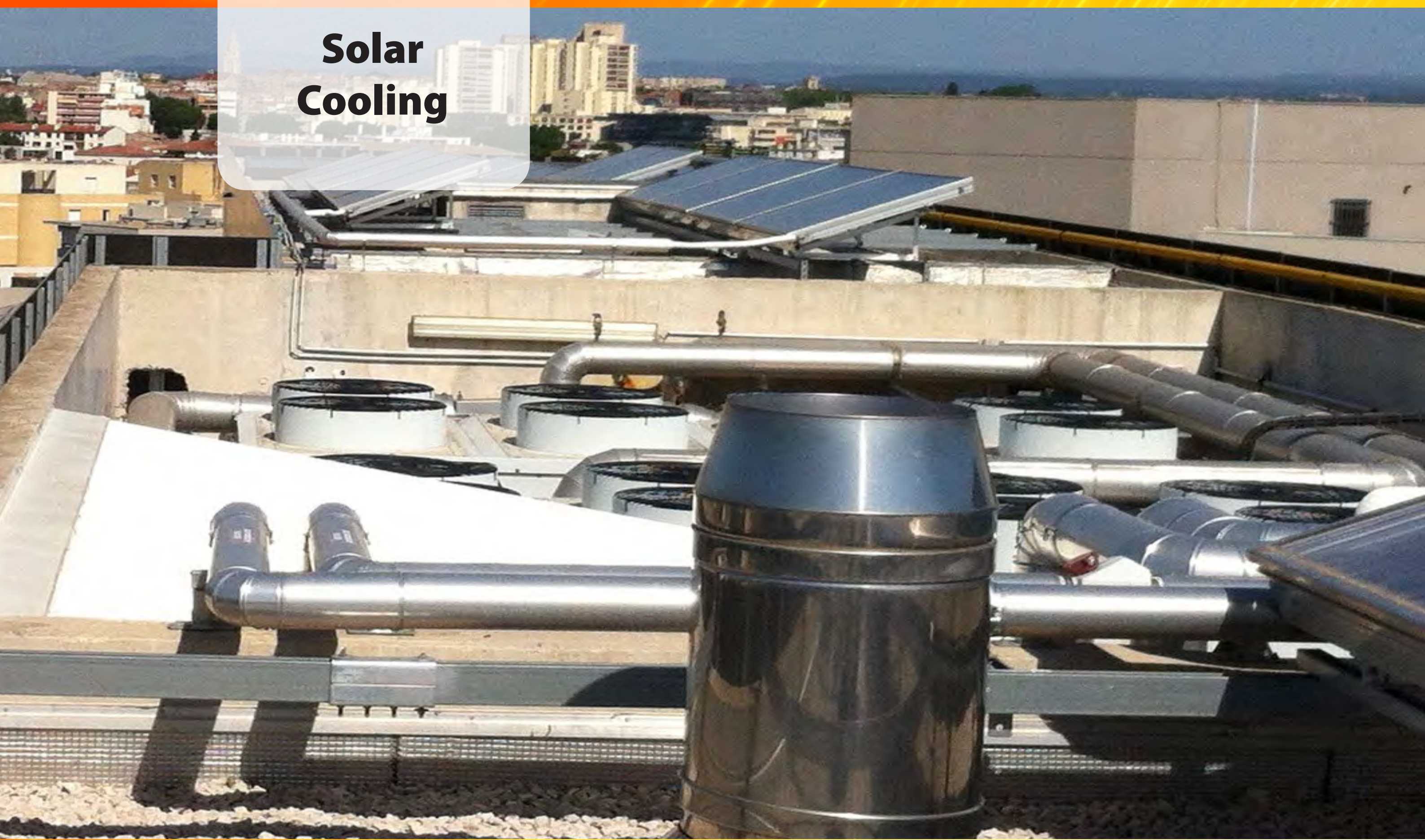
SHC
IEA SOLAR HEATING & COOLING PROGRAMME

2015

ANNUAL REPORT

Feature Article on

Solar Cooling



Technology Collaboration Programme on Solar Heating and Cooling

2015 Annual Report

Edited by
Pamela Murphy
SHC Secretariat
IEA Solar Heating and Cooling Programme

www.iea-shc.org

July 2016

Cover Photo: solar cooling and DHW system (SERM) in Montpellier, France

Table of Contents

SHC Technology Collaboration Programme Overview

ABOUT THE SOLAR HEATING AND COOLING PROGRAMME

The Technology Collaboration Programme on Solar Heating (SHC TCP) was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency. The Executive Committee agreed upon the following for the 2014-2018 term:

The SHC Programme's **vision**…

By 2050 a worldwide capacity of 5kW$_{th}$ per capita of solar thermal energy systems installed and significant reductions in energy consumption achieved by using passive solar and daylighting: thus solar thermal energy meeting 50% of low temperature[1] heating and cooling demand.

The SHC Programme's **mission**…

To enhance collective knowledge and application of solar heating and cooling through international collaboration in order to fulfill the vision

The SHC Programme's 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 Programme will carry out and co-ordinate international R&D work and will continue to cooperate with other IEA Implementing Agreements as well as the solar industry to expand the solar market. Through international collaborative activities, the will support market expansion by providing access to 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.

The Programme's target audience is 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.

1 Low temperature heat up to 250°C

The primary activity of the SHC Programme 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. Overall control of the Programme rests with the Executive Committee comprised of one representative from each member Country and Sponsor organization.

A total of 54 projects have been initiated to date. The Tasks running in 2015 were:

- Price Reduction of Solar Thermal Systems (Task 54)
- New Generation Solar Heating and Cooling (Task 53)
- Solar Heat and Energy in Urban Environments (Task 52)
- Solar Energy in Urban Planning (Task 51)
- Advanced Lighting Solutions for Retrofitting Buildings (Task 50)
- Solar Heat Integration in Industrial Processes (Task 49)
- Quality Assurance and Support Measures for Solar Cooling Systems (Task 48)
- Solar Resource Assessment and Forecasting (Task 46)
- Solar Rating and Certification Procedures (Task 43)
- Compact Thermal Energy Storage (Task 42)

In addition to the project work, an international conference on Solar Heating and Cooling for Buildings and Industry was launched in 2012 and the 4th conference was held December 2015 in Istanbul, Turkey. Also, a number of special activities – Memorandum of Understanding with solar thermal trade organizations, statistics collection and analysis, conferences and workshops – have been undertaken.

ABOUT THE INTERNATIONAL ENERGY AGENCY (IEA)

Established in 1974, the International Energy Agency (IEA) carries out a comprehensive programme of energy co-operation for its 29 member countries and beyond by examining the full spectrum of energy issues and advocating policies that will enhance energy security, economic development, environmental awareness and engagement worldwide. The IEA is governed by the IEA Governing Board which is supported through a number of specialized standing groups and committees. For more information on the IEA, see http://www.iea.org.

The IEA Energy Technology Network

The IEA Energy Technology Network (ETN) is comprised of 6 000 experts participating in governing bodies and international groups managing technology programmes. The Committee on Energy Research and Technology (CERT), comprised of senior experts from IEA member governments, considers effective energy technology and policies to improve energy security, encourage environmental protection and maintain economic growth. The CERT is supported by four specialized Working Parties:

- Working Party on Energy End-use Technologies (EUWP): technologies and processes to improve efficiency in the buildings, electricity, industry, and transport sectors

- Working Party on Fossil Fuels (WPFF): cleaner use of coal, improvements in gas/oil exploration, and carbon capture and storage
- Fusion Power Co-ordinating Committee (FPCC): fusion devices, technologies, materials, and physics phenomena
- Working Party on Renewable Energy Technology (REWP): technologies, socio-economic issues and deployment policies

Each Working Party coordinates the research activities of relevant IEA Technology Collaboration Programmes (TCPs). The CERT directly oversees TCPs of a cross-cutting nature.

The IEA Technology Collaboration Programmes (TCPs)

The IEA Technology Collaboration Programmes (TCPs) are international groups of experts that enable governments and industries from around the world to lead programmes and projects on a wide range of energy technologies and related issues, from building pilot plants to providing policy guidance in support of energy security, economic growth and environmental protection. The first TCP was created in 1975. To date, TCP participants have examined close to 2 000 topics. Today TCP participants represent more than 300 public and private-sector organisations from over 50 countries. TCPs are governed by a flexible and effective framework and organised through an Implementing Agreement. TCP activities and programmes are managed and financed by the participants. To learn more about the TCPs, please visit the IEA website http://www.iea.org/tcp.

Chairman's Report

Ken Guthrie
Sustainable Energy Transformation Pty Ltd, Australia

2015 was a year of consolidation of our activities within the IEA SHC Technology Collaboration Programme (TCP). We held our fourth international conference in Turkey. We started a new task on reducing costs for solar thermal systems and completed four important Tasks. A number of other Tasks are in the development phase and we expect that they will begin in 2016. On the administrative side, we made changes to improve our operations.

In terms of membership, whilst no new members joined in 2015, we are in advanced discussions with ISES and Slovakia and expect that they both will join in 2016.

We are almost half way through our 2014-2018 Strategic Plan. This plan is moving us toward our 2050 vision of solar thermal energy meeting 50% of low temperature heating and cooling demand.

To meet this vision, the IEA SHC TCP has five objectives:

1. To be the primary source of high quality technical information and analysis on solar heating and cooling and daylighting technologies, designs and applications.
2. To contribute to a significant increase in the performance of solar heating and cooling technologies and designs.
3. To contribute to cost reduction of solar thermal components and systems in order to increase their market competitiveness.
4. To enhance cooperation with industry, international organizations and local, regional and national governments on increasing the market share of solar heating and cooling technologies and designs.
5. To increase the awareness and understanding on the potential and value of solar heating and cooling systems by providing information to decision makers and the public.

Significant progress has been made toward delivering on all these objectives. Some details of our work can be found in this report and more details are available on our website, www.iea-shc.org.

In 2015, we continued our collaborations both internally with other IEA Technology Collaboration Programmes that cover Renewable Energy and End use Technologies, and externally with industry and information organizations to better understand industry needs and to improve the information and uptake of our research results. The new collaboration with solarthermalworld.org has significantly increased the reach of our work.

In closing, I would like to thank my Vice Chairs, He Tao, Daniel Mugnier and Michaela Meir, the members of the Executive Committee, the Operating Agents of the Tasks as well as all the experts working in our projects, the Secretariat, Pamela Murphy, and the Webmaster, Randy Martin. I look forward to continuing to work productively with the Executive Committee and Operating Agents as I coordinate this work from Australia.

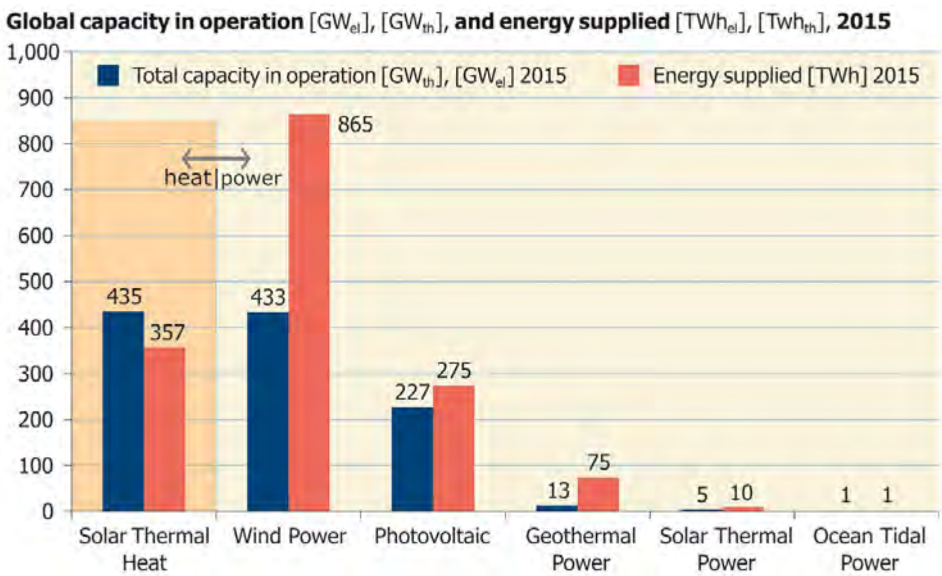
Ken Guthrie
SHC Executive Committee Chairman

2015 Recap

SOLAR THERMAL OUTLOOK

The SHC Programme publishes the only annual global solar thermal statistics report, *Solar Heat Worldwide: Markets and Contribution to the Energy Supply*. A new addition to the report is data on solar thermal cost and levelized costs of heat (LCOH), which covers the economic performance indicators and cost ranges at the system level in major solar thermal markets.

The 2016 edition reports that in 2014, solar thermal technologies produced 335 TWh – which corresponds to an energy savings equivalent of 36.1 million tons of oil and 116.4 million tons of CO_2.



The vast majority of the total capacity at the end of 2014 was in China (289.5 GW_{th}) and Europe (47.5 GW_{th}), which together accounted for 82% of the total capacity, and thus significantly impacted the global market as their markets saw a decline between 2013 and 2014 of -18% and -3% respectively. From the top 10 markets in 2014 positive growth was reported from Greece (+19.1%), Mexico (+18.2%), India (+7%), Brazil (+4.5%) and the United States (0.9%).

The number of jobs globally in the fields of production, installation and maintenance of solar thermal systems was estimated to be 730,000 in 2014. And, the worldwide turnover of the solar thermal industry was US$ 24 billion.

SHC MEMBERS

New Members

No new members joined the SHC TCP in 2015. Communication with potential new members was made with Barbados, Brazil, Chile, India, ISES, Luxembourg, Slovakia, South Korea, and Thailand.

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 2015, the following Task began:

- Task 54: Price Reduction of Solar Thermal Systems
  (Lead Country: Germany)

Completed Tasks

The following Tasks ended in 2015:

- Task 42: Compact Thermal Energy Storage
  (Lead Country: Netherlands then Switzerland)

- Task 43: Rating and Certification Procedures – Advanced Solar Thermal Testing and Characterization for Certification of Collectors and Systems
  (Lead Country: Denmark)

- Task 48: Quality Assurance and Support Measures for Solar Cooling Systems
  (Lead Country: France)

- Task 50: Advanced Lighting Solutions for Retrofitting Buildings
  (Lead Country: Germany)

SHC ACTIVITIES

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 60 documented countries represents 95% of the solar thermal market worldwide.

International Conference on Solar Heating and Cooling for Buildings and Industry

Our international conference series provides a platform for experts to gather and discuss the trending topics and learn about the work others are doing in the field. SHC 2015, the 4th SHC conference was held with ESTIF, hosted by GÜNDER, International Solar Energy Society – Turkey Department, and organized by PSE AG, The conference was held on December 2-4 in Istanbul, Turkey and over 230 people attended from 19 countries. The conference program included 95 presentations and 85 scientific posters. The next SHC Conference will be held jointly with ISES/Solar World Congress in Abu Dhabi, UAE in October 2017.

SHC Solar Award

Our prestigious award recognizes individuals, companies and institutions that have made significant contributions to the growth of solar thermal. The 2015 SHC Solar Award recognized Green Brewery Göss, a private sector company that is contributing to

the expansion and improvement of solar thermal technology through the application in their business. This 10th award was to be presented at SHC 2015 in Istanbul, but due to travel difficulties of the recipient it was presented at Gleisdorf SOLAR 2016 in Graz, Austria on June 8, 2016.

SHC Book Series

This growing collection of books on Task results is published by Wiley-VCH. In 2015, two books were published, *Modeling, Design, and Optimization of Net-Zero Energy Buildings* and *Solar and Heat Pump Systems for Residential Buildings*. And in late 2016, two additional books will be published.

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

Please take a moment to learn more about these activities and our work. Our website, http://www.iea-shc.org is a good starting point.

SHC COLLABRATION

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

Within the IEA

IEA Energy Conservation through Energy Storage Programme collaborated in *SHC Task 42: Compact Thermal Energy Storage*. This is the first fully joint Task with

Operating Agents from each TCP.

IEA Photovoltaic Power Systems Programme is collaborating in *SHC Task 46: Solar Resource Assessment and Forecasting*.

IEA SolarPACES Programme is collaborating in *SHC Task 46: Solar Resource Assessment and Forecasting* and *SHC Task 49: Solar Heat Integration in Industrial Processes.*

IEA Buildings Coordination Group is represented by the Spanish Executive Committee, Ricardo Enriquez, who attends the semiannual meetings.

Outside the IEA

Solar Industry Associations in Australia, Europe and North America are collaborating with the SHC Programme to increase national and international government agencies and policymakers awareness of solar thermal's potential and to encourage industry to use solar thermal R&D results in new products and services. To support this collaboration, the 10th SHC/Trade Association meeting was jointly organized with the European Solar Thermal Industry Federation (ESTIF) and held in conjunction with SHC 2015 in Istanbul, Turkey.

European Solar Thermal Industry Federation (ESTIF), the SHC Programme has a close working relationship with ESTIF. A Memorandum of Understanding was signed to jointly organize the SHC 2015 conference with the option to collaborate on future SHC conferences.

ISO TC 180*,* the SHC Programme, specifically through Tasks, is supporting the work of ISO TC 180. For example, Task 43: Rating and Certification Procedures defined the revisions needed to standard ISO 9806 for solar collector testing.

EXECUTIVE COMMITTEE MEETINGS

2015 Meetings

The Executive Committee held two meetings:

- June 15-17 in Rotterdam, Netherlands
- November 30 – December 1 in Istanbul, Turkey

2016 Meetings

- June 1-3 in Almeria, Spain (including Technical Tour)
- November 9-10 in Doha, Qatar (including Technical Tour on November 6 and National Day on November 7-8)

Membership

CONTRACTING PARTIES

Australia	European Commission	Mexico	Spain
Austria	Finland	Netherlands	Sweden
Belgium	France	Norway	Switzerland
Canada	Germany	Portugal	Turkey
China	Italy	Singapore	United Kingdom
Denmark		South Africa	United States

SPONSORS

ECREEE *(ECOWAS Centre for Renewable Energy and Energy Efficiency)*
ECI *(European Copper Institute)*
GORD *(Gulf Organization for Research & Development)*
RCREEE *(Regional Centre for Renewable Energy and Energy Efficiency)*

BENEFITS OF MEMBERSHIP

The SHC Programme is unique in that it provides an international platform for collaborative R&D work in solar thermal. The benefits for a country to participate in this Programme 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-government organization can join please contact the SHC Secretariat *(secretariat@iea-shc.org)*.

Feature Article

Solar Cooling

Daniel Mugnier
TECSOL SA
Task 48 Operating Agent for ADEME (France)

INTRODUCTION

The increasing demand for refrigeration and air conditioning has led to a dramatic increase in peak electricity demand in many countries. With the increase in demand comes the increase in the cost of electricity and summer brownouts, which have been attributed to the large number of conventional air conditioning systems running on electricity. As the number of traditional vapor compression cooling machines grows (more than 100 million units sold in 2014) means higher levels of greenhouse gas emissions, both from direct leakage of high GWP refrigerant, such as HFCs, and from indirect emissions related to fossil fuel derived electricity consumption.

An obvious possibility to counter this trend is to use the same energy for generation of cooling that contributes to creating the cooling demand—solar energy. The distinct advantage of cooling based on solar energy is the high coincidence of solar irradiation and cooling demand (i.e., the use of air conditioning is highest when sunlight is abundantly available). This coincidence reduces the need for energy storage, as the cooling produced from solar energy is almost immediately used.

While many professionals, such as architects and installers think of photovoltaic systems in combination with conventional vapor compression cooling machines as the most obvious solar option, the alternative option – solar thermal systems in combination with thermally driven sorption chillers are now a market ready technology.

STATUS OF THE TECHNOLOGY AND INDUSTRY

The status of solar assisted cooling (SAC) technology is described below by looking at the technical maturity, energy and cost performance, and the status of market deployment.

Technical Maturity

The key components of SAC systems are the solar collector subsystem and the thermally driven cooling subsystem. Additional key components are a heat rejection unit to reject the waste heat from the thermally driven chiller and a thermal storage system (hot, cold) to manage the intermittent availability of the solar resource.

Solar collectors and solar collector systems are common and have achieved a good status of technical maturity. For SAC systems that operate with temperatures below approximately 110°C there exists a good supply of robust, cost effective solar collectors. In the last few years, some new concepts for solar collectors have been developed that lead to increased safety and enhanced solar collection efficiency. Examples of solar collectors operated with water, include drainback systems and night recirculation.

Solar collector systems for higher temperatures, which are needed for multi-stage absorption chillers and high temperature lift applications, are still scarce. However, there are an increasing number of manufacturers entering the market with new products – typically single-axis tracking with optical concentration.

Large thermally driven chillers and open sorption cycles have existed for many decades and are established in the market. Their main operation today is with waste heat (e.g., from a co-generation system or industrial waste heat) or directly gas-fired. Typically, they are designed for operation to provide base load cooling and are not specially optimized for operation with intermittent solar energy. Good system design should enable relatively smooth thermal flows to the chiller.

In the last decade, progress was made in the field of small capacity thermally driven chillers (up to approximately 35 kW_{cold}) and SAC has significantly contributed to stimulating this development. Today, numerous systems from various manufacturers are offered on the market and have reached considerable technical maturity. However, most of the manufacturers are small start-up companies. Some of these companies have set up manufacturing capacity on an industrial scale.

Installation of thermal buffer storage is quite common in SAC installations. Sizes range from small buffers, to overcome short-term fluctuations, up to large buffer stores used to save solar gains for a number of hours (e.g., from noon to afternoon). Storage can be applied on the hot and/or cold side and are usually filled with water. In a few applications, ice storage has been applied on the cold side in order to increase the storage density (in applications with cooling demand at temperatures below 0°C). Other phase change materials are still not common in solar cooling.

Energy Performance

Solar cooling systems have been proven to save energy in comparison to conventional technology. The achieved energy savings strongly depend on system design and operation. Key factors that determine the achieved energy savings are 1) the solar fraction of the heat needed to drive the thermally driven cooling device, and 2) the overall electricity demand for auxiliary components, such as the fans (e.g., the fan in the cooling tower) and the pumps in the hydraulic circuits.

The main requirements for achieving energy savings from a SAC system are:

- Keep the design as simple as possible in order to reduce risks of errors in implementation, operation, and maintenance.
- Carefully design and plan in order to define the optimal size of key components and an appropriate design fitting to the actual load profile, including strategies for efficient backup cooling when solar heat is not available.
- Auxiliary components (pumps and fans) should be highly energy-efficient.
- An operation and control strategy has to be developed that leads to energy-efficient operation under both full and part load conditions.
- A careful commissioning phase of the system is necessary to ensure system operation as planned. An ongoing monitoring ("continuous commissioning") program is also helpful in order to enable long-term operation at highest possible performance.

Economic Viability and Environmental Benefits

As with other renewable energy systems, the first cost (investment cost including planning, assembly, construction and commissioning) of SAC systems is significantly higher than the corresponding cost of standard grid electricity based solutions. The first cost of realized SAC installations is between 2 and 5 times higher than a conventional state-of-the-art system depending on local conditions, building requirements, system size, and of course on the selected technical solution. In recent studies, first cost for total systems ranged from 2,000 € per kW_{cold} to 5,000 € per kW_{cold} and even higher in some particular cases. This large range is due to different sizes of systems, different technologies, different application sectors, and other boundary conditions.

A recent trend is the development of (solar) cooling kits; that are pre-engineered package solutions containing all of the main components of a system and where the components are well integrated with each other. These kits are mainly developed for small capacities, up to about 35 kW cooling capacity. Prices (excluding installation cost and distribution system to the building) for the package solutions dropped from about 6,000 € per kW in 2007 to about 4,500 € per kW in 2013.

The cost saving during operation very much depends on the boundary conditions. Boundary conditions in favour of a low payback time are:

- High annual solar radiation leads to high gains of the solar system.
- A long cooling season leads to a large number of hours where the system is used.
- Other heat loads such as for sanitary hot water and/or process heating increase the usefulness of the solar system, particularly in the shoulder season where building heating and cooling loads are reduced.
- High prices of conventional energy make a solar alternative more competitive.

Looking at the overall life cycle cost of a SAC system (excluding any incentives or funds) in comparison to a conventional standard solution the situation looks much better than in the case of first cost. Depending on the particular conditions SAC systems will in many cases amortize within their lifetime. Under promising conditions payback times of ten years and less can be obtained. However, commercial companies often expect a payback time of five years and less in order to justify an investment. Such low values of payback time will only be achieved under very special conditions.

SAC applications have some other advantages that are often difficult to translate into an economic advantage, but may be important to be considered by policy makers:

- SAC systems can contribute to reducing electricity infrastructure costs (and hence reduce electricity tariffs) in regions where a considerable share of peak electricity consumption from the grid is from air-conditioning with conventional techniques. Similarly, it may contribute to grid stability in regions where electricity infrastructure is insufficient to meet demand.
- Application of SAC systems may lead to (primary) energy savings and thus help to reduce the dependence of finite energy fuels, which have to be imported in many countries.
- Correspondingly, application of SAC systems will lead to reduced CO_2 emissions and thereby contribute to a reduction of climate change and related effects.

- SAC systems using thermally driven cooling cycles show additional environmental benefits since they typically employ refrigerants with no ozone depletion potential and no or a very small global warming potential.
- SAC systems can be used also for all heating applications in a building or industry. The large solar collector field also provides heat for other purposes than cooling and thus helps to avoid consumption of fuel (or electricity) for heating applications.

CURRENT BARRIERS

Currently, the main shortcoming of SAC from a technical perspective lies in system level integration. Many systems fail to achieve the planned energy savings because of shortcomings in proper design and energy management of systems that result in a high overall electricity consumption of auxiliary components. A particular area where mistakes are made is the heat rejection subsystem, which often has not received sufficient attention in the past. Another mistake made is that many systems were far too complex and as a result created non-optimal control and have required significant maintenance effort.

The main problem areas, observed from practical experience of realized installations, are:

- Heat rejection: cooling towers often need too much electricity and are not controlled for part load. Small capacity wet cooling towers are relatively expensive and need an inappropriate high effort for maintenance. Dry cooling towers need more electricity and often the re-cooling temperatures are too high for the solar thermally driven chillers. Hybrid systems (dry/wet) seem to be a promising solution, but very few systems are available on the market and they are not optimized for combination with thermally driven chillers.
- High efficiency auxiliary components and careful hydraulic design are essential. This is particularly important, as solar cooling systems need more hydraulic loops than standard solutions.
- Another technical barrier concerns the integration of all components into a complete system. The overall system design requires various professional skills for the different subsystems: solar energy at medium temperature (higher than that used for standard sanitary hot water application), hydraulics with pressurized and medium temperature water, and air-conditioning or industrial cooling.

The second main barrier for SAC is the economics. The cost of a SAC installation is between 2 and 5 times higher than a conventional state-of-the-art system. Two ways to overcome this barrier are 1) to focus on medium to large system sizes, which lead to economies of scale, and 2) to standardize as much as possible the systems to reduce on site efforts and risks. Also a higher focus should be placed on policy strategies that enable a cost reflective means of internalizing electricity system costs into the upfront purchase price of solar cooling systems.

CHALLENGES FOR SOLAR COOLING

SAC technology is at a critical stage. Mature components are available and many installations have been realized. The technology has shown that significant energy savings are possible, and it has reached a level of early market deployment. However, the financial risk for parties involved in SAC business is still too high.

The following actions should lower this risk:

- **Development of systematic quality assurance requirements and standards for SAC systems**: Currently, there are no international ISO/EN standards or norms specifically relating to solar cooling. Such standards would help give users the necessary confidence in the level of energy savings and related cost savings. They could also provide a rigorous basis for allocating funding or tax credit schemes to stimulate market development
- **Deployment of specific training for actors involved in SAC projects**: most planners and installers have little experience with SAC technology and thus the effort – and related cost – to install those systems is higher than for standard systems.
- **Implement industry development support schemes that provide like for like incentives to SAC technology as to solar PV, and additionally reflect the unique benefits of SAC to the electricity system**: These support schemes would help to avoid perverse incentives in electricity system investment decisions. And it would help build the market to achieve economies of scale and a competitive supply chain.

Measures to support sustainable market development are most important. This includes establishing large-scale demonstration programs with both 1) incentives and 2) quality assurance requirements that combine to encourage adoption and lower the risk.

All these actions should be organized at the regional and national levels. And, they should first be promoted in regions where cooling is an important issue (Middle East, South East of Asia, Sun Belt in the USA, Australia for example) and where environmental issues are a major concern (impact of pollution due to greenhouse gas emissions).

Quality procedures that cover all phases of a project are most critical in order to satisfy the expectations of all involved stakeholders. This work has been widely covered by the work of *Task 48: Quality Assurance & Support Measures for Solar Cooling Systems* of the IEA SHC Programme and these tools should be widely promoted and used in the next years.

IEA SHC SOLAR COOLING WORK

Solar Thermal Driven Heating and Cooling (STDHC) systems are included in the IEA SHC Strategic Plan's Key Technologies section[1] due to their potential to cover much of the rising demand for air-conditioning by utilizing solar energy. The completed IEA SHC tasks related to Solar Air conditioning (Task 25 and Task 38) allowed us to focus considerable collaborative international effort to develop this technology from fundamental R&D to first market introduction.

Operating from 1999 to 2004, *IEA SHC Task 25: Solar Assisted Air Conditioning of*

Buildings' primary achievements were to create an outlook for solar cooling, to initiate industrial development and to encourage maturation of the technology. During *IEA SHC Task 38: Solar Air Conditioning and Refrigeration* (2006-2010) the expert participants created tools and methods to help with the market introduction of the emerging technology. SHC Task 38 also analyzed the efficiency and reliability of the new generation of solar cooling systems and evaluated demonstration and pilot installations as well as the first commercial deployment. A recent survey shows the estimated number of installation worldwide was about 1200 systems in 2014 (Figure 1).

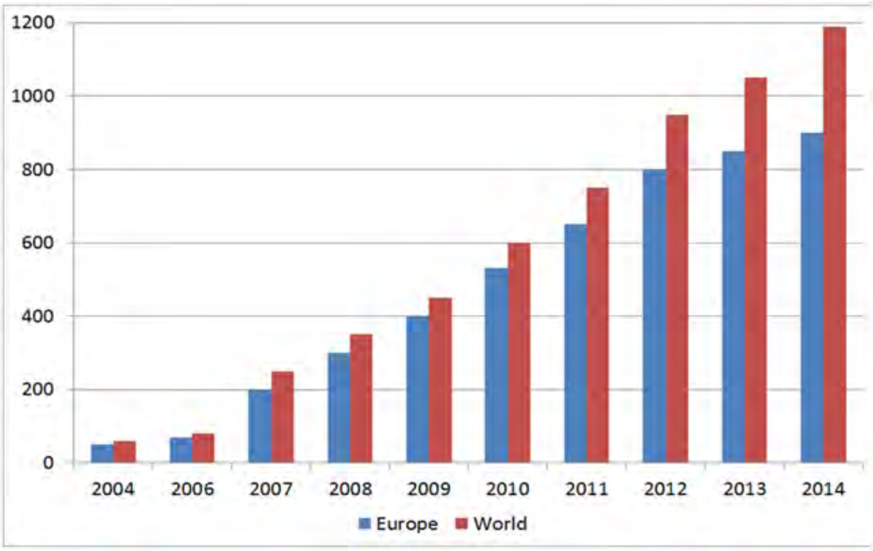


Figure 1. Estimated number of solar cooling installations worldwide. *(Source: TECSOL/SOLEM)*

Further work to collect data on new solar cooling developments shows that under certain conditions and with a considerable effort during design, installation, commissioning and operation, the technology is reliable, promising and competitive in terms of energy, amenity and environmental impact. While some earlier installations realized since 1999 could not yet be considered as reliable and cost competitive, in some of these new cases solar cooling systems have even proved not only competitive but also economical despite the emerging status of the technology.

In 2010, more than ever solar air-conditioning represented a huge potential of development for solar energy. It was reported that by 2030[2] the expected growth of energy demand in buildings, especially in developed countries, would be far bigger on the cooling side than on the heating side. However, this promising technology was perceived to face two main issues:

(1) A general lack of economic competitiveness – as is the case for many renewable energies unless incentives are in place; and
(2) Secure and proven long term energy performance and reliability.

In addition to supporting and developing solar cooling's increasingly well-known potential, and consolidating previous gains made under SHC Task 25 and SHC Task 38, addressing these barriers prompted the establishment of *SHC Task 48: Quality Assurance & Support Measures for Solar Cooling Systems.*

SHC Task 48 has addressed these obstacles[3] and the main goals of the Task were to:

(1) To develop and provide various measures which lead to highly reliable, durable, efficient and robust solar cooling (and heating) systems; and
(2) To contribute to further cost reduction throughout the technology chain and identify the most promising market areas in terms of cost competitiveness.

This Task aimed as well to enlarge current European-centric efforts and work with countries outside Europe. Countries such as China, India, Singapore, USA, Canada, South Africa and Australia are already members of IEA SHC. In these countries, Solar Thermal Driven Heating and Cooling technology is dynamic and represents a much greater market potential due to characteristics such as the climate, energy market structure and issues such as peak demand. Actions to stimulate participation in these countries have been implemented under SHC Task 48.

RESULTS FROM RECENT IEA SHC WORK – SHC TASK 48

Since SHC Task 48 began at the end of 2011, 20 reports and tools have been completed, thanks to all the activities developed by the SHC Task 48 experts.

All the Task Publications and Tools are available online on the Task 48 website: http://task48.iea-shc.org/publications and http://task48.iea-shc.org/tools/

A full and comprehensive picture of the very diversified set of reports and tools can be seen in the Figure 2.

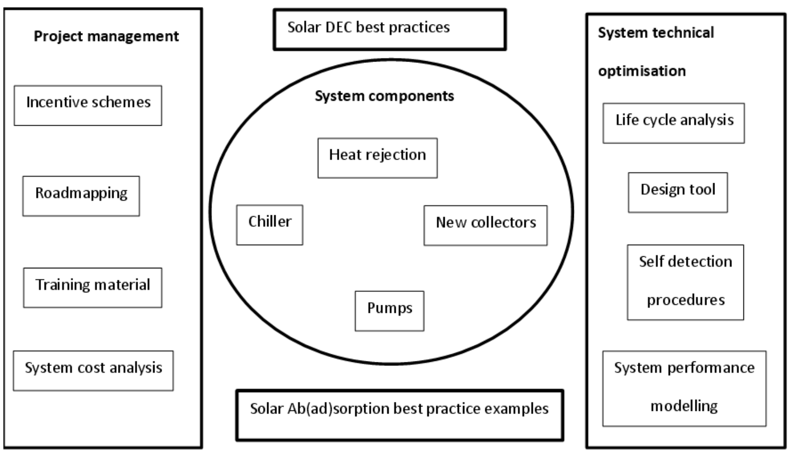


Figure 2. IEA SHC Task 48 result conceptual scheme.

Several examples of the Task's work are presented below:

Heat Rejection for Solar Cooling

A market review of approximately 1,300 devices from 22 manufacturers was conducted. Figure 3 shows performance figures. A valid reference was set to benchmark the heat rejection devices.

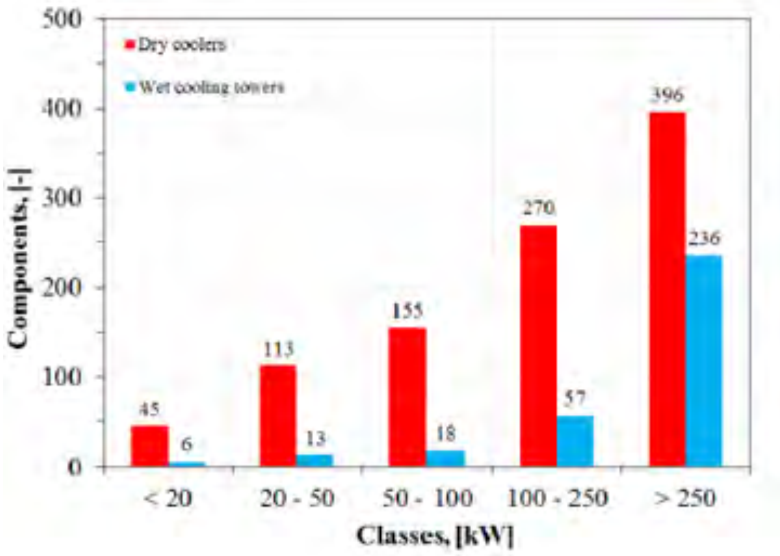


Figure 3. Data analysis for re-cooling power among dry coolers and wet cooling towers.

The survey was conducted on national and international standards: 51 standards ranging from installation and operation to security and maintenance regulations.

Lessons learned from the installed heat rejection devices monitoring data have led to the creation of nine datasets for dry coolers and five for wet coolers. The lessons learned cover installation, maintenance and control strategies and aim at significantly reducing electricity consumption.

Heat rejection devices are crucial for the performance of solar cooling systems and determining the operating boundary conditions of the thermal chillers – given a cooling target, the specific electricity consumption for different systems can vary by a factor of 4 for dry coolers and by a factor of 2 for wet cooling towers.

Pumps Efficiency and Adaptability

Since 2010 pump efficiency has greatly improved primarily due to legislative restrictions: 50-80% efficiency depending on size. Nevertheless, good design is crucial to properly size the pump and benefit from its good nominal efficiency. Chilled and cooling water loop are the most energy consuming: the use of variable speed pumps in these loops can improve the EER (Energy Efficiency Ratio) dramatically and with a low investment cost increase.

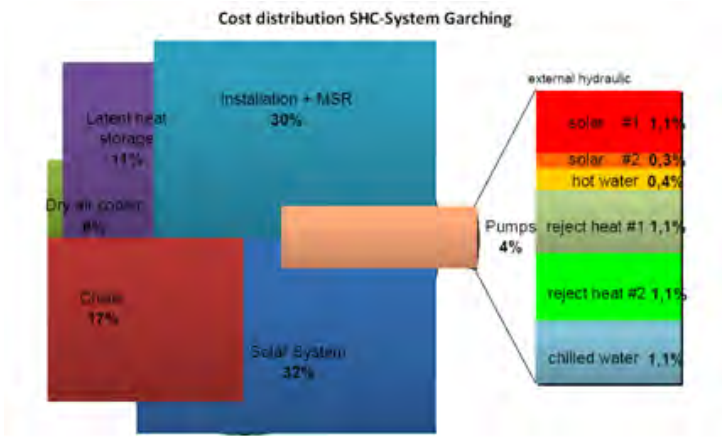


Figure 4. Cost distribution for SHC System Garching.

Intelligent high-efficiency pumps featured with internal flow, pressure, temperature and power meters can lead to high energy savings, but for complexity reasons implementation will be reserved for manufacturers of prefabricated system providers. Currently, an overall SEER of 20 seems to be feasible. A final Task 48 report details different points: design criteria, electricity consumption, and theory of rotodynamic pumps, standards, pump control, design guidelines.

Life Cycle Analysis at the System Level

Task 48 experts focused on developing studies to assess the energy and environmental performances of components of solar cooling and heating (SHC) systems. The Life Cycle Assessment (LCA) approach applied to SHC systems, started by IEA SHC Task 38, was further developed in Task 48. It provides a ready to use collection of datasheets to use for estimating the energy and environmental impacts of different SHC systems during their life cycle.

In SHC Task 38, two machines were analyzed, the PINK PSC-10 (12 kW) with H2O/NH3 and the SorTech AG ACS 08 (8 kW) with H2O/silica gel. Plus, the energy and environmental impacts of other components of SHC plants were assessed (e.g., solar thermal collectors, gas boiler, pumps, etc.). This work was then continued in SHC Task 48 to access the energy and environmental impacts of the Pink PC19 Ammonia Chiller and of a Packed Adsorbed Bed. Plus the database of life cycle inventories for components of SHC systems, developed within Task 38, was updated and completed.

The LCA database also now includes solar PV components (photovoltaic panels, inverter, storage, etc.) giving the possibility to perform analysis on conventional systems that use renewable electricity with or without connection with the grid.

SHC Task 48 developed a user-friendly LCA method tool to calculate the energy and environmental impacts and the payback time indices of different SHC systems and to compare SHC systems to conventional ones. The tool uses the database developed in Subtask A of Task 48. An important step of the tool development was the analysis of international LCA databases to check the LCA data availability for components of the SHC systems and for conventional equipment (pipes, pumps, electric components, photovoltaic panels, etc.).

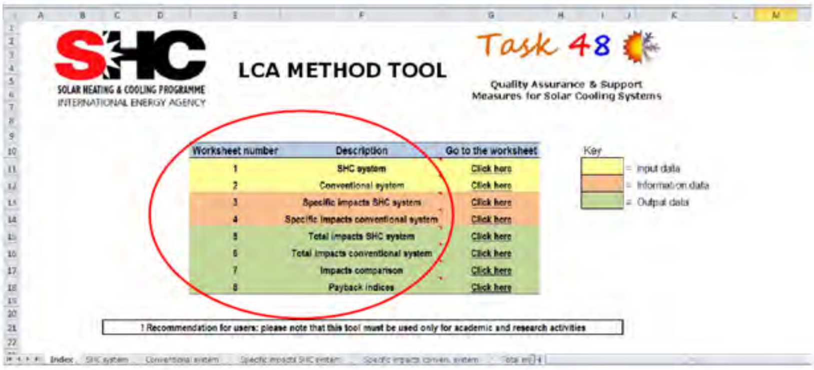


Figure 5. SHC Task 48 LCA Method tool interface.

Self-detection on Monitoring Procedure

Starting from the statement of existing efficient system control, a second generation of control system is needed that includes self-detection of faults and malfunctioning of the process based on a reduced monitoring. This new powerful functionality will be a key component assuring good long-term reliability and performance of the system.

Experts in SHC Task 48 updated the good practices in the monitoring procedure using the experiences and procedures developed in SHC Task 38. Due to the possibility of system errors in solar cooling systems and component defects over simple sensor faults to real control problems, the most recent work categorized the typical system errors. For each fault category typical errors were collected and possible methods for error detection along with the necessary monitoring equipment were analyzed. This work then turned to the possible implementation of automated fault detection systems within local system controllers and centralized internet-based observation systems. The report on this work includes the following chapters:

- Collection and Characterization of typical system errors
  - Sensors / metering
  - Hydraulic design mistakes, wrong placement of components, …
  - Typical control problems
- Existing error detection systems / ongoing development /projects
  - METHODIQA (Austrian project 2013/14 at AEE Intec)
  - InSun (EU-Project at zafhnet)
  - Project at ZAE
  - extrACT at AIT (Austrian project)
  - FDD (fault detection diagnosis) at POLIMI

Quantitative Quality and Cost Competitiveness Criteria for Systems

A proposal for an appropriate evaluation procedure for the technical and economic performance assessment of large systems was set up and tested with real cases. It delivers the basis for a comparable assessment of the installed plants independently of installation site and the specific boundary conditions. It uses the minimum economical ratios to estimate the competitiveness of solar cooling against concurrent technologies.

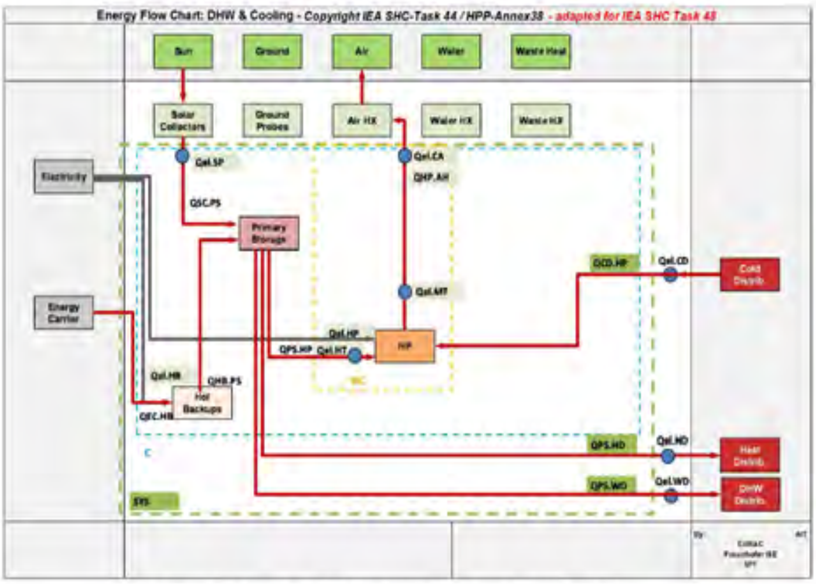


Figure 6. System boundary and possible energy flows for SPF.

A survey on the available procedures that could be adapted to solar cooling systems quality assessment was conducted.

Selection and Standardization of Best Practice Solutions

Based on the experiences with small, medium and large size solar air-conditioning systems, a reduced and documented set of system design schemes and control schemes was selected, which exhibits favorable system operation in terms of optimized performance and reliability. Three case study configurations were selected and used to define and standardize the engineering criteria, which lead to target reliability, efficiency and cost competitiveness. Much attention was given to the standardization of the system design schemes and defining the constraints of applicability of these standardized designs. In order to provide support to planners and installers a selection of proven system designs, including hydraulic schemes, were detailed in the form of design guidelines for heating, cooling and ventilation of commercial buildings. The report on this activity will be published by Wiley VCH as a “Design Guide.” This book will complement the 2013 IEA SHC book, “Solar Cooling Handbook”[4]. The Handbook provides a comprehensive, but somewhat general overview of the various technologies and equipment components to convert solar heat into useable cold. The Handbook enables engineers to design their own solar cooling system with full design flexibility, covering the breadth of possible applications. Examples are included, but prescriptive designs for specific applications aren’t mentioned. Compared to the Handbook, the Design Guide will provide more detailed and specific engineering design information targeted at a limited number of specific case study examples. These case study examples are seen as good examples, worthy of replication when appropriate.

The motivation to write this Guide stems from the analysis of recent monitoring results of a number of installed and operating SAC plants. This analysis has shown that some installations do not reach the intended level of performance. To avoid such setbacks in the future, this Design Guide provides more detailed engineering design information for three specific case studies.

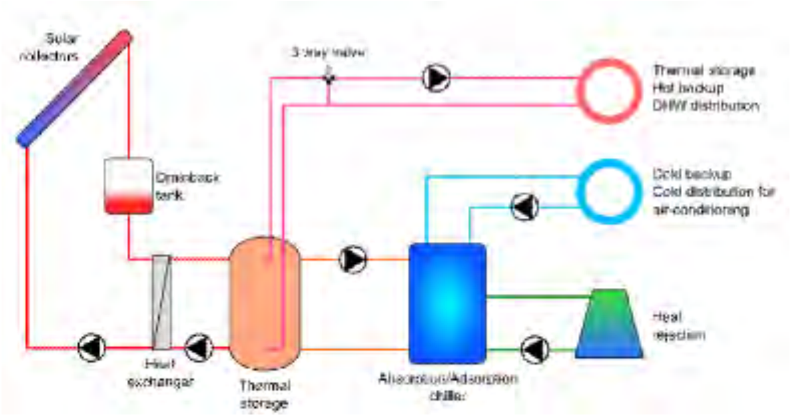


Figure 7. Principle scheme of a solar DHW/cooling system in Montpellier (France).

