calgary	National Expert
CANADA	Olivia Alarcon Herrera	University of Calgary	National Expert
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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
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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	National Expert

		Settlements, CAG	
CHINA	Xiaotong Zhang	China National Engineering Research Center for Human Settlements, CAG	National Expert
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CHINA	Xiangfeng Liu	Tianjin University	Observer/ expert
CHINA	Yang Wang	China Agricultural University in Beijing	National Expert
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ITALY	Andrea Giovanni Mainini	Politecnico Milano	Observer
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NORWAY	Herman Andersen	Erichsen & Horgen	National Expert
NORWAY	Joar Tjetland	Erichsen & Horgen	National Expert
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SWEDEN	Nicholas Baker	White Arkitekter AB	National Expert
SWEDEN	Caroline Cederström	White Arkitekter AB	National Expert
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SWITZERLAND	Raphael Compagnon	Haute école of Fribourg (HEIA-FR)	Observer/ expert
SWITZERLAND	Jérôme Kämpf	Idiap Research Institute	Observer/ expert

Task 64 – Solar Process Heat

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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 level and supply level 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 throughout the world 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 D: 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 final energy and greenhouse gas emission savings 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 uncertainties sources, taking into consideration

economic, social and environmental issues. In addition, Subtask C will devote significant efforts to assessing monitoring strategies that allow improving the performance of actual systems.

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 aims at drafting the guidelines of a market approach more prone to be successful 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 2021.

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 2021

Subtask A: Integrated energy systems

The analysis of daily heat load profiles for reference applications was completed. Four clusters with different ambient temperature dependencies were defined and incorporated into an Excel tool that allows the practical creation of typical load profiles (available at https://task64.iea-shc.org/publications).

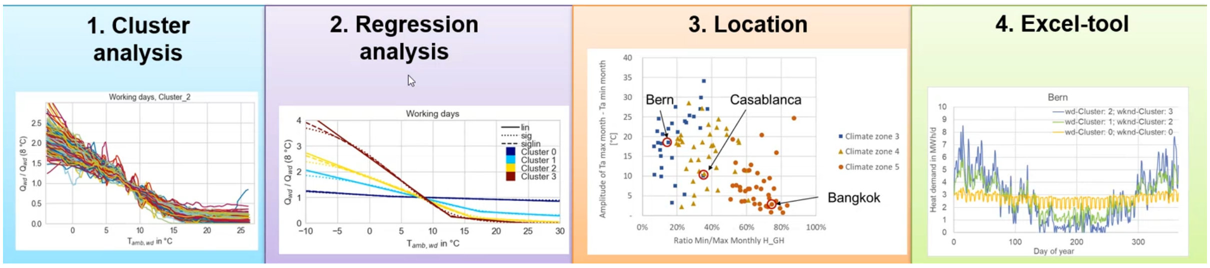

Figure 1. Analysis of heat load profiles.

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

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

- The solar yield suffers only a little if the collectors are operated at higher temperatures (system S2).
- The drawback for the seasonal COP of the heat pump is high if the heat pump has to deliver the high set temperature, so system S2 is preferable to system S1.

- The performance benefit of a serial system probably does not justify the higher installation effort compared to a parallel installation of a heat pump and solar collectors (P).

The next steps will be to verify these conclusions for higher temperature spreads between flow and return temperature and to add an economic analysis.

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 was due at the end of June 2021 but is delayed because not enough resources were attributed to it. The aim is to finalize it by the end of 2021.

In activity B2, standard packages for collectors and hydraulics (easy installation; easy dismantling) will be defined. It was decided to focus on:

- Instrumentation "guideline for instrumentation and performance assessment of solar fields in SHIP plants with line focusing collectors." The first draft of this guideline is under review within the subtask.
- Definition of a standard system for solar radiation measurement in SHIP systems
- saturated steam flow measurement at low ranges

Subtask C: Simulation and Design Tools

The activities in Subtask C are to execute comparative studies based on actual plants and identify the source of observed differences to system simulations. Four case studies were completed according to the scheme of Figure 2.

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

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

Case 3: Cancelled

Case 4: Direct steam generation with linear Fresnel collector

Case 5: Dairy in Switzerland (parabolic trough collector).

