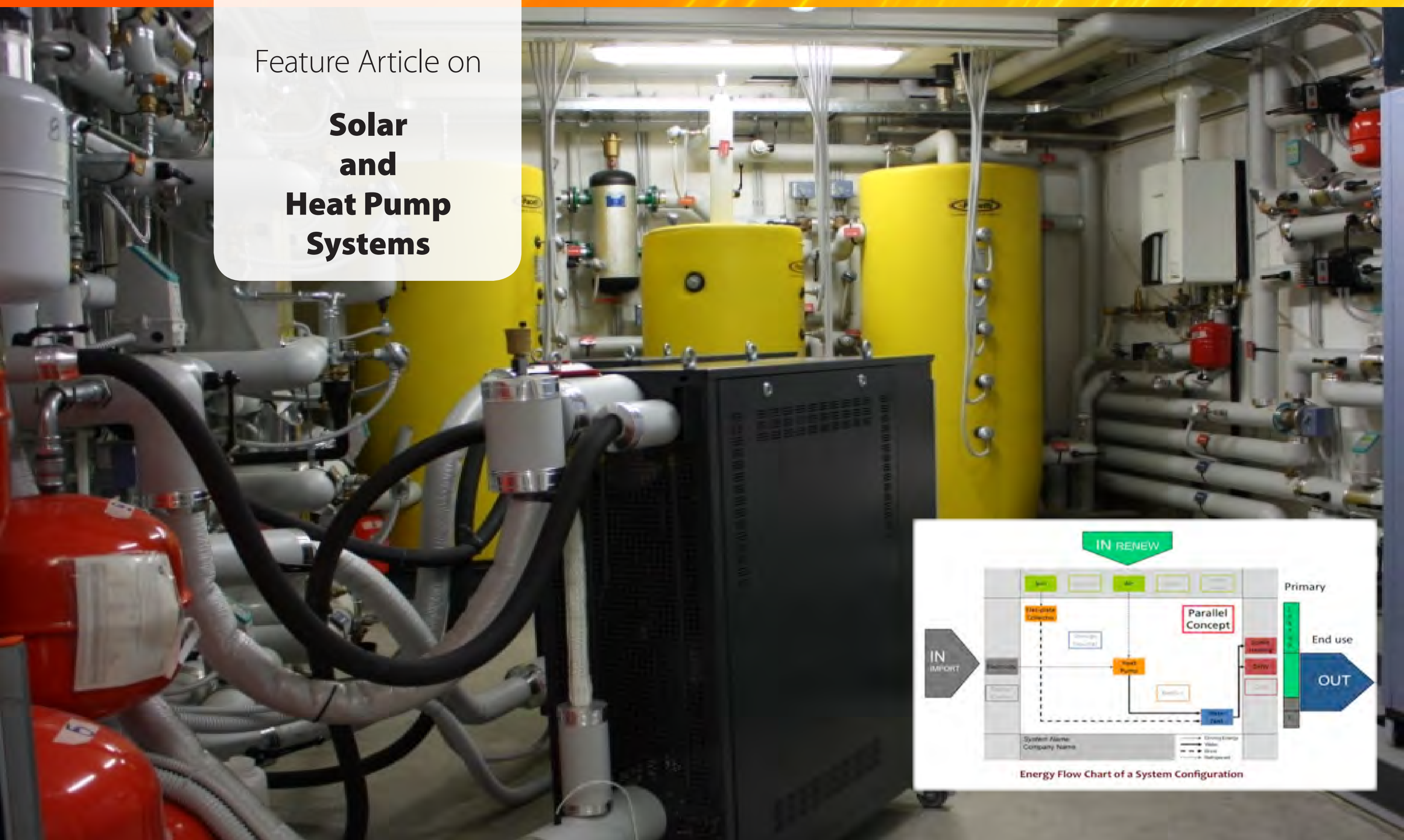
IEA SOLAR HEATING & COOLING PROGRAMME

2013

ANNUAL REPORT

Feature Article on

Solar and Heat Pump Systems



IEA Solar Heating & Cooling Programme

2013 Annual Report

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

www.iea-shc.org

June 2014

Table of Contents

Solar Heating and Cooling Programme

ABOUT THE IEA

The International Energy Agency (IEA) is an autonomous agency established in 1974. The IEA carries out a comprehensive program of energy co-operation among 28 advanced economies, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The aims of the IEA are to:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

To attain these goals, increased co-operation between industries, businesses and government energy technology research is indispensable. The public and private sectors must work together, share burdens and resources, while at the same time multiplying results and outcomes.

The multilateral technology initiatives (Implementing Agreements) supported by the IEA are a flexible and effective framework for IEA member and non-member countries, businesses, industries, international organizations and non-government organizations to research breakthrough technologies, to fill existing research gaps, to build pilot plants, to carry out deployment or demonstration programs – in short to encourage technology-related activities that support energy security, economic growth and environmental protection.

More than 6,000 specialists carry out a vast body of research through these various initiatives. To date, more than 1,000 projects have been completed. There are currently 41 Implementing Agreements (IA) working in the areas of:

- Cross-Cutting Activities (information exchange, modelling, technology transfer)
- End-Use (buildings, electricity, industry, transport)
- Fossil Fuels (greenhouse-gas mitigation, supply, transformation)
- Fusion Power (international experiments)
- Renewable Energies and Hydrogen (technologies and deployment)

The IAs are at the core of a network of senior experts consisting of the Committee on Energy Research and Technology (CERT), four working parties and three expert groups. A key role of the CERT is to provide leadership by guiding the IAs to shape work programs that address current energy issues productively, by regularly reviewing their accomplishments, and suggesting reinforced efforts where needed. For further information on the IEA, the CERT and the IAs, please consult www.iea.org.

ABOUT THE SHC IMPLEMENTING AGREEMENT

The Solar Heating and Cooling Programme 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 **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 **mission**…

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

The Solar Heating and Cooling Agreement'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 Agreement 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 Agreement'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.

The primary activity of the SHC Agreement 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 selected by the Executive Committee. Overall control of the Agreement rests with the Executive Committee comprised of one representative from each member Country and Sponsor organization in the Implementing Agreement.

A total of 53 such projects have been initiated to-date. The current Tasks are:

- New Generation Solar Heating and Cooling (Task 53)
- Solar Heat and Energy in Urban Environments (Task 52)
- Solar Energy in Urban Planning (Task 51)

1 Low temperature heat up to 250°C

- 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 Renovation of Non-Residential Buildings (Task 47)
- Solar Resource Assessment and Forecasting (Task 46)
- Large Scale Solar Heating and Cooling Systems (Task 45)
- Solar and Heat Pump Systems (Task 44)
- Solar Rating and Certification Procedures (Task 43)
- Compact Thermal Energy Storage (Task 42)
- Net Zero Energy Solar Buildings (Task 40)
- Polymeric Materials for Solar Thermal Applications (Task 39)

In addition to the project work, a number of special activities – Memorandum of Understanding with solar thermal trade organizations, statistics collection and analysis, conferences and workshops – have been undertaken. An annual international conference on solar heating and cooling for buildings and industry was launched in 2012 and the 2nd conference was held September 2013 in Freiburg, Germany.

Country Members

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

Sponsor Members

ECREEE
European Copper Institute

Chairman's Report

Werner Weiss
AEE INTEC, Austria

2013 continued to prove that the SHC Programme has much to give to the solar thermal community and that solar thermal has much to give to the world. We are working hard to share the work being done in our 14 current Tasks and the impact solar thermal is having on homes, businesses and industries. More than 300 experts from over 20 countries are working in these Tasks to develop solar thermal components and systems or to integrate solar thermal technologies in buildings, urban infrastructure or into industrial processes.

Even if the solar thermal market is challenging in some OECD countries there is growing interest in this technology and in our Implementing Agreement from all over the globe. This is shown by the fact that we welcomed a new member in 2013 and several new countries and sponsors are in the process of becoming members in 2014 and the following activities.

Our report, *Solar Heat Worldwide*, has become the most relevant source for the annual assessment of solar thermal in the important markets worldwide. The report is a leading data source due its global perspective and national data sources. The installed capacity of the 56 documented countries in 2013 represents 95% of the solar thermal market worldwide.

Our international conference series provides an opportunity for experts to gather and discuss the trending topics and learn about the work others are doing in the field. The 2nd SHC conference – *SHC 2013: International Conference on Solar Heating and Cooling for Buildings and Industry* was held September 23-25 in Freiburg, Germany and welcomed some 400 participants from 37 countries. The conference program included 100 presentations, including 10 keynote lectures, and 140 scientific posters.

Our prestigious *SHC Solar Award* recognizes individuals, companies and institutions that have made significant contributions to the growth of solar thermal. The 2013 SHC Solar Award was presented to The Drake Landing Company of Canada, comprised of four organizations – United Communities (developer), Sterling Homes (builder), ATCO Gas (utility), and the Town of Okotoks (municipality). Bruce Littke from ATCO Gas and Keith Paget from Sterling Homes received the award on the company's behalf at SHC 2013.

Our *SHC book series* being published by Wiley-VCH shares what has been learned through our work with a broad audience. The first book in the series is the first book published devoted to polymers for solar thermal applications. Other books to be published in 2014 will be on Net Zero energy Solar Buildings and Solar and Heat Pump Systems.

Each of these activities 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.

Also, come learn and share in Beijing, China at [SHC 2014: *International Conference on Solar Heating and Cooling for Buildings and Industry*](http://www.shc2014.org) on October 13-15. The Executive Committee is happy to organize this conference in cooperation with the China Academy of Building Research, and support from the Ministry of Science and Technology of the People´s Republic of China. Conference details can be found at http://www.shc2014.org.

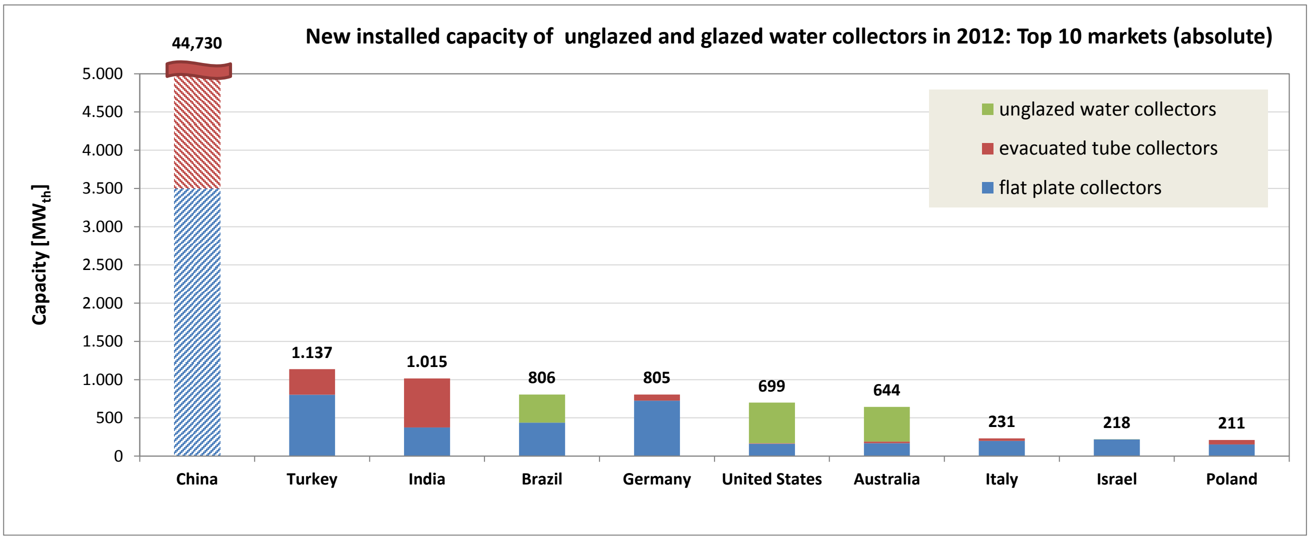
My chairmanship will come to an end in May 2014, and after four years of successful cooperation with an excellent team I want to thank the Vice Chairmen, He Tao and Ken Guthrie, all members of the Executive Committee, the Operating Agents of the Tasks as well as all the experts working in our projects, the Secretariat, Pamela Murphy, the Webmaster, Randy Martin, and our former Communications Manager, Uwe Trenkner. This excellent team has once again ensured a top-notch year for the SHC Programme.

Werner Weiss,
SHC Executive Committee Chairman

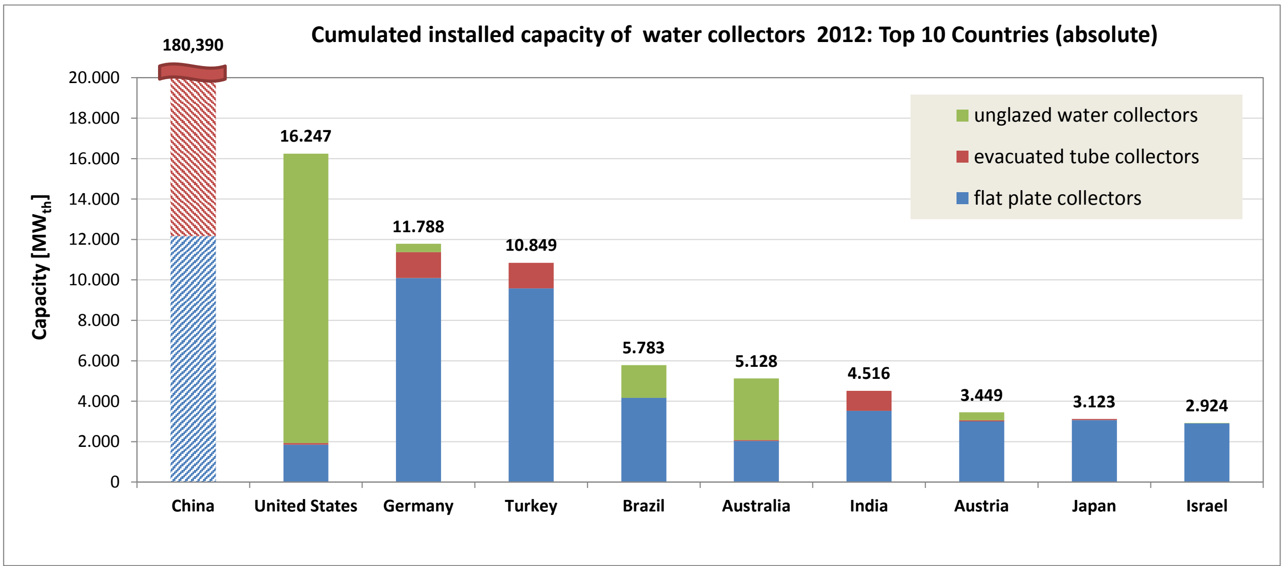
2013 RECAP

Solar Thermal Outlook

The SHC Programme publishes the only annual global statistics report, *Solar Heat Worldwide: Markets and Contribution to the Energy Supply*. The 2014 edition reports that in 2012, solar thermal technologies produced 227.8 TWh – which corresponds to an energy savings equivalent of 24.5 million tons of oil and 79.1 million tons of CO_2. The number of new installations grew by 9.4% compared to 2011 with China as a main market driver followed by Turkey, India and Brazil. In terms of the cumulated area installed, China is the absolute leader followed by the United States, Germany and Turkey.



Top 10 countries: New installations of flat-plate and evacuated tube collectors in 2012.



Top 10 countries: Cumulated water collector installations in 2012.

Key findings for 2012 data:

- Cumulated capacity in operation in 2012 was 269.3 GW_{th} (384.7 million m²):
  - 64.6% evacuated tube collectors
  - 26.4% glazed flat plate collectors
  - 8.4% unglazed water collectors
  - 0.6% unglazed air collectors

- China and Europe accounted for 92% of the world's new installations.

- Market penetration of newly installed unglazed and glazed water collectors (installed capacity per 1,000 inhabitants) leading countries:
  - China: 33 kW_{th}; Australia: 29 kW_{th}; Israel: 29 kW_{th}; Austria: 18 kW_{th}; Greece: 16 kW_{th}; Denmark: 14 kW_{th}, Turkey 14 kW_{th}, Switzerland: 14 kW_{th}, Cyprus: 14 kW_{th}

- The estimated total capacity in operation by the end of **2013** is 330 GW_{th} or 471 million square meters of collector area. This corresponds to an annual collector yield of 281 TWh.

SHC ACTIVITIES

New Member

The European Copper Institute (ECI) joined the SHC IA as our second Sponsor member. The partnership with ECI opens the door for collaboration with an organization that is critical for the growth of solar thermal technology.

Tasks

The SHC 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 2013, the Executive Committee approved:

Work started in 2013:

- ***Task 50: Advanced Lighting Solutions for Retrofitting Buildings***
  (Lead Country: Germany)
  This Task is working 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 work will build upon the results of SHC Tasks 21, 31, 46 and 47 as well as work in the ECBCS Programme.

- ***Task 51: Solar Energy in Urban Planning***
  (Lead Country: Sweden)
  This Task will support urban planners, authorities and architects to achieve urban areas, and eventually whole cities, with architecturally integrated solar energy solutions (active and passive). This will include developing processes, methods, and tools capable of assisting cities in developing a long-term urban energy strategy.

Work started in 2014:

- ***Task 52: Solar Energy and Energy Economics in Urban Environments***
  (Lead Country: Germany)
  This Task is focusing 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 tools will be developed. Good examples of integration of solar thermal systems in urban energy systems will be developed and documented.

- ***Task 53: New Generation Solar Cooling and Heating Systems***
  (Lead Country: France)
  This Task is working to support the strong and sustainable market development of 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).

SHC Conference

SHC 2013, our 2nd *International Conference on Solar Heating and Cooling for Buildings and Industry* was held in Freiburg, Germany in September.

We were happy to welcome about double the number of participants at our second conference. Around 400 participants form 37 countries listened to 100 presentations, including 10 keynote lectures and meet with over 140 experts during the scientific posters session.

I wish to thank all the Authors for their high quality contributions. Also, many thanks to the Scientific Committee members who reviewed all the abstract submissions.

SHC 2014 will take us once again to another continent – this time Asia. On October 13-15 experts and non-experts will gather together in Beijing, China to share and learn about current solar thermal research, new technology developments and market trends. The SHC Programme and the China Academy of Building Research are jointly organizing this conference.

SHC Solar Award

The 8th SHC Solar Award was given to The Drake Landing Company of Canada, comprised of four organizations – United Communities (developer), Sterling Homes (builder), ATCO Gas (utility), and the Town of Okotoks (municipality). The company was formed to oversee ownership and operation of the Drake Landing Solar Community, which uses solar thermal collectors and borehole heat storage to provide over 90% of space heating of 52 homes with solar thermal energy and recently set a new world record of 98% solar heating performance in it's sixth year of operation. Bruce Littke from ATCO Gas and Keith Paget from Sterling Homes received the award on the company's behalf at SHC 2013 in Freiburg, Germany.

The SHC Solar Award is given to an individual, company, or private/public institution that has shown outstanding leadership or achievements in the field of solar heating and cooling, and that supports the work of the IEA Solar Heating and Cooling Programme.

The 2014 SHC Solar Award will be presented at SHC 2014 in Beijing, China.

Collaboration With Other IEA Programmes & International Organizations

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

Within the IEA

IEA Energy Conservation in Buildings and Community Systems Programme is collaborating in *SHC Task 40: Net Zero Energy Solar Buildings*. In addition, another joint meeting of the Executive Committees was held June 2013 in Italy.

IEA Energy Conservation through Energy Storage Programme is collaborating in *SHC Task 42: Compact Thermal Energy Storage*. This is the first fully joint Task with Operating Agents from each Programme.

IEA Heat Pump Programme is collaborating in *SHC Task 44: Systems Using Solar Thermal Energy in Combination with Heat Pumps.*

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 SHC Chairman 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 *8th SHC/Trade Association* meeting was held in conjunction with SHC 2013 in Freiburg, Germany. The 9th meeting is planned for October 2014 in conjunction with the SHC 2014 conference in Beijing, China.

ETP RHC (European Technology Platform on Renewable Heating and Cooling), the SHC Programme, represented by Mr. Werner Weiss, Dr. Wim van Helden and Dr. Daniel Mugnier, continues to serve on the ESTTP Steering Committee and on the Platform's board to support the Platform's objectives.

European Solar Thermal Industry Federation**,** the SHC Programme has signed a Memorandum of Understanding with ESTIF to jointly organize the SHC 2013 conference with the option to collaborate on future SHC conferences.

Executive Committee Meetings

2013 Meetings

The Executive Committee held two meetings:
- June 12-15 in Rome, Italy
- October 30 – November 1 in Singapore

2014 Meetings

The Executive Committee will hold two meetings:
- May 16-18 in Calgary, Canada
- October 16-17 in Beijing, China

Membership

CONTRACTING PARTIES

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

SPONSORS

ECREEE (ECOWAS Centre for Renewable Energy and Energy Efficiency)
ECI (European Copper Institute)

Participation in the Programme remains strong with 20 Member countries, the European Commission, and the Programme's first two Sponsors, ECREEE and ECI, actively involved in the Programme's management and the work of the Tasks.

Communication continued with countries invited to join the Programme – Brazil, Chile, India, Japan, Luxembourg, RCREEE, SEIA, Slovakia, Slovenia, South Korea, Thailand, Tunisia, Turkey, Qatar (GORD), and the United Kingdom.

Why Join The SHC Programme?

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.

Learn More

Visit our website — www.iea-shc.org —to stay up to date on our Tasks, to find publications, to contact Executive Committee members and Task Operating Agents.

Become A Member

If your ***country is not a SHC Member***, but your government agency or organization is interested in joining the Progamme, please contact the SHC Secretariat for information *(secretariat@iea-shc.org).*

If you represent an ***international industry association or international non-profit organization*** it is possible to become a Sponsor Member, please contact the SHC Secretariat for information *(secretariat@iea-shc.org).*

Become An Expert

If your ***country is a SHC Member*** then contact the Operating Agent of the Task you are interested in joining and contact the Executive Committee member from your country.

Feature Article
Solar and Heat Pump Systems

Jean-Christophe Hadorn
Base consultants SA, Geneva, Switzerland
SHC Task 44 Operating Agent for the Swiss Federal Office of Energy

COMBINING SOLAR AND HEAT PUMPS FOR BEST PERFORMANCE

It has become very popular to heat a house with a heat pump as a result of promotions by electrical utilities and consumers desire not to depend on fossil fuels, particularly where electricity is produced by fossil fuels. As customers consider such a system many are attracted by the concept of combining a heat pump solution with a solar system. The market for solar and heat pump combined systems (SHP) is booming in countries like Switzerland, Austria, Germany due to several favorable conditions, such as CO2 reduction promotion programs, direct electrical heating substitution encouragement, obligation of a minimum of 30% renewable for domestic hot water production, and high electricity peak costs.

This new combination of technologies is a welcome advancement, but standards and norms are needed for its successful long-term commercialization. Such combinations are complex and need more control strategies and electronics than separate configurations, therefore, the optimization of the combination is more complex and the cost effectiveness of the combination is not obvious.

The combination of these two technologies makes sense for many reasons, including:

- A high renewable fraction can be achieved.
- Solar heat can help enhance the performance of the heat pump by raising the evaporation temperature.
- Solar heat can be stored at low temperatures (0-80° C) thus making good use of the collectors even during the cold season, cloudy days or at night. A good use of the latent heat of water changed into ice around 0° C can also be achieved.
- Solar heat storage can be used directly for the load, eventually reducing the need for peak electricity during a cold but sunny day.

There are over 130 combined solar and heat pump systems on the market, but again what is missing are standards and norms.

FIRST STEP IN SETTING STANDARDS AND NORMS

The IEA SHC Programme and the IEA Heat Pump Programme have worked together for the past four years to assess the performance and relevance of SHP systems. The main objective of the work was to provide a common definition of performances and to contribute to the successful market penetration of these new promising combinations of renewable technologies.

The work focused on the combined systems used for domestic hot water and heating in single-family homes – small systems in the range of 5 to 20 kW that used any type of solar collector.

The work was organized into four areas:

- ***Solutions and Generic Systems.*** Participants collected, created and disseminated information on current and future solutions for combining solar thermal and heat pump to meet heat requirements of a single-family house. The focus was on pre-manufactured systems and systems installed and monitored for 1-2 years.

- ***Performance Assessment.*** Participants worked on a common definition of the figures of merits of S+HP systems and how to assess them. This work led to a pre-normative definition on how to test and report the performance of a combined S+HP system.

- ***Modeling and Simulation.*** Participants developed modeling tools of all generic solar and heat pump systems and reported on the sensitivity analysis of most of the systems, including being able to pinpoint important features and marginal ones in a given system configuration. The sizing of systems and the optimizing of their controls was done using computing tools and a framework developed in the Task.

- ***Dissemination and Market Support.*** Participants disseminated information to a broad audience during the project so that the work could be transferred as fast as possible to the growing market. A handbook will be published by Wiley-VCH in June 2014.

HIGHLIGHTS OF RESULTS

Solutions and Generic Systems

Manufacturers Survey

A survey of more than 80 manufacturers from 11 countries provided information on the SHP systems on the market during 2010-2012. It was a surprise to see the number of marketed systems in a technical and standardization environment that had yet to be established. Performances were recorded without a clear definition or reliable benchmark and on top of that without any standard for the definition of the performance of a SHP hybrid system.

Survey results showed the need for test methods and performance factor definitions since the combination of solar heating and heat pumps is considered to be a complex system with no global or national standards.

The survey showed that the HVAC industry supports this technology. A clear market objective of the industry for single-family houses is to deliver complete pre-fabricated systems rather than components that installers need to assemble thus reducing the chance of improper installation and misconnection. The survey also showed that the SHP combination is delivering both heat and domestic hot water all year long with a high renewable fraction performance.

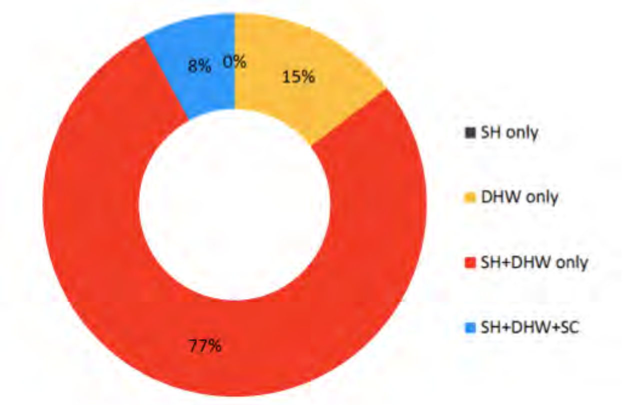


Figure 1. Survey Result: SHP system classification according to the supplied building load. The combi-system represents the vast majority of SHP systems on the market. *(Source: Fraunhofer ISE)*

System Classification

This area of work has brought some order and clarification to the systems by establishing the following classification:

- ***Parallel system*** where solar delivers heat mainly to the domestic hot water (DHW) tank and the heat pump does the heating and the back up of the DHW. There is no connection between the collectors and the evaporator of the heat pump. Often chosen with an air/water heat pump, which represents a large share of the market. This is by far the simplest system design, however, it still requires careful design particularly when the heat storage is shared between the two producers – the solar collectors and the heat pump.

➢ ***Serial concept*** where solar heat can be used by the evaporator of the heat pump enhancing the temperature of evaporation and thus the heat pump coefficient of performance (COP). Often unglazed collectors are used to avoid problems with condensation in the glazed collectors operating below the dew point of the collector atmosphere or the outdoor air.

➢ ***Regenerative concept*** for a ground source heat pump where the solar collectors can regenerate the heat into the borehole when there is excess of solar energy collected. Most of the time, the basic system is a serial system and the collectors are often unglazed collectors. The gain of the regeneration is not always decisive as shown in SHC Task 44 simulations.

➢ ***Complex systems*** where all system components can be linked together in different arrangements with 3-way valves and dedicated controller, but at the price of a more complex installation and sometimes a delicate control strategy. Those systems are found in bigger installations and where various uses (heating and cooling) at different levels of temperature need to be supplied.

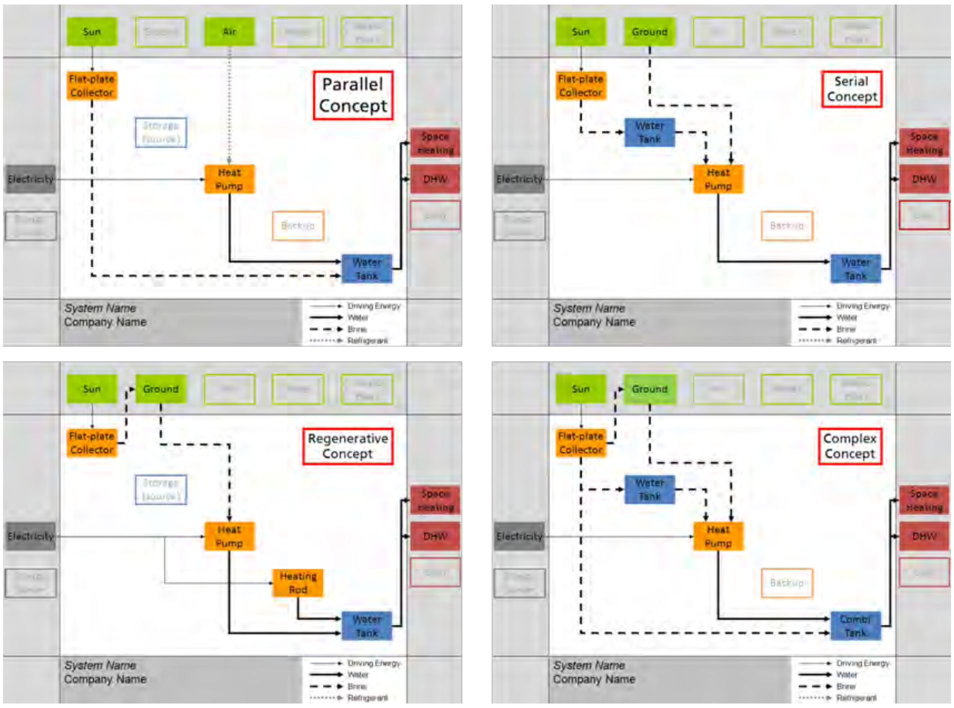


Figure 2. The four generic SHP systems, as categorized by SHC Task 44, are depicted with the "energy flow chart" designed by SHC Task 44. (*Source: IEA SHC Task 44)*

Energy Flow Chart
The experts in this project established a way to represent any combination of solar and heat pump system, and more generally, any energy system in a systematic "energy flow chart" diagram. The diagram simplifies the quick understanding of a system configuration and the energy flows without losing information compared to a classical hydraulic scheme. This chart is available as a simple Excel tool from the SHC website. Figure 3 shows all the basic concepts of a SHP using such a chart.

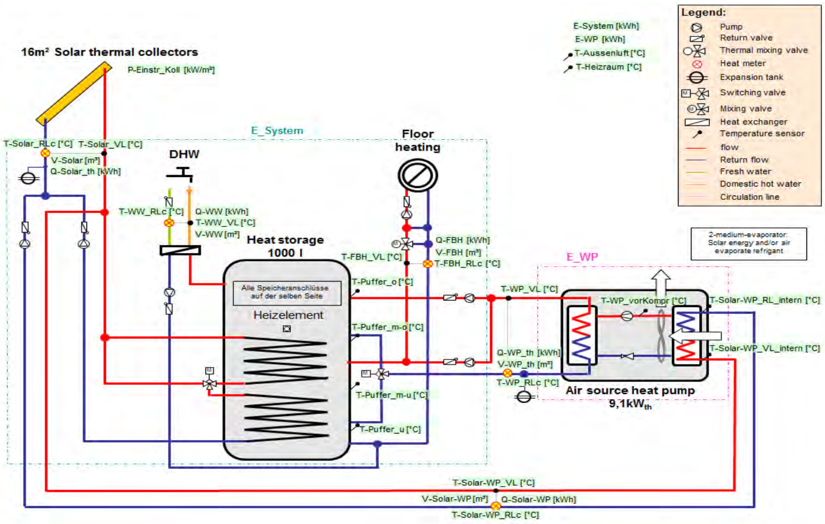


Figure 3. A typical schematic of a complex SHP system with all details. (*Source: Austria*)

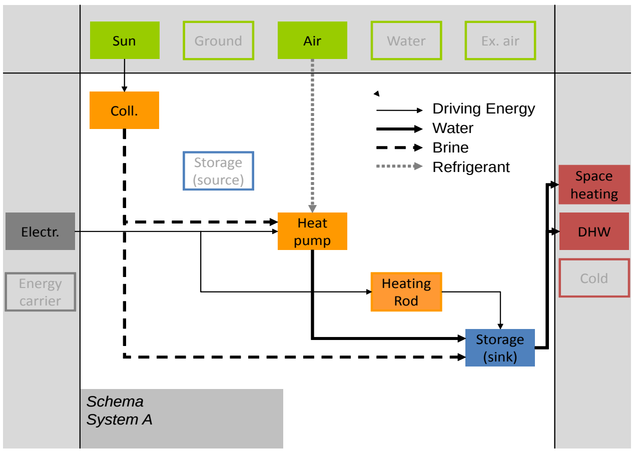


Figure 4. A parallel system described with the hydraulic scheme and with the SHC Task 44 energy flow chart. *(Source: IEA SHC Task 44)*

Systems Monitored In-Situ

Participants in this SHC work provided one to two years of monitored results from 50 different systems in seven countries, covering not only the variety of systems on the market but also prototype systems. The variance of performances was found to be large – measured seasonal performance factors (SPF) ranged from as low as 1.5 to a very good 6. Reasons for the variety of results have been analyzed and are explained in the Task's Subtask A reports as well as in the handbook that will be published in June 2014.

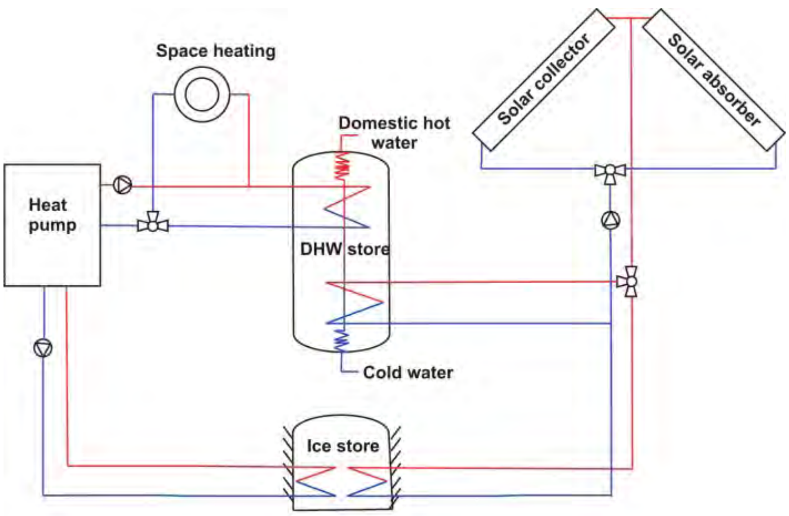


Figure 5. A SHP concept with ice storage. *(Source: IEA SHC Task 44)*

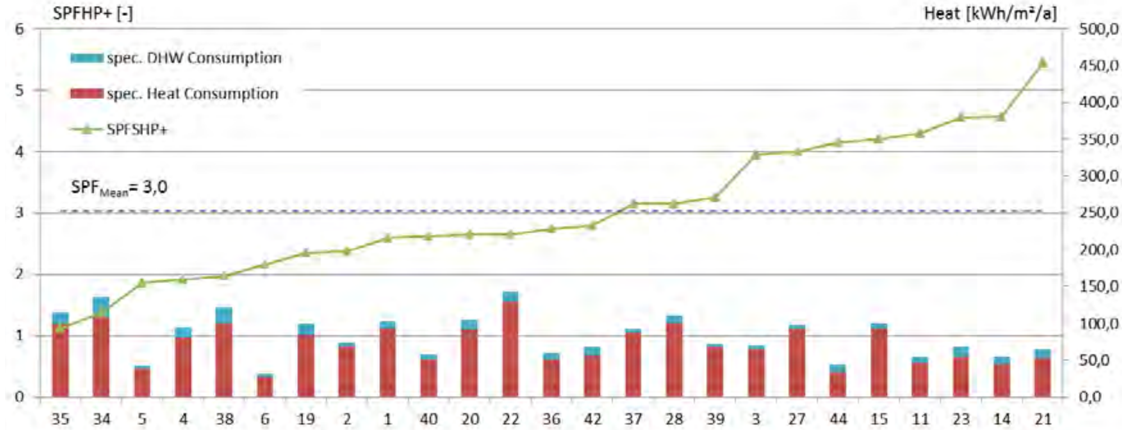


Figure 6. Monitored results of 25 SHP systems. The SPF can range from bad systems to excellent ones. *(Copyright: Fraunhofer ISE and IEA SHC Task 44)*

Although parallel systems are the most common and the simplest to operate, well-performing systems were found in all four identified categories (P/S/R/C), and good integration of all components was shown to be possible. Some best practice examples have been reported and will appear in the handbook.

Performance Assessment

Performance

In terms of reporting performance of a SHP installation, SHC Task 44 showed that there is a need for different performance figures for different purposes. These can be energy evaluation, environmental analysis or economic aspects. These various performance factors were derived in a Subtask B report where all equations and system boundaries are given.

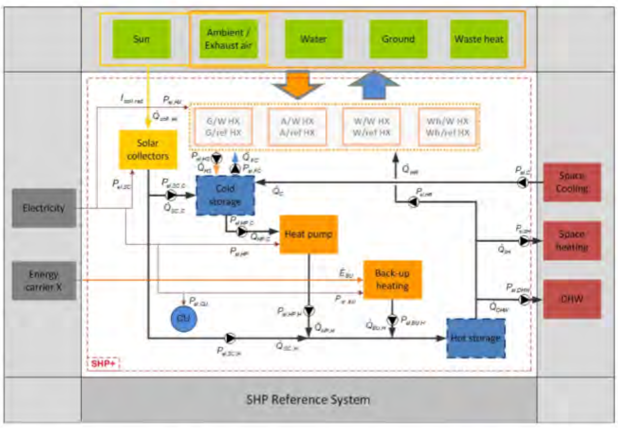


Figure 7. The definition of SPF_{SHP+} according to SHC Task 44. (*Source: IEA SHC Task 44*)

$$SPF_{SHP+} = \frac{\int \left(\dot{Q}_{SH} + \dot{Q}_{DHW} + \dot{Q}_{C}\right) dt}{\int \left(\sum P_{el,H,SHP+}\right) dt}$$

$$\sum P_{el,SHP+} = P_{el,SC} + P_{el,SC,C} + P_{el,SC,H} + P_{el,HP} + P_{el,HP,C} + P_{el,HP,H} + P_{el,HS} + P_{el,BU} + P_{el,BU,H} + P_{el,SH} + P_{el,DHW} + P_{el,C} + P_{el,FC} + P_{el,HR} + P_{el,HX} + P_{CU}$$

There is also a necessity to take all components into account in any performance calculation. The auxiliary components such as pumps, controllers, displays, fans, valves, sensors, etc. must be accounted for since this can make the difference between a good system and an unacceptable one (that is one with too low a seasonal performance factor (SPF) when auxiliary electricity is considered). And, auxiliary electricity should be considered in all cases for a fair comparison between different heating technologies.
System boundaries have been clearly defined in order to calculate all relevant performance indicators. The method to fix the boundaries uses the energy flow diagram describing all

flows in a system and can be applied to any kind of energy system (solar cooling for instance), and not only to solar and heat pump systems.

Subtask C has derived the correct definitions for System Performance Factors (SPF) that takes the overall system into account. Engineers and manufacturers can refer to this work to specify the SPF within common boundaries, which is a necessary basis for any system comparison.

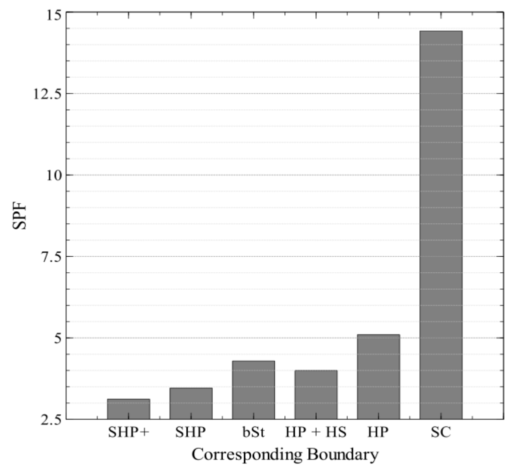


Figure 8. SPF depends strongly on the boundary considered (for definitions of boundaries in this figure refer to SHC Task 44 Subtask B reports).

Laboratory Testing

Laboratory testing is important because SHP combinations are complex systems with dynamic interactions. Solar energy is intermittent and highly variable during a day and provides dynamical situation in a solar-based system. Testing the whole system is therefore fundamental to the process of developing SHP systems and can provide relevant information for performance, failure, default behavior, etc. in a rather short period of time. Authorities should therefore encourage lab tests.

Test sequences over 12 days with variable meteorological conditions have been used to test several types of SHP systems in several European solar laboratories. The methodology used by SHC Task 44 proved to be accurate and reliable.

There are different methods of testing SHP in laboratory over this predefined sequence of 12 days. SHC Task 44 describes the main methods that are in use in the participating laboratories. The Pros and Cons of each method are analyzed in a Task technical report.

Modeling and Simulation

SHC Task 44 has shown that basic models for simulating components in solar and heat pump systems are available. Features of the most relevant models for solar collector, heat pump, heat storage, borehole have been analyzed and reported on. Recommendations for choosing an adequate model were formulated and the best ones have been integrated into the TRNSYS framework of SHC Task 44.

Simulation models of components are essential in order to be able to simulate systems. Four working groups on solar collector, ground heat exchanger, heat pump, and heat storage surveyed existing models. A new Heat Pump Model (Type 877) for TRNSYS was developed and its validation is in progress before it can be used for optimization purposes.
Modeling the frost conditions and water condensation heat exchange on solar absorbers for night operating conditions was also done. The model was tested on laboratory results and proved to be adequate. However, it was found that the heat gain from the condensation on

the surface of the solar collectors is not very important in the annual balance of heat supplied. Solar radiation and air exchange dominate.

Simulations and also field monitoring have shown the great importance of the storage component in a combined system. Also, the storage stratification is very important to ensure better performance.

SHC Task 44 also showed that there is a need for monitored data for the modeling of variable-capacity or variable-speed heat pumps, and special heat pumps based on advanced concepts. Models are not currently available for these complex machines and therefore it is difficult for researchers to find optimal combinations.

There is a need for simulation models for complex hydrothermal effects in water storage tanks. Specifically for the mixing of heated water and the loss of exergy due to high velocities of incoming flow or due to a poorly designed introduction geometry. Current CFD (Computational Fluid Dynamics) 3D software can be used for design purposes, but they are massive and slow and not adapted for system optimization where computation time is critical.

SHC Task 44 has developed a range of tools to simulate all kinds of solar and heat pump combinations. National teams have used these tools and the Task framework to optimize several aspects of a solar and heat pump combination. One of these aspects concerns the heat storage that is shared by the solar collectors and the heat pump in the most common parallel arrangements. For example, recommendations derived from many simulations were formulated:

1. The position of the DHW sensor for boiler charging control must be placed at a safe distance from the space-heating zone of the storage.
2. The return from the storage to the heat in DHW mode must be placed above the space-heating zone of the storage.
3. It can be advantageous to bypass the storage when the heat pump runs in the space-heating mode.

