SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

2019
Annual report

Feature article on solar integrated building facades

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June 2020

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: Solar air heating installation on Schluter Systems' office building in Québec, Canada. Source: MatrixAir® Solar Air Heating, SHC Task 56 product gallery, https://task56.iea-shc.org/product-gallery

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1. Message from the Chairman

In 2018, the IEA SHC Technology Collaboration Programme (TCP) members used the year to plan for the future, to reflect on past accomplishments, and to transition to a new Executive Committee Chair. All of which supported our underlying pursuit to be the leading and influencing international collaborative research program that produces high quality data and research on solar heating and cooling.

After four years of dedicated leadership, Ken Guthrie has passed the baton to me. As the new Chairman, I look forward to building upon Ken's work as the TCP enters its new 5-year term in 2019. I've worn many hats in this TCP from Task Expert to Task Operating Agent to Alternate Executive Committee member for France and plan to use these experiences to continue to raise the visibility of solar heating and cooling at the local, national and international levels.

Sharing our work and results in the most comprehensive way is a top priority, and we do it in a variety of formats. Our Solar Academy activities included four webinars hosted by ISES, two onsite training programs held in South Africa (topic: solar cooling) and China (topic: Solar district heating and cooling), and two national days in conjunction with our Stockholm, Sweden and Lisbon, Portugal Executive Committee meetings. We published our 2018 edition of Solar Heat Worldwide, Solar Update newsletter, Task 2018 Highlights, and many Task reports and online tools. Our partnership with Solarthermalworld.org is another avenue for disseminating our work as it is the leading news service in this field in addition to numerous presentations at a variety of conferences.

As we continue to address the big issues for solar thermal deployment through our seven current Tasks, collaboration with the IEA, other IEA TCPs, international organizations, and industry is essential. In 2018 we: - organized two side meetings during the Renewable Energy Working Party meeting, Ken Guthrie and I met with IEA staff and other TCPs to discuss collaboration and our LCoH calculation method, Artur Bobovnický (Slovakia ExCo member) participated in the IEA National Day in the Czech Republic, Ricardo Enriquez (Spain ExCo member) participated in the IEA Building Coordination Group meeting, Werner Weiss (Austria ExCo member), Alessandra Scognamiglio (Italy ExCo member) and Maria Wall (Task 51 Operating Agent) participated in the IEA Working Group on Cities and Communities meetings, and I met with IEA staff to discuss solar thermal trends and costs and improved communication. We held a joint meeting with the IEA Energy in Buildings and Communities Technology Collaboration Programme (EBC TCP) at our Executive Committee meeting in Stockholm, Sweden. And, have four Tasks that are collaborating with other TCPs that cover Renewable Energy and End Use Technologies. Our relationship with industry, whether through our Tasks or TCP activities, is critical if we are to better understand their perspective and issues and are to reach a key target audience for disseminating our research results.

I want to thank Ken Guthrie for his leadership as the past Chairman and welcome the new TCP Vice Chairs, He Tao (China), Elimar Frank (Switzerland), and Richard Hall (UK). I would also like to acknowledge the contributions of the Executive Committee members, the Task Operating Agents, and all the Task experts. Lastly, thank you to the Secretariat, Pamela Murphy, and the Webmaster, Randy Martin, for their support to the Programme.

2019 is on course to be another year of significant achievements and increased visibility as we implement our new Strategic Plan and once again hold our International Conference on Solar Heating and Cooling for Buildings and Industry in Chile (SHC 2019) from our Task work and valuable collaborative work with Industry and other TCPs.

Daniel Mugnier, SHC Executive Committee Chairman

2. Solar Heating and Cooling Technology Collaboration Programme

IEA

The International Energy Agency (IEA) is an international organization that is 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 the reliability, affordability and sustainability of energy. 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 IEA's Technology Collaboration Programme was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of thousands of experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

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 the application of solar technologies and designs to whole buildings, and industrial and agricultural process heat. Based on this mission, the SHC TCP will carry out and co-ordinate 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 are supporting market expansion by providing reliable information on solar system performance, design guidelines and tools, data and market approaches, and by developing and integrating advanced solar energy technologies and design strategies for the built environment and for 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 project (Task) is managed by an Operating Agent who is selected by the Executive Committee.

The Tasks running in 2019 were:

- Towards the Integration of Large SHC Systems into DHC Networks (Task 55)
- Building Integrated Solar Envelope Systems for HVAC and Lighting (Task 56)
- Material and Component Development for Thermal Energy Storage (Task 58)
- Deep Renovation of Historic Buildings Towards Zero Energy (Task 59)
- Application of PVT Collectors and New Solutions with PVT Systems (Task 60)
- Integrated Solutions for Daylight and Electric Lighting (Task 61)
- Solar Energy in Industrial Water and Waste Management (Task 62)
- Solar Neighborhood Planning (Task 63)
- Solar Heat Processes (Task 64)

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 are the SHC International Conference on Solar Heating and Cooling for Buildings and Industry (SHC 2019 was held together with ISES Solar World Congress 2019 on November 5-7 in Santiago, Chile), annual *Solar Heat Worldwide* statistics report, organization and participation in seminars, industry workshops and conferences.

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

1 East African Centre for Renewable Energy and Energy Efficiency joined in February 2020
2 European Copper Institute
3 ECOWAS Centre for Renewable Energy and Energy Efficiency
4 International Solar Energy Society
5 Mexico withdrew in November 2019
6 Regional Centre for Renewable Energy and Energy Efficiency
7 SADC Centre for Renewable Energy and Energy Efficiency

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 thorough 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.

85th Executive Committee Meeting – June 2019, Vienna, Austria

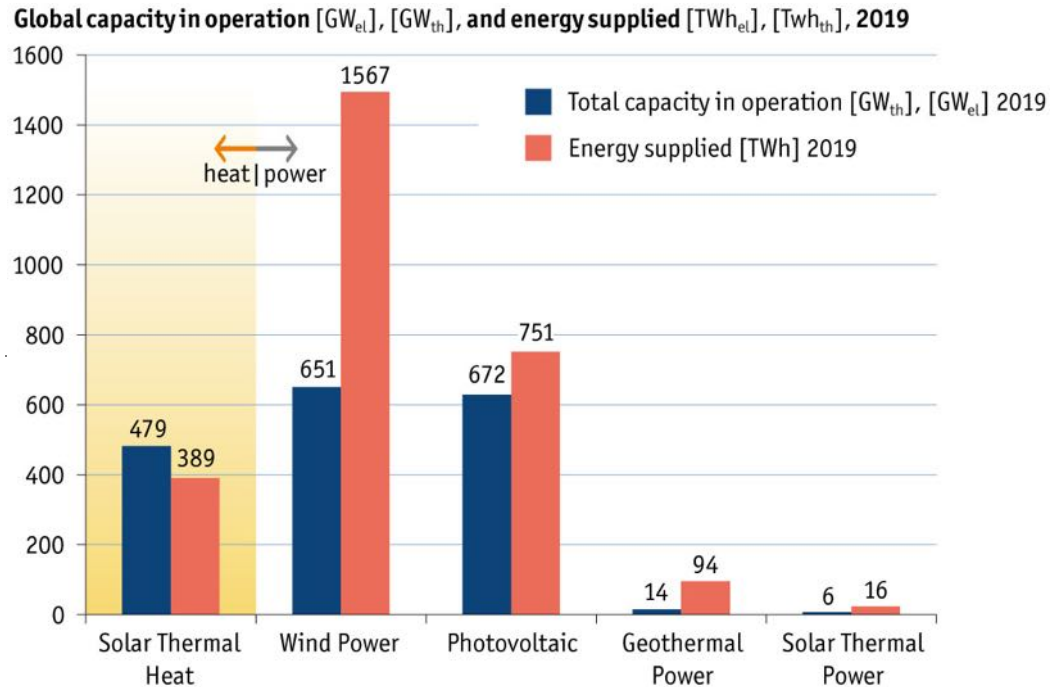
86th Executive Committee Meeting – November 2019, Santiago, Chile

3. 2019 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 2020 edition reports that in 2019, solar thermal technologies produced 389 TWh – which corresponds to an energy savings equivalent of 41.9 million tons of oil and 135.1 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 2019** and a table with the **Top Five Markets in 2018** by total MWth and per 1,000 inhabitants.



TOP FIVE MARKETS IN 2018			
New Installations (MWth)	**New Installations (kWth/1,000 inhabitant)**	**Total installations in operation (MWth)**	**Total installations in operation (kWth/1,000 inhabitant)**
China (24,801)	Israel (35)	China (337,816) ^	Barbados (565) ^
Turkey (1,316)	Cyprus (32) ^	USA (17,935) ^	Cyprus (446) ^
India (1,252) ^	Barbados (29) ^	Turkey (17,596) ^	Austria (408)
Brazil (875)	Greece (22) ^	Germany (13,877) ^	Israel (398) ^
USA (623)	China (18)	Brazil (11,258) ^	Greece (309) ^

^ denotes increase from 2017

SHC Tasks

New Tasks

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

In 2019, the following Tasks began:

- Task 63 Solar Neighborhood Planning *(Lead Country: Sweden)*
- Task 64 Solar Process Heat *(Lead Country: Switzerland)*

Completed Tasks

In 2019, the following Task ended:

- Task 58 Materials & Component Development for Thermal Energy Storage *(Lead Country: Austria)*

SHC Activities

Each of the activities below serve as a means to inform policy and decision makers about the possibilities of solar thermal as well as the achievements of our Programme.

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 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. The SHC 2019 conference was held together with the International Energy Agency's Solar World Congress on November 5-7 in Santiago, Chile. Planning for the SHC 2021 conference is underway.

SHC Solar Award

Our prestigious award recognizes individuals, companies and institutions that have made significant contributions to the growth of solar thermal. The 12th SHC Solar Award was presented the French company, KYOTHERM, for its 3rd party ESCO financing scheme at SHC 2019 in Santiago, Chile.

SHC Book Series

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

SHC Collaboration

To support our work, the SHC Programme is collaborating with other IEA Technology Collaboration Programmes (TCPs) and solar organizations.

Within the IEA

IEA District Heating and Cooling TCP is collaborating in SHC Task 55: Towards the Integration of Large SHC Systems into DHC Networks

IEA Energy in Buildings and Communities TCP is collaborating in Task 59: Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO2 Emission and Task 61: Integrated Solutions for Daylight and Electric Lighting.

IEA Energy Conservation and Energy Storage TCP is collaborating in Task 58: Material and Component Development for Thermal Energy Storage.

IEA Photovoltaic Power Systems TCP is collaborating in Task 59: Renovating Historic Buildings Towards Zero Energy. Task 60: Application of PVT Collectors and New Solutions with PVT Systems, and Task 61: Integrated Solutions for Daylight and Electric Lighting.

IEA Renewable Energy Working Party meetings in 2019 were attended by the SHC Chair, Daniel Mugnier.

IEA Buildings Coordination Group meetings in 2019 was attended by the SHC German Executive Committee member, Kerstin Krüger.

Outside the IEA

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

Solar Heat Europe (formally ESTIF), the SHC Programme has a close working relationship with this organization and will look for opportunities for collaboration in 2020.

ISO TC 180*,* the SHC TCP, specifically through Tasks, is supporting the work of ISO TC 180. For example, Task 60 on PV-Thermal Systems.

Executive Committee Meetings

2019 MEETINGS	2020 MEETINGS
85th ExCo Meeting Vienna, Austria June 5 – 7 *(included National Day and SHC ExCo reunion)*	**87th ExCo Meeting** Changed to online from Johannesburg, South Africa June 2 – 5
86th ExCo Meeting Santiago, Chile November 8 – 9 *(following SHC 2019 conference)*	**88th ExCo Meeting** Bratislava, Slovakia November 3 – 5

4. Feature Article

Solar Integrated Building Facades

Introduction

The decarbonization of the heating and cooling sector in buildings is one of the main challenges towards reducing greenhouse gas emissions and achieving the Paris Agreement objectives. The transformation of the current building stock into net-zero or positive energy buildings requires investing in energy efficiency to lower buildings' overall energy demand and to replace fossil fuel energy sources with renewables.

As of today, power to heat seems to be the designated technology to achieve this goal. Nonetheless, the high primary energy content of the electricity mix in most countries does not allow for significant reductions in the overall equivalent emissions by only exploiting heat pumps. Moreover, electric grids are not yet prepared to bear the loads potentially introduced due to a massive use of electric appliances for heating and cooling purposes.

From this perspective, the exploitation of locally available renewable energy source (RES), such as solar energy is not only desirable to reduce the import of high primary energy carriers on site; it also is needed for the reliable and resilient operation of the grids - mostly the electric grid – by means of a wise integration with local storage and building energy management.

On the one hand, building electric and thermal energy needs can be reduced by improving daylighting and managing solar gains. On the other, a share of the energy demand can be covered by harvesting, storing, and distributing the solar radiation reaching the envelope, according to the demand patterns.

The sector of building-integrated solar envelopes embraces a rather broad range of technologies – building-integrated photovoltaics, solar thermal collectors, and photovoltaic-thermal (or PVT) collectors – that actively harvest solar radiation to generate electricity or usable heat. Shading systems instead control incoming radiation to lower the energy demand for air conditioning, enhance daylighting, and improve visual comfort.

Figure 1. Examples of solar envelope systems described. From the top to bottom, Kromatix BIPV panels (photovoltaics), Lumiduct (photovoltaics and shading system), Okalux Okasolar 3D (shading system), Kindow (shading system) and SunRise façade (solar thermal system).

Current Status

Solar envelope systems may not be a consolidated practice in the construction sector. Still, a progressively increasing number of concepts and solutions are being developed and several innovative products have reached the market.

The sector of solar envelope systems can be split into two main segments. The first relates to solutions controlling solar radiation. Innovative solutions, such as motorized shadings or electrochromic glass have a place, beside traditional shading devices, such as shutters, blinds, and curtains, which already have a well-established market in the residential and tertiary buildings sectors.

The second segment relates to building-integrated solar harvesting technologies. Here the market is structured around small-size enterprises that offer their solutions primarily targeting architects and energy planners. These systems represent a niche market, even though the large number of building integrated photovoltaic products reaching the market in the last years speaks of rapid growth.

Several challenges hinder a higher level of market penetration of innovative building-integrated solar envelope systems. Their design, manufacture and installation are usually more complex and time-consuming activities compared to conventional solutions adopted in the construction sector and require the collaborative involvement of a range of professionals. Roles and responsibilities in the building construction process, information and material fluxes, legal liability for the correct installation and operation, warranties and maintenance are the relevant multi-faceted questions that must be cleared and planned before installation.

Moreover, solar envelope systems must comply with both construction codes and energy industry norms. This adds to the lack of adequate design tools adapted to estimate energy performance and architectural impact during initial concept design. The resulting regulatory gaps and the lack of consolidated international standards create an unfavorable environment that may hinder planners, investors and clients from adopting these technologies.

In addition, solar envelope systems, due to their level of innovation, have higher upfront costs compared to conventional construction materials. However, they offer several co-benefits - higher energy efficiency and user comfort, higher property value, and reduced impact on power grids – that can be properly valued once the building is assessed from a system perspective.

Potential

Challenges in delivering on-site RES include accommodating spatial constraints, adapting to the surrounding built environment, providing enough energy storage, and effectively managing a building's systems. ***For optimal performance, it is essential to integrate solutions across technologies. Industry and research are developing solar envelope systems as multifunctional solutions dealing with this requirement.***

New materials entering the market are driving product innovation. For example, high-efficiency polymers used to produce absorbers of solar thermal collectors and new light shifting species for semi-transparent photovoltaic solutions. ***The progress in solar envelope technologies is pushing advances in manufacturing and assembling existing materials, resulting in new concepts, improvement of existing technologies, and design of new applications from conventional concepts.***

The main research and development trend is towards achieving industrialized multifunctional solutions to move as much as possible of the building plants (i.e., space heating, cooling, and ventilation) into the envelope, thus speeding up the construction process. From the building construction perspective, the envelope assumes higher value since it can replace to some extent central services, such as the artificial lighting or entire parts of the HVAC system. In addition, ***prefabrication offers a huge opportunity to components manufacturers who can evolve and place higher added-value solutions on the market.***

As interdisciplinarity is more frequently requested by solar envelope systems, prefabrication is necessary, but so is collaboration among planners and installers from different specialties. If taking the conventional approach, the planning process can be more complex than usual. In contrast, ***a collaborative approach might offer new opportunities and selling points to companies that adopt a systemic approach to designing the building and organizing the construction site. Once more, new skills and high added-values services are stimulated in the construction market.***

Constructed floor space in buildings worldwide has increased by 65% since 2000, reaching nearly 240 billion square meters in 2018. Yet, average energy use per square meter has declined by only 25%, meaning progress did not offset floor area growth. Final energy use in buildings grew from 2,820 Mtoe in 2010 to around 3,060 Mtoe in 2018, while the share of fossil fuels decreased only slightly, from 38% in 2010 to 36% in 2018. As a result, direct emissions from buildings increased to just over 3 $GtCO_2$ in 2018 [1].

While more and more countries worldwide are adopting mandatory building energy codes to transform their stocks into net-zero- or plus-energy buildings in the short- to medium-term, ***packages of technologies are needed in which integrated operation is proven in a range of climate, social and economic conditions, and that cover energy demands based on locally available RES and reduces energy carriers import on site (hence reducing the loads on the networks and grids).***

Building integrated solar envelope systems can be game changers under this perspective since they allow to both reduce the energy intensity of the sector by cutting energy demand for space heating and cooling and increasing the exploitation of local RES. By maximizing the utilization of the envelope surfaces and by prompting the synergic operation with storage and building, solar thermal and photovoltaic solutions have the chance to effectively complement the renewable energy exploitation performed through technologies - such as heat pumps - towards the n-ZEB standard.

As an example, if we imagine that only 10% of the buildings globally will have solar envelope systems and that these systems will be able to cover the missing 30%-40% of renewable energy, which is not provided by a heat pump, huge savings could be achieved in the range of 90-100 Mtoe of final energy and 90-100 MtCO2 a year.

Actions Needed

Actions needed to foster the sector of the building-integrated solar envelope systems and promote better use of solar energy in buildings are:

Manufacturers – To offer systemic design and construction packages. Solar envelope technologies are intrinsically systemic solutions designed for multifunctional performance, which require the collaboration of many stakeholders in the design, manufacturing, and construction processes of buildings. A systemic approach eases this challenge and generates new opportunities based on innovative links among companies, business models and financing.

Manufacturers – To elaborate on new value propositions promoting solar envelope systems. As economic assessments are key to any decision-making process, solar envelope solutions manufacturers should be able to provide life-cycle cost and risk assessments that are adapted to their customer needs and account for commodities prices, incentives, norms, and legal frameworks.

Manufacturers should not promote solar envelope systems based on a single selling point (e.g., energy savings guaranteed); instead they should adopt a broader perspective and be able providing information on the impact of their solutions have on sustainability protocols – such as LEED or BREEAM – and on user comfort and healthiness, hence on better productivity and wellbeing in general.

User and human-centric solutions can be a strong “go to market” strategy.

Manufacturers – To offer customizable architectural appearance. There is no general rule as of what is preferred by architects, public authorities, building owners, or occupants; thus, manufacturers should offer aesthetically flexible solar envelope systems to comply with specific architect requirements.

Manufacturers and associations – To promote professionals training. Manufacturers and industry associations should stimulate targeted training and dissemination activities devoted to raising planners’ awareness of the range of opportunities offered by market available and near-to-market solar envelope systems and endorsing a collaborative design approach.

Decision-makers – To harmonize regulations and promote energy sharing economy. Building-integrated are subject to a higher level of country-specific legal approvals, since they need to comply with both construction products regulations and with industrial norms addressing compliance and performance. As this creates a

1 source IEA, Tracking buildings report, 2019

significant market-entry barrier for manufacturers, policymakers should address this obstacle by defining and enforcing a regulatory framework that is as uniform and international as possible and that facilitates dealing with both construction and industrial regulations.

At the same time, current regulations can be a barrier to sharing locally produced energy among neighboring buildings. Devising legal frameworks to allow for the practical implementation of energy communities can make a difference, by creating a playground suited to solar envelope systems.

Decision-makers – To support solar envelope systems. Decision-makers should support building integration of solar envelope systems: this should not be limited to the mere deployment of incentives supporting specific technologies; rather, it should be considered to elaborate a whole framework of measures allowing a level playing field with conventional solutions.

This could include developing practical tools like 3D solar cadasters facilitating the evaluation of the solar source availability on the buildings' façades, devising pre-commercial-procurement demonstration projects and elaborating administrative and legal procedures to promote private-public investment initiatives.

Challenge	Action needed
A large number of actors are involved in manufacturing, planning and installing solar envelope systems	To offer systemic design and construction packages
The construction market is often unaware of the potential of solar envelope systems	To promote professionals training To elaborate on new "user-centric" value propositions: • to provide LCC and risk assessment • to provide information for sustainability protocols • to provide information on user comfort and wellbeing
Architectural integration is not easy, but it is key for acceptance	To offer customizable architectural appearance
The regulatory framework is often unclear with respect to building integrated technologies.	To implement a normative framework facilitating the integration of solar technologies in the construction sector, as uniform and international as possible
Current regulations can be a barrier to the foundation of energy-sharing economies	Improve the regulations to ease the implementation of energy communities
Early-stage assessment of solar envelope technologies is crucial, but there is a lack of tools	To support the development of tools such as 3D solar cadasters allowing the evaluation of solar availability on façades
The construction sector is conservative and innovative solutions can hardly penetrate the market unless a proven record of installations is available	To promote pre-commercial-procurement demonstration projects in public buildings To devise administrative and legal procedures promoting private-public investment initiatives

*This article is one of a series of Technology Position Papers published by the IEA SHC for policy- and decisionmakers, https://www.iea-shc.org/position-papers.