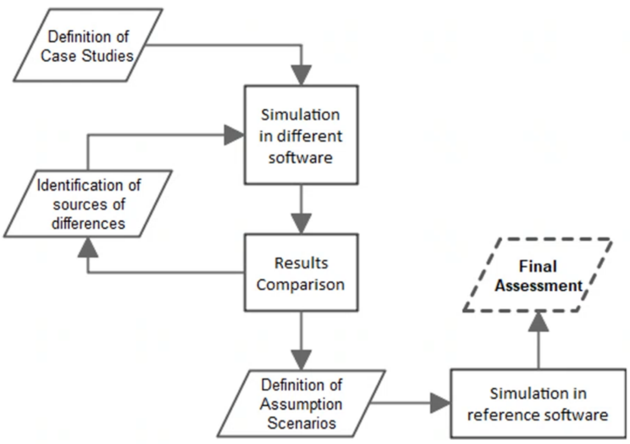

Figure 2. Flow chart for the case

The simulation tools used were:

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

The most important sources for differences were:

- control scheme
- HX modeling
- how to deal with the solar position

- internal flows
- thermal capacitance
- modeling of the storage

All results will be summarized in deliverable C1, which is due at the end of the year.

An additional activity is updating the comparison table of simulation tools that was elaborated in SHC Task 49.

Subtask D: Standardization / Certification

Deliverable D1 Standardization Plan is due at the end of the year. A draft is available that includes the following parts

- Overview of Standardization Bodies (European and International)
- Overview of Certification Schemes (European and International)
- Particular Country Cases for standardization / certification / legislative issues for Australia, Austria, China, Denmark, Germany, Greece, Indie, Morocco, Portugal, Spain, Mexico, Turkey
- Legislative issues (CE, ErP, CPR, energy labeling, pressure directive, machinery directive) for Europe, Australia, USA, India
- Mapping of relevant standards
- Discussion and preliminary identification of standardization and certification gaps

Subtask E: Guideline to Market

The deliverable E1, "Collection of available solar process heat-related national and trans-national research and funding programs," was completed. Eighteen responses from 32 countries with instruments in place were evaluated.

- Most countries have both RTD funding and incentives for SHIP plants.
- Types of incentives:
    - direct subsidy on initial investment ("CAPEX"/Grant -9)
    - taxation (8)
    - loans (6)
    - other types available in 5 countries (OPEX, Services, Finance instrument support)

The main conclusion is that funding schemes and incentives support the realization of SHIP projects, but not sufficient alone. There are many other relevant success factors (the report is available at https://task64.iea-shc.org/publications).

Activity E2 "Competitiveness indicators" plans to identify the most relevant parameters for project assessment, split into the different project development phases pre-feasibility, detailed engineering, implementation.

The feedback from an online survey of a large group of stakeholders is now being evaluated.

An important activity for statistical evaluations was started within ST E: the definition of a standard conversion factor from m^2 to kW for concentrating collectors. A first evaluation done by DLR revealed that similar to non-concentrating systems, a factor of 0.7 can be justified for commercially available systems.

A position paper was drafted and discussed within the Task. Most open questions were resolved, and the next version of the paper is expected at the end of 2021.

Work Planned For 2022

Subtask A: Integrated energy systems

Finalize the work on A.2 Integration concepts for solar process heat and continue working on A.3 System concepts for integrated renewable energy systems, which has a link to Subtask C and a deliverable due at the end of the year.

Start working on A4 Dimensioning rules and recommendations for implementation (Roadmap)

Subtask B: Modularization

Finalize the delayed deliverable B1.

Continue working on B2 Standard packages for collectors and hydraulics (easy installation; easy dismantling) and B3 Development of a modular and scalable interfaces unit for solar process heat applications

Subtask C: Simulation and Design Tools

Finalize deliverable C1.

Continue the analyses of C2 Simulation tools for solar process heat systems and start with C3 Yield assessment of solar process heat systems.

Subtask D: Standardization / Certification

Finalize deliverable D1.

Continue the work on D2 New standardization work that yields deliverable D2 at the end of the year.

Start with D3 Develop standardization document.

Subtask E: Guideline to Market

Continue working on E2 Competitiveness indicators and E3 Financing models.

Draft a position paper on the conversion factor m² → kW for concentrating collectors in market statistics.

Dissemination Activities In 2021

Reports, Published Books

None at this time.

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
Mateo Jesper, Florian Schlosser, Felix Pag, Timothy Gordon Walmsley, Bastian Schmitt, Klaus Vajen	Large-scale heat pumps: Uptake and performance modelling of market-available devices	Renewable and Sustainable Energy Reviews	Vol 137, 2021, 110646, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2020.110646, https://www.sciencedirect.com/science/article/pii/S1364032120309308
Bärbel Epp	Standardised yield assessments for industrial solar heat plants	solarthermalworld.org	2021
Jose Miguel Cardemil	IEA SHC Task64/SolarPACES Task IV – SubTask C: Assessment of uncertainties in simulation tools	SWC2021	2021
Mateo Jesper, Felix Pag, Klaus Vajen, Ulrike Jordan	Annual Industrial and Commercial Heat Load Profiles: Modeling Based on k-Means Clustering and Regression Analysis	Energy Conversion and Management: X	"Volume 10, June 2021, 100085 https://doi.org/10.1016/j.ecmx.2021.100085"
Jakob Jensen	Large-Scale SHIP Installations Without Risks	UNIDO (webinar)	April 19, 2021

