IEA SOLAR HEATING & COOLING PROGRAMME

2012

ANNUAL REPORT

Feature Article on

Compact Thermal Energy Storage – *Materials Development*

IEA Solar Heating & Cooling Programme

2012 Annual Report

Edited by
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SHC Secretariat
IEA Solar Heating and Cooling Programme

www.iea-shc.org

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Chairman's Report

Werner Weiss
AEE INTEC, Austria

This year was an exciting year for the SHC Programme and Solar Thermal. The importance of this technology in our world today was showcased in three major events and the in-depth work of our projects. The first event was *SHC 2012: 1st International Conference on Solar Heating and Cooling for Buildings and Industry*. The conference was held in July in San Francisco, California and welcomed over 220 participants from 31 countries. The conference program included 120 presentations, including 16 keynote lectures, and 90 scientific posters. The second event was the presentation of the prestigious *SHC Solar Award* to Dr. Fred Morse at SHC 2012. And to cap off the year, the IEA published its Roadmap on Solar Heating and Cooling.

Each of these events succeeded in informing policy and decision makers about the possibilities of solar thermal as well as the achievements of our Programme.

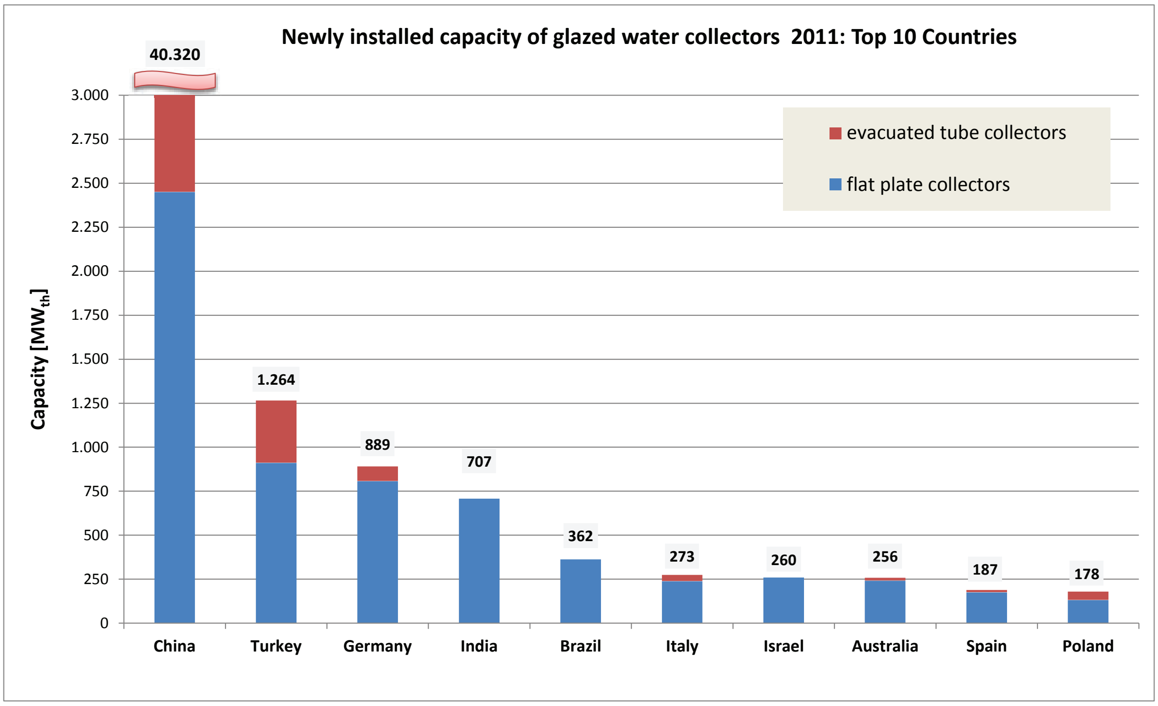
And with the start of 2013, we are continuing to advance the application of solar heating and cooling in our homes, public and private buildings, industries, and communities. We are doing this by providing focused information on our Task results, general up-to-date information on solar heating and cooling, and information on worldwide trends in the solar heating and cooling industry.

Come learn and share at SHC 2013: *2nd International Conference on Solar Heating and Cooling for Buildings and Industry* in Freiburg, Germany on September 23-25. The Executive Committee is happy to organize this conference in cooperation with the European Solar Thermal Industry Federation. Conference details can be found at http://www.shc2013.org.

Werner Weiss,
SHC Executive Committee Chairman

SOLAR THERMAL OUTLOOK

The SHC Programme publishes the only annual global statistics report, *Solar Heat Worldwide: Markets and Contribution to the Energy Supply*. The 2013 edition reports that in 2011, solar thermal technologies produced 195.0 TWh – which relates to an oil equivalent of over 20.8 million tons and an annual avoidance of 63.9 million tons of CO_2 emissions. New installations grew 14.0 % compared to 2010 again with China as a main market driver and absolute leader in terms of cumulated area installed followed by Turkey, Germany, Brazil and India.



Total capacity of newly installed flat-plate and evacuated tube collectors in the 10 leading countries in 2011.

Key findings:

- Cumulated capacity in operation in 2011 was 235.1 GW_{th} (335.8 million m²):
  - 62.1 % evacuated tube collectors
  - 28.2 % flat plate collectors
  - 9.1 % unglazed plastic collectors
  - 0.7 % air collectors
- China and Europe accounted for 92.4 % of the world's market for all new installations.
- Market penetration of newly installed glazed water collectors (installed capacity per 1,000 inhabitants) leading countries:
  - Israel: 34.8 kW_{th}; China: 30.2 kW_{th}; Austria: 19.6 kW_{th}; Cyprus: 17.8 kW_{th}; Turkey: 16.0 kW_{th}
- 2012 data estimate of the total capacity in operation is 271.6 GW_{th}

SHC ACTIVITIES

Tasks

The SHC Programme continues to push forward on cutting edge topics in solar thermal as well as in the field of solar buildings and architecture, all of which support our strategic focus on market deployment and R&D. In 2012, the Executive Committee approved:

Work to start in 2012:

- Task 49: Solar Process Heat for Production and Advanced Applications (Lead Country: Austria)
  This Task builds upon our work in Task 33 and includes collaboration with the IEA SolarPACES Programme. In this new field of solar thermal applications, the focus will be on developing and improving components and systems, developing tools for system optimization and installing and monitoring large-scale demonstration systems in the industry.