Authors: Roberto Fedrizzi of EURAC, Italy and Operating Agent of SHC Task 56: Building Integrated Solar Envelope Systems for HVAC and Lighting and Paolo Bonato of EURAC, Italy and a Task 56 expert.

5. Completed Tasks

Task 58 – Material and Component Development for Thermal Energy Storage

Wim van Helden
AEE INTEC
Operating Agent for Austrian Ministry for Transport, Innovation and Technology

Task Overview

The key objectives of this Task are:

- Development and characterization of storage materials to enhance TES performance
- Development of materials testing and characterization procedures, including material testing under application conditions
- Development of components for compact thermal energy storage systems
- Mapping and evaluating the TES application opportunities concerning the requirements for the storage material

To achieve these objectives, the work focused in 7 main topics:

1. Energy Relevant Applications for an Application-oriented Development of improved Storage Materials
2. Development & Characterization of improved Phase Change Materials
3. Development & characterization of improved Thermochemical Materials
4. PCM Measuring Procedures and Testing Under Application Conditions
5. TCM Measuring Procedures and Testing Under Application Conditions
6. Component Design for Phase Change Materials
7. Component Design for Thermochemical Materials

Scope

This joint Task dealt with advanced materials for latent and chemical thermal energy storage, Phase Change (PCM) and Thermo Chemical (TCM) materials on three different scales:

- Material properties focused on their behavior from molecular to bulk scale, including material synthesis, micro-scale mass transport and sorption reactions.
- Material performance within the storage system focused on the materials behavior and when they are implemented in the storage itself, including heat, mass, and vapor transport, wall-wall and wall-material interactions, and reactor design.
- Storage system implementation, focused on the performance of a storage within a heating or cooling system, including for instance economic feasibility studies, case studies, and system tests.

Because seasonal storage of solar heat for solar assisted heating of buildings is the main focus of the IEA SHC TCP, this was one of the primary focus areas of the Task. However, because there are many more relevant applications for TES, and because materials research is not and cannot be limited to one application only, this Task included multiple application areas.

Participating Countries

	Research Institutes	Universities	Companies
Austria	1	4	
Belgium		1	
Canada	1	3	
Germany	3	6	2
Denmark		1	
France	2	3	
Italy	2	2	
Netherlands	1	1	
Slovenia	1		
Spain	2	4	
Sweden	1		
Switzerland	2	2	
Turkey		2	
United Kingdom		3	
TOTAL	**16**	**32**	**2**

Task Duration

This Task started in **January 2017** and ended in **December 2019**. Final deliverables will be published by July 2020.

Collaboration with Other SHC Tasks and IEA TCPs

This is a fully joint Task with the ECES TCP (Annex 33). Each TCP has its own Operating Agent, Wim van Helden for SHC TCP and Andreas Hauer for ECES TCP.

Collaboration with Outside Organizations/Institutions

A number of experts from Task 58 also participated in the Mission Innovation workshop on Thermal Energy Storage Materials Acceleration Platform (TESMAP), October 2019 in Erlangen, Germany.

Collaboration with Industry

There was a low level of participation by two German industries: Vaillant, a manufacturer of heating appliances and Rubitherm, a manufacturer of Phase Change Materials.

Key Results

The main accomplishments of this Task are highlighted below. More details and specific deliverables can be found on the SHC Task 58 webpage and in the activities of the specific Subtasks:

Subtask 1: Energy Relevant Applications for an Application-oriented Development of improved Storage Materials *(Subtask Leaders: Andreas Hauer, ZAE Bayern, Germany and Wim van Helden, AEE INTEC, Austria)*

A collection of reference conditions for a number of applications was generated. A common reference system for the identification of the reference temperatures was defined, and the values of these temperatures defined for the following applications, which are described in the three Subtask 1 deliverables:

- Building application specific temperatures for the testing of phase change and thermo chemical materials, components and systems.
- Definition of boundary conditions for industrial applications and industrial peak shaving.
- Relevant boundary conditions for TES in buildings.

Subtask 2P: Development & Characterization of improved Phase Change Materials *(Subtask Leader: Christoph Rathgeber, ZAE Bayern, Germany)*

During the Task, 20 different phase change materials where investigated / improved / developed by the Task experts. Regarding characterization methods, the main focus was on enthalpy, melting temperature and supercooling. A procedure for measuring the thermal diffusivity via laser flash method was developed and a database for PCM was maintained and extended to add viscosity measurements; material properties for different materials have been stored in the database, and a Wiki for PCM created.

Subtask 2T: Development & characterization of improved Thermochemical Materials *(Subtask Leader: Alenka, National Institute of Chemistry NIC, Slovenia)*

A number of thermochemical materials were improved by Task experts 1) sorption materials (micro/mesoporous solids and liquids (hydroxide)), 2) chemical reactions (salt hydrates and metal oxides/hydroxides), 3) and combinations of both (zeolites/graphite+salt hydrates/metal oxides). The database on sorption materials was extended with new sorption material data and data on chemical reactions and liquids.

Subtask 3P: PCM Measuring Procedures and Testing Under Application Conditions *(Subtask Leader: Christoph Rathgeber, ZAE Bayern, Germany)*

An inventory was made of properties of PCM in the lab environment and under application conditions (deliverable 1 report). Properties included are degree of supercooling, phase separation, storage capacity, long-term stability, crystal structure, stability of phase change emulsions, and thermal conductivity. A collection of experimental devices to investigate degradation of PCM is described (deliverable 2, to be published). The tests consider degradation of PCM over thermal cycling, of PCM with stable supercooling and of phase change slurries (PCS).

Subtask 3T: TCM Measuring Procedures and Testing Under Application Conditions *(Subtask Leader: Daniel Lager, AIT, Austria)*

Work was done on a measurement procedure for mass and enthalpy change with defined conditions for sorption materials and salt hydrates and on a measurement procedure for specific heat capacity measurements of salt hydrates. Two round robin tests were performed for mass and enthalpy change on SrBr·6H2O with 6 participants, three round robin tests for mass and enthalpy change on zeolite 13X with 6 participants, and one round robin test on specific heat capacity of SrBr·6H2O. Furthermore, work was done on a scale up procedure from material properties to lab scale based on measured material properties from zeolite 13X.

Subtask 4P: Component Design for Phase Change Materials *(Subtask Leader: Ana Lazaro, University of Zaragoza*, Spain)

An inventory of component concepts for PCM was made. Core of the work was defining and testing the applicability of characteristics to determine the performance of PCM components (capacity, storage density and power). A review was made of the different approaches for assessing the characteristics plus a first round of comparison of the power versus time curves as a possible performance characteristic.

Subtask 4T: Component Design for Thermochemical Materials *(Subtask Leader: Benjamin Fumey, EMPA, Switzerland)*
The achievements of this Subtask are 1) a basic description of the investigated thermochemical storage processes and their impact on the component design (published paper), 2) an inventory of actual component designs currently under investigation (internal report), and 3) an identification of performance degradation from lab-scale measurements to pilot installations (prepared as a ‘Do’s and Don’ts’ paper).

Workshops and Conferences

The Task participants organized workshops for the industry players involved in the sector (solar thermal manufacturers and installers, thermally driven cooling industry, planners). These happened about once a year and before/after Task Experts meetings in order to test and receive feedback on the last Task developments. Thanks to this yearly event interested industries could be involved in the Task without requiring a large time commitment. Short reports were written for each event and posted on the Task 53 website, including all the presentations.

Dissemination Activities

Reports & Online Tools

The following table is a list of all the reports and tools produced by the Task participants.

Author(s)/ Editor	Title	Report No. Publication Date
Gaeini, M.	Thermochemical seasonal heat storage for the built environment: a multi-scale investigation	PhD thesis, Eindhoven University of Technology, The Netherlands, July 2017
Diarce, G.	Development of new eutectic PCMs and plate-based LHTES systems for domestic cogeneration applications	PhD thesis. University of the Basque country (UPV/EHU), 2017
Michael Brütting	Internal: Michael Brütting, Intercomparison of measurement results by means of flash technique,	Report ZAE 20318 - 09(2018)
Benjamin Fumey, Robert Weber	“Fertig ist die Lauge, Solarkraft aus dem Sommer im Winter zum Heizen verwenden”	3sat TV, Nano, Monday, 29. January 2018, http://www.3sat.de/mediathek/?mode=play&obj=71365
	http://forschung-energiespeicher.info/projektschau/industrielle-prozesse/projekt-einzelansicht/109/Effizienz_von_Heizkraft_und_Stahlwerken_steigern/	www.iea-shc.org
	http://www.forschungsjahrbuch-energie.de/projekt/2597	
	An internal / non-public progress report for Line A/Fraunhofer ISE was generated in February 2018 and filed to the German project agency PTJ.	
	StoreItUp Final Report (issued by AIT-Vienna)	
Z. Jiang, A. Palacios, M. E. Navarro, Y. Ding	The research of formulation and detecting methods of high temperature molten salts	2018
Z. Jiang, A. Palacios, M. E. Navarro, Y. Ding	The study of corrosion behavior of high temperature molten salts	2018
B. Fumey	Yearly report to the Swiss Federal Office of Energy	2019
	http://forschung-energiespeicher.info/projektschau/industrielle-prozesse/projekt-einzelansicht/109/Effizienz_von_Heizkraft_und_Stahlwerken_steigern/	
	http://www.forschungsjahrbuch-energie.de/projekt/2597	
	Intermediate progress report of project HYBRITES (ENE2017-87711-R) for the Spanish funding agency.	
Angerer, M.; Becker, M.; Härzschel, S.;	Abschlussbericht TcET 2018 – Thermochemischer Energiespeicher für thermische Kraftwerke und	2018

Ostermeier, P.; Würth, M.; Gleis, S.; Vandersickel, A.; Spliethoff, H.	industrielle Wärme. Bundesministerium für Wirtschaft und Energie, 2018	

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
Benjamin Fumey et al.	Task 58 Material and Component Development for Thermal Energy Storage: Objectives and Outlook	IEA SHC Solar Update	May 2017
Emanuela Mastronardo, Yukitaka Kato, Lucio Bonaccorsi, Elpida Piperopoulos, Candida Milone	"Thermochemical Storage of Middle Temperature Wasted Heat by Functionalized C/Mg(OH)2 Hybrid Materials	Energies	10, (2017),70-86 (16 pp)
Emanuela Mastronardo, Lucio Bonaccorsi, Yukitaka Kato, Elpida Piperopoulos, Maurizio Lanza, Candida Milone	Strategies for the enhancement of heat storage materials performances for MgO/H2O/Mg(OH)2 thermochemical storage system	Applied Thermal Engineering	120, (2017), 626-634
Elpida Piperopoulos, Emanuela Mastronardo, Marianna Fazio, Maurizio Lanza, Signorino Galvagno, Candida Milone	Enhancing the volumetric heat storage capacity of Mg(OH)2 induced by the addition of a cationic surfactant during its synthesis	Applied Energy	Applied Energy (submitted)
V. Brancato, A. Frazzica	Characterization of zeotype adsorbent materials for TES applications	14th International Conference on Energy Storage,	25-28 April 2018, Adana, Turkey. Submitted paper
S. Höhlein, A. König-Haagen, D. Brüggemann	„Latentwärmespeicher hoher Energie- und Leistungsdichte durch Makroverkapselung",	Oral presentation at Fachformum Thermische Energiespeicher	July Neumarkt i.d. Oberpfalz, Germany
Bendix, Phillip; Füldner, Gerrit; Möllers, Marc; Kummer, Harry; Schnabel, Lena; Henninger, Stefan; Henning, Hans-Martin	Optimization of power density and metal-to-adsorbent weight ratio in coated adsorbers for adsorptive heat transformation applications	Applied Thermal Engineering	124, S. 83–90. https://doi.org/10.1016/j.applthermaleng.2017.05.165
Bendix, Phillip B.; Henninger, Stefan K.; Henning, Hans-Martin	Temperature and Mechanical Stabilities and Changes in Porosity of Silicone Binder Based Zeolite Coatings		Ind. Eng. Chem. Res. 55 (17), S. 4942–4947. https://doi.org/10.1021/acs.iecr.6b00558

Simon Furbo	Langtidsvarmelagring baseret på salthydrater (Long term heat storage based on salt hydrates)	Heat storage meeting at The Danish Academy of Technical Sciences (ATV)	March 28, 2017
Mark Dannemand	Udvikling af langtidsvarmelager til solvarmeanlæg i enfamiliehuse (Development of long term heat storage for solar heating systems in single family houses)	DANVAK DAGEN 2017	Copenhagen, Danmark, April 5, 2017
Christoph Moser, Gerald Englmair, Hermann Schranzhofer, Andreas Heinz	Simulation Study of a Novel Solar Thermal Seasonal Heat Storage System based on Stable Supercooled PCM for Space Heating and Domestic Hot Water Supply of Single Family Houses	12th International conference on Buildings and Environment "enviBuild 2017"	Technical University of Vienna, Austria, September 7-8, 2017
Gerald Englmair	Performance Evaluation of a Demonstration System with PCM for Seasonal Heat Storage: Charge with Evacuated Tubular Collectors	ISES Solar World Congress (SWC 2017) & IEA Solar Heating and Cooling Programme´s SHC 2017 conference	Abu Dhabi, United Arab Emirates, October 29 - November 2, 2017
Gerald Englmair	Sustainable energy system: Long-term PCM heat storage for a solar space heating and domestic hot water combisystem	Sino-Danish Center for Research and Education workshop at University of Chinese Academy of Sciences	Yanqihu Campus, China, September 24, 2017
Scapino L, Zondag HA, Van Bael J, Diriken J, Rindt CCM.	Sorption heat storage for long-term low-temperature applications: A review on the advancements at material and prototype scale.	Applied Energy	2017;190:920–48. https://doi.org/10.1016/j.apenergy.2016.12.148
Scapino L, Zondag HA, Van Bael J, Diriken J, Rindt CCM.	Energy density and storage capacity cost comparison of conceptual solid and liquid sorption seasonal heat storage systems for low-temperature space heating	Renew Sustain Energy	Rev 2017;76:1314–31
Donkers PAJ, Sogutoglu LC, Huinink HP, Fischer HR	A review of salt hydrates for seasonal heat storage in domestic applications	Applied Energy	2017;199:45–68. http://doi.org/10.1016/j.apenergy.2017.04.080
Van Alebeek R, Beving MAJM, Gaeini M, Rindt CCM, Zondag HA..	Design and experimental investigation of a high power segmented zeolite 13X/water sorption energy storage system.	4th Sustain. Therm. Energy Manag. Int. Conf. (SusTEM 2017),	Alkmaar, (NL): 2017

Gaeini, M., Wind, R., Donkers, P. A. J., Zondag, H. A. & Rindt, C. C. M.	Development of a validated 2D model for flow, moisture and heat transport in a packed bed reactor using MRI experiment and a lab-scale reactor setup		International Journal of Heat and Mass Transfer 2017: 113: 1116-1129
Gaeini, M., Javed, M. R., Ouwerkerk, H., Zondag, H. A. & Rindt, C. C. M.	Realization of a 4kW thermochemical segmented reactor in household scale for seasonal heat storage		Energy Procedia 2017: 135: 105–114
Lan, S., Gaeini, M., Zondag, H.A., van Steenhoven, A.A. & Rindt, C.C.M.	Direct numerical simulation of the thermal dehydration reaction in a TGA experiment		Applied Thermal Engineering 2018: 128: 1175-1185
Stamatiou A. et al.	High power thermal energy storage using phase change material slurries	12th IIR Conference on Phase Change Materials and Slurries for Refrigeration and Air Conditioning	2018, Orford (QC), Canada.
Diarce, G., Campos-Celador, Á., Sala, J.M., García-Romero, A.	A novel correlation for the direct determination of the discharging time of plate-based latent heat thermal energy storage systems		Appl. Therm. Eng. 129, 521–534
M. Deutsch, F. Birkelbach, C. Knoll, M. Harasek, A. Werner, F. Winter	An extension of the NPK method to include the pressure dependency of solid state reactions		Thermochimica Acta, 654 (2017), 168 - 178
C. Knoll, D. Müller, W. Artner, Jan Welch, A. Werner, M. Harasek, P. Weinberger	Oxalate-hydrates in thermochemical energy storage - a so far neglected class of salt hydrates	The International Symposium on Energy 7,	Manchester, United Kingdom, 2017-08-13 - 2017-08-17
D. Müller, C. Knoll, W. Artner, J. M. Welch, A. Werner, M. Harasek, P. Weinberger	Enhancing the hydration reactivity of MgO about particle morphology and chemical dopants	The International Symposium on Energy 7	Manchester, United Kingdom, 2017-08-13 - 2017-08-17
	Porosity and density measurements of sodium acetate trihydrate for thermal energy storage	Applied Thermal Engineering Volume 131	2018, Pages 707-714
Ana Lázaro, Giulia Rinaldi, , Monica Delgado, José Mª Marín, Conchita Peñalosa, Miguel A. Lozano, Luis Serra, Vittorio Verda	Study on seasonal and short-term thermal energy storage using a phase change material emulsion for district heating applications	SHC2017. 5th International Conference on Solar Heating and Cooling for Buildings and Industry	Abu Dhabi, October 29-November 2, 2017
De Jong, A.-J., Fischer, H.	Trouton's Rule for Vapor Sorption in Solids	Applied Science	8(4), 638 2018

Sögütoglu, L. C., Donkers, P.A.J., Fischer, H.R., Huinink, H.P. & Adan, O.C.G.	In-depth investigation of thermochemical performance in a heat battery : Cyclic analysis of K2CO3, MgCl2 and Na2S	Applied Energy	215, 159-173 2018
Sögütoglu, L. C., Donkers, P.A.J., Fischer, H.R., Huinink, H.P. & Adan, O.C.G.	In-depth investigation of thermochemical performance in a heat battery : Cyclic analysis of K2CO3, MgCl2 and Na2S	Applied Energy	215, 159-173 2018
Englmair, G., Furbo S., Kong, W., Dannemand, M., Fan, J., Wang, Z.	Performance Evaluation of a Demonstration System with PCM for Seasonal Heat Storage: Charge with Evacuated Tubular Collectors	ISES Solar World Congress (SWC) 2017 conference	Abu Dhabi, United Arabian Emirates, 2018
Dannemand, M., Delgado, M., Lazaro, A., Penalosa, C., Gundlach, C., Trinderup, C., Berg Johansen, J., Moser, C., Schranzhofer, H., Furbo, S.	Porosity and density measurements of sodium acetate trihydrate for thermal energy storage.	Applied Thermal Engineering	131, pp. 707-714 2018
Englmair, G., Moser, C., Furbo, S., Dannemand, M., Fan, J.	Design and functionality of a segmented heat-storage prototype utilizing stable supercooling of sodium acetate trihydrate in a solar heating system	Applied Energy	221, pp. 522-534 2018
Deng, J., Furbo, S., Kong, W., Fan, J.	Thermal performance assessment and improvement of a solar domestic hot water tank with PCM in the mantle	Energy and Buildings	https://doi.org/10.1016/j.enbuild.2018.04.058 2018
Elpida Piperopoulos, Emanuela Mastronardo, Marianna Fazio, Maurizio Lanza, Signorino Galvagno, Candida Milone.	Enhancing the volumetric heat storage capacity of Mg(OH)2 induced by the addition of a cationic surfactant during its synthesis	Applied Energy	215 (2018) 512-522 2018
Elpida Piperopoulos, Emanuela Mastronardo, Marianna Fazio, Maurizio Lanza, Signorino Galvagno, Candida Milone	Synthetic strategies for the enhancement of Mg(OH)2 thermochemical performances as heat storage material	Energy Procedia (submitted)	
V. Brancato, L. Gordeeva, A. Sapienza, V. Palomba, S. Vasta, A. Grekova, A. Frazzica, Y. Aristov	Experimental characterization of the LiCl/vermiculite composite for sorption heat storage applications	International Journal of Refrigeration. Accepted paper	
Alenka Ristić, Fabian Fischer, Andreas Hauer, Nataša Zabukovec Logar	Improved performance of binder-free zeolite Y for	Journal of Materials Chemistry	https://doi.org/10.1039/C8TA00827B 2018