The Guide will include the explanation of the flow sheet and the application conditions for which the design is intended. Where appropriate, numerical constraints are provided to assist with the selection and sizing of equipment. By following this Design Guide, step-by-step for any of the three specific SHC systems, a reliable, robust cost-effective and energy-saving solution can be expected.

Of course there are many other attractive solar cooling technology solutions available. So the Design Guide should only serve as a positive statement on a small number of solutions (rather than a negative statement on other solutions).

CONCLUSION

IEA SHC Task 48: Quality Assurance and Support Measures for Solar Cooling represents a very interesting tool for the development of this sector. The Task fits particularly well with the sector's growing needs as it aims to improve the quality of solar air conditioning systems. Thanks to the international cooperation on this topic within the IEA Solar Heating and Cooling Program, numerous high level international experts assembled their findings and have developed reports and tools to enhance the market deployment of solar thermal cooling. Numerous interesting outcomes have been achieved and are available in the Task 48 website. It should be noted that a logical follow-up of Task 48 has started as SHC Task 53: New Generation Solar Cooling & Heating Systems (PV or solar thermally driven systems). More information can be found at http://task53.iea-shc.org.

References

[1] P. Murphy et al., “IEA Solar Heating and Cooling Programme Strategic Plan 2009-2013, http://www.iea-shc.org/Data/Sites/1/documents/strategicplan/SHC_Strategic_Plan.pdf, (2009)

[2] B. Sanner et al., “Common Vision for the Renewable Heating and Cooling Sector in Europe: 2020 - 2030 – 2050”, http://www.rhc-platform.org/fileadmin/Publications/RHC_BROCHURE_140311_web.pdf, (2011)

[3] D. Mugnier. “Quality Assurance and Support Measures for Solar Cooling - Task description and Work plan,” http://task48.iea-shc.org/documents, (2011)

[4] Henning H.M., Motta M., and Mugnier D., "Solar Cooling Handbook: A Guide to Solar Assisted Cooling and Dehumidification Processes," Walter de Gruyter & Co, ISBN 3990434381, 2013

Task 42

Compact Thermal Energy Storage - Material Development for System Integration

Prof. Matthias Rommel
University of Applied Sciences Rapperswil, Institute for Solar Technology SPF
Switzerland
Operating Agent for the Swiss Federal Office of Energy

TASK DESCRIPTION

The objective of this joint Task with the IEA Energy Conservation through Energy Storage (ECES) Programme (Annex 29) was to develop advanced materials for compact storage systems, suitable not only for solar thermal systems, but also for other renewable heating and cooling applications such as solar cooling, micro-cogeneration, biomass, or heat pumps. The Task covers phase change materials (PCMs), thermochemical materials (TCMs), and composite materials and nanostructures. It includes activities on material development, analysis, and engineering, numerical modeling of materials and systems, development of storage components and systems, and development of standards and test methods.

Participating Countries

Country	Number of Research Institutes	Number of Universities	Number of Companies
Austria	3	3	1
Australia	1	1	
Belgium	1	2	
Switzerland	2	3	1
Germany	5	6	2
Denmark		1	
Spain	4	4	1
France	2	5	1
Italy		1	
Japan	1	4	
The Netherlands	2	1	1
Sweden		2	
Slovenia	1	1	
Turkey		2	
United Kingdom		6	1
Total	22	42	8

Task Duration

This Task is now completed. Phase 2 started on **1 January 2013** and ended **31 December 2015**. The Task was jointly performed with Annex 29 of the IEA ECES Programme.

Collaboration with other SHC Tasks and Outside Organizations/Institutions

The IEA SHC Task 42 is a fully joint Task with the IEA ECES Annex 29.

Collaboration with Industry

The number of industries actively participating in the Task was limited. Most active were the companies Vaillant (heating appliances industry) and Rubitherm (manufacturer of PCM) from Germany. At the Task Experts Meetings, there were several presentations and following discussions with a number of industries, active in storage materials, heating appliances or appliers of thermal storage systems. The companies producing DSC instruments were participating in the workshops of WG_A2.

TASK ACCOMPLISHMENTS

Key Results

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

Working Group A1: Materials Engineering and Processing
Lead country: Slovenia
Subtask leader: Alenka Ristic, NIC National Institute of Chemistry

In the scope of Task 42 from 2013 to 2015 more than 20 institutions from more than 12 countries were taking part in working group A1: "Engineering and processing of TES materials."

New and improved materials for compact TES:
During this period different **new and improved PCMs** were investigated: eutectic binary mixtures of sugar alcohols, low cost paraffin, cement mortar + microencapsulated PCM, polystyrene (PS)/n-heptadecane micro/nano-capsules, inorganic PCM ternary mixtures, PEG 10,000, microencapsulated n-octadecane, binary mixtures of linear alkanes and saturated fatty acids, new sugar alcohol eutectic mixtures and others. Also the following **new and improved TCM-materials** were synthesized and investigated: binder-free zeolite Y, activated carbon, composites of salt hydrates within porous matrices, etc.

Promising PCMs for different temperature ranges and applications

- New PCMs with potential for **solar thermal regulation of buildings and food storag**e containers are polymethylmethacrylate(PMMA)/capric-stearic eutectic mixture (C-SEM) micro/nano capsules can be integrated with conventional building materials polystyrene (PS)/n-heptadecane micro/nano-capsules.
- With respect to **solar heating and domestic hot water applications** new binary mixtures of sugar alcohols comprising erythritol, sorbitol and xylitol were studied.

- **For cold storage** new binary eutectic mixtures of salt hydrate-based PCMs were prepared.

Material properties investigated and the role of material containers
Material`s properties (nontoxicity, density, solubility, specific heat, thermal conductivity, enthalpy, viscosity, phase change, degree of subcooling, cycling stability, thermal stability, etc.) structures (for example: decanoic acid/chitosan-gelatine microcomposite), compositions (salt hydrates + porous carbon or silica, paraffin wax + multi-walled carbon nanotubes, sugar alcohols+ porous carbon etc.) and the role of material containers (e.g. stainless steel 316 can be used for storing the investigated inorganic PCM and TCM) were determined for latent, chemical and sorption heat storage.

Methods for TES-materials processing
Different optimal methods for materials processing were found, like **microencapsulation** (caprylic acid/chitosan-gelatine, sugar alcohols), micro/nanoencapsulation (capric, lauric and myristic acids with polystyrene shell), **phase change slurries** (n-octadecane-water emulsion) for PCMs and new combinations of composite materials (PCMs and TCMs). TCM composite were prepared by **wet impregnation** (MgCl2/porous carbon or vermiculite, APO/carbon) and **incipient wetness impregnation** (CaCl2/porous silica). **Improvements of TCM`s properties** were achieved by the oxidation treatment of activated carbon and composites of CaCl2/porous silica (hydrophilicity), dealumination of zeolite Y (lower regeneration temperature), preparation of APO/carbon or APO coating on metal plate (thermal conductivity), mixing MgCl2 and CaCl2 (preservation of cycling stability), etc.

Two general remarks
- The research was mainly conducted in the field of PCMs, while only few research projects were performed in the field of thermochemical materials.
- It can be observed that mainly engineers/physicists were involved in the research of materials and there were very few chemists. It is recommended that in the future, experts of material science and chemists from the fields of organic and inorganic chemistry should be more involved in order to strengthen the development of TES materials.

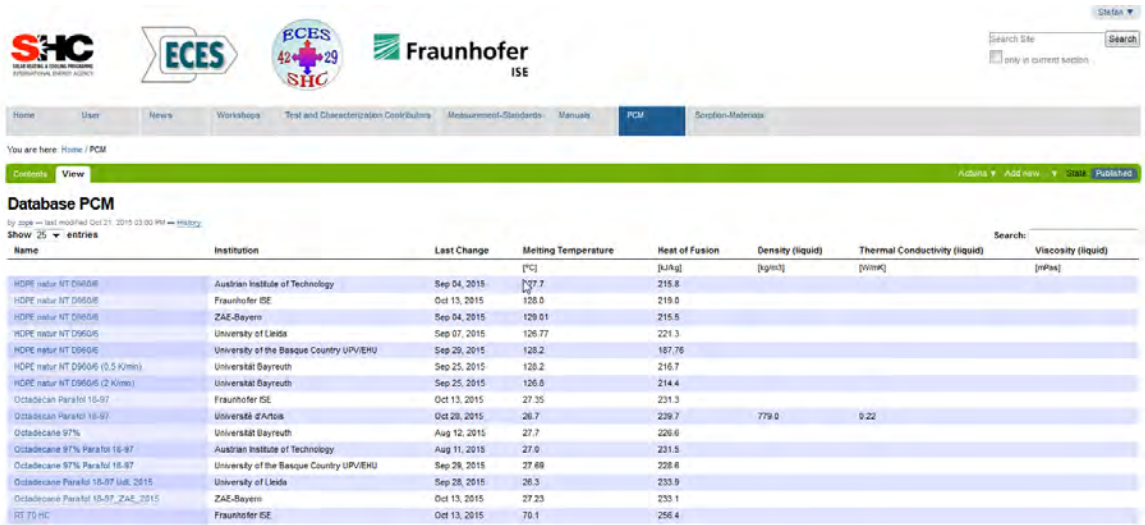
Working Group A2: Test and Characterisation
Lead country: Germany
Subtask leader: Stefan Gschwander, Fraunhofer ISE Institute for Solar Energy

Seven scientific institutions worked on the development of measurement standards for PCM characterization within the framework of IEA SHC Task 42 / ECES Annex 29 (Task 4229). The first and main focus was set on characterization of PCMs by DSC measurements, but also the T-History method as well as methods to determine the thermal conductivity and flow behavior were investigated. The second focus was set on the development and establishment of a database for PCM, TCM and sorption materials.

The **newly developed procedure for the DSC measurement of PCMs** is available at http://task42.iea-shc.org/data/sites/1/publications/Task4224-Standard-to-determine-the-heat-storage-capacity-of-PCM-vers150326.pdf and consists of five elements:

1. Heating and cooling rate test to determine suitable heating and cooling rates for the PCM to be measured. This is done by using the PCM to be characterized and applying heating and cooling rates starting from fast rates (e.g. 10 K/min) and slowing down the heating and cooling rates of consecutive cycles by halve the previous.
2. Calibration of the DSC by using 3 different calibration materials covering the desired temperature range (e.g. water, gallium and indium). The calibration has to be done with the determined heating rate.
3. Measurement of the empty crucible using the determined heating and cooling rates.
4. Sample measurements by applying the sample to the crucible (apply the same sample mass as for the heating rate test) using the determined heating rate. Four measurement cycles have to be applied and three samples have to be measured
5. Analysis of data: If necessary, baseline correction (displacement to zero heat flow) has to be applied. Carry out subtraction of heat flow signal measured with empty crucible from sample measurement. Final data evaluation and computation of enthalpy curves.

A database was developed and established to upload PCM data which is measured according to the new standard. It provides an overview table of all stored PCMs (see figure). By choosing a PCM all relevant measurement parameters are available (onset temperature, integration limits for the given heat of fusion, sample mass, heating rate, etc) as well as the measured data which is provided as ASCII table for download. The database is still less detailed with respect to TCMs.



Working Group A3: Numerical Modeling

Lead country: The Netherlands

Subtask leader: Camilo Rindt, Eindhoven University of Technology

The activities within the working group A3 in the framework of IEA SHC Task 42 / ECES Annex 29 (Task 4229) related to different level modeling and simulations. As an example of activity for developing and testing numerical models to understand and optimize material behavior, the experts of the working group A3 investigated MgCl2 hydrates.

Molecular models were used to check the effect of water vapor pressure on hydrolysis and dehydration reaction. The results of the water diffusivity in the crystalline structure were further used in higher level models in the working group. This can in a later stage be used to optimize specific properties of the storage materials with respect to their usage.

From the numerical results of material and thermophysical properties of PCM storage systems, it is clear that some deviation may occur if the enthalpy function does not perfectly fit the real behavior of the material.

Firstly, this may arise if the thermophysical characterization of the PCM is not correctly conducted. Here it becomes clear that the results of the experts' work in WG A1 and A2 is of great importance for the work in WG A3. It is clear that further research work is necessary and material measurements have to be further improved so as to define reliable numerical and simulation methods.

Secondly, such a bias could also come from the degradation of the product during its lifetime, independently of the precision of the characterization method. Consequently one has either to search for very stable materials (which may be difficult) or to determine the temporal evolution of the thermophysical properties, which is solely done and should thus be also further investigated.

Working Group B: Applications
Lead country: Japan
Subtask leader: Motoi Yamaha, Chubu University

Within the Working Group B (Applications) of the IEA joint Task/Annex 4229, a large number of experts from more than 20 research organizations worked on applications of compact thermal energy storage technologies. Application fields are cooling, room heating/domestic hot water and thermal storage for industry. The main challenges in the development of applications are in finding an optimal connection between the storage material and the other materials, the components and the system configuration. The problems to be solved are in the area of materials compatibility, like corrosion protection, prevention of side reactions and cycling stability; in the area of component design, with heat and mass transfer optimisaton; and in the area of system design with control strategies and cost minimisation.

Thermal storage for cooling applications is the most advanced. There are numerous examples of ice storage systems, running to get a higher system performance or to enable a shift of electricity consumption from daytime to nighttime. Challenges in these systems are the integration of novel PCMs with somewhat higher melting temperatures than water and the system optimisation in connection with electricity grids and heating networks.

Most application developments in T4229 are in the area of thermal energy storage for room heating and domestic hot water preparation. Here, there is a broad collection of storage technologies and system concepts being developed and tested. Phase change materials and thermochemical materials are applied as active material in open and closed systems.

A third field of application is in the transportation of residual or waste heat to a remote user by compact thermal storage technologies. Due to scaling effects, this application is first developed for industrial users.

In the Task, special attention was paid to the interaction between materials researchers and system engineers. A compact thermal energy storage material only has value in a certain application, and the application will imply certain design conditions on the storage material. A first step towards a better interaction is for system engineers to understand how materials researcher evaluate the properties of a storage material, and for materials experts to understand the practical implications of integrating material into a storage system. In the Task, work was done to couple the material properties to system performance, although this in most cases is far from straightforward. For sorption storage technologies, an approach was set up using four typical operating temperatures with which the operation boundary conditions are determined and the performance of a storage material in an application can be determined (see paper by Hauer et al. for SHC-2015 conference).

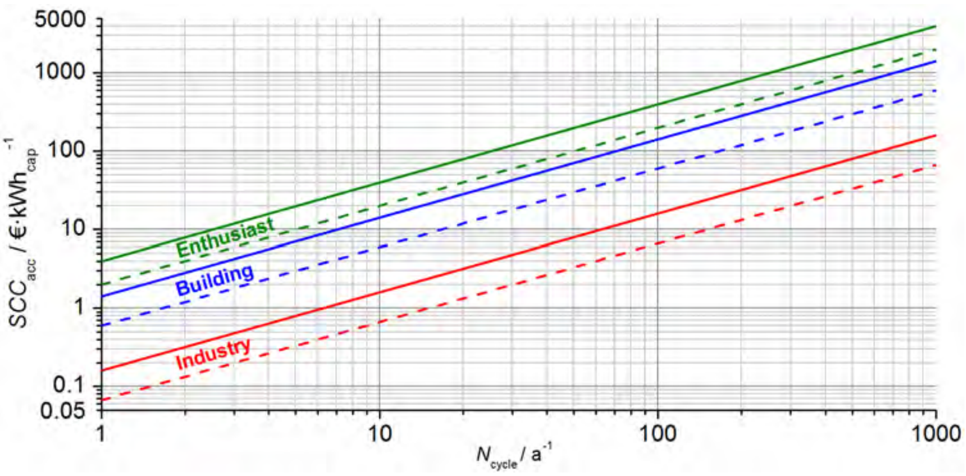
Given a certain application, it is necessary to have a common basis for determining the performance of different storage technologies. To this end, a design has been made of a set of Key Performance Indicators KPI's of compact thermal energy storage for seasonal storage. In future, these KPI's will be a valuable tool for comparison of different thermal storage concepts.

Working Group C: Theoretical Limits
Lead country: Germany
Subtask leader: Christoph Rathgeber, ZAE Bavarian Centre for Applied Energy Research

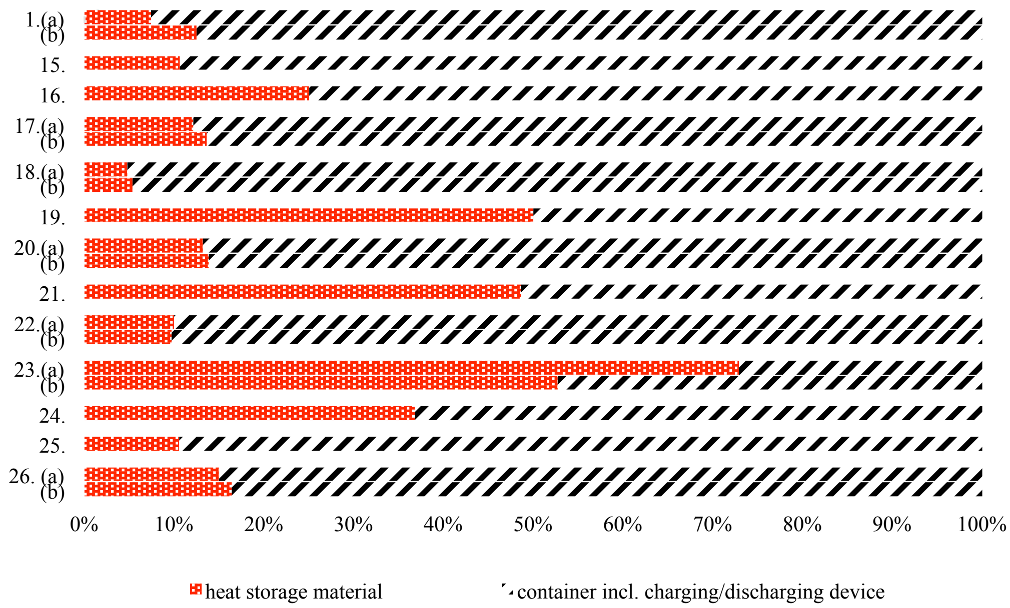
Within the framework of IEA SHC Task 42 / ECES Annex 29, a tool for the economic evaluation of thermal energy storages has been developed and tested on various existing storages. On that account, the storage capacity costs, i.e. the costs per installed storage capacity, of thermal energy storages have been evaluated via a Top-down and a Bottom-up approach.

The Top-down approach follows the assumption that the costs of energy supplied by the storage should not exceed the costs of energy from the market. The maximum acceptable storage capacity costs depend on the interest rate assigned to the capital costs, the intended payback period of the user class (e.g. industry or building), the reference energy costs, and the annual number of storage cycles.

The figure below shows the maximum acceptable storage capacity costs (SCC_{acc}) as a function of storage cycles per year N_{cycle}, determined for the three user classes industry, building sector and enthusiast. A double-logarithmic scale was chosen to visualize both SCC_{acc} of long-term storages with only few cycles per year and short-term storages with several hundred cycles per year. These results indicate that, for a fixed cycle period N_{cycle}, SCC_{acc} depend on the user's economic environment. The low case of the industry sector and the high case of enthusiasts differ by a factor of about 60 in costs. Short-term storage with several hundred storage cycles per year, however, allows several hundred times higher storage costs because of the larger energy turnover.



The Bottom-up approach focuses on the realized storage capacity costs of existing storages. It has been applied to analyze the costs of 26 thermal energy storages, also including commercial water storages to check the evaluation methodology of the bottom-up approach. It has to be stressed here that the innovative storages of Task 42/Annex 29 are subject of ongoing research and by far not yet developed for application in the market. Hence, their corresponding costs are only very rough estimations. The comparison of SCC_{acc} and SCC_{real} indicates that, at present, seasonal storage is only economical using large hot water storages; other technologies require at least an order of magnitude reduction in costs. This is a very strong indication and proof that the topic of compact thermal energy storage still needs much more R&D activities, especially with respect to long term storage. It also means that the development of storage systems which allow a high annual number of storage cycles is economically favouable over seasonal storages.



In order to identify major cost drivers and, thereby, cost reduction potentials for the investigated storage systems, the composition of the investment costs has been analyzed. The figure above illustrates how the investment costs of thermal energy storages under investigation in Task 42 / Annex 29 are divided into costs of the heat storage material itself and costs of the surrounding container or reactor incl. charging/discharging device. So, the Bottom-up analysis showed that a major fraction of the investment costs of the investigated storages are not costs of the heat storage material itself but costs of the storage container or reactor (incl. charging/discharging unit). Therefore, R&D activities on cost-effective TES systems have to consider both, cost-effective heat storage materials and cost-effective storage container or reactor components.

PUBLICATIONS

Journal Articles, Conference Papers, Press Releases, etc.

Journal/ Magazine	Article Title	Date
Green News Techno, no 84, p. 5, 2012	Vers des MCP biosoucés pour le stockage termique saisonnier" by Celzard, E. Palomo del Barrio	2012
Applied Energy 2012	Intercomparitive tests on phase change materials characterization with differential scanning calorimeter" by Lazaro A., Penalosa C., Solé A., Diarce G., Haussmann, T., Fois, M., Zalba B., Gschwander S., Cabeza L.F.	2012
Accepted for publication in International Journal of Refrigeration	Analysis of the physical stability of PCM slurries by Mónica Delgado, Ana Lázaro, Conchita Penalosa, Javier Mazo, Belén Zalba	
Journal of Computational Chemistry,34 (13), 1143-1154	Parameterization of a reactive force field using a Monte Carlo algorithm by Iype, E., Hütter, M., Jansen, A.P.J., Gaastra – Nedea, S.V. & Rindt, C.C.M.	
Applied Energy, Vol. 104, 137-148	Experimental Investigation of Dynamic Melting in a Tube-in-tank PCM System	
Advances in Heat Transfer, Vol. 15	"Distributed Solar Thermal: Innovations in Thermal Storage" by Quinnell, J.A., and Davidson, J.H. G. Chen, ed., Begell House Publishers, 2012	2012
ASME J. of Solar Energy Engineering	Buoyancy Driven Mass Transfer in a Liquid Desiccant Storage Tank" by Quinnell, J., Davidson, J.H., and Burch, J.	
Arquitectura Ecoeficiente. ISBN: 978-84-9860-688-1. pp 97-115. UPV/EHU publications. San Sebastian, Spain (2012)	Materiales de Cambio de Fase para almacenamiento térmico y su empleo en edificación" by A. Garcia-Romero; G. Diarce	2012
Applied Energy 2013	Ventilated active façades with PCM" by G. Diarce, A. Urresti,	2013

	A. García-Romero, A. Delgado, A. Erkoreka, C. Escudero, A. Campos-Celador	
Applied Energy 2013	Intercomparative tests on phase change materials characterisation with differential scanning calorimeter" by A. Lazaro, C. Peñalosa, A. Solé, G. Diarce, T. Haussmann, M. Fois, B. Zalba, S. Gshwander, L. F. Cabeza	2013
Energy Procedia. Pp 395-403. 2012	Validation of heat transfer models for PCMs with a conductivimeter" by A. Urresti, J.M. Sala, A. García-Romero, G. Diarce, C. Escudero	
Journal of Applied Polymer Science, 125(5), 3447-3455, (2012)	Thermal energy storage by poly(styrene-co-p-stearoylstyrene) copolymers produced by the modification of polystyrene by Alkan, C., Sarı, A., Biçer, A.,	2012
Materials Chemistry and Physics, 133(1), 87-94, (2012)	Synthesis and thermal properties of polystyrene-*graft*-PEG copolymers as new kinds of solid–solid phase change materials for thermal energy storage by Sarı, A., Alkan, C., Biçer, A.,	2012
Solar Energy, 86(9), 2282–2292, (2012)	Synthesis and thermal properties of poly(styrene-co-ally alcohol)-*graft*-stearic acid copolymers as novel solid–solid PCMs for thermal energy storage by Sarı, A., Alkan, C., Lafçı, Ö.	2012
Energy, 58 (2013) 438-447	Development and comparative analysis of the modeling of an innovative finned-plate latent heat thermal energy storage system by A. Campos-Celador, G. Diarce, I. González-Pino, J.M. Sala	2013
Chemistry of Materials. 25, S. 790-798	Water Sorption Cycle Measurements on Functionalized MIL-101Cr for Heat Transformation Application by Khutia, A., Rammelberg, H., Schmidt, T., Heninger, S. & Janiak, C	
Applied Thermal Engineering 59, 542 (2013)	Comparative analysis of latent thermal energy storage tanks for micro-CHP systems" by T. Nuytten, P. Moreno, D. Vanhoudt, L. Jespers, A. Solé and L.F. Cabeza	2013
Advances in Heat Transfer Vol. 15	Distributed Solar Thermal: Innovations in Thermal Storage" by Quinnell, J.A., and Davidson, J.H. G. Chen, ed., Begell House Publishers, 2012	2012
ASME J. of Solar Energy Engineering, 135(4), 041009	Buoyancy Driven Mass Transfer in a Liquid Desiccant Storage Tank" by Quinnell, J., Davidson, J.H.	2 July 2013
ASME J. of Solar Energy Engineering	Performance of Rigid Porous Stratification Manifolds with Interpretation for Off-Design by Shuping Wang, Jane H. Davidson	
Solar Energy	Heat and mass transfer during heating of a hybrid absorption/sensible storage tank," by Quinnell, J., Davidson, J.H.	
J. Chem. Phys. 139. 124312-1	A Density Functional Theory based equilibrium study on the hydrolysis and the dehydration reactions of MgCl2 hydrates	2013

	by B. Smeets, E. Iype, S. V. Nedea, H. A. Zondag, C. C. M. Rindt	
Journal of Molecular Simulation	Molecular dynamics study on thermal dehydration process of epsomite ($MgSO_4$-$7H_2O$) by Zhang ,H., Iype, E., Nedea, S.V., Rindt, C.C.M.	2013
Applied Energy, Volume 119, 15 April 2014, Pages 151-162 (S1).	Performance characterization of a PCM storage tank" by A. López-Navarro, J. Biosca-Taronger, J.M. Corberán, C. Peñalosa, A. Lázaro, P. Dolado, J. Payá	2014
Applied Thermal Engineering, Volume 63, Issue 1, 5 February 2014, Pages 11-22 (S1)	Experimental analysis of the influence of microcapsule mass fraction on the thermal and rheological behavior of a PCM slurry" by Mónica Delgado, Ana Lázaro, Conchita Peñalosa, Belen Zalba	2014
Applied Energy. 124, S. 1-16.	A systematic multi-step screening of numerous salt hydrates for low temperature thermochemical energy storage by N'Tsoukpoe, K. E., Schmidt, T., Rammelberg, H. U., Watts, B. A. & Ruck, W. K. L.	2014
Volume 1: Heat Transfer in Energy Systems; Thermophysical Properties; Theory and Fundamental Research in Heat Transfer	Modelling approach of thermal decomposition of salt-hydrates for heat storage systems by Fopah Lele, A., Kuznik, F., Rammelberg, H., Schmidt, T. & Ruck, W.	2014
Energy, 58 (2013) 438-447	Development and comparative analysis of the modeling of an innovative finned-plate latent heat thermal energy storage system by Campos-Celador, G. Diarce, I. González-Pino, J.M. Sala	2013
Energy Procedia (2014), pp. 300-308 DOI information: 10.1016/j.egypro.2014.02.035	Design of a Finned Plate Latent Heat Thermal Energy Storage System for Domestic Applications by Campos-Celador, G. Diarce, J. Terés-Zubiaga, T. Bandos, A. García-Romero, L.M. López, J.M. Sala	2014
Applied Energy, 109 (2013) 415-420.	Intercomparative tests on phase change materials characterisation with differential scanning calorimeter by Lazaro, C. Peñalosa, A. Solé, G. Diarce, T. Haussmann, M. Fois, B. Zalba, S. Gshwander, L. F. Cabeza	2013
Solar Energy Materials & Solar Cells 126, 2014, pp. 42 – 50.	Micro/nano-encapsulated n-heptadecane with polystyrene shell for latent heat thermal energy storage by Sari, A., Alkan, C., Kahraman Döğüşcü, D., Biçer, A.	2014
Applied Thermal Engineering, accepted in May 2014.	Development of a revolving drum reactor for open-sorption heat storage processes by Zettl, B., Englmair, G., and Steinmaurer G.	2014

Journal of Applied Thermal Engineering, Volume 70, Issue 1, 5 September 2014, p. 42-49	Development of a revolving drum reactor for open-sorption heat storage processes by Zettl B., Englmair G., Steinmaurer G.,	2014
Energy Conversionand Management, 2014, 77, 628 _ 636	Specification requirements for interseasonalheat storage systems in a low energy residential house by Gondre, D.; Johannes, K. and Kuznik, F.	2014
Applied Thermal Engineering. 66 (2014) 171–180	Experimental investigation of thermal characteristics of a mortar with or without a micro-encapsulated phase change material by A. Joulin, L. Zalewski, S. Lassue, H. Naji	2014
Applied Thermal Engineering, 73 (2014) 30–38	Experimental and theoretical analysis of a cement mortar containing microencapsulated PCM by Franquet E, Gibout S, Tittelein P, Zalewski L, Dumas JP.	2014
Advances in thermal energy storage. Lleida: 2014, pp. 1-7.	Improvement of water sorption capacity of composite sorbents for thermochemical heat storage by Ristić, Alenka, Birsa Čelič, Tadeja	2014
Solar Energy Materials & Solar Cells 126, 2014, pp. 42 – 50	Micro/nano-encapsulated n-heptadecane with polystyrene shell for latent heat thermal energy storage by Sari, A., Alkan, C., Kahraman Döğüşcü, D., Biçer, A.	2014
Energy Conversion and Management 86, 2014, pp. 614–621	Micro/nanoencapsulated n-nonadecane with poly(methyl methacrylate) shell for thermal energy storage by Sari, A., Alkan, C., Biçer, A., Altuntaş A., Bilgin C.	2014
Erneuerbare Energie 2014-3	Saisonale Wärmespeicherung auf Basis von Phasenwechselmaterial by Moser, Ch.	2014
Energy Procedia (ISSN:1876-6102), 2015	Laboratory test of a prototype heat storage module based on stable supercooling of sodium acetate trihydrate by Mark Dannemand, Weiqiang Kong, Jianhua Fan, Jakob Berg Johansen, Simon Furbo	2015
Participation in Green Tech Magazine, ECO World Styria	Wärmende Vorräte: So heizt die Sommersonne auch im Winter ein	
Energy Procedia, vol. 48, pp. 405-412, 2014	Sensitivity analysis of the energy density in a thermo chemical heat storage device by S. Metchueng Kamdem, K. Johannes, F. Kuznik, H. Bouia, J.J. Roux	2014
Energy Conversionand Management, 2014, 77, 628 _ 636	Specification requirements for interseasonal heat storage systems in a low energy residential house by Gondre, D.; Johannes, K. and Kuznik, F.	2014
Applied Energy, 140 (2015) 269-274	Simulation of the thermal and energy behaviour of a composite material containing encapsulated-PCM: Influence of the thermodynamical modelling by Pierre Tittelein,	2015

	Stéphane Gibout, Erwin Franquet, Kevyn Johannes, Laurent, Zalewski, Frédéric Kuznik, Jean-Pierre Dumas, Stéphane Lassue, Jean-Pierre Bédécarrats, Damien David	
Thermochimica Acta, accepted or in press	Kinetic study of the dehydration reaction of lithium sulfate monohydrate crystals using microscopy and modeling by Lan, S. Zondag, H.A., Steenhoven, A.A. van & Rindt, C.C.M.	
Journal of Thermal Analysis and Calorimetry, under review	An experimentally validated numerical model of interface advance of the lithium sulfate monohydrate dehydration reaction by Lan, S. Zondag, H.A., Steenhoven, A.A. van & Rindt, C.C.M.	
Thermal Engineering 91 (2015) 671-678	Long term thermal energy storage with stable supercooled sodium acetate trihydrate by Mark Dannemand, Jørgen M. Schultz, Jakob Berg Johansen, Simon Furbo	2015
Solar Energy. In press, 2015	Development of a numerical model for the reaction zone design of an aqueous sodium hydroxide seasonal thermal energy storage by Daguenet-Frick, X., Gantenbein, P., Frank, E., Fumey, B., Weber, R.	2015
Computational Thermal Sciences. 7 (2015) 139–156	Assessment of a lattice Boltzmann model to simulate fluid flows with complex geometries by Yehya A., Naji H., Zalewski L.	2015
Energy Conversion and Management 106 (2015) pp. 201-212	Experimental analysis of a low cost phase change material emulsion for its use as thermal storage system by M. Delgado, A. Lázaro, J. Mazo, C. Peñalosa, P. Dolado, B. Zalba	2015
Measurement Science and Technology 26 (2015) 125001	A theoretical study on the accuracy of the T-history method for enthalpy-temperature curve measurement: analysis of the influence of thermal gradients inside T-history samples by J. Mazo, M. Delgado, A. Lázaro, P. Dolado, C. Peñalosa, J.M. Marín, B. Zalba	2015
Applied Thermal Engineering 90 (2015) pp. 596-608	Uncertainty propagation and sensitivity analysis of thermo-physical properties of phase change materials (PCM) in the energy demand calculations of a test cell with passive latent thermal storage by J. Mazo, A.T. El Badry, J. Carreras, M. Delgado, D. Boer, B. Zalba	2015
Resources 4 (2015) pp. 796-818	An Approach to the Integrated Design of PCM-Air Heat Exchangers Based on Numerical Simulation: A Solar Cooling Case Study by P. Dolado, A. Lázaro, M. Delgado, C. Peñalosa, J. Mazo, J.M. Marín, B. Zalba	2015

CONFERENCES AND WORKSHOPS

Task participants presented Task work and results at 25 conferences and workshops over the course of the Task. I am not able to give an exact number but this is an estimation.

TASK MEETINGS

Meeting #	Date	Location	Number of Participants
EM9	15-17 April 2013	Freiburg, Germany	47
EM10	2-4 October 2013	Ljubljana, Slovenia	35
EM11	28-30 April 2014	Lyon, France	43
EM12	8-10 October 2014	Nagoya, Japan	36
EM13	9-11 February 2015	Vienna, Austria	49
EM14	5-7 October 2015	Zaragoza, Spain	47

SHC TASK 42/ECES ANNEX 29 NATIONAL CONTACTS

Ctry	Name		Institution/Company	E-Mail	Role
AT	Georg	Engel	AEE Intec	g.engel@aee.at	Expert
AT	Thomas	Fellner	TU Vienna, Energy Systems and Thermodynamics	thomas.fellner@tuwien.ac.at	Expert
AT	Thomas	Fellner	TU Vienna, Institute for Energy Systems and Thermodynamics	tfellner@ite.tuwien.ac.at	Expert
AT	Andreas	Heinz	IWT TU Graz	andreas.heinz@tugraz.at	Expert
AT	Florian	Hengstberger	AIT Austrian Institute of Technology	florian-h@gmx.at	Expert
AT	Patrick	Kefer	ASIC	kefer.patrick@asic.at	Expert
AT	Christoph	Moser	Institute of Thermal Engineering, TU Graz	christoph.moser@tugraz.at	Expert
AT	Hermann	Schranzhofer	Graz University of Technology, Institute of Thermal Engineering	hermann.schranzhofer@tugraz.at	Expert
AT	Gerald	Steinmaurer	ASIC	steinmaurer.gerald@asic.at	Expert
AT	Wolfgang	Streicher	University of Innsbruck	wolfgang.streicher@uibk.ac.at	Expert
AT	Alexander	Thür	University of Innsbruck	Alexander.Thuer@uibk.ac.at	Expert
AT	Andreas	Werner	TU Vienna, Energy Systems and Thermodynamics	andreas.werner@tuwien.ac.at	Expert
AT	Christoph	Zauner	AIT Austrian Institute of Technology	christoph.zauner@ait.ac.at	Expert
AT	Bernhard	Zettl	ASiC Austria Solar Innovation Center	zettl.bernhard@asic.at	Expert
AU	Frank	Bruno	University of South Australia	Frank.Bruno@unisa.edu.au	Expert
BE	Emilie	Courbon	University of Mons	emilie.courbon@umons.ac.be	Expert
BE	Marc	Frère	Universite de Mons, Energy Research Centre	Marc.Frere@umons.ac.be	Expert
BE	Oleksandr	Skrylnyk	University of Mons	oleksandr.skrylnyk@umons.ac.be	Expert

BE	Johan	Van Bael	VITO	johan.vanbael@vito.be	Expert
CA	Handan	Tezel	University of Ottawa	handan.tezel@uottawa.ca	Expert
CH	Xavier	Daguenet	HSR-SPF	xavier.daguenet-frick@spf.ch	Expert
CH	Elimar	Frank	SPF	elimar.frank@solarenergy.ch	Expert
CH	Benjamin	Fumey	EMPA	benjamin.fumey@empa.ch	Expert
CH	Paul	Gantenbein	SPF	paul.gantenbein@solarenergy.c h	Expert
CH	Matthias	Rommel	SPF Institute for Solar Technology	mrommel@hsr.ch	Operating Agent
CH	Robert	Weber	EMPA	robert.weber@empa.ch	Expert
CH	Jorg	Worlitschek	Lucern Univ. Of applied sciences	joerg.worlitschek@hslu.ch	Expert
DE	Thomas	Badenhop	Vaillant	thomas.badenhop@vaillant.de	Expert
DE	Dirk	Büttner	Rubitherm-Technologies	stefanie.kalle@rubitherm.com	Expert
DE	Gerrit	Füldner	ISE Fraunhofer	gerrit.fueldner@ise.fraunhofer.d e	Expert
DE	Stefan	Gschwander	Fraunhofer ISE	Stefan.Gschwander@ise.fraunh ofer.de	Working Group A2 Leader
DE	Andreas	Haagen	University of Bayreuth	andreas.koenig-haagen@uni-bayreuth.de	Expert
DE	Andreas	Hauer	ZAE Bayern	hauer@muc.zae-bayern.de	Operating Agent
DE	Stefan	Henninger	Fraunhofer ISE	stefan.henninger@ise.fraunhofer .de	Expert
DE	Thomas	Herzog	TH Wildau - Technical University of Applied Sciences	thomas.herzog@th-wildau.de	Expert
DE	Jochen	Jaenchen	TU Wildau	J.E.Jaenchen@T-Online.de	Expert
DE	Ulrike	Jordan	University of Kassel	jordan@uni-kassel.de	Expert
DE	Henner	Kerskes	ITW Stuttgart	kerskes@itw.uni-stuttgart.de	Expert
DE	Andreas	Koenig-Haagen	LTTT (ZET) University of Bayreuth	andreas.haagen@uni-bayreuth.de	Expert
DE	Christof	Krampe-	Vaillant	christof.krampe-	Expert

		Zadler		zadler@vaillant.de	
DE	Eberhard	Lävemann	ZAE Bayern	laevemann@muc.zae-bayern.de	Expert
DE	Harald	Mehling	ZAE Würzburg	Harald.Mehling@zae.uni-wuerzburg.de	Expert
DE	Barbara	Mette	ITW Stuttgart	mette@iwt.uni-stuttgart.de	Expert
DE	Hannah	Neumann	Fraunhofer ISE	hannah.neumann@ise.fraunhofer.de	Expert
DE	Fabian	Ochs	University of Innsbruck	Fabian.Ochs@uibk.ac.at	Expert
DE	Oliver	Opel	Leuphana Universität Lüneburg	opel@leuphana.de	Expert
DE	Rudolf	Pietschnik	University of Kassel, Chemistry	pietschnig@uni-kassel.de	Expert
DE	Holger	Rammelberg	Leuphana University	rammelberg@leuphana.de	Expert
DE	Christoph	Rathgeber	ZAE Bayern	rathgeber@muc.zae-bayern.de	Working Group C Leader
DE	Lena	Schnabel	Fraunhofer ISE	lena.schnabel@ise.fraunhofer.de	Expert
DE	Joerg	Waschull	ILK Dresden	Joerg.waschull@ilkdresden.de	Expert
DK	Elsa	Andersen	DTU	ean@byg.dtu.dk	Expert
DK	Mark	Dannemand	DTU	markd@byg.dtu.dk	Expert
DK	Jianhua	Fan	DTU	jif@byg.dtu.dk	Expert
DK	Simon	Furbo	Technical University of Denmark	sf@byg.dtu.dk	Expert
ES	Patricio	Aguirre	Tecnalia San Sebastian	patricio.aguirre@tecnalia.com	Expert
ES	Camila	Barreneche	University of Lleida	cbarreneche@diei.udl.cat	Expert
ES	Rocio	Bayon Cabeza	CIEMAT	rocio.bayon@ciemat.es	Expert
ES	Miren	Blanco	Tekniker	mblanco@tekniker.es	Expert
ES	Lluisa	Cabeza	University of Lleida	lcabeza@diei.udl.es	Expert
ES	Alvaro	Campos	University of the Basque Country UPV/EHU	alvaro.campos@ehu.es	Expert
ES	Mónica	Delgado	University of Zaragoza	monica@unizar.es	Expert

ES	Pablo	Dolado	Universidad de Zaragoza	dolado@unizar.es	Expert
ES	Stephania	Doppiu	CIC EnergiGune	sdoppiu@cicenergigune.com	Expert
ES	Inés	Fernández	University of Barcelona	ana_inesfernandez@ub.edu	Expert
ES	Ana	Garcia Romero	University of the Basque Country	anemiren.garcia@ehu.es	Expert
ES	Ana	Lazaro	Universidad de Zaragoza	ana.lazaro@unizar.es	Expert
ES	Virginia	Madina Arrese	Inasmet Tecnalia San Sebastian	virginia.madina@inasmet.es	Expert
ES	Maria Dolores	Romero	Aidico	md.romero@aidico.es	Expert
ES	Cristian	Sole	University of Lleida	csole@diei.udl.es	Expert
ES	Aran	Solé	University of Lleida - GREA	aran.sole@diei.udl.cat	Expert
ES	Aitor	Urresti	University of the Basque Country	aitor.urresti@ehu.es	Expert
FR	Erwin	Franquet	LaTEP	erwin.franquet@univ-pau.fr	Expert
FR	Frédéric	Kuznik	Thermal Science Centre of Lyon	frederic.kuznik@insa-lyon.fr	Expert
FR	Lingai	Luo-Dong	LTN-CNRS-Universite de Nantes	lingai.luo@univ-nantes.fr	Expert
FR	Elena	Palomo	University of Bordeaux	elena.palomo@bordeaux.ensam.fr	Expert
FR	Gwennyn	Tanguy	INES	gwennyn.tanguy@cea.fr	Expert
FR	Laurent	Zalewski	Laboratoire de Genie Civil et geo-environnement	laurent.zalewski@univ-artois.fr	Expert
IT	Ina	Ciulla	University of Palermo	ina@dream.unipa.it	Expert
IT	Valerio	Lo Brano	University of Palermo	lobrano@dream.unipa.it	Expert
JP	Motoi	Yamaha	Chubu University	yamaha@isc.chubu.ac.jp	Working Group B Leader
NL	Marco	Bakker	ECN	m.bakker@ecn.nl	Expert
NL	Robert	Boer, de	ECN	deboer@ecn.nl	Expert
NL	Ruud	Cuypers	TNO Built Enviroment and	ruud.cuypers@tno.nl	Expert

			Geosciences Energy		
NL	Claire	Ferchaud	ECN	ferchaud@ecn.nl	Expert
NL	Silvia	Nedea	Technical University Eindhoven	S.V.Nedea@tue.nl	Expert
NL	Camilo	Rindt	Technical University Eindhoven	C.C.M.Rindt@wtb.tue.nl	Working Group A3 Leader
NL	Wim	van Helden	Wim van Helden Renewable Heat	wim@wimvanhelden.com	Expert
NL	Herbert	Zondag	ECN	zondag@ecn.nl	Expert
SE	Justin	Chiu	KTH Royal Institut of Technology	Justin.Chiu@energy.kth.se	Expert
SE	Saman	Gunasekara	KTH Royal Institut of Technology	saman.gunasekara@energy.kth.se	Expert
SE	Viktoria	Martin	KTH	vmartin@kth.se	Expert
SI	Alenka	Ristic	National Institute of Chemistry	alenka.ristic@ki.si	Working Group A1 Leader
TR	Cemil	Alkan	Gaziomanpasa University	cemilalkan@gop.edu.tr	Expert
TR	Halime	Paksoy	Cukurova University	hopaksoy@cu.edu.tr	Expert
TR	Ahmet	Sari	Gaziomanpasa University	asari@gop.edu.tr	Expert
UK	Yulong	Ding	University of Leeds	y.ding@leeds.ac.uk	Expert
UK	Phil	Eames	CREST; University of Loughborough	p.c.eames@lboro.ac.uk	Expert
UK	Philip	Griffiths	University of Ulster	P.Griffiths@ulster.ac.uk	Expert
UK	Frederic	Pitié	Whittaker Engineering	fpitie@whittakereng.com	Expert
UK	Changying	Zhao	University of Warwick	C.Y.Zhao@warwick.ac.uk	Expert
US	Jane	Davidson	University of Minnesota	jhd@me.umn.edu	Expert
US	Jan	Kosny	Fraunhofer Center for Sustainable Energy Systems CSE, Cambridge	jkosny@fraunhofer.org	Expert

Task 43 - Extension

Solar Rating and Certification Procedures: From International Standardization to Global Certification

Jan Erik Nielsen
SolarKey International
Operating Agent for the Danish Energy Agency

TASK DESCRIPTION

The general objectives of the Task 43 extension were to:

- Reduce testing and certification costs for the global solar collector industry
- Increase quality of solar collector production throughout the world

This was done by:

- Supporting ISO TC180 in improving, harmonizing and promoting international standards (ISO)
- Establishing a "Global Solar Certification Network aiming harmonization of certification schemes.

Originally, the ambition was to establish a global certification scheme, but this was in the end not possible. Instead, a concept of mutual recognition of test and inspection reports within the framework of the Global Solar Certification Network was chosen – still making it possible to avoid re-testing of solar collectors and re- inspection of production sites.

The Task was organized in the following subtasks:

- Subtask A: Harmonization of standards for solar thermal products
(Subtask Leader: Ken Guthrie, Sustainable Energy Transformation, AU)

- Subtask B: [Harmonization of certification schemes for solar collectors
(Subtask Leader: Eileen Prado, SRCC, US & Jaime Fernandez, AENOR, ES

- Subtask C: Organizational framework for global collector certification
(Subtask Leader: Harald Drück, ITW, DE)

Task Duration

This Task is now completed. The Task 43 Extension started in **July 2013** and ended in **June 2015**.

Participating Countries

Country	Number of Research Institutes	Number of Universities	Number of Companies	Number of Test Labs	Number of Certification Bodies	Number of Associations
Australia			1			
Canada				1		
China	1		2	2	3	1
Denmark			1			
Germany				2		

Portugal				1		
Spain					1	
USA					2	
Total	1		4	6	6	1

Collaboration with other SHC Tasks and Outside Organizations/Institutions

The Task had well-functioning informal cooperation with ISO TC180 and Solar Keymark Network – and most meetings were organized together with meetings in these organizations.