Work to start in 2013:

- 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.

- Task 50: Advanced Lighting Solutions for Retrofitting Buildings (Lead Country: Germany)
  This Task will work 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.

Work to be further defined:

- Solar Thermal & Energy Economics in Urban Environments
- PV Cooling and Heating
- Innovative Low-cost Solar Water Heating Systems

SHC Conference

SHC 2012 was a successful start to the IEA SHC Programme's new series – *International Conference on Solar Heating and Cooling for Buildings and Industry.*

We were happy to welcome 220 participants from 31 countries to our first conference held in July in San Francisco, California, USA. The conference program consisted of 120 presentations, including 16 keynote lectures and the launch of the IEA roadmap on Solar Heating and Cooling. About 90 scientific posters were displayed throughout the conference.

I wish to thank all the authors for their high quality contributions. Also, many thanks to the scientific committee for their dedicated support with the reviewing procedure.

SHC 2013 will be held September 23-25 in Freiburg, Germany. The SHC Programme and the European Solar Thermal Industry Federation (ESTIF) are jointly organizing this conference.

SHC Solar Award

The 2012 SHC Solar Award was given to Dr. Fred Morse. He received the award at the SHC 2012 conference dinner in San Francisco. For many years, Fred Morse has been an outstanding promoter of solar energy and served the IEA SHC between 1976 and 2007 in various roles – amongst others, as its first chairman.

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.

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 will be 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 *7th SHC/Trade Association* meeting was held July 11, 2012 in conjunction with SHC 2012 in San Francisco, California, USA. The 8th meeting is planned for September 2013 in conjunction with the SHC 2013 conference in Freiburg, Germany.

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

2012 Meetings

The Executive Committee held two meetings:

- July 12-13 in San Francisco, California, USA
- November 27-29 in Louvain-la-Neuve, Belgium

2013 Meetings

The Executive Committee will hold two meetings:

- June 12-15 in Rome, Italy
- October 30 – November 1 in Singapore

A SUCCESSFUL TEAM

Last but not least, I want to thank the outgoing vice chairmen Markus Kratz and João A. Farinha Mendes and the incoming vice chairmen Ken Guthrie and He Tao, 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 communication manager, Uwe Trenkner. The successful collaboration of this excellent team has once again ensured a top-notch year for the SHC Programme.

Membership

CONTRACTING PARTIES

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

SPONSORS

ECREEE (ECOWAS Centre for Renewable Energy and Energy Efficiency)

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

Communication continued with countries invited to join the Programme–Brazil, Chile, European Cooper Institute, India, Japan, SEIA, Slovenia, South Korea, Thailand, Tunisia, Turkey, Qatar, and United Kingdom.

In 2012, the Executive Committee unanimously voted to invite:

- Tunisia to join the Agreement as a Contracting Party, and
- European Cooper Institute as a Sponsor.

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.

HOW TO PARTICIPATE

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*** of the Programme, but your government agency or organization is interested in joining the Progamme, please contact the SHC Secretariat for information *(secretariat@iea-shc.org).*

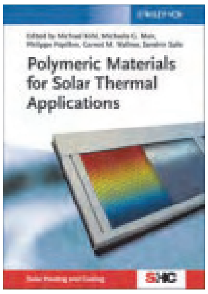
If you represent an ***international industry association or international non-profit organization*** it is possible to become a Sponsor Member, please contact the SHC Secretariat for information *(secretariat@iea-shc.org).*

Become An Expert

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

Task Highlights

TASK 39: POLYMERIC MATERIALS FOR SOLAR THERMAL APPLICATIONS



Publication of Vol. 1 of the Solar Heating and Cooling Series

The Task 39 handbook *Polymeric Materials for Solar Thermal Applications* is the first in the new Solar Heating and Cooling Series. This first of its kind book discusses how the use of polymers makes solar thermal applications more economically attractive and bridges the gap between basic science and technological applications. This application-oriented handbook is relevant for researchers, scientists, engineers, and technicians active in the solar thermal field and/or polymer sector and a useful companion for everyone who is interested in working his/her way into this promising field of research. *Polymeric Materials for Solar Thermal Applications* is available at www.wiley vch.de. ISBN: 978-3-527-33246-5.

TASK 40: TOWARDS NET ZERO ENERGY SOLAR BUILDINGS

NetZEB Evaluation Tool

This evaluation tool is an Excel-based platform tool that enables energy balance, operating cost and load match index calculation for predefined selected definitions of net-zero energy buildings. It aims to evaluate solutions adopted in building design with respect to different NetZEB definitions (for building designers), assessing the balance in monitored buildings (for energy managers), and assisting the implementation process of NetZEBs within the national normative framework (for decision makers). The Tool and supporting material are available on the SHC website.

This is a collaborative Task with the IEA Energy Conservation in Buildings and Community Systems (ECBCS) Implementing Agreement.

TASK 41: SOLAR ENERGY & ARCHITECTURE

Solar Energy Systems in Architecture – Integration Criteria and Guidelines

This document summarizes the knowledge needed to integrate active solar technologies into buildings, handling at the same time architectural integration issues and energy production requirements. For each technology, the guideline addresses the main technical information, constructive/ functional integration possibilities in the envelope, system sizing and positioning criteria, good integration examples, and standard products and Innovative market products. The report concludes with a short section describing the differences and similarities between solar thermal and photovoltaic systems, with the purpose to help architects optimize the use of the sun exposed surfaces of their buildings. The report is available on the SHC website.

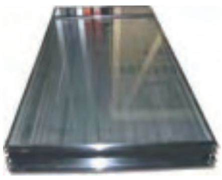
TASK 42: COMPACT THERMAL ENERGY STORAGE

Prototype Reactors for TCM Storage

Several institutes have conducted work on new types of reactors for Thermochemical Energy Storage. The active volume of this generation of reactors is in the order of several tens of liters, making it possible to see the effects of using larger quantities of the active thermochemical storage material. *(Photo: EMPA's liquid sorption prototype reactor)*

This is a collaborative Task with the IEA Energy Conservation through Energy Storage (ECES) Implementing Agreement.