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Johnson, M., Vogel, J., Hempel, M., Hachmann, B. & Dengel, A.	Design of High Temperature Thermal Energy Storage for High Power Levels.	Sustainable Cities and Society	35 (November):758-763 https://doi.org/10.1016/j.scs.2017.09.007
Johnson, M., Vogel, J., Hempel, M., Dengel, A., Seitz, M., & Hachmann, B.	High temperature latent heat thermal energy storage integration in a co-gen plant.	Energy Procedia	73 (June 2015): 281- 288
Campos-Celador, M. Delgado, E. Franquet, S. Gibout, J. Mazo, J.Pascual, P. Sanchis, A. Lázaro	Estimation of the technical and economic feasibility of two hybrid –thermal and electrical– energy storage solutions in the residential sector	ENERSTOCK 2018	25-28 April 2018, Adana, Turkey
M.Delgado, A. Lázaro, J. Mazo, C. Peñalosa, J. M. Marín, B. Zalba	Experimental analysis of a coiled stirred tank containing a low cost PCM emulsion as thermal energy storage system. Comparison to other TES systems	ENERSTOCK 2018	25-28 April 2018, Adana, Turkey
Rinaldi, G.; Lázaro, A.; Delgado, M.; Marín, J. M.; Peñalosa, C.; Lozano, M. Á.l; Serrá, L.; Verda, V.	Study on seasonal and short-term thermal energy storage using a phase change material emulsion for district heating applications	ISES Solar World Congress (SWC 2017) & IEA Solar Heating and Cooling Programme´s SHC 2017 conference	Abu Dhabi, United Arab Emirates, October 29 - November 2, 2017
B. Fumey, R. Weber and L. Baldini	Sorption based long-term thermal energy storage – Process classification and analysis of performance limitations/ A review	Renewable & Sustainable Energy Reviews Journal	https://doi.org/10.1016/j.rser.2019.05.006
C. Moser, G. Englmair, H. Schranzhofer, A. Heinz.	Simulation study of a novel solar thermal seasonal heat storage system based on stable supercooled PCM for space heating and domestic hot water supply for single family houses.	Applied Mechanics and Materials	Volume 887. Pp. 650-658 2019
G. Englmair, C. Moser, J. Fan, S. Furbo	A solar combi-system utilizing stable supercooling of sodium acetate trihydrate for heat storage: Numerical performance investigation.	Applied Energy	Volume 242, pp. 1108-1120, 2019 2019
W. Kong, M. Dannemand, J. Brinkø berg, J. Fan, G. Englmair, J. Dragsted, S. Furbo.	Experimental investigations on phase separation for different heights of sodium acetate water mixtures under different conditions.	Applied Thermal Engineering	Volume 148, pp. 796-805, 2019

G. Englmair, C. Moser, S. Furbo, H. Schranzhofer, J. Fan.	Combined short and long-term heat storage with sodium acetate trihydrate for solar heat supply in buildings.	Poster presentation at Tværpolitisk klimadebat Conference, March 2019, Kgs. Lyngby, Denmark.	2019
G. Englmair, S. Furbo, M. Dannemand, G. Wang.	Combined short and long-term heat storage with sodium acetate trihydrate.	Poster presentation at open public seminar, May 2019, Ottawa, Canada.	2019
G. Englmair	Combined short and long-term heat storage with sodium acetate trihydrate for solar combi-systems. PhD Thesis.	Department of Civil Engineering, Technical University of Denmark, 2019	2019
Dr. Christian Luger (Liebherr Transportation Systems)	Project Tes4seT: “PCM-Storage for HVAC-systems in Railway vehicles”	held at Symposium on Thermal Storage 07.03.2019 Vienna.	2019
Application” Alexander Rauch, MSc (Virtual Vehicle Institute)	Project Tes4SeT: “Analysis of a PCM Storage-Evaporator for Railway-Transportation	held at Symposium on Thermal Storage 07.03.2019 Vienna	2019
Thomas Aigenbauer, et al. (FH-Wels)	Project SKEF: “Conditioning of electric vehicles interior with sorption storage material”	at IRES 2019 Poster Exhibition, 11.03.2019, Düsseldorf	2019
S. Fujii, N. Horie, K. Nakaibayashi, Y. Kanematsu, Y. Kikuchi, T. Nakagaki	Design of zeolite boiler in thermochemical energy storage and transport system utilizing unused heat from sugar mill	Applied Energy, Elsevier	238, pp561-571 https://doi.org/10.1016/j.apenergy.2019.01.104 2019
S. Fujii, Y. Kanematsu, Y. Kikuchi, T. Nakagaki, J. NW. Chiu, V. Martin	Techno economic analysis of thermochemical energy storage and transport system utilizing “Zeolite Boiler”: Case study in Sweden, Energy Procedia	Elsevier	149, pp102-111 https://doi.org/10.1016/j.egypro.2018.08.174 2018
S. Fujii, Y. Kanematsu, Y. Kikuchi, T. Nakagaki,	Humidified air injection for zeolite boiler in thermochemical energy storage and transport system utilizing unused heat from sugar mill	International Sustainable Energy Conference 2018 ISEC 2018, 154, Graz, Austria, Oct. 2018	2018
S. Fujii, K. Nakaibayashi, Y. Kanematsu, Y. Kikuchi, T. Nakagaki	Development of zeolite boiler in thermochemical energy storage and transport system utilizing unused heat from sugar mill	14th International Conference on Energy Storage EnerSTOCK201827 Adana, Turkey, April 2018, (Best paper Award)	
	Energy Procedia, 2019, (158), 4870-4881		TU Wien
	Energy Procedia, 2019, (158), 4861-4869; Int. J.		TU Wien

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L.C. Sögütoglu, M. Steiger, J. Houben, D. Biemands, H.R. Fischer, P.A.J. Donkers, H.P. Huinink, O.C.G. Adan	Understanding the Hydration Process of Salts: The Impact of a Nucleation Barrier, Cryst.	Growth Des.	19 (4), pp 2279–2288 https://doi.org/10.1021/acs.cgd.8b01908 2019
Z. Jiang, A. Palacios, X. Lei, M. E. Navarro, G. Qiao, E. Mura, G. Xu, Y. Ding	"Novel key parameter for eutectic nitrates based nanofluids selection for concentrating solar power (CSP) systems"	Appl. Energy	vol. 235, pp. 529–542, 2019
N. Navarrete, R. Mondragón, D. Wen, M. E. Navarro, Y. Ding, and J. E. Juliá	"Thermal energy storage of molten salt –based nanofluid containing nano-encapsulated metal alloy phase change materials"	Energy	vol. 167, pp. 912–920 2019
Awad, H. Navarro, Y. Ding, and D. Wen	"Thermal-physical properties of nanoparticle-seeded nitrate molten salts"	Renew. Energy	vol. 120, pp. 275–288 May 2018
Muñoz-Sánchez et al.,	"Rheology of Solar-Salt based nanofluids for concentrated solar power. Influence of the salt purity, nanoparticle concentration, temperature and rheometer geometry"	Solar Energy Materials Solar Cells	vol. 176, pp. 357–373 March 2018
Anagnostopoulos, A. Palacios, N. Navarrete, H. Navarro, Y Ding, Morroco	Effect of Temperature on the Internal Structure of Solar Salt-SiO2	Solar Paces 2018, Casablanca	
Fumey B., Weber R., Baldini L.	Sorption based long-term thermal energy storage – Process classification and analysis of performance limitations: A Review	Elsevier Renewable & Sustainable Energy Reviews	
Ristić, Alenka, Zabukovec Logar, Natasa	New composite water sorbents CaCl2−PHTS for low-temperature sorption heat storage: determination of structural properties.	Nanomaterials	Jan. 2019, vol. 9, iss. 1, p. 1-16, https://www.mdpi.com/2079-4991/9/1/27
Ristić, Alenka, Krajnc, Andraž, Zabukovec Logar, Nataša	New water adsorbent for adsorption driven chillers.	Eurosun 2018: proceedings of the ISES	
V: HÄBERLE, Andreas (ur.)	EuroSun2018:	EuroSun Conference, Sept 10-13, 2018, Rapperswil, Switzerland.	Freiburg: International Solar Energy Society. cop. 2018, p. 1-6.
C. Rathgeber, H. Schmit, S. Hiebler, W. Voigt	Application of the modified BET model to concentrated salt solutions with relatively high water activities: Predicting solubility phase diagrams	Article submitted to Calphad	

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V. Brancato, L. Gordeeva, A. D. Grekova, A-Sapienza, V. Palomba, S.Vasta, A. Frazzica, Y. I. Aristov	"Water adsorption equilibrium and dynamics of LiCL/MWCNT/PVA composite for adsorptive heat storage"	Solar Energy Materials and Solar Cells 2019, 193, 133-140	
Rocío Bayón and Esther Rojas	Development of a new methodology for validating thermal storage media: Application to phase change materials	International Journal of Energy Research	https://doi.org/10.1002/er.4589
	"Solid-State Reactions for the Storage of Thermal Energy"	Nanomaterials	2019, vol. 9, no 2, p. 226. https://doi.org/10.3390/nano9020226
	Conference publications: "Peritectic compounds for thermal energy storage: Experimental investigation and optimization strategy"	XI Congreso Nacional y II Internacional de Ingeniería termodinámica, 12-14 June Albacete, Spain	
Vogel, J. & Johnson, M. (2019)	Natural convection during the melting process in vertical shell-and-tube latent heat thermal energy storage systems with extended fins	Applied Energy	https://doi.org/10.1016/j.apenergy.2019.04.011
Johnson, M., Vogel, J., Hempel, M., Hachmann, B. & Dengel, A. (2017	Design of High Temperature Thermal Energy Storage for High Power Levels.	Sustainable Cities and Society	35(November):758-763. https://doi.org/10.1016/j.scs.2017.09.007
Johnson, M., Vogel, J., Hempel, M., Dengel, A., Seitz, M., & Hachmann, B. (2015)	High temperature latent heat thermal energy storage integration in a co-gen plant	Energy Procedia	73 (June):281- 288.
Johnson, M., Hübner, S., Braun, M., Schönberger, M., Martin, C., Fiß, M., Hachmann, B., & Eck, M. (2018)	Assembly and attachment methods for extended aluminum fins onto steel tubes for high temperature latent heat storage units	Applied Thermal Engineering	144, 96-105 https://doi.org/10.1016/j.applthermaleng.2018.08.035
Gibb, D., Johnson, M., Romaní, J., Gasia, J., Cabeza, L., & Seitz, A. (2018)	Process integration of thermal energy storage systems – evaluation methodology and case studies	Applied Energy, 230, 750-760,	https://doi.org/10.1016/j.apenergy.2018.09.001
Thermochemical Storage of medium temperature heat (200-400 °C) by Mg(OH)2/H2O/MgO	International Sustainable Energy Conference – ISEC 2018, October 3-6, 2018 Graz (Austria) – Oral presentation	International Sustainable Energy Conference – ISEC 2018, October 3-6, 2018 Graz (Austria)	
Thermochemical Storage of medium temperature	Eurotherm Seminar #112 Advances in Thermal Energy Storage, May 15-	Eurotherm Seminar #112 Advances in Thermal	

heat (200-400 °C) by Mg(OH)2/H2O/MgO	17, 2019 Lleida (Spain) – Oral presentation.	Energy Storage, May 15-17, 2019 Lleida (Spain)	
Elpida Piperopoulos, Emanuela Mastronardo, Marianna Fazio, Maurizio Lanza, Signorino Galvagno, Candida Milone	Synthetic strategies for the enhancement of Mg(OH)2 thermochemical performances as heat storage material	Energy Procedia	155 (2018), 269-279
Yukitaka Kato, Shigehiko Funayama, Elpida Piperopoulos, Candida Milone	Experimental methods for the characterization of materials for thermal energy storage with chemical reactions	Green Energy and Technology, PartF13 (2018), 103-117	
M. Faden, A. König-Haagen, D. Brüggemann	An Optimum Enthalpy Approach for Melting and Solidification with Volume Change	Energies 2019	vol. 12, Issue 5, p. 868, March 2019 https://doi.org/10.3390/en12050868
M. Faden, C. Linhardt, S. Höhlein, A. König-Haagen, D. Brüggemann	Velocity field and phase boundary measurements during melting of n-octadecane in a cubical test cell	International Journal of Heat and Mass Transfer	vol. 135, pp. 104-114, June 2019
H. Bahrehmand, M. Bahrami	An analytical design tool for sorber bed heat exchangers of sorption cooling systems	International Journal Refrigeration	100, 2019, 368-379
H. Bahrehmand, M. Khajehpour, M.Bahrami	Finding optimal conductive additive content to enhance the performance of coated sorption beds: An experimental study	Applied Thermal Engineering	143 (2018) 308-315
H. Bahrehmand, M. Ahmadi, M. Bahrami	Oscillatory heat transfer in coated sorber beds: An analytical solution	International Journal Refrigeration	https://doi.org/10.1016/j.ijrefrig.2018.05.006
H. Bahrehmand, M. Ahmadi, M. Bahrami	Analytical modeling of oscillatory heat transfer in coated sorption beds	International Journal Heat Mass Transfer	121 (2018) 1–9
L. Kouchachvili, R. Djebbar, M. Rouhani, M. Bahrami, (2018)	Characterization of commercial grade sodium sulfide for residential heating application	ISEC 2018, Graz, Austria	
H. Bahrehmand, M. Bahrami, (2019)	Optimal design of sorber beds for sorption systems”	5th International Energy Agency experts meeting, Ottawa	
R. Abadi, M. Bahrami, (2019)	Capillary assisted low-pressure evaporator for sorption cooling systems	5th International Energy Agency experts meeting, Ottawa	
M. Rouhani, M. Bahrami, (2019)	Thermochemical energy storage for residential applications	5th International Energy Agency experts meeting, Ottawa	

M. Bollwein, H. Bahrehmand, R. Abadi, M. Bahrami, (2019)	Potential integration of sorption cooling systems in PEM fuel cell buses	5th International Energy Agency experts meeting, Ottawa	
M. Rouhani, W. Huttema, C. McCague, M. Khajehpour and M. Bahrami, (2018)	Effects of storage period on the performance of salt composite sorption thermal energy storage	Heat Powered Cycles Conference 2018, Bayreuth, Germany	
Elpida Piperopoulos, Luigi Calabrese, Emanuela Mastronardo, Shahul Hameed Abdul Rahim, Edoardo Proverbio, Candida Milone	Assessment of sorption kinetics of carbon nanotube-based composite foams for oil recovery application	Journal of Applied Polymer Science	136 (2019), 47374
Vincenzo Fiore, Elpida Piperopoulos, Luigi Calabrese	Assessment of Arundo Donax Fibers for Oil Spill Recovery Applications	Fibers	7 (2019), 75
Gerald Englmair, Simon Furbo, Mark Dannemand	Combining Short and Long-Term Heat Storage for Solar Heating Systems	Solar Update	Vol. 69, 2019, pp. 14-15
C. Rathgeber, H. Schmit, S. Hiebler, W. Voigt	Application of the modified BET model to concentrated salt solutions with relatively high water activities: Predicting solubility phase diagrams of NaCl + H2O, NaCl + LiCl + H2O, and NaCl + CaCl2 + H2O	Calphad	66 (2019) 101633, https://doi.org/10.1016/j.calphad.2019.101633
E. S. Pinto, L. M. Serra, and A. Lázaro	Economic and environmental assessment of renewable energy and energy storage integration in standalone polygeneration systems for residential buildings	presented at the International Conference on Solar Heating and Cooling for Buildings and Industry, SHC 2019, Santiago de Chile, Chile, 2019. Poster	
E. Pinto, S., L. M. Serra, and A. Lázaro	Design and optimization of polygeneration systems for residential buildings integrating renewable energy, thermal energy storage and batteries considering legal restrictions	Presented at the XI Congreso Nacional y II Internacional de Ingeniería Termodinámica (11 CNIT), Albacete, Spain, 2019	
M. Delgado et al.	Intercomparative viscosity measurements of phase change materials. Standardization in the frame of IEA ECES Annex 24 and 29 and SHC Task 42	Presented at the XI Congreso Nacional y II Internacional de Ingeniería Termodinámica (11 CNIT), Albacete, Spain, 2019	
A. Lazaro, M. Delgado, A. König-Haagen, S. Höhlein, and G. Diarce	Technical performance assessment of phase change material components	Presented at the International Conference on Solar Heating and Cooling for Buildings and Industry, SHC 2019,	

		Santiago de Chile, Chile, 2019. Oral	
A. Lazaro, M. Delgado, A. König-Haagen, S. Höhlein, and G. Diarce	Technical performance assessment of phase change material components	Presented at the International Conference on Solar Heating and Cooling for Buildings and Industry, SHC 2019, Santiago de Chile, Chile, 2019. Oral	
A. Lazaro, M. Delgado, A. König-Haagen, S. Höhlein, and G. Diarce	Technical performance assessment of phase change material components	Presented at the International Conference on Solar Heating and Cooling for Buildings and Industry, SHC 2019, Santiago de Chile, Chile, 2019. Oral	
Maxime THONONa, Gilles Fraissea, Mickael Pailhaa, Laurent Zalewskib, (a LOCIE, Université Savoie Mont-Blanc; b LGCgE, Université d'Artois);	Caractérisation de matériau à changement de phase à partir d'études expérimentales et numériques	Journées Nationales de l'Énergie Solaire, June 2019, ANNECY Poster	
Ristić, Alenka, Fischer, Fabian, Hauer, Andreas, Zabukovec Logar, Nataša	Modified binder-free zeolite NaY for low-temperature sorption heat storage. Advances in thermal energy storage	Eurotherm Seminar #112, Lleida, 15-17 May 2019. Lleida: Universitat de Lleida. 2019, pp. 1-6	
Ristić, Alenka, FIscher, Fabian, Hauer, Andreas, Zabukovec Logar, Nataša	Zeolite Y as the water adsorbent for mobile sorption heat storage	19th International Zeolite Conference, Perth, Western Australia, July 7-12, 2019. Perth: 2019, pp. 1-2	
Ristić, Alenka, Zabukovec Logar, Nataša	Design of two-component sorbents for sorption heat storage	Proceedings of the 8th Serbian-Croatian-Slovenian Symposium on Zeolites, October 3-5, 2019. Belgrade, Serbia, pp. 145-148	
Stefania Doppiu, Jean-Luc Dauvergne, Elena Palomo del Barrio	Solid-State Reactions for the Storage of Thermal Energy	Nanomaterials	2019, vol. 9, no 2, p. 226. https://doi.org/10.3390/nano9020226
Elena Palomo	Peritectic compounds for thermal energy storage: Experimental investigation and optimization strategy	XI Congreso Nacional y II Internacional de Ingeniería termodinámica. June 2019, Albacete, Spain	
Herbinger, F., Patil, A., Groulx, D. (2019)	Characterization of Different Geometrical Variations of a Vertical Finned Tube-and-Shell Heat Exchanger	Eurotherm Seminar #112 Advances in Thermal Energy Storage, Lleida, Spain, 10 p.	
Groulx, D., Herbinger, F. (2019)	Efforts vers des règles de design d'échangeurs de chaleur avec des	XIVème Colloque International Franco-Québécois en énergie,	

	matériaux à changement de phase	Baie St-Paul, Québec, Canada, 6 p.	
S. N. Gunasekara, S. Soprani, A. Karabanova, V. Martin and D. Blanchard	Numerical Design of a Reactor-Heat Exchanger Combined Unit for Ammonia-SrCl2 Thermochemical Storage System	ISES Solar World Congress (ISES SWC) / SHC 2019, November 2019, Santiago, Chile	
Ostermeier, P.; Vandersickel, A.; Gleis, S.; Spliethoff, H.	Numerical Approaches for Modeling Gas–Solid Fluidized Bed Reactors: Comparison of Models and Application to Different Technical Problems	Journal of Energy Resources Technology	141 (7), 2019, 070707
Ostermeier, P.; DeYoung, S.; Vandersickel, A.; Gleis, S.; Spliethoff, H.	Comprehensive investigation and comparison of TFM, DenseDPM and CFD-DEM for dense fluidized beds	Chemical Engineering Science	196, 2019, 291-309
Vandersickel et al.,	Hoch-Temperatur Wärmespeicherung in MW-Maßstab: von grundlegenden Experimenten bis zur Anwendung	Keynote at VDI-GEU Thermodynamik-Kolloquium 2019	
Würth, M.; Becker, M.; Talebi, E.; Gleis, S.; Vandersickel, A.; Spliethoff, H.	Thermochemical Energy Storage Employing Fluidized Bed Technology: Experimental Investigations with CaO/Ca(OH)2 on a 21kWh Reactor	FLUIDIZATION XVI, 2019	
Ostermeier, P.; Vandersickel, A.; Spliethoff, H.	Thermochemische Energiespeicher für Industrie und Kraftwerke	Fachkongress SolarChemieR, 2019	
Ostermeier, P.; Vandersickel, A.; Spliethoff, H.	Thermochemische Energiespeicher für Industrie und Kraftwerke.	Fachkongress SolarChemieR, 2019	
Würth, M.; Becker, M.; Härzschel, S.; Angerer, M.; Ostermeier, P.; Vandersickel, A.; Gleis, S.; Spliethoff, H.	Thermochemische Energiespeicherung Wärmespeicherung im Wirbelschichtverfahren	Fachforum Thermische Energiespeicher, 2019	
	The results of the RT70HC thermal diffusivity round robin as well as the SrBr2·xH2O specific heat capacity round robin were presented	Experts meeting in Messina on 10th of October 2019	

Conferences and Workshops

Task participants presented Task work and results at 35 conferences and workshops over the course of the Task.

Task Meetings

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

1. Graz, Austria April 2016
2. Vienna, Austria September 2016

Over the entire term of the Task a total of 6 Experts Meetings were held and 1 workshop.