	& Investments		
Jakob Jensen	Evaluation of high-temperature solar thermal opportunities in the Netherlands	TNO (advising the Dutch government on subsidy schemes needed to support solar thermal)	May 20, 2021
Jakob Jensen	Presentation of the market potential for industrial process heat <200C, Heliac solution, and competing solutions for this temperature range	Energistyrelsens fjernvarmegruppe under 'Center for Global Rådgivning	August 27, 2021
Jakob Jensen	Presentation of the market potential for industrial process heat <200C, Heliac solution, and competing solutions for this temperature range	Dansk Industri (conference: "Sol Over Danmark")	August 31, 2021

Conferences, Workshops, Seminars

None at this time.

Dissemination Activities Planned For 2022

Contributions to EuroSun 2022, SolarPACES, and national conferences.

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

Task Meetings in 2021 and Planned for 2022

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 5	March 24, 2021	online	60 participants (23 countries)
Task Meeting 6	June 29, 2021	online	55 participants (20 countries)
Task Meeting 7	September 21, 2021	online	50 participants (20 countries)
Task Meeting 8	December 14, 2021	online	48 participants (18 countries)
Task Meeting 9	April 5, 2022	Graz, Austria	

SHC Task 64 Participants

Country	Name	Institution / Company	Role
SWITZERLAND	**Andreas Häberle**	**SPF**	**SHC Task Manager**
AUSTRALIA	Ken Guthrie	sustainable energy transformation	National Expert
AUSTRIA	Winfried Braumann	REENAG	National Expert
AUSTRIA	Christoph Brunner	AEE INTEC	National Expert/SHC Task 62 Operating Agent
AUSTRIA	Jürgen Fluch	AEE INTEC	ST Leader
AUSTRIA	Valerie Rodin	JKU	National Expert
BELGIUM	Josep Ubach	Rioglass	National Expert
BELGIUM	Pablo del Prado	Rioglass	National Expert
BELGIUM	Irene di Padua	Solar Heat Europe	National Expert
BELGIUM	Jean-Yves Peugnieu	Sunoptimo	National Expert
BELGIUM	Costas Travasaros	Solar Heat Europe	National Expert
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CANADA	Lucio Mesquita	CanmetENERGY Ottawa	National Expert
CHILE	José-Miguel Cardemil	PUC	ST Leader
CHILE	Maria Cerda	Fraunhofer Chile	National Expert
CHINA	Yanjun Dai	Shanghai Jiao Tong University	National Expert
CHINA	Guofeng Yuan	Chinese Academy of Science	National Expert
DENMARK	Elsabet Nielsen	DTU	National Expert
DENMARK	Andreas Zourellis	Aalborg CSP	National Expert
DENMARK	Jakob Jensen	Heliac	National Expert
DENMARK	Weiqiang Kong	DTU	National Expert
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FRANCE	Valéry Vuillerme	CEA	National Expert
FRANCE	Pierre Delmas	newHeat	National Expert
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GERMANY	Bärbel Epp	SOLRICO	National Expert
GERMANY	Kai Schickedanz	Wacker	National Expert
GERMANY	Irapua Ribeiro	Industrial Solar GmbH	National Expert
GERMANY	Stefan Abrecht	Solar-Experience GmbH	National Expert
GERMANY	Mateo Jesper	University of Kassel	National Expert
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GERMANY	Peter Nitz	Fraunhofer ISE	Subtask E Leader
GERMANY	Paula Alfonso	Industrial Solar GmbH	National Expert
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GERMANY	Martin Scheuerer	protarget AG	National Expert
GERMANY	Nicolas Ürlings	protarget AG	National Expert
GERMANY	Werner Platzer	Fraunhofer ISE	National Expert
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ITALY	Alessandro Guzzini	DIN-UNIBO	National Expert
ITALY	Marco Pellegrini	University of Bologna	National Expert
KOREA	Jinyoung Kim	KIER	National Expert
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SPAIN	Marco David	UPV	National Expert
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SPAIN	Juan Diego Gil	University of Almería	National Expert
SPAIN	Mercedes Ibarra Mollá	UNED	National Expert
SPAIN	Cristóbal Villasante	Tekniker	National Expert
SPAIN	Miguel Frasquet	Solatom	National Expert
SPAIN	Raul Villalba van Dijk	Solatom	National Expert
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SWEDEN	João Gomes	Absolicon AB	National Expert
SWEDEN	Puneet Saini	Uppsala University	National Expert
SWEDEN	Rafael Guédez	KTH Royal Institute of Technology	National Expert
SWEDEN	Sahand Hosouli	MG Sustainable Engineering AB	National Expert
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TURKEY	Onur Taylan	METU	National Expert
TURKEY	Derek Baker	Middle East Technical University	National Expert
TURKEY	İbrahim Halil Yılmaz	Adana University	National Expert
UNITED KINGDOM	Huang Gan	Imperial College	National Expert
UNITED KINGDOM	Maged Soliman	Naked Energy	National Expert
USA	Lun Jiang	University of California, Merced	National Expert
USA	Parthiv Kurup	NREL	National Expert