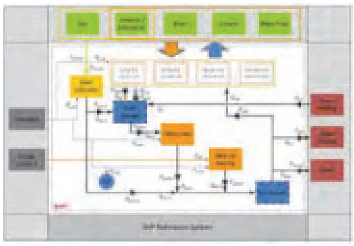
TASK 43: ADVANCED SOLAR THERMAL TESTING AND CHARACTERIZATION FOR CERTIFICATION OF COLLECTORS AND SYSTEMS



Roadmap of Collector Testing and Certification Issues

A comprehensive roadmap on existing collector testing processes was completed. It serves three purposes 1) to provide a comprehensive guide to how tests and standards are applied and how they relate to certification, 2) to identify gaps, inconsistencies and weaknesses along with approaches to addressing problems, and 3) to propose recommendations for improving procedures in order to accommodate emerging technologies where standards and testing approaches are under development.

TASK 44: SOLAR AND HEAT PUMP SYSTEMS



Definition of Performance Figures

Experts in this Task have defined system boundaries inside a typical solar and heat pump configuration. Different limits have been drawn starting from around each component (for example around the heat pump to define its COP) to the complete system defining the system seasonal or annual performance factor SPF or APF such as the SHP+ limit depicted in the illustration.

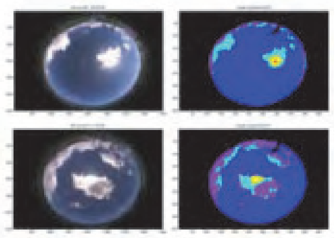
This is a collaborative Task with the IEA Heat Pump (HPP) Implementing Agreement.

TASK 45: LARGE SYSTEMS: LARGE SOLAR HEATING/COOLING SYSTEMS, SEASONAL STORAGE, HEAT PUMPS

Design Handbook

Several contributions to the Task's design handbook on design guidelines for large solar systems were finalized. Inputs included collector field performance, heat exchanger performance, collector efficiency, etc. The Operating Agent was also invited by the Chinese Lanzhou Technical University to give a presentation on the Task's work.

TASK 46: SOLAR RESOURCE ASSESSMENT AND FORECASTING

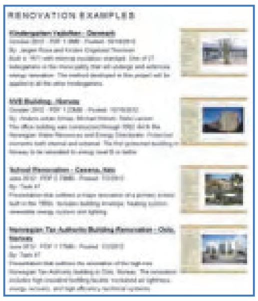


Observational and Numeric Modeling for Solar Forecasting

Work is underway to assess the suitability of various observational schemes and numerical modeling techniques to provide solar forecasts over time intervals from hour-ahead to 1-3-days ahead. For hour-ahead forecasts, critical to system operators attempting to effectively match varying loads with variable renewable energy technologies, application of Total Sky Imagers or all sky cameras appears promising. A new group that joined the Task 46, the Laboratoire PIMENT at the Université Réunion on Réunion Island, is investigating how images collected from all-sky cameras can be used to predict short-term cloud motions.

This is a collaborative Task with the IEA Photovoltaic Power Systems (PVPS) Implementing Agreement and the SolarPACES Implementing Agreement.

TASK 47: SOLAR RENOVATION OF NON-RESIDENTIAL BUILDINGS


RENOVATION EXAMPLES

Exemplary Renovations

Four exemplary renovation project summaries are available on the Task 47 webpage. The projects from Denmark, Italy and Norway, are described in 8-page brochures presenting the key renovation actions as well as energy performance numbers and costs. The projects show a 50-75% reduction in heat consumption and a 50-70% reduction in overall energy demand.

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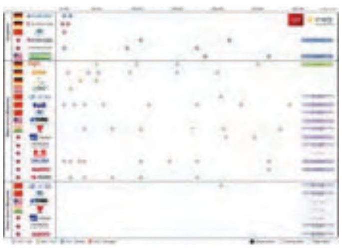
TASK 48: QUALITY ASSURANCE AND SUPPORT MEASURES FOR SOLAR COOLING



Market Assessment

A list of market available chillers compatible with solar cooling was compiled by the Task experts to give a complete overview of the actual situation in this field. In addition, 28 operating solar DEC (SDEC) system were identified. In terms of numbers, Germany, Italy and Austria cover two-thirds of all the identified SDEC installations.

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TASK 49: SOLAR HEAT INTEGRATION IN INDUSTRIAL PROCESSES

Guideline for Solar Process Heat in Breweries

Within the SOPREN project (solar process heat and energy efficiency), the University of Kassel systematically investigated the possibilities for the integration of solar heat in breweries. The outcome of this investigation is a guideline that contains all relevant information regarding applied processes and energy consumption in breweries.

This is a collaborative Task with the IEA SolarPACES Implementing Agreement.

Feature Article

Advances in Compact Thermal Energy Storage

Wim van Helden
Renewable Heat
SHC Task 42
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Andreas Hauer
ECES Annex 24
ZAE Bayren
Operating Agent for the Centre for Applied Energy Research ZAE, Germany

Advancements in Compact Thermal Energy Storage

This article was contributed by numerous experts working in the collaborative IEA SHC Task 42/ECES Annex 24 on Compact Thermal Energy Storage: Materials Development for System Integration – Wim van Helden[1], Andreas Hauer, Simon Furbo, Oleksandr Skrylnyk, Thomas Nuytten, Alenka Ristić, Stefan Henninger, Camilo Rindt, Frank Bruno, Ana Lázaro, Lingai Luo, Daniele Basciotti, Andreas Heinz, Robert Weber, Ines Fernandez, Luisa Cabeza, Justin Chiu, Herbert Zondag, Ruud Cuypers, Jochen Jänchen, Bernhard Zettl, Eberhard Lävemann

Introduction

Since January 2009, experts in the fields of material development and system integration have been working together in a joint project of the IEA Solar Heating and Cooling (SHC) Programme and the IEA Energy Conservation through Energy Storage (ECES) Programme. The objective of this project, referred to as *SHC Task 42/ECES Annex 24 - Compact Thermal Energy Storage: Materials Development for System Integration*, is to develop better materials for the compact storage of heat and to design, build and test systems in which these novel materials are applied.

To achieve this ambitious objective over 50 organisations from 17 countries have collaborated in national and international projects, and the results range from new compact storage materials, through better testing and characterisation methods to numerical methods for predicting the performance of novel materials of components and systems. This article highlights some of these developments.