Task Meetings

Meeting	Date	Location	# of Participants (# of Countries)
Experts Meeting 1	April 5-7, 2017	Lyon, France	60 (13)
Experts Meeting 2	October 4-6, 2017	Dübendorf, Switzerland	45 (12)
Experts Meeting 3	April 9-11, 2018	Ljubljana, Slovenia	46 (11)
Experts Meeting 4	October 1-3, 2018	Graz, Austria	42 (11)
Experts Meeting 5 *Plus, a workshop*	May 1-3, 2019	Ottawa, Canada	40 (11) 30
Experts Meeting 6	October 9-11, 2019	Messina, Italy	41 (13)

SHC Task 58 Participants

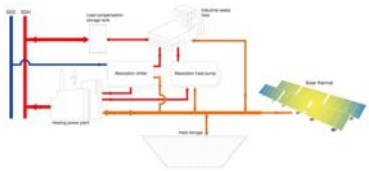
Country	Name	Institution / Company	Role
AUSTRIA	**Wim van Helden**	**AEE INTEC**	**SHC Operating Agent**
GERMANY	**Andreas Hauer**	**ZAE Bayern**	**ECES Operating Agent**
AUSTRIA	Bernhard Zettl	ASiC-Austria Solar Innovation Center	National Expert
AUSTRIA	Danny Müller	TU Vienna	National Expert
AUSTRIA	Daniel Lager	AIT Austrian Institute of Technology GmbH	Subtask 3T Leader
AUSTRIA	Hermann Schranzhofer	Graz University of Technology	National Expert
CANADA	Reda Djebbar	CanmetENERGY	National Expert
CANADA	Dominic Groulx	Dalhousie University	National Expert
CANADA	Majid Bahrami	Simon Fraser University	National Expert
CANADA	Handan Tezel	University of Ottawa	National Expert
DENMARK	Simon Furbo	DTU	National Expert
DENMARK	Gerald Englmair	DTU	National Expert
FRANCE	Sylvie Rougé	CEA	National Expert
FRANCE	Erwin Franquet	LaREP-ENSGTI	National Expert
FRANCE	Frederic Kuznik	INSA-Lyon	National Expert
FRANCE	Laurent Zalewski	University of Artois	National Expert
FRANCE	Lingai Luo	University of Nantes	National Expert
GERMANY	Andreas König-Haagen	University Bayreuth	National Expert
GERMANY	Christoph Rathgeber	ZAE Bayern	Subtask 3P Leader
GERMANY	Konstantina Damianos	University of Kassel	National Expert
GERMANY	Roger Gläser	PCM-Technologie und Thermische Analyse Consultant	National Expert
GERMANY	Maike Johnson	Rubitherm Technologies GmbH	National Expert
GERMANY	Stefan Gschwander	German Aerospace Center	National Expert

GERMANY	Henner Kerskes	University of Stuttgart	National Expert
GERMANY	Thomas Badenhop	Fraunhofer ISE	Subtask 2P Leader
GERMANY	Thomas Herzog	Vaillant GmbH	National Expert
GERMANY	Annelies Vandersickel	TH Wildau	National Expert
ITALY	Andrea Frazzica	CNR	National Expert
ITALY	Candida Milone	University of Messina	National Expert
NETHERLANDS	Henk Huinink	Eindhoven University of Technology	National Expert
NETHERLANDS	Ruud Cuypers	TNO	National Expert
SLOVAKIA	Alenka Ristic	NIC	Subtask 2T Leader
SPAIN	Ana Lazaro	University Zaragoza	Subtask 4P Leader
SPAIN	Ana Garcia Romero	Ingeneniería Minera y Metalúrgica y Ciencia de los Materiales	National Expert
SPAIN	Camila Barreneche	University of Lleida	National Expert
SPAIN	Luisa Cabeza	University of Lleida	National Expert
SPAIN	Gonzalo Diarce	University of the Basque Country	National Expert
SPAIN	Rocio Bayón	CIEMAT	National Expert
SPAIN	Elena Palomo del Barrio	CIC EnergyGune	National Expert
SWEDEN	Viktoria Martin	KTH Royal Institute of Technology	National Expert
SWEDEN	Saman Gunasekara	KTH Royal Institute of Technology	National Expert
SWITZERLAND	Anastasia Stamatiou	Hochschule Luzern	National Expert
SWITZERLAND	Benjamin Fumey	EMPA	Subtask 4T Leader
SWITZERLAND	Paul Gantenbein	SPF	National Expert
TURKEY	Cemil Alkan	Gaziosmanpsa University	National Expert
TURKEY	Halime Paksoy	Çukurova University	National Expert
UNITED KINGDOM	Philip Griffiths	Ulster University	National Expert
UNITED KINGDOM	Jonathon Elvins	SPECIFIC, Swansea University	National Expert

6. Ongoing Tasks

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

Sabine Putz
SOLID Solar Energy Systems GmbH
Operating Agent for the Republic of Austria



Task Overview

IEA SHC Task 55 elaborates on 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 aim 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 is 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 is 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)

Scope

Subtask A: Network Analyses and Integration

The main research questions of Subtask A are how to integrate significant shares of ST, what the impact on other generation units is, how to solve the integration technically, and what measures are suitable to maximize the share of solar thermal applications.

The expected outcomes are collection of best practice examples and case studies; energetic, ecologic and economic assessments of the overall solar DHC system; possible transformation strategies of DHC networks towards high shares of ST; lessons learnt on challenges and benefits of ST integration; and optimized control strategies and hydraulic options for the integration of SHC systems into DHC networks.

Subtask B: Components Testing, System Monitoring, and Quality Assurance

The main research objective of Subtask B is to elaborate on methods for in in-situ collector tests, hybrid elements, and provide methods for simple thermal and energy performance proofs. Furthermore, it will provide data on automated monitoring and failure detection software for key components and develop and describe control strategies for self-learning control systems.

Subtask C: Design of the Solar Thermal System and of Hybrid Technologies

Subtask C focuses on the simulation and design of solar thermal systems and components (storage, piping and others, e.g. heat pumps). The Subtask elaborates on characteristics of collector array units, large and seasonal storages, hydraulics, and heat pumps within system operations. Large scale collector fields will be simulated and compared to the measurements in Subtask B. If needed, the simulation tool will be corrected. Parameters of seasonal storages will be calculated and guidelines for the design and construction of different storage types updated. Hydraulics within systems are sensitive to a variety of parameters. These parameters will be optimized. Piping within large systems will be investigated as well and options for a modular conception and construction for very large systems.

Subtask D: Promotion and Dissemination of SDH/SDC and Hybrid Technologies in New Markets

Subtask D elaborates economic aspects and the promotion of results from SHC Task 55. Large scale solar thermal systems require sophisticated financing models due to high initial investment costs. Different business models are already in place and facilitate the realization of large systems. The subtask will assist planers, architects, system designers and district heating providers in their efforts for the integration of DHC applications. Stakeholders face several economic challenges and risks and can benefit from the deliverables of this subtask.

Best practice examples will collect information on different system types already in operation. Moreover, the subtask will assist the other subtasks in the promotion and dissemination of their results.

Collaboration with other IEA TCPs

The District Heating and Cooling including Combined Heat and Power Programme (IEA DHC) is officially collaborating with SHC Task 55 on a ***moderate*** level as defined by the IEA SHC.

Collaboration with Industry

Eighteen companies are actively providing expertise to SHC Task 55. As most of them are not funded for the Task work, their contribution is to highlight the work.

Several SDH installations have been built as a result of cooperation that began during Task meetings. As the SDH market is still a niche market, it´s very important that strategic business cooperation has been established among the Task Experts over the Task period.

Task Duration

The Task started in September 2016 and will end in August 2020.

Participating Countries

Austria, Canada, China, Denmark, Finland*, France, Germany, Italy, Spain, Sweden, United Kingdom

**Through IEA DHC*

Work During 2019

Subtask A: Network Analyses and Integration

- *Solar Energy into District Heating Networks* finalized and published on the Task 55 webpage.
- Summary of the Joint DHC and SHC Workshop in 2018 in Graz published on the SHC Task 55 and on the DHC Annex TS2 webpage. A presentation of the joint workshop is available.
- Final definition of the template completed for data collection and identification of best practice examples (in synergy with Subtask D).
- Data collection identified best practice examples.
- SWOT analysis published on the Task 55 webpage.
- Economic data (necessary input to evaluate or develop possible transformation strategies) of Danish solar district heating systems collected.
- Forecast study, “Evolution of the Austrian district heating and the role of solar thermal: scenarios for 2030,” completed.
- First results achieved on compressed heat storage for cross-sectoral integration of renewables from the H2020 project CHESTER.
- Simulation-based, techno-economic evaluation of different large-scale heat storage sizes and configurations completed.
- Developed and validated a numerical model in Dymola/Modelica for pit TES.
- Results from Austrian project Urban-DH-extended: lessons learned and guidelines for large-scale solar thermal and storage applications for DH.

- Developed innovative business models for reducing return temperatures in DH networks.
- Progress on H2020 demonstration project TEMPO about temperature reduction in existing urban DH systems.
- Progress on simulation-based development of a fault detection and diagnostics algorithm for district heating systems.
- Implemented a modular MILP-based Energy Management System for the operation of cross-sectoral energy systems in two real case studies + sensitivity analysis based on co-simulation for a new planned district.

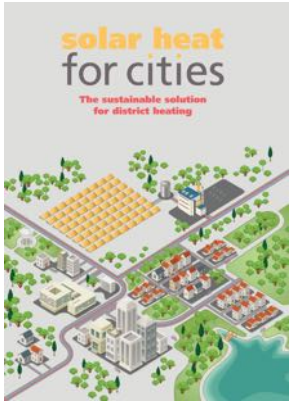
Subtask B: Components Testing, System Monitoring, and Quality Assurance

- Radiation model developed, which allows precise prediction of thermal output of collector arrays.
- Improved control of absorption heat pumping systems by means of model-based control approaches that explicitly consider the machine's dynamic operational behavior.
- ISO 9806:2017 - collector test methods available.
- First monitoring results of installation in Tibet.
- Improved control of absorption heat pumping systems by means of model-based control approaches that explicitly consider the machine's dynamic operational behavior. Mathematical modelling of a water/lithium bromide heat pumping system for control purposes.

Subtask C: Design of the Solar Thermal System and of Hybrid Technologies

- Completed final draft Fact Sheets from work on simulation and design of collector array units within large systems:
    - C.D1.1: Long-term thermal performances of solar collector fields: Measured and calculated
    - C.D1.2: Solar radiation modelling on tilted surfaces based on global radiation
    - C.D1.3: Collector types for large collector fields: Thermal performance and control strategies
    - C.D1.4: CFD models of different collector types
- Modelling of large-scale TES (thermal energy storages) results from the gigaTES project are available as well as CFD based studies on the heat transfer in large TES.

Subtask D: Promotion and Dissemination of SDH/SDC and Hybrid Technologies in New Markets



- Published an investor brochure, *Solar Heat for Cities: The Sustainable Solution for District Heating* (http://task55.iea-shc.org/publications). Info charts from the publication are also on the Task webpage (http://task55.iea-shc.org/)
- Completed 15 out of the 20 Fact Sheets on best practice installations.
- Produced additional Country reports (Austria, Canada, Denmark, France, Germany, and The Netherlands).
- Drafted Fact Sheets on the country reports for Austria, Denmark, France, and The Netherlands.
- CEA Ines is developing a calculation tool for renewable heat production installations. A first version was finished in French and will also be available in English.
- WIKI on solar district heating created by Richard Hall, the SHC UK ExCo member, https://wiki.energytransitions.uk/wiki/Solar_Heat_Networks.

Work Planned For 2020

Subtask A: Network Analyses and Integration

- Subtask A: Network Analyses and Integration:

    - Collect and analyze more transformation strategies - from Partners and literature.
- Subtask B: Components Testing, System Monitoring, and Quality Assurance
    - Heat pump controls: Adjustments of model complexity (according to application). Development of a dynamic model for ammonia/water absorption heat pumping systems. Development of model-based control strategies for both systems
- All Subtasks: publish final Fact Sheets

Dissemination Activities In 2019

Reports, Published Books

Author(s)/Editor	Title	Report No. Publication Date
Bärbel Epp	Solar Heating for Cities: The Sustainable Solution for District Heating	November 2019

Journal Articles, Conference Papers, Press Releases, etc.

Author(s)/Editors	Title	Publication/Conference	Bibliographic Reference
Abdulrahman Dahash, Fabian Ochs, Michele Bianchi Janetti, Wolfgang Streicher	Advances in seasonal thermal energy storage for solar district heating applications: A critical review on large scale hot-water tank and pit thermal energy storage systems	Applied Energy	Vol. 239, pp. 296-315, 2019
Abdulrahman Dahash, Fabian Ochs, Wolfgang Streicher	Large-Scale Thermal Energy Stores	Submitted to Energy and Buildings	Energy and Buildings Journal
Bärbel Epp	GBD 320 million for low carbon heat networks Combining the strengths of the collector technologies Sun meets 90% of district heating demand in Tibetan town Seasonal pit heat storage: Cost benchmark of 30€/m³ 1 GW - Danish SDH market reaches new milestone	solarthermalworld.org	https://www.solarthermalworld.org/news/gbp-320-million-low-carbon-heat-networks https://www.solarthermalworld.org/news/combining-strengths-collector-technologies https://www.solarthermalworld.org/news/sun-meets-90-district-heat-demand-tibetan-town https://www.solarthermalworld.org/news/seasonal-pit-heat-storage-cost-benchmark-30-eurm3 https://www.solarthermalworld.org/news/danish-sdh-market-reaches-new-milestone

Richard Hall	Solar District Heating	WIKI	https://wiki.energytransitions.uk/wiki/Solar_Heat_Networks
Aurelien Bres	Fault detection in building installations	TEMPO workshop, November 2019, Italy	
Hamid Aghaie	The role of solar thermal in the Austrian district heating – Scenarios for 2030	Sustainable District Energy Conference, October 2019, Iceland	
Paolo Leoni, Roman Geyer, Ralf-Roman Schmidt	Developing innovative business models for reducing return temperatures in district heating systems: approach and first results	5th International Conference on Smart Energy Systems, September 2019, Denmark	
Aurelien Bres, Christian Johansson, Roman Geyer, Paolo Leoni, Johan Sjögren	Coupled Building and System Simulations for Detection and Diagnosis of High District Heating Return Temperatures	Building Simulation 2019: 16th Conference of IBPSA, September 2019, Italy	
Daniel Tschopp	Project MeQuSo	Connexio: Symposium Solarthermie und innovative Wärmesysteme, May 2019, Germany	

Conferences, Workshops, Seminars

Conference/ Workshop/ Seminar	Activity & Presenter	Date & Location
Solar Academy Webinar - Task 55	Task Experts: Karin Rühling, TU Dresden; Sabine Putz, SOLID; Jan-Erik Nielsen, PlanEnergi; Lucio Mesquita, NRCAN; Jianhua Fan, DTU	March 21, 2019 Online
SDH/Task 55 Workshop *(SHC Solar Academy supported)*	Task Experts: Jan-Erik Nielsen and Christian Holter	March 8, 2019 London, UK
IEA Solar Heating and Cooling Research Co-operation; Workshop in the Austrian Ministry; presentation on Task 55 results	OA Sabine Putz	June 5, 2019 Vienna, Austria
District Heating of the Future Workshop	Joakim Byström, ABSOLICON; OA Sabine Putz	October 9, 2019 Härnösand, Sweden
SHC 2019/SWC 2019 – Task 55 Keynote speech	Sabine Putz	November 5, 2019 Santiago, Chile

Renewable Heat for Heat networks Conference *(SHC Solar Academy supported)*	Richard Hall (UK ExCo) and task experts: Grant Feasey, Christian Holter, Magdalena Kowalska, Renaldi Renaldi	December 4, 2019 London, UK

Dissemination Activities Planned For 2020

Completion of all reports and Fact Sheets.

Task 55 Transfer Workshop (half day side event) at ISEC 2020 - 2nd International Sustainable Energy Conference, 14 - 16 October 2020, Graz, Austria.

17th International Symposium for District Heating and Cooling, 6 - 9 September 2020, Nottingham, UK.

Task Meetings 2019 - 2020

Meeting	Date	Location	# of Participants (# of Countries)
Experts Meeting 6	March 8-10, 2019	Almeria, Spain	29 (11)
Experts Meeting 7 *(included workshop)*	October 7-9, 2019	Härnösand, Sweden	18 (11)
Final Experts Meeting 8	May 26-28, 2020	Stuttgart, Germany	

SHC Task 55 Participants

Country	Name	Institution / Company	Role
AUSTRIA	**Sabine Putz**	**SOLID**	**Operating Agent**
AUSTRIA	Christian Engel	Thermaflex Int Holding	National Expert
AUSTRIA	Christian Fink	AEE INTEC	National Expert
AUSTRIA	Christian Holter	SOLID	National Expert
AUSTRIA	Carles Ribas Tugores	AEE INTEC	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 Engel	AEE INTEC	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
AUSTRIA	Christian Holter	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	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	Gunnar Lennermo	Energianalys AB	National Expert
UNITED KINGDOM	Joshua King	AES Solar	National Expert

Task 56 – Building Integrated Solar Envelope Systems for HVAC and Lighting

Roberto Fedrizzi
EURAC Research
Operating Agent for ENEA

Task Overview

In the residential sector, solar thermal and PV systems are typically mounted on building roofs with limited attempt to incorporate them into the building envelope, creating aesthetic drawbacks and space availability problems. On the contrary, the use of facades is highly unexplored. Daylight control is delegated to the individuals' management of blinds and curtains, leading to high thermal loads, both during midseason and summertime.

In the tertiary segment (offices, schools, hospitals), the roof is again, most of the times, the only surface devoted to the installation of solar thermal and PV technologies. While daylight control nowadays is here state of the art in terms of shading effect, the utilization of shading devices to also redirect natural light into the room, improving visual comfort at the same time, has still to be deepened.

When energy efficient technologies are installed together with traditional ones, frequently they are just "added on top" of the main systems, resulting in high investment costs and low performance optimization. An interesting option to overcome this competition is to combine multiple functions in envelope components thus enabling hybrid systems to simultaneously cover different energy, comfort, and aesthetic needs.

SHC Task 56 focuses on simulation, laboratory tests and monitoring of multifunctional envelope systems that use and/or control solar energy, influencing thermal energy demand, thermal energy consumption, and comfort of the building.

The strategic objective of SHC Task 56 is to coordinate the research and innovation effort, taking place within the scientific community and the private sector towards the utilization of envelope integrated technologies by:

- Gathering relevant information on market available and "under-development" solar envelope systems both in terms of performance and costs.
- Assessing test methods and simulation models for the performance characterization of solar envelope elements.
- Developing design and installation guidelines for solar envelope systems, accounting for technological, architectural/aesthetical, economic, financing and customer acceptance viewpoints.
- Assessing and elaborating on business models for solar envelope systems.

The Task's work is divided into three subtasks:

- Subtask A: Solar Envelope Systems Classification and Communication (Norway)
- Subtask B: Performance Characterization of Solar Envelope Elements (Germany)
- Subtask C: Assessment of Solar Envelope Systems at Building Level (Austria)

Scope

Subtask A: Solar Envelope Systems Classification and Communication

An overview of products and solutions of solar envelope systems, which are presently available on the market, is now available in Subtask A. Work is focused on a market analysis to assess existing solutions through a literature review and the advice of the experts participating. Moreover, standards, test methods, and numerical tools will be categorized. Different products and solutions to be evaluated through a SWOT analysis, accounting for technical and non-technical issues, which in the past have determined the success or the failure of solar envelope systems.

A major activity of Subtask A is to attract and involve central actors, decision-makers, planners, builders, architects,

experts from research and industry. This will be achieved by the exchange of information generated in all Subtasks through local workshops, newsletters and an updated public website (Activity A.3).

Subtask B: Performance Characterization of Solar Envelope Elements

Subtask B aims to develop tools and strategies to foster the market penetration of industrialized solar envelope systems. In particular, it focuses on the solar envelope elements intended as the sub-systems strictly incorporated in the building envelope.

Solar envelope elements need to be integrated into the construction process at the early planning stage. To this purpose, planners need to be provided with the necessary information – integration parameters, performance measurements and modeling, etc. – when starting their task. The end target of the Subtask is a successful construction process that includes the transfer of knowledge and models, for example, between the component manufacturers and the planners of the building.

The key, therefore, is the involvement of an industrial partnership from the very beginning of the program. The activities reported next will be elaborated only with reference to the specific elements suggested by the manufacturers involved in the Task.

Subtask C: Assessment of Solar Envelope Systems at Building Level

In Subtask C complete solar envelope systems are defined based on active and passive components and integrated into the HVAC system of reference buildings. Buildings will serve as virtual case studies with the specific envelope elements proposed by the industrial partners integrated into them.

The Subtask is performed in two parallel and interacting activities:

- Solutions that are technically and economically meaningful are identified through building and HVAC simulations. A decision support instrument (pre-design tool) will be developed as part of this activity, allowing simplified calculations to be performed.
- Existing systems are evaluated by monitoring installed demonstration systems.

The solutions will be evaluated based on reference conditions and KPIs also defined in Subtask C.

Collaboration with Industry

Following each Task meeting industry workshops are organized to get in contact with industry stakeholders and to get feedback on the status and perspectives on the local solar envelopes market. In Activities A1 and A2 (state-of-the-art analysis), several manufacturers and companies were called to contribute to the analysis of solar envelope solutions and showed their interest in results of such analysis and, in general, to the activities of the Task.

In addition, industry workshops have been organized throughout the duration of the task to create valuable occasions for sharing views and ideas and discussing the topic of solar envelopes from the research and industry perspectives.

The kick-off meeting at EURAC in Bolzano was attended by 28 experts from 24 different institutions. The majority of experts was coming from Universities and Research centers, but a good participation by Industry (7 companies) was also registered, which expressed their intention to actively participate in the project elaboration.

During the second meeting held in Darmstadt, 25 experts where present out of which 5 from industry. 2 observers from BASF and MERCK glasses presented their developments in the sector of advanced solutions for the active solar gains control. The China International Investment Promotion Agency also participated in disseminating their activates and seeking for possible collaboration in China.

During the third meeting held in Dublin, 24 experts were present out of which 5 from industry. Three additional industry representatives participated in the first industry workshop.

Sixteen experts from the well-established group of participating entities have actively contributed to the meeting in Eindhoven. Overall, eight external manufacturers joined with different levels of contribution to the meeting.