Task 65 – Solar Cooling for the Sunbelt Regions

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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 bases.

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 on Solar Cooling solutions by combining MI IC7 and IEA SHC activities and the entire stakeholders.
- Provide a platform for the transfer and exchange of know-how and experiences from OECD countries, already having long experiences in Solar Cooling, towards Sunbelt countries (e.g., Africa, MENA, Asia) and vice versa.
- Support the development of Solar Cooling technologies on component and system level adapted for the boundary conditions of Sunbelt (tropical, arid, etc.) that are affordable, safe, and reliable in the medium to large scale (2 kW-5,000 kW) capacities
- Adapt existing technology, economic, and financial analyses tools to assess and compare economic and financial viability of different cooling options with a life-cycle cost-benefit analyses (LCCBA) model.
- Apply the LCCBA framework to assess case studies and use cases from Subtasks A and B to draw conclusions and recommendations for solar cooling technology and market development and policy design.
- Pre-assess 'bankability' of solar cooling investments with financial KPIs.
- Find boundary conditions (technical/economic) under which Solar Cooling is competitive against fossil-driven systems and different renewable solutions.
- Establishing 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:

- Collection of technical/climatic boundary conditions for sunbelt regions to better understand the operating conditions for all components of solar cooling systems.
- Adaptation and documentation of 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:

- Showcases on system and component level 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.
- Documentation of the lessons learned (technical & non-technical) and preparation for dissemination activities.

Subtask C: Assessment and Tools

The main objectives of Subtask C are:

- Overview, possibly update/merging of useful tools for design & assessment.
- Establishing/adapting assessment method and benchmarking (incl. reference system in different locations).
- Create a common database for technical, environmental, and economic assessment for the participating countries.
- Analyses of Subtask B results and benchmarking against reference systems and different renewable and solar solutions.
- Sensitivity analyses of high influencing parameters on the technical/economic/ environmental assessment.

Subtask D: Dissemination

The main objectives of Subtask D are:

- Communication of 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.
- Financing and business models for solar cooling.
- Mapping 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 7 (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 2021, 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 2021

Subtask A: Adaptation

Activities planned to achieve the specific objectives and their timeframe were discussed. The following results were achieved in Subtask A in 2021.

A1: Climatic Conditions & Applications
In general, climatic conditions and typical applications for (solar) cooling strongly depend on the location. Therefore, a geographic information system (GIS) has been used to process this data. GIS is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. Most relevant GIS data are already available from different sources, such as solar radiation data, climatic data, population data, etc. In activity A1, GIS software is used to combine this data in such a way that local reference boundary conditions for solar cooling systems in the sunbelt regions can be determined. In the scope of this activity A1, these results are used to derive boundary conditions for solar cooling systems and their components. By analyzing this data, information about locally applicable solar cooling systems will become available. This aims to understand the reference boundary conditions for adaptation of the components and solar cooling systems (link to Activities A2 and A3). In addition, using population density data, for example, gives a base for future market potential studies on certain products/technologies. The first step in Activity A1 has been evaluating how to combine and which dates to combine. In a first approach, the following conditions and sources are considered:

- Geographic areas that are regarded to require cooling include latitudes between 40°N and 40°S.
- Solar direct normal irradiance (DNI).
- Population density/Built-up areas/Settlement levels.
- Climate zones (Köppen–Geiger climate classification system).

A2/B1: Show cases on system and component level & Adapted components
A specific survey has been designed and spread among experts to understand better how to combine the existing components with the climatic boundary conditions and typical applications with the necessary adaptation from the technical point of view. The data are currently under the collection. The elaboration will consider the involved countries and the Köppen climate classification. Such a climate classification divides climates into five main climate groups, with each group being divided based on seasonal precipitation and temperature patterns. This approach will provide an appropriate qualitative classification of systems and components consequently.