The "Solar Certification Fund" under the Solar Keymark Network has co-funded the OA.

Collaboration with Industry

The European Solar Industry Federation has followed the Task with big interest and given input along the way.

Large Chinese and European manufacturers participated in the Task.

TASK ACCOMPLISHMENTS

Key Results

The main accomplishments of this Task are highlighted below. More details and specific deliverables can be found on the SHC Task 43 webpage.

- Significant support to ISO TC180 in **revising ISO 9806** (New ISO 9806 expected 2016)

- **Draft "Global Solar Certification Scheme"**. Although it was not chosen to establish a worldwide certification scheme for solar collectors, a well-elaborated draft for such scheme was elaborated – available as a good basis if/when time is ready for such scheme – and for inspiration for new and existing national certification schemes.

- The "**Global Solar Certification Network**" has been established with the main aim of organizing mutual accept of test reports and inspection reports by existing national and regional certification schemes – so **industry can avoid re-testing and re-inspection**.

- The **Global Solar Certification Network will start operation during 2016** (supported by new IEA SHC Task 57).

PUBLICATIONS

Reports & Published Books

Title	Publication Date (month, year)	Target Audience	Web or Print
UTILISATION OF ISO9806: 2013 IN GLOBAL SOLAR CERTIFICATION K I Guthrie1 L T Guthrie and J Osborne November 2014	November 2014	National standardization committee, test labs, certification bodies, authorities, industry	web
Global Solar Certification Scheme - Scheme Rules for Certification (DRAFT) S. Scholz, JE Nielsen, ….	September 2014	National standardization committee, test labs, certification bodies, authorities, industry	web
Global Solar Certification Scheme - Scheme Rules for Certification – Annexes A – H (DRAFT) S. Scholz, JE Nielsen, ….	September 2014	National standardization committee, test labs, certification bodies, authorities, industry	web
Global Solar Certification Scheme - Scheme Rules for Certification – Annex I. Comparison of Requirements of Different Certification Schemes	May 2014	National standardization committee, test labs, certification bodies, authorities, industry	web
Global Solar Certification Network Working Rules edited by Harald Drück	November 2015	National standardization committee, test labs, certification bodies, authorities, industry	web
Global Solar Certification Network Working Rules - Annexes edited by Harald Drück	November 2015	National standardization committee, test labs, certification bodies, authorities, industry	web

Journal Articles, Conference Papers, Press Releases, etc.

Author(s)	Title	Publication / Conference (name of journal, newsletter, conference, etc.)	Bibliographic Reference (journal number, year, place, editor, etc.)
JE Nielsen	Task 43 "Global Certification"	IEA-SHC – Solar Association meeting in connection with the SHC2013 Conference 23 September 2013 in Freiburg, Germany	2013-09-23
JE Nielsen	Task 43 "Global Solar Certification"	IEA SHC Newsletter Article	2013-10-17
H Drück	Global Solar Certification Network established!	Press release	2014-03
JE Nielsen	Global Solar Certification Network established!	IEA SHC Newsletter Article	2014-04
L Nelson	Global Solar Certification	SHC 2014 conference (Keynote)	2014-10
JE Nielsen	An introduction to "Global Solar Certification"	SHC 2014 conference (presentation)	2014-10
JE Nielsen	Task 43: Solar Rating and Certification - "Phase 2: Global Solar Certification"	SHC 2014 conference (poster)	2014-10
JE Nielsen	Task 43 "Global Solar Certification"	SHC ETI contribution	2014-11
JE Nielsen	Task 43 Highlights	IEA SHC Highlights	2015-02
JE Nielsen	"Global Solar Certification Network"	International Solar Heating and Cooling Summit, Beijing	2015-07
JE Nielsen	Task 43: Solar Rating and Certification - "Towards Global Solar Certification"	SHC 2015 conference (poster)	2015-12
JE Nielsen	How does "Global Solar Certification" work	SHC 2015 conference (Keynote)	2015-12
JE Nielsen	Outcome of Task 43: Solar Rating and Certification - "From international standardization to global certification"	SHC 2015 conference (presentation)	2015-12

CONFERENCES AND WORKSHOPS

Task participants presented Task work and results at least **18** conferences and workshops (including international meetings in the Global Solar Certification Network, the Solar Keymark Network and the ISO TC 180) over the 2-year course of the Task.

TASK MEETINGS

Meeting #	Date	Location	Number of Participants (Number of Countries)
1	2013 September	Berlin, Germany: • 1st Experts meeting • "Global Solar Certification Workshop"	35 (11) Approx. same
2	2014 March	Las Palmas, Spain: • 2nd Experts meeting • "Global Solar Certification Network" meeting	29 (12) Approx. same
3	2014 October	Beijing, China • 3rd Experts meeting • "Global Solar Certification Network" meeting	30 (11) 30 (11)
4	2015 March	Rome, Italy • 4th Experts meeting • "Global Solar Certification Network" meeting	23 (13) 29 (13)

SHC TASK 43 NATIONAL CONTACTS

Ctry/Org	Expert	Institution/Company	E-mail	Role
Australia	Ken Guthrie	Sustainable Energy Transformation Pty Ltd / ISO TC 180	ken.guthrie@setransformation.com.au	Subtask A leader
Australia	Jeremy Osborne	Energy Analysis and Engineering	Jeremy.osborne@energyae.com	Expert
Canada	Alfred Brunger	Exova	Alfred.Brunger@Exova.com	Expert
China	Sun Yuquan	SDQI/ Energy saving Product Quality Inspection	jinxiuchuan@gmail.com	Expert
China	Li YuWu	SDQI/ Energy saving Product Quality Inspection	yuwuli@gmail.com	Expert
China	Lai Hanxiang	Guangdong Vanward New Electric C., Ltd.	laihx@ms.giec.ac.cn	Expert
China	Ruicheng Zheng	China Academy of Building Research	zhengrc@vip.sina.com	Expert
China	Tong Xiaochao	China Academy of Building Research	xiaochao.tong@gmail.com	Expert
China	Wang Min	China Academy of Building Research	minwangbeijing@gmail.com	Expert
China	He Zinian	Beijing Solar Energy Research Institute	hezinian@sina.com	Expert
China	Zhou Xiaowen	Beijing Tsinghua Solar Ltd.	xwzhou2003@aliyun.com	Expert
China	Zhao Juan	Beijing Tsinghua Solar Ltd.	zhaojuan@thsolar.com	Expert
China	Jiao Qingtai	Jiangsu Sunrain Solar Energy Co., Ltd	jiaoqt@sunrain.com	Expert
China	Tian Liangguang	Shandong Supervision and Inspection Institute for Product Quality	tianlg@12365.sd.cn	Expert
China	Kang Wei	China Quality Certification Centre	kangwei@cqc.com.cn	Expert
China	Joseph Huang	International Copper Association Asia	josephhuang@copper.org.cn	Expert

Task 48

Quality Assurance and Support Measures for Solar Cooling

Daniel MUGNIER
TECSOL
Operating Agent for the French Energy Agency (ADEME)

TASK DESCRIPTION

The Task 48 project was intended to find solutions to make the solar thermally driven heating and cooling systems at the same time efficient, reliable and cost competitive. These three major targets should be reached thanks to four levels of activities:

- Development of tools and procedure to make the characterization of the main components of SAC systems.
- Creation of a practical and unified procedure, adapted to specific best technical configurations.
- Development of three quality requirements targets.
- Production of tools to promote Solar Thermally Driven Cooling and Heating systems.

Task Duration

The Task is now completed. It started in **October 2011** and ended **in March 2015**.

Participating Countries

Country	Number of Research Institutes	Number of Universities	Number of Companies
Australia	1		
Austria	3		1
Canada		1	
China		1	1
France	1		1
Germany	5		1
Italy	2	3	
USA			1
TOTAL	12	5	5

Collaboration with other SHC Tasks and Outside Organizations/Institutions

Contribution to SHC Task 45: request from Task 45 on new large solar thermal plants (including cooling ones) database: Task 48 experts has been asked to share data on solar cooling systems.

Exchanges with SHC Task 49 on Activity A6: State of the art on new collector & characterization

Definition of the contributors from Task 49 with the support from Christian Zahler (Industrial solar) involved in both Tasks 48 and 49. In September 2012: planned for the “cooperation” with Task 49.

Organized a joint internal workshop with SHC Task 45 and SHC Task 49 in September 2012 in Austria. This joint workshop between the three new Tasks on large applications (Task 45, Task 49 and Task 48) was organized by Task Operating Agents as a way to enhance the synergy and common transversal topics of the Tasks. This collaboration successfully led to exchanges on the latest work and results achieved by the Tasks.

Collaboration with Industry

According to the statistics presented just before, it clearly appears that Task 48 had a significant involvement from Industry and companies. Some pillar experts from SHC Tasks 25 and 38, such as TECSOL, INDUSTRIAL SOLAR and SOLID (Fresnel collector manufacturer, engineering companies) as well as sorption chiller manufacturers were constantly supporting or acting inside Task 48 (SORTECH, INVENSOR). Some observers have been for the full duration of the Task:

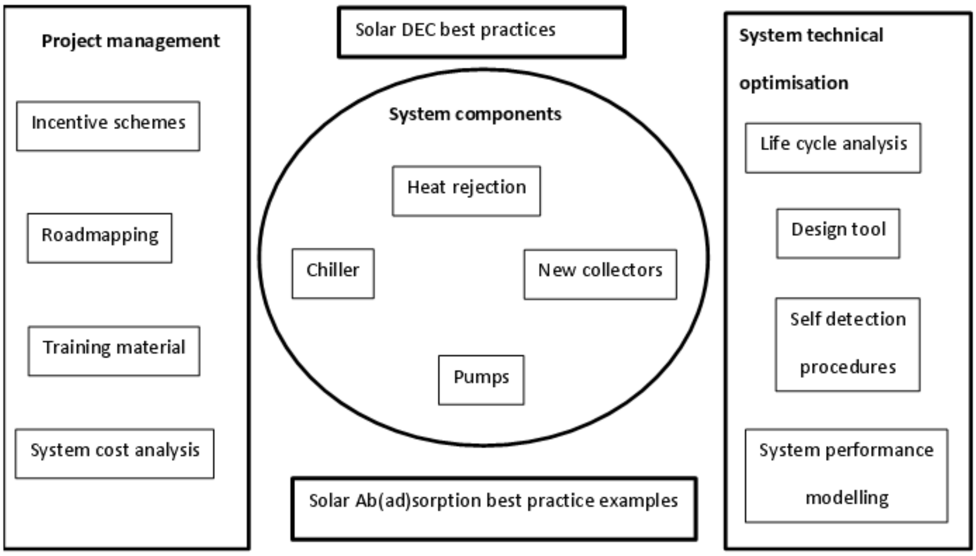
- Thermosol Consulting (Canada): consulting company
- Kawasaki (Japan): sorption chiller manufacturer
- Pink (Austria): sorption chiller manufacturer
- Aztec Solar (USA): consulting company
- SOLEM (Australia): consulting company
- Shuangliang (China): sorption chiller manufacturer
- Coolgaia (Australia): consulting company
- TVP Solar (Switzerland): solar collector manufacturer
- Polysun (Switzerland): software developer
- De Beijer (Netherlands): sorption chiller developer

From the kick-off meeting in Marseille, to Milan and then in Gleisdorf, an important effort was made to enlarge the number of participating countries outside of Europe and of industry. The last Task meeting in Gleisdorf had 33 participants from 8 countries, despite not having the usual videoconference participants. It should be noted as well the presence of Industry observers from Germany, China, Japan and the US.

TASK ACCOMPLISHMENTS

Key Results

The main accomplishments of this Task are highlighted below. More details and specific deliverables can be found on the SHC Task webpage. The main objective of Task 48 was to assist with the development of a strong and sustainable market for solar cooling systems. The Task focused on systems with solar thermal cooling technology (no power limitation or solar collector field area) that could be used in heating mode. The project was intended therefore to create a logical follow up on the IEA SHC work already carried out by trying to find solutions to make the solar thermally driven heating and cooling systems at the same time efficient, reliable and cost competitive. Below is a concept scheme showing the logic and coherency between the main deliverables.



Conceptual scheme of the deliverables of SHC Task 48.

The following is a brief report on the accomplishments of each single work activity within the Subtasks.

Subtask A: Quality Procedure on Component Level
(Subtask Leader: Marco Calderoni, POLIMI, Italy)

This Subtask concentrated on developing tools and deliverables that would show the level of quality of the most critical components of the solar cooling and heating system (i.e., chiller, the heat rejection device, the pumps and the solar collectors):

- A1: Chiller characterization
- A3: Heat rejection
- A4: Pumps efficiency and adaptability
- A6: State of the art on new collector & characterization

A1/B1: Chiller characterization

The deliverables are:

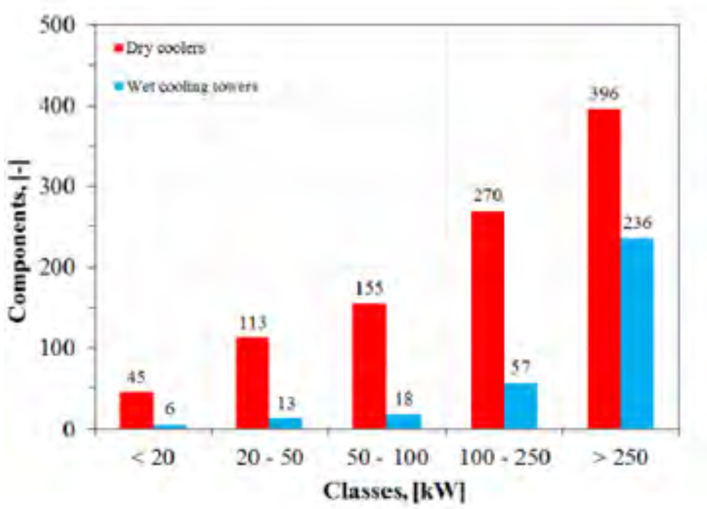
- Survey of market available chillers.
- Survey of existing standards: results served as input for test procedures.
- Test procedure for continuous chillers.
- Test procedure for discontinuous chillers.
- INES developed an Excel-based tool for checking whether test data are within the defined tolerances. Available measurement data compared with T48 procedure: in three cases (INES, ITAE CNR, ISE) data comply with the defined tolerances.
- Review of calculations and terminology.

A3: Heat rejection

Conducted a market review of approximately 1,300 devices from 22 manufacturers and elaborated on performance figures. A valid reference was set to benchmark heat rejection devices.

Survey on national and international standards: 51 standards ranging from installation and operation to security and maintenance regulations;

Lessons learned from installed heat rejection devices monitoring data: 9 datasets about dry coolers, 5 about wet coolers. Lessons learned cover installation, maintenance and control strategies and aim at significantly reducing electricity consumption.



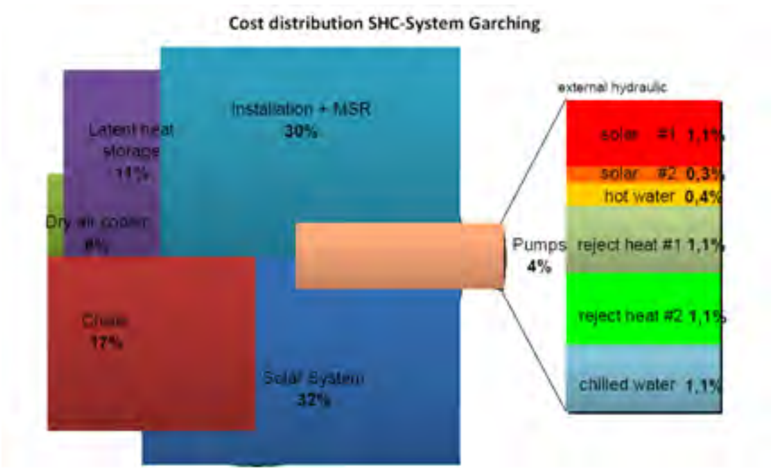
Data analysis for recooling power among dry coolers and wet cooling towers.

Heat rejection devices are crucial for the performance of solar cooling systems, determining the operating boundary conditions of the thermal chillers: given a cooling target, the specific electricity consumption for different systems can vary by a factor of 4 for dry coolers and by a factor of 2 for wet cooling towers.

A4: Pumps efficiency and adaptability

Final report is available (design criteria, electricity consumption, theory of rotodynamic pumps, standards, pump control, design guidelines).

Since 2010 pump efficiency has greatly improved due to legislative restrictions: 50-80% efficiency depending on size.



Nevertheless, good design is crucial to properly size the pump and to benefit from its good nominal efficiency.

Chilled and cooling water loops are the most energy consuming: the use of variable speed pumps in these loops can improve EER (Energy Efficiency Ratio) dramatically, at a low investment cost increase.
Intelligent high-efficiency pumps with internal flow, pressure, temperature and power meters can lead to high energy savings, but for complexity reasons implementation is reserved for manufacturers of prefabricated system providers. At the current stage the overall SEER of 20 seems to be feasible.

A6: State of the art on new collector & characterization
A final collector database and short report were produced. In general some of the first medium temperature manufacturers have left the business, while many new ones have entered the market, focusing either on power generation or process heat, and little interest in solar cooling.

Subtask B: Quality Procedure on System Level
(Subtask Leader: Alexander Morgenstern, Fraunhofer ISE, Germany)

This Subtask developed tools and deliverables to show the level of quality of solar cooling and heating systems. The Subtask was conducted in two steps:

1. Development of a procedure to extend the quality characteristics from component level to system level.

2. Extension of the procedure from single stationary states to allow performance prediction for whole year operation→ close link to results of Subtask A.

B1: System/Subsystem characterization & field performance assessment
This activity was carried out to survey publically available procedures that could be adapted to solar cooling systems quality assessment.

- A review of the test/monitoring standards within the solar sector was carried out. Standards suitable for the analysis of the performance of systems driven by other RES was taken into consideration. Examples of suitable (EU) standards are CEN/TS 12977, EN 15316, ISO 9459, EN 14511, EN 12309, EN 12975, and EN 12976. Extension of the review to the American, Asian and Australian market was considered. There was close collaboration with Activity C1. The survey profited from the work already performed in the SHC Task 34 and Task44/Annex38.

- A review and classification of the work performed at the scientific level for solar cooling systems characterization was performed. With reference to laboratory testing, the following examples can be reported: Bin method, CTSS, ACDC, SCSPT and CCT.

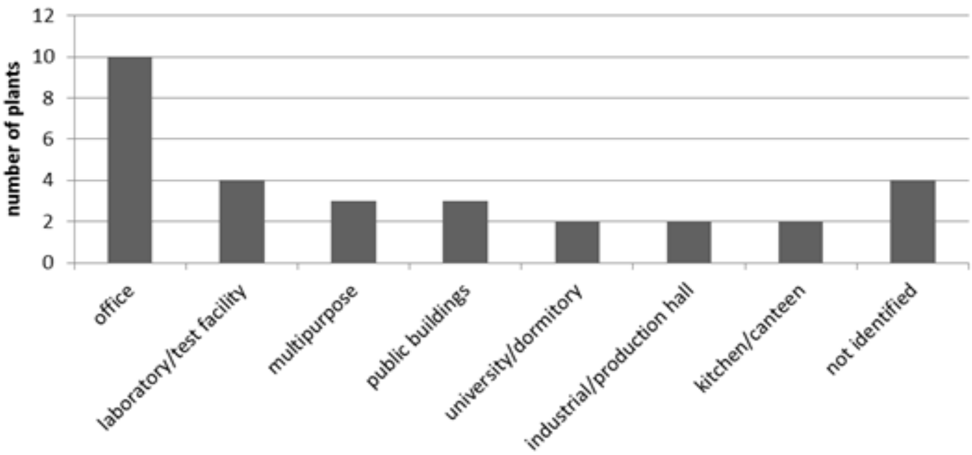
- A review of the former work elaborated with regard to solar cooling systems representation and performance figures calculation were performed. In strong collaboration with Activity C4, the material developed in earlier Tasks was collected and analyzed. A consistent methodological approach was elaborated on:
    - Represent system's hydraulics

- Represent and name energy fluxes
- Represent system's boundaries
- Calculate performance figures

- A "narrow" range of performance figures will be defined that can be computed starting from laboratory acquired data.
    - Starting from the collected material, at least one suitable test procedure should be defined to assess yearly systems' performance, which will be promoted as useful material for future tests standards.
    - Detailed monitoring data from real installations will be retrieved from participating companies and institutions to validate the agreed performance test methods. Key for the success of this activity is that research institutions are willing to assess the test methods in their laboratories/test sites.

B2: Good practice for DEC design and installation

This activity produced a technological survey and update on the best practice systems of desiccant cooling systems. This technology was not be the primary focus of the Task, but kept an observatory eye on this specific technology evolution. The report is composed of the following parts:



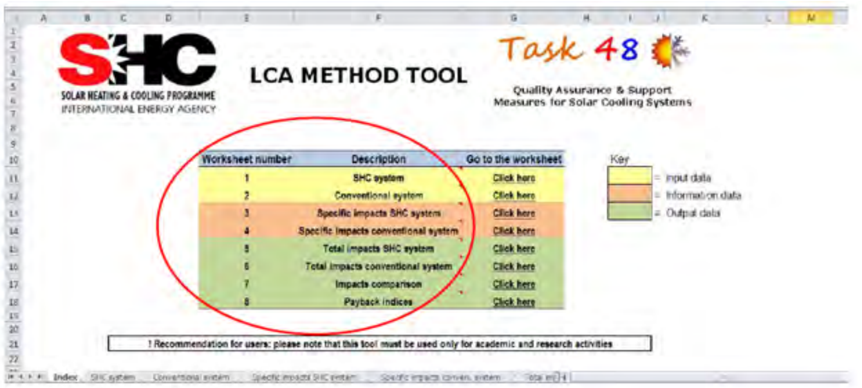
Application type – Overview for studied DEC systems.

- 30 Worldwide installed SDEC-systems (90%)
- New technical developments (75%)
    - FREESCOO (compact DEC system with fixed and cooled adsorption bed)
    - ECOS-Singapore
    - Double-Rotor System in Shanghai
    - LDEC in Kingston expected before end of March
- Quality label on DEC rotor and system
- Good practice SDEC systems
    - 3 different systems (POLIMI, CSIRO, AIT)
    - Comparable description and data sets
        - System configuration

- Energy performance figures
- Investment data
- Design phase

A2 & B3: Life cycle analysis at system level

The technical report describes the research activities developed within Subtasks A2 "Life cycle analysis at component level" and B3 "Life cycle analysis at system level".



Subtask A2 focused on developing studies to assess the energy and environmental performances of components of solar cooling and heating (SHC) systems. In detail, the Life Cycle Assessment (LCA) approach applied to SHC systems, started by SHC Task 38, was further developed to give a ready to use collection of datasheets allowing estimating the energy and environmental impacts of different SHC systems during their life cycle. The results of the activities developed within Subtask A2 are used to update and complete a database of life cycle inventories for components of SHC systems, already developed within SHC Task 38, to be used for the development of a LCA method tool.

As an outcome of SHC Task 38, two machines were already analyzed: PINK PSC-10 (12 kW) with H2O/NH3 and SorTech AG ACS 08 (8 kW) with H2O/Silica Gel. In addition, the energy and environmental impacts of other components of SHC plants were assessed (e.g., solar thermal collectors, gas boiler, pumps, etc.) starting from data of international LCA databases. An outcome of Subtask A2 of Task 48 was the assessment of the energy and environmental impacts of Pink PC19 Ammonia Chiller and of a Packed Adsorbed Bed and the database on life cycle inventories for components of SHC systems, developed within Task 38, was updated and finalized.

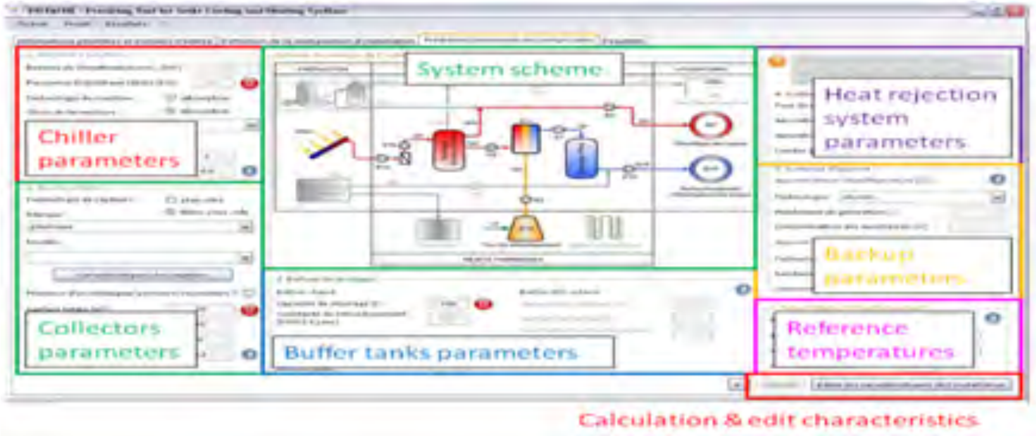
The LCA database now includes solar PV components (photovoltaic panels, inverter, storage, etc.) giving the possibility to perform analysis on conventional systems that use renewable electricity with or without connection with the grid.

Subtask B developed a user-friendly LCA method tool, useful to calculate the energy and environmental impacts and the payback time indices of different SHC systems and to compare SHC systems and conventional ones. The tool contains the database developed in Subtask A2. An important step in the tool development was the analysis of international LCA databases to check the LCA data availability for components of the SHC systems and for conventional equipment (pipes, pumps, electric components, photovoltaic panels, etc.).

Within Subtask B, the results of the SolarCoolingOpt project were also illustrated.

B4: Simplified design tool used as a reference calculation tool

The deliverable is a simple to use pre-sizing tool (available on the websites of SHC Task 48 and TECSOL). From September 2013, there have been 605 downloads. Successful comparison with four real systems (monitoring data) and with a comprehensive system simulation study by ZAE (agreement from ZAE to put their report on the webpage as well) were completed. The errors were less than 10% between experiment and simulation.



B6: Self detection on monitoring procedure

Starting from the statement of existing efficient system control (overview achieved in former SHC Task 38), a second generation of control system was needed that included self-detection of faults and malfunctioning of the process based on a reduced monitoring. This new powerful functionality is a key component assuring long-term reliability and performance of the system. This activity included an update of good practice on the monitoring procedure starting from the experience and procedures developed during SHC Task 38. However, possible system errors in solar cooling systems were diverse from component defects over simple sensor faults to real control problems. Therefore, as a basic for new developments of automated fault detection systems within working group B6 first a categorization of typical system errors was carried out. For each fault category typical errors were collected and possible methods for error detection were discussed together with necessary monitoring equipment. In the last part of the document possible implementations of automated fault detection systems within local system controllers and within centralized internet-based system observation systems are shown. The main chapters of the report are:

- Collection and Characterization of typical system errors
    - Sensors / metering
    - Hydraulic design mistakes, wrong placement of components, …
    - Typical control problems
- Existing error detection systems / ongoing development /projects
    - METHODIQA (Austrian project 2013/14 at AEE Intec)
    - InSun (EU-Project at zafhnet)
    - Project at ZAE
    - extrACT at AIT (Austrian project)
    - FDD (fault detection diagnosis) at POLIMI

B7: Quantitative quality and cost competitiveness criteria for systems

In B7, a proposal for an appropriate evaluation procedure for the technical and economic performance assessment of large systems was set up and tested with real cases. It delivered the basis for a comparable assessment of the installed plants independently of installation site and the specific boundary conditions. Besides, a reflection was carried out on minimum economical ratios to estimate the competitiveness of solar cooling against concurrent technologies.

This activity provided input to and was carried out in close collaboration with Activities B1 (System/Subsystem characterization & field performance assessment) and C2 (Methodology for performance assessment, rating and benchmarking).

This activity surveyed the available procedures that could be adapted to solar cooling systems quality assessment.

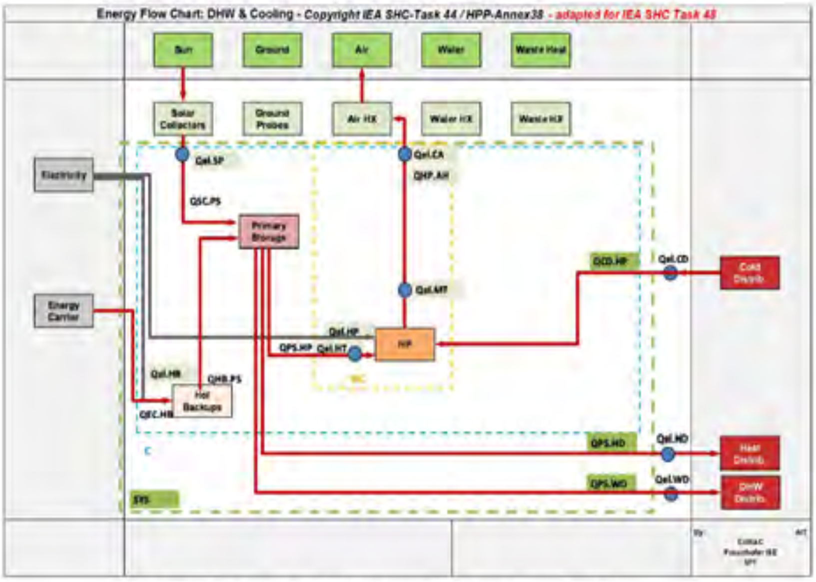


Figure 9: system boundary and possible energy flows for the $SPF_{el,sys}$

1. A collection and review of existing key figures to quantify quality and cost will be performed but also the specific tools to calculate them was reviewed.

2. Defined the crucial key figures for large-scale plants (in cooperation with B1) and found a representation for all of the key figures.

3. Review how benchmarks can be calculated (in cooperation with C2) and define minimum ratios for them.

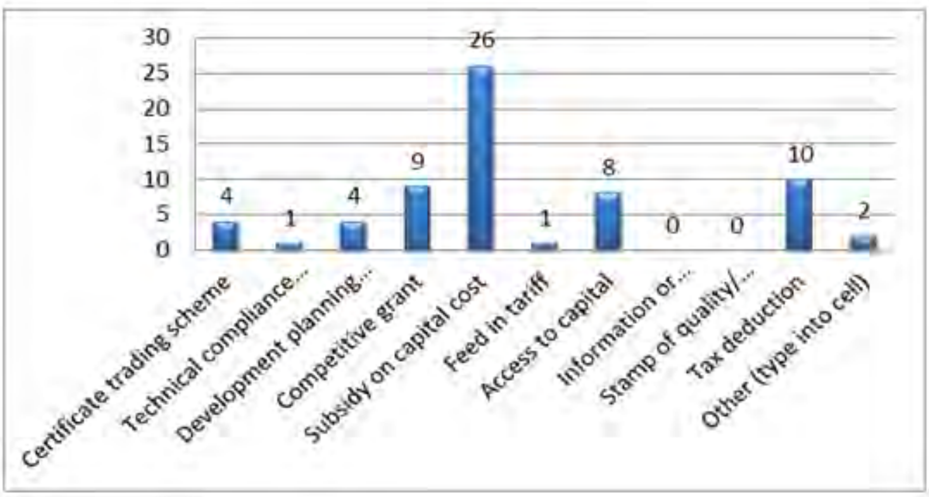
4. Data acquisition for investment (SHC + reference system) and operating (electricity, etc.) costs was done to find specific minimum economic ratios.

5. The procedure was tested and validated with real installations. Participating companies and institutions provided monitoring data. The key to the success of this activity was that the research institutions were willing to assess the test methods in their laboratories/test sites.

Subtask C: Market Support Measures
(Subtask Leader: Stephen D. White, CSIRO, Australia)

C1: Review of relevant international standards rating and incentive schemes

A large number of government incentive programs and industry development programs have been instituted in different jurisdictions to assist the renewable energy and building energy efficiency industries. These programs call up procedures for quantifying benefits, rating effectiveness and achieving robust measurement and verification. A database of relevant standards, processes and incentives was created and linked to the needs of the solar heating and cooling industry.



C2: Methodology for performance assessment, rating and benchmarking

Methodologies were developed in collaboration with the work achieved in Activity B7, and then used to quantify performance and quality of 1) alternative air-conditioning and renewable energy technologies and 2) current solar air-conditioning systems. Low and high performance bounds were identified and benchmarked, along with the factors that most influenced high performance. Benchmarks were used to set a coherent rating framework depending on the local conditions (climate, technology, application). This rating framework enables stakeholders to understand and set design criteria and performance targets for performance based solutions. The rating framework also guides design requirements for prescriptive solutions, and provide information for road mapping in activity D4.

The Activity C2 is particularly relevant to the “Measured Performance of Large Systems” approach. It is expected that Activity C2 will leverage the measurement and verification procedure of Activity C4 to obtain measured energy consumption data. The Activity C2 provided the additional procedure(s) for benchmarking the measured data against target performance criteria. The final deliverables are 1) a set of definitions of performance metrics that can be used to compare performance of alternative systems and 2) target values that a system can be benchmarked against that will define the quality of the installation.

C3: Selection and standardization of best practice solutions

From the past and present experience with small, medium and large-sized solar air-conditioning systems, a reduced and documented set of system design schemes and control schemes were selected that exhibit favorable system operation in terms of optimized performance and reliability. Three case study configurations were selected and used to define and standardize the engineering criteria, which lead to target reliability, efficiency and cost competitiveness. Particular attention was given to the standardization of the system design schemes and defining the constraints of applicability of these standardized designs.

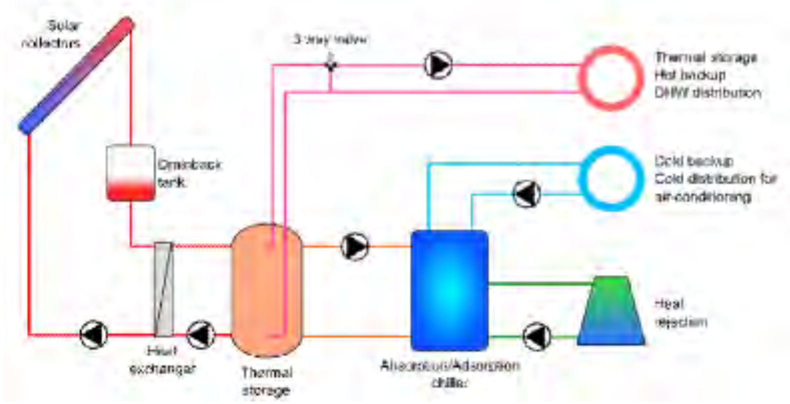
In order to support planners and installers, a selection of proven system designs including hydraulic schemes, were specified in the form of design guidelines for heating, cooling and ventilation of commercial buildings,

The deliverable of this activity will be published by Wiley VCH as part of the IEA SHC book series. The **Design Guide** complements the IEA "Solar Cooling Handbook" [Henning et. al. 2013]. The Handbook provides a comprehensive, but somewhat general overview of the various technologies and equipment components to convert solar heat into useable cold. The Handbook enables engineers to design their own solar cooling system with full design flexibility, covering the breadth of possible applications. Examples are included, but prescriptive designs for specific applications aren't mentioned.

Compared to the Handbook, this Design Guide provides more detailed and specific engineering design information targeted at a limited number of specific case study examples. These case study examples are seen as good examples, worthy of replication when appropriate.

The motivation to write this Guide stemmed from the analysis of recent monitoring results of a number of installed and operating SAC plants. This analysis showed that some installations do not reach the intended level of performance. To avoid such setbacks in the future, this Design Guide provides more detailed engineering design information for these three specific case studies.

The structure includes the explanation of the flow sheet and the application conditions for which the design is intended. Where appropriate, numerical constraints are provided to assist with the selection and sizing of equipment. By following this Design Guide step by step for any of the three specific SHC systems, a reliable, robust cost-effective and energy-saving solution can be expected.

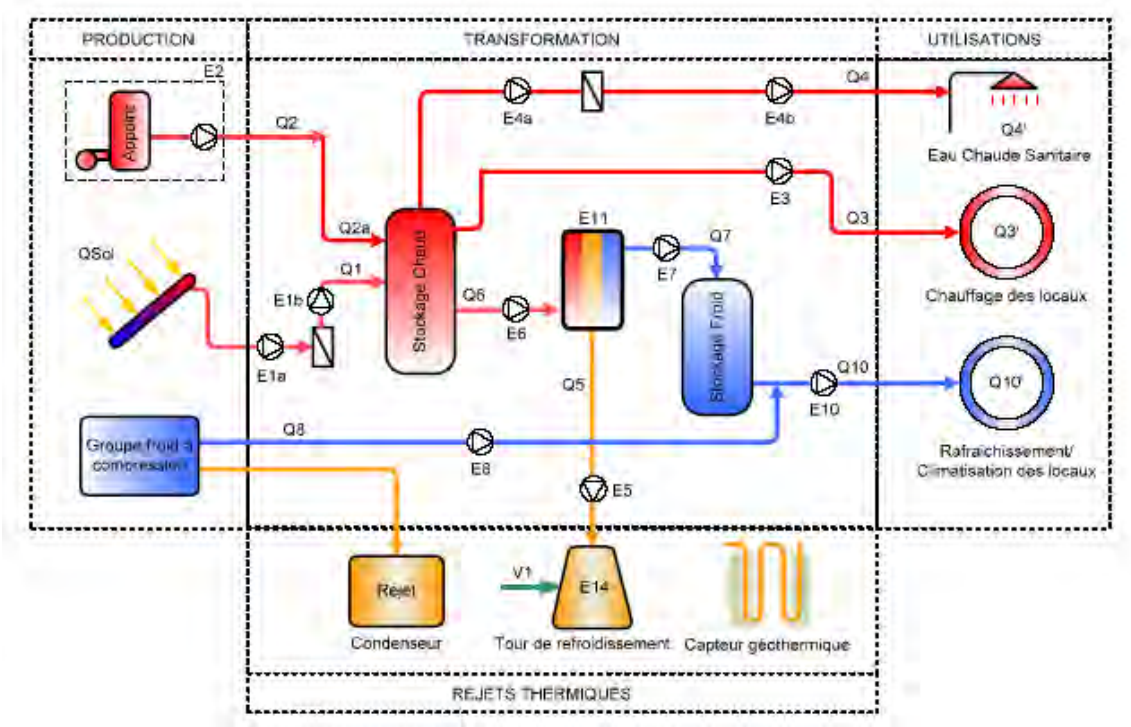


Of course there are many other attractive solar cooling technology solutions available. So the Design Guide should only be read as a positive statement on a small number of solutions (rather than a negative statement on other solutions).

The Design Guide will be published by Wiley in the first half of 2016.

C4: Final report, Measurement and Verification Procedures

While Measurement & Verification (M&V) procedures (e.g., IPMVP, ASHRAE and FEMP) exist for general energy conservation measures, it is desirable to have a more specific and targeted guide for solar cooling in order to simplify procedures, improve confidence in results and to assist M&V implementation with more detailed guidance. The resulting in-situ and exsitu measurement procedures have been written up as a document suitable for submission as a draft standard.



The present final deliverable is a monitoring procedure and a draft standard integrating the following aspects:

- Presentation of a generic scheme for solar cooling installations;
- Definition of one (or two maximum) performance indicators, with associated calculation method applied to the generic scheme;
- Prescription of the sensors required (position, technologies,) in order to obtain the needed information for calculating the performance indicator(s);
- Definition of the analysis method for reporting the performance and quality of the installation.

C5: Labeling possibilities investigation

The work within the Subtask C focused on creating a panel of measures to support the solar cooling market. These measures use the results of Subtasks A: Quality procedure on component level and Subtask B: Quality procedure on system level, and above all explored the possibilities to identify, rate and verify the quality and performance of solar cooling solutions.

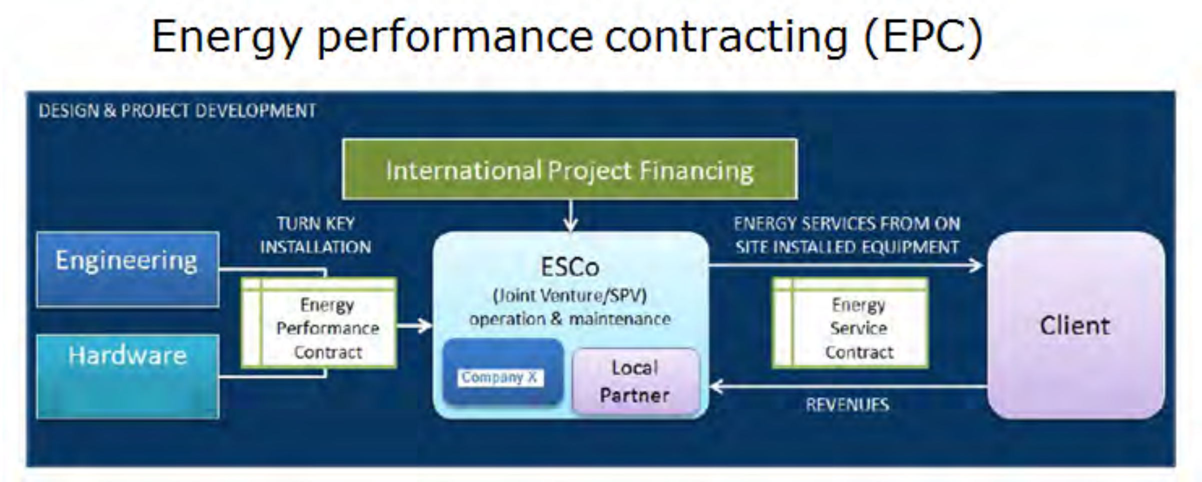
The resulting tools provide a framework for policy makers to craft suitable interventions (e.g., certificates, label and contracting, etc.) that support solar cooling on a level playing field with other renewable energy technologies.

From the past and present experiences with labeling of solar systems (e.g., Solar Keymark, Blauer Engel, etc.) or “Green quality” labels such as LEED or Green Building Council tools, within the framework of Activity C5, existing labels were investigated to create a Solar cooling label/specific Solar cooling extension(s) to the existing labels. This activity was mainly exploratory and first mad a full state-of-the-art labeling process. From this information, investigations on how to integrate them or even how to create an independent Solar Cooling Label was investigated and theorized if accurate.

C6: Contracting models for solar thermally driven cooling and heating systems

This Subtask emphasized contracting models for solar cooling systems, and for that purpose collaboration was established with SHC Task 45 on large systems for district heating and cooling systems.

Analysis focused on details, such as investment models, contracts and other relevant issues with regard to which ESCO information is limited and dispersed in the EU and worldwide. The work worked to deepen our understanding of the hurdles that ESCos face and provide information on ways to overcome such hurdles in practice.



Solar thermal technology is defined as a technology used to harness energy from the sun for use in a thermal process. There are a wide variety of applications for this technology, including, but not limited to, water/process heating, radiant heating and air conditioning. In each application, solar energy is obtained through a solar collector and transferred to a thermal process. Given the proper conditions and system design, solar thermal technology can provide a reliable and cost-effective energy source in residential, commercial, and industrial applications.

In the field of solar air conditioning, an exponential increase of activities occurred during the last years. Some solar cooling systems are small in size, starting at approximately 15 kW. Below this level much research work was conducted to achieve satisfactory results in regard to the systems´ thermal efficiency. Most solar cooling installations are between 15 kW and 500 kW, being perfectly suitable for all buildings that have a continuous and regular load profile (e.g., public buildings, offices, hospitals, etc.). Since 2011, there are also solar thermal cooling systems with cooling power beyond 1 Megawatt in operation, like in Singapore and the USA. These systems were the first solar cooling systems based on ESCo financing models.

Solar collectors for air conditioning of buildings are also used for other applications, such as space heating and domestic hot water preparation. The latter usually contributes to a reduced payback time of the investment. The technologies of concentrating solar cooling applications as well as the technology of solar flat plate cooling applications have their specific advantages or disadvantages in each case, depending on location and application characteristics. Components have to be carefully selected and developed through an integrated design approach to become a functional system.

ESCos for solar thermal air conditioning are in many cases a competitive energy service concept to execute energy efficiency projects in buildings or production facilities. Further work will be done in the IEA SHC Task 48 and other projects to make this financial service more competitive and superior to other products

C7: Certification process definition for small systems

This activity focused on the development of a certification process applied for small size solar cooling systems. The opportunity of such an initiative ongoing in Australia provided an interesting case study and all the work achieved in Subtasks A and B, in addition to other activities inside this subtask, provided tools to reach a coherent method to qualify the quality of the solar cooling systems: software tool, minimum performance requirements and installation/O&M methodology, etc. Through this example, an extension and generalization was achieved for other countries and in other ranges of cooling power.

The objective of work package C7 was to develop certification processes applied for small size solar cooling systems. Within this activity, the term “small size solar cooling system” is understood as predesigned packages and thus not as costumer designed system solutions. The focus was on standards for a measurement end performance estimation procedures.

The report includes the required elements of such a standard and the current state of the art in other related fields and describes three relevant methods applicable for solar cooling. These methods are:

- Component Testing System Simulation (CTSS): a computer simulation method to predict the performance of solar cooling systems, developed by CSIRO for Australia
- Bin-Method: a calculation procedure based on the weighting of measured performances according to the occurrence of temperatures within a reference season. This method was developed by FhG-ISE for Europe.
- Dynamic test methods (EURAC)

Subtask D: Dissemination and Policy Advice
(Subtask Leader: Uli Jakob, Green Chiller Association, Germany)

The work in this Subtask covers horizontal activities related to subtasks A, B, and C. The objectives of this subtask are the implementation of targeted promotion activities based on the collective work results; production of dissemination material for external communication; the implementation of knowledge transfer measures towards the technical stakeholders; the development of instruments and their provision for policy makers and the creation and promotion of certification and standardization schemes.

D1: Website

This website presents the Task results. The number of visitors according to the IEA SHC website statistics is nearly constant at 5,000 visitors per month, showing that this website is among one of the most visited on the site. It includes Task publications and numerous presentations from conferences, workshops and training seminars.

D2: Best Practices brochure

This brochure presents 12 success story installations or best practice examples received from CISRO, TECSOL, UIBK / Pink, SOLID (2x), ZAE, SJTU (4x), InvenSor and SorTech. The fundamental criteria consider are reliability, efficiency/performance, cost competitiveness.

D3: Simplified short brochure

This brochure underlines the methodology used to develop the quality procedures for solar cooling and the possible tools for certification, labeling and policy support.

D4: Guidelines for roadmaps on solar cooling

This report addresses to the results of D4 “Guidelines for Roadmaps on Solar Cooling”.
As a result of this work package and a summary of the whole Task activities, a list of recommendations for policy options to develop the industry was published.

- Review of existing roadmaps on Solar Thermal technology with focus on methodology and approach.
- Update with activity results of Subtask C.
- Review of the impact of existing incentive schemes (link to C1) focusing on the efficiency of the schemes for the development of the local market (increase of turnover, improvement on quality of installations, etc.).
- Guidelines for policy measures and how to make their promotion towards the local and national policy makers.

D5: Updated specific training seminar material

The result of this work package is the update of the existing training material for installers and planners, already created by SHC Task 38. This update is on the technical side (available products, new components, etc.), but also on the adaptation of the content to the Quality procedure concept.