During the Task meeting in Montreal in September 2018, an industry workshop was organized bringing together BIPV-BIST manufacturers, large utility companies and Canadian associations. During a first session of presentations and round table, manufacturers (Livio Nichilo (Internat Energy Solutions), Samuel Doyon-Bissonnette

(Unicel Architectural), Ronald Drews (Canadian Solar), John Hollick (Conserval), Ady Vyas (S2E)) presented their latest developments with respect to building integrated solar technologies, while barriers and market opportunities were discussed in a round table. In the second session, the focus of the presentations and related discussion was posed on how BIPV can contribute to the flexibility of the single buildings and the electric distribution grids, allowing utilities to offer new services to customers while improving the grid management, reducing load peaks.

During the 7th meeting held in Copenhagen in March 2019, an industry workshop has been organized in collaboration with "Smart Energy Green Cities", bringing together a total of 22 experts including architects, urban planners, manufacturers and a representative of a utility company.

Task Duration

The Task started in February 2016 and will be completed in January 2020.

Participating Countries

Austria, Canada, Denmark, Germany, Italy, Netherlands, Norway, Spain

Work During 2019

Subtask A: Solar Envelope Systems Classification and Communication

During the last year, the analysis of the solar active envelopes state-of-the-art (Deliverable DA1-2) was finalized. The report includes an analysis of the state of the art of commercial and "under development" systems as well as a SWOT analysis of the solutions. The objective was three-fold, to achieve a more comprehensive view of the market evolution, to disseminate initial Task results, and to increase industry involvement.

Installation of a ventilated façade based on glass-glass back-contact c-Si cells technology BIPV modules at Tecnalia's offices in San Sebastian, Spain. Source: ONYX SOLAR.

The original version of the products deliverable included the analysis of 15 different products developed by active partners of the Task, but thanks to the work performed in the last year it was possible to contact experts and manufacturers in the sector that are not active in the Task and extend the sample of analyzed products and collect a wider range of experiences. The report now includes a total of 30 contributions, 15 of which were submitted or revised by external experts or manufacturers. The material provided by all contributors to this product analysis underwent a quality check and a process of improvement of the content. Starting from the product analysis, it has been possible to describe common threats and opportunities as well as future trends of solar envelope systems. This information has been gathered in the section "Lessons learned" of the report.

Subtask A experts also worked on maintaining and updating the website with relevant information on publications, participation at conferences and submission of journal papers by the Task participants. A new website page with images and short explanations ("Image gallery") on the system integration is under development.

An industry workshop was organized during the last Task meeting in Copenhagen, where it has been possible to bring together architects, urban planners, manufacturers and utility companies to discuss the role of solar envelope solutions in the current and future panorama.

Project partners have also been involved in presenting solutions at conferences and workshops (more information in the related tables below).

Subtask B: Performance Characterization of Solar Envelope Elements

During the last months of 2019, the deliverable DB4 was finalized and posted on the Task webpage. It reports on a critical analysis of simulation models suited for solar envelope elements.

Task experts also have worked on elaborating strategies for market penetration of building integrated solar envelope systems (DB2). During the 8th Task 56 meeting in Freiburg, participants discussed how to improve the work, as this is considered one of the most relevant outcomes of the Task. The structure is now agreed, and the participants are working on finalizing the content by the end of the Task.

Concerning Activity B.3, over the year experts worked on drafting a report on standards and norms. The work is only partially finalized, and participants have defined how to further improve the quality of the work by analyzing standards from the daylight and BIPV sectors in addition to the work performed on the solar thermal sector and investigating the “solar” standards interact with the construction sector standards. All the considerations elaborated on will serve as a basis for recommendations on future standardization improvements.

Subtask C: Assessment of Solar Envelope Systems at Building Level

Activity C1 formally ended with the finalization of deliverable DC.1 on system simulation models in 2018. Nonetheless, the experts have worked along 2019 to further enhancing the quality of the report bringing it to its final state. In the next days the deliverable will be finally published on the Task website.

In Activity C.2, the performance of a range of solar envelope system is being analyzed. Task experts are simulating the performance of a range of building integrates solar envelope systems, when integrated in the reference buildings developed in Activity C.1 and when used in different climate conditions. At the same time the data analysis method is under discussion: while energy and LCA related KPIs have been agreed upon, economic performance figures are still under discussion, as costs are critical parameters that can easily lead to erroneous comparisons.

Concerning Activity C.4, the work for gathering and analyzing monitoring data from demonstration installations has continued: two case studies are under evaluation, namely the Varannes Library in Canada and a residential building in Innsbruck.

Dissemination Activities In 2019

Reports, Published Books

Author(s)/Editor	Title	Report No. Publication Date
Paolo Bonato, Roberto Fedrizzi, Matteo D’Antoni, Michaela Meir	State-of-the-art and SWOT Analysis of Building Integrated Solar Envelope Systems	Deliverable A.1 and A.2 November 2019
Ellika Taveres-Cachat, Roel C.G.M. Loonen, Johannes Eisenlohr, Francesco Goia, Christoph Maurer	Simulation Models of Solar Envelope Components	Deliverable B.4 December 2019

Journal Articles, Conference Papers, Press Releases, etc.

Author(s)/Editor	Title	Publication / Conference	Bibliographic Reference
Loonen, R.C.G.M., de Klijn – Chevalerias, M.L. & Hensen, J.L.M.	Opportunities and Pitfalls of Using Building Performance Simulation in Explorative R&D Contexts	Journal of Building Performance Simulation, 12(3), 2019, 272-288	
Bärbel Epp	SWOT analysis of building-integrated solar systems	Solarthermalworld.org	https://www.solarthermalworld.org/news/swot-analysis-building-integrated-solar-systems

Conferences, Workshops, Seminars

Conference/ Workshop/ Seminar	Activity & Presenter	Date & Location
Austrian Industry Meeting	Workshop	June 6, 2019 Vienna, Austria
Solar Academy Webinar - Task 56	Webinar Task Experts: Roberto Fedrizzi, Fabian Ochs, Martin Hauer	September 18, 2019 Online

Task Meetings 2019 - 2020

Meeting	Date	Location	# of Participants
Experts Meeting 7	March 5-6, 2019	Copenhagen, Denmark	11
Experts Meeting 8	October 24-25, 2019	Freiburg, Germany	17
Final Experts Meeting 9	February 3-4, 2020	Bolzano, Italy	

SHC Task 56 Participants

Country	Name	Institution / Company	Role
ITALY	**Roberto Fedrizzi**	**EURAC**	**Operating Agent**
AUSTRIA	Fabian Ochs	University Innsbruck	Subtask C Leader
AUSTRIA	Mara Magni	University Innsbruck	National Expert
AUSTRIA	David Venus	AEE INTEC	National Expert
AUSTRIA	David Geisler-Moroder	Bartenbach GmbH	National Expert
AUSTRIA	Martin Hauer	Bartenbach GmbH	National Expert
CANADA	John Hollick	Solar Wall	National Expert
CANADA	Zissis Ioannidis	Concordia University	National Expert
CANADA	Efstratios Rounis	Concordia University	National Expert
DENMARK	Vickie Aagesen	Cenergia	National Expert
GERMANY	Christoph Maurer	Fraunhofer ISE	Subtask B Leader
GERMANY	Bruno Bueno	Fraunhofer ISE	National Expert
GERMANY	Paul-Rouven Denz	Facade-Lab GmbH	National Expert
GERMANY	Jan de Boer	Fraunhofer IBP	National Expert
GERMANY	Carolin Hubschneider	Fraunhofer IBP	National Expert
ITALY	Matteo D'Antoni	EURAC	National Expert
ITALY	Paolo Bonato	EURAC	National Expert
NETHERLANDS	Roel Loonen	Eindhoven University of Technology	National Expert
NETHERLANDS	Samuel de Vries	Eindhoven University of Technology	National Expert
NORWAY	Michaela Meir	Aventa	Subtask A Leader
NORWAY	Francesco Goia	NTNU, Felles fakturamottak	National Expert
NORWAY	Ellika Taveres-Cachat	NTNU, Felles fakturamottak	National Expert
SPAIN	Roberto Garay	Tecnalia	National Expert

Task 59 – Renovating Historic Buildings Towards Zero Energy

Alexandra Troi
EURAC Research
Operating Agent 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. In order to preserve this heritage, we need to find conservation compatible energy retrofit approaches and solutions, which allow to maintain 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)

Subtasks

Subtask A: Knowledge base
Collection of Best Practice cases, following the approach of IEA SHC Task 37 and 47. Assessment of existing experience and identify energy saving potential.

Subtask B: Multidisciplinary planning process
Identification of replicable procedures on how experts can work together to maintain both the expression of the building, and at the same time make it more energy efficient. Identification and further development of tools to support the process and its single steps.

Subtask C: Conservation compatible retrofit solutions and strategies
Identification of replicable solutions from case studies. Connection to and integration of ongoing R&D on conservation compatible retrofit solutions. Assessment of technical solutions from both energy and conservation point of view.

Subtask D: Knowledge transfer and dissemination
Transfer of knowledge created in the Task to relevant stakeholders

Collaboration with Other IEA TCPs

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

Collaboration with Industry

Stakeholders of Task 59 are besides the building owners, clearly architects and planners as well as craftsmen and constructors but also public authorities and policy makers. They all are addressed in different ways in order to gather their input and needs and bring results to their realities.

Task Duration

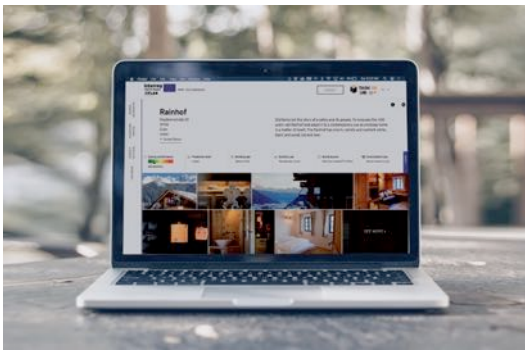
The Task started in September 2017 and will end in February 2021.

Participating Countries

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

Work During 2019

Subtask A: Knowledge Base



After the preparation and structuring work on how to create the Knowledge Base the year before, in 2019 the Historic Building Energy Retrofit Atlas – HibERATLAS for short – which collects Best Practice Cases in a visual and "fun to read" way was fully developed and implemented. The website was launched in October 8, 2019 and by the end of 2019 had around 25 best practice cases with many more in the documentation phase.

In parallel, the privacy and intellectual property rights questions were clarified and a respective workflow defined – also for the continued use of the best practice database after the Task ends. An Info Sheet with basic information for architects and building owners was prepared. The internal review process with two experts was perceived as helpful by the authors of the best practice cases. The list of experts available for the review was increased with three new TECHNICAL reviewers and four new HERITAGE reviewers.

With regards to the assessment of best practice cases, Walter Hüttler presented an overview of the published case studies (until September 2019) and the detailed structure of the assessment report was developed. In addition to this quantitative assessment, there will also be a qualitative part of the analysis focused on the "Replicability of Case Studies" and "Transferability of favorable framework conditions" and based on a number of hypotheses and define key factors for successful projects, which are verified by the cases.

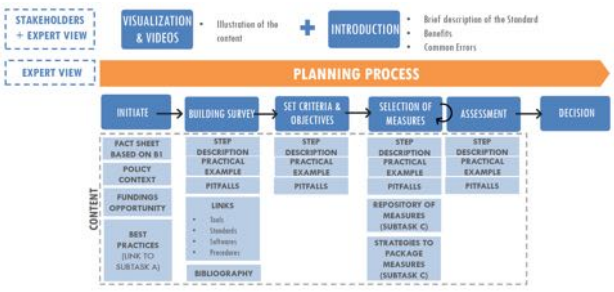
Overview on case studies

Project	City	Country	Period of construction	Building use			Building area			Protection level			Intervention			Construction details				HVAC				nevable energy sourc				Evaluation / Monitoring data				BGF
				Residential (urban)	Residential (rural)	Non-residential	Small	Large	(Area)	listed / protected	conservation area	non-listed / non-protected	Renovation	Renovation + extention	Other	External walls	Windows	Roof	Ground floor	Heating	Cooling	Ventilation	Air conditioning	PV	Solar	Biomass	Geothermal	Energy efficiency	Costs	Internal climate	Environment	
Osramhuset (The Osram Building)	Copenhagen	DK	1945-1959														plan														824.0 m²
Rainhof	Gsies	IT	before 1600													plan		plan	plan												390.0 m²
Villa Castelli	Bellano	IT	1850-1899														plan	plan	plan												564.0 m²
Klostergebäude Kaiserstrasse	Vienna	AT	1850-1899														plan	plan													2,750.0 m²
Klitgaarden	Hundested	DK	1850-1899																												221.0 m²
Basilica di Santa Maria di Collemaggio	L'Aquila	IT	before 1600																												2,140.5 m²
Lichtmayrgütl in Graming	Graming	DE	before 1600													plan	plan	plan	plan												150.0 m²
Beim Jäger	Baierbrunn	DE	before 1600															plan	plan												308.0 m²
Notarjeva vila	Tolmin	SLO	1900-1944																												412.2 m²
Hof 6, Schwarzenberg, Voralberg, Austri	Schwarzenberg	AT	1600-1700														plan	plan	plan												300.0 m²
Mercado del Val, Valladolid (Spain)	Valladolid	ES	1850-1899																												3,936.0 m²

Subtask B: Multidisciplinary planning process

The experts assessed tools and guidelines and presented their results at the Task meeting in Vienna and will also summarize them in fact sheets.

Finding cases studies for the assessment of the implementation of EN 16883 in practice has shown to be more difficult than expected, experts tried several approaches on the national level. During the Copenhagen Task meeting the experts developed a concept for an integrated platform that would follow the planning process as described in EN 16883 and enrich the quite abstract standard with examples, tools, recommendations, etc.



The paper on "Deep renovation of historic buildings. The IEA SHC Task 59 path towards the lowest possible energy demand and CO2 emissions has been published by the *International Journal on Building Pathologies* and presents the central postulates of Subtasks A and B.

For Subtask B5, Fabrizio Leonforte presented to the Task experts the content of the paper on “Dynamic thermal and hygrometric simulation of historical buildings: critical factors and possible solutions” elaborated jointly by Task 59 experts and submitted to the *International Journal on Renewable & Sustainable Energy Reviews*. Moreover, the expert group worked on the calibration of models and developed an excel sheet for the easy determination of statistical indexes.

Subtask C: Conservation compatible retrofit solutions and strategies

The working groups on SOLAR, HVAC, WALLS, WINDOWS and STRATEGIES defined the end of 2018 became fully operative and started their work. A mechanism to collect and document the retrofit solutions has been integrated in the back-office of the HiBERATLAS and is being used by the experts. For the documentation of the solutions, simple, open questions were answered to enable a continuous structure of the solutions.

Example for the documentation of a solution.

Furthermore, the expert group decided to use the Decision Guidance Tool, which will be developed within the Interreg project ATLAS, for Task 59 and thus “upgrade” the foreseen report to a more interactive tool. Experiences from P-Renewal and Interreg projects and decision trees will also feed into the tool.

Subtask D: Knowledge Transfer and Dissemination

Task 59 partnered up with the BHÖ European Congress on the Use, Management and Conservation of Buildings of Historical Value on October 16-17, 2019, where it contributed with two plenary lectures and a dedicated parallel session with eight presentations (recorded and available as videos on the Task 59 website).

The Travelling Exhibition (12 roll-ups each presenting a Best Practice Case from the HiBERATLAS) was kicked off at BHÖ congress. A reduced version (4 banners) was brought to SHC 2019 / Solar World Congress in Chile (two short videos interviews were conducted as well as).

A great opportunity to gather visibility was, when Daniel Herrera presented the Task 59 Best Practice Database, within the moderated debate “Deep energy renovations: Already all around us” in the European Parliament in Brussels on October 8, 2019.

Finally, the website was further developed with the addition of more and more detailed partner profiles, a page on the travelling exhibition, the newsletters and blog. Social media took momentum with the hiberatlas going online and linking with the launch of the Climate Heritage Network. Both twitter and the Task newsletter are also used to showcase partner profiles and the recently inserted Best Practice Cases.

Work Planned For 2020

Subtask A: Knowledge Base

The documentation of Best Practices will continue with the target to reach 50 cases by the fourth quarter of 2020. A first version of the assessment report will be presented and discussed at the April 2020 Task meeting. It will then be updated towards the end of the year, once the target number of Best Practice cases in HiBERATLAS has been reached.

In parallel, the continued use of the HiBERATLAS, after the closure of Task 59, disseminating it to research projects and programs, stakeholder associations, and last but not least as a resource and tool for education.

Subtask B: Multidisciplinary planning process

Fact sheets on the assessment of existing tools will be completed, and together with the experiences from the integrated planning process work in Subtask A’s best practice cases and Subtask B’s case studies will feed into a platform for holistic historic building retrofit. Implementation of the latter will be a major task in 2020.

For Subtask B5, the main task in 2020 will be the work on the definition of thresholds, which should result in a second paper.

Subtask C: Conservation compatible retrofit solutions and strategies

A first version of the report on conservation compatible retrofit solutions will be presented and discussed at the April meeting. The collection and documentation of solutions will continue and feed into an update deliverable at the end of the project. In parallel, the link to the decision support tool is being implemented, the decision trees are developed and the assessment of the solutions according EN 16883.

The result of the single Subgroups will also feed into the writing of a number of scientific papers – at this stage, six papers are envisaged. Several of them will be submitted to the *MDPI* special issue “Advances in Historic Buildings Conservation and Energy Efficiency”.

Subtask D: Knowledge Transfer and Dissemination

A **Solar Academy webinar** was held in January 2020 using a new format. The goal was to give a voice to the building owner and the design team through short videos and the Task experts answering their questions and concerns.

The **travelling exhibition** is already booked for a number of events in 2020: January in Coburg, Germany, February in Stirling UK, March monument fair in Salzburg, Austria and WTA day in Vienna, Austria, April Task 59 stakeholder event in Louvain, Belgium, May at ATLAS/BIPV meets History stakeholder event in Lugano, Switzerland, May at architects congress Rovereto in Italy, September at EuroSun in Athens Greece, October at EEHB in Benediktbeueren, Germany, and at ISEC in Graz, Austria and a stakeholder event in Izmir, Turkey.

Task 59 has partnered up with the REHABEND conference planned for March 2020 and will contribute heavily to the EEHB 2020 in Benediktbeuren in October 2020. Besides these events, the Task 59 experts will actively participate in numerous other conferences, workshops and events to disseminate results.

Eurac Research applied for holding the **final conference** of Task 59 * as a regional conference within the Sustainable Built Environment (SBE) series in 2021. The SBE series was launched in 2000 and has a 3-year cycle with regional conferences over two years leading to a global final event in the third year. With Task 59, we decided to apply for holding a regional conference within the series mainly to benefit from the popularity of the conference series and to attract a larger audience for a final Task conference. The deadline for submission for August 31, 2020.

* Together with Interreg project ATLAS and EFRE project Hylab, projects, which feed into Task 59.