Advancements in Thermal Storage Materials

Salt hydrates are very interesting thermal storage materials in terms of their high storage density (~1 GJ/m3) potential at relatively low temperatures. In addition, many salt hydrates are a low cost material. The Energy Research Centre of The Netherlands (ECN) and Eindhoven University of Technology are collaborating in a materials research project to study the application of several salt hydrates in seasonal thermochemical solar heat storage (see Figure 1 [10]).

Composite Materials

One new class of materials is the so-called composite materials, which are based on a porous carrier matrix and a salt. The carrier matrix fulfils different functions: it defines the stability, the shape and the size of the material, which can be specially adapted for the application. It also provides a high inner surface allowing a fine dispersion and uniform distribution of the salt within the carrier matrix. Salts on active carrier matrices as well as salts on honeycomb matrices have been produced as part of the project's collaborative work with the National Institute of Chemistry (NIC) in Slovenia and the Fraunhofer Institute for Solar Energy FhG ISE in Germany (see Figure 2). The hygroscopic salt introduced in the porous matrices was $CaCl_2$.

[1] *Renewable Heat, Oosterstraat 15, Schagen, The Netherlands. email: Wim@wimvanhelden.com phone +31 224 752098. For the complete co-authors list, see end of the article*

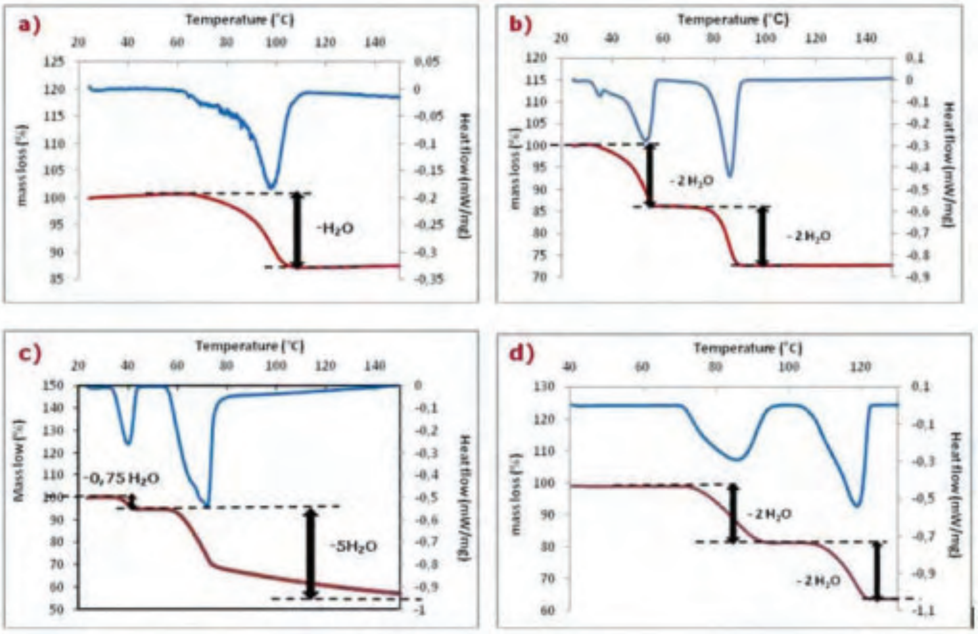


Figure 1. TG (lower curves, in red) and DSC (upper curves, in blue) of the dehydration reaction at 13 mbar water vapor pressure and a heating rate of 0.5 K/min of (a) $Li_2SO_4.H_2O$, (b) $CuSO_4.5H_2O$, (c) $MgSO_4.7H_2O$ and (d) $MgCl_2.6H_2O$ powders sieved at 100-200 µm.

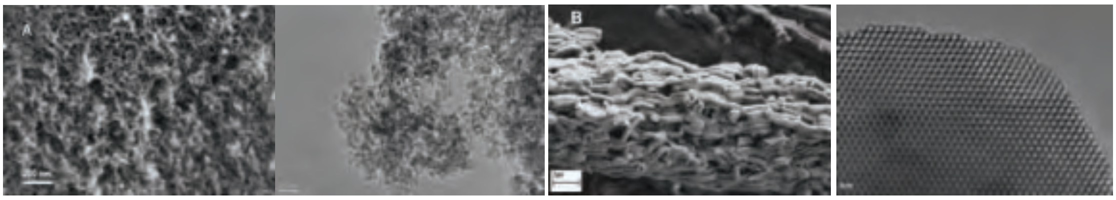


Figure 2. SEM and TEM images of A) $CaCl_2$- disordered iron silicate matrix and B) $CaCl_2$-ordered silicate matrix.

The new composite materials showed improved performance for water uptake and thus for energy storage density. The, cycling tests showed a relatively low decrease of uptake capacity of about 4% absolute after 20 cycles (see Figure 3). After the cycling tests, the porous structures of both composites had not changed and there was no leaching of $CaCl_2$ observed [12,13]. At TNO in The Netherlands, $CaCl_2$ was further successfully encapsulated in an open polymer matrix, showing decreased dehydration temperatures and adequate cycling stability while retaining its solid form during operation [18,19].

Zeolite Materials

Improvements have been made in zeolite materials. Generally, zeolite crystals have sizes of about 50 micrometer. To form granules of zeolite these crystals are bound by a clay-like binder material, which is inactive. This results in a lower storage capacity of the zeolite. New binderless zeolites have been developed in a German collaboration between the University of Applied Sciences Wildau and Chemiewerke Bad Köstritz, in which the complete granules consist of active material (see Figure 4), thus increasing the storage density of the material.