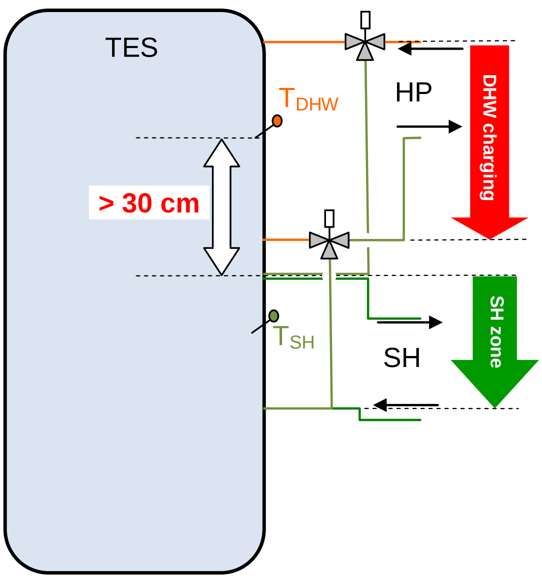


Figure 9. The DHW charging zone in the upper part of a tank must be respected in a combistore.
(Copyright: SPF Switzerland)

This Task created a framework for simulating SHP systems in different climates and for different loads. The framework is an international collaborative work and proved to be very useful for national work as well. All relevant documents for this framework are available on the Task website. As a result, more than 20 different system concepts using the common tools were simulated. Several simulation platforms were used and the framework was adapted to each platform.

Simulation results show that the solar benefit contribution to an SHP system can be substantial when optimal arrangement and a good control strategy are considered. Figure 10 shows the increase of SPF by installing collectors in a parallel system with an air/water heat pump. Installing 8 m2 of collectors on a single-family home can bring the SPF_{SHP+} to 3.5 from the typical 2.8 for a non-solar air heat pump. Combi-systems (having a single storage for DHW and heating) can also benefit from adding solar collectors to the system. The SPF can reach 4.0 with 15 m2 of collectors from the 2.8 reference case.

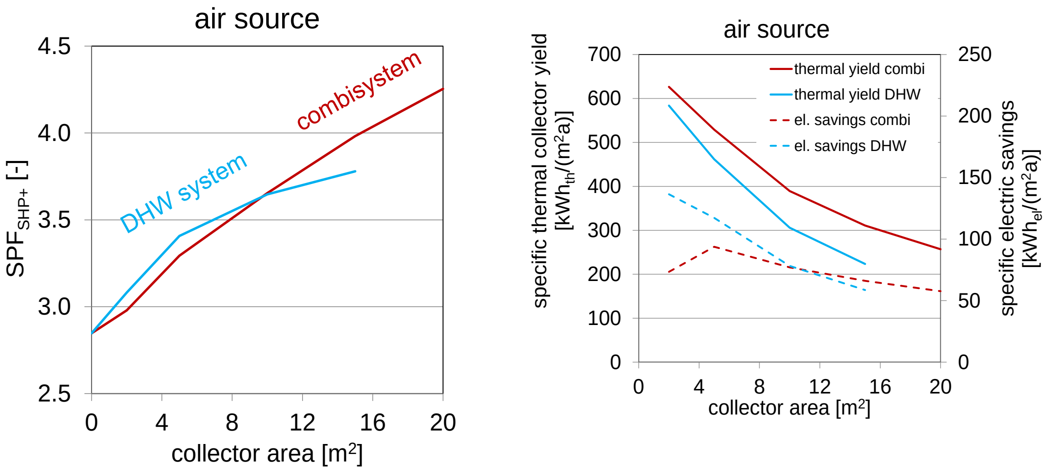


Figure 10. What does solar heating add to the whole? Performance of air-source solar and heat pump systems, where solar heating is used for DHW only (DHW) or for a combined system with combined storage (combi). (Simulations of SPF in reference conditions.) For more results refer to the soon to be published handbook.

As part of a great common effort, several Task teams conducted simulations of different system configurations with the same boundary conditions and in the same climate. Figure 11 shows the overall results in terms of SPF achieved by each system concept in the same conditions.

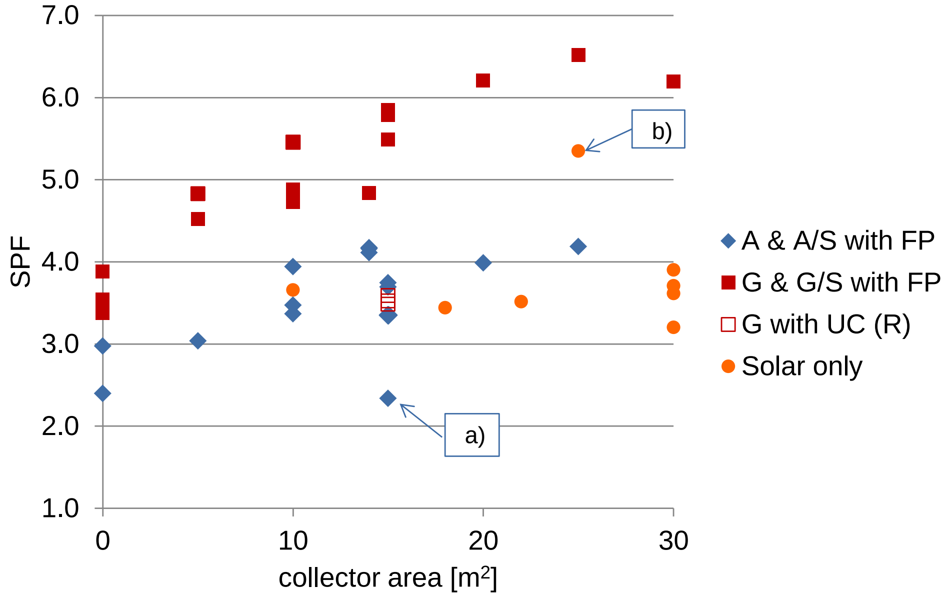


Figure 11. Simulation results for Strasbourg SFH45: SPF vs collector area for different system concepts. Outliers are a) inappropriate hydraulics and control, b) large ice-storage and collector field.

CONCLUSION

SHC Task 44 has delivered much needed information on the assessment, the design, and the performance of combined solar and heat pump systems. Tools are now available to simulate any type of system combination, as well as performance indicators that should be calculated for fair comparisons between systems. This work has demonstrated that these systems can reach high SPF values if designed and commissioned carefully.

Solar heating can be a good heat source for heat pumps as an alternative or a complement to air and ground sources.

For more information and to access these new tools go to the SHC website http://task44.iea-shc.org/.

Task 39
Polymeric Materials for Solar Thermal Applications

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

TASK DESCRIPTION

The objective of Task 39 is to assess the cost-reduction potential using polymers in solar thermal applications, as well as to study the applicability of these materials in novel, polymer based designs. A further objective is to promote increased confidence in these products by developing and applying appropriate methods for the assessment of durability and reliability. These goals will be achieved by either less expensive materials or less expensive manufacturing processes, and specially developed testing routines for collectors and materials.

The Task's work is divided into three subtasks:

Subtask A: Information (Norway)
Subtask B: Collectors (Germany)
Subtask C: Materials (Austria)

Subtask A: Information

The objective of Subtask A is to collect, create and disseminate information about the application of polymeric materials in solar thermal systems and their figures or merits, especially in terms of cost/performance ratios for an acceptable lifetime, in order to increase the market penetration of good applications.

Activities

- Update the state-of-the-art overview of existing applications of polymeric materials in solar thermal systems and other relevant industry sectors.
- Assess the performance of two case studies, where a total cost accounting approach is adopted. The aim is to assess the suitability of polymeric materials in solar thermal applications.
- Investigate standards, regulations and guidelines with regard to the applications of polymeric materials in solar thermal systems and building integration.
- Expand the database to include showcases of (mostly) polymeric solar collectors and their successful integration in architecturally appealing buildings.
- Disseminate information on Task 39 work and publish results to a wide audience.

Database showcasing buildings using solar collectors that have successfully integrated polymeric materials.

Subtask B: Collectors

Objectives

Based on the results of the first phase of this subtask, the objectives for the extension phase focuses on the development of:

- New collectors, made completely or partly with polymeric materials, with a profitable cost of ownership.
- Innovative concepts based on polymeric materials (integrated collector storage, thermo-syphon systems) or adapted to specific requirements of polymeric collectors (overheating protection, pressure, etc.), and
- Other components of a solar thermal system (piping, fitting, storage, drain back vessel, etc.) that could benefit from polymeric materials or processes.

Activities

- Based on the updated state-of-the-art of Subtask A, studies on the development of new collectors, systems and components will be produced to show the feasibility, performance, durability and cost savings.

Subtask C: Materials

As shown in Phase I of Task 39, polymer engineering and science posses great potential for new products in solar thermal systems, which simultaneously fulfills technological and environmental objectives as well as social needs. The major achievements within Phase I of Task 39 focused on the significant improvement of the long-term stability of an extruded polymer collector as well as the realization of a polypropylene based modular storage tank. In addition, a variety of novel polymeric material grades and components for solar-thermal systems (e.g., spectrally selective coatings with improved performance and commercial availability, an injection-molded installation board, extruded spacers for the fixing of an absorber in the collector frame, thermoformed casings for collectors based on polycarbonate blends, polymeric foams with enhanced service temperature) were realized.

The final product performance, its functionality, durability and costs not only depend on the type of the polymeric material used, but also on many other factors related to product design, processing and production. As evidenced in Phase I of Task 39, the different components of a solar thermal system have to fulfill a complex material property profile, which can only be provided by multi-functional polymer compounds. The classical differentiation between structural (load-carrying) and functional polymeric materials is therefore not suitable in context with the application of plastics in solar thermal systems.

Objectives

- Further develop and investigate multi-functional polymeric materials for various components in solar thermal systems considering different plant types and climate zones.
- Evaluate polymer processing methods for the production of specimen and components with special emphasis on all levels up to the sub-component level (e.g., multi-layer films and sheets). (Complete components will be developed in Subtask B.)
- Develop testing and characterization methods and modeling tools for the application-oriented assessment of the performance and durability.

Activities

- Formulate multi-functional polymeric materials for various components of solar thermal systems (e.g. absorber, insulation and frame of a collector, storage tank components). The considered polymeric material classes will include thermoplastics (i.e., melt processable materials), elastomers (i.e., chemically cross-linked soft materials) and thermosets (i.e., chemically cross-linked stiff materials).

- Compound polymeric materials considering a variety of functional fillers and additives allowing for improved process ability and enhanced performance.
- Produce specimen and sub-components by applying various mass production processing technologies (e.g., injection molding, compression molding, extrusion, coating technologies, lamination and joining technologies).
- Establish a toolbox for the quality testing of polymeric materials for specific applications in solar thermal systems considering the various material states along the value creation chain.
- Implement and apply analytical and technical methods for the characterization of properties, long-term behavior and relevant aging and degradation phenomena.
- Establish micro-structure/property/processing/performance relationships.

Duration

The SHC Executive Committee approved a 4-year Task extension. The Task started on October 1, 2006 and will end on September 30, 2014.

Participating Countries

Austria, Belgium, Canada (without public funding), Germany, Netherlands (without public funding), Norway, Portugal (now with public funding), Sweden, Slovenia (without public funding) United States (without public funding), Brazil (without public funding)

WORK DURING 2013

Subtask A: Information

The dissemination of information and results from Task 39 is an important part of Subtask A, and includes improved dialogue with new partners from industry and research, for example, through open workshops and excursions during the Task meetings.

The following list includes major activities during 2013:

- A second life-cycle assessment study with total cost accounting approach was initiated by Prof. Bo Carlsson, Linnæus University, Kalmar. The study will compare polymeric thermosiphon systems with thermosiphon systems of conventional materials. Aventa, Fraunhofer ISE and AEE-INTEC joined this project.

- A major dissemination activity during 2013 was the planning and realisation of the Task 39 Exhibition at the SHC 2013 Conference from September 23-25, 2013 in Freiburg, Germany by the title, *On the Road to a New Generation of Solar Thermal Energy Systems*. The exhibition was initiated by Subtask B, organized and arranged by Fraunhofer ISE and ITW-Stuttgart. The industry partners supported the event financially and with exhibition pieces (see "Dissemination Activities in 2013").

- A plan for the final dissemination of Task 39 outcomes was made at the 16th Task 39 experts meeting in Blumau, Austria in October 2013. The idea is to publish so-called info-sheets (condensed information leaflets, obligatory) and extended reports (optional) on key topics of each subtask. Both info-sheets and reports will be available online and downloadable as open access files via the Task 39 homepage.

- Seven new projects were added to the database of successfully integrated solar thermal systems and architecturally appealing buildings:
http://projects.iea-shc.org/task39/projects/default.aspx

- Two Newsletters were completed in 2013, summarizing the activities of each Task expert:

- Task 39 Newsletter No. 12, May 2013
  http://task39.iea-shc.org/Data/Sites/12/documents/newsletters/2013-03/index.html
- Task 39 Newsletter No. 13, November 2013
  http://task39.iea-shc.org/Data/Sites/12/documents/newsletters/2013-11/index.html

Subtask B: Collectors

Task 39 Workshop during 15th IEA SHC Task 39 on Mallorca, March 23-25, 2013
During the 15th experts meeting on Mallorca, a Subtask B workshop on polymeric solar thermal systems was held. The aim of the workshop was to define solar thermal systems that could be made with existing polymeric components to demonstrate that there are a range of polymeric products that carry a high potential for a combination in most efficient solar thermal systems.

Within this workshop four groups were formed to discuss and define the following system configurations and the dissemination of the results, respectively:

1. Standard domestic hot water system, collector area approximately 5 m², store volume approximately 300 l
2. “Cheap” thermosiphon system for sunny regions
3. Scalable system (.i.e., ‘scalable’ with respect to collector area and storage volume)
4. Dissemination

Altogether 26 experts gathered in these four groups to discuss system concepts, select components and to think about suitable dissemination measures. At the end, each group presented their ideas about different system configurations and also concrete proposals for their realization. The workshop ended with a final discussion on the challenges encountered when considering different components from diverse manufacturers and other issues that need to be taken into account in the further course of the work.

Subtask B Questionnaire
A detailed and extensive questionnaire was prepared and sent to the participants to evaluate the ongoing product developments related to polymeric solar thermal collectors and components developed in the framework of Task 39.

Task 39 Exhibition
Following the workshop held in Mallorca sponsors and exhibitors were found to support the Task 39 exhibition, which took place parallel to the SHC 2013 Conference on 23-25 September in Freiburg, Germany. During the exhibition, several existing polymeric solar thermal collectors and components as well as prototypes developed within the framework of Task 39 were shown.

Austrian Dissemination Workshop, Kunststoffe – die Wachstumsoption für die Solarthermie, Linz, November 2013
Several developments in the field of polymeric solar thermal collectors and components and major achievement were presented to the public. The following presentations were given with respect to Subtask B.

- Task 39 – Polymermaterialien für solarthermische Anwendungen Dr. Stephan Fischer, ITW/Universität Stuttgart

- Stand der Technik zu Kunststoffkollektoren Dr. Michaela Meir, Universität Oslo
- Kunststoffkollektoren mit integriertem Überhitzungsschutz Prof. Wolfgang Streicher, UIBK-EEB, Innsbruck
- Der Eine-Welt-Solarkollektor Ing. Robert Buchinger, SUNLUMO, Perg, AT
- Leistungsanforderungen an Polymermaterialien für unterschiedliche Systemtypen Dipl.-Ing. (FH) Alexander Kaiser, AEE INTEC, Gleisdorf
- Kunststoffabsorber aus technischen Kunststoffen Ing. Willibald Koller, Greiner, Kremsmünster
- Polyolefine für solarthermische Absorber Dipl.-Ing. Markus Povacz, JKU-IPMT, Linz
- Speicherkollektor mit spritzgegossenem Absorber Dipl.-Ing. Karl Schnetzinger, APC Advanced Polymer Compounds, Gai.

Subtask C: Materials

Polymeric Materials
Regarding the participation of industry partners, BOREALIS reconfirmed their interest in the topic. Representatives of BOREALIS, which is a major supplier of polyolefin materials, attended the 16th Experts Meetings and gave an overview on novel polyolefin materials for solar absorbers. BOREALIS is partner of the Austrian SolPol-consortium and is also collaborating with AVENTA and MAGEN.

Solar Absorber Compounds
Polypropylene has high potential for solar absorbers in overheating protected collectors. Currently, some PP-grades with appropriate stabilization and pigmentation are commercially available and used for swimming pool absorbers or pressurized pipe applications. In the research project *SolPol-2* the aging behavior of two commercially available, black-pigmented PP-Block-Copolymer grades is investigated considering service relevant conditions (hot air or hot heat carrier fluid at 95, 115 and 135°C). For the investigated materials a remarkable aging behavior was obtained at aging temperatures of 95 and 115°C. At 95°C now premature failure occurs for aging times up to 16000 hours (i.e., 2 years). At 135°C, the investigated materials exhibited significant differences in their aging behavior (factor of 2 in time to embrittlement). In general, a more pronounced degradation was ascertained after exposure in hot air. The better long-term behavior in hot heat carrier fluid was attributed to the corrosion inhibitors (i.e. triazoles) in water+glycol mixtures, which have a positive effect on the thermooxidation.

In the EU FP7 project SCOOP special emphasis is placed on injection molded absorbers for integrated storage collectors. Based on conceptual designs, application-relevant loading conditions and FEM modeling property requirements have been established for the polymeric materials to be used for the absorber. Due to relatively high mechanical loads and an operating temperature range up to 100°C fiber-reinforced engineering plastics have been pre-selected, compounded and characterized considering different material states. The investigated polyamide grades exhibit a high solar absorbance (> 95°C), glass transition temperatures varying from 0 to 100°C and temperature and humidity dependent mechanical properties. The material structure is significantly affected by the processing conditions. The average length of the short-glass fibers ranges from 150 to 250µm. Current research work is dealing with injection molding, joining and testing of model components and collectors.

Thermotropic Materials
For thermotropic materials with fixed domains (TSFD) a comprehensive understanding for the correlations between material formulation parameters and the switching performance was established within the PhD thesis by A. Weber (at PCCL and MU Leoben). Although a

theoretical switching potential of thermotropic materials from about 90% to 50% in hemispheric transmittance was ascertained, model materials revealed a slightly poorer performance with maximum (in the clear state) and minimum (in the switched state) transmittance values of 80% and 50%. The differences were attributed to reasons such as void formation, imperfect dispersed domain size distribution, and significant time dependency of phase formation. The achieved overheating protection performance of TSFD was inappropriate in order to protect a solar thermal collector from overheating.

Spectrally Selective

In 2013, a new generation of spectrally selective coatings was developed by NIC (Slovenia). Focus was placed on the further improvement of thickness insensitive spectral selective coatings, which are applicable to polymeric absorbers by spraying. The best non-black (i.e., blue) TISS paint coatings, which were prepared exhibited solar absorbance of about 0.92 and thermal emittance of 0.38. A major breakthrough was achieved due to the use of special dispersant (alkylalkoxysilanes), adequate aluminium flake pigments and black manganese spinel pigments, which were combined with pigments of other than black colours. The key component for the new generation of the colored TISS coatings was perfluoropolymer based resin binder, which was combined with organic flake-like blue pigment, stable up to 170°C. The mixture of the black and blue pigments finely dispersed within the paint provided a complete coverage of the aluminium flakes and solar absorbance values higher than 0.90. Furthermore, the novel coatings exhibited distinguished water repellent properties and excellent UV light stability (30 years) attributed to the inherent hydrophobicity of the perfluoropolymeric resin binder. Other colours (brick red, green), are available on request.

Liner Materials

In 2013, an update on the aging behaviour of liner materials for seasonal heat storage tanks was provided. A major breakthrough was achieved – the company partner AGRU introduced the first High Temperature Resistant (HTR HDPE) geomembrane in the marketplace. Cupasol selected the HTR geomembrane from AGRU for the internal lining of the heat storage tank. A geomembrane with a thickness of 2.5 mm was used and successfully installed. The High Temperature Resistant geomembranes are welded and installed like traditional geomembranes and they provide the same level of performance properties. Specially approved and selected resins are used for producing HTR geomembranes. A special molecular structure combined with a high quality stabilisation leads to outstanding long-term performance at elevated temperatures. The compound used was tested according to ISO 9080 and complies with DIN 16833 (PE-RT). Thus, an excellent long-term strength and good temperature resistance were confirmed.

Bioplastics

Bioplastics (that is polymers based on renewable resources and/or biodegradable polymers) are expected to have a high potential in the solar industry. At PCCL and MU Leoben the project “Bio4Sun – Bioplastics for Solar Applications” was initiated focusing on a feasibility study of biogenic polymers for the use in components for solar thermal systems. Based on material requirements and specifications an extensive literature and market survey was carried out. In total around 40 potential bioplastic candidate materials for solar applications were identified, extruded to films with a thickness of about 400µm and characterized as to application relevant thermal, thermo-mechanical, mechanical and optical properties. The generated polymer physical property profiles indicate that bioplastics in general possess a high potential for application in solar thermal devices. For example Cellulose polymers, PLA and Bio-PA turned out to exhibit excellent optical properties, which make them interesting as glazing materials or as materials for air collectors, and Bio-PE, PTT, and PHB may be appropriate materials for swimming pool collectors, for piping or framings. Current focus is on investigating ageing characteristics and long-term stability.

Methods for Aging Characterization

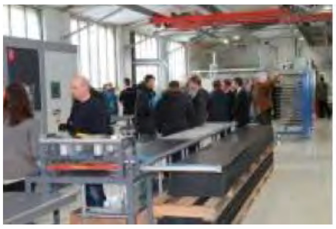
In the reporting period, a case study on the applicability of luminescence spectroscopy for the determination of aging indicators was carried out by JKU (Linz) and HU Berlin. Therefore, two commercial polyethylene grades were oven aged at 95°C and 115°C for more than 1,000 hours. Aging characterization was performed by laser-induced luminescence spectroscopy, laser confocal microscopy, infrared spectroscopy, high performance liquid chromatography, differential scanning calorimetry and tensile testing. Luminescence emission increased significantly upon oven aging, especially at 115°C. Decreasing oxidation onset temperatures and stabilizer concentrations state oxidation induced changes in the materials and were in agreement with increasing luminescence emissions. IR spectroscopy and tensile testing results showed no global oxidative degradation and no premature failure. Hence, the materials were still in the induction period of the oxidative degradation. The evolution of the luminescence signal was presumably attributed to the formation of oxygenated groups like α,β-unsaturated carbonyl groups. The investigations clearly indicated that luminescence spectroscopy is a sensitive method to monitor aging induced changes within the induction period.

DISSEMINATION ACTIVITIES IN 2013

Workshops, Seminars and Exhibitions arranged by Task 39

See: http://task39.iea-shc.org/task-39-workshops

February 5, 2013: Task 39 Mini-workshop arranged by Aventa AS in Holmestrand, Norway - IR-Welding of high-temperature Performance Polymers
See: Solarthermal World, News: Research Council of Norway (in Norwegian);



March 14, 2013: Task 39 Subtask B Workshop arranged by Fraunhofer ISE and ITW-Stuttgart at the 5th Experts meeting, Mallorca, Spain - All-Polymeric Solar Thermal Systems. More Information, Task 39 Newsletter No. 12 (2013/04);


September 23-25, 2013: Task 39 Exhibition at SHC 2013 arranged by Fraunhofer ISE and ITW-Stuttgart, in Freiburg, Germany – On the Road to a New Generation of Solar Thermal Energy Systems.

Task 39 has exhibited a range of polymer-based components for solar-thermal systems at the Solar Heating and Cooling Conference SHC 2013 in Freiburg, Germany (23.-25.09.2013). The Task 39 Exhibition was the first of its kind to put selected polymeric collectors, storage tanks and other components on stage and showed a range of possibilities for re-thinking solar thermal.

Next to polymeric collectors and thermosiphon systems from Magen Eco Energy, the companies Aventa AS, Roth, Enerconcept, Consolar and Kompetenzzentrum Holz GmbH showcase pioneering solar thermal collectors for building integration, polymer based air collectors, collector storage tanks and innovate wood plastic composites (WPC). Additional information on current research activities is provided by associated Task 39 research institutes and partners like Fraunhofer ISE, SWT Stuttgart, PCCL and the University of Leoben as well as Sunlumo.

Download Flyer - Further reading: Solar Update 2013-06, p 6-7. Announcement of Event;

October 11, 2013: Austrian Task 39 Dissemination Workshop arranged by JKU in Linz, Austria - Kunststoffe als Wachstumsmotor für die Solarthermie
Programme / Invitation, Dissemination Workshop summary;

Conferences and Symposia with Contributions from Task 39 Experts

http://task39.iea-shc.org/proceedings

SMEThermal 2013 - Solar Thermal Materials, Equipment and Technology Conference, Berlin, Germany, 29 January 2013.

23nd Symposium Thermische Solarenergie 2013
Kloster Banz, Bad Staffelstein, Germany, April 24-26, 2013.

SKZ-Experts Symposium 'Serienschweißlösungen für Kunststoffformteile' with application workshop, Würzburg, Germany, June 4-5, 2013.

SHC 2013 - International Conference on Solar Heating and Cooling
Freiburg, Germany, September 23-25, 2013.

Publications in Journals and Conference Proceedings by Task 39 Experts

http://task39.iea-shc.org/publications, http://task39.iea-shc.org/proceedings

Weber, A.; Schlögl, S.; Resch, K.: Effect of Formulation and Processing Conditions on Light Shielding Efficiency of Thermotropic Systems with Fixed Domains Based on UV Curing

Acrylate Resins, Journal of applied polymer science 130 (2013) 5 , 3299 - 3310.

K. Resch, Novel Latent Heat Storages for Solar Thermal Applications, SHC 2013 - International Conference on Solar Heating and Cooling, Freiburg, Germany, Sept. 23-25, 2013.

K. Resch, Green Systems: Bioplastics for Solar Thermal Applications, SHC 2013 - International Conference on Solar Heating and Cooling, Freiburg, Germany, Sept. 23-25, 2013.

C. Reiter, Performance optimisation of polymeric collectors by dynamic simulation and sensitivity analysis, SHC 2013 - International Conference on Solar Heating and Cooling, Freiburg, Germany, September 23-25, 2013.

A. Weber, Thermotropic Glazings: Theoretical and Practical Assessment of Overheating Protection Performance, SHC 2013 - International Conference on Solar Heating and Cooling, Freiburg, Germany, September 23-25, 2013.

M. Koehl, Task 39 Exhibition Project: Assembly of Polymeric Components for Solar Thermal Systems, SHC 2013 - International Conference on Solar Heating and Cooling, Freiburg, Germany, September 23-25, 2013.

K. Weiss, Testing of Components for Solar Thermal Collectors in Respect of Saline Atmospheres, SHC 2013 - International Conference on Solar Heating and Cooling, Freiburg, Germany, September 23-25, 2013.

M. Mihelčič, Novel Selective Coatings for Flat Plate and Tubular Absorbers Based on Sol Gel Paints, SHC 2013 - International Conference on Solar Heating and Cooling, Freiburg, Germany, September 23-25, 2013.

M. Meir et.al., Polymeric collectors or heat pump? Lessons learned from passive houses in Oslo, SHC 2013 - International Conference on Solar Heating and Cooling, Freiburg, Germany, September 23-25, 2013.

C. Hintringer, Entwicklung eines eigentemperatursicheren Kunststoffkollektors, 23nd Symposium Thermische Solarenergie 2013, OTTI Technologie-Kolleg, Bad Staffelstein, Germany, April 24-26, 2013.

C. Reiter, Entwicklung eines Kunststoffabsorbers: Strömungsmechanische & fertigungstechnische Gestaltung, 23nd Symposium Thermische Solarenergie 2013, OTTI Technologie-Kolleg, Bad Staffelstein, Germany, April 24-26, 2013.

A. Kaiser, Leistungsanforderungen an Polymermaterialien in solarthermischen Systemen, 23nd Symposium Thermische Solarenergie 2013, OTTI Technologie-Kolleg, Bad Staffelstein, Germany, April 24-26, 2013.

A. Piekarczyk, Kombinierte spektroskopische und mechanische Untersuchung der Auswirkung von Alterungsfaktoren bei der beschleunigten Alterung von Polymerwerkstoffen für die Solarthermie, 23nd Symposium Thermische Solarenergie 2013, OTTI Technologie-Kolleg, Bad Staffelstein, Germany, April 24-26, 2013.

M. Sessler, Complete polymer solutions: technical specifications and cost-saving potential, Presentation with round table discussion at SMEThermal 2013 - Solar Thermal Materials, Equipment and Technology Conference, Berlin, Germany, 29 January 2013.

S. Brunold, Collector covers: pros and cons of polymers and glass, presentation at SMEThermal 2013 - Solar Thermal Materials, Equipment and Technology Conference, Berlin, Germany, 29 January 2013.

M. Meir, Latest generation of polymer collectors: A market overview, Presentation with round table discussion at SMEThermal 2013 - Solar Thermal Materials, Equipment and Technology

Conference, Berlin, Germany, 29 January 2013.

Presentations (not listed in the conference proceedings)

Task 39 mini-workshop arranged by Aventa AS in Holmestrand, Norway: "IR-Welding of high-temperature Perfomance Polymers", February 5, 2013:

- M. Köhl, Polymeric Materials for Solarthermal Applications, Fraunhofer ISE, D.
- E. De Meersman, Aventa–Polymer Solar Collector, Chevron Phillips Chemicals, B.
- J. Rekstad, Status and opportunities, Aventa AS, N.

Task 39 Subtask B Workshop arranged by Fraunhofer ISE and ITW-Stuttgart at 5th Experts meeting in Mallorca, Spain - All-Polymeric Solar Thermal Systems, March 14, 2013:

- M. Köhl, Scope and objectives of the workshop, Fraunhofer ISE, D.
- S. Fischer, State of the art: Polymers in solar thermal applications;
- Presentation of schedule and formation of working groups, ITW-Stuttgart, D.
- T. Szuder, Use of composites in solar collectors and other devices of heating units, Vaillant Group, D.
- J. Wismans and E. Stam, Overview of suitable polymeric components for solar thermal applications, Sabic, NL.

Austrian Task 39 Dissemination Workshop arranged by JKU in Linz, Austria - Kunststoffe als Wachstumsmotor für die Solarthermie, October 11, 2013:

- Task 39 – Polymermaterialien für solarthermische Anwendungen; S. Fischer, ITW, University Stuttgart, DE
- SolPol-Projekte zu Kunststoffen in der Solarthermie – Motivation, Zielsetzungen, Highlights, Reinhold W. Lang, JKU-IPMT, Linz, AT
- Stand der Technik zu Kunststoffkollektoren, Michaela Meir, University of Oslo, NO
- Kunststoffkollektoren mit integriertem Überhitzungsschutz , W. Streicher, Universität Innsbruck, AT
- Der Eine-Welt-Solarkollektor, Robert Buchinger, SUNLUMO, Perg, AT
- Leistungsanforderungen an Polymermaterialien für unterschiedliche Systemtypen, Alexander Kaiser, AEE-INTEC Gleisdorf, AT
- Kunststoffabsorber aus technischen Kunststoffen, Willibald Koller, Greiner, Kremsmünster, AT
- Polyolefine für solarthermische Absorber; Markus Povacz, JKU-IPMT, Linz, AT
- Polymere Funktionswerkstoffe für die Solarthermie, Katharina Resch, MU Leoben, AT
- Alterungsverhalten von Polyolefin-Linermaterialien für Wärmespeicher, Klemens Grabmayer, JKU-IPMT, Linz, AT
- SCOOP – Speicherkollektor mit spritzgegossenem Absorber, Karl Schnetzinger, APC Advanced Polymer Compounds, Gai, AT

MEETINGS IN 2013

15th Experts Meeting & Subtask B Workshop
March 13-15
Palma, Mallorca, Spain (hosted by Fraunhofer ISE)
27 experts participated in the meeting and the workshop.

16th Experts Meeting
October 17-18
Blumau, Austria (hosted by the partners AEE INTEC and the University of Linz)
26 experts from research institutions and industry participated in the meeting.

MEETINGS PLANNED FOR 2014

17th Experts Meeting
April 9-11
Tel Aviv, Israel

18th Experts Meeting
September 2014
Oslo, Norway

Funded Projects: Overview of Funded Projects of Task 39 Partners

(January 2013, http://www.iea-shc.org/task39/fundedprojects/).

Project	Period	Funding Agency	Partner Countries
Bio4Sol - Bioplastics for solar applications Partners: University of Leoben, PCCL, Austria	2013-15	Austrian Klima- und Energie-fonds	AT
Use of polymeric materials in solar collectors studied from a total cost perspective, Participation in IEA SHC Task 39 Coordinator: Linnæus University; Partners: Aventa AS; Fraunhofer ISE	2013-14	Swedish Energy Agency, The Research Council of Norway	SE, NO, DE
Poly2Facade – Innovative thermal self-regulating solar fa-cades by means of functional polymers; Coordinator: Univer-sity of Leoben; Partners: PCCL, ÖFPZ Arsenal GesmbH, Forschungszentrum f. integrales Bauwesen AG	2012-15	Forschungsförderungsgesell-schaft (FFG), Programmlinie Haus der Zukunft	AT
Untersuchungen zur Fertigungstechnik und Kollektorkonstruktion für Vollkunststoff-Kollektoren Partners: HAW Ingolstadt, Roth Werke GmbH	2012-15	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit	DE
SCOOP - Solar Collectors of Polymers Coordinator: Fraunhofer ISE; Website: http://eu-scoop.org/ Partners: http://eu-scoop.org/partners.html,	2011-15	EU FP7-ENERGY-2011-1	DE, AT, FR, NO, CH
Exkoll - Konzeption von extrudierten Polymerkollektoren und Komponenten; Coordinator: Fraunhofer ISE	2012-14	Bundesministerium für Umwelt, Naturschutz+Reaktorsicherheit	DE
Participation in Phase II of IEA-SHC Task 39 Coordinator: JKU-Linz; Partner: AEE-INTEC Subcontractors: AIT, PCCL, UIBK-EGEE	2011-14	Bundesministerium für Verkehr, Innovation und Tech-nologie; FFG	AT
ISOlar - Screening of insulation materials for solar thermal collectors and thermal storages and analysis of their long-term-properties; Coordinator: Austrian Institute of Technology Partners: TiSUN GmbH, EuroFoam GmbH Website: http://www.ait.ac.at/~isolar	2011-14	Österreichische Forschungs-förderungsgesellschaft (Neue Energien 2020 - Programm)	AT
SILVER - Solar Energy in Living Environments Coordinator: Aventa AS; Partners: OBOS, University of Oslo, Linnæus University, CHCP, DSSK Website: http://www.forskningsradet.no/~silver	2011-14	Research Council of Norway	NO, SE, BE, FR
PISA - Polymers in solar thermal applications University of Oslo: Leitung, Subtask A	2011-14	Enova	NO
UNISOL - Sistema Solar Termico Universal Coordinator: Fabrica de Plasticos, Lda (Pt) Partners: Aveiro University, Oslo University, Aventa AS; Website: http://projectos.adi.pt/	2011-14	Portuguese Agency for Devel-opment and Innovation	PT, NO
POLYSOL - Development of a modular, all-POLYmer SO-Larthermal collector for DHW preparation and space heating Coordinator: Energias Renovables Aplicadas S.L. Website: http://cordis.europa.eu/projects/rcn/98108_en.html	2011-12	EU FP7-SME Research area: SME-1	UK, DE, MK, ES
Smart Windows-Smart Collectors Partners: PCCL, University of Leoben, A-P-C	2010-13	Land Steiermark, Zukun-ftsfonds Partners	AT
SOLPOL-1/2 - Solar Thermal Systems based on Polymeric Materials ; Coordinator: Johannes Kepler University - JKU Partners: http://www.solpol.at/partners Website: http://www.solpol.at/	2009-13	Klima- und Energiefonds. Management: Österreichische Forschungsförderungsgesell-schaft	AT
Use of polymeric materials in solar collectors studied from a total cost perspective - Participation in IEA SHC Task 39 Coordinator: Linnæus University; Partners: Aventa, Uni Oslo	2009-12	Swedish Energy Agency	SE, NO

SHC TASK 39 CONTACTS

TASK MANAGEMENT

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

NATIONAL CONTACTS

Austria

Susanne Beissmann
Institute of Analytical Chemistry
Johannes Kepler University Linz (JKU)
Science Park, Altenberger Str. 69
A-4040 Linz
susanne.beissmann@jku.at
www.jku.at

Christian Fink
AEE - Institute for Sustainable Technologies
Feldgasse 19
A-8200 Gleisdorf
c.fink@aee.at
www.aee-intec.at

Klemens Grabmayer
Institute of Polymeric Materials and Testing
Johannes Kepler University Linz (JKU)
Science Park, Altenberger Str. 69
A-4040 Linz
klemens.grabmayer@jku.at
www.jku.at

Robert Hausner
AEE - Institute for Sustainable Technologies
Feldgasse 19
A-8200 Gleisdorf
r.hausner@aee.at
www.aee-intec.at

Wolfgang Hohenauer
AIT Austrian Institute of Technology GmbH
A-1210 Wien
wolfgang.hohenauer@ait.ac.at
www.ait.ac.at

Alexander Kaiser
AEE - Institute for Sustainable Technologies
Feldgasse 19
A-8200 Gleisdorf
a.kaiser@aee.at
www.aee-intec.at

Fabian Ochs
University of Innsbruck-EGEE
Technikerstr. 13
A-6020 Innsbruck, AUSTRIA
fabian.ochs@uibk.ac.at
www.uibk.ac.at

Martin Payer
Polymer Competence Center Leoben
Roseggerstrasse 12
A-8700 Leoben
martin.payer@pccl.at
www.pccl.at

Markus Povacz
Institute of Polymeric Materials and Testing
Johannes Kepler University Linz (JKU)
Science Park, Altenberger Str. 69
A-4040 Linz
markus.povacz@jku.at
www.jku.at

Thomas Ramschack
AEE - Institute for Sustainable Technologies
Feldgasse 19
A-8200 Gleisdorf
t.ramschak@aee.at
www.aee-intec.at

Katharina Resch
Institute of Materials Science and Testing of Plastics
University of Leoben
Franz-Josef-Strasse 18
A-8700 Leoben
katharina.resch@unileoben.ac.at
www.unileoben.ac.at

Andrea Schmid
Institute of Materials Science and Testing of Plastics
University of Leoben

Franz-Josef-Str. 18
A-8700 Leoben
andrea.schmid@stud.unileoben.ac.at
www.unileoben.ac.at

Wolfgang Streicher
University of Innsbruck-EGEE
Technikerstr. 13
A-6020 Innsbruck
wolfgang.streicher@uibk.ac.at
www.uibk.ac.at

Alexander Thür
University of Innsbruck-EGEE
Technikerstr. 13
A-6020 Innsbruck
alexander.thuer@uibk.ac.at

Gernot Wallner
Institute of Polymeric Materials and Testing
Johannes Kepler University Linz (JKU)
Science Park Altenberger Str. 69
A-4040 Linz
gernot.wallner@jku.at
www.jku.at

Andreas Weber (until 2013)
Polymer Competence Center Leoben
Roseggerstrasse 12
A-8700 Leoben
andreas.weber@pccl.at
www.pccl.at

Christoph Zauner
AIT Austrian Institute of Technology GmbH
Giefinggasse 2
A-1210 Wien
christoph.zauner@ait.ac.at
www.ait.ac.at

Germany
Mathias Ehrenwirth
Institute of new Energy Systems
Technische Hochschule Ingolstadt
Esplanade 10
D-85049 Ingolstadt
mathias.ehrenwirth@thi.de
www.thi.de/en

Stephan Fischer
University Stuttgart, ITW
Pfaffenwaldring 6
D-70550 Stuttgart
fischer@itw.uni-stuttgart.de
www.itw.uni-stuttgart.de
Michael Koehl
Group Weathering and Reliability
Fraunhofer Institute for Solar Energy Systems
Heidenhofstr. 2
D-79110 Freiburg
michael.koehl@ise.fraunhofer.de
www.ise.fraunhofer.de

Markus Peter
dp²-Energienutzung mit Verstand
Mengeweg 2
D-59494 Soest
markus.peter@dp-quadrat.de
www.dp-quadrat.de

Andreas Piekarczyk
Group Weathering and Reliability
Fraunhofer Institute for Solar Energy Systems
Heidenhofstr. 2
D-79110 Freiburg
andreas.piekarczyk@ise.fraunhofer.de

Christoph Reiter
Institute of New Energy Systems
Technische Hochschule Ingolstadt
Esplanade 10
D-85049 Ingolstadt
christoph.reiter@thi.de
www.thi.de/en

Sandrin Saile
Group Weathering and Reliability
Fraunhofer Institute for Solar Energy Systems
Heidenhofstr. 2
D-79110 Freiburg
sandrin.saile@ise.fraunhofer.de
www.fraunhofer.ise.de

Christoph Trinkl
Institute of new Energy Systems
Technische Hochschule Ingolstadt
Esplanade 10
D-85049 Ingolstadt
christoph.trinkl@thi.de
www.thi.de/en

Karl-Anders Weiss
Group Weathering and Reliability
Fraunhofer Institute for Solar Energy Systems
Heidenhofstr. 2
D-79110 Freiburg

Karl-Anders.Weiss@ise.fraunhofer.de
www.ise.fraunhofer.de

Norway
Michaela Meir
Department of Physics
University of Oslo
PO Box 1048, Blindern
N-0316 Oslo
mmeir@fys.uio.no
www.physics.uio.no/energy

John Rekstad
Department of Physics
University of Oslo
PO Box 1048, Blindern
N-0316 Oslo
john.rekstad@fys.uio.no
www.uio.no

Portugal
Pedro Graça
University of AveiromCampus
Universitário de Santiago
PT-3810193 Aveiro
mpfg@ua.pt
www.ua.pt

Slovenia
Ivan Jerman
National Institute of Chemistry Slovenia
Hajdrihova 19 P.O. Box 660
SI-1001 Ljubljana
ivan.jerman@ki.si
www.ki.si

Boris Orel
National Institute of Chemistry Slovenia
Hajdrihova 19 P.O. Box 660
SI-1001 Ljubljana
boris.orel@ki.si
www.ki.si

Sweden
Bo Carlsson
School of Natural Sciences
Linnaeus University
SE-39182 Kalmar
bo.carlsson@lnu.se
www.lnu.se

United States
Susan Mantell
Department of Mechanical Engineering
University of Minnesota
111 Church Street SE
Minneapolis, MN 55455
smantell@me.umn.edu
www.umn.edu

Tim Merrigan
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden 80401-3393
tim.merrigan@nrel.gov
www.nrel.gov

INDUSTRY PARTICIPANTS

Austria
Robert Buchinger
Sunlumo Technology GmbH
Technologiepark 17
A-4320 Perg
robert.buchinger@sunlumo.at
www.sunlumo.at

Karl Schnetzinger
APC - Advanced Polymer Compounds
Parkring 1
A-8712 Niklasdorf
karl.schnetzinger@a-p-c.at
www.a-p-c.at

Nataliya Schnetzinger
APC - Advanced Polymer Compounds
Parkring 1
A-8712 Niklasdorf
nataliya.schnetzinger@a-p-c.at
www.a-p-c.at

Belgium
Els De Meersman
Chevron Phillips Chemicals Int. N.V.
Haendorpweg 1-Haven 1227
B-9130 Kallo (Beveren-Waas)
DEMEEE@cpchem.com
www.rytonpps.com

Brazil
Eric Rocha
Performance Polymers DuPont do Brasil S.A.
06454-080 Barueri SP

eric.rocha@bra.dupont.com
www.dupont.com
Danilo Sato
Performance Polymers DuPont do Brasil S.A.
06454-080 Barueri SP
danilo.h.sato@bra.dupont.com
www.dupont.com

Canada

Francois Brizard
Enerconcept Technologies Inc.
42 Main St. W., Office 201
J1X 2A5 Magog
f.brizard@enerconcept.com
www.enerconcept.com

Christian Vachon
Enerconcept Technologies Inc.
42 Main Street W, Office 201
J1X 2A5 Magog, QC
christian.v@enerconcept.com
www.enerconcept.com

Germany

Andreas Maegerlein
Application Engineering - Universal
BASF SE, E-KTE/EU
D-67056 Ludwigshafen
andreas.maegerlein@basf.com
www.basf.com

Axel Mueller
Dr. Axel Müller - HTCO
Rabenkopfstrasse 4
D-79102 Freiburg
am@htco.de
www.htco.de

Davorin Pavic
BlueTec GmbH & Co. KG
In der Bau 17
34388 Trendelburg
davorin.pavic@bluetec.eu
www.bluetec-germany.de

Andre Schäfer
Application Engineering - Universal
BASF SE, E-KTE/II
D-67056 Ludwigshafen
andre.schaefer@basf.com
www.basf.com

Teodora Vatahska
Dr. Axel Müller - HTCO
Rabenkopfstrasse 4
D-79102 Freiburg
tv@htco.de
www.htco.de

Norway

Ingvild Skjelland
Aventa AS
Trondheimsveien 436 A
N-0962 Oslo
is@aventa.no
www.aventa.no

Portugal

Luis Godinho
Pirev Surface Engineering
Zona Industrial de Vagos, Lote 61
Pt-3840-385 Vagos
luisgodinho@prirev.com
www.prirev.com

Task 40
Towards Net Zero Energy Solar Buildings

Josef Ayoub
CanmetENERGY
Operating Agent for Natural Resources Canada

TASK DESCRIPTION

Forty percent (40%) of primary energy use and 24% of greenhouse gas emissions, account for energy use in buildings worldwide. Energy use and emissions include both direct, on-site use of fossil fuels and indirect use from electricity, district heating / cooling systems and embodied energy in construction materials. Several International Energy Agency (IEA) countries have adopted a vision of so-called 'net zero energy buildings' as long-term goal of their energy policies. However, what is missing is a clear definition and international agreement on the measures of building performance that could inform 'zero energy' building policies, programs and industry adoption around the world.