The overall set of training material is divided into 3 different parts:

1. Introduction (25 slides)

2. Part A (88 slides)
    - Load concepts and (solar) air-conditioning
    - The cold production sub-system
        - Chillers (vapor compression, absorption and adsorption), including basics on chiller characterization (dynamic test approaches for seasonal performance assessment)
        - Desiccant cooling systems
        - Heat rejection equipment
    - The heat production (solar) system (collectors and storage), including state of the art on concentrating and new collectors
    - System configurations (solar assisted and solar autonomous systems) and control (including advanced control with self-detection of faults and malfunctioning). Solar district cooling.
    - Design approaches
        - Preliminary design aspects, backup sources and efficiency benchmarks
        - Dimensioning a solar cooling system (chiller size, collector area, storage volume)
        - Quality assurance and lessons learned aspects
3. Part B (34 slides)
    - Performance figures
        - Energy performance and primary energy balance, including COPel, electrical consumption of heat rejection and efficiency improvement potential for other components (e.g. pumps)
        - Economic and environmental analysis, energy saving certification

PUBLICATIONS

Reports & Published Books

Report No.	Report Title	Publication Date	Access (PUblic, REstricted)	Web or Print
A1	Report on characterization of solar cooling systems	06/2015	PU	Web
A3	Final report on Heat Rejection Systems for solar cooling	12/2014	PU	Web
A4	Final report on Pumps Efficiency and Adaptability	01/2015	PU	Web
A6	Final report on State of the art on new collectors & characterization for solar cooling	01/2015	PU	Web
B1	Report on system/subsystem characterization & field performance assessment	07/2015	PU	Web
B2	Collection of good practice for DEC design and installation	06/2015	PU	Web
B3	Report on Life cycle analysis and LCA tool	09/2014	PU	Web
B4	Fast predesign software tool	09/2014	PU	Web

B6	Report for self-detection on monitoring procedure	04/2015	PU	Web
B7	Collection of criteria to quantify the quality and cost competitiveness for solar cooling systems	05/2015	PU	Web
C1	Review of relevant international standards rating and incentive schemes	01/2013	PU	Web
C2	Methodology for performance assessment, rating and benchmarking	07/2015	PU	Web
C3	Selection and standardization of best practice solutions	12/2015	PU	Print Wiley Book
C4	Final report Measurement and Verification Procedures	01/2013	PU	Web
C5	Report on Labeling possibilities for solar cooling	06/2015	PU	Web
C6	Final report on Contracting Models for Solar Thermally Driven Cooling and Heating Systems	09/2014	PU	Web
D1	Website	06/2012	PU	Web
D2	Best practice brochure	06/2015	PU	Web
D3	Simplified brochure for quality procedure methodology	07/2015	PU	Web
D4	Guidelines for Roadmap methodology	07/2015	PU	Web

Journal Articles, Conference Papers, Press Releases, etc.

Author(s)	Title	Publication / Conference (name of journal, newsletter, conference, etc.)	Bibliographic Reference (journal number, year, place, editor, etc.)
Mugnier, Jakob	Keeping cool with the sun	International Airport Review & International Sustainable Energy Review Issue 1 – Vol6., 2012	January 2012
Mugnier, Jakob	Status of Solar Cooling in the World	WILEY Interdisciplinary Review Energy & Environment	April 2014
Jakob	Solar Air Conditioning	REN21 Global Status Report 2014	June 2014

CONFERENCES AND WORKSHOPS

Task participants presented Task work and results at 25 conferences and workshops over the course of the Task.

Workshop/Conference	Place	Date
Common workshop with Task 44	Marseille (France)	October 2011
Press meeting point at ESTEC 2011	Marseille (Fraunce)	October 2011
4th OTTI conference on Solar Air conditioning	Larnaca (Cyprus)	October 2011
First IEA SHC Task 48 Training Seminar - AHR Fair	Chicago (USA)	January 2012
CMPP (Centre Marocain des Productions Propres) Conference	Casablanca (Morcco)	November 2011
1st Saudi Arabia Renewable Energy Conference and Exhibition	Dahran (Saudi Arabia)	February 2012
Workshop on solar cooling and Task 48 at INTERSOLAR EUROPE Conference	Munich (Germany)	June 2012
SHC 2012 Conference	San Francisco (USA)	July 2012
Informal Meeting at SHC conference	San Francisco (USA)	July 2012
Solar cooling at the Eurosun 2012 Conference	Rijeka (Croatia)	September 2012
Solar cooling at the Gleisdorf Solar Conference	Gleisdorf (Austria)	September 2012
Workshop Solar heating for air conditioning and industrial process heat at the Klimaenergy Fair -	Bolzano (Italy)	September 2012
7th International DERBI conference on Renewable Energy	Perpignan (France)	October 2012
Common internal Workshop with Task 45 & Task 49 on Large solar systems (district heating and cooling)	Graz (Austria)	September 2012
Workshop on solar cooling and Task 48 at the Australian Solar Cooling 2013 Conference	North Ryde (Australia)	April 2013
Solar cooling crash course at the Australian Solar Cooling 2013 Conference	North Ryde (Australia)	April 2013
SHC Task 48 Workshop “Technologies for solar cooling in tropical climates” & guided tour of world’s largest solar cooling System	Singapore (Singapore)	April 2013
5th Solar cooling OTTI conference	Bad Krozingen (Germany)	September 2013
Solar cooling at the SHC 2013 Conference	Freiburg (Germany)	September 2013
Potential of Solar Thermal Cooling Technology in USA	Bethpage (USA)	October 2013
Réunion des Compétences Américano-Marocaines	Rabat (Morocco)	June 2013
AIRAH’s first Solar Cooling Workshop	Brisbane (Australia)	March 2014
EUROSUN conference	Aix les Bains (France)	September 2014

SHC 2014 conference	Beijing (China)	October 2014
1st Solar cooling Chinese conference	Shanghai (China)	March 2015

TASK MEETINGS

Meeting #	Date	Location	Number of Participants
1	18 – 19 October 2011	Marseille (France)	28
2	27 - 28 March 2012	Milano (Italy)	38 (10*)
3	10 - 11 September 2012	Gleisdorf (Austria)	33
4	9 - 10 April 2013	Newcastle (Australia)	29 (20*)
5	30 September -1 October 2013	Freiburg (Germany)	30
6	8 - 9 May 2014	Kingston (Canada)	24 (14*)
7	28 - 29 September 2014	Garching (Germany)	22 (6*)
8	23 - 24 March 2015	Shanghai (China)	31 (7*)
-	24 - 25 September 2015	6th SAC OTTI Roma (Italy)	
-	2 - 4 December 2015	SHC 2015 Istanbul (Turkey)	

** Joined the meeting via videoconference*

SHC TASK 48 NATIONAL CONTACTS

Country	Name	Institution/Company	Email	Role
France	Mugnier	TECSOL SA	daniel.mugnier@tecsol.fr	OA
Germany	Jakob	Greenchiller	uli.jakob@greenchiller.de	Subtask D leader
Italy	Frazzica	CNR ITAE	andrea.frazzica@itae.cnr.it	National Expert
Italy	Vasta	CNR ITAE	salvatore.vasta@itae.cnr.it	National Expert
Italy	Calderoni	Polimi	marco.calderoni@polimi.it	Subtask A leader
Italy	Melograno	Polimi	patrizia.melograno@polimi.it	National Expert
Australia	White	CSIRO	stephen.d.white@csiro.au	Subtask C leader
Austria	Focke	ASIC	focke.hilbert@asic.at	National Expert
Austria	Neyer	UIBK	daniel.neyer@uibk.ac.at	National Expert
Germany	Morgenstern	Fraunhofer ISE	alexander.morgenstern@ise.fraunhofer.de	Subtask B leader
Italy	Beccali	DEIM	marco.beccali@dream.unipa.it	National Expert
Germany	Safarik	ILK Dresden	mathias.safarik@ilkdresden.de	National Expert
Austria	Schubert	S.O.L.I.D	m.schubert@solid.at	National Expert
Italy	Vittoriosi	EURAC research	alice.vittoriosi@eurac.edu	National Expert
USA	Nagidi	EMC Group	khalid.nagidi@energymcg.com	National Expert
Austria	Selke	AIT	tim.selke@ait.ac.at	National Expert
Germany	Pietruschka	zafh.net	dirk.pietruschka@hft-stuttgart.de	National Expert

Germany	Dalibard	zafh.net	antoine.dalibard@hft-stuttgart.de	National Expert
Australia	Sheldon	Coolgaia Pty Ltd	marc.sheldon@coolgaia.net	National Expert
Austria	Nocke	AEE Intec	b.nocke@AEE.at	National Expert
Italy	Fedrizzi	EURAC research	roberto.fedrizzi@eurac.edu	National Expert
Germany	Helm	ZAE Bayern	martin.helm@zae-bayern.de	National Expert
Germany	Riepl	ZAE Bayern	manuel.riepl@zae-bayern.de	National Expert
Italy	Longo	DEIM	sonialongo@dream.unipa.it	National Expert
China	Dai	SJTU	yjdai@sjtu.edu.cn	National Expert
Germany	Doll	Fraunhofer ISE	jochen.doell@ise.fraunhofer.de	National Expert
Germany	Schweigler	ZAE Bayern	schweigler.christian@zae-bayern.de	National Expert
France	Boudehenn	CEA INES	Francois.boudehenn@cea.fr	National Expert
Germany	Pollerberg	Fraunhofer Umsicht	Clemens.pollerberg@umsicht.faunhofer.de	National Expert
Germany	Zahler	Industrial Solar	Christian.zahler@industrial-solar.de	National Expert
Canada	Harisson	Kingston University	harisson@me.queensu.ca	National Expert
Australia	Rowe	CSIRO	Dan.row@csiro.au	National Expert
Austria	Thür	UIBK	alexander.thuer@uibk.ac.at	National Expert

Task 50

Advanced Lighting Solutions for Retrofitting Buildings

Jan de Boer
Fraunhofer Institute for Building Physics (IBP)
Operating Agent for Forschungzentrum Jülich GmbH

TASK DESCRIPTION

The scope of the Task was general lighting systems for indoor environments with a focus on lighting appliances in non-domestic buildings. Technically, the Task dealt with:

- daylight harvesting (i.e., replacement of electric light by better façade or roof lighting concepts),
- electric lighting schemes, and
- lighting control systems and strategies (daylight and occupancy dependent controls).

The overall objective of Task 50 was to accelerate retrofitting of daylighting and electric lighting solutions in the non-domestic sector using cost-effective, best practice approaches, which can be used on a wide range of typical existing buildings. The Task targeted building owners & investors, governments & authorities, designers & consultants, and industry by providing strategic, technical and economic information and with this helping these stakeholders overcome barriers in retrofitting of lighting installations.

The work in the Task was structured into four Subtasks and a Joint Working Group that was responsible for pulling together the results of all Subtasks' results.

Subtask A: Market and Policies
Lead country: Denmark

This Subtask identified the various possible approaches of retrofitting daylighting systems and lighting installations in buildings. It proposed to provide key figures concerning costs (Total Cost of Ownership) and identify barriers and opportunities concerning lighting retrofit actions. Beyond costs, barriers could be related to inertia of stakeholders, poor habits or lack of knowledge. Opportunities may go beyond reduction of costs, reduction of energy requirements and may relate to added benefits for investors, building owners, building managers and occupants.

Subtask A had four main objectives:

- To understand, and model, the financial and energy impact associated to retrofitting daylighting and electric lighting of buildings.
- To map the context of building-retrofit, identifying barriers and opportunities, even if they are not directly related to lighting issues.
- To provide a critical analysis of documents used for energy regulation and certification and to make proposals for adjustments.
- To identify possible lack of awareness and know-how in the value chain and to identify strategic information to deliver to stakeholders.

Subtask B: Daylighting and Electric Lighting Solutions
Lead country: Germany

This Subtask dealt with the quality assessment of existing and new solutions in the field of façade and daylighting technology, electric lighting and lighting controls. For replacement solutions, the Subtask will identify and structure existing and develop new lighting system technologies.

The objectives of Subtask B were:

- To provide a set of criteria to describe lighting technologies appropriate for the retrofit process.
- To provide figures as baseline to classify and rate existing, built-in lighting installations against new retrofit concepts.
- To generate a profound state of the art overview on technology and architectural measures.
- To generate an overview on emerging new technologies and develop selected new techniques.
- To generate required technical data of selected state of the art and emerging new technologies.
- To publish a source book.

Subtask C: Methods and Tools
Lead country: Switzerland

Whether an intended retrofit is technically, from an energy point of view, ecologically and economically meaningful is at the moment not self-evident for the majority of stakeholders and building designers. This Subtask focused on simple computer design tools and analysis methods in order to improve the understanding of retrofit processes. This incorporated energy and visual comfort analysis as well as the financial aspects of lighting retrofit solutions. Also encompassed were advanced and future calculation methods aiming toward the optimization of lighting solutions, as well as energy auditing and inspection procedures, including lighting and energy performance assessments.

The objectives of Subtask C were:

- To understand the workflows, wishes and needs with respect to tools of the stakeholders by conducting and evaluating a survey.
- To establish a list of tools and methods to assist practitioners and compare their outputs with the criteria and metrics identified in Subtasks B and D.
- To benchmark the appropriateness of tools on case studies/test cases.
- To develop a simple tool (calculation engine) for a holistic approach of potential benefits of lighting retrofit solutions to be among others to be included in the retrofit adviser.
- To investigate energy audit procedures.
- To establish a review of advanced simulations tools for promoting complex fenestration systems and electric lighting (such as LED).
- To list the feature of new simulation tools for different case studies and compare them to the existing tools, and ultimately give a feed-back to the tool developers. To advance tool development for special questions like façade design.

Subtask D: Case Studies
Lead country: Sweden

Case studies are essential to communicate lighting retrofit concepts to decision makers and designers. Therefore, the main aim of Subtask D was to demonstrate sound lighting retrofit solutions in a selection of representative, typical case studies.

The selection of case studies was based on a general building stock analysis, including the distribution of building typology in relation to lighting retrofit potential. These case studies have delivered proven and robust evidence of achievable savings and show integrated retrofit strategies. Measurements and assessments include monitoring of energy savings, lighting quality and operational costs. In addition, Subtask D also provided updated information from an analysis of previously documented case studies in the literature and on websites.

The objectives of Subtask D were:

- To define the building types and categories included in this Task.
- To identify the already existing databases of case studies.
- To update key information regarding energy saving strategies and solutions demonstrated in the past by research, monitoring or demonstration projects.
- To define an applicable standard assessment and monitoring procedure for all case studies to be investigated.
- To provide a robust analysis of the performed case and derive generalized conclusions.
- To produce a very well documented, e-book of case studies linked with the Lighting Retrofit Advisor.

Joint Working Group: Lighting Retrofit Adviser
Lead Country: Germany

All Subtasks provided major parts of their results as input to this joint activity. Based on these results, the Joint Working Group developed an electronic interactive sourcebook (Lighting Retrofit Adviser). A central database includes all Task results and allows the users to obtain extensive information, according to their individual focus of interest: design inspirations, design advice, decision tools and design tools. Thus, the user is able to increase quickly and reliably his knowledge in the respective field of interest. Users have the choice of analyzing retrofit (design) scenarios themself and/or using the pool of experience gained in the case studies projects (electronic version of case study book) to access information on energy saving potentials and economic approaches.

The objectives of the Joint Working Group were:

- To define a software architecture and design complying with needs of the stakeholders.
- To incorporate results of subtasks A-D.
- To ensure meeting the demands of the target groups.
- To generate a working software tool.
- To ensure a high quality of the tool and generate country specific versions.

Task Duration

This Task is now completed. The Task started **January 2013** and ended **December 2015.**

Participating Countries

Country	Number of Research Institutes	Number of Universities	Number of Companies
Austria	0	0	1
Belgium	1	1	0
Brazil	0	1	0
China	1	0	0
Denmark	1	1	0
Finland	0	1	0
Germany	2	2	1
Japan	0	2	0
Norway	0	1	0
Sweden	0	1	1
Slovakia	0	1	0
Switzerland	0	1	1
The Netherlands	0	0	1
TOTAL	5	12	5

WORK DURING 2015

Experience with the developed Monitoring Protocol: Lessons learned

A monitoring protocol applicable to non-residential buildings retrofitted with electric lighting and/or daylighting technologies was developed. The Monitoring protocol has been tested on a total of 25 non-residential buildings in ten countries during 2015. Different building types were considered: Industry, retail, office, housing, assembly, sport/recreation and education. During the usage experience with the monitoring protocol was made. The key lessons learned from the monitoring process are summarized below:

- Reducing energy use attributed to electric lighting was the main driver for the majority of the lighting retrofits monitored in this study.
- All retrofits monitored achieved improvements in either energy efficiency or lighting quality or both.
- The best overall results could be achieved when the focus was on an effective integration of energy performance, daylight and electric lighting.

Figure 1. Overview of the case studies.

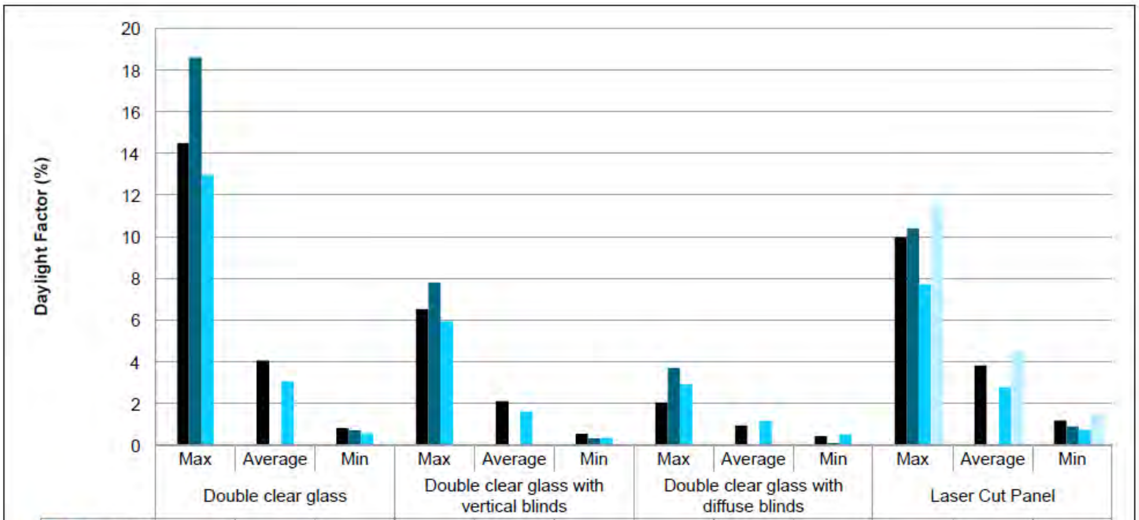
- Replacing older fluorescent with appropriate LED lighting systems can lead to substantial energy savings for electric lighting. Lighting quality and user satisfaction can also be improved at the same time by providing better visual conditions in the spaces. It is, however, not recommended to just replace fluorescent tubes with LED tubes in existing luminaires other than those with diffusing panels, as it can lead to inappropriate light distribution patterns and significantly lower illuminance levels at the work plane.
- Control systems for electric lighting or solar shading devices, are frequently found to be poorly implemented, calibrated or commissioned, or perhaps too complex, resulting in reduced energy savings, annoyance of users or even in complete deactivation of the control system. This highlights the need for better guidance on the installation, commissioning and operation of lighting control systems.

Advanced and Future Simulation Tools: Simulating Complex Fenestration Systems

To get an overview of the simulations tool that are available on the marked, advanced simulation tools for complex fenestration systems (CFS) and optical lighting fixtures for LED light sources were reviewed. The following tools were described:

- Dialux Evo
- Fener
- Geronimo
- Radiance
- Relux Pro

The tools were applied on an additional case study with a clear sky condition that was set up and evaluated in order to show the light redirection properties of the different CFS. For different systems the daylight factor was simulated and the results of the described simulation tools were compared. Only three were suitable to calculate the daylight factor. The outcome of the clear sky conditions and the previous outcome for the overcast sky conditions were included in the LRA.



	Double clear glass			Double clear glass with vertical blinds			Double clear glass with diffuse blinds			Laser Cut Panel		
	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min
Dialux EVO												
FENER	14.5	4.1	0.8	6.5	2.1	0.5	2.0	1.0	0.4	10.0	3.8	1.2
Geronimo	18.6		0.7	7.8		0.3	3.7		0.1	10.4		0.9
Radiance	13.0	3.0	0.6	6.0	1.6	0.4	2.9	1.2	0.5	7.7	2.8	0.7
ReluxPro										11.5	4.5	1.5

Figure 2. Comparison of the different available simulation tools.

Industry Involvement & Market Activities

In its third year, Task 50 has attracted huge interest in industry. The 6th industry workshop was organized during the meeting in Brazil. Several presentations were given and the Subtask Leaders and the Operating Agent presented the highlights of their work. The external presentations dealt with themes from the area of energy saving, glazing and experience with retrofitting in Brazil. The industry workshop gave the opportunity to show how the work of Task 50 mirrors the needs of the industry. The workshop was very well attended with altogether 190 participants.

Lighting Retrofit Advisor

Based on the earlier developed software architecture the different results of the subtasks and the further developed calculation components were integrated. The Lighting Retrofit Advisor (LRA) mainly consists of two parts: the Information part and the Calculation & Rating part. Regarding the Information part by now the technology viewer and the FAQ / Recommendation part are ready for beta test and first available case study data has been included. For the “stakeholder related introduction”, “collection of tools” and the “list of metrics” the relevant data was provided

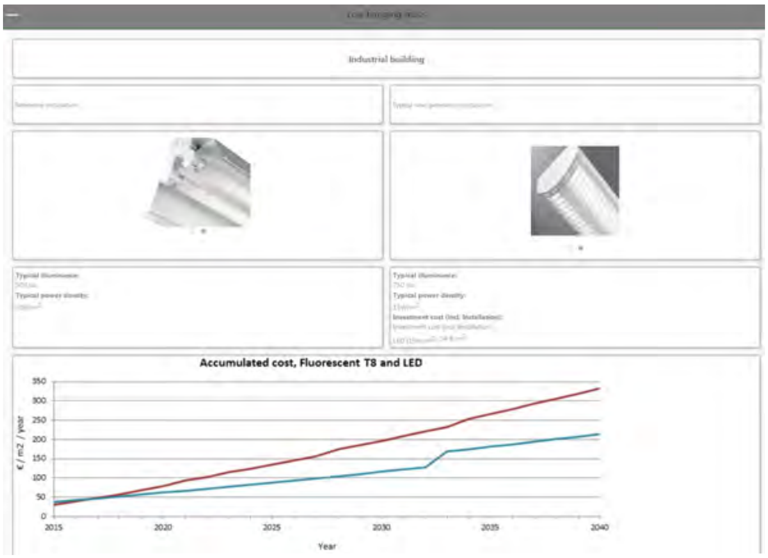


Figure 3. Screenshot of the Lighting Retrofit Advisor.

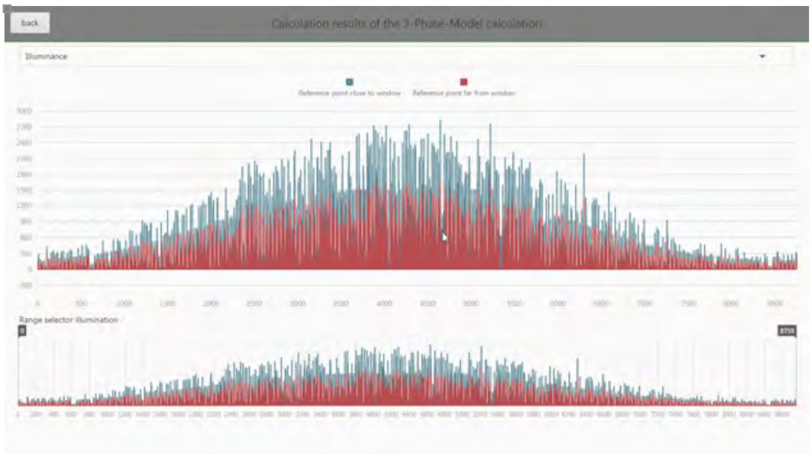


Figure 4. Screenshot of the Lighting Retrofit Advisor.

Within the calculation part the “LRA - CFS Express” 3 Phase Modell and the dynamic sky model was implemented. The layout including output graphics was designed and additional relevant façade systems were added. For the “LRA - In situ Optimizer” the energy and TCO calculation was finished. The LED data were updated and the Layout was designed. The Benchmarking and the Portfolio Analyze that are based on the baseline data were completed

WORK PLANNED FOR 2016

In early 2016 the following activities will be finalized:

- Source books and technical reports will be posted on the Task website.
- “Lighting retrofit Adviser” software will be released.

LINKS WITH INDUSTRY

Industry Workshops

Two Industry Workshops were held with active participation from (mostly) local industry, the first one on March 16, 2015 was at Hotel Brosundet in Ålesund, Norway, and the second on September 28, 2015 was at FINATEC – Universidade de Brasília in Brasília, Brazil. Around 50 architects, 10 engineering companies, 7 representatives from the façade industry and around 10 from lighting industry joined the workshops.

Industry Involvement

Philips Lighting is involved and actively participating in the Task's work as a Level II Partner. A representative from 'Philips Research' is joined the Experts Meetings.

PUBLICATIONS

Reports & Published Books

Report No.	Title	Publication Date (month, year)	Target Audience	Web or Print
Source Book	Source Book: Daylighting and electric lighting retrofit solutions	4/2016	All stakeholders involved in lighting retrofits	Web, Print TBD
A1	Global Economic Models	5/2016	Owners / Investors, Authorities, Designers / Consultants	Web
A2	Barriers and Benefits; Building energy regulation and certification	5/2016	Owners / Investors, Authorities, Designers / Consultants	Web
A3	Proposal of actions concerning the value chain	5/2016	Owners / Investors, Authorities, Designers / Consultants	Web
B1	Catalogue of Criteria	9/2015	Researchers Designers / Consultants	Web
C1	Lighting retrofit in current practice - Evaluation of an international survey	5/2016	Researchers Designers / Consultants, Industry, Lighting Software Companies	Web
C2	Methods and tools for lighting retrofits - State of the art review	5/2016	Designers / Consultants, Facility	Web

			Managers, Lighting Software Companies	
C4	Energy audit and inspection procedures	5/2016	Designers / Consultants, Facility Managers, Lighting Software Companies	Web
C5	Advanced and future simulation tools	5/2016	Designers / Consultants, Lighting Software Companies	Web
D1	Building Stock Distribution and Electricity Use for Lighting	5/2016	Researchers/ Authorities	Web
D2	Daylighting and lighting retrofit to reduce energy use in non-residential buildings: A literature review	5/2016	Researchers/ Authorities	Web
D3	Monitoring protocol for lighting and daylighting retrofits	5/2016	Researchers Faculty, Managers Authorities Consultants	Web
D5	Lessons learned from monitoring lighting and daylighting in retrofit projects	5/2016	All stakeholders involved in lighting retrofits	Web
Newsletter	Newsletter 1: Overview and first results	2/2015	All stakeholders involved in lighting retrofits.	Web
Newsletter	Newsletter 2: Main results	6/2016	All stakeholders involved in lighting retrofits.	Web

Journal Articles, Conference Papers, etc.

Author(s)	Title	Publication / Conference (name of journal, newsletter, conference, etc.)	Bibliographic Reference (journal number, year, place, editor, etc.)
Stanislav Darula, Miroslav Fabian	"Vplyv zasklenia na zníženie potreby elektrickej energie na osvetlenie" (Influence of glazing on the reduction of electric energy	Světlo	Světlo, 2013, vol. 16, no. 5, p. 38-41. ISSN 1212-0812

	demand for lighting)		
Stanislav Darula, Richard Kittler, Marta Malíková	EN criteria for evaluation of daylight in interiors	Advanced Materials Research	Advanced Materials Research, Vol. 899 (2014), pp 307-314 doi: 10.4028/www.scientific.net/AMR.899
Kondas Kristian, Darula Stanislav	Daylighting on the working plane in oriented attic rooms under overcast and clear sky	SSP - Journal of Civil Engineering	SSP - Journal of Civil Engineering, Vol. 9, Issue 1, 2014, p. 33-40
Stanislav Darula, Marta Malíková	Investigation of Useful Daylighting during a Day	Advanced Materials Research	Advanced Materials Research Vol. 1041 (2014) pp 381-385
Marie-Claude Dubois, Niko Genitle, Fabio Bisegna, Martine Knoop, Barbara Matusiak, Eino Tetri	Retrofitting the electric lighting and daylighting systems to reduce energy use in buildings: a literature review.	Energy Research Journal	Retrofitting the Electric Lighting and Daylighting Systems to Reduce Energy Use in Buildings: A Literature Review. Energy Research Journal, 6(1), 25.
Niko Gentile, Marie-Claude Dubois, Werner Osterhaus, Sophie Stoffer, Cláudia Naves David Amorim, David Geisler-Moroder, Anna Hoier, Roman Jakobiak	Monitoring protocol to assess the overall performance of lighting and daylighting retrofit projects	Energy Procedia	Monitoring Protocol to Assess the Overall Performance of Lighting and Daylighting Retrofit Projects. Energy Procedia, 78, 2681-2686.
Cláudia Amorim	Eficiência Energética em Edificações Públicas: problemática e estratégias	II Seminário de Planejamento Estratégico Sustentável do Poder Judiciário	
Cláudia Amorim, Julia Fernandes, Márcia Birck, Marina Oliveira, Marina Rebelo	Monitoramento do ambiente luminoso e satisfação do usuário: estudo de caso do Ministério do Meio Ambiente (MMA)	ENCAC – XIII Encontro Nacional e IV Latino Americano de Conforto no Ambiente Construído	
Marie-Claude Dubois, Niko Gentile, Cláudia Amorim, Werner Osterhaus, Sophie Stoffer, Roman Jakobiak, David Geisler-Moroder, Barbara Matusiak, , Fredrik Martens Onarheim, Eino Tetri.	Performance evaluation of lighting and daylighting retrofits: results from IEA SHC Task 50.	Energy Procedia (in print) (presented at SHC 2015 conference, Istanbul, Turkey)	
Niko Gentile, Marie-Claude Dubois, Werner Osterhaus, Sophie Stoffer, Cláudia Naves David Amorim, David Geisler-Moroder, Roman Jakobiak	A toolbox to evaluate non-residential lighting and daylighting retrofit in practice	"Energy & Buildings" for special edition upon request	A toolbox to evaluate non-residential lighting and daylighting retrofit in practice. Energy and Buildings, 123, 151-161.
Darula, Stanislav , Malíková Marta	Obnova osvetlenia v budovách – aplikácia LRA (Lighting retrofit in buildings - LRA application)	Svetlo, 2016 (in print)	

Software

Author(s)/ Editor	Title	Release Date (month, year)	Target Audience	Web
Simon Wössner, Jan de Boer, all experts	LRA (Lighting Retrofit Advisor)	Software (5/2016)	All stakeholders involved in lighting retrofits.	Web and Apps for IOS; Android, Windows mobile

TASK MEETINGS

An Industry Workshop was always held in conjunction with the Task meetings.

Meeting #	Date	Location	Number of Participants (Number of Countries)
Task meeting 1	19-22 March 2013	Lund, Sweden	22 (9)
Industry Workshop 1	20 March 2013	Lund, Sweden	50
Task meeting 2	23-25 September 2013	Copenhagen/Denmark	25 (11)
Industry Workshop 2	23 September 2013	Copenhagen/Denmark	30
Task meeting 3	10-12 March 2014	Aldrans/Innsbruck, Austria	32 (13)
Industry Workshop 3	10 March 2014	Aldrans, Austria	50
Task meeting 4	29 September – 1 October 2014	Fukuoka, Japan	21 (10)
Industry Workshop 4	29 September 2014	Fukuoka, Japan	35
Task meeting 5	16-19 March 2015	Hurtigruten, Norway,	25 (9)
Industry Workshop 5	16 March 2015	Ålesund, Norway,	30
Task meeting 6	27-30 September 2015	Brasilia/Brazil	20 (10)
Industry Workshop 6	28 September	Brasilia/Brazil	190

SHC TASK 50 NATIONAL CONTACTS

Country	Name	Institution/Company	Email	Role
Austria	Wilfried Pohl	Bartenbach GmbH	wilfried.pohl@bartenbach.com	National Expert
	David Geisler-Moroder		David.Geisler-Moroder@bartenbach.com	National Expert
Belgium	Arnaud Deneyer	Belgian Building Research Institute (BBRI)	arnaud.deneyer@bbri.be	National Expert
	Magali Bodart	Université Catholique de Louvain	magali.bodart@uclouvain.be	National Expert
Brazil	Prof. Cláudia Naves David Amorim	University of Brasilia	clamorim@unb.br (navesamorim@gmail.com)	National Expert
China	Luo Tao	China Academy of Building Research	daylighting@126.com	National Expert
Denmark	Prof. Werner Osterhaus	Aarhus University, Department of Engineering	werner.osterhaus@eng.au.dk	National Expert
	Sophie Stoffer		sophie.stoffer@eng.au.dk	National Expert
	Kjeld Johnsen	Danish Building Research Institute (SBi)	kjj@sbi.aau.dk	National Expert
	Prof. Marc Fontoynont		mfo@sbi.aau.dk	Subtask A Leader
Finland	Eino Tetri	Aalto University	eino.tetri@aalto.fi	National Expert
Germany	Jan de Boer	Fraunhofer Institute for Building Physics IBP	jan.deboer@ibp.fraunhofer.de	OA
	Berat Aktuna		berat.aktuna@ibp.fraunhofer.de	National Expert
	Anna Hoier		anna.hoier@ibp.fraunhofer.de	National Expert
	Simon Woessner		simon.woessner@ibp.fraunhofer.de	National Expert
	Carolin Hubschneider		carolin.hubschneider@ibp.fraunhofer.de	National Expert
	Bruno Bueno	Fraunhofer Institute for Solar Energy Systems ISE	bruno.bueno@ise.fraunhofer.de	National Expert
	Michael Bossert	University of Applied Science HFT	michael.bossert@hft-stuttgart.de	National Expert
	Roman Jakobiak	daylighting.de	roman.jakobiak@daylighting.de	National Expert
	Aicha Diakite	Technische Universität Berlin	aicha.diakite@tu-berlin.de	National Expert
	Martine Knoop		martine.knoop@tu-berlin.de	Subtask B

				Leader
	Patrick Prella		patrick.prella@tu-berlin.de	National Expert
Italy	Anna Pellegrino	Politechnico di Torino, Dipartimento di Energetica, Facolta di Architettura	anna.pellegrino@polito.it	National Expert
	Fabio Bisegna	Università degli Studi di Roma "La Sapienza"	fabio.bisegna@uniroma1.it	National Expert
	Michele Zinzi	ENEA - UTEE ERT	michele.zinzi@enea.it	National Expert
Japan	Yasuko Koga	Kyushu University, Fac. of Human-Environment Studies	koga@arch.kyushu-u.ac.jp	National Expert
Norway	Barbara Matusiak	Norwegian University of Science and Technology NTNU	barbara.matusiak@ntnu.no	National Expert
	Fredrik Martens Onarheim		fredrik.martens@gmail.com	National Expert
	Michael Gruner		michael.gruner@ntnu.no	National Expert
Slovakia	Stanislav Darula	Institute of Construction and Architecture, Slovak Academy of Sciences	Stanislav.Darula@savba.sk	National Expert
Sweden	Marie-Claude Dubois	Lund University	marie-claude.dubois@ebd.lth.se	Subtask D Leader
	Niko Gentile		niko.gentile@ebd.lth.se	National Expert
	Johan Röklander	WSP Sweden / WSP Ljusdesign	johan.roklander@wspgroup.se	National Expert
Switzerland	Jérôme Kaempf	kaemco LLC (prev. at LESO-PB/EPFL)	jk@kaemco.ch	Subtask C Leader
	Bernard Paule	Estia SA	paule@estia.ch	Subtask C Leader
	Andre Kostro	École Polytechnique Fédérale de Lausanne (EPFL)	andre.kostro@epfl.ch	National Expert
	Marilyne Andersen		marilyne.andersen@epfl.ch	National Expert
	Jan Wienold		jan.wienold@epfl.ch	National Expert
Netherlands	Peter Fuhrmann	Lighting Control Systems Group, Philips Research	peter.fuhrmann@philips.com	National Expert

Task 46

Solar Resource Assessment and Forecasting

Dave Renné
Senior Consultant, Clean Power Research
Operating Agent

TASK DESCRIPTION

Task 46: Solar Resource Assessment and Forecasting provides the solar energy industry, the electricity sector, governments, and renewable energy organizations and institutions with the means to understand the “bankability” of data sets provided by public and private sectors. A major component of the task is to provide this sector with information on how accurately solar resources can be forecast in the near future (sub-hourly, 1-6-hour, and 1-3-days time horizons) so that utilities can plan for the operation of large-scale solar systems operating within their systems. Another major component of the task is understanding short-term (1-minute or less) resource variability associated with cloud passages that cause power “ramps”, an important concern of utility operators with large penetrations of solar technologies in their system. Although solar heating and cooling technologies are not, in themselves, “grid-tied” systems, the use of these technologies also impacts grid operations since they offset the use of conventional fuels or electricity, thereby impacting the electricity load profile.

Objectives

Task 46 establishes four basic objectives in improving our understanding of solar resources, which are to: 1) evaluate solar resource variability that impacts large penetrations of solar technologies; 2) develop standardized and integrating procedures for data bankability; 3) improve procedures for short-term solar resource forecasting, and 4) advance solar resource modeling procedures based on physical principles to provide improved evaluation of large-scale solar systems using both thermal as well as PV technologies. Achieving these objectives will reduce the cost of planning and deploying solar energy systems, improve efficiency of solar energy systems through more accurate and complete solar resource information, and increase the value of the solar energy produced by solar technologies.

Scope

By addressing the four objectives listed above, Task 46 will provide research reports, summary articles, and best practices manuals addressing resource variability that impacts grid operations, data collection and processing procedures, solar resource model and solar forecasting validation results, and approaches for improving model performance.

The audience for the results of the Task includes, data users, such as energy planners, solar project developers, architects, engineers, energy consultants, product manufacturers, and building and system owners and managers, and utility organizations, Another key audience is the scientific and research community that develops the methodologies involved in this Task. These audiences will be kept informed through targeted reports, presentations, workshops and journal articles. Key results of this task will be posted to the IEA-SHC Task 46 Publications web site.

Task 46 is organized into four Subtasks.

Subtask A: Solar Resource Applications for High Penetrations of Solar Technologies
(Lead Country: United States)

This Subtask develops the necessary data sets to allow system planners and utility operators to understand short-term resource variability characteristics, in particular up and down ramp rates, to better manage large penetrations of solar technologies in the grid system. Although this work is primarily focused toward PV systems, which react almost instantaneously to cloud passages over individual panels, the information is also useful for solar thermal and CSP systems where intermittency due to variable solar resources can impact their ability to meet load demands. Subtask A consists of three main activities:

- Short-Term Variability (lead: Uni-Agder/Norway). This activity is concerned with the spatial and temporal characterization of high frequency intermittency (15 minutes or less) and ramp rates, and how this variability may impact he operation of solar technologies and their deployment on local power grids.
- Integration of solar with other RE technologies (lead: CENER/Spain). This activity is concerned with hybrid power generation involving solar and other renewable technologies (e.g., wind, biomass). Hybrid generation has pertinence to various scales from remotely operating hybrid installations, to autonomous and/or interconnected microgrids and larger scales, The focus of this activity is on weather data and irradiance data requirements to address such questions and will initially focus on smaller scale issues – autonomous hybrid systems.
- Spatial and Temporal Balancing Studies of the Solar and Wind Energy Resource (lead: Uni-Jaén/Spain). This Activity is concerned with the analysis and modeling of solar and renewable resource data to address: 1) the spatial balancing of the solar resource (based on technologies using both Global Horizontal Irradiance, or GHI, and Direct Normal Irradiance, or DNI, solar resources) across various distance scales; 2) the spatial and temporal balancing of both the solar and wind resources across various distance scales, and 3) the determination of the requirements for, and the eventual improvement of solar radiation forecasting associated with this balancing.

Subtask B: Standardization and Integration Procedures for Data Bankability
(Lead: Spain)

This Subtask addresses data quality and bankability issues related to both measurement practices and use of modeled data. Subtask activities are:

- Measurement best practices (lead: DLR/Spain, Almería/PSA): Manuals on best practices for obtaining measured irradiance data sets that provide bankable data for financial institutions will be prepared. The standardization and characterization of commonly used instruments as the Rotating Shadowband Irradiometers (RSIs) is directly connected to this objective.

- Gap Filling, QC, Flagging, Data Formatting (lead: MINES ParisTech/France). This activity documents best practices in filling missing data gaps, conducting data quality control, and flagging potentially erroneous data values when creating an archive of a database.
- Merging Ground and Modeled Data Sources (lead: CIEMAT/Spain): This activity explores procedures of combining different data sets, such as short-term ground measurements with long term satellite derived data, for extrapolating quality ground data to longer term climatic data sets, allowing for long-term cash flow analyses of projects.
- Uncertainty of model-derived historic solar radiation data (lead: Suntrace/Germany). This activity documents the importance of data uncertainty for data sets representing various time frames in ways that the risk in financing a project can be quantified.
- Evaluation of meteorological products with focus on Typical Meteorological Year and Time Series (lead: DMI/DTU, Denmark). In this activity the historical use of TMY data will be evaluated in the context of current best practices for simulating solar system design and output. Recommendations for alternative approaches to TMY data will be made, given that TMY data sets do not allow for evaluation of extreme high- and low-resource events.

Subtask C: Solar Irradiance Forecasting

(Lead: Germany)

Solar irradiance forecasting provides the basis for energy management and operations strategies for many solar energy applications. Depending on the application and its corresponding time scales different forecasting approaches are appropriate. In this subtask forecasting methods covering timescale from several minutes up to seven days ahead are developed, tested and compared in benchmarking studies. The use of solar irradiance forecasting approaches in different fields is being investigated, including PV and CSP power forecasting for plant operators and utility companies as also irradiance forecasting for heating and cooling of buildings or districts. Subtask activities are:

- Short-term forecasting (up to 7 days ahead) (co-leads: University Oldenburg, Germany; SUNY Albany, USA). The development and improvement of methods to forecast GHI and DNI is a major subject of this activity. Different forecast horizons, ranging from minutes up to several days ahead are addressed using specific methodology and data. Different forecasting approaches, characterized by the used data sources, corresponding methods and time scales, are being investigated. This activity, also addresses the comparison of these approaches in benchmarking studies focusing on different models, time scales or forecast parameters.
- Integration of solar forecasts into operations (lead: irSOLaV, Spain). This activity examines the important issue of how solar forecasts are used for different applications, including utility operations, management of PV or CSP power plants, and thermal management of buildings. A critical aspect of this

task is to seek input from users, for example, utility operators on the specific types of irradiance or power output forecasts they need in order to improve system operations and reduce the overall cost of energy and maximize the use of renewable energy within the system.

Subtask D: Advanced Resource Modeling
(Lead: MINES ParisTech, France)

Task 46 participants have identified new solar resource methodologies and improvements to existing methodologies, driven by specific information requests from energy developers and planners. They include new data sets required for the control and heating and cooling in buildings, solar resource forecasting for CSP plant operations, and the impact of climate change on solar resources, both from an historical perspective as well as estimates of future impacts. Some of these needs are being investigated in Subtask D, including:

- Improvements to existing solar radiation retrieval methods (lead: Uni-Jaén/Spain). The objective of this activity is to consider state-of-the-art and new solar radiation modeling approaches or other sources for input parameters to improve the accuracy and/or to increase the spatial, spectral and angular resolutions of solar resource data sets derived from satellite and Numerical Weather Prediction (NWP) models. An overview of the different advanced available satellite or NWP-derived solar radiation methodologies will be given as well the corresponding requirements of their input parameters. This activity will also evaluate the latest products coming out of the U.S. National Oceanic and Atmospheric Administration, such as the GOES Surface Irradiance Product, which offers a promising solution for providing near real-time irradiance values throughout the western hemisphere at 4-km resolution.
- Long term analysis and forecasting of solar resource trends and variability (co-leads: NASA-LaRC/USA; Meteotest/Switzerland). In this activity, studies of long-term solar data sets, both observed as well as satellite derived, are assessing episodes of "global dimming" and "global brightening", important for evaluating potential long-term cash flow implications from solar systems. The uncertainties of the variability are characterized from large continental to regional scales. Efforts are being undertaken to link the results of IPCC climate change scenarios to predictions of future solar resource variations.

Task Duration

The Task began July 2011 and will end December 2016.

This is a collaborative Task with the SolarPACES Implementing Agreement (where this Task is referred to as Task V), and the Photovoltaic Power Systems (PVPS) Implementing Agreement's Task 14 High Penetration of PV Systems in Electricity Grids.

Participating Countries

Australia, Austria, Canada, Denmark, France, Germany, Netherlands, Singapore, Spain, Switzerland, and the United Kingdom. The United States has withdrawn its participation in the IEA SHC thus requiring U.S. participants to serve on Task 46 as guests. Other countries, such as Slovakia, Norway, Chile, Greece, and the UAE are participating as guests.

ACTIVITIES DURING 2015

Overall Task Activities

Task 46 produced its main Interim Deliverable in early 2015. The deliverable, titled "Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications was prepared by NREL with contributions from a number of Task participants. The report is an update to NREL's original Best Practices Manual. This report also serves as the final deliverable to Task 36. The report can be found at http://www.nrel.gov/docs/fy15osti/63112.pdf.

The 6th Task Experts Meeting was held a Plataforma Solar Almería in Spain on 27-28 January, and the 7th Task 46 Experts Meeting was held at the offices of Meteotest in Bern, Switzerland on 22-24 September. About 30-35 task members participated in each meeting, including guests from Chile, Greece and the United Arab Emirates. In both meetings progress on Task Activities were reviewed, and approaches to completing the Task final deliverable were discussed. In addition, a preliminary Task Definition Workshop was undertaken on the third day of the Bern meeting, with a proposal to present the proposed new task to the IEA PVPS for their consideration.

Subtask A: Solar Resource Applications for High Penetration of Solar Technologies

Work on this Subtask was completed in 2014. A summary of outcomes was provided in the IEA SHC Task 46 Annual Report for 2014. A draft review paper on the spatial and temporal variability of solar resources was developed at the completion of this task and is available at http://asrc.albany.edu/people/faculty/perez/2015/SEVAR.pdf

Subtask B: Standardization and Integration Procedures for Data Bankability

B1. Measurement Best Practices (DLR/Spain)

In subtask B, Activity B1 an updated version of the IEA RSI specific best practices handbook has been published (Wilbert et al, 2015). A paper on the measurement of extinction between heliostat and receiver has been published (Hanrieder et al., 2015). Furthermore, a presentation on modeling of extinction in tower plants based on clear sky DNI data has been given (Hanrieder et al., 2015b).