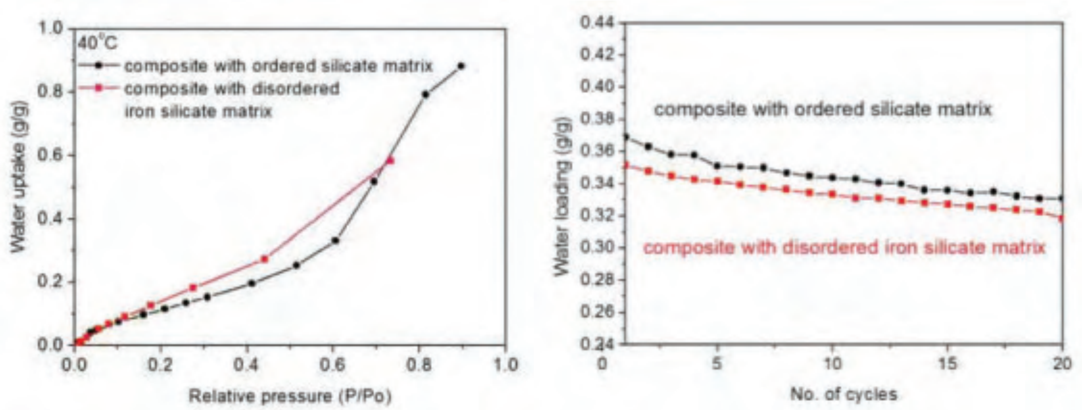


Figure 3: Water uptake curves at 40°C and hydrothermal stability after 20 cycles between 150°C and 40°C at water vapour pressure 5.6kPa.

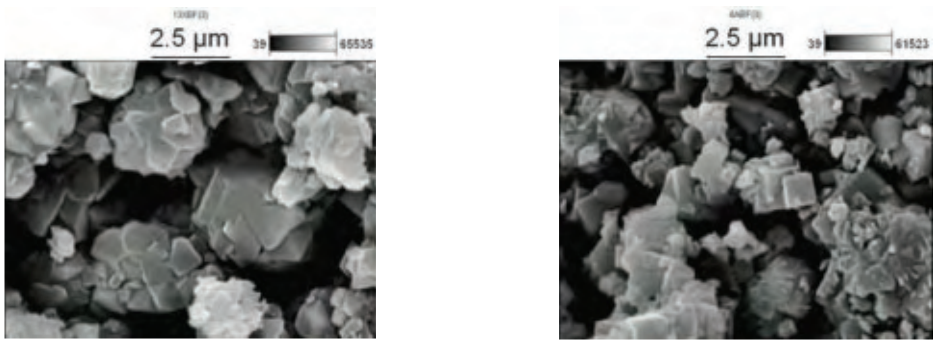


Figure 4. Microscopic images showing a detail of the surface of molecular sieve beads (diameter 1.6-2.5 mm) of 13XBF (left) and 4ABF. Both show an overall zeolitic morphology, without any binder.

Phase Change Materials

Besides as a storage material, phase change materials (PCMs) can be used as a heat transfer fluid in the form of slurries. The University of Zaragoza designed, built and tested an experimental test facility for determining the heat transfer coefficient of mPCM (microencapsulated Phase Change Materials) and emulsions (Figure 5, left). Thus the thermal behaviour of these fluids can be compared to water. The experimental results demonstrated that the energy stored in the investigated mPCM slurry is 75% higher than the energy stored in the same temperature range with water, see Figure 5, right [14].

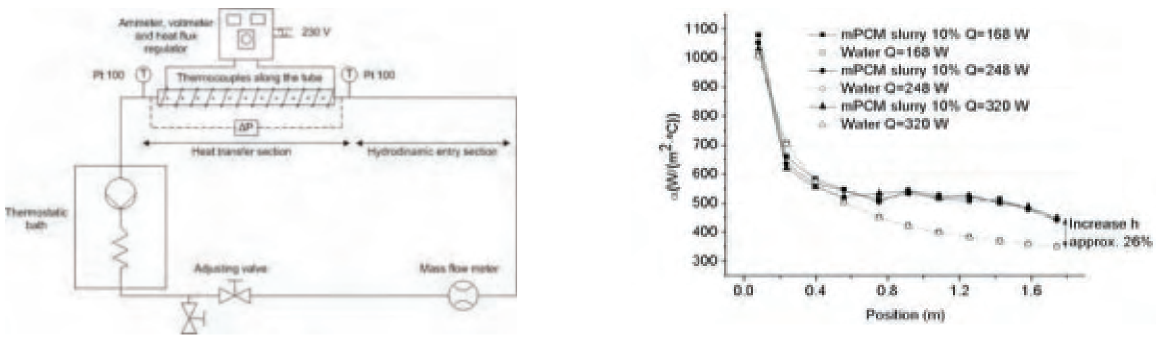


Figure 5. Schematic diagram of the experimental set up (left) and determined heat transfer coefficient using the experimental set up (right).

Solid Sensible Materials
In the field of solid sensible thermal energy storage materials for medium temperature, work is underway to find inexpensive, alternative materials for the relatively high cost materials. The Diopma (University of Barcelona), GREA at the University of Lleida and PROMES from CNRS-UPVD Perpignan are collaborating to evaluate alternative materials that are by-products from the mining and metallurgical industry. The thermal properties of several materials in granulated or powdery form were evaluated. And, two approaches were followed to shape them, 1) compression molding, if the resulting shape had mechanical integrity and 2) inclusion in some mortar formulations using either Portland, Alumina and Phosphate cements as the binder to optimize the thermal properties of the final material. A multi-criteria selection method was applied to select the materials with the best performance/cost ratio, see Figure 6.