Objective

The objective of this joint Task with the IEA ECBCS Programme (Annex 52) was to study current net-zero, near net-zero and very low energy buildings and to develop a common understanding, a harmonized international definitions framework, tools, innovative solutions and industry guidelines. A primary means of achieving this objective was to document and propose practical NZEB demonstration projects, with convincing architectural quality. These exemplars and the supporting sourcebook, guidelines and tools were viewed as keys to industry adoption. These projects aimed to equalize their small annual energy needs, cost-effectively, through building integrated heating/cooling systems, power generation and interactions with utilities.

The Task, which ended in October 2013, built upon recent industry experiences with net-zero and low energy solar buildings and the most recent developments in whole building integrated design and operation. The joint international research and demonstration activity addressed concerns of comparability of performance calculations between building types and communities for different climates in participating countries. The goal was solution sets that are attractive for broad industry adoption.

Scope

The scope included major building types (residential and non-residential), new and existing, for the climatic zones represented by the participating countries. The work was linked to national activities and will focus on individual buildings, clusters of buildings and small settlements. The work was based on analysis of existing examples that leads to the development of innovative solutions to be incorporated into national demonstration buildings. The objectives were achieved in the following Subtasks.

Duration

This Task was initiated on October 1, 2008 and was completed on October 9, 2013.

Participating Countries

Australia	Italy
Austria	Norway
Belgium	Portugal
Canada	Singapore
Denmark	Spain
Finland	Sweden
France	Switzerland
Germany	United States

SHC Task 40 / EBC Annex 52 National Experts and observers attending the 10th Experts Group Meeting, October 7 – 9, 2013, Montreal, Canada.

TASK ACCOMPLISHMENTS

The main objectives of Task 40 was to study current net-zero, near net-zero and very low energy buildings and to develop a common understanding, a harmonized international definitions framework, tools, innovative solutions and industry guidelines.

Key Results

The main accomplishments of this Task are highlighted below. Specific deliverables are available on the SHC Task 40 website.

Subtask A: Definitions & Implications
(Subtask Leaders: Karsten Voss, Germany and Assunta Napolitano, Italy)

The objective of Subtask A was to establish an internationally agreed understanding on NZEBs based on a common methodology. The Participants achieved this objective by the following activities:

- Review and analysis of existing NZEB definitions and data (site/source energy, emissions, exergy, costs, etc.) with respect to the demand and the supply side.
- Study of grid interaction (power/ heating/cooling) and time dependent energy mismatch analysis.
- Development of a harmonized international definition framework for the NZEB concept considering large-scale implications, exergy and credits for grid interaction (power/heating /cooling).
- Development of a monitoring, verification and compliance guide for checking the annual balance in practice (energy, emissions and costs) harmonized with the definition.

Subtask B: Design Processes & Tools
(Subtask Leaders: Adam Hirsch, Paul Torcellini USA and Andreas Athienitis, Canada)

Subtask B aimed to identify and refine design approaches and tools to support industry adoption. The Participants achieved these objectives by the following activities:

- Documentation of processes and tools currently being used to design NZEBs and under development by participating countries.
- Assessment of gaps, needs and problems, considering the work of Subtask A and Subtask C, and inform simulation engine and detailed design tools developers of priorities for NZEBs.
- Development and testing of design approaches and simplified NZEB tools or interfaces (e.g., spreadsheet or web-based method) linked to Subtask C Solution Sets to support integration of NZEB technologies and architecture at the early design stage.

Subtask C: Solution Sets (Design, Engineering, Technologies)
(Subtask Leaders: Michael Donn, New Zealand and François Garde, France)

The objectives of this Subtask were to develop and test innovative, whole building net-zero solution sets for cold, moderate and hot climates with exemplary architecture and technologies that would be the basis for demonstration projects and international collaboration. The Participants achieved these objectives by the following activities:

- Documentation and analysis of current NZEBs designs and technologies, benchmarking with near NZEBs and other very low energy buildings (new and existing), for cold, moderate and hot climates considering sustainability, economy and future prospects using a projects database, literature review and practitioner input (workshops).
- Development and assessment of case studies and demonstration projects in close cooperation with practitioners.
- Investigation of advanced integrated design concepts and technologies in support of the case studies, demonstration projects and solution sets.
- Development of NZEB solution sets and guidelines with respect to building types and climate and to document design options in terms of market application and CO2 implications.

Subtask D: Dissemination & Outreach
(Operating Agent and Subtask Leaders)

The objective of the dissemination activity was to support knowledge transfer and market adoption of NZEBs on a national and international level. Subtask leaders were responsible for the coordination of the individual contributions of Subtask participants and for coordination with the other Subtasks where a combined output was planned. The Participants achieved the objectives by the following activities:

- Establishment of a NZEB web page, within the IEA SHC/ECBCS Programmes' framework, and a database that can be expanded and updated with the latest projects and experiences.
- Production of a NZEB source book including example buildings for investigated building types and climates.
- Transfer of Task outputs to national policy groups, industry associations, utilities, academia and funding programs.
- Establishment of an education network, summer school and contributions to the Solar Decathlon and similar student activities.
- Workshops, articles and features in magazines to stimulate market adoption.

Publications
Publications and other Task documents can be downloaded from the Task 40 website:
http://www.iea-shc.org/task40/

Report No.	Report Title	Publication Date	Access (PUblic, REstricted)	Web or Print
DA.TR1	Zero Energy Building Definition – A Literature Review (Anna Joanna Marzal and Per Heiselberg)	September 2012	PU	Web
DA.TR2	Net-ZEB Evaluation Tool and User Guide (Annamaria Belleri, Assunta Napolitano)	November 2012	PU	Web
DA.TR3	LCA analysis of buildings - Taking the step towards Net Zero energy Buildings (Björn Berggren, and Monika Hall)	May 2013	PU	Web
DAC.TR4	Measurement and Verification Protocol for Net Zero Energy Buildings (Federico Noris, Assunta Napolitano, Roberto Lollini)	September 2013	PU	Web
DA.TR5	Analysis of Load Match and Grid Interaction Indicators in Net-ZEB with High Resolution Data (Jaume Salom)	October 2013	PU	Web
DA.TB	Source Book Volume 1: Net Zero Energy Buildings: International Projects of Carbon Neutrality in Buildings (Editors: Karsten Voss, Eike Musall)	November 2012	Purchase	Online shop from publisher (DETAIL)
DB.TB	Source Book Volume 2: Modelling, Design, and Optimization Net Zero Energy Buildings (Editors: Andreas Athienitis, William O'Brien)	With Publisher Expected Fall 2014	Purchase	Expected Online shop from publisher (Wiley
DC.TR1	Solution sets and Net Zero Energy Buildings. Review of 30 Net ZEBcase studies worldwide (Authors: Francois Garde. Michael Donn; contributions from STC members)	May 2014	PU	Web
DC.TB	Book Volume 3: Solution Sets for Net Zero Energy Buildings: Feedback from 30 Net-ZEBs worldwide (Editors: Michael Donn, Francois Garde)	Completing Draft Expected Spring 2015	Purchase	Expected Online shop from publisher Wiley-VCH

Journal Articles and Conference Papers/Presentations
Journal articles (in many languages) or contributions to relevant external investigations/ studies/reports in which Task participants played leading roles.

Journal	Author/Title	Publication Date	Access (PUblic, REstricted)	Web or Print
Journal of Green Building Volume 4 Issue 4	M. Heinze, K. Voss, *Goal: Zero Energy Building: Exemplary experience based on the Solar Estate Soalrsiedlung Freiburg am Schlierberg, Germany*	2009	RE	Web and Print

Journal	Author/Title	Publication Date	Access (PUblic, REstricted)	Web or Print
Bauphysik Vol. 32/6, 2010, 424-434	E. Musall, . Lichtmas, *Vom NiedrigeneMrgie- zum Nullenergiehaus- Standortbestimmung und Entwicklungs-perspektiven*	2010	PU	Web
Ecoconstrucción Nov./Dec./ 41	E. Cubi, *El camino hacia edificios de balance energético cero*	2010	PU	Web
XIA-intelligente Architektur Vol 01-02 2010	K. Voss, E, Musall, *Verlagsanstalt Alexander Koch GmbH*	2010	PU	Web and Print
Energy and Buildings 43 (2011) 971-979	A.J. Marszal, P. Heiselberg, J.S. Bourrelle, E. Musall, K. Voss, I. Sartori, A. Napolitano, *Zero Energy Building – A review of definitions and calculation methodologies.*	2011	PU	Web and Print
Journal of Green Building Volume 6 Issue 1	K. Voss, E. Musall, M. Lichtmas, *From low-energy to net zero-energy buildings: status and perspectives*	2011	RE	
Journal of Green Building Volume 6 Issue 3	I. Sartori T.H. Dokka, Andersen, *Proposal of a Norwegian ZEB definition: Assessing the Implications for Design*	2011	RE	
xia Intelligente Architektur 77 11/2011, 6 pp.	E. Musall, K. Voss, *Klimaneutrale Gebäude als Ziel: Internationale Projekterfahrungen*	2011	PU	
Casa&Clima 09/2011,6 pp.	A. Napolitano, R. Lollini, *Energia "quasi zero":come qunatificarla?*	2011	PU	
Energy and Buildings 43(2011) 1646-1654.	H. Lund, A. Marszal, P. Heiselberg, *Zero energy buildings and mismatch compensation factors,*	2011	PU	
Energy Efficiency DOI 0.1007/s12053-011-9138-2	E. Mlecnik, *Defining nearly zero-energy housing in Belgium and the Netherlands*	2011	PU	
ASHRAE Transactions CH-12-C011, vol. 188 n°1 pp.81.	F. Garde, E. Ottenwelter, A. Bornarel. *Integrated Building Design in Tropical Climates: Lessons learned from the ENERPOS Net Zero Energy Building.*	2011	PU	
Progress in Photovoltiacs : Research and Applications	A. Scognamiglio, H. Røstvik, *Photovoltaics and zero energy buildings: a new opportunity and challenge for design*	2012	PU	

Journal	Author/Title	Publication Date	Access (PUblic, REstricted)	Web or Print
Energy and Buildings 48 (2012) 220-232.	I. Sartori, A. Napolitano, K.Voss, *Net zero energy buildings: A consistent definition framework.*	2012	PU	
DETAIL Green Vol. 1/2012, 6 pp	E, Musall, K. Voss, *Nullenergiegebäude – ein Begriff mit vielen Bedeutungen*	2012	PU	
REHVA Journal, December 2012, 23-27.	K.Voss, I. Sartori, R. Lollini, *Nearly-zero, Net zero and Plus Energy Buildings– How definitions & regulations affect the solutions.*	2012	PU	
Architectural Science Review Journal (July 2012)	A. Lenoir, G. Baird , F. Garde. *Post-occupancy evaluation and experimental feedback of a net zero-energy building in a tropical climate.* http://dx.doi.org/10.1080/00038628.2012.702449	2012	PU	
Ecolibrium Journal July 2012, pp. 42-49	A. Lenoir, S. Cory, M. Donn, F. Garde. *User's behaviour and energy performance of Net Zero Energy Buildings*.	2012	PU	
High Performing Building Journal Summer 2012, pp. 43-55.	A. Lenoir, F. Garde. *Tropical NZEB.* http://www.hpbmagazine.org/case-studies/educational/university-of-la-reunions-enerpos-saint-pierre-la-reunion-france	2012	PU	
Renewable Energy 22 (2012) 154-165	A. Marszal, P. Heiselberg, R.Lund Jensen, J.Nørgaard, *On-site or off-site renewable energy supply options? Life cycle cost analysis of a Net Zero Energy Building in Denmark.*	2012	PU	
Bygg och Teknik 2/2012, 3 pages	B. Berggren, J. Widén, B. Karlsson, M. Wall, *Att definiera nollenergibyggnader - en internationell angelägenhet*	2012	PU	
Energy and Buildings 53 (2012) 194 -205	S. Carlucci, L. Pagliano, *A review of indices for the long-term evaluation of the general thermal comfort conditions in buildings*	2012	PU	
Cultura Energética n.179, 03/2012	J. Salom, *Els edificis de consum d'energia quasi zero*	2012	PU	
Tagungsband 16. Internationale Passivhaustagung 2012	M. Hall, B. Berggren, *Embodied Energy of Net zero energy Buildings*	2012	PU	
Tagungsband 16. Internationale Passivhaustagung 2012	E.Musall, K. Voss, *The Passive House Concept as Suitable Basis towards Net Zero Energy Buildings*	2012	PU	

Journal	Author/Title	Publication Date	Access (PUblic, REstricted)	Web or Print
Null-und Plusenergiehäuser (Book)	E. Musall, K. Voss, M. Hall, (*Chapters on theorie, defintions, examples and cross analysis in Net ZEBs)*	2012	PU	
Joint Report (Ecofys | Politechnico de Mialno | University of Wuppertal	T40A52 member contributors (L. Pagliano, P. Zangheri, K. Voss, E. Musall) *Final report: Towards nearly zero-energy buildings: Definition of common principles under the EPBD*	2013	PU	
RHVA Report of nZEB Task Force	P. Heiselberg, I. Sartori, K. Voss *et.al., REHVA nZEB technical definition and system boundaries for nearly zero energy buildings: (2013 revision for uniformed national implementation of EPBD recast prepared in cooperation with European standardization organization CEN)*	2013	PU	
Energy and Buildings 56 (2013) 189 - 203	M. Hamdy, A. Hasa, K. Sirén, *A multi-stage optimization method for cost-optimal and nearly-zero-energy building solutions in line with the EPBD-recast 2010*	2013	PU	
Edifícios e Energia	L. Aelenei, D. Aelenei, H. Gonçalves, *Edifícios de balanço energético nulo; Uma síntese das características principais*	2013	PU	
Sustainability 5 (2013) 1256-1265	M. Noguchi, *Choice of domestic Air-Sourced solar photovoltaic thermal systems through the operational energy cost implications in Scotland*	2013	PU	
Energy and Buildings 60 (2013) 110 -124	S. Attia, M. Hamdy, W. O'Brien, S. Carlucci, *assessing gaps and needs for integrating building performance optimization tools in net zero energy building design*	2013	PU	
Open House International (OHI) Vol. 38 No. 3	Guest Editor: Masa Noguchi, *Special Issue: Zero Energy Mass Custom Homes Research Paradigms;* L. Aelenei, D. Aelenei, H. Conclaves, R. Lollini, E. Musall, A. Scognamiglio, E. Cubi, M. Noguchi, *Design Issues for Net Zero energy Buildings;* H. Rostvik, *Mass Housing and Sustainability*	2013	PU	
Building and Environment 75 (2014) 114 - 131	S. Carlucci, L. Pagliano, A. Sangalli, *Statistical analysis of the ranking capability of long-term thermal discomfort indices and their adoption in optimization processes to support building design*	2014	PU	
Applied Energy 114 (2014) 385-399	A. Mohamed, A. Hasan, K. Sirén, *Fulfillment of net-zero energy building (NZEB) with four metrics in a single family house with different heating alternatives*	2014	PU	

Journal	Author/Title	Publication Date	Access (PUblic, REstricted)	Web or Print
Energy Procedia 48 (2014) 1282-1291	M. Hall, A. Geissler, B. Burger, *Two years of experience with a net zero energy balance – analysis of the Swiss MINERGIE-A® standard*	2014	PU	
Energy Procedia 48 (2014) 1236 -1243	L. Aelenei, H. Conçalves, *From solar building design to net-zero energy buildings: performance insights of an office building*	2014	PU	
Energy Procedia	A. Scognamiglio, F. Garde, H. N. Røstvik. *How Net Zero Energy Buildings and cities might look like? New challenges for passive design and renewables design*.	Accepted To be published in 2014	PU	
Energy Procedia	F. Garde, A. Lenoir, A. Scognamiglio, D. Aelenei, D. Waldren, H. N. Rostvik, J. Ayoub, L. Aelenei, M. Donn, M. Tardif, S. Cory, *Design of Net Zero Energy Buildings: Feedback from international projects*.	Accepted To be published in 2014	PU	
Energy and Buildings 72 (2014) 371-381	M. Cellura, F. Guarino, S. Longo, M. Mistretta, *Energy life-cycle approach in net-zero energy buildings balance: Operation and embodies energy of an Italian case study*	2014	PU	
Submitted to Energy and Buildings	D. Aelenei, et.al., *Design strategies for non residential zero-energy buildings*	Submitted Nov. 2013 (Accepted May 2014)	PU expected	
Submitted to Energy and Buildings	A. Lenoir, E. Ottenwelter, F. Garde, *Energy Performance of a Net Zero Energy Building in a Tropical climate*	Submitted Nov. 2013	PU expected	
Submitted to Energy and Buildings	S. Corey, *et.al., Lessons Learned from Seven Near-Zero or Net-Zero Energy building Design Teams*	Submitted Nov. 2013	PU expected	
Submitted to Advances in Building Energy Research.	J. Salom, J. Widén, J. Candanedo, K. Lindberg, *Analysis of grid interaction indicators in net zero energy buildings with sub-hourly collected data.,*	Submitted Feb. 2014 (Accepted May 2014)	PU expected	
Submitted to Applied Energy	J. Salom, J. Widén, A. Marszal, J. Candanedo, K. Lindberg, *Analysis of load match and grid interaction indicators in net zero energy buildings with simulated and monitored data.*	Submitted Feb. 2014	PU expected	
Submitted to Energy Procedia	F. Garde, A. Lenoir, A. Scognamiglio, D. Aelenei, D. Waldren, H.N. Rostovik, J. Ayoub, L. Aelenei, M. Donn, M. Tardif, S. Cory, *Design of Net Zero Energy Buildings: Feedback from international projects,* The 6th International Conference on Applied Energy ICAE 2014, May 30 – June 2, 2014, Taipei, Taiwan	Submitted Oct. 2013 (Accepted May 2014)		

Workshops and Conferences
The following are workshops and conferences Task participants contributed to with results of their work achieved within the framework of the Task or with results of the Task work.

Workshop/Conference	Place	Date
ASHRAE Winter Conference	Orlando, USA	Jan. 23 – 27, 2009
4th Annual General Meeting and Workshops of the Solar Buildings Research Network	Toronto, Ontario	June 25 – 27, 2009
SolarSummits Freiburg 2009	Freiburg, Germany	Sept. 2009
SuDBE2009 International Conference on Sustainable Development in Building & Environment	Chongqing, China	Oct. 29, 2009
Fachtagung „Energieberatung Thüringen 2010“ der Klimaschutz-Stiftung Thüringen	Jena, Germany	June, 2010
Zero Emission Buildings: Renewable Energy Research Conference 2010	Trondheim, Norway	June 7 – 8, 2010
2nd Congres d'estalvi i eficiencia energètica a l'edificació	Barcelona, Spain	June 22, 2010
Danish ZEB Conference	Aalborg, Denmark	Aug. 25, 2010
World Climate Solutions, Energy Efficiency Workshop	Copenhagen, Denmark	Sept. 9, 2010
EuroSun 2010: International Conference on Solar Heating, Cooling and Buildings	Graz, Austria	Sept. 28 – Oct. 1, 2010
BEA Congress	Bern, Switzerland	Nov. 11, 2010
Bau 2011, BMWI Congress	Munich, Germany	Jan. 22, 2011
AHSRAE Winter Conference	Las Vegas, USA	Jan. 29 – Feb 2, 2011
Academic workshop at the university of Bergamo	Bergamo, Italy	May 5, 2011
Danfoss - Heating Solution R&D Technology Event	Billund, Denmark	May 11, 2011
Renewable Energy Research Conference	Trondheim, Norway	June 7, 2011
ASHRAE Annual Conference	Montreal, Canada	June 25 – 29, 2011
ISES Solar World Congress 2011	Kassel, Germany	Aug. 28 – Sept. 2, 2011
International Conference: Cleantech for Smart Cities and Buildings - CISBAT 2011	Lausanne, Switzerland	Sept. 14 – 16, 2011
Cities of the Future Congress	Essen, Germany	Sept. 20, 2011
Energia Apero	Basel, Switzerland	Sept. 21, 2011
Smart Energy Startegies	Zurich, Switzerland	Sept. 22, 2011
Seminar: Architecture and future buildings	Oslo, Norway	Sept. 27, 2011
AICARR-SAIE conference	Bologna, Italy	Oct. 6, 2011
Belgian Passive House Symposium 2011	Brussels, Belgium	Oct. 7, 2011
3rd Nordic Passive House Conference	Aalborg, Denmark	Oct. 7, 2011
Building Simulation 2011: 12th Conference of IBPSA	Sydney, Australia	Nov. 14-16, 2011
Danvak Temadag: Energineutralt byggeri – vision eller virkelighed?	Copenhagen, Denmark	Nov. 18, 2011
Internationaler Plusenergie - Kongress 2011	Bern, Switzerland	Nov. 26, 2011
ASHRAE Winter Conference	Chicago, USA	Jan. 21 – 25, 2012
World Sustainable Energy Days (WESD) 2012	Wels, Austria	Feb. 29, 2012
Active house Workshop, ECOBUILD 2012	London, UK	March 20 – 22, 2012
IEA SHCP Workshop: Solar Energy in Urban Planning	Lisbon, Portugal	March 26, 2012
Rendimiento, Integración y Oportunidades de las Energías Renovables en la Arquitectura	Madrid, Spain	March 27, 2012
1st Annual General Meeting and Workshops of the NSERC Smart Net Zero Energy Buildings Strategic Research Network (SNEBRN)	Halifax, Nova Scotia	April 30 – May 1, 2012
16th Internationale Passivhaustagung	Hanover, Germany	May 4, 2012
Passivehouse Symposium	Brussels, Belgium	May 5, 2012
I Congreso de Edificios de Energia casi nula	Madrid, Spain	May 7, 2012
Seminario: Riqualificazione di edifici esistenti con elevati standard energetici: metodi e tecnologie	Rome, Italy	June 12, 2012

Workshop/Conference	Place	Date
1st Net Zero-Energy Buildings Conference	Lisbon, Portugal	June 25 – 26, 2012
ASHRAE Annual Conference	San Antonio, USA	June 23 – 27, 2012
High Energy Performance Buildings Workshop	Brussels, Belgium	June 24 – 26, 2013
International Conference for Solar Heating and Cooling for Buildings and Industry (SHC) 2012	San Francisco, USA	July 9 – 11, 2012
SEB12, 4th International Conference on Sustainability in Energy and Buildings	Stockholm. Sweden	Sept. 3 – 5, 2012
Nullutslippsbygg - fra forskning til byggeprosjekt. ZEB Konferansen 2012	Oslo, Norway	Sept. 5, 2012
Building Simulation and Optimization (BSO12)	Loughborough, UK	Sept. 10 - 11, 2012
1st ZEMCH International Conference	Glasgow, Scotland	Sept. 12 – 14, 2012
EuroSun 2012: ISES Europe Solar Conference	Rijeka, Croatia	Sept. 18 – 20, 2012
SHC 2013 International Conference on Solar Heating and Cooling for Buildings and Industry	Freiburg, Germany	Sept. 23 – 25. 2013
27th European PVSEC	Frankfurt, Germany	Sept. 24 – 28, 2012
CCHVAC conference 2012	Yantai, China	Sept. 26, 2012
International Building Performance Simulation Association (IBPSA) Nordic	Oslo, Norway	Oct. 17 – 18, 2012
4th Nordic Passive House Conference	Trondheim, Norway	Oct. 21 – 23, 2012
2nd ZEMCH International Conference	Orlando, USA	Oct. 30 – Nov.1, 2013
28th International PLEA Conference	Lima, Peru	Nov. 7 – 9, 2012
Smart City Expo World Congress	Barcelona, Spain	Dec. 1, 2012
ASHRAE Winter Conference	Dallas, USA	Jan. 26 -30, 2013
World Sustainable Energy Days (WESD) 2013	Wels, Austria	Feb, 27 – 28, 2013
Null- und Plusenergiehäuser	Darmstadt, Germany	March 7, 2013
VDI-Expertenforum: Wie „smart“ managen wir Energie wirklich?	Karlsruhe, Germany	March 20, 2013
Tegernseer Baufachtage	Bad Wiesse, Germany	April 24, 2013
2nd Annual General Meeting and Workshops of the NSERC Smart Net Zero Energy Buildings Strategic Research Network (SNEBRN)	Ottawa, Ontario	May 22 – 24, 2013
Clima 2013 - REHVA Congress	Prague, CzechRepublic	June 16 – 19, 2013
High Energy Performance Buildings Workshop	Brussels, Belgium	June 24 – 26, 2013
DIN Workshop - Solar Aktiv Häuser	Stuttgart, Germany	July 22, 2013
ASHRAE Annual Conference	Denver, USA	June 22 – 25, 2013
International Building Performance Simulation Association (IBPSA) 2013	Chambery, France	Aug. 25 – 28, 2013
International Conference: Cleantech for Smart Cities and Buildings - CISBAT 2013	Lausanne, Switzerland	Sept. 4 – 6, 2013
International Conference PLEA 2013	Munich, Germany	Sept. 10 - 12, 2013
International Conference for Solar Heating and Cooling for Buildings and Industry (SHC) 2013	Freiburg, Germany	Sept. 23 – 25, 2013
Klimaenergy	Bolzano, Italy	Sept. 19 – 21, 2013
Workshop Edificios de Energia Casi Nulo	Madrid, Spain	Sept. 13, 2013
Energy in Buildings and Communities Seminar	Dublin, Ireland	Nov. 13, 2013

MEETINGS IN 2013

9th Experts Meeting
April 30 - May 3
Copenhagen, Denmark

10th Experts Meeting
October 7 - 9
Montreal, Canada

SHC TASK 40/ECBCS ANNEX 52 CONTACTS

TASK MANAGEMENT

Operating Agent
Josef Ayoub
Senior Planning Advisor, Energy S&T
CanmetENERGY/Natural Resources Canada/ Government of Canada
1615 Lionel-Boulet Blvd, P.O. Box 4800
Varennes, Québec J3X 1S6
Canada
Phone: + (1) 450-652-1981
Fax: + (1) 450- 652-5177
josef.ayoub@rncan-nrcan.gc.ca
http://www.canmetenergy.nrcan.gc.ca

Subtask A Leaders
Assunta Napolitano (withdrew in 2010)
EURAC Research
Insitute for Renewable Energy
Viale Druso n°1,
39100 Bozen/Bolzano
Italy
Phone: +39 0471 055 651
Fax +39 0471 055 699
assunta.napolitano@eurac.edu

Karsten Voss
Bergische Universität Wuppertal
Haspeler Straße 27
42285 Wuppertal
Germany
Phone: 0049 (0)202 439 4094
Fax: 0049 (0)202 439 4296
kvoss@uni-wuppertal.de

Roberto Lollini
EURAC Research
Insitute for Renewable Energy
Viale Druso n°1,
39100 Bozen/Bolzano
Italy
Phone: +39 0471 055 651
Fax +39 0471 055 699
roberto.lollini@eurac.edu

Subtask B Leaders
Andreas Athienitis
Concordia University (Solar Buildings Research Network)
1455 Maisonneuve W., Montreal
Quebec, H3G1M8
Canada
Phone: +1 514-848-2424 Ext. 8791
Fax: +1 514-848-7965
aathieni@encs.concordia.ca

Paul Torcellini (withdrew in 2010)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, Colorado 80401 -3305
United States
Phone: +1 303-384-7528
Fax: +1 303-384-7540
paul_torcellini@nrel.gov

Subtask C Leaders
Michael Donn
Victoria University
Centre for Building Performance Research
PO Box 600
Wellington
New Zealand
Phone: +6444636221
Mobile: +6421611280
michael.donn@vuw.ac.nz

François Garde
Université de la Réunion
Faculty of Humanities and the Environment
Sciences Building and Environment
15, avenue René Cassin
Saint Denis, Ile de la Réunion, 97715
France
Phone: +262 (0)262 96 28 90
Fax: +262 (0)262 96 28 99
garde@univ-reunion.fr

NATIONAL CONTACTS

Austria
Karl Höfler and ***Sonja Geier***
AEE INTEC
Department for Sustainable Buildings
Feldgasse 19
A-8200 Gleisdorf
k.hoefler@aee.at
s.geier@aee.at
http://www.aee-intec.at/index.php?lang=en

Werner Nussmüller
Nussmüller Architekten ZT GmbH
Zinzendorfg. 1
8010 Graz
buero@nussmueller.at
http://www.nussmueller.at/aktuelles.php

Belgium
Roel De Coninck
3E
Quai à la Chaux 6 Kalkkaai,
1000 Brussels
roel.deconinck@3e.eu
http://www.3e.be/index.php

André De Herde
Université Catholique de Louvain
Place du Levant, 1
1348 Louvain-la-Neuve
deherde@arch.ucl.ac.be
http://www-climat.arch.ucl.ac.be

Ralf Klein
KaHo Sint-Lieven
Gebroeders Desmetstraat 1
9000 GENT
ralf.klein@bwk.kuleuven.be
http://www.kahosl.be/site/index.php?p=/en/page/11/welcome-to-kaho-sintlieven/

Erwin Mlecnik
Passiefhuis-Platform vzw
Gitschotellei 138
2600 Berchem
erwin.mlecnik@passiefhuisplatform.be
http://www.passiefhuisplatform.be/

Canada
Andreas Athienitis
NSERC Solar Buildings Research Network Professor and Concordia
Research Chair Tier I
Dept. of Building, Civil and Environmental Engineering
Concordia University
1455 Maisonneuve W.
Montreal, Québec H3G 1M8
aathieni@encs.concordia.ca
http://www.solarbuildings.ca

Véronique Delisle
CanmetENERGY/Natural Resources Canada/Government of Canada
1615 Lionel-Boulet Blvd, P.O. Box 4800
Varennes, Québec J3X 1S6
veronique.delisle@rncan-nrcan.gc.ca
www.canmetenergy.nrcan.gc.ca

Michel Tardif
CanmetENERGY/Natural Resources Canada/Government of Canada
580 Booth Street
Ottawa, Ontario K1A 0E4
michel.tardif@rncan-nrcan.gc.ca
http://www.canmetenergy.nrcan.gc.ca

Denmark
Per Heiselberg and ***Anna Marszal***
Aalborg University
Department 6 - Department of Civil Engineering
Sohngårdsholms Vej 57
9000 Aalborg
ph@civil.aau.dk
ajm@civil.aau.dk
http://en.aau.dk/
http://www.zeb.aau.dk

Søren Østergaard Jensen
Danish Technological Institute
Gregersen Vej
2630 Taastrup
soren.o.jensen@teknologisk.dk
http://www.teknologik.dk/

Kim B. Wittchen
Danish Building Research Institute
Aalborg University
Dr. Neergaards Vej 15
2970 Hørshom
KBW@SBi.dk
http://www.en.sbi.dk/

Finland
Riikka Holopainen, Jyri Nieminen and ***Sirje Vares***
VTT Technical Research Centre of Finland
P.O. Box 1000
02044 Espoo
jyri.nieminen@vtt.fi
http://www.vtt.fi/index.jsp

Ala Hasan and ***Mohamed H. Hamdy***
Aalto University
Department of Energy Technology
School of Science and Technology
PO Box 14400
FI-00076 Aalto
ala.hasan@tkk.fi
Mohamed.Hassan@tkk.fi
http://hvac.tkk.fi/index_uk.html

France
François Garde
Université de la Réunion
Campus universitaire Sud
15 avenue René Cassin, BP 7151
97715 Saint Denis Messag, Cedex 9
garde@univ-reunion.fr
http://www.univ-reunion.fr/index.html

Germany
Karsten Voss
Bergische Universität Wuppertal
Haspeler Straße 27
42285 Wuppertal
kvoss@uni-wuppertal.de
http://www.btga.uni-wuppertal.de

Italy
Stefano Avesani, Roberto Lollini, and ***Assunta Napolitano***
EURAC Research
Insitute for Renewable Energy
Viale Druso n°1,
39100 Bozen/Bolzano
stefano.avesani@eurac.edu
roberto.lollini@eurac.edu
assunta.napolitano@eurac.edu
http://www.eurac.edu

Alessandra Scognamiglio
ENEA CR Portici
P.le E. Fermi - 80055 Portici (Napoli)
alessandra.scognamiglio@enea.it
http://www.portici.enea.it/index2.html

Valerio Calderaro
Università degli Studi di Roma "La Sapienza"
Piazzale Aldo Moro 5, 00185 Roma
valerio.calderaro@uniroma1.it
http://www.uniroma1.it/default_e.php

Salvatore Carlucci, Lorenzo Pagliano and ***Paolo Zangheri***
Politecnico di Milano
Energy Department - eERG end-use Efficiency Research Group
Via Lambruschini 4, 20156 Milano
salvatore.carlucci@polimi.it
lorenzo.pagliano@polimi.it
http://www.energia.polimi.it/english/research/scheda_gruppo.php?id=14

Maurizio Cellura
Universitá degli di studi Palermo
Dipartimento di Ricerche Energetiche ed Ambientali (DREAM)
V.le delle Scienze - Ed. 9 - 90128 Palermo
mcellura@dream.unipa.it
http://portale.unipa.it/home/dipartimenti/dip_energetic

South Korea
Gi Young Yang and ***Seungho Shin***
Samsung C&T Corporation
Research Institute of Construction Technology
1321-20, Seocho2-dong, Seocho-Gu, Seoul
pius.yang@samsung.com
seungho.shin@samsung.com
http://www.secc.co.kr/

Jun Tae Kim
Kongju National University
Dept. Architectural Engineering
275 Budae-dong, Cheonan, Chungnam Province
jtkim@kongju.ac.kr
http://www.kongju.ac.kr/index.jsp

New Zealand
Michael Donn
Victoria University of Wellington School of Architecture
PO Box 600, 139 Vivian St., Wellington
michael.donn@vuw.ac.nz
http://www.victoria.ac.nz/home/

Norway
Anna Grete Hestnes
Norwegian University of Science and Technology - NTNU
The Research Centre on Zero Emission Buildings
Faculty of Architecture and Fine Art
NO-7491 Trondheim
annegrete.hestnes@ntnu.no
http://www.sintef.no/projectweb/zeb

Tor Helge Dokka and ***Igor Sartori***
NTNU/ SINTEF Building and Infrastructure
Forskningsveien 3 b
P.O.Box 124 Blindern
N-0314 Oslo
torhelge.h.dokka@sintef.no
igor.sartori@sintef.no
http://www.sintef.no/Home/Building-and-Infrastructure/

Harald N Røstvik
Sivilarkitekt Harald N. Røstvik AS
PB 806, 4004 Stavanger
hnr@telnett.no
http://www.sunlab.no/default.aspx

Portugal
Daniel Aelenei
Universidade Nova de Lisboa
Campus da Caparica
Department of Civil Engineering
Faculty of Science and Technology
2829-516 Caparica
aelenei@fct.unl.pt
http://www.fct.unl.pt/

Laura Aelenei
UEAC
Laboratório Nacional de Energia e Geologia - LNEG
Estrada do Paço do Lumiar, Edifício Solar XXI
1649-038 Lisboa
laura.aelenei@ineti.pt
http://www.ineti.pt

Helder Gonçalves
Laboratório Nacional de Energia e Geologia - LNEG
Estrada do Paço do Lumiar, Edifício Solar XXI
1649-038 Lisboa
helder.goncalves@LNEG.pt
http://www.lneg.pt

Singapore
Thomas Reindl
National University of Singapore
Solar and Energy Efficient Building Cluster
Solar Energy Research Institute of Singapore
7 Engineering Drive 1, Block E3A, #06-01
117574 Singapore, SINGAPORE
thomas.reindl@nus.edu.sg
www.seris.sg

Spain
Jaume Salom *and* ***Eduard Cubi***
IREC – Institut de Recerca en Energia de Catalunya
Thermal Energy and Building Performance Group
Josep Pla 2, B2, Ground floor
08019 Barcelona
jsalom@irec.cat
ecubi@irec.cat
http://www.irec.cat

Sweden
Joakim Widén
Uppsala University
Energy Systems Programme
Department of Engineering Sciences, Solid State Physics
P.O. Box 534
SE-751 21, Uppsala
joakim.widen@angstrom.uu.se
Personal website:
http://www.anst.uu.se/jowid957/

Björn Karlsson
Lund University
Energy & Building Design
Box 118
221 00, Lund
Bjorn.karlsson@ebd.lth.se
http://www.lu.se/lund-university

Björn Berggren
Lund University
Energy and Building Design
Box 118 SE-221 00 Lund SWEDEN
Bjorn.Berggren@skanska.se
http://www.lu.se/lund-university

Switzerland
Armin Binz and ***Monika Hall***
Institut Energie am Bau
Fachhochschule Nordwestschweiz
Hochschule für Architektur, Bau und Geomatik
St. Jakobs-Strasse 84
CH-4132 Muttenz
monika.hall@fhnw.ch
Armin.Binz@fhnw.ch
http://www.fhnw.ch/habg/iebau/

Stephen Wittkopf
National University of Singapore
Solar and Energy Efficient Buildings Cluster
Solar Energy Research Institute of Singapore (SERIS)
7 Engineering Drive 1
Block E3A, #06-01
Singapore 117574
Stephen.wittkopf@nus.edu.sg
http://www.seris.sg

United Kingdom
Masa Noguchi
MEARU, Mackintosh School of Architecture
Glasgow, UK
m.noguchi@gsa.ac.uk

United States
Adam Hirsch, Shanti Pless and ***Paul Torcellini***
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, Colorado 80401-3305
adam.hirsch@nrel.gov
shanti.pless@nrel.gov
paul.torcellini@nrel.gov
http://www.nrel.gov/about/

REGULAR PARTICIPANTS

Austria
Tobias Weiss
Nussmüller Architekten ZT GmbH

tobias.weiss@nussmueller.au

Belgium
Shady Attia
Université Catholique de Louvain
shady.attia@uclouvain.be

Katrien Biesbroek
Katholieke Hogeschool (KaHo)
katrien.biesbroeck@kahosl.be

Canada
José A. Candanedo and ***William O'Brien***
Concordia University
j_candan@encs.concordia.ca
w_obrie@encs.concordia.ca

France
Paul Bourdoukan
paul.bourdoukan@gmail.com

Aurélie Lenoir
Université de la Réunion
aurelie.lenoir@univ-reunion.fr

Germany
Eike Musall
Bergische Universität Wuppertal
emusall@uni-wuppertal.de

Italy
Isabella Calderaro
Università degli Studi di Roma "La Sapienza"
isabella.calderaro@alice.it

David Nardi Cesarini and ***Maddalena Spallacci***
The Loccioni Group
d.nardicesarini@loccioni.com
m.spallacci@loccioni.com

New Zealand
Shaan Corey
Victoria University of Wellington School of Architecture

Norway
Julien Bourrelle
Norwegian University of Science and Technology – NTNU
julien.bourrelle@ntnu.no

Marit Thyholt
NTNU/SINTEF Building and Infrastructure
marit.thyholt@sintef.no

Sweden
Henrik Davidsson
Lund University
henrik.davidsson@ebd.lth.se

Task 42

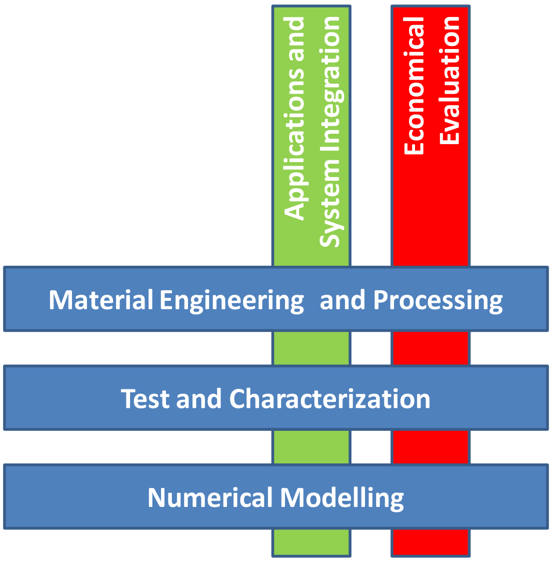
Compact Thermal Energy Storage: Material Development for System Integration

Wim van Helden
Operating Agent for the AgentschapNL, Ministry of Economic Affairs, The Netherlands

Andreas Hauer
Operating Agent for the Centre for Applied Energy Research ZAE, Germany

TASK DESCRIPTION

The objective of this Task is to develop advanced materials and systems for an improved performance storing thermal energy, 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, thermochemical and sorption materials, and composite materials and nanostructures, and includes activities such as material development, analysis, and engineering, numerical modeling of materials and systems, development of storage components and systems, and development of standards and test methods. A secondary objective of this Task is to further expand and intensify the collaboration between researchers and industry working in the field of thermal energy storage



This Task deals with advanced materials for latent and chemical thermal energy storage, on three different scales:

- Material scale, focused on the behavior of materials from the molecular to the 'few particles' scale, including for example, material synthesis, micro-scale mass transport, and sorption reactions.
- Bulk scale, focused on bulk behavior of materials and the performance of the storage in itself, including for example, heat, mass, and vapor transport, wall-wall and wall-material interactions, and reactor design.
- System scale, focused on the performance of storage with in a heating or cooling system, including for example, economical feasibility studies, case studies, and system tests.

This Task will include multiple application areas, bundled into one application Working Group. During Phase 1 of the Task, three different application Working Groups were established:

Low temperature (up to 20 ºC):

- Building cooling
- Refrigeration

Medium temperature for room heating and hot tap water (20 ºC – 100 ºC):

- Seasonal solar thermal storage
- Cogeneration, tri-generation and heat pumps

Higher temperatures (100 ºC and above):

- District heating
- Industrial waste heat
- Concentrated solar power

These application Working Groups identified reference-operating conditions for the storage materials. In the current Phase 2, these Working Groups have been merged into one group to address the possibilities of new developed materials for heating and cooling applications.

Subtask A: Materials

Working Group A1: Materials Engineering/Processing

Engineering

The activities in this Working Group focus on engineering new materials or composites (i.e., changing the properties of existing materials and developing new materials with better performance, lower cost, and improved stability). Eventually, this should lead to the ability to design new materials tailor-made to specification. The materials under consideration are those relevant to thermal energy storage using sensible mode, phase change, as well as chemical reactions and sorption technologies.

Activities include:

- Synthesis of new materials
- Determining material characteristics such as phase diagrams
- Determining the relation between material performance and material structure and composition, in order to direct the search for improved materials
- Determining the role and importance of material containers

Processing

The activities in this Working Group focus on the processing of raw materials that is required to make these materials function in a realistic environment. In nearly all cases, storage material cannot be used to store heat in its raw form, but e.g. needs to be processed into slurry, encapsulated, or otherwise processed.

Activities include:

- Finding optimal methods for micro- and macro encapsulation of storage materials (particularly phase change, sorption, and thermochemical materials)
- Processing phase-change slurries
- Finding new combinations of materials

Working Group A2: Test and Characterisation

The performance characteristics of novel thermal energy storage materials, like phase-change materials or thermochemical materials, often cannot be determined as straightforward as with sensible heat storage materials. In order to have proper comparison possibilities appropriate testing and characterisation procedures should be developed and assessed. The work in the first period of the Task showed that even the definition of a common procedure for calibrating the measurement instruments did not result in satisfactorily comparable results of measurements of PCM samples in the round robin test. Further work has to be done to understand the factors that influence the quality of the measurements.