A3: Adapted systems
In Activity A3, the goal is to summarize existing solar cooling systems and identify necessary adaptations on existing layouts. Therefore, the literature review of thermally driven systems, PV solar cooling, DEC, and free cooling adapted to Sunbelt regions, and the application of low-temperature district heating networks as heat rejection systems have started.

A4: Building and process optimization potential
One more activity was initiated: Activity has started to collect relevant studies of the assessment of loads, demands, and savings potential. The research on IEA EBC (Buildings and Communities Programme) and identification of significative data and projects (building optimization and through a workshop with related and active persons of IEA EBC in sunbelt countries) as well as a literature review of the integration of solar cooling in retrofitted HVAC systems will be initiated. The goal is to determine the best technical solutions for selected cases studies, which will be elaborated from a technical and economic point of view.

Subtask B: Demonstration

Activities planned to achieve the specific objectives and their timeframe were discussed. The following results were achieved in Subtask B in 2021.

B1/A2 & B2: Show cases on system and component level & Design guidelines
Detailed questionnaires/surveys were designed and submitted to all Task 65 experts. The expert's feedback will provide an overview of established solar cooling systems and the various components in the Sunbelt Regions and will support the notion to derive integration guidelines for solar cooling projects. The implementation of solar cooling systems across the Sunbelt Regions is a key activity among this Task. The collection of system designs and evaluated monitoring data of existing and new demonstration plants is the basis for calculating technical and economic KPIs. The comparison of calculated, designed, and practical field performance is used to evaluate and

improve the performance of the solar cooling plants. Lessons learned can be derived from the deviation of design and field performances as well as general design rules. The large diffusion of solar cooling technology in the market does not depend solely on the technical and economic aspects but also on the systematic approach for designing and installing systems in different climates. This will present manageable guidance for easy integration to professionals who are not experts on the specific technology.

Even though design guidelines are well documented in deliverables of previous tasks (Task 48, 53), the current activity leverages this knowledge to include new concepts, such as a) hybrid cooling systems (including solar thermal, solar Photovoltaic), b) systems for high solar cooling fraction, and c) standard modular packages for solar cooling solutions. This activity is dedicated to keeping an eye on the technical research and developments as well as producing an extensive report on “Good Practice” examples of existing solar-driven cooling systems.

B3: Key Performance Indicators
Although the key performance indicator definition exists, there is still no standard used by the entire solar cooling community. Instead, a mix of non-comparable KPIs is often used to express the quality of systems. This is not only confusing for end-users / operators/policymakers but also misleads discussions among the experts. Therefore, the initial focus is on the collection of existing technical and economic KPIs from IEA SHC Tasks and other sources. In addition, information collected on the definition and update of KPIs from technical and economic points of view for different stakeholders, especially end consumers, operating companies, ESCOs, policymakers, etc., has started.

B4: Standardization / solar cooling kits
In Activity B4, the goal is to collect standardization (processes) and solar cooling kits (equipment) in all capacity ranges and different technologies. The results will be used in the publishing activities of Subtask D.

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 2021.

C1: Design tools and models
It is to review and adaptation of tools and models for technical and financial assessment and design for solar cooling and the different project phases from pre-feasibility to simulation to monitoring. Different solutions are available and of interest among the interested participants (from mobile apps to dynamic simulation models for consultants, manufacturers, researchers, etc.), which need to be discussed and consolidated. Each of the tools and models can support the implementation of solar cooling in sunbelt countries if their use is target-oriented. The focus in this activity is the documentation of the tools and their specific application to provide measured data for validation of the tools and the adaptation of selected ones for sunbelt countries. At the time of writing this report, the research based on a literature review has been completed, and a set of questionnaires was developed and distributed among the participants.

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 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 the sensitivity analyses and future scenarios. The database elaboration also includes a review of existing useful information of IEA knowledge (e.g., IEA SHC Task 54, and others).

C3: Assessment mechanism
This activity is working closely with B3 activity, 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 adaption of methods and integration of the database (C2) are the core activities. Whereof the focus is to provide the corresponding methods for the analyses and creation of assessments for certain stakeholders.

Subtask D: Dissemination

Activities planned to achieve the specific objectives and their timeframe were discussed. The following results were achieved in Subtask D in 2021.

D1: Website / publications
Deliverable D1.1 was delivered in September 2020: Task 65 homepage is in operation and continuously updated. Already two National Workshops (China and Austria), as well as one Industry Workshop as part of the second Task Meeting (joint activity with the IEA HPT Annex 53), was successfully organized and informed stakeholders about the Task work (Milestone M-D6 draft).

Three publications about Task 65 were published for EuroSun 2020, FotoVolt 10/2021, and SWC 2021.