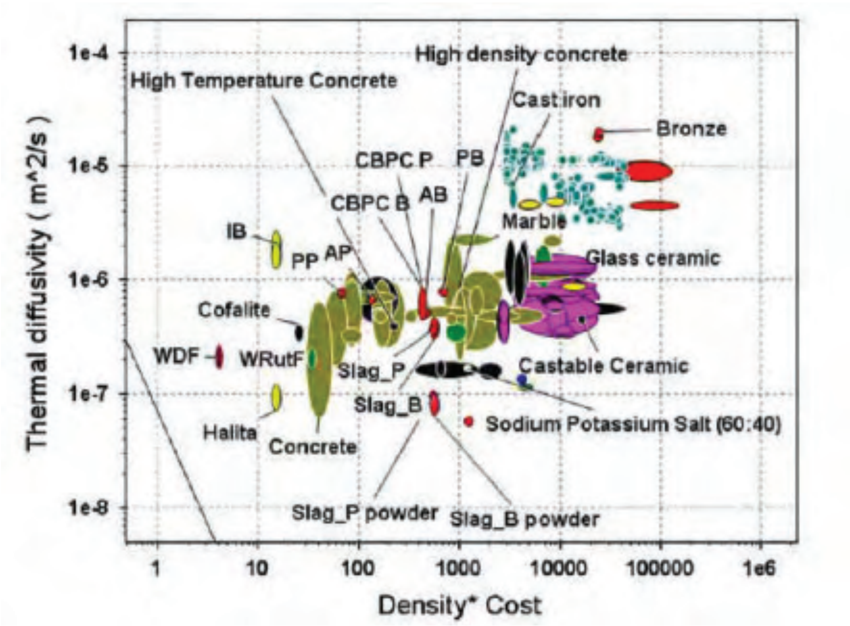


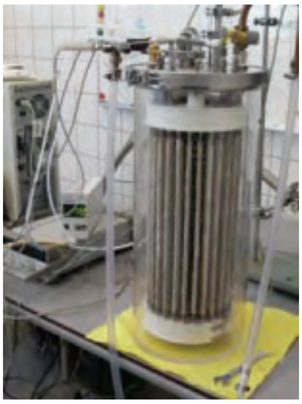
Figure 6. The density times cost value versus thermal diffusivity of several high-temperature thermal storage materials.

In an experimental set-up, two of the selected materials, by-products of the salt industry, were tested in a 50 litre stainless steel tank. The experiments showed corrosion in the tanks, despite a protective coating. Further research will address these corrosion aspects.

Components

The new compact storage materials require new devices to effectively charge and discharge the material. A number of different reactors have been designed, built and tested. These range from fixed bed reactors, falling granule reactors with cross-flow air, rotating bed reactors and liquid condenser/evaporator reactors.

TNO in The Netherlands is working on a finned heat exchanger geometry (Figure 7) with the sorption material attached to the surface of the fins. The heat exchanger is placed in a low-pressure vessel [16,17]. Also in The Netherlands, ECN is developing an open (atmospheric) sorption system for seasonal heat storage, base on a packed bed of salt hydrate. A lab prototype is shown in Figure 8 [11].



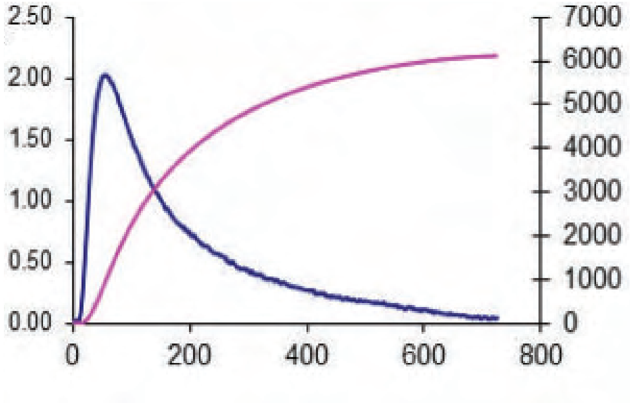


Figure 7. Left: Prototype sorption reactor from TNO, with solid sorption material attached to the fins of the heat exchanger. Right: measured cumulatively discharged heat (in J) and temperature difference (in K) during first 750 seconds discharge.

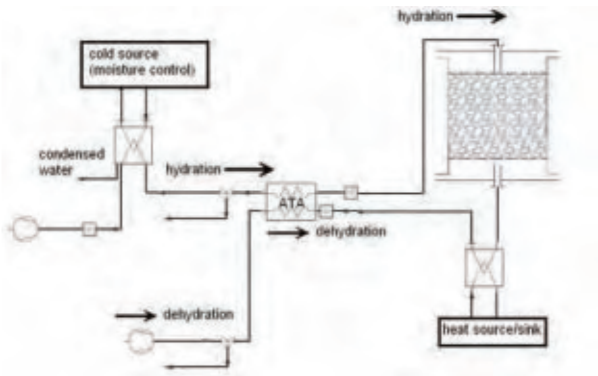


Figure 8: Left: Bulk type open sorption prototype reactor of ECN. Right: system design.

In Switzerland, EMPA has topped-up their one-stage liquid sorption reactor with a second stage to allow for the generation of higher temperatures from the thermal storage (Figure 9).

In Austria, ASiC is working on another reactor type for storage purposes (Figure 10). In this, the active material is transported slowly trough a rotating drum, in order to have an efficient heat and mass transfer between the grains of material and the air flow in the drum.

Figure 9. EMPA liquid sorption reactor first stage (left, upper dishes covered with insulation) and one of the heat/mass exchangers of the second stage (right).

In Belgium, a project consortium around the University of Mons, is working on a seasonal storage system based on a closed solid sorption system, at pressures between 1 and 60 mBar [7,8]. A laboratory-scale thermal storage apparatus has been built and experimentally tested, see Figure 11. Initial results show some degradation in the heat and mass transfer, but no changes in energetic output or chemical stability of the applied strontium bromide. Other materials will be tested in following experiments.

Figure 10. Photograph and simulation image of grain movement in a slowly rotating drum (ASiC).

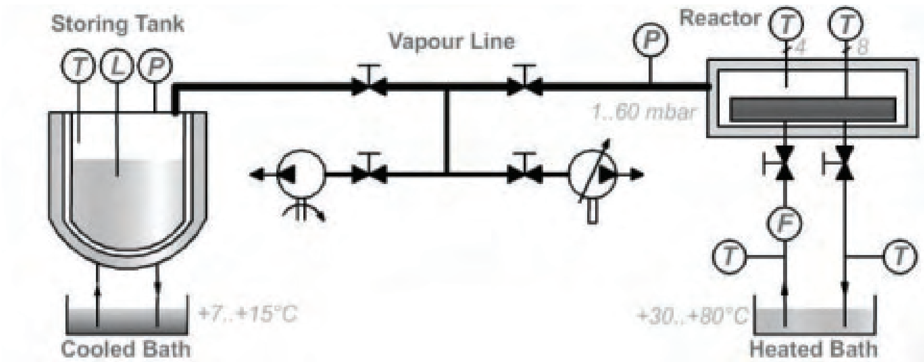


Figure 11. Laboratory scale prototype designed for Solautark project.

When using phase change materials for thermal energy storage, in general the challenge is to overcome the intrinsically low thermal conductivity of the material. At the Technical University of Denmark (DTU), a compact seasonal heat storage based on a sodium acetate water mixture with stable supercooling is being developed. Here, the sodium acetate water mixture is placed in large, thin cassettes with heat exchangers at the walls, resulting in high heat transfers to/from the active material, see Figure 12. A challenge in the development is making sure that the nucleation (initiation of the solidification process) is stable [9].