The activities of this Working Group are aimed at developing test and calibration procedures and include:

- Comparative testing of materials and their required methods
- Long-term stability determination
- (Pre-) standardization of testing methods

The long-term stability determination will be done as material tests only, it is not thought possible to find a common standard for the stability determination.

Working Group A3: Numerical Modelling

The activities in this Working Group are aimed at developing and testing numerical models that help to understand and optimise the material behaviour and the dynamic behaviour of compact thermal energy storage systems and components. Ultimately, these numerical models could help to find ways to optimise the materials in combination with the system components. The activities in this Working Group are helping to lay the foundation for such models.

The Working Group includes the following activities:
- Material modelling
- Reactor modelling
- System modelling, including (dis)charging apparatus

Subtask B: Applications
There are several applications for compact thermal energy storage technologies, each with a different set of boundary conditions for the technology. Although the applications themselves place very different requirements on storage technology, the steps that must be taken are very similar for all applications. Hence, the activities within the Working Groups in this Subtask are very similar as well.

The activities in these Working Groups serve the underlying guiding principle of the materials development within the limitations of the application. The materials development will be directed by the desired system performance. A constant assessment of performance criteria for a given application will be used to determine the chances for a given material/system combination. These criteria can come from economic, environmental, production technology or market considerations.

Activities in the Application Working Groups include:
- Expand the definition of application boundary conditions, such as load, demand, environment, dimensions, for applications beyond the scope of the Task
- Define required thermophysical properties for each application
- Select relevant candidate materials and system technologies
- Conduct performance assessment and validation
- Conduct numerical modelling on the application level
- Develop new sensor technologies to enable the efficient operation of different applications
- Prepare case studies
- Conduct economical modeling
- Conduct feasibility studies
- Conduct market potential evaluations

This subtask is subdivided in three Working Groups, each representing a particular application or group of similar applications. This subdivision will be kept flexible throughout the Task to allow for new research groups and projects to join and include new topics at a later point in the Task.
- Working Group B1: Cooling
- Working Group B2: Heating / DHW
- Working Group B3: High Temperature Applications

Working Group C: Theoretical Limits
The objective of this Working Group is to determine the theoretical limits of compact thermal storage materials and systems from a physical, technical and economical viewpoint. In short, this Working Group defines the maximum possible performance that can be expected from a thermal storage system in a given application. As such, it gives a reference point with which the performance of lab tests, field tests, and real-life systems can be compared. In a first step, physical limits shall be determined (e.g. the energy stored per volume and per mass as a function of temperature, with respect to different mechanisms as sensible, latent, sorption

or chemical storage). In a second step technical aspects shall be evaluated. In many cases the energy storage density and the efficiency of the system are deteriorated when a large specific thermal power must be drawn from the system. In a third step economic constraints of storage systems shall be evaluated.

Common Tasks

Dissemination

One of the objectives of this Task/Annex is to inform the different groups of stakeholders in the development of compact thermal storage of the Task's progress and planned activities. These stakeholders include researchers, industry representatives, and policy makers. This common activity plays a major role in reaching the secondary objective of the Task, that is, the creation of an effective international network for research and development of compact thermal energy storage.

Duration

Phase 1 of the Task ran from January 2009 – December 2012. Phase 2 started January 1, 2013 and will be completed December 31, 2015.

This is a collaborative Task with the IEA Energy Conservation through Energy Storage (ECES) Implementing Agreement. It is managed as a fully "joint" Task according to the SHC Guidelines for Collaboration with other Programs. In the ECES Implementing Agreement, the Task is referred to as Annex 29.

Participating Countries

Australia, Austria, Belgium, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States

Change in Management

The SHC Operating Agent responsibility was taken over from The Netherlands by Switzerland as from January 1, 2014. Replacing Wim van Helden as the SHC Operating Agent is Matthias Rommel from the SPF, Rapperswill.

WORK DURING 2013

The Task activities in the subsequent Working Groups were as follows.

Materials Engineering/Processing Working Group

The main deliverable of the Working Group was finalised, which gives an overview of new or improved compact thermal energy storage materials. In the nine chapters, the most important developments in CTES materials are described. The chapters cover sensible (high temperature) storage materials, phase change and thermochemical materials. The development work of several participating groups was published. Amongst others, it covered the development of aluminophosphate material coating on metal plates as a strategy for the improvement of thermal conductivity and of composite materials with salt hydrates impregnated in carrier materials that have a high thermal conductivity.

The trial version of the materials database was tested and will be filled with material properties in the coming years with both phase change materials and thermochemical materials.

Test and Characterization

A final report was written on the definition of draft standards for performing Round Robin Tests with phase change materials and with thermochemical materials. These are the outcomes of the round robin test and the DSC measuring and characterisation workshop that were done in the Task. This work was also published.

Numerical Modelling

Two final reports were made, one giving a description of the experimental data sets that will be used as a reference base for the numerical tools that are developed by the different groups in the Task. Experimental data sets are available for four configurations with phase change materials and five with thermochemical materials. The second report is a description of the numerical tools themselves.

For the previous Apparatus and Components Working Group, a report is being prepared that describes a number of approaches for the design of a thermal energy storage apparatus and contains first notes on the aspects for a performance test protocol for thermal energy storages. The report will be finalised in the second quarter of 2014.

Application Working Groups

The Cooling Application Working Group made a final report. It describes two cooling applications as case studies for their boundary conditions for storage materials. A reporting template for the description of cold storage applications was designed and will be used to gather information on a larger number of cold TES applications.

For the Heating and Hot Tap Water Working Group, the final report was completed, which included material for the three deliverables 1) Description of systems and materials, 2) Laboratory prototype development and testing, and 3) Simulated technical potential.

In the High Temperatures Application Working Group, two final reports were produced 1) Materials and systems for High temperature Thermal Energy Storage and 2) a report containing projects and activities on high temperature thermal energy storage.

Theoretical Limits

One deliverable report is prepared on Physical and technical limits and constraints of thermal energy storage. It will be finalised in the spring of 2014.

WORK PLANNED FOR 2014

Key activities, planned for 2014 include:

- Gathering of experimental data for the materials database.
- Build-up of a number of experiments with compact thermal storage systems.
- Testing of the practical value of the experimental data for numerical tool validation.
- Further discussion on replicable test methods for compact thermal storage materials.
- Start with bottom-up economical approach for thermal energy storage systems.

REPORTS PUBLISHED IN 2013

- New or Improved Materials for Thermal Energy Storage Applications
- Development of a Test-Standard for PCM and TCM Characterization
- Boundary Conditions for Thermal Energy Cooling Storage Applications
- Development of Space Heating and Domestic Hot Water Systems with Compact Thermal Energy Storage
- Materials and Systems for High temperature Thermal Energy Storage
- Projects and Activities on High Temperature Thermal Energy Storage

REPORTS PLANNED FOR 2014

- Thermal Storage Apparatus Design
- Physical and Technical Limits and Constraints of Thermal Energy Storage

MEETINGS IN 2013

9th Experts Meeting
April 15-17
Freiburg, Germany

10th Experts Meeting
October 2-4
Ljubljana, Slovenia

MEETINGS PLANNED FOR 2014

11th Experts Meeting
April 28-30
Lyon, France

12th Experts Meeting
November
Details to be decided

SHC TASK 42/ECES ANNEX 24 CONTACTS

TASK MANAGEMENT CONTACTS

Operating Agents
Andreas Hauer
ZAE Bayern
Garching, Germany
hauer@muc.zae-bayern.de

Matthias Rommel
SPF
Rapperswill, Switzerland
matthias.rommel@solarenergy.ch

Assisting the OAs
Wim van Helden
Renewable Heat
Schagen, The Netherlands
wim@wimvanhelden.com

Working Group A1 Leader
Alenka Ristic
National Institute of Chemistry
Ljubljana, Slovenia
alenka.ristic@ki.si)

Working Group A2 Leader
Stefan Gschwander
Fraunhofer Institute for Solar Energy Systems, FhG-ISE
Freiburg, Germany
Stefan.Gschwander@ise.fraunhofer.de

Working Group A3 Leader
Camilo Rindt
Eindhoven University of Technology
Eindhoven, The Netherlands
C.C.M.Rindt@wtb.tue.nl

Subtask B Leader
Motoi Yamaha
Chubu University
Tokyo, Japan
yamaha@isc.chubu.ac.jp

Working Group C Leader
Christoph Rathgeber
ZAE Bayern
Garching, Germany
rathgeber@muc.zae-bayern.de

NATIONAL CONTACTS

Australia
Frank Bruno
University of South Australia
Frank.Bruno@unisa.edu.au

Austria
Wim van Helden
AEE INTEC
w.vanhelden@aee.at

Olivier Pol
Austrian Institute of Technology
Olivier.Pol@arsenal.ac.at

Andreas Heinz
TU Graz
andreas.heinz@tugraz.at

Wolfgang Streicher
University of Innsbruck
Wolfgang.Streicher@uibk.ac.at
Bernhard Zettl
ASiC Austria Solar Innovation Center
zettl.bernhard@asic.at

Belgium
Johan Van Bael
VITO
johan.vanbael@vito.be

Canada
Handan Tezel
University of Ottawa
handan.tezel@uottawa.ca

Denmark
Simon Furbo
Technical University of Denmark
sf@byg.dtu.dk
France
Elena Palomo
Universite Bordeaux
palomo_elena@yahoo.fr

Lingai Luo
University of the Savoie
Lingai.Luo@univ-savoie.fr

Philippe Papillon
INES
philippe.papillon@cea.fr

Germany
Andreas Hauer
ZAE Bayern
hauer@muc.zae-bayern.de

Henner Kerskes
ITW Stuttgart
kerskes@itw.uni-stuttgart.de

Frank Salg
Vaillant GmbH
frank.salg@vaillant.de

Thomas Schmid
Leuphana Universität Lüneburg
thschmid@leuphana.de

Peter Schossig
Fraunhofer ISE
peter.schossig@ise.fraunhofer.de

Italy
Valerio Lo Brano
University of Palermo
lobrano@dream.unipa.it

Netherlands
Camilo Rindt
Technical University Eindhoven
c.c.m.rindt@tue.nl

Herbert Zondag
Energy research Center of the Netherlands ECN
zondag@ecn.nl

Slovenia
NatasaYabukovec
National Institute of Chemistry
natasa.zabukovec@ki.si

Spain
Ana Lazaro
Universidad de Zaragoza
ana.lazaro@unizar.es

Lluisa Cabeza
University of Lleida
lcabeza@diei.udl.es

Miren Blanco
Tekniker
mblanco@tekniker.es

Patricio Aguirre
Tecnalia
patricio.aguirre@tecnalia.com

Sweden
Viktoria Martin
KTH
vmartin@kth.se

Switzerland
Elimar Frank
SPF
elimar.frank@solarenergy.ch

Robert Weber
EMPA
robert.weber@empa.ch

Turkey
Halime Paksoy
Cukurova University
hopaksoy@cu.edu.tr

United Kingdom
Philip Griffiths
University of Ulster, Belfast
p.griffiths@ulster.ac.uk
Phil C. Eames
CREST; University of Loughborough
p.c.eames@lboro.ac.uk

United States
Jane Davidson
University of Minnesota
jhd@me.umn.edu

Task 43

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

Jan Erik Nielsen
SolarKey International, Denmark
Operating Agent

TASK DESCRIPTION

SHC Task 43 aims to harmonize test methods and certification schemes in order to remove technical trade barriers for solar thermal quality products, hence lowering the testing and certification costs for manufacturers and suppliers. This will lead to less expensive and higher quality solar thermal products – which in turn will lead to larger markets and increased use of solar thermal energy.

The Task is working towards international standardization and harmonization of test procedures and certification schemes for solar thermal products.

So far the work has focused on the international standardization and important results have been achieved concerning harmonization of test methods - especially for solar collectors.

Work will continue in the field of standardization towards harmonizing of standards for system test methods, test methods for internal collector components, and test methods for other relevant solar thermal components and systems in the solar thermal field. But the main focus will be on harmonization of requirements in national and regional certification schemes, working towards a global certification scheme for solar collectors. If and when global harmonized certification of solar collectors is realized, this could pave the way for harmonizing certification schemes for other solar thermal products - including solar water heating systems.

SHC Task 43 - extension is organized into three Subtasks:

Subtask A: Harmonization of Standards for Solar Thermal Products
(Leader: Ken Guthrie, Australia)
This subtask will support ISO/TC180[1] in their work on the ISO standards for solar systems and components – and promote the use of these standards in the IEA-SHC and ISO countries – having also in mind the perspective of possible future harmonized certification of more solar thermal products (e.g., compact solar water heaters).

Subtask B: Harmonization of Certification Schemes for Solar Collectors
(Leader: Eileen Prado, US; Jaime Fernandez, Spain)
The objective of this subtask is to define the set of requirements national and regional certification schemes shall fulfil in order to be accepted under the global "umbrella" certification scheme for collectors.

Subtask C: Organizational Framework for Global Collector Certification
(Leader: Harald Drück, Germany)
The objective of this subtask is to set up rules for the organizational framework of a global certification of solar collectors. This includes defining the structure of framework/network, deciding who can/shall participate in the framework/network, defining voting rights, setting meeting frequencies, setting fees, and establishing the Global Solar Certification Network.

Main Outcome
The main outcome will be a frame/scheme for global certification of solar collectors.

---

[1] ISO/TC 180 - Solar Energy deals with *"Standardization in the field of solar energy utilization in space and water heating, cooling, industrial process heating and air conditioning".*

Duration
Phase 2 of Task 43 began July 2013 and will end June 2015.

WORK DURING 2013

Subtask A: Harmonization of Standards for Solar Thermal Products

- Work plan for Subtask A updated according to outcome of first Experts Meeting, September 2013.

Subtask B: Harmonization of Certification Schemes for Solar Collectors

- Work plan for Subtask B updated according to outcome of first Experts Meeting, September 2013.
- Initial "discussion document" on rules/requirements made.
- Discussion on the above document at workshop and first Experts Meeting, September 2013.

Subtask C: Organizational Framework for Global Collector Certification

- Work plan for Subtask C updated according to outcome of first Experts Meeting, September 2013.
- First draft of "Internal Working Rules" made.
- Discussion on the above document at workshop and first Experts Meeting, September 2013.
- Informal Global Solar Certification Network Established: Chair: H. Drück, Deputy chair: L. Nelson, treasurer: E. Prado, secretary: J.E. Nielsen

Presentations

- IEA SHC Solar Trade Associations meeting in connection with the SHC 2013 Conference 23 September 2013 in Freiburg, Germany (J.E.Nielsen)
- ISO TC 180 meeting 27 September 2013 in Freiburg, Germany (J.E.Nielsen)
- "Global Solar Certification Workshop" 30 September 2013 in Berlin, Germany (J.E.Nielsen)

Workshop

- "Global solar certification", Berlin 30th September

WORK PLANNED FOR 2014

Subtask A: Harmonization of Standards for Solar Thermal Products

- Promote EN/ISO 9806 worldwide.
- Support elaboration on ISO/AWI 22975 series on "Solar Energy – Collector components and materials.
- Support harmonization of ISO 9459-4 with EN 12977 series.
- Provide ideas/inputs to first draft of ISO standards for test methods for reliability/durability and safety of solar heating systems.
- Support ISO/NP 9488 "Solar Energy – Vocabulary."

Subtask B: Harmonization of Certification Schemes for Solar Collectors

- Prepare final draft set of requirements.
- Publish approved version of the harmonized requirements.

Subtask C: Organizational Framework for Global Collector Certification

- Prepare final draft set of rules for organizational framework.

- Publish approved version of the set of rules for organizational framework.
- Start operation of the “Global Solar Certification Network.”

REPORTS PUBLISHED IN 2013

No reports were published in 2013.

REPORTS PLANNED FOR 2014

The following documents will be published in 2014:

- *Harmonized Requirements for Global Certification of Solar Collectors.*
- Set of rules for organizational framework requirements and test methods for collector loop pipes: list of standards, experience on operating conditions.

MEETINGS IN 2013

1st Task Meeting
September 30t
Berlin, Germany

MEETINGS PLANNED FOR 2014

2nd Task Meeting
March 12-13
Las Palmas, Spain

3rd Task Meeting
October 30-31
Beijing, China

SHC TASK 43 CONTACTS

TASK MANAGEMENT

Operating Agent
Jan Erik Nielsen
SolarKey Int.
Aggerupvej 1
4330 Hvalsö
DENMARK
jen@solarkey.dk

Subtask A Leader
Ken Guthrie
Sustainable Energy Transformation Pty Ltd
ken.guthrie@setransformation.com.au

Subtask B Leaders
Eileen Prado
eprado@solar-rating.org
SRCC

Jaime Fernandez
AENOR
JAFERNANDEZ@aenor.es

Subtask C Leaders
Harald Drueck
ITW, Stuttgart University
drueck@itw.uni-stuttgart.de

NATIONAL CONTACTS

Australia
Ken Guthrie
Sustainable Energy Transformation Pty Ltd
ken.guthrie@setransformation.com.au

Canada
Alfred Brunger
Exova
Alfred.Brunger@Exova.com

China
Ma Jie
CABR / Certification Centre

Tong Xiaochao
CABR / Certification Centre
xiaochao.tong@gmail.com

Wang Min
CABR / Solar Thermal Testing Centre
minwangbeijing@gmail.com

He Zinian
Beijing Solar Energy Research Institute
hezinian@sina.com

Zhou Xiaowen
Tsinghua Solar Ltd.
xwzhou2003@aliyun.com

Zhao Juan
Tsinghua Solar Ltd.
zhaojuan@thsolar.com

Jiao Quingtai
Jiangsu Sunrain
jiaoqt@sunrain.com

Tian Liangguang
Shandong Supervision and Inspection Institute for Product Quality
tianlg@12365.sd.cn

Li YuWu
Shandong Supervision and Inspection Institute for Product Quality
yuwuli@gmail.com

Joseph Huang
International Copper Association Asia

Kang Wei
China Quality Certification Centre

Bian Ji
CCQS UK Ltd.

Denmark
Jan Erik Nielsen
SolarKey Int.
jen@solarkey.dk

Germany
Harald Drueck
ITW, Stuttgart University
drueck@itw.uni-stuttgart.de

Korbinian Kramer
Frauenhofer ISE
Korbinian.kramer@ise.fraunhofer.de

Portugal
Maria Joao Carvalho
LNEG
mjoao.carvalho@lneg.pt

Spain
Jaime Fernandez
AENOR
JAFERNANDEZ@aenor.es

United States
Eileen Prado
eprado@solar-rating.org
SRCC

Jim Huggins
SRCC
jhuggins@solar-rating.org

Les Nelson
IAPMO
les.nelson@iapmo.org

Task 44
Solar and Heat Pump Systems

Jean-Christophe Hadorn
BASE Consultants SA
Operating Agent for the Swiss Federal Office of Energy

TASK DESCRIPTION

SOLAR + HEAT PUMP

The objective of this Task that ended officially in December 2013 was to assess performances and relevance of combined systems using solar thermal collectors and heat pumps, to provide a common definition of performances of such systems, and to contribute to successful market penetration of these new promising combinations of renewable technologies.

The scope of the Task considered the supply of domestic hot water and heating in family houses that use small systems in the range of 5 to 20 kW). A larger 100 kW system for multifamily houses was also included in the scope since it was similar in design.

Several types of solar collector were considered: unglazed, glazed and "PVT" collectors and several heat sources were considered for the heat pumps: air, water and ground. All systems investigated had heat pumps driven by electricity due to the market orientation since 2008. Thermally driven heat pumps were not included in the work.

Solar cooling of buildings was not directly addressed in the Task's common work only heating and DHW preparation.

The Task was organized in the following Subtasks:

Subtask A: Solutions and Generic Systems
(Lead Country: Germany, Fraunhofer ISE, Sebastian Herkel)

The objective of Subtask A was to collect, create and disseminate information about the solutions for combining solar thermal and heat pump to meet heat requirements of a one family house. Subtask A dealt mainly with manufactured systems and systems installed and monitored.

Subtask B: Performance Assessment
(Lead Country: Austria, AIT, Ivan Malenkovic and Michael Hartl)

The objective of this subtask was to reach a common definition of the figures of merits of solar + heat pump systems and how to assess them. This work lead to pre-normative definition on how to test and report the performance of a combined solar and heat pump system.

Subtask C: Modeling and Simulation
(Lead Country: Switzerland, SPF, Michel Haller)

The objective of Subtask C was to provide modeling tools of all generic solar and heat pump systems and to report sensitivity analysis on most of the systems such as being able to pinpoint important features and marginal ones in a given system configuration. This has been achieved! Sizing of systems is now also possible using the output of this Subtask.

Subtask D: Dissemination and Market Support
(Lead Country: Italy, EURAC, Wolfram Sparber)

The objective of this subtask was to provide information to those beyond the Task so that value added created by the participants could be transferred as fast as possible to the market. A second objective was to deliver the final book of Task 44 aimed as a reference document in the field of solar heat and heat pumps. This will be achieved during 2014 due to the review process of all documents,

Duration
The Task started on 1 January 2010 and ended on 31 December 2013.
Participating Countries
Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Portugal, Spain, Sweden, Switzerland, United States.

This Task was a joint effort with the IEA Heat Pump Programme (HPP). It is referred to as Task 44 in the SHC Programme and Annex 38 in HPP, and was abbreviated T44A38 for this reason.

TASK ACCOMPLISHMENTS

Key Results
The main accomplishments of this Task are highlighted below. Specific deliverables are available on the SHC Task 44 website.

Publications

Report No.	Report Title	Publication Date	Access (PUblic, REstrict-ed)	Web or Print
A1	A Review of Market-Available Solar Heat Pump Systems	March 2013	PU / RE for details	Web
A2	Field test monitoring of SHP systems	March 2014	PU	Web
A3	Dissemination Activities of Subtask A of the IEA SHC Task 44 / HPP Annex 38	March 2014	PU	Web
B1	Definition of Main System Boundaries and Per-formance Figures for Reporting on SHP Systems	December 2013	PU	Web
B2	Testing Solar and Heat Pump Systems in labora-tory	Dec 2013	PU	Web
B3	Definition of a standard test for SHP systems	March 2014	PU	Web
B4	Dissemination Activities of Subtask B of the IEA SHC Task 44 / HPP Annex 38	March 2014	PU	Web
C1	The Reference Framework for System Simula-tions of the IEA SHC Task 44 / HPP Annex 38 Part A: General Simulation Boundary Conditions Part B: Buildings and Space Heat Load	March 2013	PU	Web
C2	Models of Sub-Components and Validation for the IEA SHC Task 44 / HPP Annex 38 Part A: Summary Part B: Collector Models Part C: Heat Pump Models Part D: Ground Heat Exchangers Part E: Storage models	March 2013	PU	Web
C3	System Simulation Reports for the IEA SHC Task 44 / HPP Annex 38	March 2014	PU	Web
C4	Synthesis of System Simulation Results for the IEA SHC Task 44 / HPP Annex 38	March 2014	RE	Web
C5	Dissemination Activities of Subtask C	March 2014	PU	Web

	of the IEA SHC Task 44 / HPP Annex 38			
D1	Presentation of system performance calculation Educational material	Oct. 2013	PU	Web
D2	Newsletters issued by IEA Task 44 / Annex 38 from 2010 to 2013	Oct. 2013	PU	Web
D3	T44A38 presentations in conferences	March 2014	PU	Web
D4	*Cancelled - information is included in C4*			
D5	Solar and heat pump systems – A handbook *(part of the IEA SHC book series published by Wiley-VCH)*	June 2014	PU	Print

Workshops and Conferences

Task participants presented Task results or results of their work accomplished within the framework of the Task at the following events.

Workshop/Conference	Place	Date
OTTI 2010	Bad Staffelstein	May 2010
Intersolar 2010	Freiburg	June 2010
EUROSUN 2010	Graz	Sept-Oct 2010
Heat Pump Conference 2011	Tokyo	May 2011
ESTEC 2011	Marseille	Oct 2011
ISES 2011 Solar World Congress	Kassel	Aug 2011
European Heat pump Summit 2011	Nuremberg	Sept 2011
SHC 2012	San Francisco	July 2012
SHC 2013	Freiburg	Sept 2013
European Heat pump Summit 2013	Nuremberg	Oct 2013
Heat Pump Conference 2014	Montreal	May 2014

LINKS WITH INDUSTRY

Several solar or heat pump manufacturers or system installers collaborate with university labs in our Task and benefit from our recommendations for better performances since it was observed a lot of improvement potential.

HIGHLIGHTS FROM 2013

Subtask A: Solutions and Generic Systems

Review of Existing and New Systems
Deliverable A1 a report called "A review of market-available Solar Heat pump systems" was distributed. More than 80 companies have responded and 100 systems reported. The analysis shows that most systems are designed for both heating and DHW and most use flat plate collectors. The great majority of systems on the market are a combination in parallel for solar and heat pump simpler than the serial or regenerative combination.

Reporting Field Test Results
During 2013, participants reported on all projects combining solar and heat pumps that were

monitored by national teams. The results were presented during Task meetings. Some of these projects also gave the basic material for simulation and models validation for Subtask C.

A template for reporting field results was used by most of the projects and deliverable A2 the final report presenting was sent for ExCo approval in early 2014.

Dissemination and Information
Several projects were presented at the SHC Programme's SHC 2013 conference in Freiburg, the papers are available for all in the Task work area on the SHC website.

The square view representation of a system was renamed to "energy flow chart." It is a consistent and global, yet simple, way to represent all fluxes in a system (Figure 1).

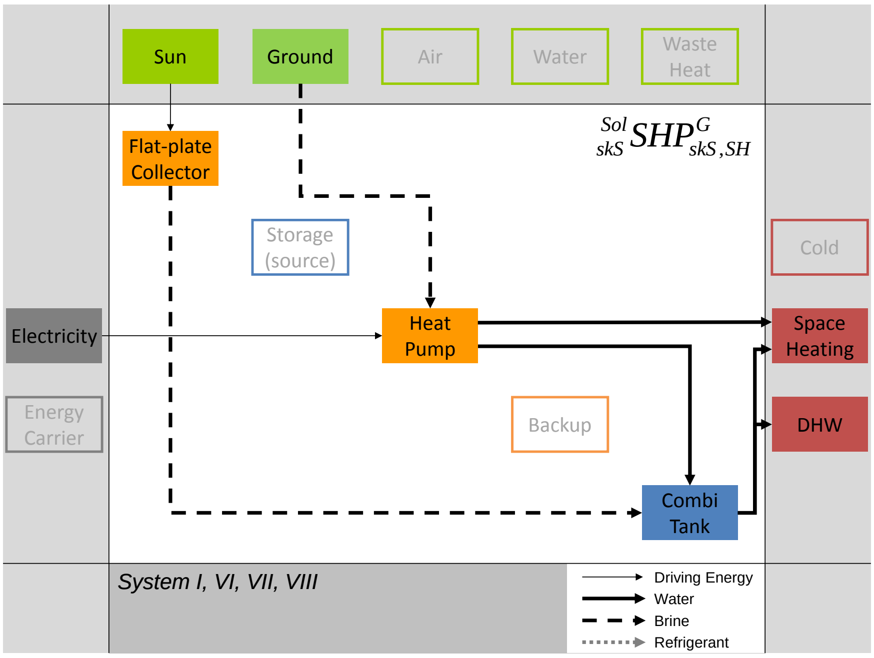


Figure 1. The "energy flow chart" of a parallel SHP ground source heat pump system (report B2)

Subtask B: Performance Assessment

Definition of Performance Indicators
This deliverable B1 was issued in 2013. SPF (seasonal performance factors) and environmental indicators were defined detail for all configurations of SHP systems. For environmental considerations, we used the Primary Energy Ratio and the Global Warming Potential as indicators.

System Boundary	Purpose	Target Group
Overall system performance including energy distribution system	Possibility of an energy, economy and ecology related evaluation of the whole system – overall energy balance, traded energy, free energy, emissions etc.	Users, policy makers, statistical evaluation
Overall system performance without the energy distribution system	Possibility of an energy, economy and ecology related evaluation of the energy producing system, without the energy distribution system, which may vary for different applications. Comparison between different systems and technologies, product quality assurance, labelling	Manufacturers, planers, installers, users, funding institutions, policy makers
Performance of the system without the influence of the end-user storage losses	Mainly interesting for system analysis – storage management	System and component manufacturers, planners
Performance of each energy transformation unit, including all parts needed for its proper functioning	Performance of each unit under given circumstances gives information about the efficiency of every subsystem and possible improvements	Component and subcomponent manufacturers, planners and installers
Performance of each energy transformation unit itself, without influence of the auxiliary energy	This closely corresponds to the energy balance used currently in most quality assurance schemes both for solar thermal collectors and heat pumps (e.g. Solar Keymark, EHPA Quality Label). By comparison with other performance figures, an analysis of the system regarding peripheral energy consumption can be made	System and component manufacturers, planners, installers

Figure 2. Subtask B achievement: main principles used in the definition of system boundaries for performance evaluation of SHP Systems (report B1)

Testing on Stands - Procedure and Results

Five institutes have tested solar and heat pump systems on bench stands. A common procedure of testing was not reached since different approaches remain possible. Deliverable B2 was written during autumn 2013 for Exco approval early 2014.

Standard Test Definition – Pre-normative

Deliverable B3 presenting the standard tests was drafted and will be completed in early 2014.

Subtask C: Modeling and Simulation

Reference Framework

Deliverable C1 presents a common framework for simulations study and is available through our website upon request. It is a Trnsys useful framework already known in a larger simulation community than our Task circle.

Models of Sub Component and Validation

The four working groups—solar collector, ground heat exchanger, heat pump, and heat storage—issued Deliverable C2 “Models of sub components and validation.” New components now have dedicated models, such as ice storage, heat pump with desuperheater, uncovered collectors that can freeze sides, PVT collectors, etc. Some are freely available.

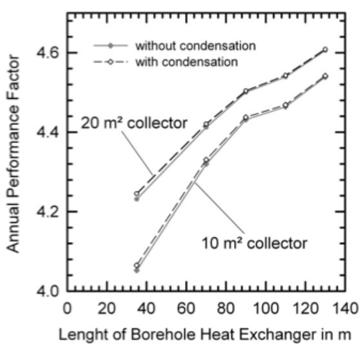


Figure 3. Simulation results in terms of the SPF_{HP} in a heat pump system with unglazed solar collector with and without respect to condensation effects on the collector surface (report C3)

System simulations and validation

“System simulation and validation” is almost completed. Two templates to describe systems simulation methods and results have been used by 10 teams.
Five simulation platforms are being used in the Task (Trnsys, Polysun, Rdmes, Mathlab, and IDA) and the framework has been adapted to all.

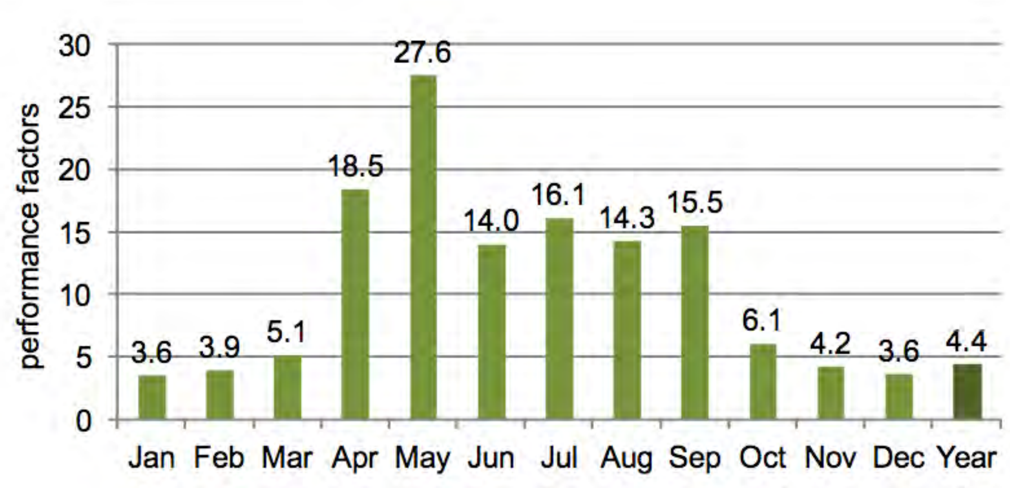


Figure 4. Performance factors of monitored air/water system after the storage in Switzerland (report C3)

System intercomparison data

The simulation work in Subtask C was completed end of 2013. Results of the comparison have been discussed at the last meeting. Deliverable C4 will present the results comparing the SPF of various types of SHP combinations within the same framework in March 2014.

MEETINGS IN 2013

7th Experts Meeting
April 8-9-10
Mechelen, Belgium

8th Experts Meeting
October 23-24-25
Chandolin, Switzerland

SHC TASK 44 CONTACTS

TASK MANAGEMENT

Operating Agent
Jean-Christophe Hadorn
BASE Consultants SA
8 rue du Nant
CH-1207 Geneva, Switzerland
Tel: + 41 22 840 20 80
jchadorn@baseconsultants.com

Subtask A Leader
Sebastian Herkel
Dept. Thermal Systems and Buildings
Fraunhofer Institute for Solar Energy Systems
Heidenhofstrasse 2,
79110 Freiburg, Germany
Tel: +49 761 4588 5117
sebastian.herkel@ise.fraunhofer.de

Subtask B Leader
Ivan Malenkovic, Michael Hartl
Energy Department
Sustainable Thermal Energy Systems
AIT Austrian Institute of Technology
Österreichisches Forschungs und Prüfzentrum Arsenal Ges.m.b.H.
Giefinggasse 2
1210 Vienna, Austria
Tel: +43(0) 50550-6350
ivan.malenkovic@ait.ac.at

Subtask C Leader
Michel Haller
Institut für Solartechnik SPF
Hochschule für Technik Rapperswil HSR
Oberseestr. 10
CH-8640 Rapperswil, Switzerland
Tel: +41 55 222 48 36
michel.haller@solarenergy.ch

Subtask D Leader
Wolfram Sparber
Institute for Renewable Energy
EURAC research
Viale Druso 1
I-39100 Bolzano, Italy
Tel: +39 0471 055 601
wolfram.sparber@eurac.edu

NATIONAL CONTACTS

Austria
Alexander Thür
AEE - Institut für Nachhaltige Technologien
a.thuer@aee.at

Martin Vukits
AEE intec
m.vukits@aee.at

Ivan Malenkovic
AIT Vienna
ivan.malenkovic@ait.ac.at

Hilbert Focke
ASIC - Austria Solar Innovation Center
focke.hilbert@asic.at

Martin Hallegger
General Solar Systems GmbH
martin.halleger@generalsolar.com

Christian Struger
General Solar Systems GmbH
christian.struger@generalsolar.com

Andreas Heinz
Institut für Wärmetechnik TU Graz
andreas.heinz@tugraz.at

Werner Lerch
Institut für Wärmetechnik TU Graz
werner.lerch@tugraz.at

Fabian Ochs
UNI Innsbruck
fabian.ochs@uibk.ac.at

Belgium
Jan Verheyen
Campus De Nayer
Filip.VandenSchoor@mech.kuleuven.be

Canada
Jeremy Sager
Natural Resources Canada
jsager@nrcan.gc.ca

Roberto Sunyé
Natural Resources Canada
rsunye@nrcan.gc.ca

Denmark
Ole Balslev-Olesen
Cenergia Energy Consultants
obo@cenergia.dk

Ivan Katic
Danish Technological Institute
ik@teknologisk.dk

Elsa Andersen
DTU
ean@byg.dtu.dk

Klaus Ellehauge
Ellehauge & Kildemoes
klaus.ellehauge@elle-kilde.dk

Flemming Hedegaard
Grundfos Holding A/A
Poul Due Jensens Vej 7
DK-8850 Bjerringbro
fhedegaard@grundfos.com

European Association
Thomas Nowak
EHPA
thomas.nowak@ehpa.org

Finland
Sunliang Cao
Aalto University
sunliang.cao@tkk.fi

Kai Sirén
Aalto University School of Science and Technology Department of Energy Tech.
kai.siren@tkk.fi

France
Cedric Paulus
CEA INES
cedric.paulus@cea.fr

Radulescu Mihai
EDF R&D
mihai.radulescu@edf.fr

Germany
Ulrich Leibfried
Consolar
ulrich.leibfried@consolar.de

Sebastian Herkel
Fraunhofer Institut
sebastian.herkel@ise.fraunhofer.de

Korbinian Kramer
Fraunhofer Institut
korbinian.kramer@ise.fraunhofer.de

Jörn Ruschenburg
Fraunhofer Institut
joern.ruschenburg@ise.fraunhofer.de

Christian Stadler
General Solar Systems Deutschland GmbH
christian.stadler@generalsolar.com

Antoine Dalibard
HFT Hochschule für Technik Stuttgart
Antoine.Dalibard@hft-stuttgart.de

Ruben Pesch
HfT-Stuttgart
ruben.pesch@hft-stuttgart.de

Christoph Trinkl
Hochschule Ingolstadt Institut für Angewandte Forschung
christoph.trinkl@fh-ingolstadt.de

Peter Pärisch
Institut für Solarenergieforschung GmbH
paerisch@isfh.de

Erik Bertram
Institut für Solarenergieforschung Hameln/Emmerthal GmbH
bertram@isfh.de

Christian Schmidt
ISE
christian.schmidt@ise.fraunhofer.de

Harald Drueck
ITW University of Stuttgart
drueck@itw.uni-stuttgart.de

Frank Thole
Schueco
fthole@schueco.com

Sebastian Bonk
Universität Stuttgart Institut für Thermodynamik und Wärmetechnik (ITW)
bonk@itw.uni-stuttgart.de

Anja Loose
Universität Stuttgart Institut für Thermodynamik und Wärmetechnik (ITW)
loose@itw.uni-stuttgart.de

Wolfgang Kramer
Wagner & Co. Solartechnik GmbH
wolfgang.kramer@wagner-solar.com

Italy
Pietro Finocchiaro
Dipartimento dell'Energia - UNIPA
finocchiaro@dream.unipa.it

Bettina Nocke
Dipartimento dell'Energia - UNIPA
bettinao@dream.unipa.it

Roberto Fedrizzi
EURAC
roberto.fedrizzi@eurac.edu

Gerhard Frei
EURAC
gerhard.frei@eurac.edu

Wolfram Sparber
EURAC
wolfram.sparber@eurac.edu

Matteo D'Antoni
EURAC Research
matteo.dantoni@eurac.edu

Osama Ayadi
Politechnico di Milano
osama.ayadi@polimi.it

Alberto Mauro
Politechnico di Milano
alberto.mauro@polimi.it

Lorenzo Pistocchini
Politechnico di Milano
lorenzo.pistocchini@polimi.it

Portugal
Jorge Facao
LNEG Lisbon
jorge.facao@ineti.pt

Spain
Òscar Càmara Moreno
Aiguasol
oscar.camara@aiguasol.coop

Daniel González
Castellví Aiguasol
dani.gonzalez@aiguasol.coop

Jorge Payá Herrero
Institute for Energy Engineering
Universidad Politécnica de Valencia
jorpaher@iie.upv.es

Sweden
Elisabeth Kjellsson
Building Physics
Lund University
elisabeth.kjellsson@byggtek.lth.se

Bengt Perers
DTU DK & SERC Sweden
beper@byg.dtu.dk

Hatef Madani
KTH
hatef.madani@energy.kth.se

Ulrik Pettersson
SP Sveriges Tekniska Forskningsinstitut
SP Technical Research
ulrik.pettersson@sp.se

Chris Bales
SREC, Borlange
cba@du.se

Switzerland
Bernard Thissen
Energie Solaire SA
bernard@energie-solaire.com

Marc Baetschmann
ETH Zürich
marc.baetschmann@3s-pv.ch

Christian Hutter
H+S Solar
ch.hutter@hssolar.ch

Sara Eicher
HEIG-VD
sara.eicher@heig-vd.ch
Catherine Hildbrand
heig-vd
catherine.hildbrand@heig-vd.ch

Jacques Bony
HEIG-VD
jacques.bony@heig-vd.ch

Mircea Bunea
HEIG-VD
Mircea.Bunea@heig-vd.ch

Peter Kurmann
Hochschule für Technik und Architektur
Peter.Kurmann@hefr.ch

Thomas Afjei
Institut Energie am Bau - FHNW
thomas.afjei@fhnw.ch

Ralf Dott
Institut Energie am Bau - FHNW
ralf.dott@fhnw.ch

Daniel Philippen
SPF
daniel.philippen@solarenergy.ch

Elimar Frank
SPF Institut für Solartechnik
elimar.frank@spf.ch

Michel Haller
SPF Institut für Solartechnik
michel.haller@spf.ch

Pierre Hollmuller
Université de Genève - ISE
pierre.hollmuller@unige.ch

Floriane Mermoud
Université de Genève - ISE
floriane.mermoud@unige.ch

Carolina Fraga
Université de Genève - ISE
floriane.mermoud@unige.ch

Jörg Marti
Vela Solaris
joerg.marti@velasolaris.com

Andreas Witzig
Vela Solaris
andreas.witzig@velasolaris.com

United States
Tim Merrigan
NREL
Tim.Merrigan@nrel.gov

Tim Moss
SANDIA
tamoss@sandia.gov

Les Nelson
Western Renewables
lnelson@westernrenewables.com

Mark Swansburg
Paradigmpartners
Mark@paradigm-partnership.com

Task 45
Large Solar Heating/Cooling Systems, Seasonal Storage, Heat Pumps

Jan Erik Nielsen
PlanEnergi
Operating Agent for the Danish Energy Agency

TASK DESCRIPTION

The main objective of this Task is to assist in a strong and sustainable market development of large solar district heating and cooling systems. The systems can include seasonal storages and/or heat pumps/chillers.

The main focus is on the system level – how to match the actual system configuration to the actual needs and local conditions, including the surrounding regional energy system (free electricity market). Or in other words, for the given conditions of load and energy prices and selection of system type and size to have a competitive heat price and a large solar fraction.
It is important that the systems are installed and controlled/operated properly in order to perform well. To secure that, guidelines and standards have to be updated and developed and recognised performance guarantee procedures established.

To push the market development, a strong effort will be done in promoting the benefits of the technologies and results from the Task to the decisions makers in the sectors of district heating and cooling and process heating and cooling. The issue of financing the "upfront investment in 25 years of heat production" will be dealt with - and models for services of Energy Service Companies (ESCo's) will be proposed and tried out.

The scope of the Task covers large-scale solar thermal systems – pre-heat systems as well as any combination with storages, heat pumps, CHP-units, boilers, etc. for the supply of block and district heating & cooling.
Task 45 is organized into three Subtasks:

Subtask A: Collectors and Collector Loop
(Lead Country: Denmark)
The general objectives of Subtask A are to:

- Assure use of suitable components
- Assure proper and safe installation - including compatibility with district heating and cooling network
- Assure the performance of the collector field

Subtask B: Storage
(Lead Country: Germany)
The general objectives of Subtask B are to:

- Improve the economy of (seasonal) storage technologies
- Increase knowledge on durability, reliability and performance of (seasonal) storage technologies
- Demonstrate cost effective, reliable and efficient seasonal storage of thermal energy

Subtask C: Systems
(Lead Country: Austria)
The general objectives of subtask C are to:

- Provide decision makers and planners with a good basis for choosing the right system configuration and size
- Give decision makers and planners confidence in system performance

Main Deliverables
The main result of the Task will be "Fact Sheets" dealing with design, installation and operation of large **collector fields**, large scale thermal **storages**, large scale solar heating and cooling thermal **systems** with seasonal storage and/or heat pumps.

Duration
The SHC Executive Committee approved a 1-year Task extension The Task started on January 1, 2011 and will end on December 31, 2014.

Participating Countries
Austria, Canada, China, Denmark, France, Germany, Italy, Spain.