D3: Guidelines/roadmaps for Sunbelt countries
Work has been started on the compilation of new guidelines for solar cooling roadmaps with a focus on the specific constraints and opportunities in Sunbelt countries based on the adaptation of 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
In March 2021, the second National Workshop for Austria was held online and the first Industry Workshop, a joint online activity with HPT Annex 53. In addition, the second SHC Solar Academy Training course was organized and successfully held in November 2021 for SOLTRAIN onsite in Stellenbosch, South Africa.

D6: Stakeholder engagement
The stakeholder engagement in Activity D6 focuses on the identification of key stakeholders around the Sunbelt countries. This activity was highly supported by several EU Horizon 2020 call proposal development among the task participants in the second half of the year 2020 to build relationships with stakeholders, e.g., in India and the African continent. Further, a first round of identifying potential stakeholders in sunbelt countries was completed. The stakeholders shall then be encouraged and assisted in initiating the first solar cooling projects in their respective countries.

Work Planned For 2022

Subtask A: Adaptation

The main activities planned for Subtask A in 2022 are:

- Finally, deliver a base for market studies for certain components and solar cooling systems.
- 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 different storage possibilities on the hot/cold side or any other state.
- Evaluate the economic potential of adaption to certain climates and applications, especially when they can be simplified on component and system levels.

Subtask B: Demonstration

The main activities planned for Subtask B in 2022 are:

- Update and transfer procedures for measuring the performance of the solar cooling systems and communicate existing monitoring procedures for field tests or demo projects.
- Define and select technical and economic key performance factors for the different stakeholders in the entire 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 the 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 2022 are:

- Continue to collect supporting decision tools for technical, economic, and financial analyses with

different levels of detail, from simple pre-study tools to sophisticated dynamic simulation models.
- Adapt existing technology, economic, and financial analyses tools to assess and compare economic and financial viability of different cooling options with a life-cycle cost-benefit analyses (LCCBA) model.
- Apply 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.
- Decision support in various phases of a project cycle from initial project ideas, comparison of technology options to detailed investment grade calculation up to optimization of the operation phase based on case studies and use cases from subtasks A and B.

Subtask D: Dissemination

The main activities planned for Subtask D in 2022 are:

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

Dissemination Activities In 2021

Reports, Published Books

As the Task began in mid 2020, it is still too early for the publication of reports and books.

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
Bärbel Epp	IEA SHC Solar Cooling Task: "We can make a difference"	solarthermalworld.org	September 2021
Uli Jakob, Daniel Neyer	Refrigeração solar para as regiões do Sunbelt, incluindo Brasil	FotoVolt	Ano 7, No 42, October 2021, pp. 30-41
Uli Jakob, Salvatore Vasta, Wolfgang Weiss, Daniel Neyer, Paul Kohlenbach	Solar Cooling for the Sunbelt Regions	ISES SWC 2021 conference	October 2021
Lu Aye, Nayrana Daborer-Prado, Daniel Neyer, Uli Jakob	An Update on Activity C1 Design Tools and Models, Task 65 Solar Cooling Sunbelt Regions	Asia-Pacific Solar Research Conference 2021	December 2021

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
IEA SHC Task 64 6th Expert meeting	Solar Cooling for the Sunbelt Regions. Uli Jakob, JER	June 29, Virtual	22
Web Forum Solarthermie 2021, Bauzentrum München	Solare Kühlung und Klimatisierung – Technologie und Entwicklungen. Gerrit Füldner, ISE	July 22, Virtual	40

ISES SWC 2021 conference – Session I4: RE & Efficient Heating and Cooling Systems	Solar Cooling for the Sunbelt Regions. Uli Jakob, JER	October 29, Virtual	20
MI 2.0 Workshop – Innovation Community on Affordable Heating and Cooling of Buildings	Heating/cooling with PV/solar thermal for the Sunbelt Regions. Uli Jakob, JER	November 30, Virtual	40
sol.e.h.2 & IEA SHC Task 65 Workshop	Solar Cooling for the Sunbelt Regions – Introduction of IEA-SHC Task 65. Uli Jakob, JER	December 2, Virtual	35
Asia-Pacific Solar Research Conference APSRC 2021	An Update on Activity C1 Design Tools and Models, Task 65 Solar Cooling Sunbelt Regions. Lu Aye, Uni Melbourne	December 16-17, Sydney, Australia	n/a

Dissemination Activities Planned For 2022

A fourth public workshop is planned in conjunction with one of the Task meetings in 2022. Moreover, the second industry workshop is planned to be held during the Task Meeting in September 2022, which will be held in collaboration with the SHC Task 64 experts.

Contributions at ISEC 2022, EuroSun 2022, and national conferences.