Thermal energy storage solutions at the residential level may help to decouple the heat demand from the electricity demand in the future and thus increasing electrically-coupled, thermal installations. VITO of Belgium has studied the incorporation of commercially available phase change materials (PCMs) in domestic thermal storage tanks, focusing on the coupling with micro-CHP units in terms of system power and temperature regime. See Figure 13.

The University of South Australia has undertaken several research projects to characterise and subsequently optimise to maximise the usefulness of PCMs in thermal energy storage systems. For different PCM geometries, generic equations were developed that are capable of determining the heat exchange as a function of phase change fraction [5,6]. This method enables direct assessment of a design as well as the benefit of any improvement in the heat transfer within PCMs. Figure 14 shows some results of the method.

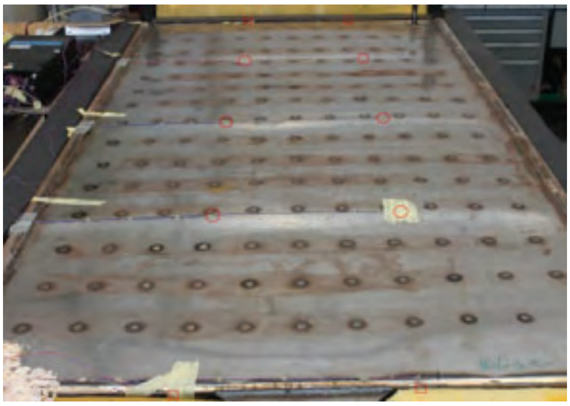


Figure 12. Prototype 160 litres module for sub-cooled sodium acetate storage tested at DTU.

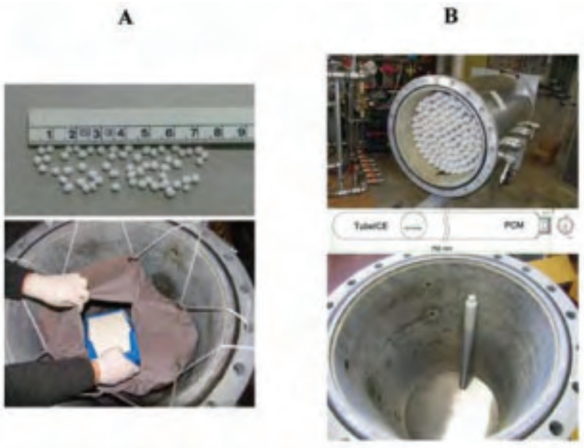


Figure 13. Pictures of the two different VITO concepts using Mikrotec (A) and TubeICE (B) PCM.

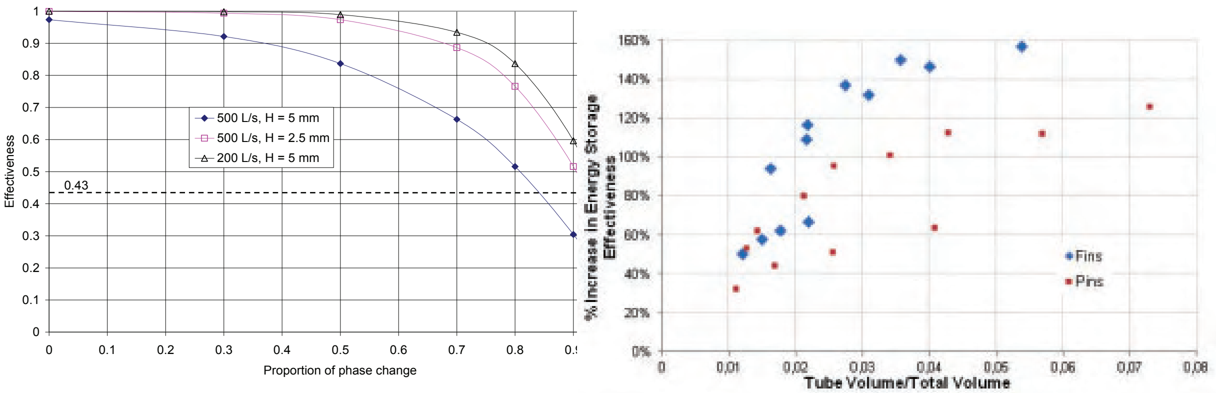


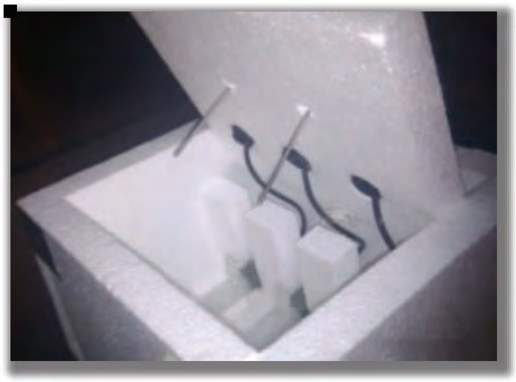
Figure 14. Left: Local effectiveness versus proportion of phase change for PCM in plates.
Right: percentage increase in energy storage effectiveness for pinned and finned tubes over the plain tube based on the ratio of tube volume over total volume.

Characterization

One disadvantage of phase change materials and thermochemical materials is that the state of charge of a storage using such materials cannot be determined directly from temperature, as with the common, sensible storages. Moreover, the compact materials show different results if the testing methods are not exactly identical. Considerable work has been done on finding and defining testing procedures with which the performance of materials can be determined accurately and reproducibly.

A cost effective enthalpy characterizing method, T-history, was studied and compared against traditional means of material testing by the Royal University of Technology KTH in

Stockholm, Sweden. It was found that the T-history method gave reproducible and accurate results, provided that the samples were placed horizontally (see Figure 15).