Dissemination Activities In 2019

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
D. Herrera, F. Haas, G. Leijonhufvud, T. Broström, A. Buda, V. Pracchi, A. Laurel Webb, W. Hüttler, A. Troi	Deep renovation of historic buildings. The IEA SHC Task 59 path towards the lowest possible energy demand and CO_2 emissions	International Journal of Building Pathology and Adaptation	Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/IJBPA-12-2018-0102
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

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
European Heat Pump Forum	Presentation: Villa Castelli: towards the nZEB renovation of a historic building	May 16, 2019 Brussels, Belgium	150+
IEA SHC National Day	Presentation “Deep Renovation of Historic and Listed Buildings Towards Lowest Possible Energy Demand and CO_2 Emission” by Alexandra Troi and Rainer Pfluger	June 5, 2019 Vienna, Austria	
IEA SHC National Day	Participation in Panel Discussion by Alexandra Troi	June 5, 2019 Vienna, Austria	

Solaris # 03 Event	Presentation of "L'involucro attivo nell'esistente, tra timori e dialogo, tutela e Innovazione" by Daniel Herrera	July 5, 2019 Lugano,	72
Stadt der Zukunft Themenworkshop	Presentation "Renovating Historic Buildings Towards Zero Energy – IEA SHC Task 59/EBC Annex 76" by Alexandra Troi and Walter Hüttler	September 25, 2019 Innsbruck, Austria	100?
Stadt der Zukunft Themenworkshop	Participation in the "Fragerunde für Praktiker" (questions for practitioners) by Alexandra Troi	September 25, 2019 Innsbruck, Austria	100?
Renovate Europe Day	Presentation of Task 59 Best Practice Database by **Daniel Herrera** Within the moderated debate "Deep energy renovations: Already all around us"	October 8, 2019 Brussels European Parliament	120
BHÖ Congress	Plenary presentation "IEA Project: SHC Task 59 Renovating Historic Buildings Towards Zero Energy" by Alexandra Troi	October 15-16, 2019 Vienna, Austria	
BHÖ Congress	Plenary presentation "Use of Renewable Energy in Historic Buildings –What Can Research Do?" by Walter Hüttler	October 15-16, 2019 Vienna, Austria	
BHÖ Congress	Lightning Talk by Daniel Herrera "ATLAS, a Best Practice Database for the Energy Retrofit of Historic Buildings" in the stream "Best Practices: Engaging Owners in Energy Renovations"	October 15-16, 2019 Vienna, Austria	
BHÖ Congress	Lightning talk by Julien Borderon "Case Study in France" in the stream "Best Practices: Engaging Owners in Energy Renovations"	October 15-16, 2019 Vienna, Austria	
BHÖ Congress	Lightning talk by Tpr Broström on Standard EN16883:2017 in the stream "Quality Assurance in Energy Retrofits: The Role of Standards"	October 15-16, 2019 Vienna, Austria	

BHÖ Congress	Lightning talk by Valentina Marincioni on “Driving Retrofit Quality in the UK” in the stream “Quality Assurance in Energy Retrofits: The Role of Standards	October 15-16, 2019 Vienna, Austria
BHÖ Congress	Lightning talk by Fabrizio Leonforte on “Energy Performance” in the stream “Simulation and Energy Retrofits: Tools for Better Decision-Making”	October 15-16, 2019 Vienna, Austria
BHÖ Congress	Lightning talk by Ernst Ja De Place Hansen on “Guidelines from the European project RIBuild” in the stream “Simulation and Energy Retrofits: Tools for Better Decision-Making”	October 15-16, 2019 Vienna, Austria
BHÖ Congress	Participation in the Panel discussion “Energy Efficiency and Historic Buildings - Contradiction or Reality?”	October 15-16, 2019 Vienna, Austria

Task Meetings 2019 - 2020

Meeting	Date	Location	# of Participants (# of Countries)
Experts Meeting 4	April 8-10, 2019	Copenhagen, Denmark	34 (13)
Workshop together with RIBUILD project	April 8, 2019	Copenhagen, Denmark	~30
Experts Meeting 5	October 14-15, 2019	Vienna, Austria	27
Workshop BHÖ conference	October 16-17, 2019	Vienna, Austria	~180 (11)
Experts Meeting 5	April 23-24, 2020	online	
Experts Meeting 5	October 2020	Louvaine-la-Neuve, Belgium	
Workshop together with P-Renewal	October 2020	Louvaine-la-Neuve, Belgium	

SHC Task 59 Participants

Country	Name	Institution	Role
ITALY	**Alexandra Troi**	**EURAC**	**Operating Agent**
AUSTRIA	Walter Hüttler	E-7	Subtask A Leader
AUSTRIA	Rainer Pfluger	UIBK	Subtask C Leader
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BELGIUM	Samuel Dubois	BBRI	National Expert
BELGIUM	Yves Vanhellemont	BBRI	National Expert
BELGIUM	Sophie Trachte	UCL	National Expert
BELGIUM	Dorothée Stiernon	UCL	National Expert
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DENMARK	Kirsten Thomsen	SBI	Subtask D Leader
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FRANCE	Julien Burgholzer	CEREMA	National Expert
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GERMANY	Sebastian Herkel	Fraunhofer	National Expert
GERMANY	Johannes Eisenlohr	Fraunhofer	National Expert
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IRELAND	Leila Budd	ICOMOS	National Expert
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ITALY	Daniel Herrera	EURAC	National Expert
ITALY	Franziska Haas	EURAC	National Expert
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ITALY	Valeria Pracchi	POLIMI	National Expert
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ITALY	Marta Calzolari	UNIFE	National Expert
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ITALY	Giuseppe Margani	UNICT	National Expert
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ITALY	Alessandro Lo Faro	UNICT	National Expert
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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 60 – PVT Systems

Jean-Christophe Hadorn
Solar Energies and Strategies
Operating Agent for the Swiss Federal Office of Energy

Task Overview

Task 60 focuses on the application of PVT collectors. The aim is to assess existing solutions and to develop new system solutions principles in which the PVT technology really offers advantages over classical “side by side installations” of solar thermal collectors and PV modules.

Energy yield, exergetic efficiency, KPIs, simulation tools, sensitivity analysis, benefits, competitive cost, safety and reliability of systems are in the scope of the Task.

Increasing awareness of the PVT solutions to all stakeholders is a key objective.

The Task’s work is divided into four subtasks:

- Subtask A: Systems in Operation (Austria)
- Subtask B: PVT Performance Characterization (Germany)
- Subtask C: PVT Systems Modelling (Spain)
- Subtask D: PVT Systems Design Examples and Dissemination and Market Support (Switzerland)

Scope

The scope is on applications with PVT collecting devices in systems of any size and any type of consumers.

The objectives of the Task are to:

1. Provide a state-of-the-art of the PVT technology worldwide.
2. Gather operating experience with existing PVT systems.
3. Improve the testing, modelling and adequate technical characterization of PVT collectors.
4. Find typical PVT solutions
5. Explore potential cost reductions in the balance of PVT systems.

Subtask A: PVT Systems in Operation
The objective is to gather data and report information on heating and cooling systems with PVT collectors in operation.

Subtask B: PVT Performance Characterization
The objective is to provide testing methods for PVT collectors of all types that can become an international standard.

Subtask C: PVT Systems Modelling
The objective is to provide models of systems with PVT collectors.

Subtask D: PVT Systems Design Examples and Dissemination and Market Support
The objective is to evaluate the overall performance of PVT systems and designs and to disseminate the Task produced information and knowledge to all identified stakeholders.

Collaboration with Other IEA TCPs

Contacts with the PVPS, HPT, ECES Technology Collaboration Programmes (TCPs) have been initiated to enhance awareness in PVT solutions.

Collaboration with Industry

Task 60 has several companies involved in the collaborative work and interest from industry is high.

Collaborating companies during 2019 have been: DualSun from France, PA-ID from Germany, Solarus from the Netherlands, Abora from Spain, Endef also from Spain, 3F solar from Austria, Trigo energies from Canada, Solink from Italy, Consolar from Germany, SunOyster also from Germany, Solar Speedflex, Photonomi from UK, Systovi and GSE from France, Sunovate from Australia. Some have been very collaborative to share knowledge especially in markets and positioning. In return they get advices and opinions from PVT experts within the Task.

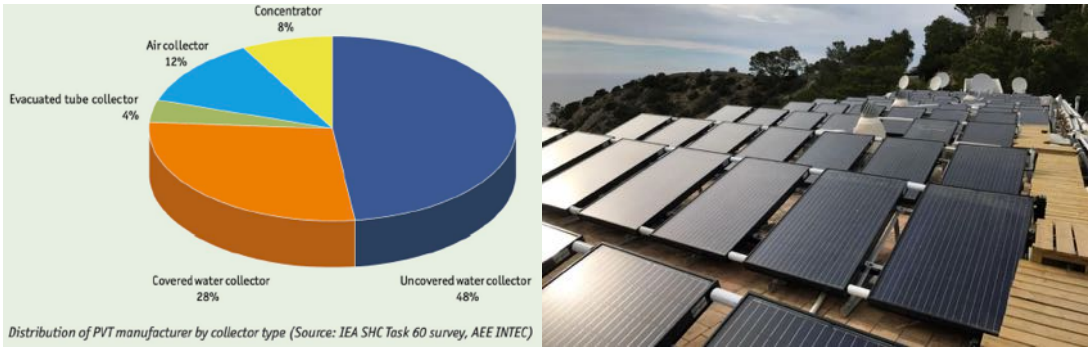
Task Duration

This Task started in January 2018 and will be completed in December 2020.

Participating Countries

Australia, Austria, Canada, China, Denmark, France, Germany, Italy, Netherlands, South Africa, Spain, Sweden, Switzerland, UK

Work During 2019



PVT market situation from Task 60 2019 survey and example of a glazed PVT application for a hotel.

Two meetings were held in 2019 with between 25 to 35 participants. Two industry workshops were held the day before the Task meetings with 20 to 30 participants. Task 60 findings have been presented in the two workshops and a keynote speech was given at SHC 2019 in Santiago.

Subtask A: PVT Systems in Operation

1. For the first time, statistics on worldwide PVT applications were gathered and published in the SHC TCP's report, "Solar Heat Worldwide." Data showed 1.1 million m^2 of PVT collectors installed! This represents about 50% of the world market of PVT collectors.
2. Our list of PVT projects has 24 projects described in "info sheets" and compiled in report A1. This report on activity A1 and A2 will be available in early 2020.
3. A geographical representation will be implemented on the Task 60 webpage to easily access each project description.
4. The past Task 44 "square view" system to describe a system concept and its components was modified to account for PVT situations and used in report A1.
5. The A2 report on comparison of PVT systems will use KPIs from Subtask D. For qualitative assessment of projects, four strategic topics were defined (decision, design, operations, lessons) and statements from participants gathered to qualify miscellaneous PVT solutions.

Subtask B: PVT Performance Characterization

1. Report 1 for the activities B1 and B2 will be published in 2020. Among many other scientific topics, wind and condensation effects on WISC collectors was discussed, proposals how to handle those effects were incorporated to characterize a PVT collector. Design guidelines of a PVT circuit from collector to exchanger will be reported on an exploded view of the circuit so that it is easy to understand the recommendation. It will be the heart of report B2 and of the new Wikipedia page that was designed during 2019 in Subtask D.

2. Contact with ISO committee has been maintained so that PVT needs are taken into account in future standards.
3. Discussion on standard test procedures for PV and T to reduce costs was conducted during 2019. No simple solution emerged, and this also will be discussed at the ISO level.
4. Labels for PVT were discussed during 2019. The Solar Keymark committee has been approached and discussions are still on the agenda. A new annex was developed and is now officially in force.

Subtask C: PVT Systems Modelling

1. Report 1 on modeling tools for component and systems (activities C1 and C2) is in Task review process.
2. Discussion on series / parallel connection of PVT modules was done to decide how to consider a field of PVT collectors.
3. Discussion on how to report the Task's simulation results concluded to let analysts calculate the KPIs using their own methods and then supply the variables in the equations to be used for each KPIs. This is a more pragmatic and efficient way to make a reasonable comparison between very different systems just sharing the PVT choice for collecting solar energy.
4. Reference system for comparison purposes will be defined on a case by case basis since it is not relevant to have the same reference heating system for every country and application.
5. Seven participants validated their model against field results and will provide sensitivity analysis as defined by the Task in 2020.

Subtask D: PVT Systems Design Examples and Dissemination and Market Support

1. A new LinkedIn group was created, https://www.linkedin.com/groups/12245439/ (#PVT, #PVThermal, #PVTSolar).
2. A report D4 on "Square views", a former Task 36 method but adapted to PVT situations was approved.
3. Report 1 on the definition of KPIs was discussed and a final draft issued.
4. The assessment and comparison of the example systems of Subtask A was started. Priorities were given to 5 or 6 KPIs that every project should report on, either measured, simulated or guessed. It was decided that CO_2 emissions would be calculated by the Subtask leader for all projects in order to be sure that the same method is used.
5. A webinar on PVT certification was held with around 40 participants from industry, research and testing.
6. Several participants presented papers at the SHC 2019 conference.
7. The future Wikipedia page on PVT has been designed and also will be issued as a report.
8. Control strategies were discussed as a way to describe the peculiarities of a PVT system compared to more classical solutions with solar or heat pump (HP). The global controlling of a PVT system with HP is still a problem since the components have different suppliers and controllers do not interface easily between each other. No real simple solution can be found but one manufacturer only for the whole system. It was proposed that Task 60 should write recommendations for heat pump manufacturers namely on how to deal with the interface of the PVT field properly.

Work Planned For 2020

Subtask A: PVT Systems in Operation

1. Disseminate report A1: Collection of data sheet on existing PVT systems and solutions.
2. Produce and disseminate report A2: Comparison of systems with Subtask D with recommendations for improvements of future PVT systems.
3. Survey PVT collectors globally for year 2.

Subtask B: PVT Performance Characterization

1. Disseminate report B1: methods for testing PVT collectors and definitions of PVT systems efficiency.
2. Produce and disseminate report B2: Design Guidelines for PVT collectors and systems.
3. Discuss a PVT label with the Solar Keymark committee.

Subtask C: PVT Systems Modelling

1. Disseminate report C1: Numerical Simulation Tools for the simulation of PVT collectors and systems.
2. Produce systems simulation for various PVT projects (5 to 7).
3. Disseminate report C2: PVT systems simulation and validation.
4. Disseminate report C3: Optimized PVT systems (or include into C2).

Subtask D: PVT Systems Design Examples and Dissemination and Market Support

1. Disseminate report D1: KPIs definition and performance assessment of PVT systems.
2. Produce and disseminate report D2: Control strategies for PVT systems.
3. Produce report D3: Collection of documents prepared along the Task for industry and market.
4. Disseminate report D4: Visualization of energy flows in PVT systems.
5. Produce report D5: Basic concepts in PVT technologies.
6. Finalize a Wikipedia page on PVT systems based on report D5.

Dissemination Activities In 2019

Reports, Published Books

Author(s)/ Editor	Title	Report No. Publication Date
	Collection of data sheet on existing PVT systems and solutions	A1 December 2018
	Numerical Simulation Tools for the simulation of PVT collectors and systems	C1 December 2019
	Visualization of energy flows in PVT systems	D4 June 2019

Conferences, Workshops, Seminars

Workshop/Conference/Seminar	Activity & Presenters	Date & Location
Webinar on PVT certification	A. Bohren, Solarkeymark Network; L. Brottier, DualSun, France; S. Martin, SRCC, USA; M. Intrieri, SunDrum Solar, USA	April 9, 2019
PVT Industry Workshop before meeting 3	Task 60 findings / members	May 8, 2019 Eindhoven, The Netherlands
PVT Industry Workshop before meeting 4	Task 60 findings / members	October 9, 2019 Lyngby, Denmark

SHC 2019	5 papers, 1 keynote speech / JC Hadorn	November 2019 Santiago, Chile

Task Meetings 2019 - 2020

Meeting	Date	Location
Task Meeting 3	May 8-10, 2019	Eindhoven, Netherlands
Task Meeting 4	May 17-18, 2019	Lyngby, Denmark
Industry Workshop	May 16, 2019	Lyngby, Denmark
Task Meeting 5	April 23-24, 2020	Catania, Sicily
Industry Workshop	April 22, 2020	Catania, Sicily
Task Meeting 6	October 2020	TBD

SHC Task 60 Participants

Country	Name	Institution / Company	Role
SWITZERLAND	**Jean-Christophe Hadorn**	**Solar Energies & Strategies**	**Operating Agent**
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AUSTRIA	Alexander Friedrich	3F Solar Technologies GmbH	National Expert
AUSTRIA	Thomas Ramschak	AEE INTEC	Subtask A Leader
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DENMARK	Mark Dannemand	DTU BYG	National Expert
DENMARK	Adam Jensen	DTU BYG	National Expert
FRANCE	Jean-Baptiste Beyssac	CESP Univ. Perpignan	National Expert
FRANCE	Gabriel Blaise	Dualsun	National Expert
FRANCE	Laetitia Brottier	Dualsun	National Expert
GERMANY	Joseph Bergner	HTW Berlin	National Expert
GERMANY	Sonja Helbig	Institute Solarenergieforschung Gmbh	National Expert
GERMANY	Danny Jonas	University Saarbrücken	National Expert
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GERMANY	Johannes Kneer	SunOyster	National Expert
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GERMANY	Manuel Lämmle	Fraunhofer ISE	National Expert
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SPAIN	Isabel Guedea	EndeF Engineering	National Expert
SPAIN	Maria Herrando	University of Zaragoza	National Expert
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SWITZERLAND	Andreas Häberle	SPF	Alternate Subtask D Leader
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UNITED KINGDOM	John Quinn	Photonomi	National Expert
UNITED KINGDOM	Adrian Murrell	Naked Energy	National Expert

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

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Operating Agent for the German Government (PtJ for BMWi)

Task Overview

The overall objective of this joint activity with the IEA EBC TCP is 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 widespread lighting design software.
- Combine competencies: Bring companies from electric lighting and façade together in workshops and specific projects. Thereby support allocation of added value of integrated solutions in the market.

The Task’s work is divided into four subtasks and a working group:

- Subtask A: User Perspective and Requirements (Norway)
- Subtask B: Integration and Optimization of Daylight and Electric Lighting (Denmark)
- Subtask C: Design Support for Practioners (Austria)
- Subtask D: Lab and Field Study Performance Tracking (Denmark)
- Joint Working Group: Evaluation Method for Integrated Lighting Solutions & Virtual Reality (VR) Based Decision Guide

Scope

The scope of the Task is on general lighting systems for indoor environments. The focus is laid on lighting appliances in non-domestic buildings. Technically the Task deals with integrating:

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

The Task targets building designers and consultants, industry (façade, electric lighting, software companies), owners (investors) and authorities by providing strategic, technical and economic information and with network activities helping these stakeholders overcome barriers in integrating lighting installations and implementing holistic lighting solutions.

Collaboration with Other IEA TCPs

The Task is collaborating at the maximum collaboration level with the IEA EBC TCP, which is referred to by the EBC TCP as EBC Annex 77.

Task Duration

This Task started in January 2018 and will end in June 2021.

Participating Countries

Australia, Austria, Belgium, Brazil*, Canada, China, Denmark, Germany, Italy, Japan*, Netherlands, Norway, Poland*, Slovakia, Sweden, Switzerland, United States*. **Through EBC TCP*

Work During 2019

Subtask A: User Perspective and Requirements

In project A.1 “User Requirements” the review and analysis of more than 100 articles was completed, covering: Visual perception, Visual comfort, Psychological aspects and Non-visual aspects of lighting. The final version of the report was drafted, and a scientific paper based on the content of the A.1 report is planned for spring 2020.

Use cases (“profiles”) – i.e., typical daily occupancy schedules with specific multi-criteria lighting needs as a function of activities in the space – are under development in project A.2 “Use Cases” for main building types like a) education buildings, b) offices, c) healthcare premises, d) industrial buildings. For these standards and requirements (CIE, CEN, ISO, DIN) were reviewed. Occupancy behavior in non-residential buildings was analyzed in a literature review. Occupancy simulation and registration were addressed. The structure of the report will include chapters: 1) Introduction, 2) Building Codes and Requirements, 3) Literature review on building use, 4) Occupancy simulation, 5) Occupancy-behavior registration. Specifically, the occupancy simulation (Annex 66 occupancy simulator) turned out to be difficult to use for lighting purposes, as the simulation results are not compatible with lighting simulation programs and the occupancy simulation tool is limited to office buildings only. To study the use of lighting in buildings, both electric lighting and daylight, another approach will be used, which is lighting diaries.

The activity A.3 “Representation of user behavior – personas” has been started, now that relevant results from A.1 and A.2 are available. In the presentations and discussion, it was worked on a common understanding of the term “personas” as user representations. Personas are available and used in many different fields. It was discussed how to effectively include lighting requirements (numerical values for day- and electric lighting for particular buildings) into this concept and how to work with and benefit from already existing concepts (like "personas" for research or learning purposes, buyer personas: https://www.hubspot.com/make-my-persona).

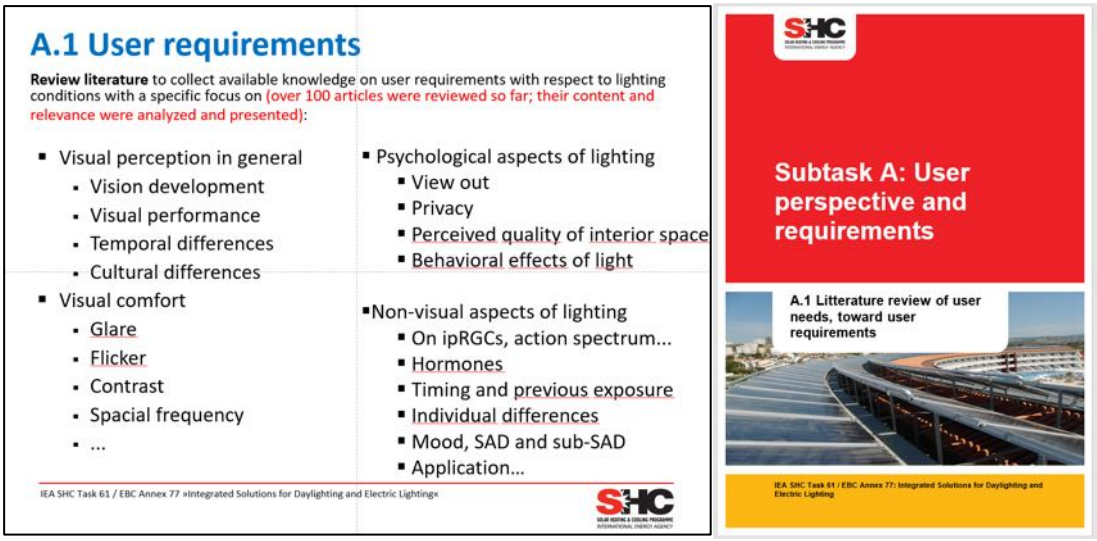

Figure 2. Criteria for the assessment of user requirements (left), draft A.1 report (right).

Subtask B: Integration and Optimization of Daylight and Electric Lighting

In project B.1, "Interview of professionals: opportunities and barriers," the report on the questionnaire to identify opportunities and barriers in the market was drafted and covers the following aspects:

- Demands from building managers/facility managers
- Aspects related to occupants/demand from occupants
- Aspects related to building owners/lease holders
- New technology opportunities available

The report in project B.2, "Critical review of existing control systems and their functionalities," was refocused on existing solutions, such that the report – instead of waiting for further emerging solutions in the course of the task – can be finished as planned on short notice and can be distributed to interested practitioners. New solutions, coming up from now, to the end of the task shall then be possibly be addressed in a further report, or an update of the first one. In project B.3 "Critical review of new approaches under development": Information on systems, views and opinions on possible trends have continuously being collected. In project B.6, "Link with standardization activities," the collection of relevant documents from relevant bodies, such as CIE, ISO, CEN, CN Standards, BREAM, LEED, DGNB is ongoing.