Activity B1 participating experts have investigated the uncertainty of RSIs and Si pyranometers (Wilbert et al., 2015b). Average standard uncertainties for corrected 10 min data of 2% for GHI, and 2.9% for DNI (for GHI and DNI over 300 W/m²) were found for the 2012 dataset at the Plataforma Solar de Almeria when separate GHI and DHI calibration constants were used. The study defines a method for the derivation of the spectral error and spectral uncertainties and presents quantitative values of the spectral and overall uncertainties. Spectral uncertainties and cosine errors are important uncertainty contributions. Correction functions showed to reduce the uncertainty noticeably. An example for the daily variation of uncertainty can be seen in Figure B1.

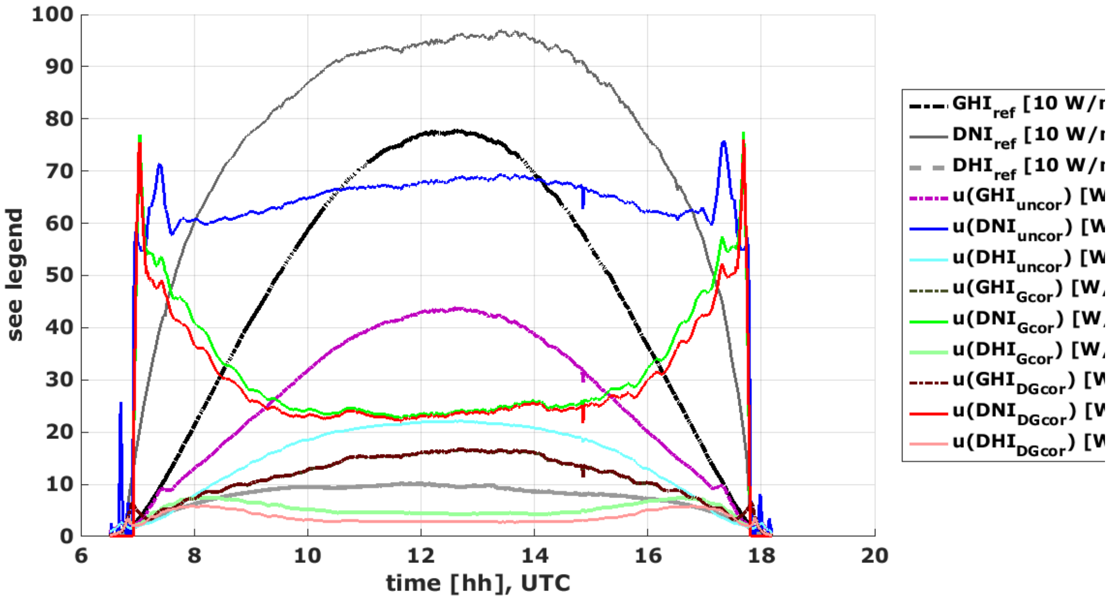


Figure B1. Standard uncertainties of an RSI's GHI, DHI and DNI in 1min resolution with different calibration and correction options for a clear sky day (March 1st 2012; u (GHI_{uncor}), u (DHI_{uncor}) for uncorrected data; index "Gcor" for corrected data with GHI calibration; index "DGcalcor" for corrected data and DHI calibration).

B2. Gap Filling, QC, Flagging, Data Formatting (MINES ParisTech/France)

A detailed description of a recommended data format for site-specific time series has been prepared. The format is an update of the MESOR (Modeling and Exploitation of SOlar Resources) format. The MESOR2 format is described in more detail in order to avoid the coexistence of different dialects of the MESOR2 format. Also more options are contained to include flags and quality control results. A better readability for FORTRAN and the application for forecasted and TMY (Typical Meteorological Year) data is now included.

B3. Integration of data sources (CIEMAT/Spain)

Ciemat organized a webinar on integration of ground measurements in model-derived data in July 2015 with the attendance of around 15 experts. The discussions and conclusions from the webinar were included in the deliverable planned for this activity. As a consequence, the final report on Integration of ground measurements in model-derived data has been recently published and can be downloaded from the task web site (http://task46.iea-shc.org/).

B5.Evaluation of meteorological products with focus on Typical Meteorological Year and Time Series (DMI/DTU, Denmark)

A review of the current methods for making TMY and Reference Year data sets is being made. The current methodologies diverge. The general purpose TMYs that are widely used for solar heating and cooling and building energy simulations are no longer considered the best choice for specific solar technologies. Thus, for Concentrating Solar Power, or Solar Thermal Electric (CSP/STE) a standard for generating yearly datasets weighted with the direct normal irradiance is prepared in IEC TC 117. A first committee draft has been discussed and last open questions could be resolved in a meeting by the IEC TC117 core team and expert guests from SHC task 46 at the SolarPACES conference. The draft will be submitted officially soon.

In the newly started SolarPACES *BeyondTMY* project, several of the task experts are participating in a collaborative effort of making guidelines for the preparation of meteorological datasets for CSP/STE simulations that addresses issues such as: Non-Gaussian annual distributions, accounting for data uncertainty, major volcanic impacts, long-term trends and synthetic generation of data sets with high temporal resolution from low resolution data sets. These topics are generally important for how to generate bankable meteorological data such as P90. BeyondTMY is made within the SolarPACES Task V framework.

Subtask C: Solar Irradiance Forecasting

Task members involved in irradiance forecasting have been continuously working on further development of forecasting algorithms for both GHI and DNI. Another focus of C1 activity is the comparison of different forecasting approaches (benchmarking studies). Deliverable C1.2 “Conference and journal article on benchmarking of NWP model irradiance forecasts for central and northern Europe” has been completed. Forecast data for Deliverables C1.1 and C1.4 have been prepared for exchange among partners and first validation results are available.

Activity C1. Short-term Forecasting (up to 7-days ahead)

Research on different algorithms to forecast solar radiation is a major subject of Activity C1.

C1.1. Time series models based on ground-measured irradiance data

The University of South Australia, forecasting as well as PIMENT (U. of La Reunion), are continuing work on time-series. Presently, the University of South Australia is developing the combination of systematic and stochastic variance models for probabilistic forecasting of solar radiation. Fig C1 gives an example of preliminary results for a one-hour ahead forecast confidence intervals.

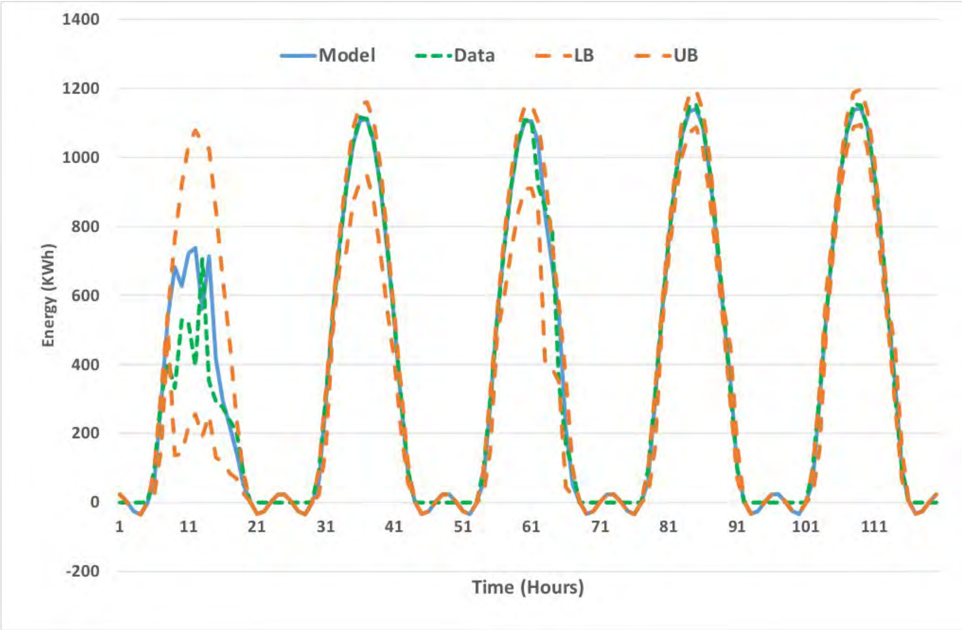


Figure C1. Example time series of measured (green) and forecast (blue) data with confidence intervals (upper bound UB and lower bound LB, orange) for one-hour ahead forecasts.

C1.2. Total sky imagers

Solar forecasting with sky imagers has been a focus of the last IEA SHC Task 46 expert's meeting in Bern with presentations by University of California San Diego (UCSD), U of Oldenburg, DLR and Meteotest. UCSD has investigated the impact of high PV penetration using solar resource assessment with sky imager and distribution system simulations (Nguyen et al. 2015) and a sky camera geometric calibration using solar observations (Urquhart et al. 2015). They have proposed a new method to estimate cloud optical depth by coupling sky images with three-dimensional radiative transfer models (Mejia et al 2015) and a new approach for cloud base estimation (Guang et al 2015). U of Oldenburg has presented an evaluation of the spatial-temporal performance of sky imager based solar irradiance analysis and forecasts for a dense network of irradiance sensors located in area of 10 km x 12km (Schmidt et al. 2015). Meteotest tested their concept for the development of a Meteotest sky camera.

DLR has presented requirements for nowcasting systems that can be applied for concentrating solar technologies (Hirsch et al. 2015). The application of voxel carving to derive 3D cloud coordinates from four all sky imagers were published by Prahl et al, 2015 and Oberländer et al., 2015. The voxel carving compares the viewing cones of the four cameras to derive the volume elements in which a cloud could have been present. The voxel carving results were validated in terms of derived shadow patterns with shadows determined from photos of the ground that were taken from the solar tower CESA 1 at the Plataforma Solar de Almeria (Fig. C2). Voxel carving has shown to be a possible approach to derive 3D cloud coordinates.

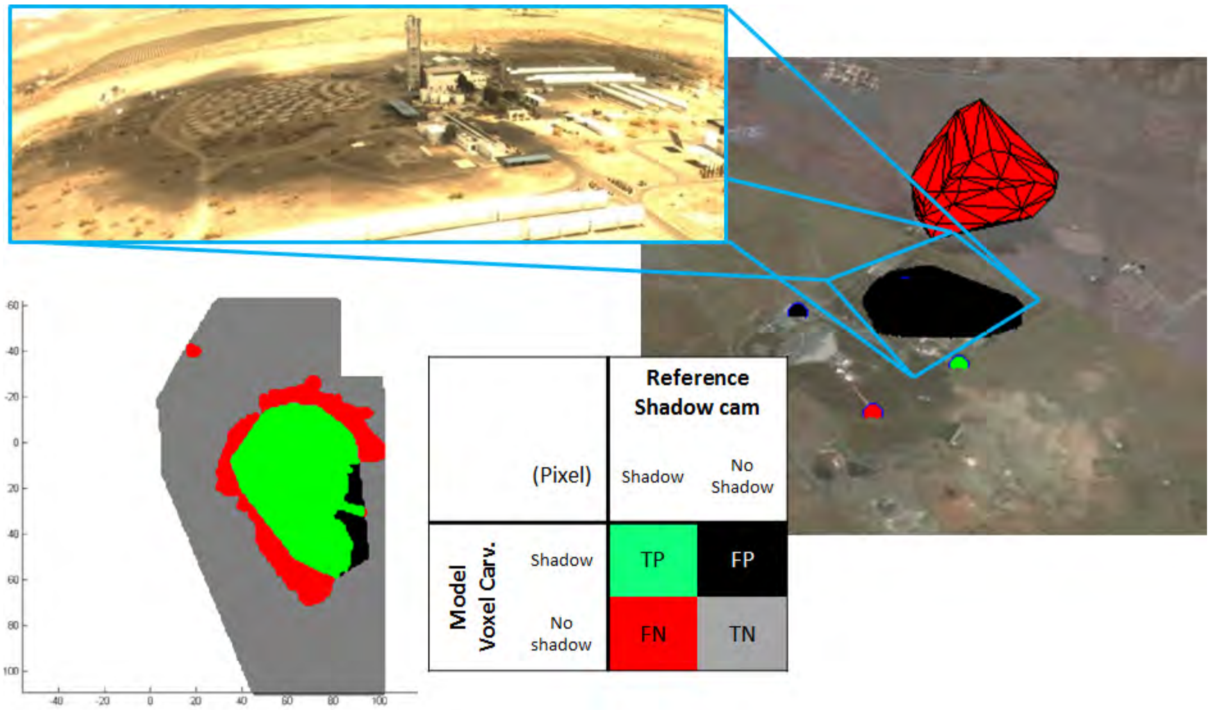


Figure C2. Comparison of cloud shadow derived from four all sky imagers (right) and "shadow-cameras" (left) (Oberländer et al., 2015).

C1.3. Motion vectors from satellite data

U of Oldenburg, Meteotest and Reuniwatt are continuously working on evaluation and further development of their cloud motion vector (CMV) forecasting algorithm based on Meteosat Second Generation (MSG) satellite images. Forecasts produced with their different methods are included in the benchmarking exercise.

The MATRAS group of the University of Jaén (Spain) has proposed and evaluated a hybrid method for short-term GHI and DNI forecasting (Quesada-Ruiz et al., 2015). The method makes use of wind forecast derived from the Weather Research and Forecasting (WRF) Numerical Weather Prediction (NWP) model for the advection of MSG derived cloud index estimates. Cloud Base Heights (CBH), derived from a ceilometer, are used for this purpose. Finally, the solar radiation forecasts were derived based on a clear-sky model and the corresponding advected cloud index. In this way, GHI and DNI forecasts out to a 6-hour time horizon, with a time step of 15 minutes, were obtained. The proposed hybrid model was tested against a smart persistence model as well as a CMV-based model and the WRF model solar radiation forecasts for a set of 24 days of mostly broken cloud conditions. Evaluation results showed a considerable dependence on the variable (GHI vs. DNI) and the sky conditions. While for the GHI the best performing model was the WRF, for the DNI the proposed hybrid model showed a superior performance. In particular, a relative improvement in the Root Mean Square Error (RMSE) values of about 20% was attained compared to the CMV-based method.

Figure C3 shows the skill of the proposed model (WRF-Advection) against the persistence model, in terms of the RMSE. Also the skill of the reference cloud motion-based model (CMV) is presented as well as the skill of the WRF model itself (WRF-Radon). The skill is presented both for GHI and DNI as a function of the forecasting horizon. Evaluation was conducted for 22 days of broken-cloud conditions, using radiometric data collected at the University of Jaén Meteo Station.

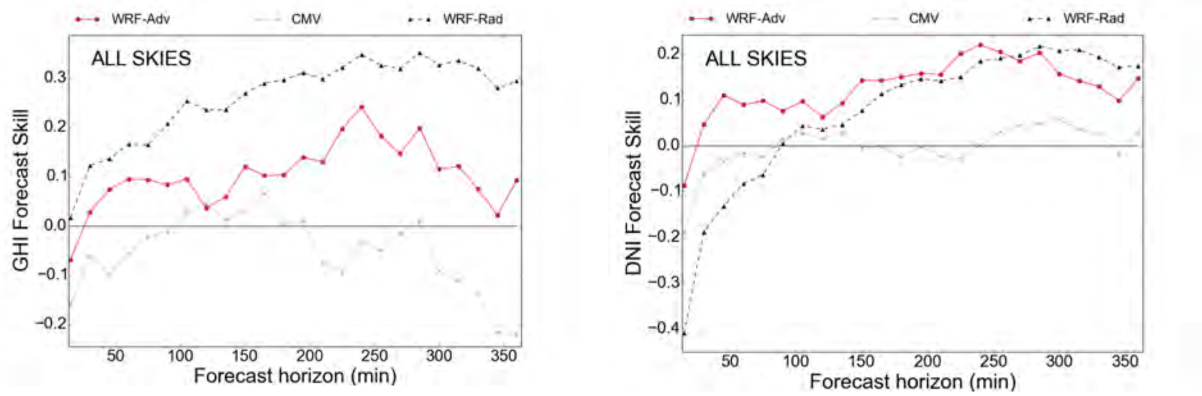


Figure C3: Forecast skill of different forecasting methods for GHI (left) and DNI (right) (Quesada-Ruiz et al., 2015).

C1.4 NWP forecasts models

UCSD is investigating coastal stratocumulus forecast with WRF. In particular, they presented a method processing WRF initial conditions (Yang and Kleissl, 2015). DMI is running the mesoscale model HIRLAM SKA and a rapid updated cycle model RADAR RUC, which are both included in deliverable C1.2. They presented a detailed analysis of the shortwave irradiances from the mesoscale model HARMONIE (Gleeson et al., 2015).

C1.5. Statistical models integrating different data sources

U of Oldenburg is continuing research on the use of machine learning methods (support vector regression SVR) for improving solar power predictions by integrating different data sources. PIMENT is working on different statistical methods to improve the numerical weather predictions for La Reunion.

C1.6. Benchmarking studies

Deliverable C1.2 “Conference and journal article on benchmarking of NWP model irradiance forecasts for central and northern Europe” was completed. Results were presented at ICEM 2015 (Lorenz et al., 2015a) and at the EUPVSEC 2015 as a plenary presentation (Lorenz et al., 2015b). We compare solar global horizontal irradiance forecasts based on numerical weather predictions for a variety of different models. These include direct model output of several numerical weather prediction models, a rapid update cycle model assimilating satellite derived cloud products as well as radar data, the multi model ensemble prediction system GLAMEPS, and two

MOS systems. In order to allow for a transparent and comparable analysis of the different methods we have set up a joint, consistent framework of evaluation. As a basis for the comparisons we have compiled a common data set of hourly measured solar irradiance values for Denmark, Germany, and Switzerland. Local and regional forecasts are analyzed with respect to different properties. In particular we show that spatial and temporal averaging effects have a strong impact on the RMSE when comparing solar irradiance forecasts from NWP models with different output resolutions. Furthermore we investigate a new approach to evaluate the model's ability to represent and forecast solar irradiance and cloud variability. The benefit of high-resolution mesoscale models in this respect is demonstrated. Fig. C1.4 shows a comparison of different forecast models for single site predictions (left) as well as regional forecasts (right).

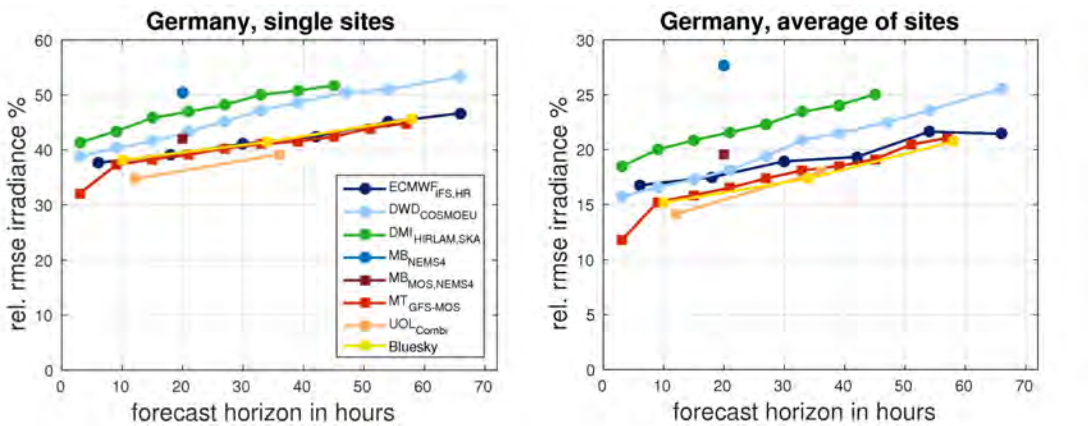


Figure C4: Forecast error (relative RMSE) in dependence of forecast horizons for single site predictions (left) and regional forecasts (right).

Forecast data for Deliverables C1.1 and C1.4 have been prepared for exchange among partners. The first validation results were presented at the 8th Task Experts meeting in Bern. Additionally CENER presented a new dissimilarity measure, the "Temporal Distortion Index" (TDI), and its use in a bi-dimensional forecast analysis.

Activity C2. Integration of Solar Forecasts into Operations

The Austrian Solar Innovation Center (ASiC) presented a project about electric storage management (Estore-M) using solar forecasts. The aim of this project is to develop an adaptive scheduling controller, which integrates user input, weather- and load forecasts as well as robustness against uncertainties. In a case study it was shown that forecasts can contribute to reduced curtailment of PV Power.

DLR has worked on a needs and requirements analysis for the CST industry sectors in the framework of the project DNIcast. Results where published in three reports:

- Technical report on the functional requirements for the nowcasting method (http://www.dnicast-project.net/documents/DNICast_Deliverable2

1_final 20140313.pdf)

- Workshop report for the 1st workshop (http://www.dnicast-project.net/documents/D5.1%20Workshop%20report%20for%20the%201st%20workshop.pdf)
- Report of bilateral consultations with key stakeholders (http://www.dnicast-project.net/documents/D5.4 Report of Bilateral Consultations with Key Stakeholders_V1.pdf)

Subtask D: Advanced Resource Modeling

Activity D1. Improvements to Existing Solar Resource Retrieval Methods

The Danish Meteorological Institute (DMI) has made some comparisons of various types of two-stream radiative transfer schemes from NWP models against a 30-stream DISORT scheme used as a reference. The tested schemes are the clear sky and cloudy sky schemes from the *Morcrette radiation module* used in the AROME/ALADIN/IFS models, *aero_rt6* from the Enviro-HIRLAM model, and the *Ritter & Geleyn scheme* from the ALARO model. The relative errors for the schemes are shown as a function of the optical thickness for a single layer with a single scattering albedo of 0.95 and an asymmetry factor of 0.7. These optical properties are similar to those of aerosols from forest fires. The layer is irradiated at a cosine angle of 0.6.

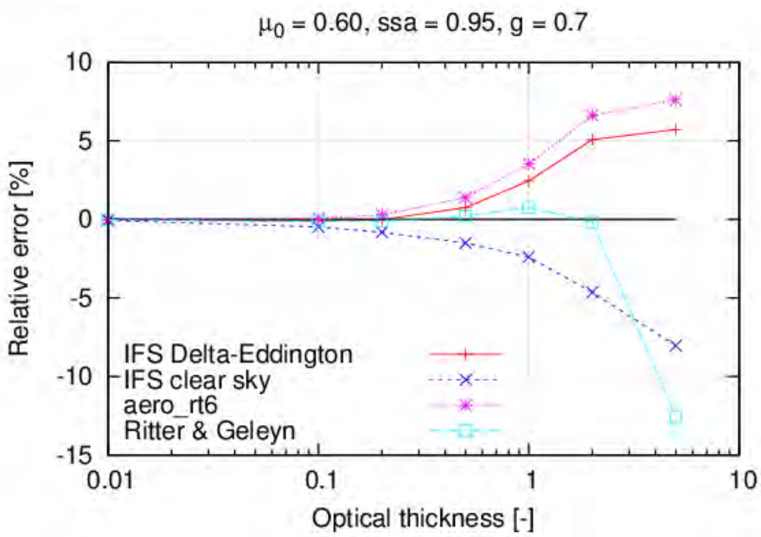


Figure D1: Relative error of the tested NWP schemes with respect the optical thickness (single layer, single scattering albedo of 0.95, asymmetry factor of 0.7).

MINES ParisTech has on-going research notably on clear-sky modeling, circumsolar and sunshape estimation under clear-sky and desert conditions (Eissa et al., 2015) and on spectral irradiance estimation. MINES ParisTech is also developing advanced tool for temporal variability analysis (Badulescu et al., 2015) that may have some impacts in solar modeling.

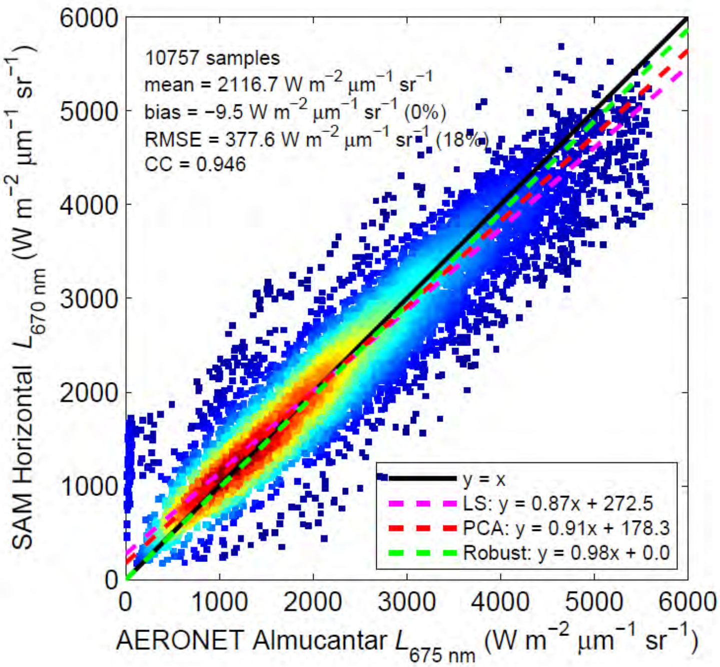


Figure D2. Scatter density plot between the circumsolar luminance from SAM and AERONET.

The MATRAS group of the University of Jaén (Spain) has evaluated the ability of the WRF model to represent various macroscopic cloud characteristics at multiple spatial and temporal resolutions (Arbizu-Barrena et al, 2015). In particular, the model prediction skill of cloud occurrence, cloud base height and cloud cover are assessed separately for low-, middle- and high-level clouds. The evaluation is conducted based on observations gathered with a ceilometer and a sky camera located at the campus of the University of Jaén (southern Spain). In the study site, the WRF model tends to: (i) over-predict the occurrence of high-level clouds irrespectively of its spatial resolution, (ii) under-estimate the cloud base height and (iii) over-estimate the cloud cover. In parallel, the performance of the WRF model to evaluate surface solar radiation has been evaluated in Spain using a multiannual ground validation dataset (Ruiz-Arias et al., 2015). The major model biases have been related to model deficiencies in the simulation of convective clouds.

The University of Jaén has also devised an evolutionary Artificial Neural Network (ANN) ensemble model to generate hourly DNI estimates using various spectral channels from Meteosat-9 imagery (Linares-Rodriguez et al., 2015). The procedure combines a genetic algorithm for selecting the best inputs with an ANN ensemble method. The ensemble model was calibrated and evaluated using three years of Meteosat-9 data and DNI observations measured at 28 ground stations over Europe and Northern Africa. The ensemble estimates were nearly unbiased (MBE = 2%) and the RMSE was 24.3% across an independent spatial and temporal dataset. This represents an improvement of 35% over other common methods for the estimation of DNI.

In collaboration with Solar Consulting Services (USA), the University of Jaén has also conducted a comprehensive study of the performance of 140 GHI-to-DNI separation models selected from the literature using high-quality 1-min solar radiation observations at 54 research-class stations from 7 continents (more than 25 million valid data points). The work has been published in the Solar Energy Journal (Gueymard and Ruiz-Arias, 2015). It is found that, for all models, cloud enhancement and high-albedo induced effects exacerbate the errors. A higher number of predictors used by a model appears to improve its performance, but not in a consistent way, since there are many exceptions. These are attributed to the risk of overfitting. Over the arid, temperate and tropical zones, two models consistently deliver the best predictions.

Within the publication of subtask B "Review on site-adaptation techniques for satellite-derived solar radiation datasets" (Polo et al., 2016, in press) the usefulness of re-analysis data (MERRA, ERA and NCEP) for long term adaptation and for estimation of long-term trends have been validated as a deliverable of subtask D.

A simple measure-correlate-predict (MCP) method based on yearly averages has been used. The results of the original RMSE values before and after application of the MCP correction method are listed in Table D1.

Table D1. Relative RMSE of the estimation of the long term averages for the 5 measurement sites in Europe and Northern Africa.

Dataset	Original RMSE [%]	MCP RMSE [%]
Re-analysis NCEP	20.3	6.8
Re-analysis MERRA	16.3	3.3
Re-analysis ERA	11.2	3.4
Satellite (Helioclim)	3.8	3.0

The simple MCP method enhances the quality of re-analysis data by 60-70%, compared to 20% for the satellite data. MCP applied to satellite data leads to the best results (RMSE = 3.0%). MCP with re-analysis data results in only slightly higher uncertainties (3.3% for MERRA and 3.4% for ERA). It could be shown that even though irradiance data derived from re-analysis tend to have higher uncertainties than those derived from satellite observations, they can still be useful for long-term approximations after proper MCP correction. Both long-term trends and year-to-year variability are strongly underestimated by re-analysis data.

WORK PLANNED FOR 2016

Subtask A: Solar Resource Applications for High Penetration of Solar Technologies

Work on this Subtask has been completed. A comprehensive report on short-term resource variability, led by SUNY/Albany, has been published.

Subtask B: Standardization and Integration Procedures for Data Bankability

Activity B1. Measurement Best Practices

In 2016 Activity B1 will contribute to the next update of the best practices handbook for solar resource assessment. One of the new contributions will be the uncertainty analysis of Rotating Shadowband Irradiometers. This update of the handbook will also represent the final manual on solar radiation measurements. Furthermore, a report on new measurands for solar resource assessment will be compiled and published.

Activity B2. Gap Filling, QC, Flagging and Data Formatting

In 2016 a benchmarking for gap filling will be published. A final report on data formatting will be published. Activity B2 will contribute to the next update of the best practices handbook for solar resource assessment.

Activity B3. Integration of Data Sources

The report on the integration of ground measurements in satellite data sets has been used as a basis for a journal paper. This paper will be revised for publication. Activity B3 will contribute to the next update of the best practices handbook for solar resource assessment.

Activity B4. Data Uncertainties over Various Temporal and Spatial Resolutions

Activity B4 will contribute to the next update of the best practices handbook for solar resource assessment.

Activity B5. Evaluation of Meteorological Products

A best practices document for TMY and P90/P70 calculation will be developed. Furthermore, a proposal and an evaluation of new products for risk analysis are foreseen. Activity B5 will contribute to the next update of the best practices handbook for solar resource assessment.

Subtask C: Solar Irradiance Forecasting

Task members involved in irradiance forecasting will continue working on further development of their forecasting algorithms for global horizontal and direct normal irradiance.

A focus of joint work in 2016 will be on the completion of the remaining benchmarking studies: Benchmarking of Irradiance Forecasts of Global Models for Worldwide Locations:

1) Benchmarking study of NWP irradiance forecasts for Southern Europe and La Reúnion Island
2) Benchmarking of satellite based irradiance forecasts

The evaluations will be finalized and published in 2016.

The contribution to the final deliverable, an update of the forecasting section of the "Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications" will be prepared.

Subtask D: Advanced Resource Modeling

Activity D1: Improvements to Existing Solar Resource Retrieval Methods

The collaborative work within the activity D1 will focus on two topics in 2016 to wrap up the activity:

- an evaluation/comparison of different approaches for classification of clear/cloudy sky conditions,
- a worldwide benchmarking of clear-sky solar radiation models using a common input dataset.

Activity D2: Long-term Analysis and Forecasting of Solar Resource Trends and Variability

Work in this activity has been completed.

LINKS WITH INDUSTRY

Several small companies involved in solar resource data production and services are directly or indirectly participating in the Task: Green Power Labs (Canada), Suntrace GmbH (Germany), Black Photon Instruments GmbH (Germany), CSP Services (Germany), Meteotest (Switzerland), Blue Sky Wetteranalyzen (Austria), GeoModel. s.r.o. (Slovakia), IrSOLaV (Spain), Meteotest (Switzerland), Irradiance Corp. (USA), Augustyn and Co. (USA), Clean Power Research (USA), Solar Consulting Services (USA), and Peak Design (UK).

The audience for the results of Task 46 includes the technical laboratories, research institutions, and universities involved in developing solar resource data products. More importantly, data users, such as energy planners, solar project developers, architects, engineers, energy consultants, product manufacturers, and building and system owners and managers, and utility organizations, are the ultimate beneficiaries of the research, and will be informed through targeted reports, presentations, web sites, handbooks and journal articles.

REPORTS/PAPERS/REFERENCES PUBLISHED IN 2015

Task Deliverables

Polo, J., S. Wilbert, J. A. Ruiz-Arias, R. Meyer, C. Gueymard, M. Šúri, L. Martín, T. Mieslinger, P. Blanc, I. Grant, J. Boland, P. Ineichen, J. Remund, R. Escobar, A. Troccoli, M. Sengupta, K. P. Nielsen, D. Renne, and N. Geuder. 2015. Integration of ground measurements with model-derived data. IEA SHC Task 46 report.

Sengupta, M., A. Habte, S. Kurtz, A. Dobos, S. Wilbert, E. Lorenz, T. Stoffel, D. Renné, D. Myers, S. Wilcox, P. Blanc, and R. Perez. 2015. Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications. Technical Report NREL/TP-5D00-63112. IEA SHC Task 46 report.

Wilbert, S, N. Geuder, M. Schwandt, B. Kraas, W. Jessen, R. Meyer, and B. Nouri. 2015. Best Practices for Solar Irradiance Measurements with Rotating Shadowband Irradiometers. International Energy Agency; Solar Heating & Cooling Programme. IEA SHC Task 46 report.

Subtask B Publications

Cebecauer, T., and M. Suri. 2015: Typical Meteorological Year data: SolarGIS approach. Energy Procedia 69 (2015): 1958-1969

Cebecauer, T., et al., 2015: Site-Adaptation of Satellite-Based Time Series: Overview and SolarGIS Approach. GeoModel Solar. SolarPACES conference 2015 Cape Town.

Fernández-Peruchena, C. M., et al., 2015: Estimation of the Probability of Exceedance of Direct Normal Solar Irradiation Series, National Renewable energy Centre (CENER). SolarPACES conference 2015, Cape Town.

Fernández-Peruchena, Carlos M., Lourdes Ramírez, Manuel A. Silva-Pérez, Vicente Lara, Diego Bermejo, Martín Gastón, Sara Moreno-Tejera, Jesús Pulgar, Juan Liria, Sergio Macías, Rocío Gonzalez, Ana Bernardos, Nuria Castillo, Beatriz Bolinaga,

Geuder, N., F. Wolfertstetter, S. Wilbert, D. Schüler, R. Affolter, B. Kraas, E. Lüpfert, and B. Espinar, 2015: Screening and Flagging of Solar Irradiation and Ancillary Meteorological Data. Energy Procedia no. 69 (0): 1989-1998. DOI: http://dx.DOI.org/10.1016/j.egypro.2015.03.205.

Hanrieder, N., S Wilbert, R. Pitz-Paal, C. Emde, J. Gasteiger, B Mayer, and J. Polo. 2015: Atmospheric extinction in solar tower plants: absorption and broadband correction for MOR measurements. Atmos. Meas. Tech. no. 8:3467-3480. DOI: 10.5194/amt-8-3467-2015.

Hanrieder, N., M Sengupta, Y. Xie, S Wilbert, and R Pitz-Paal. 2015: Modelling Beam Attenuation in Solar Tower Plants Using Common DNI Measurements. Presentation ICEM, Boulder, CO, USA. (also submitted to Solar Energy)

Jessen, W., S. Wilbert, B. Nouri, N. Geuder, and H. Fritz. 2015: Calibration methods for rotating shadowband irradiometers and evaluation of calibration duration." Atmos. Meas. Tech. Discuss. No. 8 (10): 10249-10282. DOI: 10.5194/amtd-8-10249-2015

Mavromatakis, Fotis and Frank Vignola, 2015: Spectral Corrections for PV Performance Modelling. 4th PV Performance Modelling and Monitoring Workshop – October 22-23, 2015 Cologne, Germany

Merrouni, A. Alami, F. Wolfertstetter, A. Mezrhab, S. Wilbert, and R. Pitz-Paal. 2015: Investigation of Soiling Effect on Different Solar Mirror Materials under Moroccan Climate. Energy Procedia no. 69 (0): 1948-1957. DOI: http://dx.DOI.org/10.1016/j.egypro.2015.03.194.

Peterson, Josh, Frank Vignola, Stefan Wilbert, and Philippe Blanc. 2015: Alternative method for characterizing photodiode pyranometers for Rotating Shadowband Irradiometers. Presentation ICEM, Boulder, CO, USA.

Polo, J. et al., 2015: Solar Resources and power potential mapping in Vietnam using satellite-derived and GIS-based information, Energy Conv. Manag. 98, 348-358.

Polo, J., and G. Estalayo, 2015: Impact of atmospheric aerosol loads on Concentrating Solar Power production in arid-desert sites. Solar Energy 115, 621–631. DOI: 10.1016/j.solener.2015.03.031.

Polo, J., L. Martín, and J. M. Vindel, 2015: Correcting satellite derived DNI with systematic and seasonal deviations: Application to India. Renewable Energy 80, 238–243. DOI: http://dx.DOI.org/10.1016/j.renene.2015.02.031.

Valenzuela, Rita X. and Luis F. Zarzalejo, 2016: A statistical characterization of the long-term solar resource: Towards risk assessment for solar power projects. Solar Energy no. 123:29-39. DOI: http://dx.DOI.org/10.1016/j.solener.2015.10.051.

Wilbert, S. et al., 2015: Uncertainty of Rotating Shadowband Irradiometers and Si-Pyranometers Including the Spectral Irradiance Error. SolarPACES conference 2015, Cape Town.

Subtask C Publications

Boland, John and Ted Soubdhan, 2015: Spatial-temporal forecasting of solar radiation. Renewable Energy, 75, pp. 607-616.

Chow, C.W., S. Belongie, and J. Kleissl, 2015: Cloud Motion and Stability Estimation for Intra-hour Solar Forecasting. Solar Energy 115 (2015): 645-655.

Chu, Y., B. Urquhart, S. M. Gohari, H. T. Pedro, J. Kleissl, and C. F. Coimbra, 2015: Short-term reforecasting of power output from a 48 MWe solar PV plant. Solar Energy, 112, 68-77.

Gleeson, E., K. P. Nielsen, V. Toll, L. Rontu, E. Whelan, 2015: Shortwave Radiation Experiments in HARMONIE Tests of the cloud inhomogeneity factor and a new cloud liquid optical property scheme compared to observations. ALADIN-HIRLAM Newsletter. 2015; 5: 92-106.

Hammer A, J. Kühnert, K. Weinreich, and E. Lorenz, 2015: Short-Term Forecasting of Surface Solar Irradiance Based on Meteosat-SEVIRI Data Using a Nighttime Cloud Index. Remote Sensing 7(7), July 17, 2015, http://www.mdpi.com/2072-4292/7/7/9070.

Kleissl, J., 2014: Development of a sky imaging system for short-term solarpower forecasting. Atmos. Meas. Tech. Discuss. 7, 4859-4907, DOI: 10.5194/amtd-7-4859-2014, 2014.

Lipperheide, M., J. L. Bosch, and J. Kleissl, 2015: Embedded nowcasting method using cloud speed persistence for a photovoltaic power plant. Solar Energy, Volume 112 232–238, 2015. DOI: 10.1016/j.solener.2014.11.013

Lorenz, E., D. Heinemann, K. P. Nielsen, J. Remund, S. C. Müller, and W. Traunmüller, 2015: Comparison of irradiance forecasts based on numerical weather prediction for Central and Northern Europe. 3rd International Conference on Energy Meteorology (ICEM), 22-26. June 2015, Boulder, CO, USA.

Lorenz, E., J. Kühner, D. Heinemann, K. P. Nielsen, J. Remund, S. C. Müller, W. Traunmüller, P. Rechberger, S. Cros, 2015: Comparison of irradiance forecasts based on numerical weather prediction and satellite data for Central and Northern Europe. European Photovoltaic Solar Energy Conference (EUPVSEC), 14-18 September 2015 Hamburg, Germany.

Mejia, Felipe A., Ben Kurtz, Keenan Murray, Laura Hinkelman, Manajit Sengupta, Yu Xie, J Kleissl, 2015: Coupling sky images with three-dimensional radiative transfer models: a new method to estimate cloud optical depth. Atmospheric Measurement Techniques Discussions, 8, 11285-11321, DOI: 10.5194/amtd-8-11285-2015, 2015.

Nguyen, Fung (Andu) and J. Kleissl, 2014: Stereographic methods for cloud baseheight determination using two sky imagers. Solar Energy, 2014. 107:495-509, http://dx.DOI.org/10.1016/j.solener.2014.05.005.

Schmidt, T., J. Kalisch, E. Lorenz, and D. Heinemann, 2015: Evaluating the spatio-temporal performance of sky imager based solar irradiance analysis and forecasts. Atmospheric Chemistry and Physics Discussions 15, Nr. 19, October 7, 2015. http://www.atmos-chem-phys-discuss.net/15/26997/2015/acpd-15-26997-2015.html.

Urquhart, B., Kurtz, B., and J Kleissl: Sky camera geometric calibration using solar observations." Atmospheric Measurement Techniques.

Subtask D Publications

Arbizu-Barrena, C., D. Pozo-Vázquez, J.A. Ruiz-Arias, and J. Tovar-Pescador, 2015: Macroscopic cloud properties in the WRF NWP model. An assessment using sky camera and ceilometer data. Journal of Geophysical Research: Atmospheres, Vol. 120, pp. 1-16, DOI: 10.1002/2015JD023502.

Fernández-Peruchena, Carlos M. and Martín Gastón, 2016: A simple and efficient procedure for increasing the temporal resolution of global horizontal solar irradiance series. Renewable Energy (2016). Volume 86, Pages 375–383.

Fernández-Peruchenaa, Carlos M., Martín Gastón, Marcelino Sánchez, Javier García-Barberena, Manuel Blanco, and Ana Bernardos 2015: MUS: A multiscale stochastic model for generating plausible meteorological years designed for multiyear solar energy yield simulations. Solar Energy 120:244-256.

Fernández-Peruchena, Carlos M., Manuel Blanco, Martín Gastón, and Ana Bernardos, 2015: Increasing the temporal resolution of direct normal solar irradiance series in different climatic zones. Solar Energy115: 255-263.

Gastón-Romeo, Martin, Laura Frías-Paredes, Fermin Mallor, and Teresa Leon, 2016: Introducing the Temporal Distortion Index to perform a bidimensional analysis of renewable energy forecast. Energy (2016). Volume 94, Pages 180-194.

Gueymard, C.A., and J.A. Ruiz-Arias, 2015: Extensive worldwide validation and climate sensitivity analysis of direct irradiance predictions from 1-min global irradiance, Solar Energy, in press, DOI: 10.1016/j.solener.2015.10.010.

Linares-Rodríguez, A. S. Quesada-Ruiz, D. Pozo-Vázquez, and J. Tovar-Pescador, 2015: An evolutionary artificial neural network ensemble model for estimating hourly direct normal irradiances from Meteosat imagery, Energy, Vol. 91, pp. 264-273, DOI: 10.1016/j.energy.2015.08.043.

Ramírez, L., R. Bojo, J. Valero, S. Wilbert, L.F. Zarzalejo, A. Paz, G. García, W. Reinalter, R.X. Valenzuela, G. Díaz-Herrero, A. Campos, and F. Wolfertstetter, 2015: Proyecto ARES - Acceso a red de estaciones solares. ERA SOLAR 187. Julio/Agosto 2015.

Röttinger, N., F. Remann, R. Meyer, and T. Telsnig, 2015: Calculation of CSP Yields with Probabilistic Meteorological Data Sets: A Case Study in Brazil. Energy Procedia 69:2009-2018.

Ruiz-Arias, J.A., C. Arbizu-Barrena, F. J. Santos-Alamillos, J. Tovar-Pescador, and D. Pozo-Vázquez, 2015: Assessing the surface solar radiation budget in the WRF model: A spatio-temporal analysis of the bias and its causes. Monthly Weather Review, Vol. 144, pp. 703-711, DOI: 10.1175/MWR-D-15-0262.1.

Zarzalejo, L.F., L. Ramírez, R.X. Valenzuela, J. Polo, S. Wilbert, F. Wolfertstetter, N. Hanrieder, B. Nouri, G. García, J. Liria, and A. Campo. 2015: METAS - Estación meteorológica para el desarrollo de las tecnologías solares. ERA SOLAR 186. Mayo/Junio 2015. 18.

MEETINGS IN 2015

6th Task Experts Meeting
January 27-28
PSA, Almería, Spain (Hosted by DLR and CIEMAT)
This meeting focused on technical progress in each of the four sub-Task areas, and initiated preliminary discussion of a new Task, perhaps to be proposed under IEA PVPS.

7th Task Experts Meeting
September 22 - 24
Berne, Switzerland (Hosted by Meteotest)
This meeting focused on technical progress in each of the four sub-Task areas, and included a one-day Task Definition Workshop for a new Task being proposed under IEA PVPS.

MEETINGS IN 2016

8th Task Experts Meeting
April 6 - 8
Sophia Antipolis, France (Hosted by MINES Paris Tech)
This meeting will focus on developing the final deliverable for Task 46 as well as prepare the semi-annual report for the 79th IEA SHC EXCO meeting in June. An additional one-day Task Planning Workshop for a new Task under IEA SHC PVPS will be conducted.