Task Meetings in 2021 and Planned for 2022

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 2	March 24-25, 2021	Virtual	45 participants (19 countries)
Public Workshop	March 24, 2021	Virtual	
Industry Workshop	March 25, 2021	Virtual	
Task Meeting 3	November 11, 2021	Virtual	30 participants (10 countries)
Public Workshop	2 December 2021	Virtual	
Task Meeting 4	March 22-23, 2022	Virtual	

SHC 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	Roland Schneemeyer	Ecotherm	National Expert
AUSTRIA	Antoni Castells	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
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		Blanc	
FRANCE	Nolwenn Le Pierres	University of Savoie, Mont Blanc	National Expert
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GERMANY	Roland Kühn	Coolar	Observer
GERMANY	Christian Kemmerzehl	EAW	Observer
GERMANY	Ursula Wittstadt	Fahrenheit	National Expert
GERMANY	Gerrit Füldner	Fraunhofer ISE	National Expert
GERMANY	Mathias Safarik	ILK Dresden	National Expert
GERMANY	Michael Strobel	JER	National Expert
GERMANY	Siddharth Dutta	protarget	National Expert
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GERMANY	Martin Helm	ZAE Bayern	National Expert
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ITALY	Francesca Martorana	CNR ITAE	National Expert
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SPAIN	Manuel Lucas	Miguel Hernandez University	National Expert
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SWITZERLAND	Guglielmo Cioni	TVP	National Expert
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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
USA	Monika Weiss	ergSol	Limited Sponsor
ZIMBABWE	Samson Mhlanga	National University of Science and Technology	National Expert

Task 66 – Solar Energy Buildings

Harald Drück
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Task Manager for the German Government (PtJ for BMWi)

Task Overview

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

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

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

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

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

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

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

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

The Task's work is divided into four subtasks:

- Subtask A: Boundary Conditions, KPIs, Definitions and Dissemination (Lead Country: Germany)
- Subtask 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 Planned for 2022

Subtask A: Boundary Conditions, KPIs, Definitions and Dissemination

The main activities planned are:

- Finalize the Task brochure and video.
- Hold Industry Workshop 1 on March 23 (online).
- Finalize deliverable D.A1: Draft list of KPIs (for discussion within the Task).
- Continue work on deliverable D.A2: Final list of KPIs.
- Finalize deliverable D.A3: Draft definition of reference buildings/cases (for discussion within the Task).
- Continue work on deliverable D.A4: Final definition of reference buildings/cases.
- Hold Industry Workshop 2 on September 29 in Kassel, Germany.

Note: The industry workshops are related to deliverable D.A5.

Subtask B: Thermal stand-alone buildings and building blocks

The main activities planned are:

- Continue work on deliverable D.B1: Summary of demonstration cases (case studies).
- Continue work on deliverable D.B2 Description of processes and tools currently used to design new Solar Energy Buildings.
- Continue work on deliverable D.B3: Description of processes and tools currently used to convert existing buildings into Solar Energy Buildings.

Subtask C: Thermal grid-connected buildings and building blocks

The main activities planned are:

- Finalize deliverable D.C1: Summary of demonstration cases (case studies).
- Continue work on deliverable D.C2 Description of processes and tools currently used to design new Solar Energy Buildings.
- Continue work on deliverable D.C3: Description of processes and tools currently used to convert existing buildings into Solar Energy Buildings.

Subtask D: Current and future technologies and components

The main activities planned are:

- Finalize deliverable D.D1: Description of the available technology portfolio.
- Continue work on deliverable D.D2: Description of promising future technologies.

Dissemination Activities In 2021

Reports, Published Books

As the Task began in 2021, it is still too early for the publication of reports and books.

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference

Harald Drück et. al.	Mit Eis und Sonne heizen	GebäudeEnergieberater	Juli 2021
Bärbel Epp	How to design an 85% solar-heated and 100% solar air-conditioned house	solarthermalworld.org	April 2021
Harald Drück et. al.	Solare Konzepte für klimaneutrale Gebäude	Solarthermie-Jahrbuch	2021
Bärbel Epp	Solar-heated multi-family buildings gain popularity in Germany	solarthermalword.org	October 2020
Bärbel Epp	Solar houses: above 95 % solar fraction is possible	solarthermalword.org	October 2020
Bärbel Epp	Solar Energy Buildings to make cities fit for the future	solarthermalword.org	February 2020

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
IEA PVPS Task 15 Workshop “BIPV beyond IEA PVPS Task 15”	Presentation on Task 66 by Harald Drück	November 23, 2021, SUPSI, Manno, Switzerland and online	Around 70