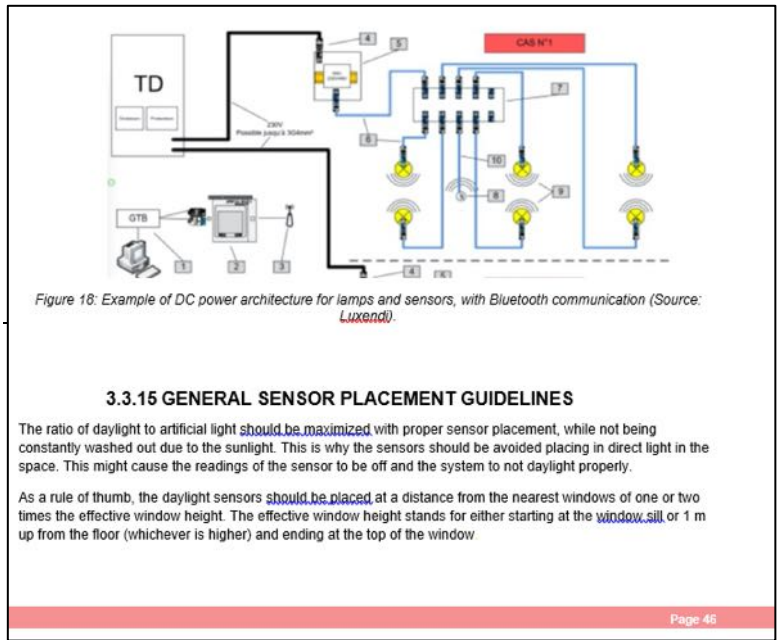

Figure 3. Excerpt from "Critical review of existing control systems and their functionalities," draft report B.

Subtask C: Design support for practitioners (Tools, Standards, Guidelines)

In project C1, “Review of state of the art design workflows” a third example design project (CABR NZEB building Beijing), an additional workflow (ESTIA) and software descriptions (RELUX, GBSWARE, PKPM, DIAL+) were included and the report is now completed.

In project C2, “Standardization of BSDF daylight system characterization,” the work on defining the BSDF requirements is ongoing. Additional inputs from Soochow University and their current BSDF measurement and simulation procedures have been included. The sensitivity analyses and work on the requirement definitions continued. Subtask leader David Geisler Moroder participated in a BSDF workshop held at LBNL in June 2019 with several stakeholders from the US. In California, standardization and regulation authorities are looking into BSDFs to be included in their documents.

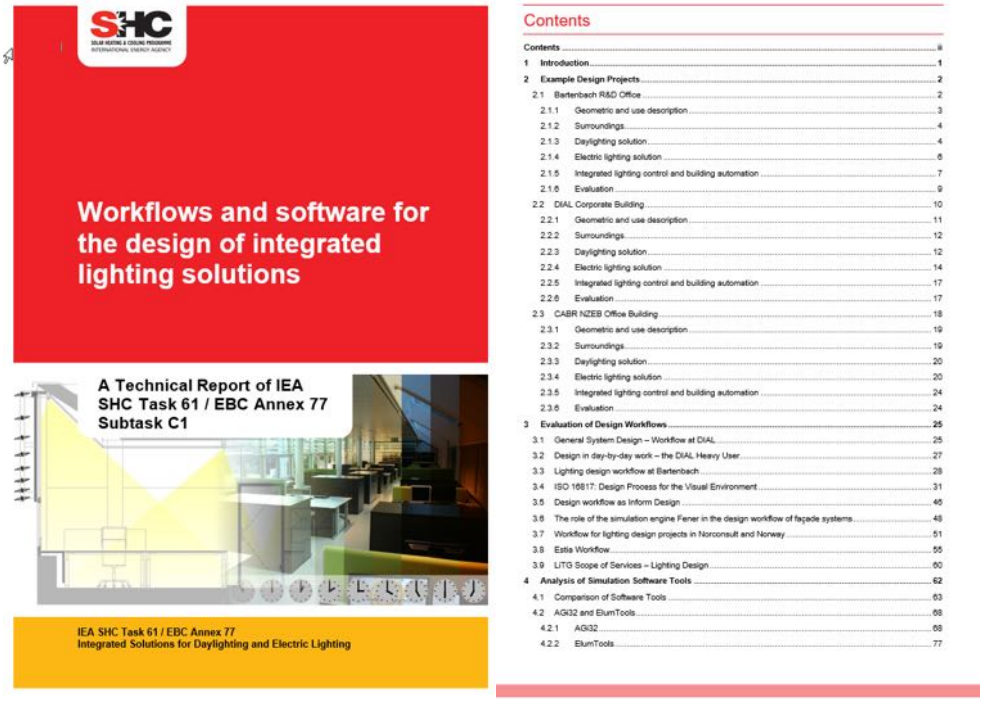

Figure 3. Report C.1: Workflows and software for the design of integrated lighting solutions

In project C3, “Spectral sky models for advanced daylight simulations,” it is aimed at supplementing the current sky models describing the spatial luminance distribution with spatial color temperature information. The structure of the report is now available. The planned finalization of the report is planned for mid-2020. The collaboration with IEA PVPS Task 16 continued. Spectral measurement data are shared, and knowledge about spectral modeling is exchanged.

Project C4 meeting “Hourly rating method for integrated solutions” has been run as a joint activity with the ISO TC274 Task Force for the revision of ISO 10916. The existing methodology should be preserved, and the standard extended with the new, hourly method to provide an improved second approach. It is intended to follow the syntax as specified in the ISO 16484 for BACS. The idea is that lighting designers set up the control, and the installer can later use this implementation in the real building. The next step will be to document the model in full, serving also as a proposal for the standard.

Subtask D: Lab and Field Study Performance Tracking

A draft of the D1 “Literature review” report currently covers the review of about 200 papers. Results from the literature review have been summarized in conference papers presented at/submitted to the 29th CIE Session in Washington, DC in June 2019, the Professional Lighting Design Convention in Rotterdam in October 2019, and the ISES Solar World Congress in Santiago de Chile in November 2019. Finalization of the report is now planned for early 2020.

The D2 “monitoring protocol” is available and considered stable enough to now serve as the basis for the case study assessment. Its application was tested in two monitored case studies from Brazil. QUT developed a new measurement device for getting a better understanding of the directionality of light in a space, Figure 4.

In project D3 ”Case Studies,” 18 case studies are now planned to be studied. First case studies have been assessed (Furniture store in Germany, two buildings in Brasilia, Living Lab in Germany).

In project D4, “Lessons learned,” it was discussed how to collect, manage, and later on to display the information. The concept of the case study viewer used in IEA SHC Task 50 was retrieved. A first example is shown in Figure 5. Generally, the mechanism and existing software set-up was considered suited. Nevertheless, this has to be adopted to the higher diversity in case study assessments of this task, compared to the very much standardized approach in Task 50. The subtask leaders also proposed to develop a 4-page summary document for each case study that interested persons could download from the IEA SHC Task 61 Website in pdf-format.

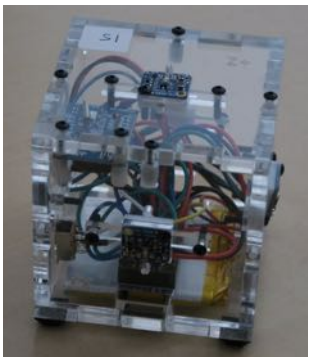

Figure 4. New measurement device (QUT’, Australia) for getting a better understanding of the directionality of light in a space.

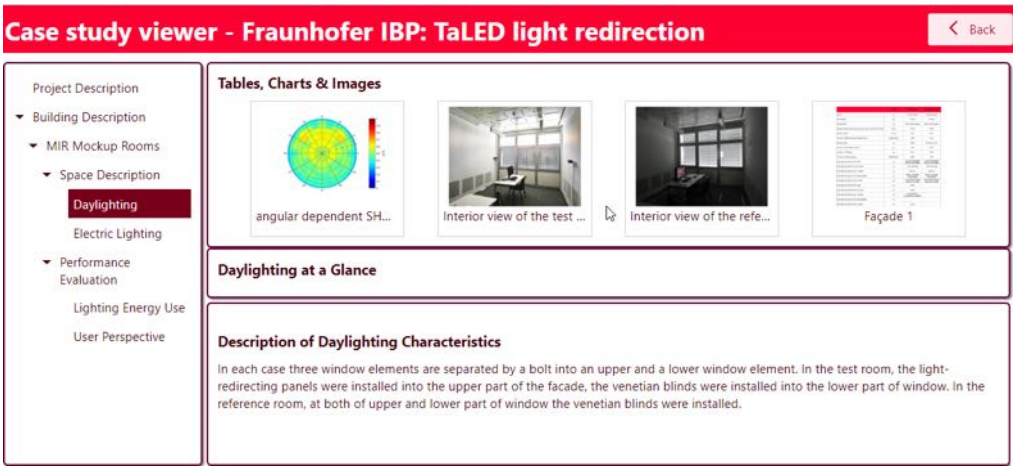

Figure 5. Test of the representation of a case study (on light redirection) in the case study viewer framework of SHC Task 50.

Joint Working Group: Evaluation Tool & VR Decision Guide

The integrative concept of the joint working group with its two development activities, “Evaluation Method for integrated lighting solutions” and “VR Decision Guide” relies on a high degree of collaboration from the Subtasks and need to be integrated using concise, jointly defined formats. The status of these activities is as follows.

Evaluation model

The work on the generic model for the hourly rating method continued. This is based on logical, clear segregation introduced 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. The latter is kept identical to standard BACS description semantics as in VDI 3813 / ISO 16484, i.e., allowing to be directly used/implemented

into the later automation hardware of the building. By this common double modeling in lighting design and design of the BACS can be avoided in the future, boosting efficiency.

The software architecture for the web-based tool was set up, see Figure 6. The first implementation of a modellica kernel linking to an early version of the emulators was performed and tested for a single and a group office.

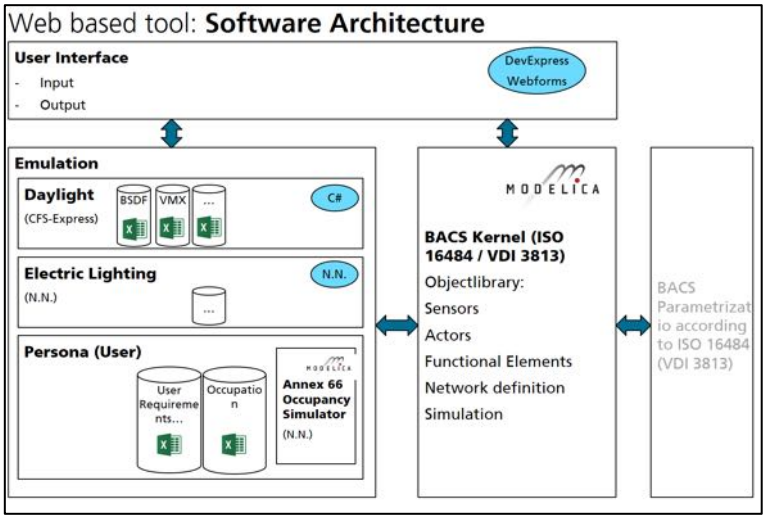

Figure 6. Software Architecture of web-based tool for hourly rating method.

"VR Decision Guide"

The objective of this activity is to create visual sequences to be seen on the platform of the IEA task. These sequences should facilitate the understanding of the control strategies through a passive or active simulation of lighting controls with response to daylight variations, see Figure 7. Subtasks C and D will identify 7-8 case studies and provide suited pictures and simulations following a specific procedure.

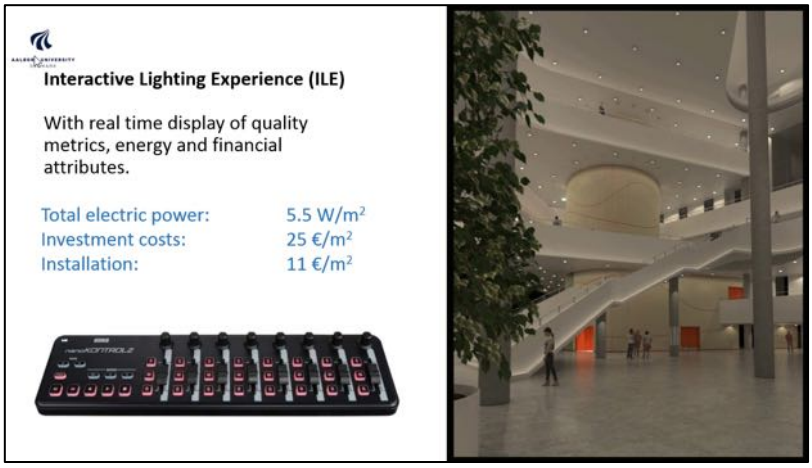

Figure 7. VR Decision Guide to provide interactive lighting experiences.

Highlights of Industry Involvement and Market Activities

Industry Workshops

As part of the Task 61 activities, two industry workshops (in Beijing and Gdansk) were organized and hosted, with 20 presentations in total on different daylighting and electric lighting topics. With the industry workshops, the objective is to mirror the work of the Task with respect to the needs of the industry. In Beijing, the 2019 International daylighting and electric lighting innovation technology conference & IEA SHC Task 61's 3rd industry workshop was held on March 27th. Altogether 150 participants, including researchers, engineers, designers, other technical staff,

attended ten presentations, 2586 viewers followed the presentations online live. In Gdansk, the 4th industry workshop was held on September 16th with 45 participants and nine presentations.

Figure 8. Impressions from the 3rd and 4th industry workshops in Beijing (upper photos) and Gdansk (lower photos).

IEA SHC Technology Position Paper

The IEA SHC Technology Position Paper, "Daylighting of Non-Residential Buildings," was published and can be downloaded from the SHC website.

Work Planned For 2020

Subtask A: User Perspective and Requirements

- Report on user requirements for lighting conditions and lighting controls.
- Report on use cases.

Subtask B: Integration and Optimization of Daylight and Electric Lighting

- Report: The control technology seen by users and installers.
- Report on existing control systems and their functionality.

Subtask C: Design Support for Practitioners (Tools, Standards, Guidelines)

- Report on Spectral sky model (ready for implementation in software).
- Continued collaboration with ISO TC 274 on hourly rating method.

Subtask D: Lab and Field Study Performance Tracking

- Collection of documented experience with state-of-the-art integrated daylighting and electric lighting systems and the operation of their control systems, especially with respect to user-behavior impacts on energy use gathered through an extensive literature review.
- Monitoring protocol for use in the assessment of the performance of integrated lighting systems and their control concerning required user- and energy-focused performance targets.

Joint working group: Evaluation tool & VR Decision Guide

- First sessions of the VR decision guide.
- First draft hourly rating model (method and implementation).

Dissemination Activities In 2019

Reports, Published Books

Author(s)/ Editor	Title	Report No. Publication Date	Target Audience
de Boer, J.	Daylighting of non-residential Buildings, IEA SHC Position Paper	February 2019	Authorities, industry, building owners, investors
Campama Pizarro, R.	Daylighting and electric lighting integration in the retail sector: case study of IKEA Kaarst store	November 2019	Academia, architects, façade designers
IEA Task 61 / EBC Annex 77 Subtask C1	IEA SHC Task 61 Report: Workflows and software for the design of integrated lighting solutions	November 2019	

Journal Articles, Conference Papers, etc.

Author(s)/Editor	Title	Publication/Conference	Bibliographic Reference
Diakite, A.K.	A data-driven colorimetric analysis of CIE Standard General Skies	CIE 2019, June 14-22, 2019; Washington DC, U.S.A.	Conference Proceedings
Knoop, M.	Approach to analyze seasonal and geographical variations in daylight illuminants	CIE 2019, June 14-22, 2019; Washington DC, U.S.A.	Conference Proceedings
Gentile, N.; Osterhaus, W.; Alvarez García, M.; Naves David Amorim, C.; Altomonte, S.; Garcia-Hansen, V.; Obradovic, B.	Energy saving potential for integrated daylighting and electric lighting design via user-driven solutions: a literature review	CIE 2019, June 14-22, 2019; Washington DC, U.S.A.	Conference Proceedings
Osterhaus, W.; Gentile, N.; Alvarez García, M.; Naves David Amorim, C.; Altomonte, S.	Lighting designers improve lighting energy performance through user-centred lighting design	PLDC 2019, October 23-26, 2019; Rotterdam, The Netherlands	Conference Proceedings
Gremmelspacher, J.M. (on behalf of Niko Gentile and Werner Osterhaus)	IEA SHC Task 61 / EBC Annex 77 Integrated solutions for daylighting and electric lighting – subtask D: lab and field study performance tracking	ISES SWC 2019 (SHC Conference) November 4-7, 2019; Santiago de Chile, Chile	Conference Proceedings
Campama Pizarro, R.; Gentile, N.	A case study addressing the benefits of integrated solutions for daylighting and electric lighting in the retail sector	ISES SWC 2019 (SHC Conference) November 4-7, 2019; Santiago de Chile, Chile	Conference Proceedings

Conferences/Workshops/Seminars

Conference / Workshop / Seminar Name	Activity & Presenter (keynote, presentation, poster, etc.)	Date & Location	# of Attendees
IEA SHC 61 / EBC 77 3rd Industry Workshop / Conference	10 presentations from industry and Task experts	March 27, 2019 Beijing, China	150 and 2,500 via web
CIE 2019	3 presentations by Task experts	June 14-22, 2019 Washington DC, U.S.A.	
IEA SHC 61 / EBC 77 4th Industry Workshop	9 presentations from industry and Task experts	September 16, 2019 Gdansk, Poland	45
Velux Daylight Symposium 2019	Presentation from Task expert	October 9, 2019 Paris, France	800
PLDC 2019	Presentation from Task experts	October 23-26, 2019 Rotterdam, Netherlands	
ISES SWC 2019 (SHC Conference)	2 presentations from Task experts	November 4-7, 2019 Santiago de Chile, Chile	➢ 400

Dissemination Activities Planned For 2020

5th Industry Workshop in Aversa, Italy.

Task Meetings 2019 - 2020

Meeting	Date	Location
Task Meeting 3	March 27-29, 2019	Beijing, China
Industry Workshop 3	March 27, 2019	Beijing, China
Task Meeting 4	September 16-18, 2019	Gdansk, Poland
Industry Workshop 4	September 16, 2019	Gdansk, Poland
Task Meeting 5	September 5-7, 2020	Aversa, Italy
Industry Workshop 5	September 5, 2020	Aversa, Italy

SHC Task 61 Participants

Country	Name	Institution / Company	Role
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BELGIUM	Bertrand Deroisy	Belgian Building Research Institute (BBRI)	National Expert
BELGIUM	Ruben Delvaeye	Belgian Building Research Institute (BBRI)	National Expert
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CHINA	Yu Cheng		National Expert
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DENMARK	Jens Christoffersen	VELUX A/S	National Expert
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GERMANY	Daniel Witzel	DIAL GmbH	National Expert
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ITALY	Michelangelo Scorpio	University of Campania	National Expert
ITALY	Sergio Sibilio	University of Campania	National Expert
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NETHERLANDS	Rajendra Dangol	Eindhoven University of Technology	National Expert
NETHERLANDS	Alexander P.L. Rosemann	Eindhoven University of Technology	National Expert
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POLAND	Natalia Sokol	Gdansk University of Technology	National Expert
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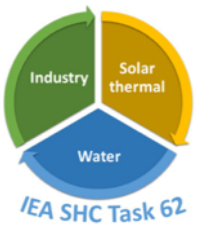
UNITED STATES	Eleanor Lee	Lawrence Berkeley National Laboratory	National Expert
UNITED STATES	Gregory J. Ward	Anyhere Software	National Expert

Task 62 – Solar Energy in Industrial Water and Wastewater Management

Christoph Brunner
AEE – Institute for Sustainable Technologies
Operating Agent for The Republic of Austria



Task Overview

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

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

The Task's work is divided into three subtasks:

- Subtask A: Thermally Driven Water Separation Technologies and Recovery of Valuable Resources (Germany)
- Subtask B: Solar Water Decontamination and Disinfection Systems (Spain)
- Subtask C: System Integrations and Decision Support for End-User Needs (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 Industry

Since the 2nd Task Meeting in Almería, Spain, the interest in the Task from the industry side is increasing. In addition to the 14 universities and research institutes, nine companies participated in the Almería meeting (2 companies

from the solar side and 7 companies from the water side). At the 3rd Task Meeting in Freiburg, Germany around 40% of the participants were represented by companies/industry.

There is ongoing contact with specific technology developer companies related to membrane distillation and water treatment. In particular, industry partners working on membrane distillation showed interest in the Task during the Freiburg meeting. And, industry players, Aquastill (Netherlands), EvCon (Germany) and Solar Spring (Germany), who are working on module development and production joined the Task Meeting. During the meeting for instance EvCon shared their impressive development in an automatic production line for their modules. Market activities of the company will be published in the 3rd quarter of 2020 and shared within the Task 62 group – strong input for especially Subtask A is expected.

At the moment, membrane distillation is delivering good outputs from different projects, which is helping to bring the technology to the market and show the market potential in different sectors. Projects to be mentioned are:

- The BMBF project, HighCon "Konzentrate aus der Abwasserwiederverwendung (brines from wastewater reuse)," ended successfully for most of its partners in September 2019. The results were presented during the final meeting in Emmendingen.

- In the EU H2020 project, ReWaCEM "Resource recovery from industrial wastewater by cutting edge membrane technologies," the operation of all four demonstration systems was evaluated and shared at the project meeting in Gijon, Spain in October 2019. Latest results for the demonstration plants also were presented by Fraunhofer ISE and AEE INTEC during the 3rd Task Meeting.

In Subtask B, there are strong links with technology providers and end-user associations (APRIA SYSTEMS, DeNORA, IQD INVESQUIA, AINIA, SOLARDEW, LIQTECH, etc.) to work on identifying potential markets for industrial wastewater decontamination and disinfection. And, the leader of Subtask B is part of the SFERA-III project (CSA of H2020) within WP7 focused, among other areas, on the design and development of new concepts of solar reactors for joint applications of thermal and photons on industrial wastewater treatment and disinfection (cooperation between CIEMAT, University of EVORA, University of Almería (CIESOL) and Cyprus University).