RESULTS IN 2013

Subtask A: Collectors and Collector Fields
Subtask A is more or less advancing according to the revised Work Plan (including the approved prolongation of the Task). Results include:

- Paper on models for correction of collector efficiency parameters depending on flow rate and tilt.
- Drafts Guidelines for requirements for collector loop installation, hydraulic scheme including precautions for safety and expansion including checklist for checking installation accordingly.
- New proto type of advanced model for calculating thermal output of large fields of evacuated tubular collectors will be developed.
- Procedure for guaranteeing **annual** performance of collector field installation - including how to check the guarantee has been developed, and a fact sheet has been made, see: http://task45.iea-shc.org/fact-sheets.

Subtask B: Storages
Experts continued to work according to the Work Plan.

Subtask C: Systems

- Final overview of system categories.
- Extensive database for large solar system updated (now 268 systems from around the world).

WORK PLANNED FOR 2014

Subtask A: Collectors and Collector Fields

- Draft and final report, “Models or Correction Of Collector Efficiency Parameters Depending on Collector Type, Flow Rate, Tilt and Fluid Type.”
- Propose inputs to ISO 9806 based on the above work.
- Report on work on requirements and test methods for collector loop pipes: list of standards, collect experience on operating conditions.
- Publish final report on “Guidelines for Requirements for Collector Loop Installation.”
- Finalize advanced model on collector fields.
- Decide on additional Fact Sheets and produce.
- Prepare Subtask A summary report.

Subtask B: Storages

- Finalize report, “State of the Art Report with Best Practice Examples.”
- Finalize report “Identification of Necessary R&D.”
- Develop simple design tool for centralized SDH plants with seasonal storages.
- Transfer the knowledge platform www.saisonalspeicher.de into an English version www.seasonalstorage.com.
- Decide on and produce Fact Sheets.
- Prepare Subtask B summary report.

Subtask C: Systems

- Decide on and produce Fact Sheets.
- Prepare Subtask C summary report.

DISSEMINATION ACTIVITIES IN 2013

Reports Published In 2013

Fact Sheet: *Giving and Checking Guarantee for Annual Output of Collector Fields*, J.E. Nielsen, PlanEnergi, http://task45.iea-shc.org/fact-sheets
Paper: *Investigations on Efficiencies of HT Solar Collectors for Different Flow Rates and Collector Tilts*. Solar District Heating Conference Proceedings, Malmö, Sweden, 2013. Ziqian Chen, Bengt Perers, Simon Furbo, Jianhua Fan.

Conferences and Symposia with Contributions from Task 45 Experts

OTTI, 23. Symposium - Thermische Solarenergi, April 2013, Kloster Banz, Bad Staffelstein, Presentation: Jan Erik Nielsen.

InterSolar Conference, 17-20 June 2013, ICM Munich, Germany (J.E.Nielsen).

International Energy Conference 10-12 September 2013, DTU Copenhagen, Denmark (J.E. Nielsen).

SHC2013, 23-25 September, Freiburg, Germany, Keynote: Doug McClenahan and Keynote: He Tao.

"TRNSYS Collector Field Simulation Model: Testing, development and demonstration of large scale solar district heating system." Department of Civil Engineering, Technical University of Denmark, December 2013.

REPORTS PLANNED FOR 2014

Correction of collector efficiency parameters depending on collector type, flow rate, tilt and fluid type.

Requirements and test methods for collector loop pipes: list of standards, experience on operating conditions.

Guidelines for requirements for collector loop installation.
State of the art & best practise examples for large storages and identification of necessary R&D" for large storages.
Guidelines for planning, installation, commissioning, operation.

MEETINGS IN 2013

5th Experts Meeting
May 21-22
Stuttgart, Germany

6th Experts Meeting
October 21-22
Champery, France

MEETINGS PLANNED FOR 2014

7th Task Meeting
May 8-9
Braedstrup, Denmark

8th Task Meeting
October 30-31
Beijing, China

SHC TASK 45 CONTACTS

TASK MANAGEMENT

Operating Agent
Jan Erik Nielsen
PlanEnergi
Aggerupvej 1
4330 Hvalsö
DENMARK
jen@planenergi.dk
Phone: +45 4646 1229

Subtask A Leader
Simon Furbo
Technical University of Denmark
DENMARK
sf@byg.dtu.dk

Subtask B Leader
Dirk Mangold
Solites
GERMANY
mangold@solites.de

Subtask C Leader
Sabine Putz
SOLID GmbH
AUSTRIA
s.putz@solid.at

NATIONAL CONTACTS

Austria
Christian Fink
AEE – INTEC
c.fink@aee.at

Sabine Putz
SOLID GmbH
Austria
s.putz@solid.at

Canada
Alfred Brunger
Exova
Alfred.Brunger@Exova.com

Doug McClenahan and ***Bruce Sibbitt***
Natural Resources Canada
Doug.McClenahan@NRCan-RNCan.gc.ca
Bruce.Sibbitt@NRCan-RNCan.gc.ca

China
Sun Yuquan and ***Li YuWu***
SDQI/ Energy saving Product Quality Inspection
jinxiuchuan@gmail.com
yuwuli@gmail.com

Denmark
Simon Furbo
Technical University of Denmark
sf@byg.dtu.dk

Jan Erik Nielsen
PlanEnergi
jen@planenergi.dk

France
Cédric Paulus and ***Philippe Papillon***
CEA INES
cedric.paulus@cea.fr
philippe.papillon@cea.fr

Germany
Dirk Mangold
Solites
mangold@solites.de

Harold Drueck
ITW, Stuttgart University
drueck@itw.uni-stuttgart.de

Italy
Maurizio De Lucia
Università degli Studi di Firenze
delucia@unifi.it

Spain
Detta Schaefer and ***Marc Vives***
IREC
dschaefer@irec.cat
mvives@irec.cat

Aitor Sotil and ***Maider Epelde***
TECNALIA
aitor.sotil@tecnalia.com
maider.epelde@tecnalia.com

Luis M. Serra and ***Mateo de Guasalfjara***
Universidad de Zaragoza
serra@unizar.es
mateog@unizar.es

Task 46
Solar Resource Assessment and Forecasting

Dave Renné
National Renewable Energy Laboratory (retired) and
Senior Consultant, Clean Power Research
Operating Agent for U.S. Department of Energy

TASK DESCRIPTION

Task 46: Solar Resource Assessment and Forecasting continues the work accomplished under *Task 36: Solar Resource Knowledge Management*. Task 46 provides the solar energy industry, the electricity sector, governments, and renewable energy organizations and institutions with the means to understand the "bankability" of solar resource data sets provided by public and private sectors.

Objectives

Task 46 establishes four basic objectives in improving our understanding of solar resources: 1) evaluating solar resource variability that impacts large penetrations of solar technologies; 2) producing standardization and integrating procedures for data bankability; 3) improving procedures for short-term solar resource forecasting; and 4) advancing solar resource modeling procedures based on physical principles to provide improved evaluation of large-scale solar systems using both thermal as well as electrical conversion technologies.

Scope

At the conclusion Task 36, the participants recognized that all sectors of the solar industry are growing at a significant rate, therefore creating new, stringent data requirements that were not adequately addressed under Task 36. These requirements include ways to characterize the variability of the resource under very short time scales (1-minute or less), the ability to assess the "bankability" of data sets so that financial institutions understand the risks involved in using the data to predict project cash flows, a continuation of the benchmarking of solar resource forecasting methods so that system operators have the appropriate tools for operating utility systems with large penetrations of solar technologies, and advanced methods to estimate solar resources from modern weather satellite imagery, taking into consideration 3-dimensional cloud characteristics and other physical phenomenon. Therefore, Task 46, by addressing the four objectives listed above, will provide research reports, summary articles, and best practices manuals addressing resource variability that impacts grid operations, data collection and processing procedures, 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 utility operators, energy planners, solar project developers, architects, engineers, energy consultants, product manufacturers, and building and system owners and managers. In addition, technical laboratories, research institutions and universities involved in developing solar resource data products will benefit from the outcomes of Task 46, and will be informed through targeted reports, conference presentations, workshops, and journal articles.

Task 46 participants are addressing these objectives through sharing a co-coordinated work plan encompassing four subtasks:

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

(Lead Country: United States)

This Subtask develops data sets that 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. Key Subtask activities to meet this objective are:

- *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). There are various scales of hybrid generation that are pertinent, ranging from remotely operated hybrid installations, to autonomous and/or interconnected microgrids and larger-scale systems. The focus of this activity will be placed on weather data and irradiance data requirements to address hybrid system operations, with initial focus on smaller scale issues – autonomous hybrid systems.
- *Spatial and Temporal Balancing Studies of the Solar And Wind Energy Resource (Lead: U-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 (both Global Horizontal Irradiance, or GHI and Direct Normal Irradiance, or DNI 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)*

The objective of this Subtask is to provide best practices documentation on solar resource measurement and data management procedures to improve the bankability of data sets. Key subtask activities to meet this objective are:

- *Measurement Best Practices (Lead: DLR-Almería, Germany)*: 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 such as Rotating Shadowband Irradiometers (RSIs) is directly connected to this objective.
- *Gap-filling, QC, Flagging, and 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 a database archive.
- *Integration of Data Sources (Lead: CIEMAT, Spain):* This activity focuses on merging short-term ground measurements with long term satellite derived data in order to extrapolate quality ground data to longer term climatic data sets, allowing for long-term cash flow analyses of projects.
- *Data Uncertainties over Various Temporal and Spatial Resolutions (Lead: SunTrace GmbH, 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 (Lead: GeoModel s.r.o., Slovakia):* 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. Also higher time resolutions should be considered.

Subtask C: Solar Irradiance Forecasting
(Lead: Germany)

Solar irradiance forecasting provides the basis for energy management and operational 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 timescales from several minutes up to seven days ahead will be developed, tested and compared in benchmarking studies. The use of solar irradiance forecasting approaches in different fields will be investigated, including PV and CSP power forecasting for plant operators and utility companies, and irradiance forecasting for heating and cooling of buildings or districts. Key activities to meet this objective are:

- *Short-term Forecasting (up to 7-days ahead) (Co-Leads: U-Oldenburg, Germany and SUNY/Albany, USA):* The development and improvement of methods to forecast GHI and DNI is a major subject of this subtask. Different forecast horizons, ranging from minutes up to several days ahead are addressed using specific methodologies and data. Different forecasting approaches, characterized by the used data sources, corresponding methods and time scales, are covered. The comparison of these approaches in benchmarking studies focusing on different models, time scales or forecast parameters is also addressed.
- *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)

Although most of the work in Task 36 involved the testing and evaluation of existing solar resource methodologies, some specific new methodologies have been identified that will be addressed in Task 46. These methodologies are driven by specific information requests from energy developers and planners, such as improved satellite retrieval methods over certain types of ground features and the interannual variability of the solar resource. Key activities in this Subtask are:

- *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.
- *Long-Term Analysis and Forecasting of Solar Resource Trends and Variability (Co-Leads: NASA/Larc, USA And Meteotest, Switzerland):* In this activity, studies of long-term solar data sets, both observed as well as satellite derived, will continue to asses episodes of “global dimming” and “global brightening”, important for evaluating potential long-term cash flow implications from solar systems.

Task Duration
The Task began July 1, 2011 and will end June 30, 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.

ACTIVITIES DURING 2013

Overall Task Activities

A joint workshop between IEA/SHC Task 46 and PVPS Task 14 titled "Solar Resource and Forecast Data for High PV Penetration" was held as a parallel event at the PVSEC Conference in Paris on October 1, 2013. Sessions on high penetration of PV in distribution grids, forecast of PV at the transmission level, and solar forecast systems on the local and regional level were offered, followed by a moderated discussion. The event was well attended with well over 100 participants filling a packed room.

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

Activity A1: Short Term Variability

A.1.1 Characterization and modeling of solar irradiance sets with sub-hourly time resolution with application to solar energy systems

In this activity irradiance time series with time resolution down to one minute are collected and analyzed. With respect to the analysis of both, PV and CSP system data sets are inspected for their statistical characteristics in terms of frequency distributions and temporal characteristics. This information is used for the direct analysis of the fluctuation characteristics of the solar energy systems and for generating synthetic data sets to be used for system studies at sites where measured high resolution data sets are not available. Task participants from Spain, France, Germany, the US and Norway have developed the respective characterization and modeling tools based on various approaches. These tools are being inter-compared in view of their applicability for system studies involving the system dynamics.

A 1.2: Space and time characteristics of solar irradiance fields with application to grid integration studies

Task participants from USA, Germany and Spain had been active in the assembly of spatio-temporal data sets based on both ground measurements and satellite derived data. The current focus is on spatial scales of tens of meters up to several kilometers in to be used for the analysis of grid interference studies of dispersed PV-generation in municipality scale grids. Special emphasis is being placed on linking information on the meteorology-induced variability to the study of the stability of the operation of the electric distribution network. Part of the respective results will be adapted to the study of the response of CSP systems.

SUNY/Albany has concentrated on large scale studies with relevance to design and analysis of large scale utility networks. Special emphasis is placed on the analysis of options to level out the irradiance induced fluctuations in the power flow. The Task participants from Spain have been working on similar studies, but have extended their study by including wind generation (Activities A2 and A3).

The University of California at San Diego (UCSD) has set up an operational system to infer the fluctuating input to the distribution system from both sky images and numerical weather forecasts. This will provide the appropriate tools for the characterization of the fluctuations, including the development of tools to generate synthetic irradiance flields.

A1.3 Analysis dedicated to irradiance enhancements
The University of Agder (Norway) and UCSD have collected irradiance time series with a time resolution of down to 1s. During situations where scattered clouds cause irradiances that are well above the extraterrestrial irradiance, up to about 1500 W/m^2 can be observed. This finding ia also reported in the literature for other locations worldwide. Due to the almost instantaneous reaction of photovoltaic cells, this also defines the maximum expected input to the inverter of a PV-system. This has consequences both to inverter sizing, given that the inverter is scaled to the expected clear sky irradiance for the energy gain of the systems. The respective data analysis is focusing on the identification of the basic stastistical properties (duration, intermittency) of 'overirradiance' (irrdiances higher than expected clear sky irrdiance) events . This is backed up with dedicated studies based on sky photography to track down the causes of the irradiance enhancements and to improve the respective modeling capabilities. A respective camera system will be opertational by the end 2013. Modelling tools for a systematic analysis of the temporal and spatial extension of over-irradiance events making use of radiative transfer codes (Libradtran) will then be established.

Activity A2: Integration of Solar with Other RE Technologies
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 micrograms and larger scales. The focus of this activity is placed on weather data and irradiance data requirements to address such questions and will initially focus on smaller scale issues – autonomous hybrid systems. Sub activities include: A.2.1 Issues & data needs, A.2.2 Modeling and A.2.3 Case studies.

The CENER team is working in the design of hybrid plants by using small-scale solar thermal and biomass. This work seeks to identify the technical parameters for these types of plants and will be used to define some of the meteorological data that must be taken into account in the optimization of hybrid plants. Other types of information such as biomass availability will be also included.

Activity A3: Spatial and Temporal Balancing Studies of the Solar and Wind Energy Resource
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 (both GHI and DNI driven 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. Subactivities include: A.3.1 Solar Data & model needs, A.3.2 Solar and wind temporal and spatial balancing case studies, and A.3.3 forecast application studies

The Uni-Jaén has published a study on the balancing between the solar resources (GHI) and wind energy resources in Southern Spain (*Santos-Alamillos* et al., 2012)[1]. In this work, hourly values of wind and solar energy resources were generated over

[1] Santos-Alamillos FJ, Pozo-Vázquez D, Ruiz-Arias JA, Lara-Fanego V, Tovar-Pescador J. 2012. Analysis of Spatiotemporal Balancing between Wind and Solar Energy Resources in the Southern Iberian Peninsula. J*. of Applied Meteorol. and Climatol*., 51:2005-2024.

Southern Spain based on a numerical weather prediction model integrated over a period of 3 years. Then a Canonical Correlation Analysis (CCA) was used to analyse the spatial balancing between these resources. As result of the analysis, valuable balancing patterns in the study region were obtained, but with a marked seasonality in strength, sign and spatial coverage. The autumn season showed the most noteworthy results, with a balancing pattern extending almost over the entire study region.

When locating reference wind farms and PV plants according to the balancing patterns, their combined power production showed to have a substantially lower variability than the production of the wind farms and PV plants separately and that the combined production obtained by any other locations. Notably, over the course of a year, the standard deviation of the wind energy and PV capacity factor time series was 0.33 and 0.31, respectively for the selected locations. On the other hand, for the combined capacity factor time series, standard deviation reduced to 0.21. In order to have a reference for the benefit of the balancing, the average of the standard deviation of the combined capacity over the entire study region, assuming the windmill and solar PV plants are located at the same site, was computed. Value obtained was 0.24. That is a substantial reduction in the standard deviation of the combined capacity factor is obtained when locating the wind farm and PV plants based on the CCA results.

As presented during the 4th Task Experts Meeting in Oldenburg on 7-8 October the Uni-Jaen study is now being expanded into a larger geographical context including the entire Iberian Peninsula and beyond.

Subtask B: Standardization and Integration Procedures for Data Bankability

Activity B1: Measurement Best Practices

In 2013, best practices for measurements with Rotating Shadowband Irradiance (RSI) instruments were reviewed. During the DNI workshop in Sophia Antipolis the best practices were presented and the most crucial points were discussed. Topics that were not addressed sufficiently were identified and will now be included in the manual. The workshop’s results were delivered to the activity members in a report (deliverable B.1.2) and the required changes were partially included.

An update of NREL’s “Best Practices Handbook for the Collection and Use of Solar Resource Data” is under preparation. The RSI specific chapter and the section on DNI and circumsolar radiation have been revised and extended.

CSP Services and DLR have investigated the stability of the calibration constants of RSIs as a component of the uncertainty analysis. They found only one case where the calibration constant drifted by more the 2 %/year, and in this case the measurement data already indicated an instrumental error (Geuder, et al., 2013).

MeteoSwiss continued and finished the measurement phase of the intercomparisons of three different RSIs (twice each) and various Delta-T SPN1 in Payerne, Switzerland, in the framework of the COST Action ES1002 WIRE. The investigated RSIs are the RSR2 (Irradiance), the RSP (Solar Millennium/Reichert GmbH) and the Twin RSI (CSP Services). The reference data from MeteoSwiss BSRN station has been prepared for the comparison and a working group was formed for the following data evaluation. Final results and a report are expected at the beginning of 2014.

A new measurand for resource assessment that is investigated in B1 is the sunshape and the circumsolar radiation. Approximately 2 years of data for the Plataforma Solar de Almería (PSA) and half a year from Odeillo/France have been evaluated and a statistical analysis of the datasets is presented in (DLR/CNRS, 2013). A peer reviewed publication on the used measurement system is now available online (Wilbert et al., 2013). The data set from PSA was also used for the qualification of two less maintenance intense measurement methods for circumsolar radiation. An RSI based method was presented at Sophia Antipolis during the DNI Workshop and a publication of the validation is under preparation. A system with hardware from Black Photon Instruments GmbH was presented in (Wilbert et al., 2013b).

Another new parameter for resource assessment that is investigated is the atmospheric extinction in concentrating plants. Different methods to determine the extinction coefficient in the lowest ~300 m are under development at PSA's meteorological station METAS (MEteorological stAtion for Solar technologies). Besides visibility and transmittance measurements, radiative transfer calculations with ground measurements of relative humidity, aerosol particle concentration (and other parameters) are also performed. In addition, a tiltable backscatter LIDAR system is used (Hanrieder, 2013).

The extension to meteorological stations with solar trackers called "TraCS" for the measurement of mirror soiling rates has been further developed. TraCs was designed for the routine measurement of soiling levels of solar test mirrors in addition to the standard DNI measurements performed with solar trackers. It was found that the spatial inhomogeneity of the soiling on the mirror sample has a significant influence on the measurement accuracy. The area of the exposed sample mirror, which is used for the reflectivity measurement, represents the measurement volume. In order to increase the measurement volume the mirror probe can now be periodically moved relative to the detector, so that different measurement spots on the mirror surface are scanned (Wolfertstetter et al, 2013). The publication also includes a recommendation for the cleaning of irradiance stations with two pyranometers and a pyrheliometer that can be used to determine the soiling of each of the three sensors.

Activity B2: Gap-Filling, QC, Flagging, Data Formatting

MINES ParisTech developed a robust algorithm for gap filling derived from the non-local mean approach. Methods for selecting clear-sky instants are also being compared for having an appropriate dataset of reference for quality control procedures that use clear sky estimations.

The University of Geneva has been working on quality control (QC) procedures. Three aspects have been studied 1) time stamp shift, 2) sensor calibration coefficient, and 3) coherence between the three solar components. The stability of the sensor is studied as well. Results can be found at http://www.unige.ch/energie/forel/energie/equipe/ineichen/annexes-iae.html.

Recent tests done by CIEMAT and University of Geneva have demonstrated some limitations in the results of the common quality control procedures. Related to the application of quality control to data at different time scales, CIEMAT has proposed the multiple applications of the quality control procedures after each step before the gap filling. After the application of quality control, sometimes there is an asymmetry of flagged data with respect to the solar noon. CIEMAT has used this asymmetry for detecting mistakes in the data time stamp.

Another limitation of quality control procedures is the lack of information about metadata. If the user doesn't know the origin of data, consistency quality controls may be inefficient. One example for that is that in mountainous areas, a distance of some hundred meters between two sensors causes different horizon profiles.

International initiatives such as the International Renewable Energy Agency (IRENA) Global Atlas aim at addressing the reporting of quality in metadata for any renewable resource. A concept report has been published explaining the global approach (http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=368)

Suntrace has presented a gap-filling method, which depends on how many solar radiation components are available as well as the duration of the lack of data. When only one solar component is missing, the missing values are calculated from the two other using linear interpolation. When two components are missing, external modeling is used to estimate one of the missing components, then using the case where one component is missing. When the three components are missing, the clearness index and the beam clearness index are used for the temporal interpolation. The accuracy of the applied basic gap filling methodology has been tested and the results show a mean bias of 3 % over GHI, DNI and DHI over all types of gaps.

Activity B3: Merging Ground and Modeled Data Sources

Armines developed an innovative fusion method to combine a one-year short time series of ground-based sub-hourly irradiation data with long-term satellite-based data to create calibrated, sub-hourly and long-term TMY irradiation data.

DLR has offered their good quality ground data from the PSA site for subactivity B3.1. In addition, a selection of several sites with good quality ground data is made available from BSRN and from task participants. For this activity the requirements will be the use of only recent ground data (no more than two years) in order to be closer to the actual situations that can be found in bankability processes.

Ciemat has performed a sensitivity study for the use of different external inputs and models in satellite estimations of solar radiation using PSA station during the years 2011 and 2012. The study analyzed the impact of the uncertainty of using satellite estimates based on aerosol input from four different sources (Aeronet, MODIS, MISR and MACC), different clear sky models (ESRA, SOLIS and REST2) and different direct-to-global conversion models (Louche, DirInt and DirIndex).

Good results were achieved using accurate aerosol data from AERONET, as expected; however, for the gridded aerosol databases, MACC yielded to slightly better results. In the case of clear sky the different sensitivity to the atmospheric input plays an important role, and thus REST2 yielded to quite good results when accurate data from AERONET were used as input, and in the other cases the models showed similar results. Finally, again DirIndex plays a role in DNI estimations when the aerosol input from AERONET is used.

Several sites with good quality ground data from BSRN and from task participants were selected in recent months. Besides the quality high frequency data (1-min) with measurements of the three components also simultaneous daily AOD measurements are of interest. BSRN sites, SURFRAD, PSA-DLR and eventually data offered by the Pontificia University of Chile have been identified as good candidates.

An initial review of existing methods for statistically correcting or merging satellite data with ground measurements has been initiated by CIEMAT. Bias removal, corrections of fitted scatter plots and methods based on geometric considerations will be explored, among others, to identify conditions where specific systematic errors of satellite retrievals could be observed.

Under a Spanish standardization committee for solar radiation series generation for CSP simulation, it has been established that when data from estimated sources are used, those data have to be analyzed during one year with simultaneous measurements in order to verify the general behavior of the estimated series in that location. A validation has been carried out by CIEMAT/UC3M, in order to verify these proposed procedures. One procedure is based on the application of TMY methodology, although estimates during more than 10 years are used instead of measurements. Measurements from four locations have been used as well as estimations from satellite images supplied by IrSOLaV. The behavior of the estimations has been analyzed following the proposed standard.

CSIRO is working on correcting and merging methods for CCAM (Conformal Cubic Atmospheric Model) mesoscale model DNI retrievals. Using this approach, for example, they have shown the correlation coefficient improve by up to about 0.2 in Spring/Winter for Wagga Wagga and Mildura. The ultimate goal of this work is to combine atmospheric model data (30+ years, 1979-2012) with satellite data (ca. 20 years) and of course ground station data.

Activity B4: Uncertainty of model-derived historic solar radiation data

An extensive validation of long-term satellite derived DNI and GHI data sets was prepared and presented by the University of Geneva. Six different satellite models and 18 European and Mediterranean Sites were analyzed. In total 110 years of data were quality checked and processed. The validation statistics include the mean bias difference, the root mean square deviation, the standard deviation, the correlation coefficient and the Kolmogorov-Smirnov integrals. The inter-annual variability was also studied. A detailed report of the results will be published soon.

Activity B5: Evaluation of meteorological products with focus on Typical Meteorological Year and Time Series

Spanish institutions and companies closely related to CSP have been working within the AENOR framework (Spanish Association for Standardization and Certification) on standards for the industry. Part of this work consists of the development of a methodology for generating a year of solar irradiance data and other key variables to be used by the CSP industry. Through the consensus, the group proposed a methodology for generating the so-called Representative Solar Year (abbreviated as ASR from the Spanish name). Two Master thesis were finished at the UCM3 that describe the creation of the ASR based on ground measurements and modeled data respectively. The results of these works were presented at the expert meeting in Oldenburg (October 7th).

Subtask C: Solar Irradiance Forecasting

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

Research on different algorithms to forecast solar radiation is a major subject of C1. 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 is the comparison of different forecasting approaches (benchmarking studies). The framework of these studies has been defined and the task members have started to prepare measurement data and process forecasts for these studies.

C.1.1. Time series models based on ground-measured irradiance data

The University of South Australia is working on hourly and intra hourly forecasting of solar radiation with statistical models. In Huang et al, (2013) a method for forecasting solar radiation on an hourly time scale using a Coupled Auto Regressive and Dynamical System (CARDS) model is introduced and evaluated. The trends of solar radiation are not easy to capture and become especially hard to predict when weather conditions change dramatically, such as with clouds blocking the sun. At present, the better performing methods to forecast solar radiation are time series methods, artificial neural networks and stochastic models. The paper describes a new and efficient method capable of forecasting 1-h ahead solar radiation during cloudy days. The method combines an autoregressive (AR) model with a dynamical system model. In addition, the difference of solar radiation values at present and lag one time step is used as a correction to a predicted value, improving the forecasting accuracy by 30% compared to models without this correction.

University of Oldenburg has started to work on the application of machine learning methods for very short term PV power forecasting [Wolff et al. 2013]. Due to fast changing weather conditions, e.g., clouds and fog, a precise forecast in the minute to hour range can be a difficult undertaking. On the basis of big data sets of PV measurements, methods from statistical learning are applied for one-hour ahead predictions. Nearest neighbors regression and support vector regression are employed for PV power predictions based on measurements and numerical weather predictions. An emphasis is put on the analysis of feature combinations based on PV time series and numerical weather predictions as additional exogenous input.

C.1.2. Total sky imagers

The University of California/San Diego (UCSD) is continuously working on improving cloud detection from ground based sky imagers as a basis for very short term forecasting with high resolution. The new UCSD prototype produces high-quality sky imagery with a high dynamic range, allowing for more accurate cloud fields and more reliable thin cloud detection. No shadow band is necessary, leading to 10% more imagery available and interpolation errors eliminated. The state-of-the-art sky imager-forecasting device with algorithms for 15 minute ramp forecasting has a high temporal and spatial resolution, a reasonable coverage of approx. 15 km2 and is applicable for short time-horizon up to 20 minutes.

As an alternative to the detection of cloud motion with sky imagers, UCSD is investigating also an approach to determine of cloud motion vectors from a network of ground sensors in a solar power plant. In Bosch and Kleissl (2013) a new method for deriving cloud speed from data collected at a triplet of sensors at arbitrary positions is presented; cloud speed and the angle of the cloud front are determined from the time delays in two cloud front arrivals at the sensors. Five reference cells at the 48 MW PV plant at Henderson (NV), were used to provide two different triplets of sensors. Over a year of operation cloud speeds from 3 to 35 m/s were obtained. Cloud speeds are validated using cross-correlation of power output from 96 inverters at the plant. Overall bias errors were less than 1% and the overall annual RMSE was 20.9%, but results varied with season.

MinesParisTech, in cooperation with EDF R&D, is working on 3D reconstruction of cloud motion and corresponding shadow on the grounds from stereoscopic and optical flow analysis of hemispherical images from 2 fish-eye cameras. The stereoscopic analysis with correlation-based cloud matching to assess parallax and therefore 3D position is combined with a Kalman filter to detect cloud heights. First results are encouraging and the value of the application of a Kalman filter has been shown.

University of Oldenburg has also started the development of forecasts of solar radiation and PV power using a sky imager. The measurement devices at U of Oldenburg currently include the sky imager, a spectrometer, PV modules, and global horizontal and tilted, diffuse and direct measurements. They will be complemented by several photodiode pyranometers, distributed in the area around the sky imager. An approach for cloud classification [Heinle et. al, 2010] for daylight conditions will be applied to infer cloud information from the sky images in a first step. Further topics are the projection of cloud information from the sky images onto the surface for approximation of shading, cloud-motion-vectors from sky imagery, and analysis and modeling of radiative fluctuations.

C.1.3. Motion vectors from satellite data

University of Oldenburg is working on evaluation and further development of their cloud motion vector (CMV) forecasting algorithm based on Meteosat satellite images [Kühnert et al, 2103 a]. Images from Meteosat Second Generation (MSG) satellites provide valuable information for forecasting clouds and solar irradiance several hours ahead by using cloud motion vectors (CMV). An approach to derive irradiance information from MSG images and of predicting the cloud situation by applying CMV is described and an evaluation of the irradiance forecast for single sites and regional averages on basis of a one-year data set is presented. The CMV forecast shows a superior performance in comparison to forecasts with NWP models up to 5 hours ahead.

IrSOLaV has developed a CMV forecasting algorithm based on images from operational Meteosat satellites (First and Second generation). Currently IrSOLaV is providing service to several concentrated solar thermal plants in Spain.

Meteotest is following a different approach for short term forecasting up to six hours ahead. They investigate the combination of cloud and radiation fields from satellite images with wind fields from the NWP model WRF. This shortest-term solar forecasting algorithm, which is updated every 15 minutes, has been evaluated for more than 20 sites in Switzerland, including low lands, alpine and high-alpine stations (see example for one site in Fig. C1-1). The RMSE ranges between 75 – 200 W/m2 (20 - 60%), depending on season, station and forecast horizon. The uncertainty is low in flatland and much higher in the Alps. The improvement of this approach over NWP WRF model outputs for 3 - 6 hours is about 40%. A particular focus during the reporting period has been on the investigation of Kalman filters to improve the forecasts. This post-processing approach has been found to be useful to correct for clear sky days.

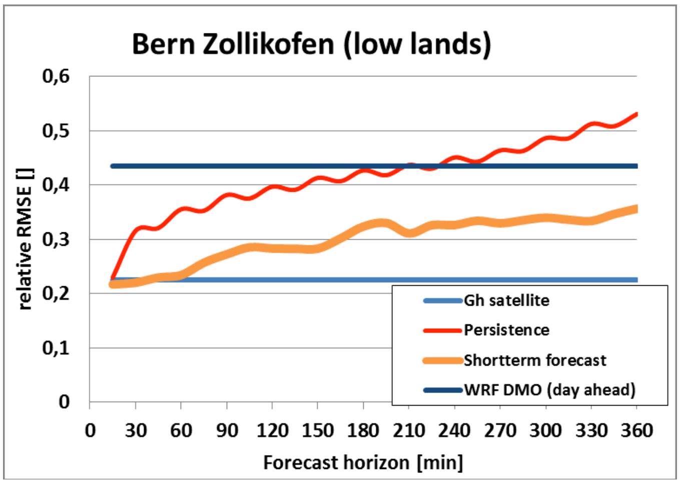


Figure C1-1: Relative RMSE of the Meteotest short term forecasting scheme in comparison to WRF Forecasts and persistence in dependence on the forecast horizon for a station in Switzerland.

University of Oldenburg has investigated the use of wind fields from NWP model forecasts, as proposed by Meteotest, in comparison to satellite derived CMVs to advect clouds. Wind fields from the IFS model operated at the ECMWF are used for this purpose and a first study for May 2012 was performed. As a first result, a very similar performance of forecasts based on cloud advection with NWP wind fields and satellite derived CMVs was found for the investigated period

C.1.4 NWP forecast models

The Danish Meteorological Institute (DMI) is running several numerical weather prediction models, including the High Resolution Limited Area Model (HIRLAM) 7.3 "SO5" 25-member ensemble prediction system and RADAR RUC model. A detailed evaluation of different aspects of the global radiation forecasts of the DMI ensemble prediction system has been performed in the PhD of Sisse Ludholm. The evaluation not only gives traditional measures of forecast quality, e.g. RMSE and skill scores, which are usually applied in the more user oriented evaluations in the context of energy meteorology, but follows a more general approach of forecast verification, based on the analysis of joint distributions and observations. The investigation of consistency revealed the evidence of under-dispersivity, which is demonstrated e.g. by a too low capture rate and the RMSE versus spread rate. Apart of the properties of the complete ensemble, the performance of ensemble mean and median is also investigated, revealing a superior performance of the ensemble mean compared to the deterministic control forecast, not only in terms of RMSE and skill, but also for discrimination. This indicates the possible benefit of complementing deterministic forecasts with the ensemble mean.

Furthermore, DMI has added HIRLAM and the Integrated Forecast System (IFS) from the GLAMEPS (Grand Limited Area Model Ensemble Prediction System) ensemble to the models tested in the benchmarking exercise (C1.6). GLAMEPS is a multi-model ensemble system that includes ensemble models from the HIRLAM-ALADIN consortium and ECMWF. The resolution of GLAMEPS is 0.15° in rotated latitudinal/longitudinal coordinates. Average GHI is output every 3-hours. The GLAMEPS domain can be seen in Fig. C1-2, together with the other DMI ensemble domains. From the other ensemble domains of DMI both GHI and scattered solar irradiance are output every hour. The S05 domain has a resolution of 0.05°. The ECT10 domain has a resolution of 0.10°. Output from ECT10 will be included starting from November 2013. S05 and ECT10 only include members from the HIRLAM model. Additionally, DMI runs a rapid update cycle (RUC) model with a resolution of 0.03° and output of GHI and scattered solar irradiance every 10 minutes.

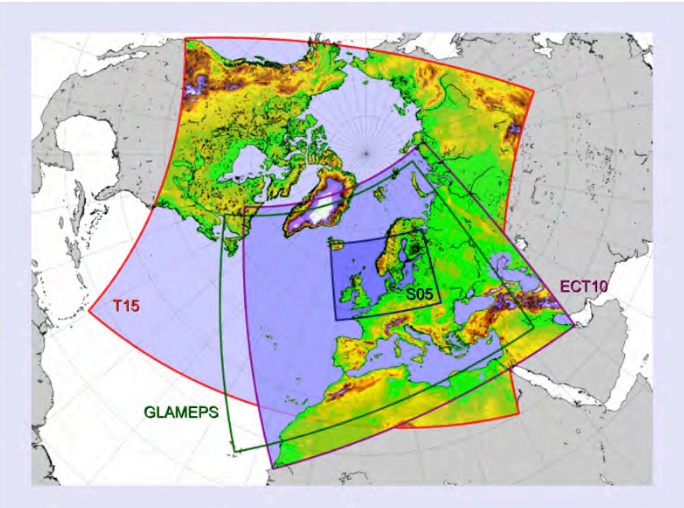


Figure C1-2: The three ensemble domains for solar irradiances are forecasted at DMI: S05, ECT10 and GLAMEPS. Ensemble models are not run for the domain labeled T15.

DLR-DFD has worked on the development of spatial error characteristics for operational day ahead solar irradiance forecasts [Schroedter-Homscheidt and Killius, 2013]. According to weather patterns the reliability of solar energy forecasts is expected to have a spatial dependence. The available ground measurement network for DNI is extremely sparse in Europe and Northern Africa and not sufficient for any spatial analysis. For GHI the situation is much better, but still a dense network of uniformly distributed stations is lacking. Therefore, MSG-based observations have been used as reference for the verification of current numerical weather prediction capabilities of the ECMWF IFS model with respect to global and direct irradiance forecasts. Three hourly values of global solar radiation for the next 72 hours have been interpolated to hourly day-ahead forecasts. The Skartveith/Olseth model has been applied to derive the direct component. The evaluations are performed for 2006 as a test year. It was shown that day ahead forecast errors are dependent on cloud types and structure of cloud fields (e.g. scattered, thin ice clouds) and that one can use satellite retrievals as transfer standard to give spatial information on error statistics.

Furthermore, DLR has been working on aerosol forecasts for solar forecasts assessment [Schroedter-Homscheidt et al, 2013]. For a larger share of electricity to come from fluctuating solar and wind energy-based electricity, production forecasts are required to ensure successful grid integration. Concentrating solar power holds the potential to make the fluctuating solar electricity a dispatchable resource by using both heat storage systems and solar production forecasts based on a reliable weather prediction. These solar technologies exploit the direct irradiance at the surface, which is a quantity very dependent on the aerosol extinction with values up to 100%. Results from present-day numerical weather forecasts are inadequate, as they generally use climatology for dealing with aerosol extinction. Therefore, meteorological forecasts have to be extended by chemical weather forecasts. The study aims at quantifying on a global scale the question if and where daily mean or hourly forecasts are required, or if persistence is sufficient in some regions. The study assesses the performance of recently introduced NWP aerosol schemes by using the ECMWF-MACC forecast; a preparatory activity for the upcoming European GMES (Global Monitoring for Environment and Security) Atmosphere Service [Schroedter-Homscheidt et al, 2013].

CSIRO has investigated the skill of global and direct radiation forecasts by the ECMWF model for an Australian site (Rockhampton, Queensland, NE of Australia). Forecasts are 3-hourly out to 120 hours. A simple standard bias correction based on solar zenith angle and the clear sky index has been applied and appears to improve scores.

University of Oldenburg has analyzed probabilistic irradiance forecasts of the ECMWF ensemble prediction system (EPS) to support photovoltaic power predictions [Przybilla et al, 2013].

In particular, the intrinsic uncertainty information provided by the EPS has been investigated. The ensemble has 50 members; the temporal resolution is 3 hours and the spatial resolution 0.25° and here the UTC 0:00 run is used. The forecasts are evaluated against pyranometer measurements from 290 meteorological stations in Germany, for the period 5 May 2011 to 30 April 2012. The evaluation is performed for single sites and regional average values. Among other tools to evaluate the EPS uncertainty information, the capture rate is analyzed, defined as percentage of values with the observation lying inside the ensemble spread ('hit'). The evaluation revealed a considerable underestimation of the forecast uncertainty and the need for ensemble calibration for a reliable estimation of forecast uncertainty.

UCSD has published their worked on a high-resolution, cloud-assimilating numerical weather prediction model for solar irradiance forecasting [Mathiesen et al, 2013]. They state a limited applicability of most operational NWP models for day-ahead solar forecasting. Overall, error is related to the expected meteorological conditions. For regions with dynamic cloud systems, forecast accuracy is low. Specifically, the North American Model (NAM) predicts insufficient cloud cover along the California coast, especially during summer months. Since this region represents significant potential for distributed photovoltaic generation, accurate solar forecasts are critical. To improve forecast accuracy, a high-resolution, direct-cloud-assimilating NWP model based on the Weather and Research Forecasting model (WRF-CLDDA) was developed and implemented at UCSD. Using satellite imagery, clouds were directly assimilated in the initial conditions. Furthermore, model resolution and physics parameterizations were chosen specifically to facilitate the formation and persistence of the low-altitude clouds common to coastal California. Compared to the UCSD pyranometer network, intra-day WRF-CLDDA forecasts were 17.4% less biased than the NAM and relative mean absolute error (rMAE) was 4.1% lower. For day-ahead forecasts, WRF-CLDDA accuracy did not diminish; relative mean bias error was only 1.6% and rMAE 18.2% (5.6% smaller than the NAM). Spatially, the largest improvements occurred for the morning hours along coastal regions when cloud cover is expected (see Fig. C1-4). In addition, the ability of WRF-CLDDA to resolve intra-hour variability was assessed. Though the horizontal (1.3 km) and temporal (5 min) resolutions were fine, ramp rates for time scales of less than 30 min were not accurately characterized. Thus, it was concluded that the cloud sizes resolved by WRF-CLDDA were approximately five times as large as its horizontal discretization.

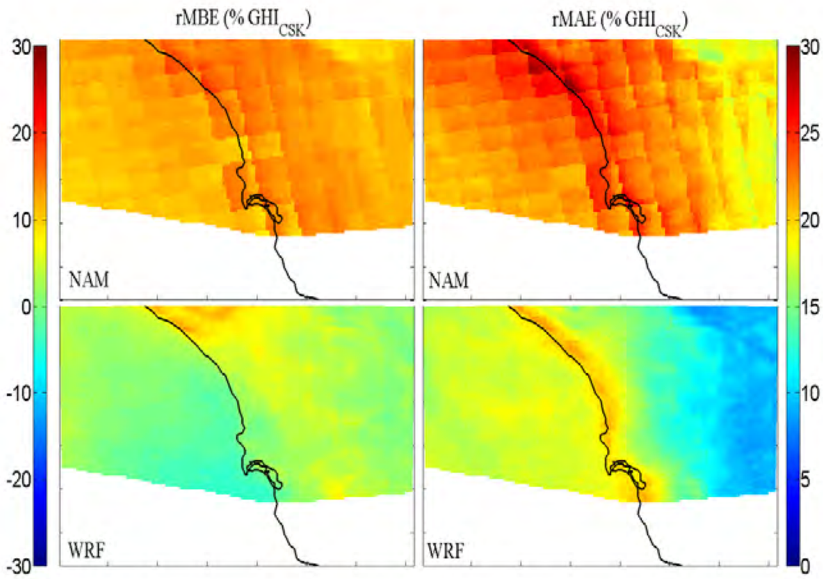


Figure C1-4: Spatial distribution of rMBE and rMAE (evaluated against SolarAnywhere satellite-derived solar data) along the Californian coastline of the NAM and WRF-CLDDA.

C.1.5. Statistical models integrating different data sources

University of Oldenburg is investigating the use of machine learning methods (support vector regression) for improving solar power predictions by integrating different data sources. The different input data are dealt with as exogenous input to time series models (see also Subactivity C1).

C.1.6 Benchmarking studies

The framework of four benchmarking studies, defined at the Tasks Expert's meeting in January 2013 includes:

- Benchmarking of irradiance forecasts of 4 global models for worldwide location
- Benchmarking of NWP model irradiance forecasts for central and northern Europe
- Benchmarking of NWP model irradiance forecasts for Southern Europe and La Reunion
- Benchmarking of short term forecasting algorithms based on cloud motion vectors

During the reporting period Task members started to collect measurement data for the different evaluation regions (Canada, USA, Australia, Austria, Switzerland, Spain, Denmark, Germany, La Reunion) and to process the forecasts for these sites.

At the October Task meeting in Oldenburg a session dedicated to the benchmarking exercise took place. A detailed plan for the next steps was developed. The accuracy measures to be applied were discussed. Besides the standard measures RMSE, MAE and bias it was agreed that a new measure should be introduced to assess the ability of a forecast model to describe the expected variability.

Activity C2: Integration of Solar Forecasts into Operations

C.2.1 Link with industry

Under Subactivity C.2.1 two deliverables were completed during the reporting period, both defined as workshops with industry involvement.