9th Task Experts Meeting
TBD (Fall, 2016)

SHC TASK 46 NATIONAL CONTACTS

TASK MANAGEMENT

OPERATING AGENT
Dave Renné
Senior Consultant, Clean Power Research
2385 Panorama Ave.
Boulder, CO 80304
UNITED STATES
drenne@mac.com

SUBTASK A (CO-LEADS)
Richard Perez
State University of New York/Albany
Atmospheric Sciences Research Center
251 Fuller Road
Albany, NY 12203
UNITED STATES
perez@asrc.cestm.albany.edu

Hans-Georg Beyer
Department of Engineering Sciences,
Faculty of Engineering and Science, Post Box 509, No. 4894, Grimstad
NORWAY
hans-georg.beyer@uia.no

SUBTASK B
Stefan Wilbert
DLR Institut für Technische Thermodanamik
DENMARK
Stefan.wilbert@dlr.de

SUBTASK C
Elke Lorenz
Carl von Ossietzky Universität Oldenburg, EHF
D-26111 Oldenburg
GERMANY
elke.lorenz@uni-oldenburg.de

SUBTASK D
Philippe Blanc
MINES ParisTech
Center Observation, Impacts, Energy
CS 10207, F-06904 Sophia Antipolis
FRANCE
Lucien.wald@mines-paristech.fr

NATIONAL CONTACTS

AUSTRALIA
Alberto Troccoli, Jing R. Huang, and Daniel Rowe
CSIRO
Alberto.troccoli@csiro.au
jing.r.huang@csiro.au
Daniel.Rowe@csiro.au

Ian Grant and Ian Muirhead
Bureau of Meteorology
I.grant@bom.gov.au
I.Muirhead@bom.gov.au

John Boland
University of South Australia
John.boland@uisa.edu.au

AUSTRIA
Wolfgang Traunmuller and Klaus Reingruber
Bluesky Wetteranalyzen
wolfgang.traunmueller@blueskywetter.at
klaus.reingruber@blueskywetter.at

Gerald Steinmaurer
Austria Solar Innovation Center
steinmaurer.gerald@asic.at

Robert Höller
FH OÖ Studienbetriebs GmbH
robert.hoeller@fh-wels.at

CANADA
Alexandre Pavlovski, Vlad Kostylev
Green Power Labs
ampavlovski@greenpowerlabs.com
vkostylev@greenpowerlabs.com

DENMARK
Kristian Paugh Nielsen
DMI/DTU
kpn@dmi.dk

FRANCE
Philippe Blanc and Lucien Wald
MINES ParisTech
Center Observation, Impacts, Energy
philippeblanc@mines-paristech.fr
Lucien.wald@mines-paristech.fr

Philippe Lauret and David Mathieu
Laboratoire PIMENT/Université Réunion
Philippe.lauret@univ-reunion.fr
Mathieu.david@univ-reunion.fr

Sylvain Cros
Reuniwatt SAS
Réunion
sylvain.cros@reuniwatt.com

Ted Soubdhan
University of the Antilles (LARGE
Guadalupe
tsoubdha@univ-ag.fr

GERMANY
Detlev Heinemann, Elke Lorenz, and Jethro Betcke
Carl von Ossietzky Universität Oldenburg, EHF
detlev.heinemann@uni-oldenburg.de
elke.lorenz@uni-oldenburg.de
jethro.betcke@uni-oldenburg.de

Richard Meyer
Suntrace GmbH
R.Meyer@suntrace.de

Gerd Heilscher
University of Applied Sciences
Hochschule Ulm
heilscher@hs-ulm.de

Carsten Hoyer-Klick, Marion Schroedter-Homscheidt, Steffen Stoeckler, Stefan Wilbert, and Bernhard Reinhardt
DLR Institut für Technische Thermodanamik
carsten.hoyer@dlr.de
Marion.schroedter-homscheidt@dlr.de
Steffen.stoeckler@dlr.de
Stefan.wilbert@dlr.de
Bernhard.reinhardt@dlr.de

Joachim Jaus
Black Photon Instruments GmbH
Joachim.jaus@blackphoton.de

Holger Ruf
Hochschule Ulm
ruf@hs-ulm.de

Norbert Geuder
CSP Services
n.geuder@cspservices.de

NETHERLANDS
Alexander Los
Delft University of Technology
a.los@tudelft.nl

SLOVAKIA
Marcel Suri and Tomas Cebecauer
GeoModel, s.r.o.
marcel.suri@geomodel.eu
tomas.cebecauer@geomodel.eu

SPAIN
Martín Gastón and Inigo Pagola
CENER
mgaston@cener.com

Jesús Polo, Lourdes Ramirez, Ana A. Navarro and Luis F. Zarzalejo
Plataforma Solar de Almeria
Departmento de Energia
CIEMAT
jesus.polo@ciemat.es
Lourdes.ramirez@ciemat.es
lf.zarzalejo@ciemat.es

José Louis Torres and Marian de Blas
Public University of Navarra (UPNA)
Dpto. Proyectos e Ingeniería Rural
jlte@unavarra.es
mblas@unavarra.es

David Pozo Vazquez and Jose Antonio Ruiz Arias
University of Jaen
dpozo@ujaen.es
jaarias@ujaen.es

Marco Cony
Universida Computense de Madrid
macony@fis.ucm.es

Luis Martin and Diego Bermejo
IrSOLaV
Luis.martin@irsolav.com

UNITED KINGDOM
John Wood
Peak Design
john@peakdesign.co.uk

UNITED STATES
Paul Stackhouse
NASA Langley Research Center
Paul.w.stackhouse@nasa.gov

Richard Perez
State University of New York/Albany
Atmospheric Sciences Research Center
perez@asrc.cestm.albany.edu

Manajit Sengupta
National Renewable Energy Laboratory
Manajit.sengupta@nrel.gov

Jan Kleissl
University of California at San Diego
jkleissl@ucsd.edu

Ed and Chris Kern
Irradiance Corp.
chris@irradiance.com

Jim Augustyn
Augustyn and Co.
jimaugustyn@solarcat.com

Frank Vignola
University of Oregon
fev@uoregon.edu

Task 49

Solar Process Heat for Production and Advanced Applications

Christoph Brunner
AEE INTEC
Operating Agent for The Republic of Austria

TASK DESCRIPTION

The Task was focused on solar thermal technologies for converting solar radiation into heat and was working further to enable the intelligent integration of the produced heat into industrial processes (that is starting with the solar radiation reaching the collector and ending with the hot air, water or steam being integrated into the application). The Task scope included all industrial processes that are thermal driven and running in a temperature range up to 400°C.

The objectives of the Task were:

- Improve solar process heat collectors and collector loop components.
- Provide a basis for the comparison of collectors with respect to technical and economical conditions.
- Give comprehensive recommendations for standardized testing procedures.
- Improve solar thermal system integration for production processes by advanced heat integration and storage management, advanced methodology for decision on integration place and integration types
- Increase the solar process heat potential by combining process intensification and solar thermal systems and fostering new applications for solar (thermal/UV) technologies
- Provide a worldwide overview of results and experiences of solar heat for industrial process systems. This includes the evaluation of completed and ongoing demonstration system installations using monitoring data, as well as carrying out economic analyses.
- Develop a performance assessment methodology for a comparison and analysis of different applications, collector systems, regional and climatic conditions.
- Support future project stakeholders by providing design guidelines and simplified, fast and easy to handle calculation tools for solar yields and performance assessment.
- Investigate system solutions for stagnations behavior, control and hydraulics of large field installations.
- Identify, address and lower the barriers for market deployment by providing examples of successful implementations, by describing suitable financing and incentive schemes, and developing relevant project constellations.
- Disseminate the knowledge to the main target groups involved—solar manufacturers, energy consultants, process engineers, installers and potential buyers (industry), and policy makers and platforms.

Task Duration

This Task is now completed. The Task started in **February 2012** and ended in **January 2016**.

It was a collaborative Task with the IEA SolarPACES Implementing Agreement.

Participating Countries

Country	Number of Research Institutes	Number of Universities	Number of Companies
Austria	3	1	2
Belgium	1		
China	1		
France	1		2
Germany	5	4	5
India			3
Italy	1	1	1
Mexico	3		
Portugal		1	
South Africa		1	
Spain	4	1	2
Sweden		2	3
Switzerland	2	1	2
UK		1	
USA			2
Total	21	13	22

Collaboration with Other SHC Tasks and Outside Organizations/Institutions

- Continuous exchange with SolarPaces (Klaus Hennecke, DLR).
- Task 45 Large Scale Solar Heating and Cooling Systems
- Participation in ICG - Industrial waste heat recovery webinar - 19 Feb 2015
- Presentation of Task 49/IV activities in IEA WS on Renewable Energies for Manufacturing Industries on the 12th of May 2015 in Paris

Subtask B collaborated with the EFCE Working Party on Process Intensification and organised a common workshop on Energy Supply for Intensified Processes in June, 2014. The aim was to bring together experts from process engineering and solar thermal experts to commonly discuss the potential of solar process heat via new/emerging technologies.

Collaboration with Industry

A high number of companies have been active in the Task 49 activities, showing the high interest of industry in the field of solar process heat. The increasing availability of solar process heat collectors marked by companies all over the world, also shows the technology readiness for realising large solar process heat plants. Such have also been demonstrated within the period of Task 49.

TASK ACCOMPLISHMENTS

Key Results

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

Subtask A: Process Heat Collectors
Subtask Leader since 2014: Pedro Horta, Fraunhofer ISE, Germany
Subtask Leader until 2014: Elimar Frank, SPF, Switzerland

General requirements and relevant parameters for process heat collectors and specific collector loop components

Part A1 of Subtask A aimed to improve (and develop) all types of collectors, collector loops and collector loop components (e.g. thermal insulation, hydraulic parts, heat carriers etc.) for process heat applications. All devices were investigated with respect to performance, reliability and cost effectiveness. A first step was to increase the knowledge about general requirements and relevant parameters of process heat collectors and their improvement, and to agree on these criteria among the Task 49 participants. These requirements comprise the thermal and optical performance of collectors andcomponents, but also the reliability/durability and costs. A report on these general requirements and parameters for process heat collectors was the first achievment of Subtask A.

Overheating prevention and stagnation handling in solar process heat applications

Solar process heat plants have to operate totally reliable in all the operation modes that may occur. Other than for conventional closed hot water or steam supply systems solar thermal applications in general require specific technical solutions to cope with the phenomenon of stagnation. For small to medium scale residential solar thermal applications, measures to control stagnation can be regarded as state of the art. Usually, pressure release through the safety valve can be avoided by larger expansion vessels and, if additionally needed, simple heat dissipaters in the solar loop.

The same concepts may work for larger scale solar thermal applications as well, but particularly when it comes to industrial applications designed for higher supply temperatures and hence equipped with more efficient solar thermal collectors other strategies, such as additional active cooling devices for overheating prevention or de-focusing (in case of tracked collectors) might be favored in order to guarantee a long-term, reliable and low-maintenance operation.

This report gives an overview about topics related to stagnation and overheating in general and specifically with regard to solar assisted process heat applications. The report focused on the following main topics:

- Definition of terms
- Introduction to stagnation and overheating of collectors and collector fields
- Overheating prevention and control measures for solar process heat applications:
    - Measures for solar process heat applications with non-concentrating collectors
    - Special challenges for concentrating and tracked collectors
- Good-practice examples of implemented measures
- References to related literature

Brochure on the state-of-the-art of process heat collectors

A large number of available process heat collectors exist on the market, and a high variety of collectors were presented within the Task 49 meeting by numerous companies. A brochure on the State of the Art of process heat collectors describes the concepts of the available collector technologies on the market. A corresponding database on medium temperature collectors has been developed in the project STAGE [1].

Overview of collector output and key figures for defined conditions

During Task 49 different simplified methodologies and tools for predicting collector output for defined conditions have been presented and partly evaluated by the Task participants. These were tools, such as GainBuddy and ScenoCalc and more simplied methodologies such as nomorgramms, or key figures following the US standards based SRCC methodology. Based on the use and discussion of these methods, improvements could be identified and a common report on collector output and key figures for defined conditions was compiled. Aiming a preliminary technical-economic analysis of process heat projects based on collector data and on simplified methodologies, the contents include an overview of collector technologies, performance rating methods, economic analysis parameters and a decision matrix to planners.

Guideline on testing procedures for collectors used in solar process heat

Solar process heat collectors include a wide range of collector technologies, from standard flat plate collectors over air heating collectors to highly concentrating Parabolic Trough or Linear Fresnel collectors. All of these technologies compete against conventional energy sources but may also compete against other renewable energies and even against each other.

To enable solar thermal technologies to successfully enter the important market of process heat applications, it is crucial for the manufacturers to be able to provide reliable figures to succeed in tenders, to be able to predict energy yields with sufficient accuracy and to be able to prove liability in operation. All of this requires commonly agreed key figures and testing procedures to provide these.

Existing test standards provide solutions for many of these questions and the majority of technologies. First and foremost the ISO 9806:2013, which origins in the field of low temperature domestic hot water systems, has a wide scope and nowadays also includes highly concentrating collectors. But as the range of solar thermal technologies has much increased, and the formerly almost separated fields of non-concentrating low temperature

and concentrating high temperature applications meet and merge in the middle, many questions arise, as to how all of these can be tested and compared fairly.
The present guideline targets manufacturers, project engineers, contractors and end-users and tries to give an outline of the existing regulations to be aware of, to help understand, interpret and compare test results and to also highlight lacks and shortcomings in the directives that may be obstructive to fair competition.
In spite of the diverse technologies available, the present guideline mostly focusses on problems connected to concentrating collectors as no contributions from other fields were made.

Subtask B: Process Integration and Process Intensification Combined with Solar Process Heat
Subtask Leader: Bettina Muster, AEE INTEC, Austria

Methodologies and software tools for integrating solar heat into industrial processes
The general methodology for the integration of solar thermal energy into industrial processes was developed during IEA SHC TASK 33/SolarPACES Annex IV. It was shown that the Pinch analysis for the total production site and - building upon it - the design of an optimized heat exchanger network for the production system is one of the best approaches for an intelligent integration. Due to the fact that in the identified industry sectors with high potential for solar integration there are very often production processes running in batches, the classic Pinch methodology can only be a rough estimation of the real profile of heat sources/sinks, as it does not consider time dependency of the production schedules and integration of heat storages. In order to fulfill these needs of further improvements to model the real heat management of a production system it was necessary to further develop the existing methodology and software tools.
Bringing together the know-how and expertise of several experts dealing with heat integration and heat management tools, several tools have been compared and applied for solar process heat studies. Also, new tools were being developed within Task 49, for the first time with the aim to enable the identification of ideal integration places of solar heat in industrial processes, namely PinCh 2.0 (currently expanded to PinCh 3.0) and SOCO.

A comprehensive report, targeted at process integration experts, shows the interlinkages between process integration and solar process heat aspects, lists available tools and gives recommendations for further developments.

Integration Guideline
The Integration Guideline has been published within Task 49 as a comprehensive guideline for identification of best suitable places where to integrate solar heat within the industrial heat management.

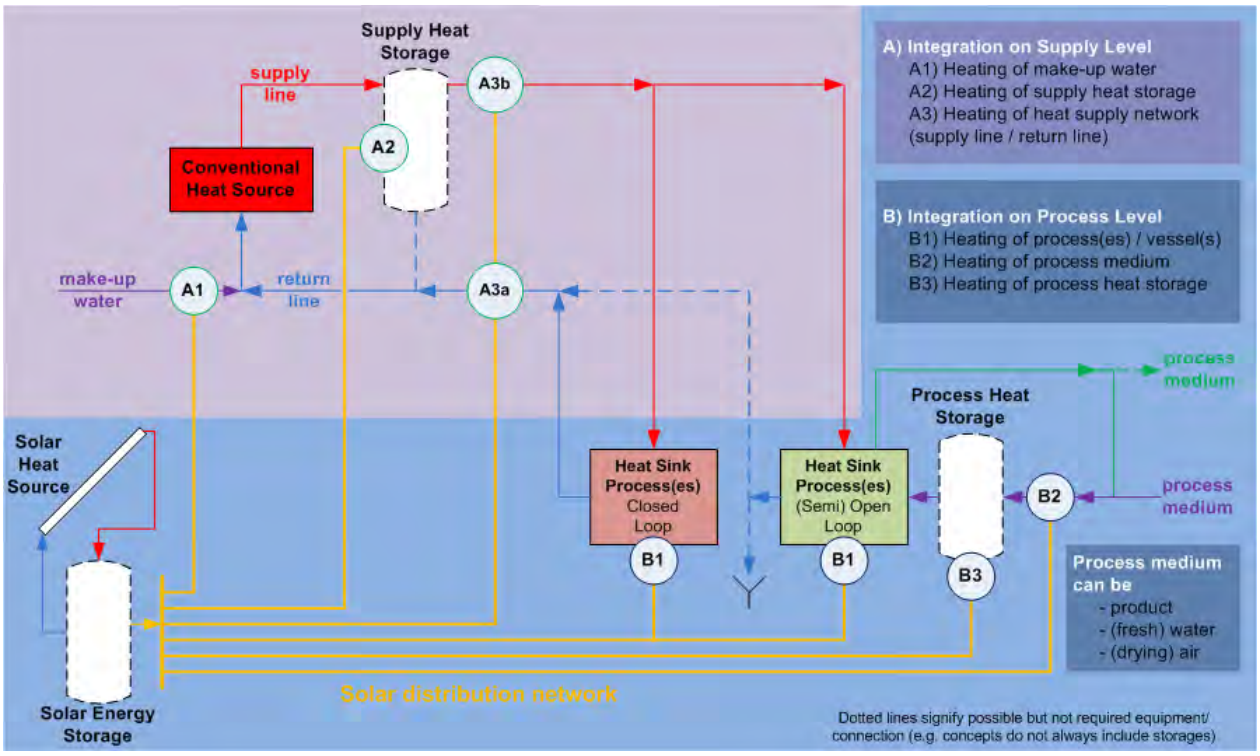


Figure 1. Possible integration points for solar process heat (AEE INTEC, 2012).

When integrating solar heat into industrial or commercial processes, the aim is to identify the most technically and economically suitable integration point and the most suitable integration concept. Due to the complexity of heat supply and distribution in industry, where a large number of processes might require thermal energy, this task is usually not trivial. This document provides guidance for planners of solar thermal process heat systems (SHIP), energy consultants and process engineers. It describes a general procedure for the integration of solar heat into industrial processes, including the necessary steps to identify suitable integration points for SHIP and integration concepts. Based on these concepts, SHIP system concepts are given. The document can be used as supporting material in solar process heat trainings of planners, energy managers and consultants, or as additional help for energy experts besides their own practical experiences. The scope of this document does not include a description of detailed planning steps of the solar thermal system itself.

Potential Enhancement of Solar Process Heat by Emerging Technologies

In its strive towards green, safe and efficient production processes, industry is starting to change its traditional practices. In engineering research, the aimed changes have been even called "re-industrialization" towards a green and safe economy. Obviously changes of the industrial processes will effect the energy supply stratgies of companies. Some of the upcoming technologies rely on electricity as energy supply, such as microwave, ultrasound or plasma technologies, so there might be a shift towards more electrically driven processes. However, emerging technologies can act on several levels to reach a more sustainable energy supply:

- by increasing process efficiencies the energy requirement is lowered;

- by changing driving forces the required energy form may change; and finally
- by enabling new efficient conversion technologies new energy sources (e.g. hydrogen production in fuel cells) can be tapped.

Based on workshops, literature review and exchange among experts, a report was compiled on the potential enhancement of solar process heat by emerging technologies. In this context the questions were tackeled:

- Which new technologies can stimulate the use of solar heat?
- Which technologies must be developed for stimulating the use of solar heat?

For the latter question, there are two main research strategies that target the technical bottlenecks of existing processes:

- Adapt processes to become more efficient and better suitable for solar process heat, and
- Develop "solar process technologies" as process technologies that are based on the use of solar light and heat.

The report shows that close cooperation between process engineers and energy experts will be necessary to reach these future targets.

Subtask C: Design Guidelines, Case Studies and Dissemination
(Subtask Leader: Werner Platzer, Fraunhofer ISE, Germany)

Guidelines
This document gives a comprehensive guidance for planning and realising Solar Process Heat Projects with respect to the criteria and sequence of decisions during the system design process. It is based on specific work from all subtasks and puts together the key results in a comprehensive document. The guideline will be published within 2016.

Overview and description of simulation tools for solar industrial process heat components
Whereas most solar thermal process heat projects work with non-concentrating collectors, in the last years also a number of concentrating collectors are being developed. With these higher temperatures can be achieved. Therefore especially in countries with high DNI radiation often the question arises whether a concentrating collector or a non-concentrating collector should be used. Integration of solar heat can be done on the process level, but also on the supply level. All these different approaches to solar process heat should be analysed easily by simulation. However up to now the limitations of individual programs with respect to all technologies and integration possibilities were not known. A comparison study with defined reference cases has been performed within Task 49 in Subtask C2.

Based on this work a comprehensive report has been compiled giving a short description of various simulation tools. The document does not aim at a complete description of the tools with all its mathematical, numerical and modelling details, it only intends to identify the main features and characteristics of tools which may affect the modelling of solar process heat case studies and their results. All the tools have been used at least in some of the case studies. The compilation is based also on a survey of simulation tools performed at the beginning of IEA Task 49.

Potential studies on Solar Process Heat Worldwide

A review on Potential studies for the use of solar heat for industrial processes (SHIP) has been done, based on studies available from Spain, Portugal, Austria, Italy, Netherlands, Sweden , Cyprus, Greece, Wallonia (Belgium), Germany and Australia. More recent studies included in the review were available from Germany, India, South Africa, Tunesia, Chile, Morocco, Pakistan and Egypt. In addition to the country studies, European and worldwide potential studies are also integrated in the document.

The total global process heat demand was about 98 EJ in 2008 [19]. Based on the evaluation within the review, about 4 % or 3.9 EJ global technical potential for solar process heat should be a conservative estimate. To very roughly calculate the order of magnitude of this, one could assume a mean useful annual solar irradiance (not specifying if global or beam) of 1200 kWh/(m^2a) and an annual solar thermal system efficiency of 40 %. This would result in a solar collector area of close to 2300 Mio. m^2. For the year 2050, Taibi et al. estimate a technical potential of 5.6 EJ, corresponding to then about 3200 Mio. m^2.

This may be compared with individual country studies. 2.4 Mio. m^2 for Morocco, 4.6 Mio. m^2 for Egypt, 6 Mio. m^2 for Chile, 7.1 Mio. m^2 for Pakistan, 35 Mio. m^2 for Germany, and 155 Mio. m^2 for Europe complement and confirm this magnitude.

Demonstration Projects and SHIP Database

As part of SHC Task 49, a SHIP database was established, collecting information from international demonstration projects. So far 188 SHIP applications that have been surveyed have sufficient data to be published on ship-plants.info.

Figure 2. Location of reported SHIP applications (ship-plants.info).

According to the SHIP database, 154.574 m² of gross area solar heat collectors for industrial processes are installed worldwide in the reported projects. Most of these systems are experimental and relatively small in scale. However, in recent years the number of very large applications has increased significantly. An example of such a large-scale installation is at a copper mine in Chile, which pushes the country to first place in installed collector area for SHIP. In total, 22 SHIP applications have a gross collector area > 1000 m², which represents 69% of the total installed gross collector area.

Most of the reported plants use flat plate collectors (88 plants), followed by evacuated tube (35 plants) and parabolic troughs (22 plants). This is obviously influenced by the region where the solar thermal plant is installed.

The integration point is reported for 105 plants. Based on these projects 38% of the plants integrate solar heat on supply level, with 18 plants heating mak-up water and 10 plants directly feeding the (steam) supply line. 62% of the plants integrate on process level, with the majority of plants (33 plants) directly heating a specific process, followed by the pre-heating of a process medium (24 plants).

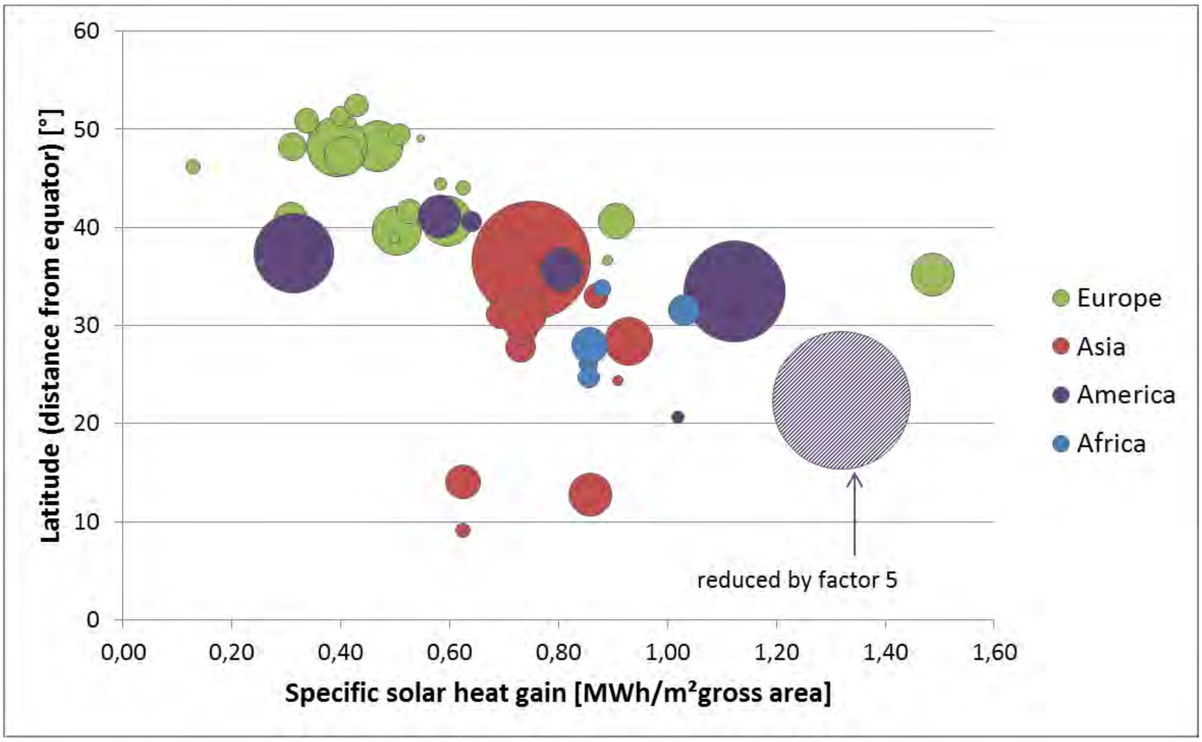


Figure 3. Solar heat gain per gross collector area based on 49 plants out of the SHIP database; bubble sizes in relation to plants size (exception: to generate a visible picture, the bubble size for the largest plant was reduced by a factor of 5) (evaluation based on ship-plants.info, AEE INTEC)

PUBLICATONS

Reports & Published Books

Report No.	Title	Publication Date (month, year)	Target Audience	Web or Print
A 1.1	General requirements and relevant parameters for process heat collectors and specific collector loop components	December 2012	Task 49 participants, collector manufacturers	Web
A 1.2	Overheating prevention and stagnation handling in solar process heat applications	January 2015	Solar planners, operators, collector manufacturers	Web
A 1.3	Brochure on the state of the Art of process heat collectors	April 2016	Solar planners	Web
A 2	Overview of collector output and key figures for defined conditions	April 2016		Web
A 3	Guideline on testing procedures for collectors used in solar process heat	April 2016	Collector manufacturers	Web
B 1	Methodologies and Software Tools for Integrating Solar Heat into Industrial Processes	February 2015	Process engineers, process integration experts	Web
B 2	Integration Guideline	February 2015	Process engineers, solar planners	Web
B 3	Summary report on updates of Wikiweb „Efficiency Finder“	April 2016	Process engineers, solar planners	Web
B 4	Catalogue for required components for advanced integration*	April 2016	Process engineers, solar planners	Web
B 5	Potential Enhancement of Solar Process Heat by Emerging Technologies	April 2016	Process engineers, solar researchers, stakeholders	Web
B 6	Subtask B Booklet	April 2016	Process engineers, solar planners	Web
C1	Design Guidelines	June 2016	Energy planners, solar planners, operators	Web
C 2	Overview and description of simulation tools for solarindustrial process heat	April 2016	Solar planners,	Web

	systems		operators	
C 3	Performance assessment methodology and simulation case studies	April 2016	Process engineers, solar planners, operators	Web
C 5	Potential studies on solar process heat worldwide	April 2016	Stakeholders	Web

The following books or book chapters have been written during the course of the Task with close link to the Task activities.

Author(s)	Title	Bibliographic Reference (year, place, editor, etc.)
Muster-Slawitsch, B., Brunner, C. & Fluch, J.	Application of an advanced Pinch Methodology for the food and drink production, WIREs Energy Environment 3, (2014)	WIREs Energy Environment 3, (2014)
Hess, Stefan	Low-Concentrating, Stationary Solar Thermal Collectors for Process Heat Generation	Dissertation, De Montfort University Leicester, 2014
Davd Reay, Colin Ramshaw, Adam Harvey	Process Intensification - Engineering for Efficiency, Sustainability and Flexibility. 2nd Edition	Butterworth-Heinemann, Oxford. ISBN-10: 0080983049 ISBN-13: 978-0080983042
Hess, S	Solar Thermal Technologies for Process Heating	Hess, S 2015 'Solar Thermal Technologies for Process Heating' in *Renewable Heating and Cooling - Markets, Technologies and Applications*, ed G Stryi-Hipp, Woodhead, Cambridge, ISBN: 978-1-78242-213-6 (print), ISBN: 978-1-78242-213-6 (online), pp. 41-66.

Journal Articles, Conference Papers, Press Releases, etc.

Author(s)	Title	Publication / Conference (name of journal, newsletter, conference, etc.)	Bibliographic Reference (journal number, year, place, editor, etc.)
Mauthner F., Brunner C., Hubmann M.	7,845 m² solar thermal collectors for the Heineken Brewery	Gleisdorf Solar	June 2014
Mauthner F., Brunner C., Hubmann M.	Beschreibung und Analyse der Systemtechnik und des Anlagenbetriebes am Beispiel der solaren Prozesswärmeanlage in der	Proceedings in 24. Symposium Thermische Solarenergie in Bad Staffelstein,	May 2014

	Brauerei Goess	Deutschland	
Mauthner F., Brunner C., Hubmann M.	Angepasste solare Prozesswärmekonzepte für Brauereien	Proceedings in 23. Symposium Thermische Solarenergie in Bad Staffelstein, Deutschland	May 2013
Mauthner F., Brunner C., Hubmann M.	Manufacture of malt and beer with low temperature solar process heat	Energy Procedia	Energy Procedia Volume 48, 2014, Pages 1188–1193
Brunner C.	Ergebnisse aus dem IEA Task 49/IV Solar Process Heat for Production and Advanced Application	25. Symposium Thermische Solarenergie	OTTI, Bad Staffelstein, 6.5. – 8.5. 2015
Brunner C.	Solar Heat for Industrial Production Processes - Design Guidelines for Solar Process Heat – Tools, Monitoring and Best Practice Examples	SHC 2015 International Conference on Solar Heating, Cooling and Solar Buildings	IEA Solar Heating and Cooling Programme, Istanbul, Turkey, 02.12.15
T. Barz, C. Zauner, D. Lager, F. Hengstberger:	Modelling with experimental validation of a latent heat thermal energy storage for industrial high temperature applications	10th European Congress of Chemical Engineering	Nizza; 27.09.2015 - 01.10.2015
C. Zauner, F. Hengstberger, W. Hohenauer, C. Reichl, A. Simetzberger, G. Gerald:	Methods for Medium Temperature Collector Development Applied to a CPC Collector	International Conference on Solar Heating and Cooling for Buildings and Industry	San Francisco, USA; 09.07.2012 - 11.07.2012
C. Zauner, T. Ferhatbegović, M. Hartl, S. Manglberger, T. Themessl, S. Aigenbauer, A. Simetzberger:	Energy Labelling and Advanced Insulation for Thermal Energy Storages in Solar Applications	ISES Solar World Congress 2013	Cancun (Mexico); 04.11.2013 - 07.11.2013
C. Zauner	Simulation, Entwicklung und Prüfung von Miteltemperaturkollektoren	Gleisdorf Solar 2012,	Gleisdorf; 12.09.2012 - 14.09.2012
Bhoovarahan Thirumalai	Pay-as-you-save: Solar Energy for Industrial Heating	UNDP	
Epp, B.	ESCO concept for wheel producer	Global Solar Thermal Energy Council	2014, Baerbel Epp
Srikanth, R.	Going Solar, the economical way	The Hindu	2014, Srikanth, Chennai
Silva, R., Pérez, M., y Fernández-Garcia, A.	Modeling and co-simulation of a parabolic trough solar plant for industrial process heat	Applied Energy	Vol. 106, pp. 287-300, (2013).
R. Silva, M. Pérez, M. Berenguel, L. Valenzuela, E. Zarza	Uncertainty and global sensitivity analysis in the design of parabolic-trough direct steam generation plants for process heat applications	Applied Energy	Vol. 121, pp. 233-244, (2014).

Loreto Valenzuela, David Hernández-Lobón, Eduardo Zarza	Sensitivity analysis of saturated steam production in parabolic trough collectors	Energy Procedia	Vol. 30, pp. 765-774, (2012). SHC 2012.
Manuel Quirante, Loreto Valenzuela	Dimensioning a small-sized PTC solar field for heating and cooling of a hotel in Almería (Spain)	Energy Procedia	Vol. 30, pp. 967-973, (2012). SHC 2012.
Mario Biencinto, Lourdes González, Loreto Valenzuela, Aránzazu Fernández	Design and simulation of a solar field coupled to a cork boiling plant	Energy Procedia	Vol. 48, pp. 1134-1143, (2014). SHC 2013.
David H. Lobón, Loreto Valenzuela	Impact of pressure losses in small-sized parabolic-trough collectors for direct steam generation	Energy	Vol. 61, pp. 502-512, (2013).
Cabrera, F. J., Fernández-García, A., Silva, R. M. P., y Pérez-García, M.	Use of parabolic trough solar collectors for solar refrigeration and air-conditioning applications	Renewable and Sustainable Energy Reviews	Vol. 20, pp. 103-118, (2013).
Y. García-Ortiz, L. Valenzuela, J.J. Serrano-Aguilera, J. Yañez	Diseño de concentrador solar cilindro-parabólico de bajo costo mediante acero inoxidable para aplicaciones de bajo requerimiento energético		Oral communication. In XXXVIII Semana Nacional ANES - XI Congreso Iberoamericano, 8-10 October, 2014, Querétaro, México
Y. García-Ortiz, L. Valenzuela, J.J. Serrano-Aguilera, J. Yañez	Sistema híbrido de deshidratado de chile con energía solar fototérmica por medio de concentradores cilindro-parabólicos		Oral communication. In XXXVIII Semana Nacional ANES - XI Congreso Iberoamericano, 8-10 October, 2014, Querétaro, México
Fernández-García, A.; Rojas, E., Pérez, M., Silva, R., Hernández-Escobedo, Q., Manzano-Agugliaro, F.	A parabolic-trough collector for cleaner industrial process heat		Journal of Cleaner Production, 89, 272-285, 2015
García-Ortíz, Y., Yáñez-Mediola, J., Valenzuela, L.	Colectores cilindro parabólicos a partir de material de bajo coste (acero inoxidable) aplicado a un sistema híbrido de deshidratado		DYNA 91, 0-10, January 2016.
H. Schenk, S. Dieckmann, M. Berger, C. Zahler, O. Stoppok, D. Schulz, D. Krüger	SolSteam - Innovative integration concepts for solar-fossil hybrid process steam generation	SolarPaces 2014, Bejing	

Klaus Hennecke	Solar Process Heat and Co-Generation a review of recent developments	SolarPaces 2014, Bejing	Energy Procedia 2015 Proceedings of SolarPACES 2014
Mario Adam, Sebastian Schramm	Hydraulische Einbindung von Speichern in solare Prozesswärmesysteme	OTTI 2012 - 22. Symposium Thermische Solarenergie	Poster Session, May 2012, Bad Staffelstein, Germany
Mario Adam, Sebastian Schramm	Storage in solar process heat applications	International Conference on Solar Heating and Cooling for Buildings and Industry	Poster Session, September 2013, Freiburg, Germany
Mario Adam, Sebastian Schramm	Hydraulische Einbindung von Speichern in solare Prozesswärmesysteme	OTTI 2012 - 22. Symposium Thermische Solarenergie	Poster Session, May 2012, Bad Staffelstein, Germany
Mario Adam, Sebastian Schramm	Storage in solar process heat applications	International Conference on Solar Heating and Cooling for Buildings and Industry	Poster Session, September 2013, Freiburg, Germany
Anette Anthrakidis, Christian Faber, Marco Lanz, Mario Adam, Sebastian Schramm	Konzeptionierung, Aufbau und wissenschaftliche Begleitung einer Pilotanlage	OTTI 2010 - 20. Symposium Thermische Solarenergie	Poster Session, May 2010, Bad Staffelstein, Germany
Mario Adam, Martina Dreher, Sebastian Schramm, Anette Anthrakidis, Christian Faber, Marco Lanz	Solare-Prozesswärme-Standards	World Sustainable Energy Days 2011	Poster Session, March 2011, Wels, Austria
Christian Faber, Anette Anthrakidis, Marco Lanz, Mario Adam, Sebastian Schramm	Barriers to Solar Process Heat Applications	ISES Solar World Congress 2011	Poster Session, August 2011, Kassel, Germany
Anette Anthrakidis, Christian Faber, Marco Lanz, Mario Adam, Sebastian Schramm, Hans-Peter Wirth	Monitoring und Analyse solarer Prozesswärmeanlagen	OTTI 2013 - 23. Symposium Thermische Solarenergie	May 2013, Bad Staffelstein, Germany
Platzer, W., Heß, S., Helmke, A.	Climate Relevance in Solar Process Heat System Optimization - Case Studies with Different Temperatures and Load Profiles	SASEC 2014 Proceedings of South African Solar Energy Conference SASEC	
Helmke, A., Kumar, D., Heß, S., Stryi-Hipp, G.	Solare Prozesswärme in Indien – Markterschließung und Systemtechnik	23. OTTI-Symposium Thermische Solarenergie. Proceedings. 24.-26.04.2013, Bad Staffelstein	

Fahr, S., Kramer, K., Mehnert, S., Heß, S.	Solar Keymark certification for concentrating collectors - Comparing the quasi-dynamic and the steady-state method of EN 12975-2:2006-A1:2010	SolarPACES 11.-14.09.2012, Marrakesh	
Heß, S., Oliva, A., Helmke, A., Stryi-Hipp, G., Platzer, W.	Ergebnisse des IEE-Projekts SO-PRO: Auslegung von Solaranlagen für vier ausgewählte industrielle Prozesse	22. OTTI-Symposium Thermische Solarenergie. Proceedings 09.-11.05.2012, Bad Staffelstein	
Cuevas F., Murray C., Platzer W., Heimsath A.	Large Scale Solar Plants Integration in Electro-winning Copper Recuperation Process	SHC 2014, International Conference on Solar Heating and Cooling for Buildings and Industry. 13.-15.09.2014, Beijing	Energy Procedia
Heß, S., Hanby, V.	Collector Simulation Model with Dynamic Incidence Angle Modifier for Anisotropic Diffuse Irradiance	SHC 2013, International Conference on Solar Heating and Cooling for Buildings and Industry. 23.-25.09.2013, Freiburg	Energy Procedia
Ben Hassine, Ilyes	Operational Improvements of a Large Scale Solar Thermal Plant Used for Heat Supply in the Ham Production	EuroSun and Gleisdorf Solar	Sept. 2014 / June 2014
Ben Hassine, Ilyes	Hardware-in-the-loop Test for a Parabolic Trough Collector Plant in the Meat Industry	SHC 2015, International Conference on Solar Heating and Cooling for Buildings and Industry, 2.-4.12.2015, Istanbul	
Föste S., Giovannetti F.	Thermal Insulation for High Efficiency Flat Plate Collectors	Proceedings Eurosun 2012	Sept. 2012, Rijeka, Croatia
Jack S., Katenbrink N., Parzefall J., Rockendorf G.	Heat Transfer Characteristics of Manifolds in Solar Thermal Collectors with Heat Pipes	Proceedings Eurosun 2012	Sept. 2012, Rijeka, Croatia
Föste S, Giovannetti F, Ehrmann N, Rockendorf G	Performance and reliability of a high efficiency flat plate collector –final results on prototypes	Energy Procedia	Vol. 48, 2014, 48-57, Elsevier
Jack S., Parzefall J., Luttmann T., Janßen P., Giovannetti F.	Flat Plate Aluminum Heat Pipe Collector with Inherently Limited Stagnation Temperature	Energy Procedia	Vol. 48, 2014, 105 - 113, Elsevier
Föste S., Müller S., Giovannetti F., Rockendorf G.	Temperaturbedingte Verformung von Absorbern in hocheffizienten Flachkollektoren	OTTI 2013 - 23. Symposium Thermische Solarenergie	May 2013, Bad Staffelstein, Germany
Jack S., Föste S.,	Neuartige Sonnenkollektoren	OTTI 2014 - 24.	May 2014, Bad

Schiebler B., Giovannetti F.	mit Wärmerohren zur Begrenzung der Stagnationstemperatur und Reduzierung der Systemkosten	Symposium Thermische Solarenergie	Staffelstein, Germany
Föste S., Jack S., Schiebler B., Giovannetti F., Rockendorf G.	Heat pipe collectors for cost reduction of solar installations	Proceedings Eurosun 2014	Sept. 2014, Aix les Bains, France
Föste S., Schiebler B., Giovannetti F., Rockendorf G.	Butane Heat Pipes for Stagnation Temperature Reduction of Solar Thermal Collectors	Proceedings International Conference on Solar Heating and Cooling for Buildings and Industry 2015	December 2015, Istanbul, IN PRESS
Föste S., Pazidis A., Reineke-Koch R., Giovannetti F., Hafner B., Mercs D., Delord C.	Flat Plate Collectors with Thermochromic Absorber Coatings to Reduce Loads During Stagnation	Proceedings International Conference on Solar Heating and Cooling for Buildings and Industry 2015	December 2015, Istanbul, IN PRESS
Föste S., Pazidis A., Reineke-Koch R., Giovannetti F., Hafner B., Mercs D., Delord C., Leconte A., Papillon P.	Leistungsfähigkeit und Stagnationsverhalten von Kollektoren mit thermochromen Absorberbeschichtungen	OTTI 2015 - 25. Symposium Thermische Solarenergie	May 2015, Bad Staffelstein, Germany
Oliver Iglauer, Christian Zahler	Solar process heat for sustainable automobile manufacturing	Elsevier, Energy Procedia	Volume 30, 2012, Pages 775–782, 1st International Conference on Solar Heating and Coolingfor Buildings and Industry, San Francisco
Oliver Iglauer, Christian Zahler	A new solar combined heat and power system for sustainable automobile manufacturing	Elsevier, Energy Procedia	SHC 2013, International Conference on Solar Heating and Cooling for Buildings and Industry September 23-25, 2013, Freiburg, Germany
Bernd Hafner, Olaf Stoppok, Christian Zahler, Michael Berger, Klaus Hennecke, Dirk Krüger	Development of an integrated solar-fossil powered steam generation system for industrial applications	Elsevier, Energy Procedia	SHC 2013, International Conference on Solar Heating and Cooling for Buildings and Industry September 23-25, 2013, Freiburg, Germany

Christian Zahler, Wolfgang Striewe, Michael Berger, Oliver Iglauer, Olaf Stoppok, Dirk Krüger	Joining forces to open the market for solar heat in industry		SASEC 2014, 2nd Southern African Solar Energy Conference January 27-29, 2014, Port Elizabeth, South Africa
Martin Haagen, Christian Zahler, Elke Zimmermann, Mahmoud M. R. Al-Najami	Solar process steam for pharmaceutical industry in Jordan	Elsevier, Energy Procedia	SHC 2014, International Conference on Solar Heating and Cooling for Buildings and Industry October 13-15, 2014, Beijing, China
Martin Haagen, Christian Zahler, Elke Zimmermann	First Solar Process Steam System in Jordan at RAM Pharma		OTTI - International Conference on Solar Energy Technology in Development Cooperation November 6-7, 2014, Frankfurt, Germany
Marwan Mokhtar, Michael Berger, Christian Zahler, Dirk Krüger, Heiko Schenk and Robert Stieglitz	Direct steam generation for process heat using Fresnel collectors	International Conference of Young Scientists on Innovative Applied Renewable Energy Researches, May 18 – 20, 2015, Amman, Jordan	
M. Berger, M. Mokhtar, C. Zahler, M. M. R. Al-Najami, D. Krüger and K. Hennecke	Solar Process Steam for a Pharmaceutical Company in Jordan	SolarPaces 2015,	to be published in Energy Procedia proceedings of SolarPACES 2015
Michael Berger, Mirko Meyer-Grünefeldt, Dirk Krüger, Klaus Hennecke, Marwan Mokhtar, Christian Zahler	First Year of Operational Experience with a Solar Process Steam System for a Pharmaceutical Company in Jordan	SHC 2015	to be published in Energy Procedia of SHC 2015
Marwan Mokhtar, Michael Berger, Christian Zahler, Dirk Krüger, Heiko Schenk, Robert Stieglitz	Direct Steam Generation for Process Heat using Fresnel Collectors	Int. J. of Thermal & Environmental Engineering	Volume 10, No. 1 (2015) 3-9
Stephan Fischer, Patrick Frey	Comparison of different collector technologies for temperatures above 150 °C	Proceedings of the "Internationale Konferenz für	

		thermische Solarnutzung Gleisdorf 2012"	
Stefan Minder	Experiences with three concentrated solar thermal plants in the Swiss dairy industry	Gleisdorf Solar	June 2014
David Reay	Heat-powered cycles: are the process industries 'missing the boat'?		Int. J. Low Carbon Technology 2013; doi: 10.1093/ijlct/ctt017
David Reay, Adam Harvey	The role of heat pipes in intensified unit operations		Applied Thermal Engineering, Vol. 57, Issues 1-2, pp. 147-153, 2013.
Richard Law, Adam Harvey, David Reay	Opportunities for low-grade heat recovery in the UK food processing industry		Applied Thermal Engineering, Vol. 53, Issue 2, pp. 188-96, 2013.
Robert MacGregor, Peter Kew, David Reay	Investigation of low Global Warming Potential working fluids for a closed two-phase thermosyphon		Applied Thermal Engineering, Vol. 51, Issues 1-2, pp. 917-925, 2013.
Krummenacher P. Muster-Slawitsch B.	Methodologies and software tools for integrating solar heat into industrial processes	Paper E10049 presented at the 13th International Conference on Sustainable Energy Technologies (SET2014), 25-28th August, 2014, Geneva Paper selected for publication in a special issue of the Journal of Applied Thermal Engineering	
A. Frein, M. Calderoni, M. Motta	Solar thermal plant integration into an industrial process	SHC Freiburg 2013, later on on elsevier	
A. Fein, L. Pistocchini, V. Tatay, M. Motta	Modeling and sizing of a MW solar DSG plant	SHC 2015, International Conference on Solar Heating and Cooling for Buildings and Industry, 2.-4.12.2015, Istanbul	
Marco Calderoni, Marcello Aprile, Salvatore Moretta, Aristotelis Aidonis, Mario Motta	Solar Thermal Plants for Industrial Process Heat in Tunisia: Economic Feasibility Analysis and Ideas for a New Policy	Energy Procedia	
Walmsley, MRW, Walmsley, TG, Atkins, MJ, Neale, JR	Options for Solar Thermal and Heat Recovery Loop Hybrid System Design	Chemical Engineering Transactions	Vol 39, p361-366, (2014)

Anna Durst	Fassadenkollektoren mit Durchblick	BINE Informationsdienst, FIZ Karlsruhe GmbH Leibnitz Institut für Informationsinfrastruk tur	Projektinfo 07/2013
Rolf Meißner	Sinn und Unsinn von Solarspeichern	Heizungsjournal	HZJ 09/2012
Rolf Meissner	CPC evacuated tube collector systems for process heat up to 160 °C	ASES conference Baltimore 04/2013 paper	
Rolf Meißner	Solar Thermal System to support the district heating network in Wels	Website Ritter XL Solar	
Rolf Meißner	Solarthermische Unterstützung von Fernwärme	Sanitär- und Heizungtstechnik	SHT 11/2013
Rittmann-Frank M.H., Caflisch M., Rommel M.	Evaluation Solarer Prozesswärmesysteme in der Schweiz	Tagungsband 26. Symposium Thermische Solarenergie, Bad Staffelstein 2016	coming soon
Sallaberry F., Pujol R.,Larcher M., Rittmann-Frank M.H.	Direct tracking error characterization on a single-axis solar tracker	Energy Conversion and Management	Energy Conversion and Management 11/2015; 105:1281 - 1290. DOI: 10.1016/j.enconman.2015.08.081
J. Möllenkamp, H. Marty, M. Rommel, E. Frank, M.H. Rittmann-Frank, S. Minder	Untersuchung und Evaluierung eines Parabolrinnenkollektorfeldes für Prozesswärme in einer Schweizer Molkerei	Tagungsband 25. Symposium Thermische Solarenergie, Bad Staffelstein, 2015	
Rommel M. and Larcher M.	Experimental Investigation on the Accuracy of Alternative Devices to Measure DNI in Comparison to Tracking Pyrheliometers	SolarPACES2015 Conference, 13-16 Oct 2015, Cape Town, South Africa	SolarPACES2015 Conference
Larcher, M.; Rommel, M.; Frank, E.; Bohren, A.	CHARACTERIZATION MEASUREMENTS ON A PARABOLIC TROUGH COLLECTOR FOR PROCESS HEAT APPLICATIONS	Proceedings ISES Solar World Congress 2013; EnergyProcedia	
Rommel M. and Larcher M.	Experimental Investigation on the Accuracy of Alternative Devices to Measure DNI in Comparison to Tracking Pyrheliometers	SolarPACES2015 Conference, 13-16 Oct 2015, Cape Town, South Africa	SolarPACES2015 Conference
Frank, E.; Marty, H.; Hangartner, L.; Minder, S.	Evaluation of Measurements on Parabolic Trough Collector Fields for Process Heat Integration in Swiss Dairies	Proceedings ISES Solar World Congress 2013; EnergyProcedia	

Jordan, U., Vajen, K., Bales, C., Cortés Fortezac, P.J., Drück, H., Frank, E., Furbo, S., Heinzen, R., Lukea, A., Martinez Moll, V., Pietschnig, R., Streicher, W., Wagner, W., Witzig, A.	SolNet - PhD-scholarships and courses on Solar Heating	Proceedings ISES Solar World Congress 2013; EnergyProcedia	
Frank, E., Feuerstein, M., Minder, S.	Parabolrinnenkollektoren für Prozesswärme in Schweizer Molkereien	Tagungsband 23. Symposium Thermische Solarenergie, Bad Staffelstein, 2013	
Rommel, M., Larcher, M., Frank, E., Bohren, A., Keller, M., Riedesser, F.:	Experimental Investigations on the Optical and Thermal Characterization of a Parabolic Trough Collector.	Proceedings EuroSun Conference, Rijeka, 2012.	
Hess, S	Stationary Booster Reflectors for Solar Thermal Process Heat Generation	Hess, S 2015, 'Stationary Booster Reflectors for Solar Thermal Process Heat Generation'. Paper presented at *3rd South African Solar Energy Conference*, 11 to 13 May, Skukuza. UPSpace Institutional Repository – Dept. of Library Services, pp. 153-158.	
Iparaguirrea, I., Huidobro, A. , Fernández-García, A., Valenzuela, L., Horta, P., Sallaberry, F., Osório, T., Sanz, A.	Solar thermal collectors for medium temperature applications: a comprehensive review and updated database	SHC 2015, International Conference on Solar Heating and Cooling for Buildings and Industry, 2.-4.12.2015, Istanbul	
Pedro Horta, Tiago Osório	"Optical characterization parameters for line-focusing solar concentrators: measurement procedures and extended simulation results"	Proceedings of the SOLARPACES 2013, September 2013, Las Vegas, USA	Energy Procedia
João Marchã, Tiago Osório, Manuel Collares Pereira, Pedro Horta	"Development and test results of a calorimetric technique for solar thermal testing loops, enabling mass flow and Cp measurements independent from fluid properties of the HTF used "	Proceedings of the SOLARPACES 2013, September 2013, Las Vegas, USA	Energy Procedia
M Walmsley, T walmsley, M Atkins	Integration of Solar Heating into Heat Recovery Loops	Chemical Engineering	DOI: 10.3303/CET1335

	using Constant and Variable Temperature storage	Transactions, pp1183, vol 35, 2013	195 Copyright © 2013, AIDIC Servizi S.r.l., ISBN 978-88-95608-26-6; ISSN 1974-9791
A. Frein, M. Calderoni, M. Motta	Solar thermal plant integration into an industrial process	SHC Freiburg 2013, later on on elsevier	
Muster, B. & Brunner, C.	Solar process heat and process intensification	Process Intensification for Sustainable Energy Conversion	Wiley: Netherlands, 2015

CONFERENCES AND WORKSHOPS

Task participants presented Task work and results at 32 conferences and workshops over the course of the Task.