Dissemination Activities Planned For 2022

Event	*Date and Location*	# of Participants (# of Countries)
Industry Workshop No 1	March 23, 2022, online	
Industry Workshop No 2	September 29, 2022, Kassel, Germany	

Task Meetings in 2021 and Planned for 2022

Meeting	Date	Location	# of Participants (# of Countries)
Experts Meeting 1	July 1-2, 2021	Virtual meeting	37 participants (14 countries)
Experts Meeting 2	November 4-5, .2021	Virtual meeting	37 participants (14 countries)
Experts Meeting 3	March 23-24, 2022	Virtual meeting	29 participants (15 countries)
Experts Meeting 4	September 29-30, 2022	Kassel, Germany	

SHC Task 66 Participants

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
BELGIUM	Emilia Motoasca	KU Leuven	National Expert
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
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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
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MEXICO*	Carlos Espino	Centro de Investigación en Materiales Avanzados, S.C., (CIMAV Durango)	National Expert
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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
UK	Richard Lewis	Swansea University	National Expert

*Mexico participation through the PVPS TCP.

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

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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, and these 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 mostly determined 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 2021

Subtask A: Material Characterization and Database

For the Materials Characterization and Database, good progress was made in the composition of groups that will contribute to the round-robin tests for the different material classes and properties. Already 27 institutes have agreed to participate in the round robins.

Subtask B: CTES Material Improvement

First discussions in the CTES Material Improvement Subtask were held on how to map the different materials improvement techniques for pure, doped, or composite materials, how to define Key Performance Indicators for CTES materials and on promising material development pathways.

Subtask C: State of Charge – SoC Determination

Regarding State of Charge determination, a first inventory was made of the physical material properties other than temperature that can serve as the basis for the SoC determination. It was concluded that machine learning or other artificial intelligence technologies would probably be needed for a good functioning SoC determination and that we need a proper reference technique to calibrate the novel developments.

Subtask D: Stability of PCM and TCM

For the Stability of PCM and TCM Subtask, it was concluded that we need to differentiate between stability testing at prototype level (with a storage component) and stability testing for material development. Also, kinetic models to extrapolate thermal degradation can be used to predict the long-term behavior of CTES materials.

Subtask E: Effective Component Performance with Innovative Materials

A difficult task lies with the Subtask on Effective Component Performance with Innovative Materials, as there is an extensive collection of combinations of storage components (heat exchanger, reactor) with CTES material. The first step will be to devise representative performance parameters that can compare the different concepts, which can ultimately help to optimize the concepts for a given application. Although different subgroups have been formed for PCM and TCM storages, the gathered knowledge will be brought together during the following steps to gain as much synergy as possible.

Work Planned For 2022

Subtask A: Material Characterisation and Database

A questionnaire was sent out to inventory the devices, methods, and infrastructure available for the different materials round robin tests. The outcome will be used to rank the quantities and methods operated by the most participants to get the highest possible number of participants in the round-robin tests. Additional round-robin tests on specific heat capacity and hydration enthalpy of $SrBr_2$ based on already defined procedures will be discussed, next to the possibility of more round-robin tests on adsorption enthalpy of zeolite 13X.

Subtask B: CTES Material Improvement

In two midterm meetings, the advances and synergies for materials development within Task 67 will be discussed, a common presentation on the results achieved prepared, and the synergies with other Subtasks described.

Subtask C: State of Charge – SoC Determination

Research experiences on proof of concepts for SoC determination (small scale, laboratory experiments, demonstration projects, numerical models on a component level) will be collected. Here, both descriptions of methods and control logics will be included. Next, a discussion will be organized on where and how SoC determination will be used to define a set of design parameters.

Subtask D: Stability of PCM and TCM

A review of the possible degradations mechanisms for storage materials will be performed, together with the methods to determine long-term material stability. In parallel, work will be done to arrive at a common wording for the different stability mechanisms.

Subtask E: Effective Component Performance with Innovative Materials

An update will be made of the participant table to indicate PCM and TCM. Based on a template, a collection will be made of presently used performance indicators for TCM components. The input will be used as the basis for constructing a set of KPIs.

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

Dissemination Activities In 2021

Task 67 started in October 2021 so no dissemination activities were undertaken in these first months.

Dissemination Activities Planned For 2022

The second Task Meeting will be held in April in Graz, Austria, in conjunction with the International Sustainable Energy Conference (ISEC). A number of experts submitted abstracts for this conference.

Task Meetings in 2021 and Planned for 2022

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 1	October 27-29, 2021	Vitoria Gasteiz, Spain	35 participants (15 countries)
Task Meeting 2	April 4-5, 2022	Graz, Austria	
Task Meeting 3	September/October 2022	TBD	

Task 67 Participants

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