IrSOLaV and CIEMAT organized a "Workshop on Applications of Solar Forecasting" on 11th June 2013 at Ciemat (Deliverable C 2.1). The objective of this workshop was to increase and spread theoretical and practical knowledge on solar energy forecasting and integration of solar into the electric grid, targeted to industry representatives and scientists working in the solar energy sector. More than 100 participants joined the workshop. The program and presentations are available at http://www.irsolav.com/workshop/.

The joint workshop on solar forecasting of IEA/SHC Task 46 and IEA/PVPS Task 14 (Deliverable C 2.3) took place during the reporting period. This workshop, organized by Meteotest, was held on 1 October 2013 as a parallel event of the EU PVSEC 2013 conference in Paris. The workshop objective was described as follows: "The higher the penetration of PV the more important is the precise knowledge of the past and future solar resource. Additionally it becomes more and more important that engineers and meteorologists understand each other and work closely together. That's why the IEA tasks SHC 46 ("solar resource assessment and forecasting") and PVPS 14 ("high penetration of PV") are working together and are holding this common workshop. In the workshop we will present some of the on-going work of the two tasks with a focus on solar (short term) forecast." Information on the program can be found at http://www.photovoltaicconference.com/parallelevents/solarresourceandforecastdataforhighpvpenetration2013.html/

C.2.2 Applications of solar forecasting

DLR has been working on the economic analysis of a forecasting systems for CSP [Kraas et al, 2013]. Forecasts of power production are necessary for the electricity market participation of CSP plants. Deviations from the production schedule may lead to penalty charges. Therefore, the accuracy of DNI forecasts is an important issue. This paper elaborates on the mitigation impact on deviation penalties of an electricity production forecasting tool for the 50 MW parabolic trough plant Andasol 3 in Spain. Only a few commercial DNI forecast schemes are currently available. One of them, based on a model output statistics (MOS) forecast for the period July 2007 to December 2009, is assessed and compared to the zero cost 2-day persistence approach, which assumes yesterday's weather conditions and electricity generation also occur the following day.

The quality of the meteorological forecasts is analyzed both with forecast verification methods and from the perspective of a power plant operator. Using MOS, penalties in the study period are reduced by 47.6% compared to the 2-day persistence case. Typical error patterns of existing MOS forecasts and their financial impact are discussed. Overall, the paper aims at quantifying the economic value of readily available numerical weather prediction in this use case. A special feature of our study is its focus on a real market case and the use of real data, rather than following a purely academic approach, and thus to provide some new insights regarding the economic benefit of using and improving state-of-the- art forecasting techniques.

University of Oldenburg has analyzed the application of their satellite based cloud motion vector forecasts for local and regional PV power forecasting [Kühnert et al, 2013].

Subtask D: Advanced Resource Modeling
Activity D1: Improvements to Existing Solar Resource Retrieval Methods

D.1.1. Direct/diffuse transposition model, radiative transfer code for direct/diffuse and angular distribution of irradiance, circumsolar (sunshape) analysis
Improvement of albedo retrieval for satellite-based estimation of surface solar irradiance (CIEMAT).

A revision of the computation of ground albedo in satellite methods has been performed by CIEMAT and a new method for calculating ground albedo is proposed. This new method is based on the method of Dagestad and Olseth but allows for the local computation of the relationship between ground albedo and scattering angle. Consequently, this new formulation improves the solar radiation estimations in high reflective areas, such as the Sahara desert, where the dependence of the ground albedo with the co-scattering angle can vary notably with respect to other regions (Europe for instance). An analysis of the angular dependence of the albedo with the scattering angle is also being performed using Meteosat first and second-generation Prime and Indian Ocean Data Coverage (IODC) images and GOES images as well.

Determination of Circumsolar Radiation from Meteosat Second Generation (DLR)
DLR has proposed a method to assess circumsolar radiation from MSG observations (Reinhardt et al., 2013). Reliable data on circumsolar radiation, which is caused by scattering of sun light by cloud or aerosol particles, is becoming more and more important for the resource assessment and design of concentrating solar technologies. However, measuring circumsolar radiation is demanding and only very limited data sets are available. As a step to bridge this gap, we have developed a method to determine circumsolar radiation from cirrus cloud properties retrieved by geostationary satellites such as the MSG family. The method takes output from the COCS algorithm to generate a cirrus mask from MSG data, then uses the retrieval algorithm APICS to obtain the optical thickness and the effective radius of the detected cirrus, which in turn are used to determine the circumsolar radiation from a

pre-calculated lookup table. The lookup table was generated from extensive calculations using a specifically adjusted version of the Monte Carlo radiative transfer model MYSTIC and by developing a fast yet precise parameterization. APICS was also improved such that it determines the surface albedo, which is needed for the cloud property retrieval, in a self-consistent way instead of using external data. Furthermore it was extended to consider new ice particle shapes to allow for an uncertainty analysis concerning this parameter. We found that the nescience of the ice particle shape leads to an uncertainty of up to 50%. A validation with ground based measurements of circumsolar radiation show good agreement with the new “Baum v3.5” ice particle shape parameterization. For the circumsolar ratio (CSR) the validation yields a mean absolute deviation (MAD) of 0.10, a bias of 11% and a Spearman rank correlation $r_{rank, CSR}$ of 0.54. If measurements with sub-scale cumulus clouds within the relevant satellite pixels are manually excluded, the results improve to MAD= 0.07, bias= −3% and $r_{rank, CSR}$ = 0.71.

Heliosat-4: new satellite-based Surface Solar Irradiance estimation method with radiative transfer code (MINES ParisTech, DLR)
The new Heliosat-4 method calls upon the McClear model for the clear-sky part and on a variant of Delta-Eddington approximation for the cloudy part. Inputs for clear-sky originate from the MACC project, those for the clouds originate from the APOLLO algorithm applied to Meteosat images at the DLR. Ground albedo data originate from MODIS.

A comparison has been made between hourly values estimated by Heliosat-4 and those measured at 8 BSRN sites (Cabauw, Camborne, Carpentras, Lerwick, Payerne, Sede Boqer, Tamanrasset, Toravere). The same exercise was performed but with the standard HelioClim3v3 (HC3) product from the SoDa Service. Figure D1-1 exhibits the comparison of the RMSE obtained by HC3 and by the Heliosat-4 method (noted as MACC-RAD). The Heliosat-4 provides better results as a whole than HC3. This is encouraging knowing that HC3 has undergone several improvements while this is the first version of Heliosat-4.

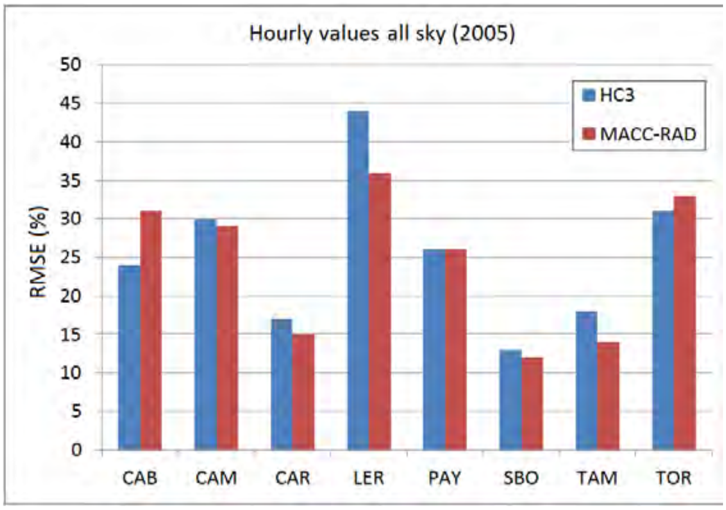


Figure D1-1: Comparison of the RMSE obtained by HelioClim 3 (HC3) and Heliosat 4 (MACC-RAD) for various BSRN stations (horizontal axis). (MINES ParisTech, DLR).

MACC McClear: a model of clear-sky irradiance Assessment of the performances of the McClear model to estimate the surface solar irradiance under clear-sky (MINES ParisTech, DLR)

The model McClear has been developed under the European project MACC-II (Lefèvre et al., 2013). It has been evaluated using 11 BSRN stations. The 1 min measurements from these stations have been screened in order to retain clear sky instants only. The article on McClear is under revision at Atmospheric Measurement Techniques. Meanwhile, another comparison was performed with another model estimating the aerosol forcing and developed in MACC. The MACC-AF model estimates also the SSI under clear sky. Figure D1-2 exhibits the comparison of the RMSE obtained by McClear and the MACC-AF model for the same 11 BSRN stations.

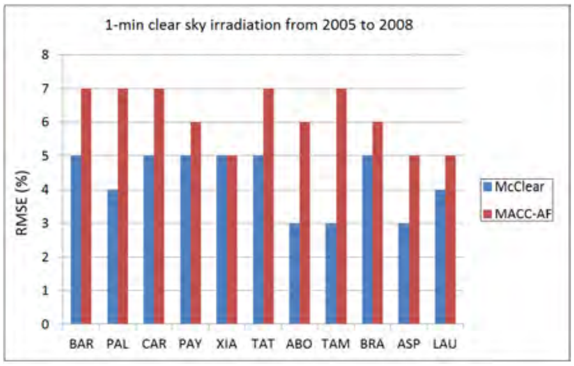


Figure D1-2: Comparison of the RMSE obtained by McClear and the MACC-AF (aerosol forcing) model for various BSRN stations (horizontal axis). (MINES ParisTech, DLR).

Modeling the distribution of radiances in the sky vault under clear-sky conditions for an accurate assessment of the beam and circumsolar radiation (Masdar Institute of Science and Technology and MINES ParisTech)

A PhD thesis, started in September 2012 by M. Yehia Eissa under the co-supervision of the Masdar Institute of Science and Technology and MINES ParisTech, under the project Prédisol lead by Total, deals with modeling the distribution of radiances in the sky vault under clear-sky conditions for an accurate assessment of the beam and circumsolar radiation. The first results from this PhD thesis were presented at the ISES Solar World Congress in November 2013 (Eissa et al., 2013). The objective was to present Circumsolar Ratio (CSR) values over a cloudless turbid atmosphere using a sky radiance model and a Radiative Transfer Model (RTM). The model of Perez et al. (1993), named the all-weather model (AWM), and the libRadtran RTM (Mayer and Kylling, 2005) were employed to compute the CSR. The dataset utilized in this study comprised of 10 months of solar irradiance (global, diffuse and direct normal) and aerosol optical depth (AOD) measurements collected at Masdar City located in Abu Dhabi, United Arab Emirates. A comparison of the CSR estimated from both models was then conducted.

Evaluation of surface solar irradiance retrieved by the MERRA re-analysis using in-situ measurements in the tropical Atlantic Ocean (MINES ParisTech)

Meteorological re-analyses are currently available, such as the Modern-Era Retrospective Analysis (MERRA) from NASA. These re-analyses contain estimates of the surface solar irradiance (SSI). MINES ParisTech has performed a study to evaluate the daily means of the SSI from MERRA using in situ measurements made at 23 sites in the tropical Atlantic Ocean for the period 1985-2011. The ocean was selected as there is no orographic influence on the results. The analysis shows that the MERRA re-analysis overestimates the SSI and the clearness index. The RMSE is large, ranging from 40 to 74 W/m2. The correlation coefficient is very low; typically 0.5 for the flux and 0.4 for the clearness index. The clearness index is underestimated in clear-sky conditions, and overestimated in other conditions, indicating that the re-analysis may have deficiencies in the modeling of the clear-sky conditions, cloud optical properties and cloud amount.

Extension of the WRF NWP model to assess direct and diffuse solar irradiance (Uni-Jaén)
Uni-Jaén has added the Weather Research and Forecasting (WRF) NWP model to assess DNI and DIF surface fluxes and is currently developing a fast method to update the Shortwave (SW) surface fluxes in WRF. This approach allows computing surface fluxes at higher spatio-temporal resolution without a significant computational cost increase (http://www.mmm.ucar.edu/wrf/users/wrfv3.5/updates-3.5.1.html). The ability of the WRF model to assess clear-sky GHI, DNI and DIF fluxes has been demonstrated in a benchmarking study against high-quality instantaneous ground observations from the BSRN and SURFRAD networks and the SMARTS2 SW spectral model (Ruiz-Arias et al., 2013a). Overall, all models demonstrated good skills for GHI assessment regardless whether the runs were driven with observed aerosols. However, only when the models are driven with observed aerosols, DNI and DIF simulations are reliable. In particular, the RRTMG SW scheme showed the best skill, comparable to the top-class SMARTS2 model.

A parameterization of the short-wave aerosol optical properties tailored for surface solar irradiance assessment and forecasting in NWP models has been developed and implemented in the WRF NWP model. This requires only the aerosol optical depth at 550 nm that can be introduced in the WRF model in the form of a time-varying spatial grid with virtually any temporal resolution (as long as it is compatible with the model time step). The rest of the optical properties of the aerosol are inferred from a built-in type of predominant aerosol, which can be selected by the user (currently, either rural or urban), and relative humidity. The parameterization has showed an outstanding performance for surface solar irradiance assessment.

Radiation sensitivity tests of the HARMONIE NWP model (DMI)
DMI has been working on radiation sensitivity tests of the HARMONIE NWP model (Nielsen et al., 2013), and on the sky radiance distribution modeling under all-sky conditions. Their analysis shows that, even in the case of homogeneous stratiform clouds, the distribution of scattered radiance is not simple and far from uniform as is often assumed. Since DISORT calculates values for a 1-dimensional atmosphere only, such simulations are not expected to be valid for fractional cloud cover.

Harmonization of the definitions of DNI (collective outcomes)
DNI is of particular relevance to concentrating technologies. However, disagreement between the various interpretations of DNI can be found depending upon its usage. Through Task 46, these issues as well as more specific ones have been identified and have been discussed with experts from around the world on two occasions in dedicated meetings.

The outcomes of these meetings are i) a report within the European MACC-II project on further standardization regarding computation of DNI, and ii) an agreement on definitions, nomenclature and ways of performing elementary calculations, namely the position of the sun with respect to an observer and the conversion of the beam irradiance received on a horizontal surface into DNI.

The first part of the three speeches (speakers: Dr. Philippe Blanc, Dr. Christian Gueymard, Dr. Richard Meyer, Moderator: Dave Renné) organized on May 2013 during the ISES Webinar "Improving DNI Information for CSP Development" was dedicated to these consensual definitions related to DNI. An oral presentation on this topic was also given by Blanc et al. (2013) during the ICEM conference on Toulousse, France in June.

D.1.2. Spectrally Resolved Irradiance

Assessing the spectral distribution of the solar radiation by numerical models and satellite images. Application cases: photovoltaic, UV, photosynthesis, daylight (MINES ParisTech - PhD Thesis, 2012-2015). This thesis, carried out by M. William Wandji-Nyamsi under the supervision of MINES ParisTech is “Assessing the spectral distribution of the solar radiation by numerical models and satellite images”.

A better knowledge of surface solar irradiance (SSI) needs the estimation of the spectral distribution of the solar irradiance at any time and place. Some spectral bands of interest are the Ultraviolet (UV) band, Photosynthetically Active Radiation (PAR) band, daylight band and interval bands related to the photovoltaic (PV) cells.

Ground measurements are rare on the surface, limited in the time due to the cost and the maintenance of the material. An accurate way for having a spatial and temporal variability of this spectral distribution is the use of the Radiative Transfer Models (RTMs) for the spectral calculations. However, RTMs require a lot of time run time. In order to speed calculations, a noticeable approach of calculations is the k-distribution method and correlated-k approximation of Kato et al. (1999) originally designed for the broadband shortwave calculations. It leads to the representation of the spectral distribution of solar irradiance in 32 discrete wavelengths intervals between 240 nm and 4606 nm, hereafter, named as Kato Bands (KB).

The main objective is to know how this approach performs in the spectral calculations. The study is done by the mean of a) Monte Carlo simulations for describing a wide diversity of the atmospheric states in the clear-sky conditions and b) the RTMs libRadtran and SMARTS considered like reference in each Kato band.

The comparisons are carried on the physical quantities direct clearness index which is defined as the ratio between the direct normal irradiance and the normal irradiance at the top of the atmosphere and clearness index which is the ratio between the horizontal global irradiance at Earth surface and the horizontal irradiance at the top of the atmosphere. In general, the results show a good agreement of this approximation. We can conclude that the k-distribution method and correlated-k approximation of Kato et al. (1999) is an adequate way for retrieving the spectral distribution of the solar irradiance in the particular spectral band like UV, PAR and others narrow spectral bands.

D.1.3. Enhanced atmospheric parameters for radiative transfer code based modeling: aerosol optical depth, enhanced cloud parameters, including 3-D cloud characterization

Performance assessment and improvement of AOD retrieval from MODIS

Ruiz-Arias et al. (2013a) demonstrate the high sensitivity of DNI to the aerosol content and, in particular, to the aerosol optical depth (AOD). Consequently, any reliable computation of DNI fluxes in the WRF NWP model will require the model to be driven by a time-varying gridded AOD input. The AOD observations gathered with the MODIS instrument aboard the polar-orbiting Terra and Aqua satellites are a convenient candidate data source. Uni-Jaén has assessed the performance of the 1ºx1º daily Level-3 MODIS AOD product over a period of 11 years against more than 600 AERONET stations worldwide (Ruiz-Arias et al., 2013b). It has shown acceptable skills to track the large-scale spatio-temporal variability of AOD. Nonetheless, it is typically biased with, eventually, very large regional biases and uncertainty, as can be seen in Figure D1-3. For this reason, a distributed bias correction method based on Geostatistics and ground observations has been proposed Ruiz-Arias et al., (2013c), and consists of a two-step procedure for data-gap filling and bias removal.

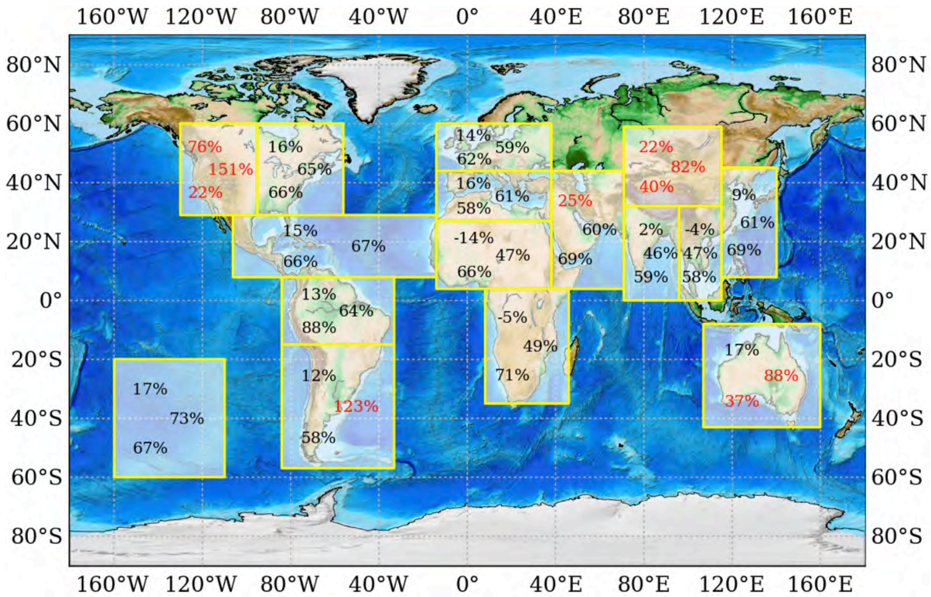


Figure D1-3: MBE (top), RMSE (middle) and squared Pearson correlation coefficient R2 (bottom) for each individual region over the entire study period. The entire dataset scores are shown in the square domain over the South Pacific Ocean.

Validation of Aerosol Optical Depth (AOD) from MACC-ECMWF re-analysis in United Arab Emirates

The influence of the limited accuracy of the aerosols on the solar resource assessment in the Middle East, where dust is the most critical atmospheric parameter, has been also studied. The EU-funded MACC aerosol has been identified as the most suitable publicly available source of AOD for irradiance calculations (Oumbe et al., 2013). However, in the Middle East, it overestimates the aerosol optical depth (AOD) measured in the AERONET network by 26% and the standard deviation (SD) amounts to 42. The analysis of these deviations shows that they are due to the relatively high spatial and temporal variability of aerosols in the region, since the spatial and temporal resolution of MACC are approximately 125 km and 3h in the Middle East. A global linear adjustment with AERONET measurements has been made. But it corrects only the systematic error and not the SD. The AOD was converted into irradiance by means of radiative transfer in the atmosphere. Therefore, the same ΔAOD (variation on AOD) value can have different influence on the estimated irradiance, depending on the solar position, the actual AOD itself and other atmospheric conditions. This influence is being quantified, with the goal of estimating the maximum accuracy that can be expected on the assessed solar resource in the region, when state-of-the-art re-analysis aerosol is used.

D.1.4 Other model upgrades: pixel desegregation (down-scaling solar irradiation data) for high spatial resolution solar map
Work on this sub-activity has not yet commenced.

Activity D2: Long-term Analysis and Forecasting of Solar Resource Trends and Variability
The NASA/LaRC team continues its efforts in conjunction with SUNY, NREL and NOAA NCDC to develop a long-term satellite solar irradiance resource data set beginning in 1983 through within about 1 year of present. The data set will be incorporated into the IRENA Global Atlas when completed. During the past 6 months, the NOAA NCDC data set GRIDSat was tested and progress was made toward finalizing the production system. A report on the progress was made at the April National Solar Conference 2013 in Baltimore, USA (Cox et al., 2013). Work continues to verify the results from version run at SUNY for single locations over BSRN sites and global runs here at NASA. Once verification proceeds, the NASA team will then begin gap filling at the 3-hourly level for the nearly global data coverage.

Due to lack of funding at NASA and Meteotest only minimal work could be done in this activity. Nevertheless two topics have been investigated recently:

1. Meteotest (Jan Remund) looked at the difference of long term global radiation anomalies (2081 – 99 compared to 1981 – 2000) in Switzerland based on different Regional Climate Models (CLM, RCA, REGCM3; all based on ECHAM5) of the ensemble project (http://www.ensembles-eu.org/). Generally the radiation anomalies are small (+/- 2%) and the differences between the RCMs as well – even if the three chosen RCMs show big differences in temperature and precipitation trends.

2. Fraunhofer ISE (Björn Müller et al., 2013) analyzed the past trends in Germany (dimming and brightening phase) and investigated the optimal duration of the historic period to use for site evaluations. The result of this work is submitted to Solar Energy and has been presented in the German Energiemeteorologie meeting (Müller et al, 2013).

WORK PLANNED FOR 2014

Subtask B: Standardization and Integration Procedures for Data Bankability
Activity B1: Measurement Best Practices
In 2014 the best practices manual for RSI based measurements will be finalized and published. The work on the general best practices manual including other instruments will be continued. A PhD thesis on circumsolar radiation will be published. The work on the uncertainty analysis of RSI measurements will be intensified. Research on the advanced measurands “soiling” and “beam attenuation” in tower plants will be continued.

Activity B2: Gap Filling, QC, Flagging and Data Formatting
In 2014, the manual on best practices for quality control will be finished. A publication in a peer-reviewed article on quality check procedure for ground-based data is planned. Further work on flagging data and data formatting will be done in order to gathering best practices.

Activity B3: Integration of Data Sources

In 2014 a first draft of the report on integration of ground measurements to satellite data sources will be finished.

Activity B4: Data Uncertainties over Various Temporal and Spatial Resolutions
The methodology for benchmarking of model-derived solar radiation data sets will be defined until July 2014. Also, a report on the geographical distribution of uncertainties from satellite-derived solar radiation products will be prepared.

Activity B5: Evaluation of Meteorological Products
In 2014 a data format description for meteorological time-series data for solar energy will be defined.

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 2013 will be on the benchmarking studies to compare forecasting algorithm of the different partners. Four different studies starting in March 2013 have been defined at the third meeting in Sophia Antipolis, France, 21-23 January 2013. For three of these studies the evaluation period is 1 March 2013 -28 February 2014 and evaluation will be completed in 2014:

For Deliverable C1.1, Benchmarking of Irradiance Forecasts of Global Models for Worldwide Locations, four global models will be compared for locations in Canada, US; Spain, Germany, Austria, Switzerland, Denmark and La Reunion.

Publication of the following Deliverables is planned for 2015:
- Deliverable C1.2: Benchmarking study of NWP irradiance forecasts for Central and Northern Europe:
- Deliverable C1.4: Benchmarking of satellite based irradiance forecasts

Also the work on the fourth benchmarking study (Deliverable C1.3) concerning NWP irradiance forecasts for Southern Europe and La Reunion with the evaluation period 3 January 2014 – 2 February 2015 will start.

Subtask D: Advanced Resource Modeling
The updated list of research works and outcomes that have been conducted so far and are foreseen during 2014 within this subtask's activity are the following:
- Common definitions related to DNI and circumsolar:
  - **May 2012 – Jan 2013**: Discussions on specific sessions of SHC46
  - **Oct 2013**: Draft a first version of a review paper on the topic
  - **Feb 2014**: Submission of the review paper to the Solar Energy or Renewable Energy journals
- Accuracy and performance of different sources of AOD and analysis of their impact on surface solar irradiance assessment and forecasting:
  - **Jun 2012 – Jan 2013**: Multi-year worldwide assessment of daily Level-3 MODIS AOD performance against AERONET AOD observations. Expected uncertainty in surface solar irradiance assessment. Research paper in Jan 2013.

- **Feb 2013 – Jul 2013**: Data gaps and bias removal post-processing method for gridded AOD databases. Expected uncertainty in surface solar irradiance assessment. Research paper in Jul 2013.
- **Jan 2013 – Dec 2013**: Performance assessment of MACC AOD in the United Arab Emirates (UAE)
- **Jan 2014 – Dec 2014**: Performance assessment of GOCART AOD
- **Jan 2014 – Jun 2014**: To evaluate different methods for site-adapted AOD forecasting and its application to NWP modeling.
- **Mid 2015**: Synthesis report on accuracy and performance of different sources of AOD
- **Late 2015**: Draft of a joint review paper on the results of the performance analysis

▪ Comparison of clear-sky irradiation models (broadband and spectral)

- **Jan 2013 – Dec 2013**: Development of short-wave aerosol optical properties parameterization (AOPP) for NWP models tailored for surface solar irradiance assessment and forecasting. Research paper submitted for publication.
- **2013**: Performance assessment of MACC McClear prediction on UAE
- **Jun 2013 – Aug 2013**: Short-wave clear-sky closure experiments for GHI, DNI and DIF assessment with the WRF model in the Contiguous US region. Research paper in Aug 2013.
- **Apr 2014 – May 2014**: Worldwide performance assessment of MACC McClear prediction
- **Oct 2014 – Mar 2014**: Analysis of the WRF/AOPP performance assessment of surface solar irradiance in the Contiguous US region using MODIS AOD
- **Jan 2014 – May 2014**: Analysis of the WRF/AOPP performance assessment of surface solar irradiance in Spain using MACC reanalyzes.
- **Apr 2014 – May 2014**: Worldwide performance assessment of MACC AOD
- **Mid 2015**: Synthesis report on the different Clear-Sky models (and corresponding sources of parameters)
- **End 2015** : Draft of a collective review paper

▪ Cloud representation in NWP models

- **Oct 2013 – May 2014**: To evaluate WRF unresolved clouds against local cloud observing methods.

• Measurement and modeling of directional radiance distribution in all-sky conditions.

- **Aug 2013**: Measurements of directional radiances (full solar spectrum).
- **Apr 2013 – Dec 2014**: Theoretical study of directional radiances.
- **Mar 2015**: Report that summarizes the results.

LINKS WITH INDUSTRY

Several small companies involved in solar resource data production and services are directly 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), Sun to Market Solutions (Spain), Meteotest (Switzerland), Irradiance Corp. (USA), Augustyn and Co. (USA), and Clean Power Research (USA). There is also guest participation by Peak Design (UK), and Solar Consulting Services (USA).

The audience for the Task results 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 PUBLISHED IN 2013

Journal Articles and Book Chapters

Subtask A

Matthew Lave, Jan Kleissl, Cloud speed impact on solar variability scaling – Application to the wavelet variability model, Solar Energy, Volume 91, May 2013, Pages 11-21.

J.L. Bosch, J. Kleissl, Cloud motion vectors from a network of ground sensors in a solar power plant Original, Solar Energy, Volume 95, September 2013, Pages 13-20.
J.L. Bosch, Y. Zheng, J. Kleissl, Deriving cloud velocity from an array of solar radiation measurements, Solar Energy, Volume 87, January 2013, Pages 196-203

Patrick Mathiesen, Craig Collier, Jan Kleissl A high-resolution, cloud-assimilating numerical weather prediction model for solar irradiance forecasting, Solar Energy, Volume 92, June 2013, Pages 47-61

Subtask B

(Wilbert et al., 2013) Wilbert, S., B. Reinhardt, J. DeVore, M. Röger, R. Pitz-Paal, C. Gueymard, and R. Buras. "Measurement of Solar Radiance Profiles with the Sun and Aureole Measurement System." Journal of Solar Energy Engineering 135, no. 4 (2013): 041002-02.

Subtask C

A special achievement during 2013 was the publication of the joint Task 36 benchmarking exercise on solar forecasting:

Perez, R., Lorenz, E., Pelland, S., Beauharnois, M., van Knowe, G., Hemker Jr., K., Heinemann, D., Remund, J., Müller, S.C., Traunmüller, W., Steinmauer, G., Pozo, D., Ruiz-Arias, J., Lara-Fanego, V., Ramirez-Satigosa, L., Gaston-Romero, M., Pomares, L.M.: 2013, 'Comparison of numerical weather prediction solar irradiance forecasts in the US, Canada and Europe', Solar Energy, Volume 94, 305-326 DOI: 10.1016/j.solener.2013.05.005

Bosch JL, Kleissl J, Cloud motion vectors from a network of ground sensors in a solar power plant, Solar Energy, 95:13-20, 10.1016/j.solener.2013.05.027, 2013.

Maimouna Diagne, Mathieu David, Philippe Lauret, John Boland, Nicolas Schmutz (2013) Review of solar irradiance forecasting methods and a proposition for small-scale insular grids, Renewable and Sustainable Energy Reviews, 27, pp. 65-76.

Jing Huang, Małgorzata Korolkiewicz, Manju Agrawal, John Boland, Forecasting solar radiation on an hourly time scale using a Coupled AutoRegressive and Dynamical System (CARDS) model, Solar Energy Volume 87, January 2013, Pages 136–149

Mathiesen, P, C Collier, J Kleissl, A high-resolution, cloud-assimilating numerical weather prediction model for solar irradiance forecasting, Solar Energy, 92:47-61, 10.1016/j.solener.2013.02.018. 2013.

B. Kraas, M. Schroedter-Homscheidt, R. Madlener Economic merits of a state-of-the-art
concentrating solar power forecasting system for participation in the Spanish electricity
market, Solar Energy, 93, 244-255, 2013.

M. Schroedter-Homscheidt, A. Oumbe, A. Benedetti, J.-J. Morcrette Aerosols for concentrating solar electricity production forecasts: requirement quantification and ECMWF/MACC aerosol forecast assessment, Bull. Amer. Met. Soc., 2012, pre-view available, to be published in June 2013, doi: 10.1175/BAMS-D-11-00259

M. Schroedter-Homscheidt and A. Oumbe: Validation of an hourly resolved global aerosol model in answer tosolar electricity generation information needs
M. Schroedter-Homscheidt and A. Oumbe Atmos. Chem. Phys., 13, 3777-3791, 2013, doi:10.5194/acp-13-3777-2013

Members of IEA SHC Task 46 contributed a major share of the book “Solar Resource Assessment and Forecasting”, edited by Jan Kleissl of UCSD and published in August 2013:

- R. Perez, T Cebecauer, and M. Suri: Semi-Empirical Satellite Models

- S.D. Miller, A.K. Heidinger, M. Sengupta: Physically Based Satellite Models
- R. Perez, T.D. Hoff: Solar Resource Variability
- M. Clave, J. Kleissl, and J. Stein: Quantifying and Simulating Solar-Plant Variability using irradiance data
- C.F.M. Coimbra, J. Kleissl, R. Marquez: Overview of Solar- Forecasting Methods and a Metric for Accuracy Evaluation
- B. Uruquart, M. Ghonima, D. Nguyen, B Kurtz, C.W. Chow, and J. Kleissl: Sky-imaging Systems for Short-Term Forecasting
- R. Perez, T.D. Hoff: SolarAnywhere Forecasting
- J. Kühnert, E. Lorenz, And D. Heinemann: Satellite-Based Irradiance and Power Forecasting for the German Energy Market
- P. Mathiesen, J. Klessl, C. Collier: Case Studies of Solar Forecasting with the Weather and Research Forecasting Model at GL- Garrad Hassan

Subtask D

Polo, J., J.M. Vindel, L. Martín, (2013). Angular dependence of the albedo estimated in models for solar radiation derived from geostationary satellites. Solar Energy 93, 256-266.

Reinhardt, B., Buras, R., Bugliaro, L., Wilbert, S., & Mayer, B. (2013). Determination of circumsolar radiation from Meteosat Second Generation. Atmospheric Measurement Techniques Discussions, 6(3), 5835–5879. doi:10.5194/amtd-6-5835-2013.

Lefèvre, M., Oumbe, A., Blanc, P., Espinar, B., Gschwind, B., Qu, Z., Morcrette, J.-J. (2013). McClear: a new model estimating downwelling solar radiation at ground level in clear-sky conditions. *Atmospheric Measurement Techniques*, *6*, 2403–2418. doi:10.5194/amt-6-2403-2013.

Ruiz-Arias, J.A., Dudhia, J., Santos-Alamillos, F.J., Pozo-Vázquez, D. (2013a) "Surface clear-sky shortwave radiative closure intercomparisons in the Weather Research and Forecasting model", J. Geophys. Res. Atmos., Vol. 118, pp. 1-13, doi:10.1002/jgrd.50778, 2013.

Ruiz-Arias, J.A., Dudhia, J., Gueymard, J., Pozo-Vázquez, D. (2013b) "Assessment of the Level-3 MODIS daily aerosol optical depth in the context of surface solar radiation and numerical weather modeling", Atmos. Chem. Phys., Vol. 13, pp. 675-692, doi: 10.5194/acp-13-675-2013

Ruiz-Arias, J.A., Dudhia, J., Lara-Fanego, V., Pozo-Vázquez, D. (2013c) "A geostatistical approach for producing daily Level-3 MODIS aerosol optical depth analyses", Atmos. Environ., Vol. 79, pp. 395-405. doi: 10.1016/j.atmosenv.2013.07.002.

Conference Proceedings

Subtask A

Ruf, H., G. Heilscher, M. Schroedter-Homscheidt, H.G. Beyer, F. Meier, Erstellung einer Wolkenstatistik für lokale Verteilnetze, 29. Symp. Photovoltaische Solarenergie, 06.2.-8.3. Bad Staffelstein, Germany (2013)

H. Ruf & G. Heilscher, M. Schroedter-Homscheidt, H.G. Beye, F. Meier, Analysis of Cloud Indicators to Derive the Bus Bar Voltage at a Local Low Voltage Distribution Grid Transformer, 28th EUPVSEC, Paris, 30.09-4.10 (2013)

G Yordanov, T Saetre, O Midtgård, Optimal Temporal Resolution for Detailed Studies of Cloud-Enhanced Sunlight (Over irradiance), to be presented at 39th IEEE PVSC, Tampa. FL, 16-21. July, 2013

Perez, R., T. Hoff, J. Dise, D. Chalmers and S. Kivalov (2013): The Cost of Mitigating Short-Term PV Output Variability – anticipated for publication as part of ISES World Forum Proceedings, Cancun, Mexico.

Perez, R., T. Hoff, J. Dise, D. Chalmers and S. Kivalov (2013): Mitigating Short-Term PV Output Variability -- 28th European Photovoltaic Solar Energy Conference and Exhibition EUPVSEC Proceedings, Paris, France.

G.H. Yordanov, H.G. Beyer, Characteristics in highly time resolved solar irradiance data at a higher latitude location, 13th EMS Annual meeting and 11th conference on Applications of Meteorology, Reading (UK), 9-13.089 (2013)

Reig, A., L. del Re, G. Steinmaurer, B. Pla and C. Guardiola: An Efficient Reciding Horizon Approach for Optimal Control of Diesel Hybrid Electric Vehicles, submitted to 2013 American Control Conference, June 17 - 19, Washington, DC.

Subtask B

Wilbert, S., Pitz-Paal, R., & Jaus, J. (2013). Comparison of measurement techniques for the determination of circumsolar irradiance. AIP Conference Proceedings, 1556(1), 162-167. doi: doi:http://dx.doi.org/10.1063/1.4822222

N. Geuder, R. Affolter, B. Kraas, S. Wilbert. Long-term behavior, accuracy and drift of LI-200 pyranometers as radiation sensors in Rotating Shadowband Irradiometers (RSI). . SolarPACES conference 2013, Las Vegas (accepted for publication in Elsevier Energy Procedia SolarPACES conference proceedings)

Fabian Wolfertstetter, Norbert Geuder, Roman Affolter, Klaus Pottler, Ahmed Alami Merrouni, Ahmed Mezrhab, Robert Pitz-Paal. Monitoring of mirror and sensor soiling with TraCS for improved quality of ground based irradiance measurements. SolarPACES conference 2013, Las Vegas (accepted for publication in Elsevier Energy Procedia SolarPACES conference proceedings).

Schwandt, Marko, Kaushal Chhatbar, Richard Meyer, Indradip Mitra, Ramadhan Vashistha, Godugunur Giridhar, and Ashvini Kumar. 2013. “Quality Check Procedures and Statistics for the Indian SRRA Solar Radiation Measurement Network.” *Energy Procedia*: 2013, ISES Solar World Congress, 10p.

Schwandt, M., Chhatbar, K., Meyer, R., Fross, K., Mitra, I., Giridhar, G., Gomathinayagam, S. and Kumar, A., 2013. “Development and test of gap filling procedures for solar radiation data of the Indian SRRA measurement network.” *Energy Procedia*: 2013, ISES Solar World Congress.

Vindel J.M., Polo, J., Antonanzas-Torres, F., (2013). Improving daily output of global to direct solar irradiance models with ground measurements. Journal of Renewable and Sustainable Energy 5, 063123.

Subtask C

Müller C.S., and J. Remund. Shortest term regional solar energy forecast for the 1 to 6 hours, 28th European Photovoltaic Solar Energy Conference and Exhibition in Paris, 30.9- 4.10. 2013 France.

J. Kühnert, E. Lorenz, A. Hammer, and D. Heinemann. Satellite Based Short Term Prediction of Photovoltaic Power for the Application at the Energy Market; Presentation at ICEM 25. -28.6.2013, Toulouse, France.

K. Przybilla, J. Kühnert, E. Lorenz, and D. Heinemann. Probabilistic irradiance forecasts of the ECMWF Ensemble Prediction System for photovoltaic power predictions; Poster presentation at ICEM 25. -28.6.2013, Toulouse, France.

M. Schroedter-Homscheidt and N. Killius. Spatial error characteristics for operational day ahead solar irradiance forecasts. EMS Annual Meeting Abstracts, Vol. 10, EMS2013-575, 2013, 13th EMS / 11th ECAM.

B. Wolff, E. Lorenz, and O. Kramer. Statistical Learning for Short-Term Photovoltaic Power Predictions. Proc. European Conference on Machine Learning (ECML), Workshop Data Analytics for Renewable Energy Integration (DARE), 2013.

S. Lundholm 2013: Verification of Global Radiation Forecasts from the Ensemble Prediction System at DMI, Ph.D. thesis available at http://www.nbi.ku.dk/english/research/phd_theses/phd_theses_2013/sisse_camilla_lundholm.

Subtask D

Eissa, Y., P. Blanc, A. Oumbe, H. Ghedira, L. Wald (2013). Estimation of the Circumsolar Ratio in a Turbid Atmosphere. 2013 ISES Solar World Congress, November 2013, Cancùn.

Oumbe, A., H. Bru, Z. Hassar, P. Blanc, L. Wald, Y. Eissa, P. Marpu, I. Gherboudj, H. Ghedira, D. Goffe. On the improvement of MACC aerosol spatial resolution for irradiance estimation in the United Arab Emirates. 2013 ISES Solar World Congress, November 2013, Cancùn.

Ruiz-Arias, J.A., Dudhia, J., Pozo-Vázquez, D., 2013d. A New Aerosol Parameterization in the Weather Research and Forecasting (WRF) Mesoscale Model for Improved Solar Resource Assessment and Forecasting. 2nd International Conference Energy and Meteorology (ICEM), Weather and Climate for the Energy Industrie, 24-28 June 2013, Toulouse, France.

Blanc, P., Espinar, B., Wald, L., 2013. On the definition of the direct normal irradiance (DNI). 2nd International Conference Energy and Meteorology (ICEM), Weather and Climate for the Energy Industrie, 24-28 June 2013, Toulouse, France.

Blanc, P., 2013. ISES Webinar : Improving DNI Information for CSP Development. Part I : DNI definitions. Webinar recording available at www.ises.org.

Cox, Stephen. J., Stackhouse, P.W., Jr., William Chandler, James Hoell, Taiping Zhang, David Westberg, Charles Whitlock, Richard Perez, Charles Hemker, Jim Schlemmer, David Renne, Manajit Sengupta, John Bates, and Kenneth Knapp, 2013. Progress towards deriving an improved long-term global solar resource. National Solar Conference 2013, Baltimore, MD, 16-20 April.

Müller B., A. Driesse, M. Wild, and K. Behrens, Ertragsgutachten für PV-Anlagen vor dem Hintergrund von Global Dimming and Brightening, Fachtagung Energiemeteorologie, Grainau, 2013 (ftp://ftp.dfd.dlr.de/pub/EOC-Publikationen/Fachtagungen_Energiemeteorologie/3._Fachtagung_Energiemeteorologie_2013/02_Anwendungen_Klimatologie/Mueller_enmet.pdf)

MEETINGS IN 2013

3rd Task Experts Meeting
January 21-23
Sophia-Antipolis, France.
Approximately 25-30 Task Participants attended, including a few by phone or Skype.

4th Task Experts Meeting
October 7-8
Oldenburg, Germany
Over 40 participants, observers and guests participated.

MEETINGS PLANNED FOR 2014

5th Task Experts Meeting
April 15-16
La Reunion Island

6th Task Experts Meeting
Late 2014/early 2015
Location: to be decided

SHC TASK 46 CONTACTS

TASK MANAGEMENT

Operating Agent
Dave Renné
National Renewable Energy Laboratory (retired)
Senior Consultant, Clean Power Research
2385 Panorama Ave.
Boulder, CO 80304
UNITED STATES

Subtask A
Richard Perez
State University of New York/Albany
Atmospheric Sciences Research Center
251 Fuller Road
Albany, NY 12203
perez@asrc.cestm.albany.edu

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, Robert Davy, Peter Coppin
CSIRO
Alberto.troccoli@csiro.au
Robert.davy@csiro.au
Peter.coppin@csiro.au

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

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

Austria
Klaus Reingruber, Wolfgang Traunmuller
Bluesky Wetteranalyzen
klaus.reingruber@blueskywetter.at
wolfgang.traunmueller
@blueskywetter.at

Gerald Steinmaurer
Austria Solar Innovation Center
steinmaurer.gerald@asic.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, Lucien Wald, Lionel Ménard, and Bella Espinar
MINES ParisTech
Center Observation, Impacts, Energy
philippeblanc@mines-paristech.fr
Lucien.wald@mines-paristech.fr
lionel.menard@mines-paristech.fr
bella.espinar@mines-paristech.fr

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

Germany
Detlev Heinemann, Elke Lorenz, 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, Daniel Stetter, Marion Schroedter-Homscheidt, Steffen Stoeckler, Stefan Wilbert, Bernhard Reinhardt
DLR Institut für Technische Thermodanamik
carsten.hoyer@dlr.de
Daniel.stetter@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

Slovakia
Marcel Suri, Tomas Cebecauer
GeoModel, s.r.o.
M. Marecka 3
marcel.suri@geomodel.eu
tomas.cebecauer@geomodel.eu

Spain
Martín Gastón, Inigo Pagola
CENER
mgaston@cener.com

Jesús Polo, Lourdes Ramirez, Ana A. Navarro, 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, Marian de Blas
Public University of Navarra (UPNA)
Dpto. Proyectos e Ingeniería Rural
jlte@unavarra.es
mblas@unavarra.es

David Pozo Vazquez, 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
IrSOLaV
Luis.martin@irsolav.com

Juan Liria, Beatrice Frade, Yasmina Navarro, Juan Andujar, Daniel Pereira
Sun 2 Market Solutions
Parque Cientifico-Tecn. LEGATEC
ipagola@cener.com
ynavarro@s2msolutions.com

Switzerland
Pierre Ineichen
University of Geneva, CUEPE
pierre.ineichen@unige.ch

Jan Remund
Meteotest
Jan.remund@meteotest.ch

United States

Paul Stackhouse
NASA Langley Research Center
Paul.w.stackhouse@nasa.gov
Richard Perez (Subtask A lead)
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 47

Renovation of Non-Residential Buildings Towards Sustainable Standards

Fritjof Salvesen
Asplan Viak AS
Operating Agent for the Norwegian Agency Enova SF

TASK DESCRIPTION

Buildings are responsible for up to 35% of the total energy consumption in many of the IEA countries. The EU Parliament approved in April 2009 a recommendation that member states have to set intermediate goals for existing buildings as a fixed minimum percentage of buildings to be net zero energy by 2015 and 2020.