TASK MEETINGS

Plus Task workshops/seminars/joint meetings held in conjunction with the Task meetings.

Meeting #	Date	Location	Number of Participants (Number of Countries)
1	29 February – 1 March 2012	Fraunhofer ISE, Freiburg, Germany	32
	5 September 2012	Workshop Solar Process Heat and Process Intensification – Applications in the food industry AEE INTEC, Graz, Austria	25
2	6-7 September 2012	AEE INTEC, Graz, Austria	32
3	5-6 of March 2013	SPF, Rapperswill, Switzerland	43
4	1-2 October 2013	Tecnalia, Spain	31
5	23-24 January 2014	Stellenbosch, South Africa	25
	25 June 2014	Workshop Energy Supply for Intensified Processes	32

		AEE INTEC, Gleisdorf, Austria	
6	25-26 September 2014	Mailand, Italy	38
7	12-13 March 2015	San Sebastian, Spain	34
	15 September 2015	Industry Workshop Montpellier, France	62
8	16-17 September 2015	Montpellier, France	35

SHC TASK 49 NATIONAL CONTACTS

Country	Name	Institution/Company	Email	Role
Sweden	Joakim Byström	Absolicon Solar Concentrator AB	joakim@absolicon.com	Industry
Austria	Werner Weiss	AEEINTEC	w.weiss@aee.at	National Expert
Austria	Wolfgang Glatzl	AEE INTEC	w.glatzl@aee.at	National Expert
Austria	Franz Mauthner	AEE INTEC	f.mauthner@aee.at	National Expert
Austria	Christian Fink	AEE INTEC	c.fink@aee.at	National Expert
Austria	Christoph Brunner	AEE INTEC	c.Brunner@aee.at	Operating Agent
Austria	Muster - Slawitsch Bettina	AEE INTEC	b.muster@aee.at	Subtask B Leader
India	Viji Suresh	Aspiration Energy	viji.suresh@aspirationenergy.com	Industry
India	Karthik Krishna	Aspiration Energy	karthik.k@aspirationenergy.com	Industry
India	Bhoovarahan Thirumalai	Aspiration Energy	bhoo.thirumalai@aspirationenergy.com	Industry
Austria	Michael Monsberger	Austrian Institute of Technology	Michael.Monsberger@ait.ac.at	National Expert
Austria	Franz Helminger	Austrian Institute of Technology	franz.helminger@ait.ac.at	National Expert
Austria	Christoph Zauner	Austrian Institute of Technology	Christoph.Zauner@ait.ac.at	National Expert
Spain	Fabienne Sallaberry	Cener (Fundacion Cener - Ciemat)	fsallaberry@cener.com	National Expert
Mexico	Iván Salgado Transito	Centro de investigaciones en optica a.c.	isalgadotr@cio.mx	National Expert
Mexico	Rodolfo Coria	Cidesi	rcoria@cidesi.mx	National Expert
Mexico	Jesús Licea	Cidesi	jlicea@cidesi.mx	National Expert
Spain	Miguel Frasquet	CTAER	miguel.frasquet@ctaer.com	National Expert
Germany	Klaus Hennecke	DLR	klaus.hennecke@dlr.de	National Expert
Germany	Dirk Krüger	DLR	dirk.krueger@dlr.de	National Expert
Germany	Christian Sattler	DLR	christian.sattler@dlr.de	National Expert

Germany	Markus Peter	dp quadrat	markus.peter@dp-quadrat.de	National Expert
Germany	Sebastian Schramm	E² - Erneuerbare Energien und Energieeffizienz Fachhochschule Düsseldorf	sebastian.schramm@fh-duesseldorf.de	National Expert
Germany	Mario Adam	E² - Erneuerbare Energien und Energieeffizienz Fachhochschule Düsseldorf	mario.adam@fh-duesseldorf.de	National Expert
France	Sandrine PELLOUX-PRAYER	EDF	sandrine.pelloux-prayer@edf.fr	Industry
Belgium	Thijs Defraeye	Faculteit Bio-ingenieurswetenschappen - KU Leuven	Thijs.Defraeye@biw.kuleuven.be	National Expert
Germany	Platzer Werner	Fraunhofer ISE	werner.platzer@ise.fraunhofer.de	Subtask C Leader
Germany	Pedro Horta	Frauenhofer ISE	Pedro.horta@ise.frauenhofer.de	National Expert
Germany	Korbinian Kramer	Fraunhofer ISE	Korbinian.Kramer@ise.fraunhofer.de	National Expert
Germany	Annie Hofer	Fraunhofer ISE	annie.hofer@ise.fhg.de	National Expert
Germany	Anabell Helmke	Fraunhofer ISE	Annabell.Helmke@ise.fraunhofer.de	National Expert
Austria	Hartmut Schneider	Fresnex	hartmut.schneider@fresnex.com	Industry
Switzerland	Pierre Krummbacher	HEIG-VD / IGT - LPTherm	pierre.krummenacher@heig-vd.ch	National Expert
Switzerland	Matthias Rommel	HSR Hochschule für Technik Rapperswil	mrommel@hsr.ch	National Expert
Switzerland	Elimar Frank	HSR Hochschule für Technik Rapperswil	elimar.frank@hsr.ch	Subtask A Leader
Germany	Bastian Schmitt	IdE Institut dezentrale Energietechnologien gemeinnützige GmbH	b.schmitt@ide-Kassel.de	National Expert
Spain	Aguirre Mugica Patricio	INASMET-Tecnalia	patri.aguirre@inasmet.es	National Expert
Spain	Inigio Iparraguirre	INASMET-Tecnalia	inigo.iparraguirre@tecnalia.com	National Expert
Germany	Christian Zahler	Industrial Solar GmbH	christian.zahler@industrial-solar.de	Industry
Germany	Federico Giovannetti	ISFH - Institut für Solarenergieforschng Hameln	giovannetti@isfh.de	National Expert

Germany	Stephan Fischer	ITW Uni Stuttgart	fischer@itw.uni-stuttgart.de	National Expert
Germany	Harald Drueck	ITW Uni Stuttgart	drueck@itw.uni-stuttgart.de	National Expert
USA	Mark Thornbloom	KELELO Engineering	kelelo1@kelelo.com	Industry
France	Pierre Delmas	Montperal Energy	p.delmas@exosun.net	Industry
Switzerland	Stefan Minder	NEP Solar	stefan.minder@nep-solar.com	Industry
USA	Mark Swansburg	Paradigm Partners | A Top Down Approach to Building Efficiency	Mark@paradigm-partnership.com	Industry
India	C. Palaniappan	Planters Energy Network - PEN	info@pen.net.in	National Expert
Spain	Loreto Valenzuela Gutiérrez	Plataforma Solar de Almería - CIEMAT	loreto.valenzuela@psa.es	National Expert
Spain	Esther Rojas	Plataforma Solar de Almería - CIEMAT	esther.rojas@ciemat.es	National Expert
Spain	Aránzazu Fernández-García	Plataforma Solar de Almería - CIEMAT	arantxa.fernandez@psa.es	National Expert
Italy	Mario Motta	Politecnico di Milano	mario.motta@polimi.it	National Expert
Italy	Marco Calderoni	Politecnico di Milano	marco.calderoni@polimi.it	National Expert
Italy	Antoine Frein	Politecnico di Milano	antoine.frein@polimi.it	National Expert
United Kingdom	David Reay	Process Intensification Group School of Chemical Engineering and Advanced Materials [CEAM] Newcastle University, UK	david.reay@newcastle.ac.uk	National Expert
China	He Tao	Professor, Deputy Director for National Center for Quality Supervision and Testing of Solar Heating Systems, China Academy of Building Research (“CABR”)	he.tao@ymail.com	National Expert
Germany	Andreas Häberle	PSE AG	ah@pse.de	National Expert
Germany	Rolf Meissner	Ritter solar	r.meissner@ritter-xl-solar.com	Industry
Austria	Putz Sabine	S.O.L.I.D.	s.putz@solid.at	Industry

Austria	Robert Söll	S.O.L.I.D.	r.soell@solid.at	Industry
Austria	Melanie Bader	S.O.L.I.D.	m.bader@solid.at	Industry
Austria	Harald Blazek	S.O.L.I.D.	h.blazek@solid.at	Industry
Austria	Christian Holter	S.O.L.I.D.	c.holter@solid.at	Industry
Italy	Tiziana Melis	Sardegna Ricerche	melis@sardegnaricerche.it	National Expert
Italy	Marco Camerada	Sardegna Ricerche	camerada@sardegnaricerche.it	National Expert
Germany	Stauss, Reiner - Smirro	Smirro GmbH	r.stauss@smirro.com	Industry
Germany	Klemens Jakob	Smirro GmbH	k.jakob@smirro.com	Industry
Italy	Vittorio Orioli	Soltigua	vorioli@soltigua.com	Industry
Italy	Francesco Orioli	Soltigua	forioli@soltigua.com	Industry
Switzerland	Mercedes Hannelore Rittmann-Frank	SPF Institut für Solartechnik SPF Hochschule für Technik HSR	mh.rittmann-frank@spf.ch	National Expert
Switzerland	Marco Larcher	SPF Institut für Solartechnik SPF Hochschule für Technik HSR	marco.larcher@solarenergy.ch	National Expert
Switzerland	Andreas Bohren	SPF Institut für Solartechnik SPF Hochschule für Technik HSR	andreas.bohren@solarenergy.ch	National Expert
Spain	Ralf Wiesenberg	Sun to Market Solutions S.L.	rwiesenberg@s2msolutions.com	Industry
Spain	Daniel Rayo	Sun to Market Solutions S.L.	drayo@s2msolutions.com	Industry
France	Kevin MOZAS	Sunti	km@sunti.fr	National Expert
Spain	Víctor Martínez Moll	Tecnologia Solar Concentradora	victor.martinez@tsc-concentra.com	National Expert
India	Kiran Deshpande	Thermax	kdeshpan@thermaxindia.com	Industry
Austria	Schnitzer Hans	TU Graz IPP	hans.schnitzer@tugraz.at	National Expert
Switzerland	Marco Scarpellino	TVP	scarpellino@tvpsolar.com	Industry
Switzerland	Vittorio Palmieri	TVP	palmieri@tvpsolar.com	Industry
Austria	DRAECK, Mark	UNIDO	M.Draeck@unido.org	National Expert
Austria	Khac Tiep NGUYEN	UNIDO	K.Nguyen@unido.org	National Expert
Mexico	M. Humberto González Bravo	Universidad Autónoma	hegb@correo.azc.uam.mx	National Expert

		Metropolitana		
Mexico	Fernando Sosa Montemayor	Universidad Autónoma Metropolitana	fernando.sosa@cimav.edu.mx	National Expert
Germany	Klaus Vajen	Universität Kassel	vajen@uni-kassel.de	National Expert
Germany	Steven Meyers	Universität Kassel	meyers@uni-kassel.de	National Expert
Germany	Dominik Ritter	Universität Kassel	d.ritter@uni-kassel.de	National Expert
Germany	Bastian Schmitt	Universität Kassel	bschmitt@uni-kassel.de	National Expert
Portugal	Tiago Osório	University of Évora	tiagoosorio@uevora.pt	National Expert
Spain	Julian Hertel	University of the Balearic Islands	julian.hertel@uib.es	National Expert
South Africa	Van Niekerk Wikus	University Stellenbosch	wikus@sun.ac.za	National Expert
South Africa	Stefan Hess	University Stellenbosch	stefanhess@sun.ac.za	National Expert
South Africa	Eugéne Joubert	University Stellenbosch	ecjoubert@sun.ac.za	National Expert
South Africa	Billy De Lange	University Stellenbosch	billyde@iafrica.com	National Expert
Germany	Ilyes Ben Hassine	ZAFH - Hochschule für Technik Stuttgart	ilyes.benhassine@hft-stuttgart.de	National Expert
Germany	Pietruschka Dirk	ZAFH - Hochschule für Technik Stuttgart	dirk.pietruschka@hft-stuttgart.de	National Expert
Germany	Michael Zettl	Zettl	michael.zettl@zettl-munich.de	Industry

1. Huidobro, A., et al., *Medium temperature solar collectors Database* 2015: project funded under the 7th framework programme (FP7).

Task 51

Solar Energy in Urban Planning

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

TASK DESCRIPTION

The main objective is to support urban planners, authorities and architects to achieve architectural integration of solar energy solutions (active and passive) in urban areas, and eventually whole cities, thus creating cities with a large renewable energy supply. The types of support being developed in this Task include processes, methods and tools capable of assisting cities in developing a long term urban energy strategy, including heritage and aesthetic issues and solar integration in sensitive landscapes. As part of this work, participants will work to strengthen solar energy in urban planning education at universities by testing and developing teaching material for programs in architecture, architectural engineering and urban planning. The material will also be appropriate for postgraduate courses and continuing professional development.

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

1. Legal framework, barriers and opportunities for solar energy implementation
2. Development of processes, methods and tools
3. Case studies and action research (implementation issues, test methods/tools/ processes, test concepts for example NZEB, NZEC)
4. Education and dissemination

Task 51 will require a dialogue and cooperation with municipalities in each participating country. This ensures good communication with different key actors, gives the possibility to develop and test methods and tools, to document good examples of how to work (methods and processes) with solar energy in urban planning, and to show inspiring examples of urban planning with solar energy integration. The municipalities are also a target group in the dissemination phase.

The main objectives of the Task are subdivided into four key areas and involve:

Subtask A: Legal Framework, Barriers and Opportunities
(Lead Country: Australia)

- Investigate current legal and voluntary frameworks, barriers and urban planning needs of specific relevance to solar energy implementation.
- Review existing targets and assess the practical potential of solar energy in urban environments to support urban planning design and approval processes.
- Recommend areas in need of attention to improve the uptake of solar energy in urban planning.

Subtask B: Processes, Methods and Tools
(Lead Country: Sweden)

- Identify factors among existing processes and supportive instruments (knowledge/ methods/tools) that enable decision processes for solar energy integration in urban planning, and to elucidate development needs.
- Develop new and/or improve urban planning processes in order to facilitate passive

and active solar strategies in urban structures, both in new and existing urban area developments as well as in sensitive/protected landscapes.

- Develop new and/or improve supportive instruments (knowledge/methods/tools) and show how guidelines along with existing and new supportive instruments regarding active and passive solar energy can be incorporated and at what stage in the planning process.

Subtask C: Case Studies and Action Research

(Lead Country: Norway)

The main objective is to facilitate replication of successful practice. Complementing objectives are to:

- Coordinate a database of best practice case studies and stories across Subtask topics.
- Establish and manage action research in each participating country.
- Facilitate and document the development and testing of supportive instruments and process models in at least one city in each participating country, in cooperation with local decision makers.

View from the case study Beauséjour in Re-union Island, France.

Subtask D: Education and Dissemination

(Lead Country: Germany)

- Strengthen the knowledge and competence in solar energy and urban planning of relevant stakeholders such as universities and professionals.
- Develop and make available education material based on e.g. results from the Task. Give information on where to find relevant courses.
- Provide for dissemination and education by developing an e-learning platform, integrating methods, tools and case studies.

Scope

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

1. New urban area development
2. Existing urban area development
3. Sensitive/protected landscapes (solar fields)

In all three environments listed above, both solar thermal and photovoltaics will be taken into account within the Task. In addition, passive solar will be considered in the urban environment (1 and 2). Passive solar includes passive solar heating, daylight access and outdoor thermal comfort.

In order to achieve a substantial contribution to increased use of solar energy, Task 51 focuses on how to improve and accelerate the integration of solar energy in urban planning that respects the quality of the urban context. The main work will be on active solar strategies due to a great need of development in this area, related to urban planning. The Task will not cover the whole complex context of urban planning.

Subtasks A to C reflect different stages in the urban planning process. Subtask A sets the current boundary conditions for solar integration, deals with the assessment of available potential and elucidates opportunities. Subtask B deals with processes, methods and tools and developments for the applied phase related to specific situations (new development areas, existing urban areas, landscapes). Subtask C focuses on implementation issues; tests of processes, methods and tools, tests of concepts (e.g. NZEB/NZEC) through case stories and showing good examples as case studies. Finally, Subtask D covers the dissemination focused on tertiary education and continuing professional development (CPD).

Main Deliverables

Subtask A: Legal Framework, Barriers and Opportunities

D.A1. Review on existing urban planning legislations and voluntary initiatives (Subtask A) and on existing urban planning processes (Subtask B) in participating countries.

D.A2. Report on the barriers, challenges and needs of urban planning for solar energy implementation.

D.A3. Report on current solar energy targets and assessment of solar energy potential in urban areas from participating countries.

Subtask B: Processes, Methods and Tools

D.B1. Review on existing urban planning legislations and voluntary initiatives (Subtask A) and on existing urban planning processes (Subtask B) in participating countries.

D.B2. Improved and/or new supportive instruments (knowledge/methods/tools).

D.B3. Guidelines: Presentation of developed generic process models with recommendations and guidelines on how to use them when adjusting for local planning, based on lessons learnt from Subtask C, as well as recommendations of needs for improved or new supportive instruments (knowledge/methods/ tools).

D.B4. Report on Multi-Criteria Decision Making. NEW!

Subtask C: Case Studies and Action Research

D.C1. Database of best practices.

D.C2. Documentation of activities supporting the creation and management of action research in each participating country: exhibitions, public hearings, quality programmes, jury work, presentations to decision makers, interviews, legislation work, creation of incentives etc.

D.C3. Documentation reports of testing of supportive instruments in partner cities: preparation, implementation and assessment of results (link to Subtask B).

Subtask D: Education and Dissemination

D.D1. Report on the state-of-the-art in education regarding urban planning with solar energy, for countries participating in the Subtask.

D.D2. Make available and inform about teaching material/packages for tertiary education and for CPD.

D.D3. Carry out seminars, workshops, summer schools and symposia, which support the knowledge exchange.

D.D4. A web-based learning platform.

D.D5. Website on innovative solar products.

D.D6. Best practice guidelines for urban planning with solar energy based on, and referring to, developed processes, methods, tools, strategies and case studies/stories – presented in an "umbrella document" with links to Task results and deliverables (joint with all Subtasks).

Task Duration

This Task started on May 1, 2013 and will end April 30, 2017.

Participating Countries

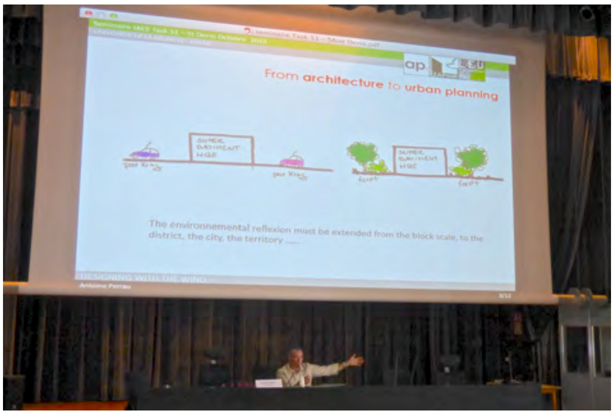
Australia, Austria, Canada, China, Denmark, France, Germany, Italy, Norway, Sweden and Switzerland.

Luxembourg is also participating, while waiting to become a formal member of the IEA SHC Programme. See the list of the participants at the end. Updates on participation and results from the Task are available on the website http://task51.iea-shc.org/.

WORK DURING 2015

We are reviewing existing urban planning legislation and voluntary initiatives (Subtask A) and urban planning processes (Subtask B) in participating countries. Barriers, challenges and needs have been studied. Development needs regarding methods and tools have been identified to see what we need to focus on in our next developments. A report on this work will be finalized (D.A1/D.B1) in mid 2016. Also, Subtask B decided to add a new deliverable, a report on multi-criteria decision making (D.B4). This report will give a theoretical background to the complex decision making context in urban planning, present ways on how to inform and support decision making in urban planning regarding solar, and present how new and developed approaches, methods and tools fit into this context. Subtask C focused on identifying, analyzing and documenting case studies. So far 34 cases have been documented and more will be added. Two deliverables are documenting case studies; one report including all the cases and brochures describing single case studies or comparisons between cases. In Subtask D the work has mainly centered on the state-of-the-art report on education regarding urban planning with solar energy. The final draft report will be published in 2016.

In connection to the Task meeting in Trondheim in March, a full day symposium was held with presentations by Task 51 experts and by local actors. In conjunction to the Task meeting in Reunion Island in October, a public symposium was also held.



The symposium in Saint-Denis, Reunion Island. Approximately 160 participants representing urban planners, architects, consultants, regional councils, French government representatives, local energy agency, social housing companies, private (energy) companies, researchers, teachers and master students. The symposium was held in a bioclimatic lecture theater.

WORK PLANNED FOR 2016

- Finalize the review on existing urban planning legislation and voluntary initiatives (Subtask A) and on existing urban planning processes (Subtask B), in participating countries.
- Finalize the state-of-the-art in education regarding urban planning with solar energy, for participating countries (Subtask D).
- Work on the reports D.A2 on the barriers, challenges and needs of urban planning for solar energy implementation, and D.A3 on current solar energy targets and assessment of solar energy potential in urban areas. (Subtask A)
- Work on the first draft of the new deliverable; D.B4 Report on Multi-Criteria Decision Making. (Subtask B)
- Test supportive instruments (knowledge/methods/tools) (Subtask B linked to Subtask C).
- Work on describing the developed generic process model, to include in different deliverables (Subtask B linked to Subtask C).
- Work on documenting all case studies and finalize brochures and a report on the case studies (Subtask C).
- Identify and finalize additional key cases (Subtask C).
- Continue to develop and test the web-based learning platform. (Subtask D).
- Continue to develop the structure of the common guideline (umbrella document) (Subtask D with support from all Subtasks).
- Three public seminars will be arranged in conjunction with the meeting in Stockholm (March 2016).
- A summer school will be arranged in conjunction with the Task meeting in Berlin, in September.

TASK REPORTS/RESULTS PUBLISHED IN 2015

No main reports were published in 2015.

OTHER PUBLICATIONS AND PRESENTATIONS IN 2015 (examples)

- Scognamiglio, A. 'Photovoltaic landscapes': Design and assessment. A critical review for a new transdisciplinary design vision. In *Renewable and Sustainable Energy Reviews*, 55 (2016), pp 629–661. http://dx.doi.org/10.1016/j.rser.2015.10.072
- Peronato, G., Nault, E., Cappelletti, F., Peron, F. & Andersen, M. A parametric design-based methodology to visualize building performance at the neighborhood scale. In *Proceedings of BSA 2015*.
- Hachem C., Cubi, E., & Bergerson, J. Energy performance of a solar mixed-use community. *Sustainable cities and communities Journal* (2015).
- Hachem, C. Integrated design considerations for solar communities. *Journal of Green Buildings*, vol. 10, N2.2015.
- Hachem C., Cubi, E. & Bergerson, J. Energy performance of a solar mixed-use community. *4th Climate Change Technology Conference*, Montreal, Canada (2015).
- Hachem C. Design of a base case mixed-use community and its energy performance. *6th International Building Physics Conference*, Torino, Italy (2015).
- Daiva Jakutyte-Walangitang. Tapping Solar Energy in Urban Areas as significant means to Climate Change Mitigation. The *1st International Academic Conference on Climate Change and Sustainable Heritage*, the Technical University Graz (2015).
- Nault, E., Peronato, G., Rey, E., & Andersen, M. Review and critical analysis of early-design phase evaluation metrics for the solar potential of neighborhood designs. Journal: *Building and Environment*, 92, 679–691 (2015). doi.org/10.1016/j.buildenv.2015.05.012
- Peronato, G., Rey, E., & Andersen, M. Sampling of building surfaces towards an early assessment of BIPV potential in urban contexts. The *PLEA 2015 - 31st International Conference on Passive and Low Energy Architecture*, Bologna (2015). http://www.plea2015.it/book/download.php?id=642.
- Nault, E., Rastogi, G., Rey, E., & Andersen, M. The sensitivity of predicted energy use to urban geometrical factors in various climates. *The PLEA 2015 - 31st International Conference on Passive and Low Energy Architecture*, Bologna (2015). http://www.plea2015.it/book/download.php?id=458.
- Nault, E., Rey, E., & Andersen, M. Towards a predictive model for assessing the passive solar potential of neighborhood designs. *The Building Simulation* (2015), Hyderabad.
- Lobaccaro, G., Chatzichristos, S. & Leona, V.A. Solar optimization of housing development. *SHC 2015, International Conference on Solar Heating and Cooling for Buildings and Industry*. Istanbul (2015).
- Siems, T., Simon, K. & Voss, K. State-of-the-Art: Solar Energy in Urban Planning Education. *Solar Update Newsletter* (2015).
- Kappel, K. Chapter on ´Solar City Copenhagen´ in the book *Green Solar Cities* (editors Peder Vejsig Pedersen, Jakob Klint, Karin Kappel, Katrine Vejsig Pedersen). 2015. Routledge http://www.routledge.com/books/details/9780415731195/
- Kanters, J. *Planning for solar buildings in urban environments. An analysis of the design*

process, methods and tools, PhD Thesis (2015). Lund University, Division of Energy and Building Design; Report EBD-T-15/19.
- Nault, E., Peronato, G., & Andersen, M. (2015). Forme urbaine et potential solaire (2015). In E. Rey (Ed.), *Urban Recovery.* Lausanne: Presses Polytechniques et Universitaires Romandes (PPUR).

SEMINARS AND WORKSHOPS IN 2015 (Task organized)

- Public symposium on solar energy in urban planning. Organized by the PIMENT Laboratory, ESIROI, the Engineering School of the University of Reunion Island and ADEME. Presentations and round table discussions, by Task experts and local actors. 2nd October 2015, Saint-Denis, Reunion Island.
- Workshop/seminar on solar energy in urban planning; education, tools and case studies. Presentations and posters by experts and international students. Coordinated by NTNU. 18th March 2015, Trondheim.
- Public Symposium on solar energy in urban planning. Presentations by Task 51 experts and local actors. Coordinated by NTNU. 20th March 2015, Trondheim.

MEETINGS IN 2015

5th Experts Meeting
March 17 - 20
Trondheim, Norway
(Including student workshop and public symposium)

6th Experts Meeting
September 28 - October 2
Reunion Island, France
(Including public symposium)

MEETINGS PLANNED FOR 2016

7th Experts Meeting
March 7 - 11
Stockholm, Sweden
(Including two seminars and a public symposium)

8th Experts Meeting
September 27 - 30
Berlin, Germany
(Including summer school and public symposium)

SHC TASK 51 NATIONAL CONTACTS

TASK MANAGEMENT

OPERATING AGENT
Maria Wall
Energy and Building Design
Lund University
P.O. Box 118
SE-221 00 Lund
SWEDEN
maria.wall@ebd.lth.se

SUBTASK A LEADER
Mark Snow
School of PV and Renewable Energy Engineering
University of New South Wales
NSW 2052, Sydney
AUSTRALIA
m.snow@unsw.edu.au

SUBTASK B LEADERS
Marja Lundgren & Johan Dahlberg
White Arkitekter AB
Östgötagatan 100
Box 4700
SE-116 92 Stockholm
SWEDEN
marja.lundgren@white.se
johan.dahlberg@white.se

SUBTASK C LEADERS
Annemie Wyckmans, Carmel Lindkvist & Gabriele Lobaccaro
Department of Architectural Design, History and Technology, Faculty of Architecture and Fine Art
Norwegian University of Science and Technology (NTNU)
NO-7491 Trondheim
NORWAY
annemie.wyckmans@ntnu.no
carmel.lindkvist@ntnu.no
gabriele.lobaccaro@ntnu.no

SUBTASK D LEADERS
Tanja Siems & Katharina Simon
Lehrstuhl Städtebau
Bergische Universität Wuppertal
Haspeler Str. 27
DE-42285 Wuppertal
GERMANY
siems@uni-wuppertal.de
ksimon@uni-wuppertal.de

NATIONAL CONTACTS

AUSTRALIA
Mark Snow
School of PV and Renewable Energy Engineering
University of New South Wales
m.snow@unsw.edu.au

AUSTRIA
Daiva Jakutyte-Walangitang & Hans-Martin Neumann
Energy Department
AIT, Austrian Institute of Technology
daiva.walangitang@ait.ac.at
hans-martin.neumann@ait.ac.at

Thomas Mach
Institut für Wärmetechnik
Technische Universität Graz
thomas.mach@tugraz.at

Michael Malderle
Institute for Urbanism
University of Technology Graz
malderle@tugraz.at

Ernst Rainer
Institute for Urbanism
University of Technology Graz
ernst.rainer@tugraz.at

Beatrice Unterberger
BauXund Forschung und Beratung GmbH
unterberger@bauxund.at

Tobias Weiss
Fachhochschule Salzburg GmbH
Salzburg University of Applied Sciences
tobias.weiss@fh-salzburg.ac.at

CANADA
Caroline Hachem-Vermette
University of Calgary
caroline.hachem@ucalgary.ca

Pamela Robinson Elisa Bernier & Graham Haines
School of Urban and Regional Planning
Ryerson University
pamela.robinson@ryerson.ca
ebernier@ryerson.ca
ghaines@ryerson.ca

Miljana Horvat & Kelsey Saunders
Department of Architectural Science
Ryerson University
mhorvat@ryerson.ca
kelsey.saunders@ryerson.ca

Alexandre Pavlovski, Vladimir Kostylev & Marlene Moore
Green Power Labs Inc.
ampavlovski@greenpowerlabs.com
vkostylev@greenpowerlabs.com
marlene.moore@greenpowerlabs.com

CHINA (observer)
Jianqing He
CTO, China National Engineering Research Centre for Human Settlements
hejq@cadg.cn

DENMARK
Olaf Bruun Jørgensen
Esbensen Consulting Engineers A/S
obj@esbensen.dk

Karin Kappel
Solar City Copenhagen
Arkitekternes Hus
kk@solarcity.dk

Stig Mikkelsen
Mikkelsen Arkitekter A/S
smi@mikkelsengroup.dk

Simon Stendorf Sørensen
PlanEnergi
sss@planenergi.dk

FRANCE
François Garde, Aymeric Delmas & Divya Leducq
ESIROI/PIMENT
University of La Réunion
francois.garde@univ-reunion.fr
aymeric.delmas@imageen.re
divya.leducq@univ-reunion.fr

Christophe Menezo
University of Savoie Mont-Blanc
INSA-LYON
christophe.menezo@insa-lyon.fr

Anne Monnier
Akuo Energy
monnier@akuoenergy.com

Marjorie Musy
Laboratoire CERMA UMR CNRS/MCC
ENSA Nantes
marjorie.musy@cerma.archi.fr

GERMANY
Christoph Maurer & Christoph Cappel
Fraunhofer Institute for Solar Energy Systems ISE
Solar Façades, Division Thermal Systems and Buildings
christoph.maurer@ise.fraunhofer.de
christoph.cappel@ise.fraunhofer.de

Gustav Hillmann & Margarethe Korolkow
IBUS GmbH – Institut für Bau-, Umwelt- und Solarforschung
hillmann@ibus-berlin.de
margarethe.korolkow@ibus-berlin.de

Tanja Siems & Katharina Simon
Lehrstuhl Städtebau
Bergische Universität Wuppertal
siems@uni-wuppertal.de
ksimon@uni-wuppertal.de

Karsten Voss
Lehrstuhl Bauphysik und Technische Gebäudeausrichtung
Bergische Universität Wuppertal
kvoss@uni-wuppertal.de

Ursula Eicker, Romain Nouvel & Sylvia Bialk
Stuttgart University of Applied Sciences (HFT)
ursula.eicker@hft-stuttgart.de
romain.nouvel@hft-stuttgart.de
alexandra.fischer@hft-stuttgart.de
sylvia.bialk@hft-stuttgart.de

ITALY
Daniele Vettorato, Giulia Degan & Roberto Vaccaro
European Academy EURAC
daniele.vettorato@eurac.edu
giulia.degan@eurac.edu
roberto.vaccaro@eurac.edu

Andrea Giovanni Mainini
Architecture, Built Environment and Construction Engineering Department
Politecnico di Milano
andreagiovanni.mainini@polimi.it

Rossana Paparella, Matteo Gobbi & Giovanni Brugnaro
Department of Civil, Environmental and Architectural Engineering
Padua University
rossana.paparella@unipd.it
matteo.gobbi@libero.it
giovanni.brugnaro@gmail.com

Alessandra Scognamiglio
Photovoltaic Technologies Unit
ENEA
Research Centre Portici
alessandra.scognamiglio@enea.it

LUXEMBOURG (observer)
Ulrich Leopold
Luxembourg Institute of Science and …Technology
ulrich.leopold@list.lu

NORWAY
Bjørn Brekke, Lene Lad Johansen & John Paloma Nwankwo
Oslo Municipality
bjorn.brekke@oby.oslo.kommune.no
llj@oby.sol.kommune.no
johnpalo-
ma.nwankno@oby.oslo.kommune.no

Clara Good, Carmel Lindkvist, Gabriele Lobaccaro & Annemie Wyckmans
Department of Architectural Design, History and Technology, Faculty of Architecture and Fine Art
Norwegian University of Science and Technology (NTNU)
clara.good@ntnu.no
carmel.lindkvist@ntnu.no
gabriele.lobaccaro@ntnu.no
annemie.wyckmans@ntnu.no

Siri M L Joli & Lisbet F. Nygaard
Dale Eiendomsutvikling AS
siri.joli@daleeiendom.no
lisbet.nygaard@daleeiendom.no

SWEDEN
Marja Lundgren, Johan Dahlberg & Sara Dahman Meyersson
White Arkitekter AB
marja.lundgren@white.se
johan.dahlberg@white.se
sarah.dahman@white.se

Maria Wall & Jouri Kanters
Energy and Building Design
Lund University
maria.wall@ebd.lth.se
jouri.kanters@ebd.lth.se

SWITZERLAND
Pierluigi Bonomo, Francesco Frontini, Erika Saretta & Cristina Polo Lópes
University of Applied Sciences and Arts of Southern Switzerland (SUPSI)
Department of Environment Constructions and Design (DACD)
Institute of Applied Sustainability to the Built Environment (ISAAC)
Swiss BiPV Competence Centre
pierluigi.bonomo@supsi.ch
francesco.frontini@supsi.ch
erika.saretta@supsi.ch
cristina.polo@supsi.ch

Maria Cristina Munari Probst, Christian Roecker & Pietro Florio
Laboratory for Solar Energy and Building Physics (LESO-PB)
Ecole Polytechnique Fédérale de Lausanne (EPFL)
EPFL ENAC IIC LESO-PB
mariacristina.munariprobst@epfl.ch
christian.roecker@epfl.ch
pietro.florio@epfl.ch

Emilie Nault & Guiseppe Peronato
Interdisciplinary Laboratory of Performance-Integrated Design
Ecole Polytechnique Fédérale de Lausanne (EPFL)
EPFL – ENAC – IA – LIPID
emilie.nault@epfl.ch
guiseppe.peronato@epfl.ch

Task 52

Solar Heat and Energy Economics in Urban Environments

Sebastian Herkel
Fraunhofer ISE
Operating Agent for BMWi

TASK DESCRIPTION

Objectives

The Task focuses on the analysis of the future role of solar thermal in energy supply systems in urban environments. Based on an energy economic analysis - reflecting future changes in the whole energy system - strategies and technical solutions as well as associated chains for energy system analysis will be developed. Good examples of integration of solar thermal systems in urban energy systems will be assessed and documented.

Scope

Subtask A: Energy Scenarios
(Lead Country: Denmark)

The content of Subtask A is about:

- Using energy system analyses and GIS based data for creating scenarios highlighting the use of solar thermal in future energy systems in different types of energy systems
- Identifying balances between heat or cooling savings and supply systems with relation to solar thermal
- Identifying balances between building level solar thermal and solar thermal in local district heating networks
- Identifying the role of solar thermal in integrated renewable energy systems (smart energy systems) and in particular the interrelation with combined heat and power (CPH) and heat pump production.

Subtask B: Methodologies, Tools and Case studies for Urban Energy concepts
(Lead Country: Switzerland)

The content of Subtask B is about:

- Development of methodologies with focus on performance indicators
- Energy planning tools and toolboxes (from Urban planning to neighbourhoods)
- Case studies analysis of different regions

Subtask C: Technology and Demonstrators
(Lead Country: Austria)

The content of Subtask C is about:

- Classification of relevant (renewable-based) technologies and demonstrators in urban environments
- Screening of best practice examples
- Analysis and documentation of selected best practice examples
    - Technological and economic analysis
    - Analysis of bottleneck's and success factors, lessons learned
    - Analysis of monitoring data (subject to data availability)
- Further development of (existing) business opportunities with regard to future energy supply systems

Task Duration

This Task started on 1 January 2014 and will end 31 December 2017.

Participating Countries

Austria, Denmark, Germany, Portugal and Switzerland

WORK DURING 2015

Subtask A: Energy Scenarios

The second year's activities in Subtask A were on developing and harmonizing the methodologies for energy scenarios. For four selected countries an overall Energy scenario reflecting the role of Solar Heat in four countries will be identified, including Austria, Denmark, Germany and Italy. The following modelling approaches and tools were chosen.

Model	**EnergyPLAN**	**REMod-D**	**Invert/EE-Lab**
Organisation	AAU	Fraunhofer ISE	EEG/TUV
Scenarios	100% renewable energy in 2050 Solar thermal share	100% renewable energy in 2050 Solar thermal share	100% renewable energy in 2050 Solar thermal share
Countries	AT,DE,DK,IT	DE	AT

A more detailed view on the input data for scenario development was done using the Modelling environment Invert/EE-Lab of the TU Wien.

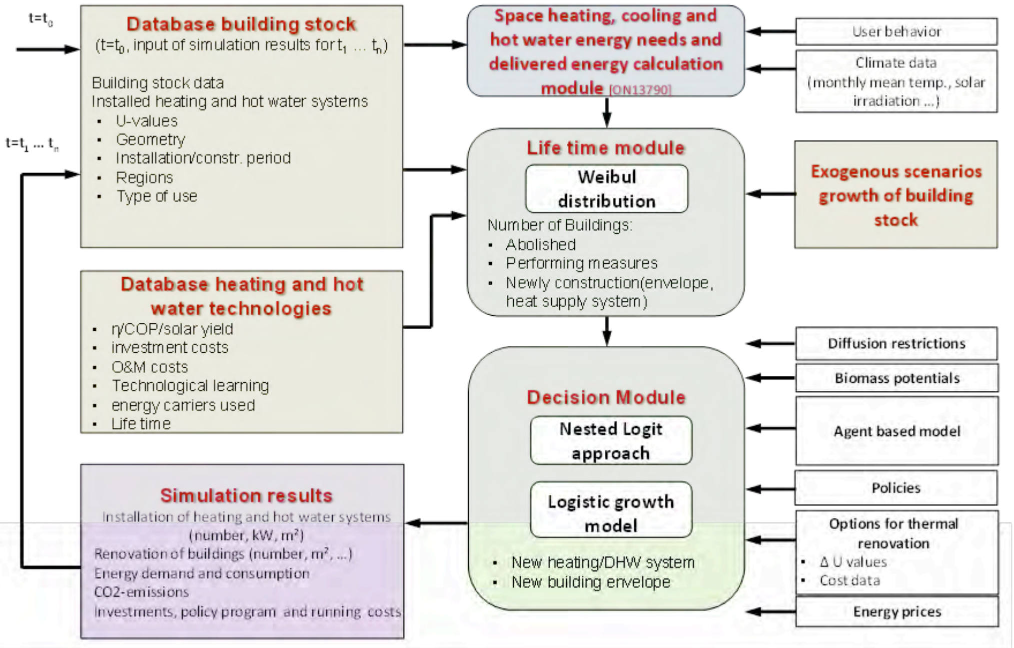


Figure 1. Overview on structure of Simulation-Tool Invert/EE-Lab. Source M. Hummel, TU Wien

Invert/EE-Lab is a dynamic bottom-up simulation tool developed to evaluate effects of different promotion schemes on the energy demand and supply in buildings in the future. It sets on a detailed database of existing buildings, heating and hot water supply systems, refurbishment options and the related costs for EU on a country level. In Task 52 Invert/EE-Lab is used in two ways: 1) detailed data on the existing building stock in the four countries under investigation (Austria, Germany, Denmark and Italy) is exported from the database, and 2) cost-potential curves for thermal energy saving measures in the building stock are developed. Both results feed into the other models used in the Task (RemoD and EnergyPLAN) to 1) build on the same data regarding properties for the existing building stock, and 2) to determine low-cost combinations of thermal savings and thermal supply for buildings. The Modelling will include 2010 as the Reference Year and 2050 as the time horizon for the scenarios. As Germany will be modelled in both available environments, it is used to bridge the modelling.

Subtask B: Methodologies, Tools and Case Studies for Urban Energy Concepts

B1: Methodology

In Subtask B the focus was on the development of the Methodology regarding the aspects off different actors in the implementation process, namely authorities, utilities and customers. The following Figures show how these were connected to each other and the indicators developed for assessment.

Methodology 1

Local and regulatory authorities

Topic	Required indicator	Unit
Technical	Irradiance density	[kWh/m2/t]
	Available area for solar potential	[m2]
	Heat density	[kWh/ha/an]
	Supply temp levels - Techno	[°C]
	Supply temp levels - Demand side	[°C]
	Shading effects	f(kWh_solar)
	Building and urban morphology	f(kWh_solar)
	Solar fraction	[%]
	System energy efficiency	[%]
Economics	System NPV (or Total Cost of Ownership)	[$]
	Price of service	[$/kWh]
	Existing subsidies	[$]
	Required subsidies	[$]
Politics	Solar penetration rate	[%]
	fossil substitution rate	[%]
	Increase of the solar rate	[%]
	Identified favorable buildings/areas	[high/low/none]
Legislation	Architectural regulations	[-]
	Land use plan (allowing for in-filed panels)	[-]
	Political framework	[-]

Tools

Methodology 2

Utilities & private business

Required indicator	Unit
Available surfaces allowing for solar panels: - Roof surface - Ground surface	 [m2/roof type] [m2/ground type]
Bldg energy system (gas boiler, electric heater, HP...) in use per service (heating, DHW)	[system type/service]
Energy services not being available (because of actual system in place) for accepting solar thermal	[lost $kWh_{solar\ th\ prod}$/ service]
Building heat demand for space heating and DHW	[kWh/bldg/service]
Concerned building-district	[$kWh_{solar\ th\ prod}$/ bldg-district]
Optimized deigned solar fraction	[kWh solar thermal/kWh needs]
Optimized deigned solar fraction	[kWh solar PV/kWh needs]
System units sizing	[m3 storage, m piping, m2 panels, kW, ...]
Cost of installing solar panels	[$/kWh/roof type] [$/kWh/ground surface]
Price of energy sold	[$]
TCO	[$]

Tools

Methodology 3

Consumers

Required indicator	Unit
Architectural, space, integration to existing system constraints,...	[high, medium, low]
Thermal substitution rate per service using solar	[%]
Recommended heat systems (incl. solar use) and priorization of the alternatives	[-]
Cost of subtitution rate	[$]
ROI of the substitution	[years/substitution rate]
Savings of own produced solar energy for own use	[$/kWh]
Savings of own produced solar energy for shared use (injected to a netwok)	[$/kWh]

Tools

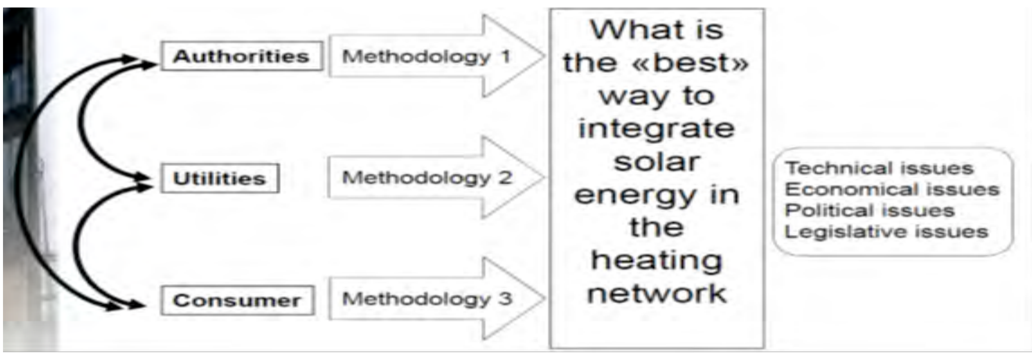


Figure 2. Methodology Matrix and Performance Indicators.