To sum it up, the awareness of Task 62 is increasing within industry. The change to a sustainable, resource- and energy-efficient production will be a major challenge in the coming years in industrial companies. The Task shows that the NEXUS Solar Energy-Water-Industry has a very important role in future strategies for energy and CO2 reduction in industrial companies. The expectations of the industry participants are to receive options and concrete solutions (e.g., decision-making framework/guidelines, new solar thermal collector concepts, etc.) for economic and technical successful introduction of solar thermal heat in the application of wastewater treatment. International experts and technology suppliers in the field of solar thermal energy as well as wastewater treatment and separation are working worked together on innovative ideas for the long-term and successful introduction of solar thermal energy in the application of wastewater treatment.

Task Duration

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

Participating Countries

Australia, Austria, France, Germany, Italy, Netherlands, Portugal, Spain, Sweden

Work During 2019

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

- The technological focus was defined.
- Experts from membrane distillation industries were contacted and experts successfully invited to join Subtask A.
- Survey (within Activity A.2. Assessment of concepts and best practices and as basis for D.A3.) on existing simulation models (focus on thermal technologies) was set up to get feedback, especially from experts working on membrane distillation (MD), and to collect information on ongoing work and topics. Feedback on existing simulation model survey was collected and evaluated.

- In the first round, eight expert groups sent back the questionnaire (2 companies, 6 research groups). It turned out that most of the models are physical models calculating heat and mass transfer on basis of physical transport phenomena. One model is a statistical model based on experimentally gained data input. One model, which is still under development, is also able to consider and investigate fouling.

- Based on the results, different parameter sets consisting of geometrical module data, membrane and material specifications and operation conditions (temperatures, volume flow rates, feed composition, etc.) were defined and will be sent out for comparative simulation studies. The Key Performance Indicators (KPIs) and boundary conditions for MD were specified namely flux, specific thermal energy demand, specific electrical energy demand and salt rejection at defined operation parameter (A.2.5.). The MD configuration for the comparative simulation study was defined to be DCMD (Direct-Contact-Membrane Distillation) and AGMD (Air-Gap-Membrane Distillation) (Milestone M.A4 "Boundary conditions including technology set up and KPIs for comparative simulation and experimental studies are set"). The associated Deliverable D.A3 "Specification of System design and key performance indicators as basis for comparative simulation studies" is in progress and was postponed by 31st January 2020 (month 16).
- Work started in Activity A.1. Analysis on the identification of potential target groups and customers, a matrix was elaborated for the collection of the different industrial sectors and their substances to be treated (A.1.1.). It became clear that the exact composition of fluids must be known to decide about the appropriate treatment technology. From the collected detailed data, potential applications for MD will be identified. This is important on the one hand in order to create the market for MD and on the other hand for R&D in order to adapt the technology to the particular needs of the applications. During the Task 62 meetings, it became obvious that the MD manufacturers, who are already active in industrial processes, are not really willing to disclose their successful applications at the moment since they are still in the test phase and are afraid of competitors. Through discussions within the meeting, it became clear that within the next year (end of 2020) major testing will be finalized and more information about streams from different industrial sectors will be published. Main outcomes will be integrated into the work from Task 62.
- Within the public funded projects, for example EU H2020 “ReWaCEM” and BMBF “HighCon,” potential applications for MD were analyzed and tested for particular cases in metal plating industry, food and beverage and cosmetic production. It became clear that a completion of the planned matrix on target group of industries and potential customers most suitable for the implementation of solar thermal separation processes will need more time for the collection of validated data.
- The BMWI (Germany, national) funded project, Green Manufacturing, started with a kick-off meeting in October 2019. The objective of this project is to investigate options for a sustainable production of PV cells and modules.

Subtask B: Solar Water Decontamination and Disinfection Systems

- Work on Deliverable D.B1 is underway and scheduled to be finished by March 2020.
  - Survey to identify potential applications in industry for water decontamination and disinfection (Activity B.1. “Solar Photocatalytic Systems for industrial process water and wastewater treatment”). Submission of the survey on water treatment technologies and potential new applications of solar energy in industrial wastewater decontamination and disinfection to newly identified industrial associations, end-users and water management companies.
  - Identification of:
    - state-of-the-art and potential applications of solar water decontamination and disinfection systems in industrial water management.
    - cross-lined points and potential industrial applications between solar thermal and photons adsorption technologies.
    - existing and new economic and political barriers for the implementation of available industrial wastewater treatment technologies.
- Pushing Water-Energy nexus in industry through workshops and other events (e.g., INTERSOLAR conference and exhibition in Munich, Germany), Participation in Action Groups of Industry &

SHC Task 62 booth at COP25 in Madrid with Subtask B leader Isabel Oller (CIEMAT – P.S.A)

Water of the Water Supply and Sanitation Technology Platform in Europe (WssTP) and in the related Working Group in the EIP Water).

- Meeting with the WssTP working group as a way to attract new potential industrial partners, considering the increasing interest
  in this group to reduce the industrial water footprint.
- Active participation in COP25 in Madrid (December 2019), with
  a stand on solar wastewater treatment and disinfection activities as a tool for fighting climate change.

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

- Started the technology analysis to figure out which technologies will be included in the guideline. Parameters were defined to characterize technologies and an excel template was sent out to national experts.
- The C1 "Literature and market review report on established and emerging technologies" focused on gathering information from other Task Subtask leaders and external contacts and compiling a summary report. The main activity was developing and sending a user need and technology profile (UNTP) form to 314 technology developers and end users). Of the responses 32 indicated interest in the Task and 12 responded with details to begin creating a technology profile. Responses were received based in Australia, Chile, Italy, Spain, Netherlands, Malaysia, Germany, South Africa, Sweden, Austria, Portugal and Switzerland.

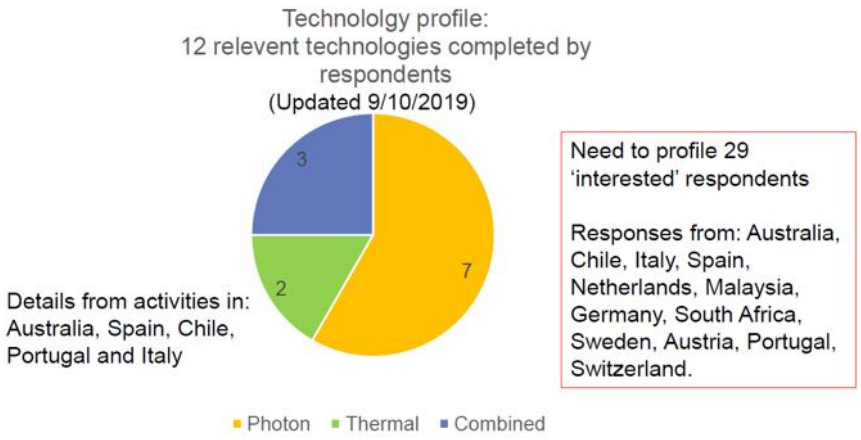


Figure 1. UNTP responses for actions set in Subtask C within last reporting period

- Promotion of the Task at the Asia Pacific Solar Research Conference held in Canberra, Australia on December 3-5, 2019 (http://apvi.org.au/solar-research-conference/).
- Representation of the Task while chairing the conference session theme on Clean Water Technologies at SHC 2019/SWC 2019 https://www.swc2019.org/ in Santiago Chile on 4-7 November 2019.

Work Planned For 2020

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

- Conducting and assessing the comparative simulation studies within Activity A.2. Assessment of concepts and best practices
- Acquiring information and compiling a matrix of different industrial needs for thermal separation versus applicable technologies (D.A1 Matrix of different industrial separation demands to be subjected to cutting edge thermal technologies versus availability of different low exergy heat sources).
- Compiling results and lessons learned from running and recently closed research projects in the field of industrial wastewater treatment

Subtask B: Solar Water Decontamination and Disinfection Systems

- Complete report on existing solar based technologies applied to industrial water decontamination and disinfection, focusing on those considering energy-water nexus necessities. Few results obtained in UNTP will be used and direct contact with agro-food industries are completed. (D.B1 Report on existing solar based technologies applied to industrial water decontamination and disinfection (real and research cases). Potential applications on industrial new sectors.
- Use feedback from ongoing projects specifically related with wastewater reuse for trying to create a communication, dissemination and analyzing tool for thermal/photons technology with potential interest in the market. Where is exactly the necessity? Activity B.4.3. Awareness and dissemination for solar industry
- Focus on the possible development of new solar reactors concept for industrial wastewater reuse by combining thermal and photons action from solar energy.

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

- Complete technology review (Deliverable D.C1 Report on technologies to be considered for guidelines)
- Organize 5th Task Meeting with technology developers/manufacturers and end-users in Australia and present literature review findings and seek input from attendees.
- Utilize feedback to prepare report on how energy-water nexus is being applied in the industry (Deliverable D.C2 Report on how water-energy nexus concept is actually being applied in the industry).

Dissemination Activities In 2019

Reports, Published Books

Author / Editor	Title	Bibliographic Reference
Subtask C team	Technology list - Part B of Solar water treatment user need technology template form	
Subtask B team	Identification of need - Part A of Solar water treatment user need technology template form	
Book editors: T.-S. Chung and K.-J. Lu Chapter authors: M. C. Duke and N. Dow	Book title: Membrane distillation: membranes, hybrid systems and pilot studies, Chapter title: Membrane Distillation for Industrial Water Treatment: Experiences from Pilot Trials. Membrane distillation: membranes, hybrid systems and pilot studies	Publisher: Taylor & Francis
Subtask B team	Book chapter (8): Economic Assessment and Possible Industrial Application of a (Photo)catalytic Process: A case study	Chapter 8 in Heterogeneous photocatalysis. Relationships with Heterogeneous Catalysis and Perspectives. Elsevier Editorial

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference	Bibliographic Reference
C. Brunner, A. Grubbauer	Solarenergy im industriellen Wasser- und Abwassermanagement	Nachhaltige Technologien,	journal number 01/2019

C. Brunner, A. Grubbauer, A. van der Kleij	Solar Heat for Industrial Water and Wastewater Management	Abstract for Solar World Congress	Date: 03/2019
Mikel Duke	Using solar in managing water for Industry. IEA SHC Task 62 : Solar Energy in Industrial Water Management	2018 Asia Pacific Solar Research Conference in Sydney, Australia, on 5 Dec 2018	http://apvi.org.au/solar-research-conference/proceedings-apsrc-2018/
Amaya-Vías, D., J. A. López-Ramírez, S. Gray, J. Zhang and M. Duke	Diffusion behavior of humic acid during desalination with air gap and water gap membrane distillation.	Publication	Water Research 2019/ 158: 182-192
R. Schwantes, J. Seger, L. Bauer, D. Winter, T. Hogen, J. Koschikowski and S. -U. Geißen	Characterization and Assessment of a Novel Plate and Frame MD Module for Single Pass Wastewater Concentration–FEED Gap Air Gap Membrane Distillation	Publication	MDPI Membranes September 2019
A.Ruiz-Delgado, M.A. Roccamante, I. Oller, A. Agüera, S. Malato.	Natural Chelating agents from Olive Mill Wastewater to enable photo-Fenton like reactions at natural pH	Publication in Catalysis Today	Catalysis Today 328 (2019) 281-285
R. Poblete, I. Oller, M.I, Maldonado, E. Cortes.	Improved landfill leachate quality using ozone, UV solar radiation, hydrogen peroxide, persulfate and adsorption processes	Publication in Journal of Environmental Management	Journal of Environmental Management 232 (2019) 45-51
A Cabrera Reina, S. Miralles-Cuevas, L. Cornejo, L. Pomares, J. Polo, I. Oller, S. Malato	The influence of location on solar photo-Fenton: Process performance, photoreactor scaling-up and treatment cost	Publication in Journal Renewable Energy	Renewable Energy 145 (2020) 1890-1900

Conferences, Workshops, Seminars

Conference / Workshop / Seminar Name	Activity & Presenter	Date & Location	# of Attendees
INTERSOLAR conference	Presentation	May 15 Munich, Germany	20
Workshop in the framework of the H2020 funded project ReWaCem	Presentation of results from installation of demonstrators (technologies: MD and DD)	May 24 Palermo, Italy	30
Desalinización y Tratamiento Solar de Agua	Solar thermal water desalination with membrane technologies. Joachim Koschikowski, Fraunhofer ISE,	May 7-8 Santiago, Chile	30
Konzentrate – eine Herausforderung der	Experimental investigation of membrane distillation	May 8-9	65

Zukunft? / Workshop in the frame of the BMBF Project HighCon	with nearly saturated salt solutions Vinay Hegde, Fraunhofer ISE	Freiburg, Germany	
EAAOP6: 6th European Conference on Environmental Applications of Advanced Oxidation Processes	Keynote: Industrial wastewater treatment by combining AOPs, biological and membrane technologies: Ammonium recovery	June 29 Portoroz, Slovenia	150
A two-day Intensive Course on Solar Driven Desalination and Water Purification	Class: Solar Technologies applied to wastewater purification	March 26 Algeria	
Course: Curso Internacional de Transferencia del Conocimiento Tecnológico sobre la Energía Solar y Tratamiento Solar de Aguas de la Macro Región Centro Sur Andina	Class: Tecnologías Solares aplicadas al tratamiento, desinfección y reutilización de aguas	July 17 Arica, Chile	150
Journees techniques solaire thermique – ADEME	Le potentiel du ST en industrie, et son intégration dans le process industriel	September 25-26 France	100

Dissemination Activities Planned For 2020

- NEXUS Water-Energy-(Bio) Industry conference organized by AEE INTEC in Vienna, Austria, January 2020.
- IFAT 2020 in Munich Germany, May 2020.

Task Meetings 2019 - 2020

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 2	March 18-19, 2019	Almería, Spain	33 (7)
Task Meeting 3	October 8-9, 2019	Freiburg, Germany	24 (8)
Task Meeting 4	April 21-22, 2020	Florence, Italy	
Task Meeting 5	Autumn 2020 (date TBD)	Australia	

SHC Task 62 Participants

Country	Name	Institution / Company	Role
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AUSTRALIA	Yunchul Woo	University of Technology Sidney	National Expert
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Task 63 – Solar Neighborhood Planning

Maria Wall
Energy and Building Design, Lund University
Operating Agent for the Swedish Energy Agency

Task Overview

The main objective of Task 63 is to support key players to achieve solar neighborhoods that support long-term solar access for energy production and for daylighting buildings and outdoor environments – resulting in sustainable and healthy environments. Key players include e.g. 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 the design of new and existing communities with focus on solar energy, comprising methods to secure sunlight access (right to light). Furthermore, the Task aims to focus on economic strategies and business models for better use of passive and active solar energy. Apart from economic values, added values or co-benefits of solar energy 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 above described key areas:

- Subtask A: Solar planning strategies and concepts
- Subtask B: Economic strategies and stakeholder engagement
- Subtask C: Solar planning tools
- Subtask D: Case studies

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 (Lead Country: Canada)
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:

- Analyse 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). Analyse 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

Planned participation from Australia, Canada, China, Denmark, France, Germany, Italy, Norway, Sweden, Switzerland and United Kingdom, and from the organizations ECREEE, EACREEE and RCREEE.

Work During 2019

Subtask A: Solar Planning Strategies and Concepts

Activities planned to achieve the specific objectives, and their timeframe were discussed. The first activity has the goal to define design options and analyze solar neighborhoods in participating countries, to identify key influencing factors in reaching NZE or low-carbon neighborhoods. A first draft matrix was created in order to characterize different archetypes of neighborhoods. The matrix should then be used to collect information about typical neighborhoods from different countries, for simulations and analyses regarding solar planning strategies and concepts for neighborhoods.

Subtask B: Economic Strategies and Stakeholder Engagement

The New Urban Agenda was discussed; how the work in Task 63 is connected and how to implement these principles in planning solar neighborhoods. It was agreed to use the NUA principles as the backbone and motivation for the Task's work. This will be especially useful as a way to communicate the concrete outputs of the Task and link them to the global visions.

Two more activities were initiated: Activities B.2 "Identify and describe conflicts and synergies of the different and potential urban surface usages, with specific relevance to solar energy harvest," and B.4 "Develop a framework to assess the multiple-benefits created by the adoption of hybrid and integrated strategies for urban surface usage." Urban surfaces categorization in the three dimensions of the urban environment was discussed. Further discussions dealt with surface uses classification, identification of synergies among surface uses, and discussion on how these synergies could contribute in planning solar neighborhoods and pursuing climate resiliency and sustainability objectives. Based on this, a proposal for classification of urban surfaces and surface uses, and a matrix of conflicts and synergies among surface uses will be developed.

Subtask C: Solar Planning Tools

Activities planned to achieve the specific objectives, and their time frame, were discussed. Activity C.1 "Identification of current tools and tool workflows on all platforms" was started. Key questions discussed were a) how can we best identify current tools and workflows and their abilities?, b) which Key Performance Indicators should an ideal tool / toolchain be able to provide? and c) how can we identify the needs of (external) key actors in the planning of solar neighborhoods in the best possible way? It was decided to start up a literature survey of available tools and common Key Performance Indicators.

The activities started in Subtask C will lead to a report on existing types of tools and workflows. The focus is on analyses of different types of tools and how they can be linked, the types of output (Key Performance Indicators), visualization of results, users (needed competences) and target audiences. Thus, it will not be a list of existing specific (single) tools, since such a report would be outdated very fast. This report will be a basis for the next phase/report.

Subtask D: Case Studies

In Subtask D, a matrix was developed to fill in potential case studies including some key information (category, stage of project, goals for planning of the neighborhood, solar strategies used, energy targets, tools used, economic issues, other benefits, stakeholder engagement etc.). This matrix is presently circulated to collect potential solar neighborhood cases from different (participating) countries, to study within Task 63. Case studies could be new area developments or existing areas to be further developed (refurbishments, infills etc.).

We also started to develop a template for describing the Task 63 case studies, in relation to the topics of each Subtask A/B/C, to ensure that we will work on and get all the information needed. A first draft will be developed based on the initial discussions.

The activities started in Subtask D will support the work on case studies in participating countries and clarify our needs. The cooperation with different local solar neighborhood planning projects will give us feedback on our work and also give us the opportunity to present our results. Selected case studies will be presented according to the template we will develop and published on the SHC website.

Work Planned For 2020

Subtask A: Solar planning strategies and concepts

The proposed draft matrix describing archetypes will be modified and discussed further. This will assist in developing a universal matrix to collect all relevant information for archetype development. Information will be collected about 2-3 neighborhoods to analyze and test the draft matrix. Links to the other subtasks will be further discussed, including how to use the archetypes for separate or joint studies. Planned main activities in 2020:

- Review existing case studies and fill information in the archetype matrix.
- Extract main criteria that can be used in the development of neighborhood archetypes.
- Start drafting the review of existing neighborhoods and detailing criteria of selection of archetypes (internal report).
- Start design neighborhood archetypes that encompass combinations of design parameters.

Subtask B: Economic strategies and stakeholder engagement

The main activities planned for Subtask B in 2020 are:

- Propose a classification of urban surfaces and surface uses.
- Develop a matrix of conflicts and synergies among surface uses.
- Literature review on surface uses, synergies and conflicts, and existing case studies.
- Develop a method to define urban surface uses and to start testing the method on archetypes (Subtask A).
- First overview on innovative financial models and trends for solar neighborhoods / Test of methodology for evaluating added values from solar systems.
- First draft of framework to assess the multiple benefits created by the adoption of hybrid and integrated strategies for urban surface usage.
- Start development of framework for stakeholder engagement.

Subtask C: Solar planning tools

The main activities planned for Subtask C in 2020 are:

- Coordinating with subtask B on interviewing key actors.
- Setting up and performing a literature review on available tools and workflows.
- Setting up and performing a literature review on Key Performance Indicators.
- Identify and describe current tools and workflow.
- Combine and generalize workflow.
- Drafting report on the identification of existing tools and workflows.
- Identify missing parts in tool workflow.

Subtask D: Case studies

The main activities planned for Subtask D in 2020 are:

- Draft template for describing case studies, based on identified key aspects and indicators.
- Test template on case study, revise and finalize template.
- Identify potential case studies per country.
- Create matrix with an overview of potential case studies and topics and identify missing ones.

- Prepare and carry out the first workshop/seminar in conjunction with the Task meeting in September 2020.

Dissemination Activities In 2019

Task 63 started in September 2019. Therefore, no reports have been published or workshops/seminars held.

Dissemination Activities Planned For 2020

A first workshop/seminar is planned in conjunction with the Task meeting in September 2020.

Task Meetings 2019 - 2020

Meeting	Date	Location	# of Participants (# of Countries)
Task Meeting 1	October 22-24, 2019	Le Bourget-du-Lac, France	25 (9)
Task Meeting 2	March 10-12, 2020	Lund, Sweden/Virtual	
Task Meeting 3	September 22-24, 2020	Padua, Italy	
Public workshop	September 25, 2020	Padua, Italy	

SHC Task 63 Participants

Since the Task recently started, only the leaders are listed so far. The leaders below are also jointly leading Subtask D. Participants are still being confirmed from the countries and organizations mentioned above.

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ITALY	Silvia Croce	EURAC Research	Subtask B Leader
SWEDEN	Jouri Kanters	Energy and Building Design, Lund University	Subtask C Leader
FRANCE	Christophe Ménézo	University Savoie Mont-Blanc - INES	Subtask C Leader

7. SHC Programme Contacts

These were the members as of December 2019. *Please check www.iea-shc.org for current members & contact information.*

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