For existing non-residential buildings a dramatic reduction in primary energy consumption is crucial to achieve this goal.

A few exemplary renovation projects have demonstrated that total primary energy consumption can be drastically reduced together with improvements of the indoor climate. The experience gained from these projects has not been systematically analyzed to make it a reliable resource for planners. Because most property owners are not even aware that such savings are possible, they set energy targets too conservative. Buildings renovated to mediocre performance can be a lost opportunity for decades. It is therefore important that building owners be aware of such successes and set ambitious targets.

Equally important, local authorities, companies and planners also need knowledge on how to achieve market penetration of such solutions. Success stories and planning knowledge will be communicated to target audiences to accelerate a market break-through of highly effective renovations in non- residential buildings.

The objectives of this Task are to:

- Develop a solid knowledge base on how to renovate non-residential buildings towards the NZEB standards in a sustainable and cost efficient way.
- Identify the most important market and policy issues as well as marketing strategies for such renovations.

The Task deals with several types of non-residential buildings, including protected and historic buildings:

- Office buildings
- Educational buildings
- Nursing homes
- Hotels
- Supermarkets and shopping centers

Depending on available projects among the participating countries, the following types may also be included, hospitals, industrial halls and indoor swimming pools.

A broad range of technologies will be included and solar energy will play a significant role in bringing the use of primary energy down to NZEB standard.

The Task is organized in the following Subtasks.

Subtask A: Advanced Exemplary Projects - Information Collection & Brief Analysis
(Lead Country: Norway)

Objectives:

- Systematically analyze and document renovation projects meeting Task selection criteria in order to quantify which measures achieve the greatest energy savings or improvement in comfort and at what costs.
- Identify the driving forces and barriers in the decision-making processes for detailed analysis in Subtask B.

- Identify innovative, promising concepts and technologies for detailed analysis in Subtask C.
- Identify environmental impacts and architectural quality for detailed analysis in Subtask D.

Subtask B: Market and Policy issues and Marketing Strategies
(Lead Country: Norway)

Objectives:

- Identify segments in the non- residential building stock with high potential for energy efficiency savings and which types of owners are most likely to go for major renovation projects.
- Identify the most important barriers and driving forces in decision-making processes for high ambition renovation in the non-residential sector and how to overcome them.
- Develop knowledge about which boundary conditions are important to make renovations attractive/ affordable/cost effective and more available.
- Increase the understanding of how improved non-energy benefits (including outcome subtask D) as a result of substantial renovation increases the value of the building and thereby makes the investments profitable.

Subtask C: Assessment of Technical Solutions and Operational Management
(Lead Country: Germany)

Objectives:

- Describe the HVAC and control systems of the recommended retrofit concept. This includes information about the building shell, the HVAC system, the daylighting and artificial lighting concepts as well as available measurement or energy consumption data. The documentation of the data is an important contribution to subtask A.
- Identify required measuring points for a basic monitoring of building and HVAC system.
- Develop a methodology for evaluating the different building and plant concepts.
- Identify and develop successful NZEB concepts considering the building envelope as well as the heating, cooling, ventilation and lighting concept.
- Evaluate the building and plant performance on basis of energy monitoring or monthly energy bills (if measurements are made available by participants).
- Analyze the fault detection and identify optimization potential due to smart building and plant control.

Subtask D: Environmental and Health Impact Assessment
(Lead Country: Belgium)

Objectives:

- Develop a global (including local and global environment) approach for building renovation based on environmental, urban infrastructure, comfort and health impacts.
- Identify quantifiable and qualitative criteria and requirements for environmental impacts of renovation projects based on BREEAM assessment methodology.
- Identify indoor climate and indoor space issues with particular relevance to the topic of the user's health and user's comfort (visual, acoustical etc.).
- Identify "quality of life" issues with particular relevance to the topic of the urban infrastructure, of the urban transportation network and of the collective or public spaces.

- Identify the adaptability of building and flexibility issues with particular relevance to the acceptance of renovations without causing heavy impact on the environment.

Main Deliverables

In general, the dissemination of the Task results will take place at the national level. The publications listed below will be available from the SHC website as PDFs. The publications may be used as a basis for making national publications.

The following documents and information meetings are planned and some of them accomplished:

1. The Task website was publicly available in 2011, including secure sites for the Task participants.
2. First brochures of exemplary renovation projects were posted on the website in the 2nd quarter of 2012. Target groups are designers, planners and building owners.
3. Two seminars in conjunction with expert meetings to present exemplary projects from the participating countries. The first one was organized in Brussels September 7, 2012 in connection with the Passive House Exhibition.
4. “Lessons learned summary” from the exemplary projects of Subtask A.
5. Publication describing decision making processes, non-energy benefits as well as barriers and driving forces from the case studies of Subtask B.
6. Publication summarizing renovation policies and strategies.
7. Presentations at national and international conferences that have the building industry and/or the real estate sector as a target group.
8. Technical report with recommendations and conclusions from Subtask C
9. “Guideline for designers and planners” with recommendations from Subtask D.

Duration

The Task started on January 1, 2011 and will end on June 30, 2014.

WORK DURING 2013

Information

In connection with an expert meeting, a public Task 47 seminar was organized in Sydney, Australia on 5. April. The seminar was organized by the University of Sydney and was attended by about 20 persons. All presentations are available at http://task47.iea-shc.org/seminar-2013-04-05

Three Task presentations were given at SHC 2013:

- *Sustainable Renovation of non-Residential Buildings, a Response to Lowering the Environmental Impact of the Building Sector in Europe*, by Sophie Trachte
- *Renovation of Non-Residential Buildings towards NZEB Standards – Lessons Learned from Exemplary Projects,* by Fritjof Salvesen
- *Renovation of Schools in Germany,* by Johann Reiss

Other Task presentations:

- *Analysis of the thermal behavior of historical box type windows for renovation concepts with CFD*, by Daniel Brandl and Thomas Mach at SGB13 on September 28 at Graz University of Technology.

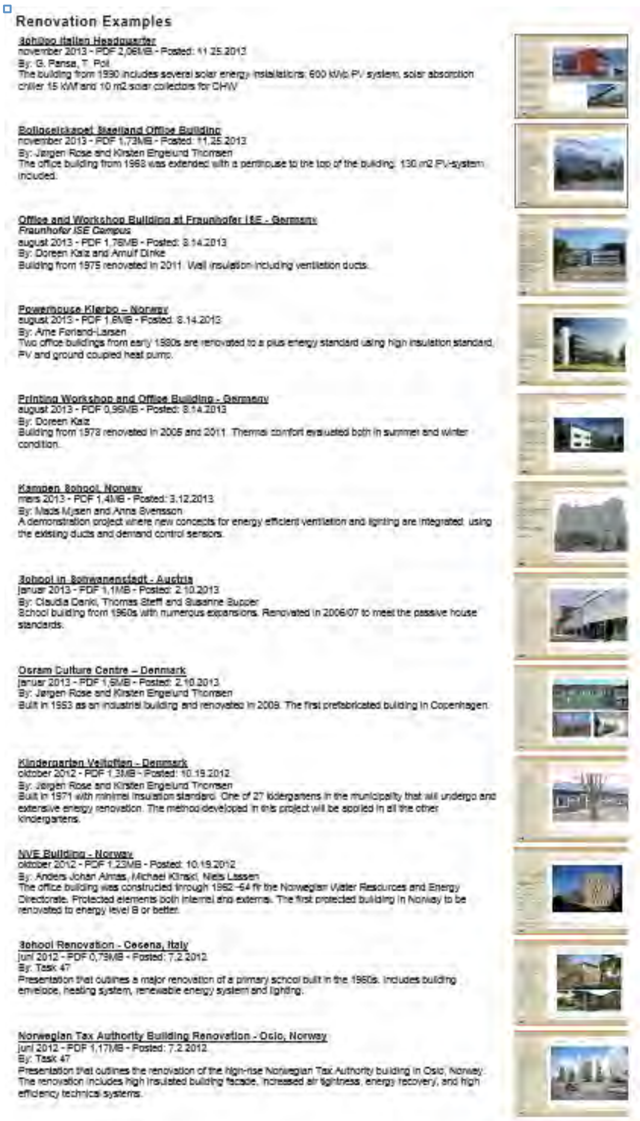
- *Renovation of Non-Residential Buildings – outcome from UPGRADE and SHC Task 47*, by Fritjof Salvesen at a seminar for Norwegian industry representatives on April 24.

Subtask A: Exemplary Renovation Projects

For the public presentation of the Task 47 exemplary projects, an eight-page brochure template has been developed. The brochure describes the key project information, including the context and background, the decision-making processes, the building envelope, the building services system, the energy and environmental performances and finally the costs. Eight exemplary project brochures were uploaded to the Task webpage in 2013 – four office buildings (Denmark, Germany, Italy, Norway), two schools (Austria, Norway), one cultural center (Denmark) and a workshop building (Germany). The twelve brochures can be downloaded from https://task47.iea-shc.org/publications.

Preliminary findings from these 12 projects:

- Windows upgraded to 0.6 – 1.2 W/m^2C
- Demand controlled mechanical ventilation system with heat recovery often in combination with controlled natural ventilation system during summer months
- Limited mechanical cooling needed, mostly covered by night–time ventilation
- Decrease in heat demand 50-95%
- Efficient lamps with daylight control and/or movement sensors
- Multidisciplinary team of experts is necessary in the early stage of planning to achieve a high standard renovation; architects, consultants, owner, tenant and contractor; integrated energy design
- Plus energy standard achieved with PV-system even in Norwegian climate, within acceptable economic conditions
- BREEAM outstanding achieved in at least one project
- Documentation of pupils in a school project showed significant improvement in their concentration test scores and health and well-being questionnaires after a renovation that included an upgrade of the ventilation system


Renovation Examples

Office and Workshop Building at Fraunhofer ISE - Germany
Fraunhofer ISE Campus
august 2013 - PDF 1,78MB - Posted: 8.14.2013
By: Doreen Kalz and Arnulf Dinkel
Building from 1975 renovated in 2011. Wall insulation including ventilation ducts.

Powerhouse Kjørbo – Norway
august 2013 - PDF 1,6MB - Posted: 8.14.2013
By: Arne Førland-Larsen
Two office buildings from early 1980s are renovated to a plus energy standard using high insulation standard, PV and ground coupled heat pump.

Printing Workshop and Office Building - Germany
august 2013 - PDF 0,95MB - Posted: 8.14.2013
By: Doreen Kalz
Building from 1978 renovated in 2005 and 2011. Thermal comfort evaluated both in summer and winter condition.

Kampen School, Norway
mars 2013 - PDF 1,4MB - Posted: 3.12.2013
By: Mads Mysen and Anna Svensson
A demonstration project where new concepts for energy efficient ventilation and lighting are integrated, using the existing ducts and demand control sensors.

School in Schwanenstadt - Austria
januar 2013 - PDF 1,1MB - Posted: 2.10.2013
By: Claudia Dankl, Thomas Steff and Susanne Bupper
School building from 1960s with numerous expansions. Renovated in 2006/07 to meet the passive house standards.

Osram Culture Centre – Denmark
januar 2013 - PDF 1,6MB - Posted: 2.10.2013
By: Jørgen Rose and Kirsten Engelund Thomsen
Built in 1953 as an industrial building and renovated in 2009. The first prefabricated building in Copenhagen.

Kindergarten Vejtoften - Denmark
oktober 2012 - PDF 1,3MB - Posted: 10.19.2012
By: Jørgen Rose and Kirsten Engelund Thomsen
Built in 1971 with minimal insulation standard. One of 27 kindergartens in the municipality that will undergo and extensive energy renovation. The method developed in this project will be applied in all the other kindergartens.

NVE Building - Norway
oktober 2012 - PDF 1,23MB - Posted: 10.19.2012
By: Anders Johan Almas, Michael Klinski, Niels Lassen
The office building was constructed through 1962-64 for the Norwegian Water Resources and Energy Directorate. Protected elements both internal and external. The first protected building in Norway to be renovated to energy level B or better.

School Renovation - Cesena, Italy
juni 2012 - PDF 0,79MB - Posted: 7.2.2012
By: Task 47
Presentation that outlines a major renovation of a primary school built in the 1960s. Includes building envelope, heating system, renewable energy system and lighting.

Norwegian Tax Authority Building Renovation - Oslo, Norway
juni 2012 - PDF 1,17MB - Posted: 7.2.2012
By: Task 47
Presentation that outlines the renovation of the high-rise Norwegian Tax Authority building in Oslo, Norway. The renovation includes high insulated building facade, increased air tightness, energy recovery, and high efficiency technical systems.

Task 47 Glossary

A glossary of the most widely used expressions and terms was created. During this work, it was noticed that the new draft standard prEN 15603:2013 Energy Performance of Buildings, which supersedes EN 15603:2008 and from which many of the Task 47 terms come from, did not include the terms "Embodied Energy" and "Green Energy." These are important terms in Life Cycle Analysis and CO_2 footprint calculations for NZEB and plus-energy buildings. This was commented on to the Norwegian Standard Organization, but the outcome is not yet known.

Subtask B: Market and Policy Issues

To identify barriers and opportunities in the renovation process, a number of interviews of key persons involved in renovation projects were accomplished. Some of the lessons learned when it comes to the decision process are:

- There is still skepticism about indoor air quality in Passive-House-standard buildings.
- The BREEAM classification system is a useful tool to put energy saving on the agenda.
- The innovative attitude is considered important for the Passive-House-standard decision.

Building stock analyses shows that the biggest potential is in office buildings, schools and retail/shopping centers. Unfortunately, no retail buildings are represented in Task 47. Across the different building types, the experts see a large potential in historic buildings. These buildings also face more complicated decision-making processes.

All researchers in Task 47 participated at an internal workshop to systematize the group's knowledge of decision-making processes. The outcome showed that the Task 47 experts have experiences mainly from educational buildings and offices. Some of the findings from the workshop include:

- Based on known building stock analysis it seems that future research project should look more into:
  - Retail buildings: the main focus should be directed towards national shopping centers.
  - Schools: kindergarten/pre-school buildings should be included as high energy saving potential.
  - Hospitals and elderly homes: due to demographics these represent a huge potential.
  - Across the different building types, the experts see a large potential in historic buildings. These buildings face also more complicated decision-making processes.
- There are mixed experiences regarding attitudes among private and public actors. Some of the experts have experienced public actors to be easier to work with, but at same time tendering processes complicate innovation projects in the construction sector.

The researchers in Task 47 have interviewed key actors of the decision process in nine projects from six of the partner countries. It is too soon to draw any conclusions as a cross analysis will be done in the first half of 2014. Interestingly, in some projects the ambition level has changed during the process. How and why this has happened will be discussed in the final report of Subtask B. For example:

- In a Norwegian case study the renovation process for an office building in Asker first focused on improving the indoor air quality and energy efficiency. However, the property owner experienced that this was not enough to attract new tenants and so the whole façade of the office building was updated.
- In a Danish case study it was shown that the main driver for an office building of Boligselskabet Sjælland in Roskilde was "green image" combined with economy.

Subtask C: Technical Solutions and Operational Management

An individual technical database for the demonstration projects and their energy concepts has been established. The database includes performance numbers for monitored buildings as well as technical descriptions. The performance of eight buildings is analyzed in terms of energy consumption and thermal comfort achieved using long-term monitoring data in high time resolution. In particular, a comparison was made between the performance before and after the retrofit. It can be seen that the buildings studied achieve the ambitious target values set during the design stage of the building.

The Austrian AIT investigated energy efficiency improvements with weather predictive controls. The quality of the weather forecast is crucial. In the analyzed building, energy savings can be achieved by changing start and stop times of the main heat pump serving the concrete core activation.

Subtask D: Environmental and Health

Subtask D work addresses indoor comfort and quality of life, with a special focus on school building refurbishment.

The objective of Subtask D is to offer any designer or developer guidelines to follow during renovation projects with the goal to significantly improve the school's energy performance as well as the comfort of the children and teachers and the quality of life and use of the school building.

All these recommendations are included in a guide in four chapters:

- Improve the comfort and quality of life
- Reduce the consumption of fossil fuels
- Reduce the consumption of non-energy resources (materials, water, etc.)
- Reduce waste (waste water, building and domestic waste building)

The guide is in its final stage. It is illustrated with innovative concepts of exemplary projects and links with BREEAM assessment methodology.

WORK PLANNED FOR 2014

The Task will end in June 2014 and all reports will be completed by the end of 2014.

A public seminar in connection with the final Task experts meeting in Frankfurt will be held on April 3, 2014.

LINKS WITH INDUSTRY

Some of the Task participants represent consulting companies, for example, the OA and the leader of Subtask B. And, in some countries, as with Norway, national Task 47 projects are organized in collaboration with several industry partners.

REPORTS PUBLISHED IN 2013

Eight exemplary renovation project brochures were published and posted on the Task website.

REPORTS PLANNED FOR 2014

About ten more exemplary project brochures will be posted on the SHC website.
All the four subtasks will complete their reports in 2014:

- Subtask A: Lessons learned from 25 exemplary renovation projects
- Subtask B: Publication describing decision making processes, non-energy benefits as well as barriers and driving forces from the case studies of subtask B.

- Publication summarising renovation policies and strategies.
- Subtask C: Technical report with recommendations for renovation projects
- Subtask D: Renovation of schools – guideline for designers and planners

MEETINGS IN 2013

5rd Experts Meeting
April 3 - 5
Sydney, Australia

6th Experts Meeting
September 30 – October 2
Graz, Austria

MEETINGS PLANNED FOR 2014

7th Experts Meeting (Final meeting)
April 1-3
Frankfurt, Germany
(Task 47 Seminar, April 3)

SHC TASK 47 CONTACTS

TASK MANAGEMENT

Operating Agent &
Subtask A Leader
Fritjof Salvesen
Asplan Viak AS
P.O. Box 24
NO-1300 Sandvika
fritjof.salvesen@asplanviak.no

Subtask B Leader
Trond Haavik
Segel AS
Box 284
NO-6770 Nordfjordeid
trond.haavik@segel.no

Subtask C Leader
Doreen Kalz
Fraunhofer - Inst. Solar Energy Systems
Heidenhofstrasse 2
DE-79110 Freiburg
Doreen.kalz@ise.fraunhofer.de

Subtask D Leader
Sophie Trachte
Architecture et Climat - University of Louvain La Neuve
Place Du Levant 1
BE-1348 LOUVAIN LA NEUVE
sophie.trachte@uclouvain.be

NATIONAL EXPERTS

Australia
Richard Hyde
Faculty of Architecture, Design and Planning
University of Sydney

Francis Barram
Faculty of Architecture, Design and Planning
University of Sydney

Nathan Groenhout
Faculty of Architecture, Design and Planning
University of Sydney

Austria
Thomas Mach
Graz University of Technology

Daniel Brandl
Graz University of Technology

Stefan Holper
Graz University of Technology

Claudia Dankl
Østerreichische Gesellschaft fur Umwelt und Technik

Belgium
Wouter Hilderson
Passiefhuis-Platform vzw

Denmark
Kirsten Engelund Thomsen
Danish Building Research Institute

Jørgen Rose
Danish Building Research Institute

Germany
Johann Reiss
Fraunhofer – Institute Bauphysik

Roman Jakobiak
Daylighting

Italy
Ezilda Costanzo
ENEA – Energy and Sustainable
Economic Development

Giorgio Pansa
Politecnico di Milano – BEST Department

Norway
Anna Svensson
SINTEF Building and Infrastructure

Ann Kristin Kvellheim
Enova SF

Arne Førland-Larsen
Asplan Viak AS

Task 48

Quality Assurance and Support Measures for Solar Cooling

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 (the most recent 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, they showed that further work is necessary to achieve economically competitive systems and to provide solid long-term energy performance and reliability.

Objectives

This Task is working to find solutions to make solar thermally driven heating and cooling systems at the same time efficient, reliable and cost competitive. These three major targets should be reached by focusing the work on four levels of activity:

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

Scope

The scope of the Task is the technologies for production of cold water or conditioned air by means of solar heat, that is, the subject that is covered by the Task starts with the solar radiation reaching the collector and ends with the chilled water and/or conditioned air transferred to the application. However, the distribution system, the building and the interaction of both with the technical equipment are not the main topic of the Task, but this interaction will be considered where necessary.

Structure

The Task is divided into 4 subtasks (including the detailed activities corresponding for each as noted below).

Subtask A: Quality procedure on component level

A1: Chiller characterization
A2: Life cycle analysis at component level
A3: Heat rejection
A4: Pumps efficiency and adaptability
A5: Conventional solar collection
A6: State of the art on new collector & characterization

Subtask B: Quality procedure on system level

B1: System/Subsystem characterization & field performance assessment
B2: Good practice for DEC design and installation
B3: Life cycle analysis at system level
B4: Simplified design tool used as a reference calculation tool: design facilitator
B5: Self detection on monitoring procedure
B6: Quantitative quality and cost competitiveness criteria for systems

Subtask C: Market support measures

C1: Review of relevant international standards rating and incentive schemes
C2: Methodology for performance assessment, rating and benchmarking
C3: Selection and standardisation of best practice solutions

C4: Measurement and verification procedures
C5: Labelling possibilities investigation
C6: Collaboration with Task 45 for contracting models
C7: Certification process definition for small systems

Subtask D: Dissemination and policy advice
D1: Web site
D2: Best Practices brochure
D3: Simplified short brochure
D4: Guidelines for roadmaps on solar cooling
D5: Updated specific training seminars adapted to the quality procedure
D6: Outreach report

Main Deliverables
The main deliverables include:

- Report on best practices on solar collection components for quality, reliability and cost effectiveness.
- Quality procedure document/check lists guidelines for solar cooling.
- Self detection on monitoring procedure report.
- Soft tool package for the fast pre-design assessment of successful projects.
- Report and database of existing international standards, rating and incentive systems relevant to solar cooling.
- Report on the rating, measurement and verification of solar cooling performance and quality.
- Report on the selected standard engineering systems ,
- Report on alternative uses of the developed standards and rating framework.
- Technical report on the results of the Life Cycle Assessment of Solar Cooling systems and LCA tool.
- Website dedicated to the Task.
- Training material for installers and planners and training seminars feedback report.
- Semi-annual e-newsletter for the industry.
- Industry workshops in national languages in participating countries addressing target groups (related to Experts meetings).
- Best practices brochure.
- Simplified short brochure (jointly edited by the Subtask Leader (Greenchiller) and IEA SHC Programme.
- Guidelines for Roadmaps on Solar Cooling and possibly general international roadmap on solar cooling (optional).

Duration
The Task started in October 2011 and will be completed in March 2015.

Participating Countries
Australia, Austria, Canada, China, France, Germany, Italy, Japan, United States

WORK DURING 2013

The main organizational progress was the consolidation of the adaptation of the Work Plan with aggregations of activities, due to reduced budgets of some participants, to make efficient use of the available resources.

The combined activities are:

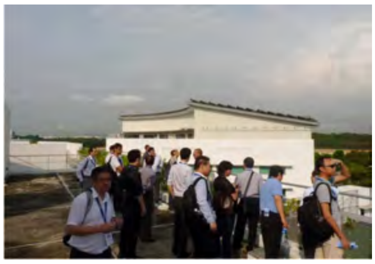
- A2/B3: Life Cycle analysis on component/system
- C1/C6: Review relevant international standards rating and incentive schemes/

Collaboration with T45 for contracting models
- B7/C2: Quantitative quality and cost competitiveness criteria for systems/ Methodology for performance assessment, rating and benchmarking
- B1/C7/C4: System/Subsystem characterization & field performance assessment/ Certification process definition for small systems / Measurement and verification procedures

Task Training Seminars and Workshops

Solar cooling crash course at the Australian Solar Cooling 2013 Conference Sydney (Australia) on April 11, 2013. The course was led by Dr. Stephen White (CSIRO Solar Cooling Research Leader, ausSCIG Chair, IIR Australia Chair) and Dr. Daniel Mugnier (Task 48 Operating Agent). This successful course had more than 20 attendees from Australia and other countries from Asia.

Workshop on Heat Rejection for Solar Cooling (SolarRück Project) in connection with the 5th Solar cooling OTTI conference on September 27, 2013. It was organized by Fraunhofer ISE and the Green Chiller Association and presented the latest development on heat rejection for solar cooling. The SolaRück workshop focused on results concerning performance analysis and evaluation of existing heat rejection systems.



IEA SHC Task 48 Workshop "Technologies for Solar Cooling in Tropical Climates" and a guided tour of world's largest solar cooling system in Singapore on April 5, 2013. The workshop and site visit were jointly organized by the SOLID company, Nanyang University and the Austrian Embassy. Nearly 60 persons took part in the Workshop.

Conference Presentations and Articles

Australian Solar Cooling Conference in Sydney, Australia on April 12, 2013. The Australian Solar Cooling Interest Group (ausSCIG) supported by the Australian Institute of Refrigeration, Air conditioning and Heating (AIRAH) held its 2013 conference at CSIRO's North Ryde Auditorium on Friday April 12.

5th Solar cooling OTTI conference from 25 to 27th September in Bad Krozingen, Germany. The "place-to-be" for the solar cooling R&D.

SHC 2013 conference in Freiburg, Germany. There were three sessions on solar cooling.

Press Releases
- Australian Solar Cooling Conference announcement (March 2013)
- Solar Thermal Energy week in Germany's Black Forest (July 2013)
- Australian Solar cooling standard published (September 2013)
- Workshop on Heat Rejection for Solar cooling systems in Bad Krozingen (September 2013)

Draft Reports

Fourteen draft reports were completed. These draft reports are only available internally at this time.

- ***Subtask A***
  - MA1-1: Definition of a common testing protocol
  - MA6-2: Creation of the database on market available concentrating technologies
  - MA3-1: Draft report on heat rejection

- MA4-1: Draft report on pumping systems
- MA5-1: Template for report on best practices on solar collection components for quality, reliability and cost effectiveness

- ***Subtask B***
  - MB1-1: Template structure report on system/subsystem characterization & field performance assessment
  - M-B3.1 : Template for LCA method tool
  - M-B4.1: Template for software tool for the fast pre-design and performance estimation of best practice projects

- ***Subtask C***
  - MC2-1: Template for Methodology for performance assessment, rating and benchmarking
  - M-C5.1: Template report structure on Labelling possibilities
  - M-C6.2 : Draft report on contracting models
  - M-C7.1 : Template report structure on certification process definition for small systems

- ***Subtask D***
  - M-D2.1: Template for best practice installations
  - M-D5.2 : Template for updated specific training seminar material

WORK PLANNED FOR 2014

According to the Work Plan, the following deliverables should be available by the end of 2014:

- Subtask A:
  - Final Report on Experimental activities on chillers characterisation for solar cooling
  - Technical report on heat rejection
  - Final report on pumping systems
- Subtask B:
  - Report on system/subsystem characterization & field performance assessment
  - Collection of criteria to qualify the quality and cost competitiveness of solar cooling systems
- Subtask C:
  - Methodology for performance assessment, rating and benchmarking
  - Report on contracting models.
- Subtask D:
  - Updated website.

LINKS WITH INDUSTRY

Industry representives participating in Task Experts Meeting as observers include: CoolGaia Pty Ltd (Australia), Pink (Austria), Kawasaki (Japan), SOLEM (Australia), Sortech (Germany), Invensor (Germany).

They represent primarily chiller, engineering companies and solar cooling system manufacturers. The results of Task 48 are profitable for their business and their involvement consists of supporting and analysing the work of Task 48.

MEETINGS IN 2013

4th Experts Meeting

April 9-11
Newcastle, Australia
In conjunction with the Australian Solar Cooling Conference.
29 experts from 7 countries (Germany, Austria, Australia, Italy, Canada, France, China). A videoconferencing system was used to connect half of the attendees from Europe (see picture).

5th Experts Meeting

September 30-October 1
Freiburg, Germany
In conjunction with OTTI 5th SAC conference and SHC conference 2013.
30 experts from 7 countries (Germany, Austria, Australia, Italy, USA, France, China).

MEETINGS PLANNED FOR 2014

6th Experts Meeting

May 12-13
Kingston, Canada

7th Experts Meeting

September
Garching, Germany

SHC TASK 48 NATIONAL CONTACTS

TASK MANAGEMENT
Operating Agent
Daniel Mugnier
TECSOL SA
105 avenue Alfred Kastler – BP90434
FR – 66000PERPIGNAN
France
Tel: + 33 4 68 68 16 40
daniel.mugnier@tecsol.fr

Subtask A: Quality Procedure on Component
Marco Calderoni
Politecnico di Milano
Dep. Energy - Via Lambruschini 4
Milano 20156, Italy

Subtask B: Quality Procedure on System Level
Dr. Alexander Morgenstern
Fraunhofer ISE
Heidenhofstraße 2
Freiburg 79110, Germany

Subtask C: Market Support Measures
Dr. Stephen White
CSIRO
PO Box 330
Newcastle, NSW 2300, Australia

Subtask D: Dissemination and Policy Advice
Dr. Uli Jakob
Green Chiller Association
Verband für Sorptionskälte e.V.
Stendaler Str. 4
10559 Berlin, Germany

NATIONAL EXPERTS & CONTACTS
The following is a list of national experts & contacts as identified as participants of Task meetings during 2013.

Please go to the Task page on the SHC website for updates: http://task48.iea-shc.org/participants

Australia
Stephen White
CSIRO

Mark Sheldon
CoolGaia Pty Ltd

Austria
Bettina Nocke
AEE Intec

Tim Selke
Anita Preisler
AIT Vienna

Hilbert Focke
ASIC

Moritz Schubert
SOLID

Daniel Neyer
University of Innsbruck

Canada
Steve Harrison
Queen's University

China
Prof. Yanjun Dai
Yao Zhao
Shanghai Jiao Tong University (SJTU)

France
Romain Siré
TECSOL

François Boudehenn
CEA INES

Germany
Alexander Morgenstern
Jochen Doll
Fraunhofer ISE

Christian Zahler
Industrial Solar GmbH

Mathias Safarik
ILK Dresden

Christian Schweigler
Martin Helm
Manuel Riepl
ZAE Bayern

Dirk Pietruschka
ZAFHNET

Clemens Pollerberg
Fraunhofer Umsicht

Uli Jakob
Green Chiller Association

Italy
Roberto Fedrizzi
EURAC

Andrea Frazzica
CNR ITAE

Marco Calderoni
Patrizia Melograno
University Politechnico di Milano

Marco Beccali
Pietro Finocchiaro
University of Palermo, Dept Energia

United States
Khalid Nagidi
Energy Management Consulting

Task 49

Solar Process Heat for Production and Advanced Applications

Christoph Brunner
Operating Agent for AEE INTEC Austria

TASK DESCRIPTION

The Task is focused on solar thermal technologies for converting solar radiation into heat and is working to further 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 includes aall industrial processes that are thermal driven and running in a temperature range up to 400°C.

Task 49 is structured around three subtasks with the following main activities.

Subtask A: Process Heat Collectors
Lead Country: Switzerland (Dr. Elimar Frank - SPF)

In this Subtask, the further development, improvement and testing of collectors, collector components and collector loop components is being investigated. All types of solar thermal collectors with an operating temperature level up to 400°C will be addressed: uncovered collectors, flat-plate collectors, improved flat-plate collectors (for example, hermetically sealed collectors with inert gas fillings or vacuum) with and without reflectors, evacuated tubular collectors with and without reflectors, CPC collectors, parabolic trough collectors, Fresnel collectors, air collectors etc.

In addition, an overview of collector output and key figures will be compiled to identify and select the most suitable collector technology for specific boundary conditions. It is assumed that for all activities of this Subtask the temperature range will need to be separated in several segments. For instance up to around 200°C, water and steam can be used as heat carriers with acceptable pressure. But higher temperatures combined with another heat carrier (e.g., oil) the boundary conditions change substantially. A simple up scaling of the results from the investigations and recommendations for the temperature range up to 200°C or 250°C will not be possible. This is true both for the investigations aiming at improvements of the solar loop as well as for recommendations with regards to test rigs, testing procedures and standardization.

Based on existing approaches, methods and parameters for the assessment of the collector and collector loop performance as well as of the impact of the properties of materials and components will be developed and identified. Appropriate durability tests will be applied to specific materials/components to allow for a deeper understanding of the collector and collector loop behavior for a wide range of operation conditions and the prediction of service lifetime. Based on the investigation of the dynamic behavior of solar process heat collectors and loops (both experimentally and theoretically), recommendations for process heat collector testing procedures will be worked out.

Subtask A has three main objectives:

- Improving solar process heat collectors and collector loop components.
- Providing a basis for the comparison of collectors with respect to technical and economical conditions.
- Giving comprehensive recommendations for standardized testing procedures.

The participants will achieve the objectives by:

- Updating the IEA SHC Task 33 state of the art survey of process heat collectors.
- Increasing the knowledge of general requirements and relevant parameters for process heat collectors and their improvement.
- Determining parameters for modelling collectors in simulation programs to reflect the realistic performance of medium temperature collectors in process heat systems and

comparable measurement data evaluation also from dynamic data for different locations, applications etc.

- Developing and/or improving collectors, components and solar loops for process heat applications in co-operation with the involved industry. The main aspects are performance, reliability and cost effectiveness. Both new and improved collector or component/solar loop concepts and design details will be addressed.
- Investigating the collector behaviour by collector testing at high temperatures and by the evaluation of measurement data from existing plants.
- Investigating material aspects for collectors with up to 400°C operating temperature and system components.
- Investigating the overheating behaviour and constructive prevention measures of medium temperature collectors in large fields.
- Measurements on the thermal performance of other components and solar loops of solar thermal systems operating at high temperatures.
- Elaboration of recommendations for collector testing standards for the medium temperature level.

A Special effort will be made to involve the solar industry in the analysis of all working fields, through industry-dedicated workshops.

Subtask B: Process Integration and Process Intensification Combined with Solar Process Heat
Lead country: Austria (DI Bettina Muster – AEE INTEC)

The general methodology for the integration of solar thermal energy into industrial processes was developed during SHC Task 33. It was shown that the pinch analysis for the total production site (with building upon it) and the design of an optimized heat exchanger network for the production system is one of the best approaches for smart integration. Due to the fact that in the identified industry sectors with high potential for solar integration production processes very often run in batches, the developed pinch methodology is only be a rough estimation of the real profile of heat sources/sinks.

Beside the system optimization by the pinch analysis, a technology optimization of the applied process technologies will also reduce the energy demand and increase the potential for solar thermal integration. Process intensification (PI) can be seen as a key word for emerging technologies that achieve the framework conditions for effective, solar (thermal and/or UV) driven production processes.
Subtask B has two main objectives:

- Improved 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 of the solar process heat potential by combining process intensification and solar thermal systems and fostering new applications for solar (thermal/UV) technologies

Subtask C: Design Guidelines, Case Studies and Dissemination
Lead country: Germany (Dr. Werner Platzer - Fraunhofer ISE)

The main objective of this Subtask is to provide information and planning methodologies to solar manufacturers, process engineers, installers and potential buyers (industry). This shall support the marketing, planning and installation phase of future SHIP plants. Experience and results from pilot projects covering a broad variety of technologies in suitable applications representing a significant part of industrial process heat consumers (in terms of size, temperature levels, heat transfer media, load patterns, etc.) shall be evaluated. The operation of projects will be monitored for a representative period to provide feedback on the design and operation concept as a basis for future development and improvements. "Best practice" reference cases shall encourage other potential users to employ these technologies. Tools for a simplified performance assessment and conceptual planning shall be developed. Regional market surveys, case studies and financing schemes will be investigated which should facilitate the market introduction of solar process heat.

The objectives of Subtask C are to:

- 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.

Duration

This Task was initiated February 2012 and will end January 2016.

This is a collaborative Task with the IEA SolarPACES Implementing Agreement. It is managed on the “maximum level” according to the SHC Guidelines for Collaboration with other Programs.

Participating Countries

Australia, Austria, China, Denmark, France, Germany, India, Japan, Italy, Mexico, Netherlands, New Zealand, Poland, Portugal, Spain, South Africa, Sweden, Switzerland, Tunisia, United Kingdom, USA

WORK DURING 2013

Develop System Concepts and Integration Guideline

The content of the integration guideline has been discussed in detail, as well as the methodology developed by the core team who met in Stuttgart in November 2012. The visualisation of integration schemes was defined and the input possibilities into the matrix of indicators. The matrix will be updated within several on-going projects and new integration schemes will be integrated into the section “solar integration schemes.” First, existing schemes will be updated, and new schemes shall be added over the course of the Task.

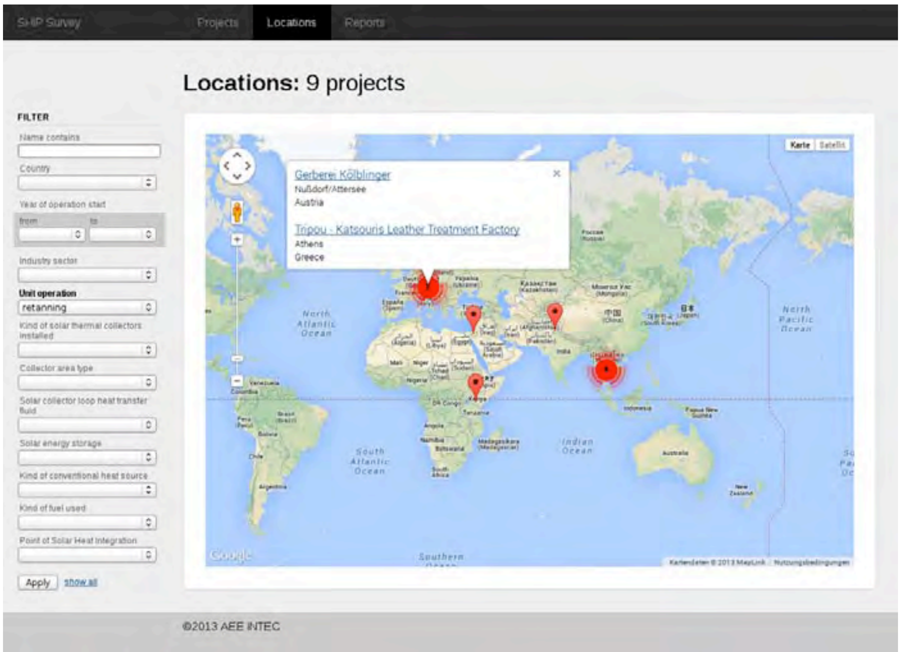
The integration guideline has the following structure:

- Thermal processes and heat distribution networks in industry
    - Conventional heat supply systems in industry, Classification of industrial processes
- Assessment methodology for solar thermal integration

- Process integration and energy efficiency measures
    - The importance of thermal energy efficiency and process integration in industry, Process integration - providing a good basis for solar thermal integration
- Classification of integration concepts
- Classification of Solar Process Heat System Concepts
- Identification of suitable integration points

Survey on Integration Methodologies for Solar Process Heat
A survey was developed to collect data of existing SHIP plants. The survey was distributed to installers and operators of solar thermal plants. While collecting information on existing SHIP plants the survey also collects information on integration concepts and general technical and economic performance of the plants.

At the moment there is data on 122 SHIP plants. This database will be published in March 2014.



Online database of existing SHIP plants.

New Process Collector Development
Ritter Plasma Collector (D. Seidler, Ritter XL)
The new Evacuated Tube Collector called “Plasma” has an absorber coating and an AR coating on the outer side of the glass tube, which is supplied by Plasma Coating. Stagnation temperature is 340 °C. Ritter XL also is analyzing and trying to reduce the Carbon Footprint of their collectors. A Solar Keymark was done for the Plasma Collector.

Double Glazed and Heat Pipe Collector Development (F. Giovanetti, ISFH)
ISFH investigated a FPC with spectral selective double glazing that is designed for operating temperatures in the range of 70-110 °C. In another project, ISFH developed a model and a concept to reduce the thermal resistance of the heat pipe connection with the header. With the detailed model, suitable working fluids for both a high thermal conduction and a suitable stagnation behavior can be found. ISFH also took part in the development of the first commercial heat pipe flat plate collector.

Comparison of Collectors with Respect to Technical and Economical Conditions

In Subtask A it was decided that as far as the **thermal output of the collectors** is concerned the focus of the work should be on gross heat gain calculations. To calculate gross heat gains seems to be the right path to have a first guess of the thermal performance without setting up elaborated system simulations, but that still includes some information on the location and the required temperature to be supplied. In particular, the comparison of calculation results with the ScenoCalc Tool was discussed.

Effect of Dust Accumulation Ono the Collector Performance (V. Palmieri, TVP Solar)

With measurements at a TVP high vacuum flat plate collector test field installation in Masdar, UAE, and the effect of dust accumulation on the collector performance has been assessed. The panels were cleaned, then measured and evaluated with daily-cumulated heat gains over a period of one month and then cleaned and measured again. First results (corrected for different irradiance and fluid temperature values) showed that at this location the performance continuously decreased down to 80% of the clean collector values course of two weeks before the performance seem to stay on this level. It was agreed to to have further activities within Subtask A on this topic, including the evaluation of further measurement data (for different collector technologies) and gathering of information from other projects.

Measurements on Parabolic Trough Collectors (M. Larcher, SPF)

At SPF two different NEP Solar parabolic trough collectors have been measured, one with an aperture width of about 1.2 m and a length of 4 m and one with an aperture width of about 1.8 m and a length of 10 m. Both a hydraulic circuit with water/glycol mixture up to 120 °C and a newly developed test rig with water up to 200 °C has been used. Results of the collector output, the efficiency curves and the IAM were reported.

Performance Testing of mid temperature collectors (F. Helminger, AIT)

Different collectors have been tested at AIT. Performance curves and IAM were reported for anonymized collectors: One FPC (double glazed) up to 130 °C and one CPC ETC up to 140 °C, one CPC FP and one PTC up to 180 °C, all with both the steady state testing method (SST) and quasi-dynamic testing method (QDT). AIT plans to do InSitu measurements in 2013.

Collector Field Measurements

With respect to efficiencies and general operating behavior of the field, two presentations were given:

Measurements Zehnder, Festo and Wels (D. Seidler, Ritter XL)

Measurements of Ritter XL Aqua installations at three sites were documented. In all installations, the guaranteed solar yield was met or exceeded. Ritter XL analyzed that the frost protection of their system concept in the Festo installation only needs 1,7% of the heat collected whereas the start up losses are responsible for 5,9 %.

Measurements of Parabolic Collector Field at Swiss Dairy (E. Frank, SPF)

The evaluation of measurements at the Bever plant (PTC, up to 180 °C) was presented. Diagrams with the cumulated daily solar gains over the cumulated direct irradiance on the one-axis tracked aperture area were shown. The control of the system seems to work quite well, and collector field efficiencies is in the range of 25-45% were calculated, depending on the cumulated daily irradiances.

Development of Simulation Tools

Fraunhofer ISE developed a round robin simulation activity and six different cases have been defined, with four different collectors and three different locations. The objective is to cross compare the tools and simulation approach, not collectors, applications or locations directly.