A second topic was the analysis of the relationship of the installed capacity of large solar systems in Denmark and the heat density. It could be stated that most of the installed systems were near small town urban structures. So both key requirements were fulfilled: a relative high heat density in a distance < 5 km, but free and cheap space available. The following map shows a heat density map of Denmark and installed large solar systems.

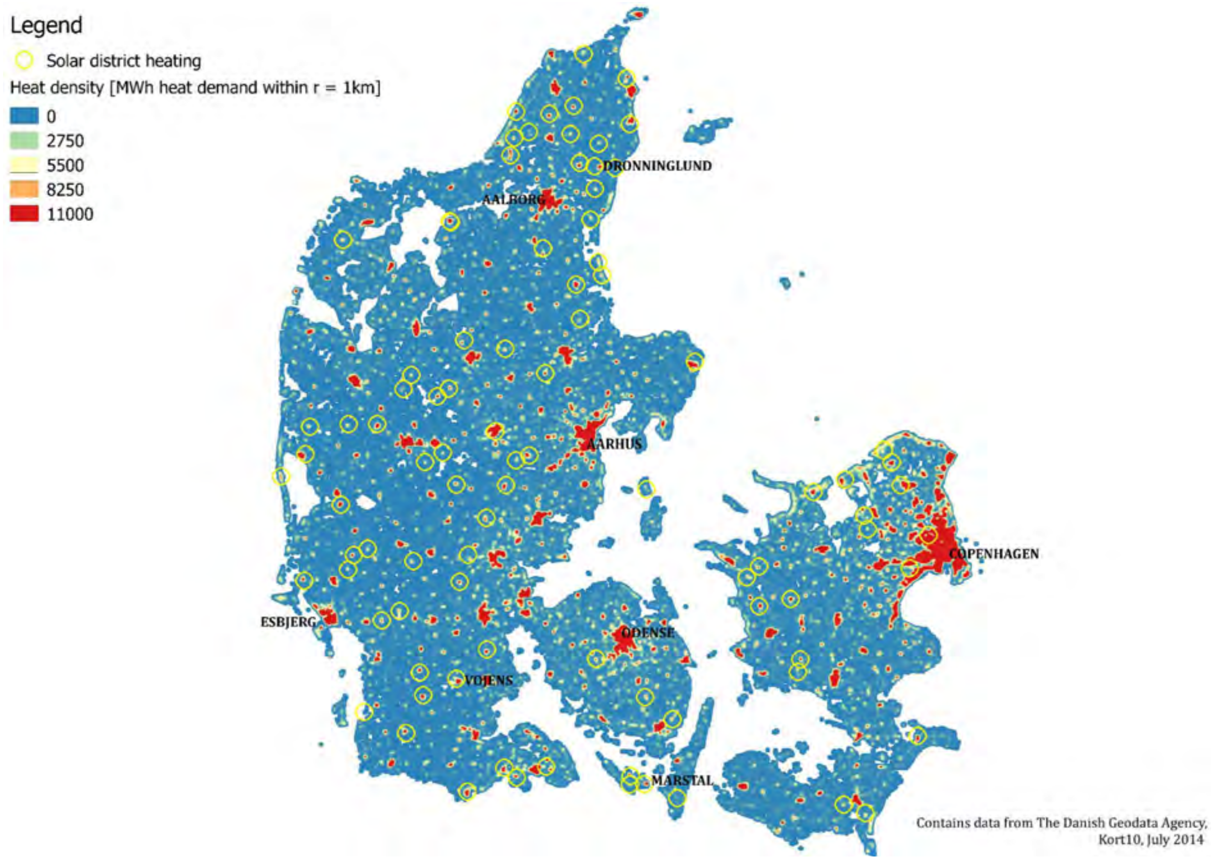


Figure 3. Heat density map of Denmark and installed large solar systems. Source: D. Trier, PlanEnergy

Subtask C: Technology and Demonstrators

In 2015 mainly activities were on a detailed cost evaluation of installation cost. Based on this evaluation cost curves for collector fields was derived for use in Subtask A (see figure 6). The following classification was developed and used for the characterization:

- ***Solar assisted heating of individual buildings***
  A1) Solar domestic hot water systems in single family homes (DHW-SFH)
  A2) Solar-combi systems in single family homes (CS-SFH)
  A3) Solar-combi systems in multi-family homes (CS-MFH)

- **Solar assisted heating of multiple buildings via thermal grid**
  B1) Solar assisted district heating (SDH)
  B2) Solar assisted heating of building blocks and urban quarters (SBH)

Results show a strong correlation of the cost of installed systems depending on the field size. While small, roof mounted systems reduce the cost down to 55%, seasonal storage will have still a relatively strong impact. Installing the systems in large areas ground mounted (SDH) will reduce the cost to a quarter compared to small systems (CS-SFH).

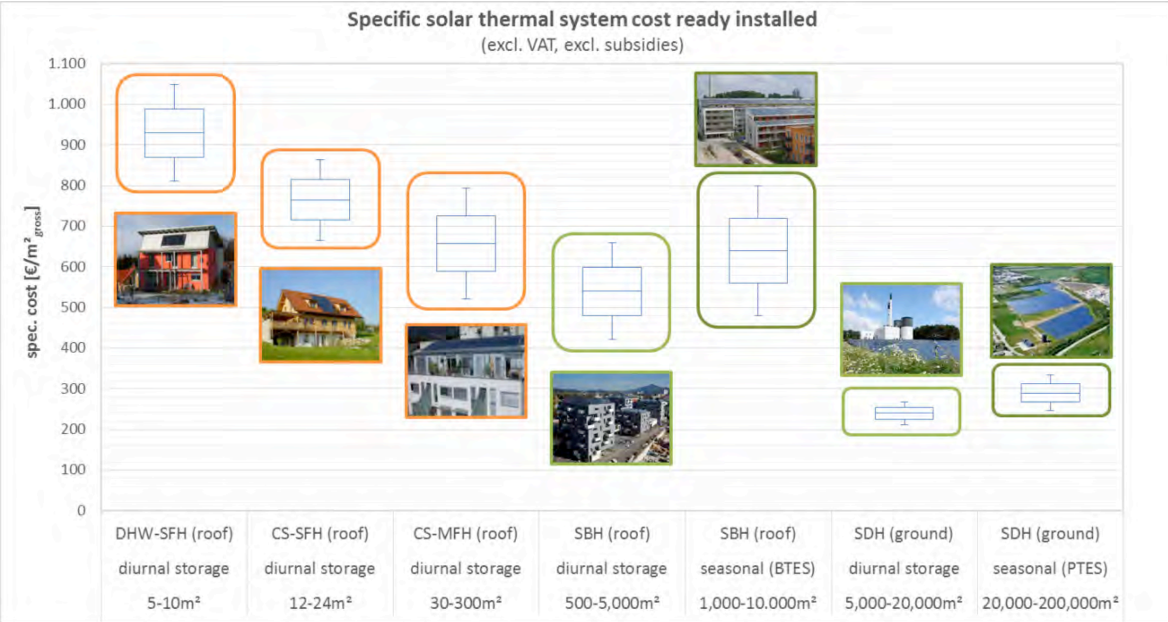


Figure 4. Typical range of specific costs per solar thermal (ST) system category ready installed (excluding VAT and subsidies). Orange: ST systems in single and multi-family homes with diurnal storage. Light Green: ST systems connected to thermal grids with diurnal storage. Dark Green: ST systems connected to thermal grids with seasonal storage. Source: F. Mauthner, AEE Intec

WORK PLANNED FOR 2016

In the three Subtasks the following work is planned for 2016.

Subtask A: Energy Scenarios

The first scenarios for the reference case for energy system analysis will be implemented. A first comparison of the different modelling approaches will be available

Subtask B: Methodologies, Tools and Case Studies for Urban Energy Concepts

The development of methodologies and performance criteria and Review on existing tools will be finalized. Based on this a tool chain for integration Solar thermal in design processes on the urban and district level will be identified. First case studies will be performed.

Subtask C: Technology and Demonstrators

The market screening and development of a matrix for best practice examples description and analysis will be finalized. The analysis and documentation of best practice examples will be started as well as an analysis and Identification of business opportunities and success factors.

REPORTS PUBLISHED IN 2015

Journal Articles, Conference Papers, etc

Author(S)	Title	Publication / Conference (name of journal, newsletter, conference, etc.)	Bibliographic Reference (journal number, year, place, editor, etc.)
Sebastian Herkel	Energiewirtschaftliche Fragestellungen der Solarthermie	Erneuerbare Energie AEE Intec	
Daniel Trier	Solare Fernwärme in Dänemark - Entwicklungen und Tends	Erneuerbare Energie AEE Intec	
Rager, Jakob, Silvia Coccolo, Jérôme Kämpf, François Maréchal, and Samuel Henchoz.	Optimisation of the Heating Demand of the EPFL Campus with an MIP Approach	In CISBAT 2015 Future Buildings and Districts - Sustainability Form Nano to Urban Scale, Vol. 1. Lausanne, Switzerland, 2015.	http://infoscience.epfl.ch/record/188138?ln=en
Rager, Jakob, François Maréchal, Mathias Pernet, Loïc Darmayan, and Gaëtan Cherix. "	Smart Heat Design: Integration and Optimization of Solar Thermal Energy and Other Resources in District Energy System Design Using Mathematical Programming	In Solar. Toulouse, France, 2015.	http://solar-district-heating.eu/newsevents/sdhconference2015.aspx
Rager, Jakob Moritz Fabian	Urban Energy System Design from the Heat Perspective Using Mathematical Programming Including Thermal Storage	EPFL, 2015.	http://infoscience.epfl.ch/record/210788
Bengt Perers	Tårs 10000 m² CSP + Flat Plate Solar Collector Plant. Cost-Performance Optimization of the Design	SHC 2015	
S. Herkel SHC	Solar Heat and Energy Economics in Urban Environments	SHC 2015	

REPORTS PLANNED FOR 2016

- Report A1 “Report on advanced energy system analyses of solar thermal concepts: Methodology report”
- Report A2 “Report on advanced energy system analyses of solar thermal concepts: Results report”
- Report C1 “Classification and benchmarking of solar thermal systems in urban environments”
- Report C2: “Analysis of built best practice examples and conceptual feasibility studies”

MEETINGS IN 2015

3rd Experts Meeting
16 - 17 April
Freiburg, Germany

4th Experts Meeting
7 - 8 October
Copenhagen, Denmark

MEETINGS PLANNED FOR 2016

6th Experts Meeting
29 - 30 September
Aalborg, Denmark

7th Experts Meeting
To be decided

SHC TASK 52 CONTACTS

TASK MANAGEMENT

Operating Agent
Sebastian Herkel
Fraunhofer ISE Germany
sebastian.herkel@ise.fraunhofer.de

Subtask A Leader
Brian Mathiesen
Aalborg University Denmark
bvm@plan.aau.dk

Subtask B Leader
Paul Bourdoukan
Sorane Switzerland
paul.bourdoukan@sorane.ch

Subtask C Leader
Franz Mauthner
AEE Intec Austria
f.mauthner@aee.at

NATIONAL CONTACTS

AUSTRIA
Marcus Hummel
TU Wien EEG Austria
hummel@eeg.tuwien.ac.at

DENMARK
David Connolly
Aalborg University Denmark
david@plan.aau.dk

Bengt Perers
DTU Denmark
beper@byg.dtu.dk

Daniel Trier
Planenergi Denmark
dt@planenergi.dk

GERMANY
Jan-Bleicke Eggers
Fraunhofer ISE Germany
jan-bleicke.eggers@ise.fraunhofer.de

Andreas Gerber
HS Biberach
gerber@hs-biberach.de

PORTUGAL
Miguel Amado
Universidade Nova de Lisboa Portugal
ma@fct.unl.pt

João Freitas
Universidade Nova de Lisboa Portugal
Jc.freitas@fct.unl.pt

Francesca Pocci
Universidade Nova de Lisboa Portugal
f.poggi@fct.unl.pt

SWEDEN
Chris *Bales*
Dalarna University, Sweden
cba@du.se

SWITZERLAND
Florian Humbert
Sorane Switzerland
florian.humbert@sorane.ch

Gabriel Ruiz
CREM Switzerland
gabriel.ruiz@crem.ch

Christine Weber
BKW, Switzerland
christine.weber@bkw.ch

Task 53

New Generation Solar Cooling & Heating Systems (PV or Solar Thermally Driven Systems)

Daniel Mugnier
TECSOL SA
Operating Agent for the French Energy Agency (ADEME)

TASK DESCRIPTION

A tremendous increase in the market for air-conditioning can be observed worldwide, especially in developing countries. The results of the past IEA SHC Tasks and work on solar cooling (for example, SHC Task 38: Solar Air-Conditioning and Refrigeration) on the one hand showed the great potential of this technology for building air-conditioning, particularly in sunny regions. On the other hand, showed that solar thermal cooling has had difficulty emerging as an economically competitive solution. There is therefore a strong need to stimulate the solar cooling sector for small and medium power sizes, which this new Task on new generation PV and solar thermal driven cooling and heating systems will focus on.

Objective and Scope

The Task objective is to create a logical follow up of the IEA SHC work already carried out by trying to find solutions to make the solar driven heating and cooling systems cost competitive. This major target should be reached thanks to five levels of activities:

1. Investigate new small to medium size PV & solar thermal driven cooling and heating systems and develop best suited cooling & heating system technology focusing on reliability, adaptability and quality.
2. Prove cost effectiveness of the above-mentioned solar cooling & heating systems.
3. Investigate life cycle performances on energy and environmental terms (LCA) of different options.
4. Support market deployment of new solar cooling and heating systems for buildings worldwide.
5. Support energy supply safety and influence virtuous demand side management behaviors.

The Task is focusing on technologies for the production of cold/hot water or conditioned air by means of solar heat or solar electricity. That is the Task will start with the solar radiation reaching the collector or the PV modules and end with the chilled/hot water and/or conditioned air transferred to the application. Although the distribution system, the building and the interaction of both with the technical equipment, is not the main topic of the Task this interaction will be considered where necessary. The main objective of this Task is to assist with the development a strong and sustainable market for solar PV or new innovative thermal cooling systems. It is focusing on solar driven systems for both cooling (ambient and food conservation) and heating (ambient and domestic hot water).

The project is divided into four Subtasks:

Subtask A: Components, Systems & Quality

A1: Reference systems
A2: New system configurations for cooling and heating
A3: Storage concepts and management
A4: Systems integration into buildings, micro grid and central Grid

A5: LCA and techno-eco comparison between reference and new systems

Subtask B: Control, Simulation & Design
B1: Reference conditions
B2: Grid access conditions and building load management analysis
B3: Models of subcomponents and system simulation
B4: Control strategy analysis and optimization for ST and PV
B5: System inter-comparison

Subtask C: Testing and Demonstration Projects
C1: Monitoring procedure and monitoring system selection criteria
C2: System description for field test and demo project
C3: Monitoring data analysis on technical issues & on performances
C4: Best practices / feedback

Subtask D: Dissemination and Market Deployment
D1: Website dedicated to the Task
D2: Handbook and simplified brochure
D3: Newsletters, workshops and conferences

Main Deliverables

The following documentation or information measures are planned during the course of the Task (corresponding the Subtask in brackets):

- State of the art of new generation commercially available products (A)
- Techno-economic analysis report on comparison between thermal and PV existing solar cooling systems including as well LCA approach and Ecolabel sensibility (A)
- Technical report on optimized control strategies for solar cooling & heating systems (B)
- Design tool including a country- and climate-sensitive economic analysis (B)
- Technical report on monitoring data analysis (technical issues + performances) (C)
- Technical report presenting a draft testing method for a quality standard on new generation cooling & heating systems (C)
- Website dedicated to the Task (D)
- Industry workshops addressing target groups (related to Experts meetings) (D)
- Handbook for new generation solar cooling and heating systems (D)
- Simplified short brochure (D) jointly edited by the Subtask Leader and IEA SHC program
- Guidelines for Roadmaps on New generation Solar Cooling and Heating systems (D)

Task Duration

The Task started in March 2014 and will be completed in June 2017. This is a collaborative Task with the IEA PVPS Programme.

Participating Countries

Australia, Austria, China, France, Italy, Spain, Sweden, and Switzerland

WORK DURING 2015

Task 53 held its 3rd Expert meeting in March 2015 during the Solar Cooling Week organized in Shanghai with SJTU and its 4th Expert meeting in September 2015 just before the 6th SAC OTTI conference organized in Roma.

Year 2015 has been dedicated:

- to progress on the first activities of the Task's Subtasks A, B and C, and
- to make successful dissemination action happen in Shanghai during a popular First Chinese Solar Cooling conference, just after the 3rd Task expert meeting and in Rome during a specific Task 53 workshop, just after the Task expert meeting.

Task 53 Logo Project

A logo was created for the Task to use in all the communication documents of the Task.

Task 53 Poster

A Task poster was presented during OTTI 6th SAC and SHC 2015 conferences.

Collaboration with IEA PVPS

Activities include:

- Task Liaison Officers (mainly PVPS Task 1 and SHC Task 53)
- Joint Task Meetings when possible
- Meetings at the same place & time when possible
- Joint Workshops at conferences

Conference Presentations

OTTI'S 6TH INTERNATIONAL CONFERENCE ON SOLAR AIR-CONDITIONING

OTTI e.V and Task 53 organized in autumn 2015 a specific workshop on New Generation Solar Cooling & Heating Systems focused on the status of solar cooling technology research and market developments. About 40 professionals gathered in Rome for this half-day event, which was organized by IEA SHC Task 53.

SHC 2015

The Operating Agent presented a special keynote and there were two sessions on solar cooling.

Task Training Seminars and Workshops

During these 6 events mentioned bekow, nearly 350 persons have been reached through the Task's communication.

Workshop/Seminar	Activity	Date & Location	Number of Participants	Event
Solar cooling Chinese conference – Keynote and Task results presentations (http://task48.iea-shc.org/solar-cooling-week--solar-cooling-Chinese-conference)	keynote	27/03/2015 - Shanghai	100	IEA SHC Programme
Workshop on Solar Energy for nZEB in Mediterranean Countries: Photovoltaic and Thermal	presentation	Juan les Pins – 10/09/2015	20	CLIMAMED 2015 conference
IEA PVPS Task 1 at 31st EU PVSEC Hamburg, Germany "Competitiveness, Soft Costs and New Business Cases for PV"	presentation	Hamburg - 14/09/2015	50	IEA PVPS Task 1
IEA SHC Task 49 final meeting	presentation	Montpellier – 16/09/2015	30	IEA SHC Programme
Workshop on The New Generation Solar Cooling & Heating Systems (PV or solar thermally driven systems) / IEA SHC Task 53	presentation	Roma, 23/09/2015	40	OTTI 6th SAC conference
6th OTTI SAC conference	keynote	Roma, 24/09/2015	80	OTTI 6th SAC conference

REPORTS PUBLISHED IN 2015

Several draft reports were completed. The final versions will be posted on the Task webpage when completed.

- Draft state of the art of new generation commercially available products including costs, efficiency criteria ranking and performance characterization
- Draft technical report on best practices for energy storage including both efficiency and adaptability in solar cooling systems (including KPI's).
- Draft Monitoring procedure for field test & demo systems (depending on size and

application)

WORK PLANNED FOR 2016

According to the Work Plan, the following deliverables should be available in 2016.

Subtask A: Components, Systems & Quality

- Definition of the existing cooling reference systems
- State of the art of new generation commercially available products including costs, efficiency criteria ranking and performance characterization
- Technical report on best practices for energy storage including both efficiency and adaptability in solar cooling systems (including KPI's).

Subtask B: Control, Simulation & Design

- Template for Definition of reference conditions
- Template for overview on peak demand & demand side management possibilities

Subtask C: Testing and Demonstration Projects

- Monitoring procedure for field test & demo systems (depending on size and application)
- Template for Catalogue of test/demo systems (with full description)

LINKS WITH INDUSTRY

Industry representatives participating in Task Experts Meetings as observers or participants include: COSSECO (Switzerland), CLIMATEWELL (Sweden), ATISYS (France), SOLARINVENT (Italy), VELASOLARIS (Switzerland), and YAZAKI (China).

They represent primarily engineering companies and solar cooling system manufacturers. The results of Task 53 are profitable for their business and their involvement consists of supporting and analyzing the Task work.

MEETINGS IN 2015

3rd Experts Meeting
March 25 - 26
Shanghaï, China

4th Experts Meeting
September 20 - 21
EURAC, Italy
Side event: OTTI SAC conference in Rome

MEETINGS PLANNED FOR 2016

5th Experts Meeting

April 12 - 13
Madrid, Spain
Side event: Solar Cooling Industry Workshop was held April in conjunction with the Task meeting as well as a joint exchange meeting with IEA PVPS Task 1. The objective of the industry workshop was to promote research and applications of solar cooling technologies among Spanish industry players on HVAC.

6th Experts Meeting
September 5 - 7 *(date to be confirmed)*
Winterthur, Switzerland
Side event: Conference on the Simulation of energy related building services

SHC TASK 53 NATIONAL CONTACTS

TASK MANAGEMENT

OPERATING AGENT
Daniel Mugnier
TECSOL SA
FRANCE
daniel.mugnier@tecsol.fr

SUBTASK A: COMPONENTS, SYSTEMS & QUALITY
Tim Selke
Austrian Institute of Technology GmbH
Energy Department
Sustainable Buildings and Cities
AUSTRIA
tim.selke@ait.ac.at

SUBTASK B: CONTROL, SIMULATION AND DESIGN
Roberto Fedrizzi
EURAC Research
Institute for Renewable Energy
ITALY
roberto.fedrizzi@eurac.edu

SUBTASK C: TESTING AND DEMONSTRATION PROJECTS
Richard Thygesen
Mälardalen University
School of Business, Society & Engineering
SWEDEN
richard.thygesen@mdh.se

SUBTASK D: DISSEMINATION AND MARKET DEPLOYMENT
Daniel Mugnier
TECSOL SA.
FRANCE
daniel.mugnier@tecsol.fr

NATIONAL EXPERTS & CONTACTS

AUSTRALIA
Subbu Sethuvenkatraman
CSIRO

AUSTRIA
Bettina Nocke
AEE Intec

Tim Selke
AIT Vienna

Daniel Neyer and Alexander Thür
University of Innsbruck

CHINA
Prof. Yanjun Dai
Shanghai Jiao Tong University (SJTU)

Wei Zheng
YAZAKI China

FRANCE
Daniel Mugnier
TECSOL

Paul Byrne
University of Rennes

Philippe Esparcieux
ATISYS

ITALY
Roberto Fedrizzi and Anton Soppelsa
EURAC

Marco Beccali and Sonia Longo
University of Palermo, Dept Energia

Pietro Finocchiaro
SOLARINVENT

Switzerland
Elena-Lavinia Niederhaeuser
HEFR

Andreas Witzig
VELASOLARIS

Lukas Omlin
SPF

SPAIN
Pedro Vicente Quiles
UMH

SWEDEN
Richard Thygesen
MDH

Task 54

Price Reduction of Solar Thermal Systems

Dr. Michael Köhl
Fraunhofer ISE
Operating Agent for the Projektträger Jülich

TA$K 54

TASK DESCRIPTION

Task 54 aims at the purchase price reduction for end-users of installed solar thermal systems by evaluating and developing sustainable means to reduce production and/or installation costs on material, sub-component, system-component and system level. Special emphasis is placed on the identification and reduction of post-production cost drivers such as e.g. channels of distribution and installation. An extensive market research and the definition of reference systems, cost analyses, and the study of socio-political boundary conditions for solar thermal prices in selected regions will provide the basis for the evaluation of cost-structures and the cost reduction potential. Additionally, ways to make solar thermal more attractive by improved marketing and consumer-oriented design will be explored.

The Task's work is divided into four subtasks:

Subtask A: Market success factors and cost analysis (Norway)
Subtask B: System design, installation, operation and maintenance (Germany)
Subtask C: Cost-efficient materials, production processes and components (Austria)
Subtask D: Information, dissemination and stakeholder involvement (Germany)

Subtask A: Market success factors and cost analysis

Objectives
Investigation of costs for regionally typical solar thermal systems and cost analyses of optimized systems as well as the development of suitable and innovative marketing measures.

Activities

- Definition of solar thermal and conventional reference systems:
- Cost analysis of post-production cost drivers for reference systems
- Comprehensive cost-analysis (cradle-to-grave) for reference systems
- Cost analysis of post-production cost drivers for optimized systems
- Comprehensive cost-analysis (cradle-to-grave) for optimized systems
- Political, legal and social boundary conditions
- Market success factors

Subtask B: System design, installation, operation and maintenance

Objectives
Optimization of system designs through standardized and/or prefabricated components and investigation cost-reduction potential though standardized installation.

Activities

- Definition of standardized components
- Manufacturing costs
- Technical after sales costs
- Cost optimization of reference systems
- New proposals for a 40% price reduction

Subtask C: Cost-efficient materials, production processes and components

Objectives

Evaluation of cost efficient and reliable materials and components for solar thermal systems.

Activities

- Identification of major cost drivers
- Material substitution and functional integration
- Innovative, cost-efficient processes and components

Subtask D: Information, dissemination and stakeholder involvement

Objectives

Disseminate Task 54's results to the interested public and its stakeholders through online publications (homepage, newsletters, articles), presence on conferences and scientific publications. Involve stakeholders through suitable dissemination events, e.g. workshops, expert rounds, presentations.

Activities

- Industry liaison
- Information and dissemination

Task Duration

The Task started on October 1, 2015 and will end on September 30, 2018.

Participating Countries

Australia, Austria, China, France, Germany, Italy, Norway and Switzerland

WORK DURING 2015

Subtask A: Market success factors and cost analysis

- Definition of collaboration with Editors of Solar Heat Worldwide for collection of cost data.
- Preparation of cost questionnaire for individual markets.
- Memo on procedure for publication of cost figures (when, where and by whom) early 2016.
- Distribution of responsibilities for acquiring cost data for the individual markets.

Subtask B: System design, installation, operation and maintenance

- Promising developments in collector design were presented by the following participants: KBB Kollektorbau, Viessmann, ISFH, University of Kassel, HTCO, HSR-SPF, Fraunhofer ISE, University of Florence and Sunlumo.
- Discussed was the need for more industrial partners and know how for installation and maintenance for the acquisition of these partners, Subtask B works in close

cooperation with Subtask D and plans an industry workshop in the first quarter of 2016.

Subtask C: Cost-efficient materials, production processes and components

At the Kick-Off meeting, the main objectives and planned activities were discussed and confirmed by the current participants in Subtask C Austria (AEE INTEC, APC, JKU-IPMT, Sunlumo, UIBK), Germany (Fraunhofer ISE) and Norway (Aventa, Univ. Oslo). The following results were presented:

Project C1: Identification of major cost drivers

- Overview on potential, cost-efficient system components (push-fit connectors, valves, water pumps) from other industrial sectors (automotive, floor heating)

Project C2: Material substitution and functional integration

- Polypropylene grade with improved long-term behavior under service relevant conditions
- Multi-layer inorganic-organic laminate with selective coating for pressurized single-loop non-pumped collectors

Project C3: Innovative, cost-efficient processes and components

- Design for a pumped-controlled valve for fully overheating controlled collectors (using the backcooling principle)
- Designs and manufacturing concepts for polymer based integrated collector storages
- Concept and functional model of a polymer-based cost-efficient thermosiphon collector "ThermX"

Subtask D: Information, dissemination and stakeholder involvement

- Definition of task forces for installer involvement and contact to the building industry.
- Development of a questionnaire to better understand current obstacles in installation.
- Planning of a workshop / expert round in connection to Subtask A at Intersolar 2016
- Preparation of the Task 54 presentation at SHC 2015.
- First discussions with ESTIF on how to coordinate work and benefit from mutual support.

DISSEMINATION ACTIVITIES IN 2015

- Presentation of Task 54 at the SHC 2015 Conference, Istanbul, Turkey.
- Preparation of Industry Workshop at the beginning of 2016 in cooperation with ESTIF.
- Set up and maintenance of homepage.
- First press release announcing Task 54 and kick-off.

MEETINGS IN 2015

1st Experts Meeting
October 21 - 22
Freiburg, Germany
28 participants from research and industry

MEETINGS PLANNED FOR 2016

2nd Experts Meeting
May 3 - 4
Florence, Italy

3rd Experts Meeting
May 2016
Place TBD

FUNDED PROJECTS: OVERVIEW OF FUNDED PROJECTS OF TASK 54 PARTNERS

(March 2016, to be updated: http://task54.iea-shc.org/funded-projects).

KoST: Kostenreduktion in der Solarthermie durch standardisierte Komponenten und Schnittstellen / Cost reduction in solar heat by standardized components and interfaces (04/2016 - 03/2019)
Funding: *BMWi Bundesministerium für Wirtschaft und Energie*
Partners: *Institut für Thermodynamik und Wärmetechnik (ITW) der Universität Stuttgart*

TEWISOL: Technisch-wirtschaftliche Optimierung von Solarthermischen Kombianlagen (01/2016 - 12/2018)
Funding: *BMWi Bundesministerium für Wirtschaft und Energie (Projektträger PTJ)*
Partners: *Fraunhofer-Institut für Solare Energiesysteme ISE*

IEA SHC Task 54: Preisreduktion von thermischen Solaranlagen (11/2015 - 09/2018)
Funding: *Bundesministerium für Verkehr, Innovation und Technologie BMVIT/ Österreichische Forschungsförderungsgesellschaft FFG*
Partners: *AEE INTEC, Johannes Kepler University Linz - Institute of Polymeric Materials and Testing, Universität Innsbruck, Sunlumo*

SolPol-4/5: Solar Energy Technologies based on Polymeric Materials - Novel pumped and non-pumped collector-systems (05/2014 - 04/2018)
Funding: *Klima- und Energiefond/ Österreichische Forschungsförderungsgesellschaft FFG*
Partners: *AEE INTEC, APC Advanced Polymer Compounds, Johannes Kepler University Linz - Institute of Polymeric Materials and Testing, Universität Innsbruck, Sunlumo*

HP-Koll: Kostengünstige und zuverlässige Solarsysteme durch neuartige Wärmerohr-Kollektoren / Cost Efficient and Reliable Solar Thermal Systems by Novel Heat Pipe Collectors (09/2014 - 08/2017)
Funding: *BMWi Bundesministerium für Wirtschaft und Energie (Projektträger PTJ)*
Partners: *Institut für Solarenergieforschung (ISFH), KBB Kollektorbau*

SolStream: Solarthermie – Hydroblock (05/2015 - 07/2016)
Funding: *Basisprogramm der Österreichischen Forschungsförderungsgesellschaft FFG*
Partners: *Sunlumo*

Untersuchungen zur Fertigungstechnik und Kollektorkonstruktion für Vollkunststoff-Kollektoren (runs until mid-2016)
Funding:
Partners: *Technische Hochschule Ingolstadt - Institut für neue Energie-Systeme (InES)*

SolarPipe: Solarthermie – Kunststoffrohre (05/2015 - 02/2016)
Funding: *Land Oberösterreich*
Partners: *Sunlumo*

Wirtschaftlichkeit mit System (03/2015 - 12/2015)
Funding: *Hessisches Ministerium für Umwelt, Energie, Landwirtschaft und Verbraucherschutz, Hessen Agentur*
Partners: *Universität Kassel*

SHC TASK 54 CONTACTS

TASK MANAGEMENT

Operating Agent
Dr. Michael Köhl
Fraunhofer Institute for Solar Energy Systems
Heidenhofstr. 2
D-79110 Freiburg
GERMANY
michael.koehl@ise.fraunhofer.de
www.ise.fraunhofer.de

NATIONAL CONTACTS

AUSTRALIA
Harry Suehrcke
Sunspin Pty Ltd
suehrcke@bigpond.com

AUSTRIA
Patrick Bradler
JKU Linz
patrick.bradler@jku.at

Robert Buchinger
Sunlumo
robert.buchinger@sunlumo.at

Michael Grabmann
JKU Linz
michael.grabmann@jku.at

Thomas Ramschak
AEE INTEC
t.ramschak@aee.at

Karl Schnetzinger
Advanced Polymeric Compounds
karl.schnetzinger@a-p-c.at

Nataliya Schnetzinger
Advanced Polymeric Compounds
nataliya.schnetzinger@a-p-c.at

Alexander Thür
UIBK
alexander.thuer@uibk.ac.at

Gernot Wallner
JKU Linz
gernot.wallner@jku.at

Max Wesle
Sunlumo
max.wesle@sunlumo.at

CHINA
Ma Guangbai
Linuo-Paradigma Company
whitetree3@126.com

DENMARK
Simon Furbo
Department of Civil Engineering, Technical University of Denmark (DTU)
sf@byg.dtu.dk

Klaus K.D. Kattenhøj
Grundfos Holding A/S
kkattenhoej@grundfos.com

Jan Erik Nielsen
SolarKey Int.
jen@solarkey.dk

FRANCE
Daniel Mugnier
TECSOL
daniel.mugnier@tecsol.fr

GERMANY
Sebastian Barg
WZL RWTH Aachen
s.barg@wzl.rwth-aachen.de

Mathias Ehrenwirth
Technische Hochschule Ingolstadt, Institut für neue Energie-Systeme (InES)
mathias.ehrenwirth@thi.de

Mathias Ehrenwirth
InES / Technische Hochschule Ingolstadt
mathias.ehrenwirth@thi.de

Stephan Fischer
ITW University of Stuttgart
fischer@itw.uni-stuttgart.de

Sebastian Föste
Institut für Solarenergieforschung (ISFH)
foeste@isfh.de

Federico Giovanetti
Institut für Solarenergieforschung (ISFH)
giovannetti@isfh.de

Bernd Hafner
The European Technology Platform on Renewable Heating and Cooling (RHC-Platform)
drhf@viessmann.com

Steffen Jack
KBB Kollektorbau GmbH
jack@kbb-solar.de

Lotta Koch
Fraunhofer ISE
lotta.koch@ise.fraunhofer.de

Wolfgang Kramer
Fraunhofer ISE
wolfgang.kramer@ise.fraunhofer.de

Yoann Louvet
University of Kassel
yoann.louvet@uni-kassel.de

Axel Oliva
Fraunhofer ISE
axel.oliva@ise.fraunhofer.de

Andreas Piekarczyk
Fraunhofer ISE
andreas.piekarczyk@ise.fraunhofer.de

Norbert Rohde
KBB Kollektorbau GmbH
rohde@kbb-solar.de

Sandrin Saile
Fraunhofer ISE
sandrin.saile@ise.fraunhofer.de

Bert Schiebler
Institut für Solarenergieforschung (ISFH)
schiebler@isfh.de

Karl-Anders Weiss
Fraunhofer ISE
karl-anders.weiss@ise.fraunhofer.de

ITALY

Maurizio De Lucia
University of Florence
delucia@unifi.it

Filippo Gangi
Pleion
filippo.gangi@pleion.it

Dario Saggioro
Pleion
dario.saggioro@pleion.it

NORWAY

Michaela Meir
Aventa
mm@aventa.no

John Rekstad
Aventa
jr@aventa.no

SWITZERLAND

Andreas Bohren
HSR-SPF
andreas.bohren@solarenergy.ch

Andreas Bohren
SWISSOLAR - Schweizerischer Fachverband für Sonnenenergie
andreas.bohren@solarenergy.ch

Michel Haller
HSR-SPF
michel.haller@spf.ch

Daniel Philippen
HSR-SPF
daniel.philippen@spf.ch

SHC Programme Members

As of December 2015
(check www.iea-shc.org for 2016 members & address changes)

EXECUTIVE COMMITTEE MEMBERS

AUSTRALIA

Mr. Ken Guthrie *(Chair)*
Sustainable Energy Transformation Pty Ltd
148 Spensley Street
Clifton Hill, Victoria 3068
ken.guthrie@setransformation.com.au

Alternate
Mr. Stefan Preus
Sustainability Victoria
Level 28
58 Lonsdale Street
Melbourne 3000
Stefan.preuss@sustainability.vic.gov.au

AUSTRIA

Mr. Werner Weiss
AEE INTEC
Feldgasse 19
A-8200 Gleisdorf
w.weiss@aee.at

Alternate
Mrs. Sabine Mitter
BMVIT
Radetzkystrasse 2
A-1030 Vienna
Sabine.mitter@bmvit.gv.at

BELGIUM

Prof. André De Herde
Architecture et Climat
Université Catholique de Louvain
Place du Levant, 1 (5.05.02)
B-1348 Louvain-la-Neuve
deherde@matriciel.be

CANADA

Mr. Doug McClenahan
Natural Resources Canada
1 Haanel Drive
Ottawa, Ontario K1A 1M1
doug.mcclenahan@canada.ca

CHINA

Prof. He Tao *(Vice Chair)*
China Academy of Building Research
No. 30 Beisanhuan Donglu
Beijing 100013
iac@vip.sina.com

Alternate
Mr. Zhang Xinyu
(same address as above)
zxyhit@163.com

DENMARK

Mr. Jens Windeleff
Danish Energy Agency
Amaliegade 44
DK-1256 Copenhagen K
jew@ens.dk

Alternate
Mr. Jan Erik Nielsen
SolarKey International
Aggerupvej 1
DK-4330 Hvalsö
jen@solarkey.dk

ECOWAS/ECREEE - Sponsor

Mr. Hannes Bauer
Achada Santo Antonio
ECREEE Building, 2nd Floor
Praia - C.P. 288, Cape Verde
hbauer@ecreee.org

Alternate
Mr. Jansenio Delgado
(same address as above)
jdelgado@ecreee.org

EUROPEAN COMMISSION

Mrs. Szilvia Bozsoki
European Commission – ENER C2
New Energy Technologies, Innovation and Clean Coal
Rue De Mot 24 (DM 24 3/92)
1040 Brussels, Belgium
Szilvia.BOZSOKI@ec.europa.eu

Alternate
Mr. Piero De Bonis
RTD G3: Renewable Energy Sources
European Commission
Rue du Champ de Mars 21
Office 00/066
1050 Brussels, Belgium
Piero.de-bonis@ec.europe.eu

EUROPEAN COPPER INSTITUTE – Sponsor

Mr. Nigel Cotton
Program Director
Avenue de Tervueren 168 bt 10
1150 Brussels, Belgium
Nigel.cotton@copperalliance.eu

FRANCE

Mr. Paul Kaaijk
ADEME
500 route des Lucioles
06560 Valbonne
paul.kaaijk@ademe.fr

Alternate
Dr. Daniel Mugnier *(Vice Chair)*
TECSOL SA.
105 av Alfred Kastler - BP 90434
66 004 Perpignan Cedex
daniel.mugnier@tecsol.fr

GERMANY

Ms. Mira Heinze
Projektträger Jülich
Forschungszentrum Jülich GmbH
52425 Jülich
m.heinze@fz-juelich.de

Alternate
Dr. Peter Donat
Projektträger Jülich
Forschungszentrum Jülich GmbH
Zimmerstraße 26-27
10969 Berlin
p.donat@fz-juelich.de

GULF ORGANIZATION FOR RESEARCH AND DEVELOPMENT (GORD) - Sponsor

Dr. Esam Elsarrag
GORD
Qatar Science and Technology Park
Tech 1, Level 2, Suite 203
P.O. Box 210162
Doha, Qatar
e.elsarrag@gord.qa

ITALY

Mr. Giovanni Puglisi
ENEA
Via Anguillarese 301
00123 Rome
giovanni.puglisi@enea.it

MEXICO

Dr. Wilfrido Rivera Gomez-Franco
National University of Mexico
Apdo. Postal #34
62580 Temixco, Morelos
wrgf@cie.unam.mx

NETHERLANDS

Mr. Lex Bosselaar
Netherlands Enterprise Agency
Postbus 8242
3503 RE UTRECHT
Lex.bosselaar@rvo.nl

NORWAY

Dr. Michaela Meir
Board Director
Norwegian Solar Energy Society
University of Oslo
Department of Physics
PO Box 1048 Blindern
N-0316 Oslo
mmeir@fys.uio.no

Alternate
Ms. Åse Lekang Sørensen
General Secretary
Norwegian Solar Energy Society
als@solenergi.no

PORTUGAL

Mr. João A. Farinha Mendes
LNEG – Edificio H
Estrada do Paco do Lumiar, 22
1649-038 Lisbon
Farinha.mendes@lneg.pt

Alternate
Ms. Maria João Carvalho
LNEG
Estrada do Paco do Lumiar, 22
1649-038 Lisbon
mjoao.carvalho@lneg.pt

REGIONAL CENTER FOR RENEWABLE ENERGY AND ENERGY EFFICIENCY (RCREEE) - Sponsor

Mr. Ashraf Kraidy
Senior Advisor to the Energy Department
League of Arab States
On behalf of the Federal Ministry for the Environment
Nature Conservation and Nuclear Safety in Germany
1 Tahreer Square
Cairo, Egypt
ashraf.kraidy@las.int

Alternate
Mr. Maged K. Mahmoud
Senior Technical Expert
Capacity Building Portfolio Manager
Hydro Power Building (7th Floor)
Block 11 - Piece 15, Melsa District
Ard El Golf, Nasr City
Cairo, Egypt
maged.mahmoud@rcreee.org

SINGAPORE

Mr. Tan Tian Chong
Building and Construction Authority
200 Braddell Road
579700
tan_tian_chong@bca.gov.sg

SOUTH AFRICA

Dr. Thembakazi Mali
SANEDI
P.O. Box 786141
Sandton, 2146
thembakazim@sanedi.org.za

Alternate
Mr. Barry Bredenkamp
(same address as above)
barryb@sanedi.org.za

SPAIN

Dr. María José Jiménez Taboada
Renewable Energy Division
CIEMAT
Carretera de Senés s/n
E-04200 Tabernas (Almeria)
mjose.jimenez@psa.es

Alternate
Dr. Ricardo Enríquez Miranda
Renewable Energy Division
CIEMAT
Avenida Complutense, 40
E-28040 Madrid
ricardo.enriquez@ciemat.es

SWEDEN

Dr. Jörgen Sjödin
Energy Technology Department
Swedish Energy Agency
Box 310
SE-631 04 Eskilstuna
jorgen.sjodin@swedishenergyagency.se

Alternate
Ms. Marie Claesson
(same address as above)
Marie.Claesson@swedishenergyagency.se

SWITZERLAND

Mr. Andreas Eckmanns
Federal Office of Energy
CH 3003 Bern
andreas.eckmanns@bfe.admin.ch

Alternate
Mr. Jean-Christophe Hadorn
Base Consultants SA
8 rue du Nant
CH-1211 Geneva
jchadorn@baseconsultants.com

TURKEY

Dr. Bulent Yesilata
Professor & Director
Harran University, GAP REEC
Sanliurfa
byesilata@yahoo.com
byesilata@harran.edu.tr

Alternate
Dr. Kemal Gani Bayraktar
GUNDER
Bestekar Sok, Cimen Apt. No: 15/12
Kavaklidere
Ankara
bayraktar@izcam.com.tr

UNITED KINGDOM

Dr. Robert Edwards
Dept. of Energy and Climate Change (DECC)
Science and Innovation Directorate
Area 6E
3 Whitehall Place
London, SW1A2AW
robert.edwards@decc.gsi.gov.uk

Alternate
Dr. Penny Dunbabin
(same address as above)
penny.dunbabin@decc.gsi.gov.uk

OPERATING AGENTS

Task 42 - Compact Thermal Energy Storage

Prof. Matthias Rommel
SPF Institute for Solar Technology
University of Applied Sciences Rapperswil
Oberseestr. 19
Rapperswil CH 8640, SWITZERLAND
matthias.rommel@solarenergy.ch
mrommel@hsr.ch

Task 43 - Rating and Certification Procedures

Mr. Jan Erik Nielsen
SolarKey International
Aggerupvej 1
DK-4330 Hvalsö, DENMARK
jen@solarkey.dk

Task 46 - Solar Resource Assessment and Forecasting

Dr. David S. Renné
2385 Panorama Ave.
Boulder, CO 80304 UNITED STATES
drenne@mac.com

Task 48 - Quality Assurance and Support Measures for Solar Cooling

Dr. Daniel Mugnier
TECSOL SA.
105 av Alfred Kastler - BP 90434
66 004 Perpigan Cedex, FRANCE
daniel.mugnier@tecsol.fr

Task 49 - Solar Process Heat for Production and Advanced Applications

Mr. Christoph Brunner
AEE INTEC
Feldgasse 19
A-8200 Gleisdorf, AUSTRIA
c.brunner@aee.at

Task 50 - Advanced Lighting Solutions for Retrofitting Buildings

Dr. Jan de Boer
Fraunhofer Institute of Building Physics
Nobelstr. 12
D-70569 Stuttgart, GERMANY
jdb@ibp.fraunhofer.de

Task 51 - Solar Energy in Urban Planning

Prof. Maria Wall
Dept. of Architecture and Built Environment
Lund University
P.O. Box 118
SE-221 00 Lund, SWEDEN
maria.wall@ebd.lth.se

Task 52 - Solar Heat & Energy Economics

Mr. Sebastian Herkel
Fraunhofer Institute for Solar Energy Systems
Heidenhofstr. 2

D-79 110 Freiburg, GERMANY
sebastian.herkel@ise.fraunhofer.de

Task 53 - New Generation Solar Cooling and Heating Systems

Dr. Daniel Mugnier
(same address as Task 48)

Task 54 - Price Reduction of Solar Thermal Systems

Dr. Michael Köhl
Fraunhofer Institute for Solar Energy Systems
Heidenhofstr. 2
D-79 110 Freiburg, GERMANY
michael.koehl@ise.fraunhofer.de

ADMINISTRATION

SHC Secretariat

Ms. Pamela Murphy
KMGroup
9131 S. Lake Shore Dr.
Cedar, Michigan 49621, USA
pmurphy@KMGrp.net
secretariat@iea-shc.org
communications@iea-shc.org

Webmaster

Mr. Randy Martin
R. L. Martin & Associates, Inc.
1059 Fairfield Ave.
Windsor, Colorado 80550, USA
randy@rlmartin.com

IEA Secretariat Liaison

Mr. Yasuhiro Sakuma
International Energy Agency
9 rue de la Fédération
75739 Paris Cedex 15, FRANCE
Yasuhiro.SAKUMA@iea.org

IEA SOLAR HEATING & COOLING PROGRAMME

iea Energy Technology Network

www.iea-shc.org