It includes concentrating collectors having more complexity and also several heat transfer fluids (water, thermo-oil, steam, air). The system complexity has to be limited as a comparison of the tools is the objective, whereas more complex systems may differ in the approach different simulators will take. The simulation in C2 shall deal with the collector field (solar loop), the storage and the industrial process. However the industrial process as such is not modelled with these tools but only load profiles will be used. Nevertheless control strategies had to be defined for the solar part.

The general objectives of the participants concerning tools are:

- Extension of the capabilities of tools
- Comparison of tools
- Standardization of simulation approaches
- Validation of tools and component models (Storage, collectors)

Therefore this activity will also address collector models and storage models, on the one hand side identification of possible needs for extension of models and tools, and on the other hand, which testing parameters have to be taken for different operation modes and regimes. A unified simulation strategy might be treated after. Validation will be addressed when comparing complex cases where monitoring data are available.

Development of Advanced Pinch and Storage Management Tool(s)
The aim is to identify suitable integration places of solar heat in industrial processes with the following requirements:

- Tools can model current heat flows including their real-time profiles (batch or continuous processes with varying loads)
- System is optimized via heat integration and ideal heat management
- Planners can choose suitable places to integrate solar thermal heat

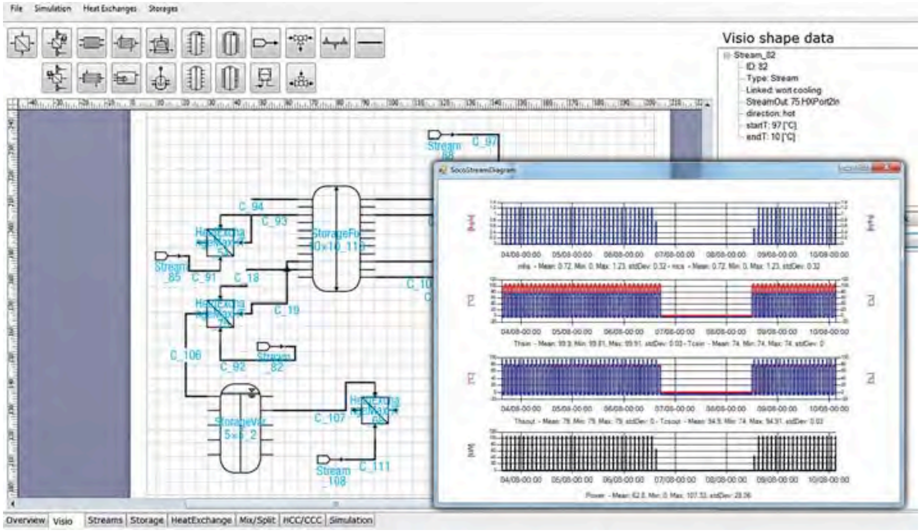
The collection of such pinch and process analysis tools will be on going over the next months. The software SOCO was developed by AEE INTEC and a first release has been presented. This software has the following features and benefits:

Features

- ➢ Enter/Import real, variable stream data
- ➢ Define single heat exchangers and heat storages
- ➢ Propose heat exchanger and heat storage network
- ➢ Drawing flow sheet of suggest or adapted proposal
- ➢ Simulate defined network

Benefits

- ➢ Considers time variable streams
- ➢ Individual HEX and storage configurations
- ➢ Detailed storage optimisation
- ➢ Flow sheet



Screenshot from SOCO software tool.

The software SOCO is tested by different Task partners on various test cases in order to optimize the tool and compare it with other existing tools like the Pinch software from the company Planair.

WORK PLANNED FOR 2014

Key activities planned for 2014 include:

- Discussion and decision on the design guidelines
- Development of the first draft of the design guidelines
- Definition of general requirements and relevant parameters for process heat collectors (and specific collector loop components) and their improvement
- Overview of collector output and key figures for defined conditions
- Perform a Workshop of Pi and solar energy
- Report on overheating/stagnation issues including the high temperature behavior of the investigated components

REPORTS PUBLISHED IN 2013

Integration Guideline (Methodology for Advanced Integration, System Concepts, Guidelines on Integration Types, Checklists, etc.), (B.2.1)

REPORTS PLANNED FOR 2013

Overheating/Stagnation Issues Including the High Temperature Behavior of he Investigated Components (A1.2), February 2014

Comparison of Collectors with Respect o Technical and Economical Conditions; an Overview of Collector Output and Key Figures for Defined Conditions (A2), March 2014

MEETINGS IN 2013

3rd Experts Meeting
March 5-6
Rapperswill, Switzerland, 5-6
35 experts from 11 countries attended the meeting.

4th Experts Meeting
October 3-4
Evora, Portugal
31 experts from 10 countries attended the meeting.

MEETINGS PLANNED FOR 2014

5th Experts Meeting
23-24 January
Stellenbosch, South Africa

6th Experts Meeting
25-26 September
Italy

SHC TASK 49 CONTACTS

TASK MANAGEMENT

Operating Agent
Christoph Brunner
AEE INTEC
Austria
c.brunner@aee.at

Subtask A Leader
Elimar Frank
SPF Institut für Solartechnik SPF
Hochschule für Technik HSR
Switzerland
Elimar.Frank@solarenergy.ch

Subtask B Leader
Bettina Muster-Slawitsch
AEE INTEC
Austria
b.muster@aee.at

Subtask C Leader
Werner Platzer
Fraunhofer Institute for Solar Energy Systems FhG-ISE, Freiburg
Germany
werner.platzer@ise.fraunhofer.de

NATIONAL CONTACTS

Austria
Christoph Brunner
AEE INTEC
c.brunner@aee.at

Schnitzer Hans
TU Graz IPP
hans.schnitzer@tugraz.at

Michael Monsberger
Austrian Institute of Technology
www.ait.ac.att

Putz Sabine
S.O.L.I.D.
s.putz@solid.at

Hartmut Schneider
Fresnex
hartmut.schneider@fresnex.com

Belgium
Thijs Defraeye
Faculteit Bio-ingenieurswetenschappen - KU Leuven
thijs.defraeye@biw.kuleuven.be

China
He Tao
China Academy of Building Research (CABR)
iac@vip.sina.com

France
Pierre Delmas
Montperal Energy
pierre.delmas@montperalenergy.com

Sandrine Pelloux-Prayer
EDF
sandrine.pelloux-prayer@edf.fr

Germany
Mario Adam
E² - Erneuerbare Energien und Energieeffizienz
mario.adam@fh-duesseldorf.de

Pietruschka Dirk
ZAFH - Hochschule für Technik Stuttgart
dirk.pietruschka@hft-stuttgart.de

Stephan Fischer
ITW Uni Stuttgart
fischer@itw.uni-stuttgart.de

Federico Giovannetti
ISFH - Institut für Solarenergieforschng Hameln
giovannetti@isfh.de

Andreas Häberle
PSE AG
ah@pse.de

Klaus Hennecke
DLR
klaus.hennecke@dlr.de

Rolf Meissner
Ritter solar
r.meissner@ritter-xl-solar.com

Markus Peter
dp quadrat
markus.peter@dp-quadrat.de

Stauss Reiner-Smirro
Smirro GmbH
r.stauss@smirro.com

Dominik Ritter
Universität Kassel
d.ritter@uni-kassel.de

Bastian Schmitt
IdE Institut dezentrale Energietechnologien gemeinnützige GmbH
b.schmitt@ide-kassel.de

Christian Zahler
Industrial Solar GmbH
christian.zahler@industrial-solar.de

Michael Zettl
Zettl
michael.zettl@zettl-munich.de

India
G.S. Deshpande
Thermax
kdeshpan@thermaxindia.com
C. Palaniappan
Planters Energy Network - PEN
info@pen.net.in

Italy
Mario Motta
Politecnico di Milano
mario.motta@polimi.it

Francesco Orioli
Soltigua
forioli@soltigua.com

Netherlands
Geert-Jan Witkamp
TU Delft, Laboratory for Process Equipment, TU Delft
geertjanwitkamp@me.com

New Zealand
M. Walmsley
Waikato
m.walmsley@waikato.ac.nz

Portugal
Pedro Horta
University of Évora
phorta@uevora.pt

South Africa
Van Niekerk Wikus
University Stellenbosch
wikus@sun.ac.za

Spain
Loreto Valenzuela Gutiérrez
Plataforma Solar de Almería - CIEMAT
loreto.valenzuela@psa.es

Víctor Martínez Moll
Tecnologia Solar Concentradora
victor.martinez@tsc-concentra.com

Aguirre Mugica Patricio
INASMET-Tecnalia
patri.aguirre@inasmet.es

Daniel Rayo
Sun to Market Solutions S.L.
drayo@s2msolutions.com

Sweden
Joakim Byström
Absolicon Solar Concentrator AB
joakim@absolicon.com
Switzerland
Andreas Bohren
SPF Institut für Solartechnik - Hochschule für Technik HSR
andreas.bohren@solarenergy.ch

Pierre Krummenacher
Planair
pierre.krummenacher@planair.ch

Marco Larcher
SPF Institut für Solartechnik - Hochschule für Technik HSR
marco.larcher@solarenergy.ch

Heinz Marty
SPF Institut für Solartechnik - Hochschule für Technik HSR
heinz.marty@solarenergy.ch

Stefan Minder
NEP Solar
stefan.minder@nep-solar.com

Vittorio Palmieri
TVP
palmieri@tvpsolar.com

Matthias Rommel
HSR Hochschule für Technik Rapperswil
mrommel@hsr.ch

United Kingdom
Adam Harvey
School of Chemical Engineering and Advanced Materials [CEAM]
Newcastle University
adam.harvey@newcastle.ac.uk

Simon Perry
The University of Manchester Centre for Process Integration School of Chemical Engineering and Analytical Science
simon.perry@manchester.ac.uk

Tony Roskilly
Director of Research
Newcastle Institute for Research on Sustainability
Newcastle University
tony.roskilly@newcastle.ac.uk

United States
Mark Swansburg
Paradigm Partners
mark@paradigm-partnership.com

Mark Thornbloom
KELELO Engineering
kelelo1@kelelo.com

Task 50
Advanced Lighting Solutions for Retrofitting Buildings

Jan de Boer
Operating Agent for Fraunhofer Institute for Building Physics (IBP), Germany

TASK DESCRIPTION

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

- 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 is 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 targets 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 is structured into four Subtasks and a Joint Working Group concluding the (Sub-) Task's results.

Subtask A: Market and Policies
(Lead Country: Denmark)

This Subtask identifies the various possible approaches of retrofitting daylighting systems and lighting installations in buildings. It proposes 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 has 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 deals 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 are:

- 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 focuses on simple computer design tools and analysis methods in order to improve the understanding of retrofit processes. This incorporates energy and visual comfort analysis as well as the financial aspects of lighting retrofit solutions. Also encompassed are 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 are:

- 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 is to demonstrate sound lighting retrofit solutions in a selection of representative, typical case studies.

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

The objectives of Subtask D are:

- 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 will provide major parts of their results, as input to this joint activity. Based on these results, the Joint Working Group will develop an electronic interactive source book (Lighting Retrofit Adviser). A central database will include all task results and will allow 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 will be able to increase quickly and reliably his knowledge in the respective field of interest. Users will 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 are:
- 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.

Duration
The Task commenced in January 2013 and will end in December 2015.

Participating Countries
Austria, Belgium, China, Denmark, Finland, Germany, Italy, Japan, Norway, Slovakia, Sweden, Switzerland

WORK DURING 2013

Analysis of Processes and Decision Makers Involved in the Lighting Retrofit Process
To analyze and understand influences, interactions, effects and participants in the lighting retrofit market as well as dependencies on policies, information was collected and examined. The analysis was started by the development of a structure to sort and include all relevant aspects.

Development of a Criteria Catalogue to Describe Technologies
The first collection of criteria to describe lighting technologies appropriate for the retrofit process has been consolidated to practitioners needs. The aspect to assure that information is up to date was addressed. Especially the development of the LED market shows rapid changes towards technically better and cheaper products.

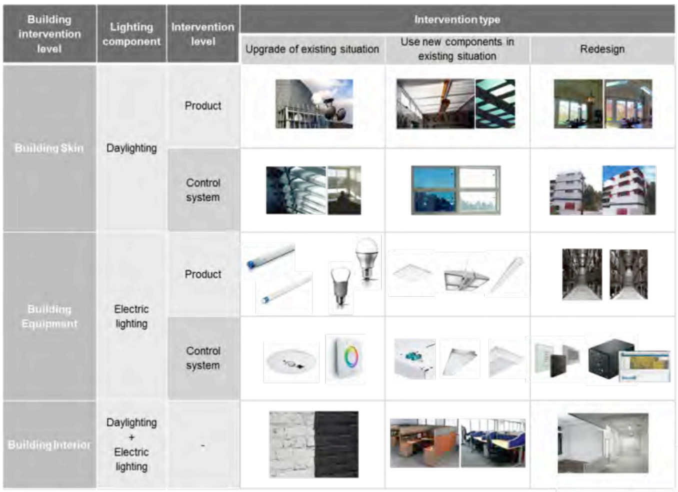
Catalogue of Criteria – Daylighting component

Energy efficiency	energy savings potential, light guiding into depth of the room, primarily used daylight
Environmental footprint	primary energy consumption in manufacturing stage, with or without energy embodied in raw materials
Visual comfort	provides glare protection
Visual amenity	reduces / increases wall illuminance, colour rendering, CCT, impact on non visual effect of light, spectral selectivity, visual transmittance, blockage & distortion of view, view out, privacy, effective aperture
Use / maintenance	control possibilities, maintenance, need for tracking
Retrofit process	installation time, retrofit classification
Costs (initial)	initial costs
Climate restrictions	most suitable for ... building location / orientation based
Related to HVAC	SHGC, U value, solar protection, solar gains, Relative Energy Impact
Additional benefits (e.g. effect on productivity, academic results, sales, ...)	

Draft catalogue of criteria – daylighting components (© Dr. Martine Knoop, TU-Berlin)

Development of a Systematic Approach to Classify Renovation Strategies

Based on the catalogue of criteria established, a systematic approach was developed to classify renovation strategies and the technologies to be considered. The collection of information on performance and characteristics of different technologies (state of the art as well as new techniques) was started.

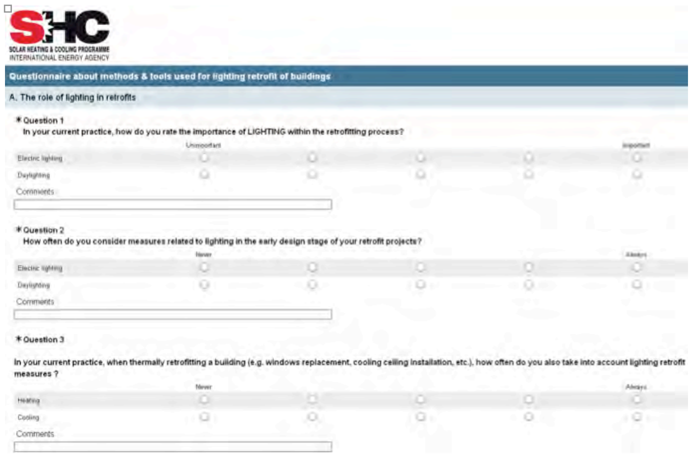


Developed systematic approach to classify renovation strategies (© Dr. Martine Knoop, TU-Berlin)

Questionnaire about Methods & Tools Used for Lighting Retrofit of Buildings

In order to analyze workflows and needs in practical retrofitting processes, a questionnaire was developed and transferred into a web based survey system.

The survey is directed to all actors involved in building retrofit processes, focusing on electric lighting and design strategies to increase daylight utilization. The survey's results aim to contribute to the understanding of the retrofit process, barriers, and needs.



Screenshot of the online-questionnaire (©LESO-PB/EPFL)

The questionnaire is subdivided into the following four parts:

1. The role of lighting in retrofits.
2. The design methods within the retrofitting process.
3. Tools for lighting design.
4. Background information for statistical purpose.

The questionnaire is available in different languages and can be found on the following website: http://leso2.epfl.ch/task50/.

Analysis of Building Stock Distribution and Typical Installations

In order to define the most important building types and the typical installations used to be focused on within the Task, the current distribution of the building stock in the non-residential sector was analyzed as well as average energy intensity for electric lighting for each building type and the characteristics of the existing lighting installations.

Preliminary results from this analysis show that the non-residential building stock can by approximation be characterized by seven dominant building types: "offices", "educational buildings", "wholesale and retail trade", "industrial buildings", "hotels and restaurants", "hospitals and healthcare" and "sports buildings". Regarding energy intensity for lighting, generally higher values are found for "wholesale and retail trade", "hotels and restaurants", "hospitals and healthcare" and "sports buildings". The results found further indicate that fluorescent lighting is the dominant light source in the non-residential sector and that roughly half of fluorescent lamps are of the older type (i.e., T12 or T8 lamps with conventional ballasts).

Collection of Case Studies and First Assessments
Suitable case studies from different countries representing the typical building types were collected. So far 22 possible case studies have been reported by participants. From the identified building types no case studies for ‘hotels and restaurants’ as well as for ‘sport facilities’ could be identified. The search for representatives of these types has been intensified.

From some case studies, where the majority of photometric measurements and first user surveys were already completed, preliminary conclusions regarding the success of the retrofit could be drawn and valuable information for the monitoring protocol could be gained.

Development of a Monitoring Protocol (draft)
The need of a monitoring protocol on different levels of detail was defined to cope with the different available resources and information. It was decided to have 2 levels of monitoring in the protocol: “basic” and “comprehensive”. The protocol itself will cover 3 main aspects 1) energy efficiency, 2) lighting environment, and 3) user comfort and space perception. It is intended to be used not only for the case studies within the Task, but also to serve as an exemplary monitoring protocol for external use. Based on the experiences from the first case studies and the experts involved, the draft of a monitoring protocol with procedures, metrics, and information to collect (in space and time) was developed.

Development of the Lighting Retrofit Adviser’s (LRA) Structure
A first proposal of the Lighting Retrofit Adviser’s (LRA) structure was developed and first mock-ups of screens were drafted. In addition, issues regarding the software technology to employ were discussed and possible solutions were identified.

WORK PLANNED FOR 2014

Key activities planned for 2014 include:

- Further analysis of market and policies.
- Further development of a “technology sheet” and collection of input for different technologies.
- Evaluation of the questionnaire’s result.
- Collection of further case studies.
- Revision of the monitoring protocol.
- Description and evaluation of case studies using the monitoring protocol.
- Development of databases to organize results and include them in the LRA.
- Further elaboration of structure and content of the lighting retrofit adviser.

LINKS WITH INDUSTRY

Industry Workshops
Two Industry Workshops were held with active participation from (mostly) local industry, the first-one on March 20, 2013 at Lund University in Sweden, and the second-one on September 23, 2013 at Aalborg University in Copenhagen in Denmark.

The following institutions presented insights and experiences regarding the issue of lighting retrofit:

- Somfy, Sweden
- Department of Environmental Psychology, Lund University, Sweden
- Philips Lighting, Netherlands
- Fagerhult, Denmark
- Henning Larsen Architects, Denmark

In addition, the workshops were joined by representatives from:

- Belysningsbranschen, Sweden
- Ramboll DK Department of Lighting Design, Sweden
- Velux Danmark A/S, Denmark
- Marinov Consult, Denmark
- Martin EMEA Projects, Denmark
- Ellen Katrine Hansen arkitekt, Sweden
- White arkitekter AB, Sweden
- Fojab arkitekter AB, Sweden

Industrial Involvement

A connection to *Lighting Europe* was established and possibilities of collaboration are currently being discussed.

Philips Lighting is involved and actively participating in the Task's work as a Level II Partner. A representative from 'Philips Research' is joining the experts' meetings.

REPORTS PUBLISHED IN 2013

As the task was in its first year, in 2013, no (technical) reports have been published yet.

REPORTS/DOCUMENTS PLANNED FOR 2014

- Building stock distribution and electricity use for lighting
- Lighting retrofits: a literature review
- Monitoring protocol
- Evaluation of the questionnaire

MEETINGS IN 2013

1st Experts Meeting
March 19 - 22
Lund, Sweden

2nd Expert Meeting
September 22 - 25
Copenhagen, Denmark

MEETINGS PLANNED FOR 2014

3rd Expert Meeting
March 10 - 12
Aldrans/Innsbruck, Austria

4th Expert Meeting
September 29 - October 1
Yonezawa, Japan

SHC TASK 50 CONTACTS

TASK MANAGEMENT

Operating Agent
Jan de Boer
Fraunhofer IBP
Germany
jdb@ibp.fraunhofer.de

Subtask A Leader
Marc Fontoynont
Danish Building Research Institute (SBi)
Denmark
mfo@sbi.aau.dk

Subtask B Leader
Martine Knoop
Technische Universitaet Berlin (TUB)
Germany
martine.knoop@tu-berlin.de

Subtask C Leaders
Bernard Paule / Jérôme Kaempf
Estia SA / École Polytechnique Fédérale de Lausanne (EPFL)
Switzerland
paule@estia.ch
jerome.kaempf@epfl.ch

Subtask D Leader
Marie-Claude Dubois
Lund University
Sweden
marie-claude.dubois@ebd.lth.se

NATIONAL CONTACTS

Austria
Wilfried Pohl, David Geisler-Moroder
Bartenbach Lichtlabor GmbH

Belgium
Arnaud Deneyer
Belgian Building Research Institute (BBRI)

Magali Bodart
Université Catholique de Louvain

China
Luo Tao
China Academy of Building Research

Denmark
Werner Osterhaus, Sophie Stoffer
Aarhus University, Department of Engineering

Kjeld Johnsen, Marc Fontoynont
Danish Building Research Institute (SBi)

Finland
Eino Tetri
Aalto University

Germany
Jan de Boer, Berat Aktuna, Anna Hoier
Fraunhofer Institute for Building Physics (IBP)

Jan Wienold, Bruno Bueno
Fraunhofer Institute for Solar Energy Systems (ISE)

Michael Bossert
University of Applied Science (HFT)

Roman Jakobiak
daylighting.de

Martine Knoop
Technische Universitaet Berlin (TUB)

Italy
Fabio Bisegna
Università degli Studi di Roma "La Sapienza"

Anna Pellegrino
Politechnico di Torino

Japan (Observer)
Yauko Koga
Kyushu University

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

Slovakia (Observer)
Stanislav Darula, Marta Malikova
Institute of Construction and Architecture, Slovak Academy of Sciences

Sweden
Marie-Claude Dubois, Nico Gentile
Lund University

Peter Pertola
WSP Sweden / WSP Ljusdesign

Switzerland
Jérôme Kaempf, Andre Kostró, Marilyne Andersen
École Polytechnique Fédérale de Lausanne (EPFL)

Bernard Paule
Estia SA

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 provide support to urban planners, authorities and architects to achieve urban areas, and eventually whole cities, with architecturally integrated solar energy solutions (active and passive), highly contributing to cities with a large fraction of renewable energy supply. This includes the objective to develop processes, methods and tools capable of assisting cities in developing a long-term urban energy strategy. Heritage and aesthetic issues will be taken into account. Also, the goal is to prepare for and strengthen education at universities on solar energy in urban planning by testing and developing teaching material for programs in architecture, architectural engineering and/or urban planning. The material will also be useful for post-graduate courses and continuing professional development (CPD).

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.

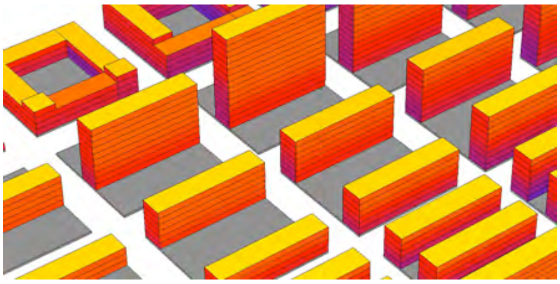
The main objectives of the Task are subdivided into four key areas and involve:

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



Solar potential study (Jouri Kanters)

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.

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.

Task 51 will not cover the whole complex context of urban planning; in order to achieve a substantial contribution to increased use of solar energy, this Task will focus 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.

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).

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 (preliminary)

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 2013

The first half-year was focused on clarifying available experts and their input, and to detail the planned work based on available resources.

In Subtasks A, B, and D work began on literature reviews, surveys and interviews to identify the state-of-the-art regarding current legislative frameworks and voluntary initiatives (Subtask A), barriers, challenges and needs (Subtask A), urban planning processes (Subtask B), needs for supportive instruments (Subtask B) and education regarding urban planning with solar energy (Subtask D). Subtask C developed a draft evaluation template to be used in the case studies. A set of evaluation criteria were proposed and discussed.

WORK PLANNED FOR 2014

Key activities planned for 2014 include:

- Work on and finalize a review on existing urban planning legislation and voluntary initiatives (Subtask A) and on existing urban planning processes (Subtask B), in participating countries.
- Start testing supportive instruments (knowledge/methods/tools) (Subtask B linked to Subtask C).
- Start developing generic process models in case stories (Subtask B linked to Subtask C).
- Final templates for case studies and evaluation (Subtask C).
- Identification of key cases (Subtask C).
- Draft of database for cases (Subtask C).
- Work on and finalize a report on the state-of-the-art in education regarding urban planning with solar energy, for participating countries (Subtask D).
- Prepare for the web-based learning platform; first tests by students (Subtask D).
- Create a general structure of the planned guideline (umbrella document) (Subtask D with support from all Subtasks).
- Carry out workshops.

TASK REPORTS/RESULTS PUBLISHED IN 2013

No reports were published in 2013.

OTHER PUBLICATIONS AND PRESENTATIONS IN 2013

- Bonomo, P., De Berardinis, P. & Frontini, F. (2013). *Analysis of BiPV case studies through a multi-criteria evaluation tool*. In proceedings of EUPVSEC 2013 – 28th European Photovoltaic Solar Energy Conference and Exhibition. Paris, France, 2013.
- Bozonnet, E., Musy, M., Calmet, I., & Rodriguez, F. (2013). *Modelling methods to assess urban fluxes and heat island mitigation measures from street to city scale*. International Journal of Low-Carbon Technologies; doi:10.1093/ijlct/ctt049.
- De Berardinis, P., Bonomo, P. (2013). *BiPV in the refurbishment of minor historical centers. The project of integrability between standard and customized technology*. Journal of Civil Engineering and Architecture, ISSN 1934-7359, USA September 2013, Volume 7, No. 9 (Serial No. 70), pp. 1063-1079.
- De Berardinis P., Bonomo P. (2013). *BiPV and Refurbishment of Historical Minor Centres*. In proceedings of 39th IAHS World Congress, Milan, Italy. September 17-20, 2013.
- De Berardinis P. & Bonomo P. (2013). *PV integration in the open urban space redevelopment of historical villages in Italy*. In proceedings of SB13 GRAZ Sustainable Building Conference 2013, September 25-27, 2013, Graz, Austria.
- De Berardinis P. & Bonomo P. (2013). *PV integration in minor historical centers:*

proposal of guide criteria in post-earthquake reconstruction planning. SHC 2013, International Conference on Solar Heating and Cooling for Buildings and Industry September 23-25, 2013, Freiburg, Germany.

- Nault, E., Rey, E. & Andersen, M. (2013). *Early design phase evaluation of solar potential: Insights from the analysis of six projects*. In Proceedings of IBPSA 2013, Chambéry.
- Kanters, J., Kjellsson, E. & Wall, M. (2013). *The solar map as a knowledge base for solar energy use*. In Proceedings of SHC 2013: International Conference on Solar Heating and Cooling for Buildings and Industry, Freiburg, Germany.
- Kanters, J., Dubois, M-C., & Wall, M. (2013). *Active solar energy in urban planning: effect of design, density and orientation of urban districts on annual energy production*. In Proceedings of SHC 2013: International Conference on Solar Heating and Cooling for Buildings and Industry, Freiburg, Germany.
- Scognamiglio, A. (2013). *Il contributo italiano alle afvità di SHC-Task 51 Solar Energy in Urban Planning.* Presentation at the workshop “Riqualificazione di edifice esistenti con elevati standard energetici: metodi e tecnologie”.
- Scognamiglio, A. (2013). *Ongoing activities at the IEA – SHC Task 51 “Solar Energy in Urban Planning*”. Conference Energy Forum, Brixen, Italy, November 5-6, 2013.

SEMINARS AND WORKSHOPS IN 2013

- Horvat, M., Solar Energy in Urban Planning, presentation on the research needs and IEA Task 51 project given at the Toronto City Hall as a part of: Toronto Green Innovation Partnership Lunch & Learn series, August 23rd, 2013.
- Photovoltaics, Forms, Landscape on the topic: beauty and power of designed photovoltaics. Event at the 28th European Photovoltaic Solar Energy Conference (EUPVSEC), organized by ENEA, Italy. 1st of October 2013, Paris. See: www.pv-landscapes.com.
- Society and Energy: Contribution of Social Sciences and prospects towards an interdisciplinary research with Engineering Sciences. Seminar organized by CERMA laboratory and IRSTV (Research Institute for Urban Sciences et Techniques), France. 22th November 2013.
- Solar Mapping workshop (May 2013) at UNSW Sydney with Tria Case, City University of New York and NREL. Link of presentations can be found at: www.apva.org.au/solarmap-ppt
- VegDUD day in the frame of WGIC (World Green Infrastructure Congress): Time devoted to the presentation of the research program VegDUD "Role of vegetation in Sustainable Urban Development". Seminar organized by CERMA laboratory and IRSTV (Research Institute for Urban Sciences et Techniques), France. 9th September 2013.
http://vegdudwgic.sciencesconf.org

MEETINGS IN 2013

1st kick-off Meeting
May 29-30
Stuttgart, Germany

2nd Experts Meeting
September 26-27
Freiburg, Germany
(in connection with SHC 2013)

MEETINGS PLANNED FOR 2014

3rd Experts Meeting
March 25-28
Naples, Italy
(Including workshop and bilateral meetings)

4th Experts Meeting
Week of September 22-26
Toronto, Canada

SHC TASK 51 CONTACTS
(Preliminary)

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
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

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
NSW 2052, Sydney
m.snow@unsw.edu.au

Austria
Kersten Ch. Hofbauer
Institute for Urbanism Graz
University of Technology
Rechbauerstrasse 12
AT- 8010 Graz
hofbauer@tugraz.at

Daiva Jakutyte-Walangitang
Energy Department
AIT, Austrian Institute of Technology
Giefinggasse 2
AT-1210 Vienna
daiva.walangitang@ait.ac.at

Thomas Mach
Institut für Wärmetechnik
Technische Universität Graz
Inffeldgasse 25B
AT - 8010 Graz
thomas.mach@tugraz.at

Beatrice Unterberger
BauXund Forschung und Beratung GmbH
Ungargasse 64-66 / 4 / 2
AT - 1030 Vienna
unterberger@bauxund.at

Tobias Weiss
Nussmueller Architekten ZT GmbH
Zinzendorfgasse 1
AT-8010 Graz
tobias.weiss@nussmueller.at

Canada
Caroline Hachem
Solar Research Group

Concordia University
1455 de Maisonneuve Blvd. West
H3G 1M8 Montréal, QC
carolinehachem@gmail.com

Pamela Robinson & Graham Haines
School of Urban and Regional Planning
Ryerson University
350 Victoria St.
M5B 2K3 Toronto, ON
pamela.robinson@ryerson.ca
ghaines@ryerson.ca

Miljana Horvat & Kelsey Saunders
Department of Architectural Science
Ryerson University
350 Victoria St.
M5B 2K3 Toronto, ON
mhorvat@ryerson.ca
kelsey.saunders@ryerson.ca

Alexandre Pavlovski & Vladimir Kostylev
Green Power Labs Inc.
1 Research Drive,
Dartmouth, Nova Scotia, B2Y 4M9
ampavlovski@greenpowerlabs.com
vkostylev@greenpowerlabs.com

China
Jianqing He
Dept. of R&D, National Engineering Research Center for Human Settlements
China Architecture Design & Research Group
19, Che Gong Zhuang Street
Beijing 100044
hejq@cadg.cn

Denmark
Olaf Bruun Jørgensen
Esbensen Consulting Engineers A/S
Galionsvej 64
DK-1437 Copenhagen K
obj@esbensen.dk

Karin Kappel
Solar City Copenhagen
Arkitekternes Hus
Strandgade 27 A
DK-1401 Copenhagen
kk@solarcity.dk

Stig Mikkelsen
Mikkelsen Arkitekter A/S
Vesterbrogade 95A 3 sal
DK-1620 Copenhagen V
smi@mikkelsengroup.dk

France
François Garde
ESIROI/PIMENT
University of La Réunion
117 rue Général Ailleret
97430 Le Tampon
francois.garde@univ-reunion.fr

Anne Monnier
Akuo Energy
91, Av. des Champs Elysées
FR-75 008 Paris
monnier@akuoenergy.com

Marjorie Musy
Laboratoire CERMA UMR CNRS/MCC
ENSA Nantes
6 quai François Mitterrand
BP 16202
FR-44262 Nantes cedex 2 Nantes
marjorie.musy@cerma.archi.fr

Germany
Christoph Maurer & Christoph Cappel
Solar Façades, Division Thermal Systems and Buildings
Fraunhofer Institute for Solar Energy Systems ISE
Heidenhofstrasse 2
DE-79110 Freiburg
christoph.maurer@ise.fraunhofer.de
christoph.cappel@ise.fraunhofer.de

Gustav Hillmann & Margarethe Korolkow
IBUS GmbH – Institut für Bau-, Umwelt- und Solarforschung
Alt-Tempelhof 18
DE-12099 Berlin
hillmann@ibus-berlin.de
margarethe.korolkow@ibus-berlin.de

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

Karsten Voss
Lehrstuhl Bauphysik und Technische Gebäudeausrichtung
Bergische Universität Wuppertal
Haspeler Str. 27
DE-42285 Wuppertal
kvoss@uni-wuppertal.de

Andreas Wagner
Karlsruhe Institute of Technology (KIT)
Englerstrasse 7
DE-76131 Karlsruhe
wagner@kit.edu

Ursula Eicker, Romain Nouvel & Alexandra Fischer
Stuttgart University of Applied Sciences (HFT)
Schellingstraße 24
DE-70174 Stuttgart
ursula.eicker@hft-stuttgart.de
romain.nouvel@hft-stuttgart.de
alexandra.fischer@hft-stuttgart.de

Italy
Daniele Vettorato & Elisabetta Caharija
European Academy EURAC Bozen/Bolzano
Via Luis-Zuegg 11
IT-39100 Bolzano
daniele.vettorato@eurac.edu
elisabetta.caharija@eurac.edu

Andrea Giovanni Mainini
Architecture, Built Environment and Construction Engineering Department
Politecnico di Milano
Via Ponzio, 31
IT-20133 Milano
andreagiovanni.mainini@polimi.it

Laura Maturi
Photovoltaic systems, Institute for Renewable Energy
European Academy EURAC Bozen/Bolzano
Via Luis-Zuegg 11
IT-39100 Bolzano
laura.maturi@eurac.edu

Rossana Paparella, Erika Saretta & Mauro Caini
Department of Civil, Environmental and Architectural Engineering
Padua University
Via Marzolo, 9
IT - 35131 Padova
rossana.paparella@unipd.it
erika.saretta@studenti.unipd.it
mauro.caini@unipd.it

Alessandra Scognamiglio
Photovoltaic Technologies Unit
ENEA
Research Centre Portici
largo Enrico Fermi 1
IT-80055 Portici (NA)
alessandra.scognamiglio@enea.it

Luxembourg (observer)
Ulrich Leopold
Resource Centre for Environmental Technologies
Public Research Centre Henri Tudor
6A, avenue des Hauts-Fourneaux
L-4362 Esch-sur-Alzette
ulrich.leopold@tudor.lu

Norway
Bjørn Brekke, Lene Lad Johansen & John Paloma Nwankwo
Oslo Municipality
Postboks 2773 Solli
NO-0201 Oslo
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)
NO-7491 Trondheim
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
Dale
NO-4329 Sandnes
siri.joli@daleeiendom.no
lisbet.nygaard@daleeiendom.no

Parmita Saha
Faculty of Engineering and Science
Sogn og Fjordane University College
P.O. Box 133
NO-6856 Sogndal
parmita.saha@hisf.no

Sweden

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

Elisabeth Kjellsson
Building Physics
Lund University
P.O. Box 118
SE-221 00 Lund
elisabeth.kjellsson@byggtek.lth.se

Maria Wall & Jouri Kanters
Energy and Building Design
Lund University
P.O. Box 118
SE-221 00 Lund
maria.wall@ebd.lth.se
jouri.kanters@ebd.lth.se

Switzerland

Pierluigi Bonomo & Francesco Frontini
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
Campus Trevano
CH-6952 Canobbio
pierluigi.bonomo@supsi.ch
francesco.frontini@supsi.ch

Maria Cristina Munari Probst & Christian Roecker
Laboratory for Solar Energy and Building Physics (LESO-PB)
Ecole Polytechnique Fédérale de Lausanne (EPFL)
EPFL ENAC IIC LESO-PB
LE 0 04 (Bâtiment LE), Station 18
CH-1015 Lausanne
mariacristina.munariprobst@epfl.ch
christian.roecker@epfl.ch

Emilie Nault
Interdisciplinary Laboratory of Performance-Integrated Design
Ecole Polytechnique Fédérale de Lausanne (EPFL)
EPFL – ENAC – IA – LIPID
LE 1 114 - Station 18
CH-1015 Lausanne
emilie.nault@epfl.ch

SHC Programme Members

As of December 2013

EXECUTIVE COMMITTEE MEMBERS

AUSTRALIA
Mr. Ken Guthrie *(Vice 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 *(Chairman)*
AEE INTEC
Feldgasse 19
A-8200 Gleisdorf
w.weiss@aee.at

Alternate
Mrs. Sabine List
BMVIT
Renngasse 5
A-1010 Vienna
Sabine.list@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
andre.deherde@uclouvain.be

CANADA
Mr. Doug McClenahan
CanmetENERGY
580 Booth Street
Ottawa, Ontario K1A 0E4
dmcclena@nrcan.gc.ca

CHINA
Prof. He Tao *(Vice Chair)*
China Academy of Building Research
30#, Beisanhuandonglu
Chaoyang District
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
Mr. Jansenio Delgado
Achada Santo Antonio
2nd Floor, Electra Building
Praia - Cape Verde C.P. 288
jdelgado@ecreee.org

Alternate
Mr. Martin Lugmayr
(same address as above)
mlugmayr@ecreee.org

EUROPEAN COMMISSION
Mrs. Szilvia Bozsoki
European Commission – ENER C2
New Energy Technologies, Innovation and Clean Coal
Rue De Mot 24 (DM23 3/134)
1040 Brussels
Szilvia.BOZSOKI@ec.europa.eu

FINLAND
Mr. Martti Korkiakoski
Tekes, Finnish Funding Agency for Technology and Innovation
P.O.Box 69
FI-00101 Helsinki
martti.korkiakoski@tekes.fi

FRANCE
Ms. Céline Coulaud
Département Energies Renouvelables
ADEME - Centre de Sophia Antipolis
500 route des Lucioles
06560 VALBONNE
celine.coulaud@ademe.fr

GERMANY
Ms. Mira Heinze
Projektträger Jülich
Energietechnologien (ERG1)
Forschungszentrum Jülich GmbH
52425 Jülich
m.heinze@fz-juelich.de

Alternate
Dr. Peter Donat
Projektträger Jülich
Geschäftsbereich Erneuerbare Energien
Forschungszentrum Jülich GmbH
Zimmerstraße 26-27
10969 Berlin
p.donat@fz-juelich.de

ITALY
Mr. Michele Zinzi
ENEA UTEE-ERT s.p. 104
Via Anguillarese, 301
00123 Rome
michele.zinzi@enea.it

MEXICO
Dr. Wilfrido Rivera Gomez-Franco
National University of Mexico
Apdo. Postal #34
62580 Temixco, Morelos
wrgf@cie.unam.mx

Alternate
Dr. Camilo Arancibia Bulnes
same address as above
caab@cie.unam.mx

NETHERLANDS
Mr. Lex Bosselaar
Netherlands Enterprise Agency
Postbus 8242
3503 RE UTRECHT
Lex.bosselaar@rvo.nl

NORWAY
Ms./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 Lisboa
Farinha.mendes@lneg.pt

SINGAPORE
Mr. Kian Seng Ang
Building and Construction Authority
Director, Research
200 Braddell Road, ZEB Level 3
579700
ang_kian_seng@bca.gov.sg

SOUTH AFRICA
Dr. Thembakazi Mali
SANERI
P.O. Box 786141
Sandton, 2146
thembakazim@saneri.org.za

Alternate
Mr. Barry Bredenkamp
SANEDI
P.O. Box 786141
Standton 2146
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
Mr. 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. Urs Wolfer
Same address as above
urs.wolfer@bfe.admin.ch

UNITED STATES
Dr. Bahman Habibzadeh
U.S. Department of Energy
1000 Independence Ave, SW
Washington, DC 20585-0121
Bahman.Habibzadeh@ee.doe.gov

OPERATING AGENTS

TASK 39 - POLYMERIC MATERIALS FOR SOLAR THERMAL APPLICATIONS
Dr. Michael Köhl
Fraunhofer Institute for Solar Energy Systems
Heidenhofstr. 2
D-79 110 Freiburg, GERMANY
michael.koehl@ise.fraunhofer.de

TASK 40 - TOWARDS NET ZERO ENERGY SOLAR BUILDINGS
Mr. Josef Ayoub
CanmetENERGY
Natural Resources Canada
1615 Lionel-Boulet Blvd.
Varennes QC J3X 1S6, CANADA
Josef.Ayoub@rncan-nrcan.gc.ca

TASK 42 - COMPACT THERMAL ENERGY STORAGE
Mr. Wim van Helden
Renewable Heat
Oosterstraat 15
1741 GH Schagen, NETHERLANDS
wim@wimvanhelden.com

TASK 43 - RATING AND CERTIFICATION PROCEDURES
Jan Erik Nielsen
SolarKey International
Aggerupvej 1
DK-4330 Hvalsö, DENMARK
jen@solarkey.dk

Mr. Les Nelson
IAPMO
5001 E. Philadelphia St.
Ontario, CA 91761 USA
Les.nelson@iapmo.org

TASK 44 - SOLAR AND HEAT PUMP SYSTEMS
Mr. Jean-Christophe Hadorn
BASE Consultants SA
8 rue du Nant
CH-1211 Geneva, SWITZERLAND
jchadorn@baseconsultants.com

TASK 45 - LARGE SOLAR HEATING & COOLING SYSTEMS
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 47 - RENOVATION IN NON-RESIDENTIAL BUILDINGS
Mr. Fritjof Salvesen
Asplan Viak AS
Kjørboveien 20
P.O.Box 24
Sandvika, NORWAY
fritjof.salvesen@asplanviak.no

TASK 48 - QUALITY ASSURANCE ANDSUPPORT MEASURES FOR SOLAR COOLING
Mr. 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
jdb@ibp.fraunhofer.de

TASK 51 - SOLAR ENERGY IN URBAN PLANNING
Ms. 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

ADMINISTRATION

SHC SECRETARIAT
Ms. Pamela Murphy
KMGroup
9131 S. Lake Shore Dr.
Cedar, Michigan 49621, USA
Tel: +1/231 620 0634
pmurphy@KMGrp.net
secretariat@iea-shc.org
communications@iea-shc.org

WEBMASTER
Mr. Randy Martin
R. L. Martin & Associates, Inc.
6851 Spanish Bay Drive
Windsor, Colorado 80550, USA
Tel: +1 /970 219 2605
Fax: +1/303 379 4498
randy@rlmartin.com

IEA SECRETARIAT LIAISON
Mr. Yoshiki Endo
International Energy Agency
9 rue de la Fédération
75739 Paris Cedex 15, FRANCE
Tel: +33/1 40 57 65 62
Fax: +33/1 40 57 67 59
yoshiki.endo@iea.org

SHC CONFERENCE
Dr. Andreas Häberle
PSE AG
Emmy-Noether-Str. 2
79110 Freiburg
Germany
Tel: +49 761 479 14 14
Fax: +49 761 479 14 44
andreas.haeberle@pse.de

IEA SOLAR HEATING & COOLING PROGRAMME

www.iea-shc.org

Energy Technology Network