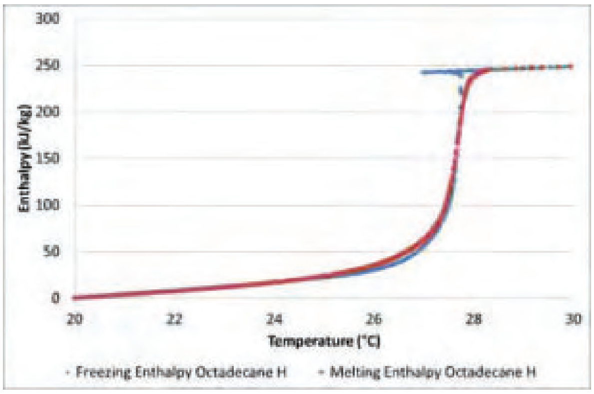
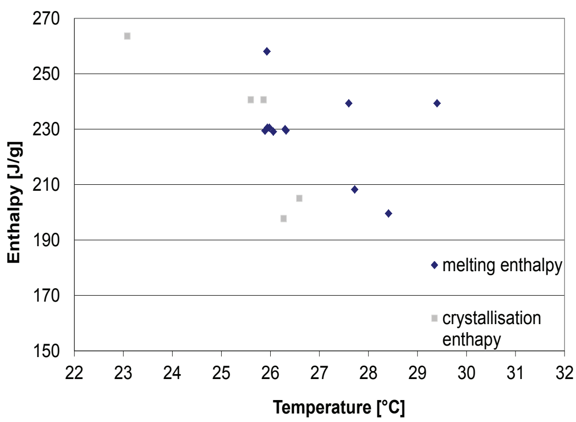


Figure 15. Horizontally Placed T-history Setup (left) and Enthalpy Mesurement (right).

A number of laboratories in the SHC/ECES Task contributed to a Round-Robin Test (RRT), in which one sample of a PCM was measured consecutively by the different laboratories. After which a protocol for the testing and for the calibration of the equipment was developed, and the results for the final tests were very satisfactory, as shown in Figure 16. The RRT was a collaboration with the EU-funded COST action on PCM materials, and was led by the University of Zaragoza and the FhG-ISE [15].



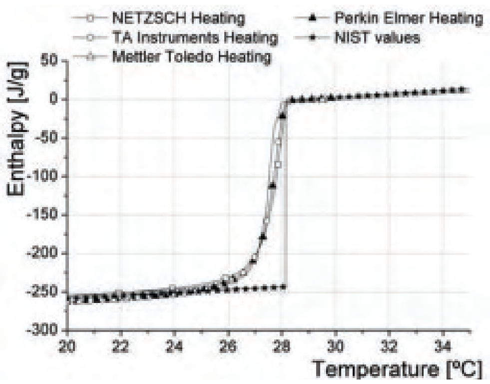


Figure 16. Comparison of the DSC results from different laboratories in the first RRT (left) and of the DSC enthalpy as a function of temperature results for heating in the third RRT (right).

Numerical Simulation

Important steps have been made in the development of numerical methods to model and predict the basic performance of storage materials. The numerical models work on a very wide range of sizes: from the molecular level, using basic physical principles to calculate the reaction kinetics of the materials, to the grain scale, where the heat and mass transfer behaviour in a bulk can be calculated. Important steps have been made in coupling the models to each other for the different length and time scales.

At Eindhoven University of Technology, a molecular level study was carried out to understand the chemical behavior of magnesium salts (chlorides and sulphates) during hydration and dehydration stages. Density Functional Theory (DFT) was used to study the molecular structures of magnesium sulfate hydrates [3,4]. Figure 17 shows the optimized structure of Magnesium sulfate hexahydrate. From the modeling, conclusions can be drawn about the functioning of bonds in the different stages of hydration.

Systems and Applications

Several new system concepts were developed and tested, mainly for the seasonal storage of solar energy, but also for district heating and for cooling applications. For seasonal heat storage, a system based on liquid sorption was designed and tested by the University of Savoie in France [1,2]. It consisted of two storage tanks with two falling film heat exchangers (desorber/absorber, condenser/evaporator), shown in Figure 18.

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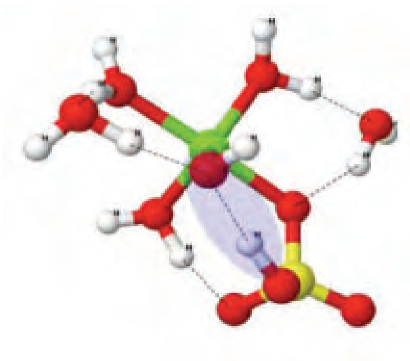

Figure 17. Optimized structure of magnesium sulfate hexa-hydrate. Mg: green, S: yellow, O: red and H: white. Hydrogen bonds are shown with dotted lines and proton transfer with the purple region.

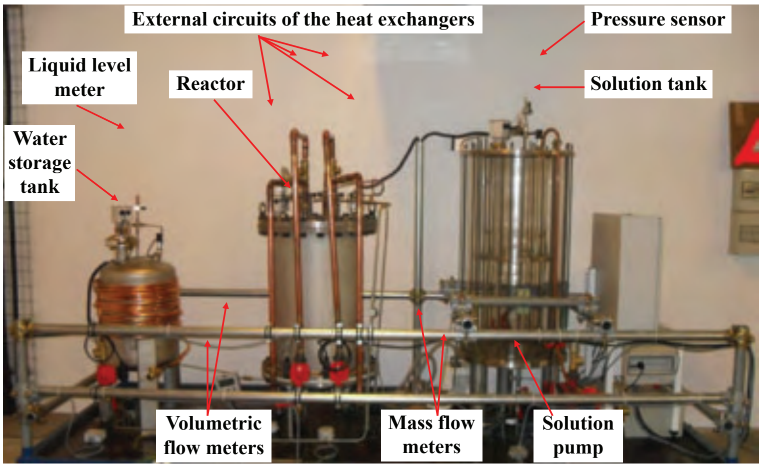

Figure 18. Experimental prototype for the liquid sorption system developed at the University of Savoie.

The Technical University of Graz, Austria, is working on improving the solar fraction of systems using phase change materials in cylindrical modules in the thermal storage. With TRNSYS numerical system modelling, optimal configurations can be found for a given relative volume of PCM in the storage, see Figure 19.

On the larger scale of district heating (DH) networks, the Austrian Institute of Technology (AIT) has modelled the impact of small-scale thermochemical storage units. It was found, amongst others, that the position of storage units in a DH network mainly influences the pumping costs and that heat distribution losses can be reduced, see Figure 20.

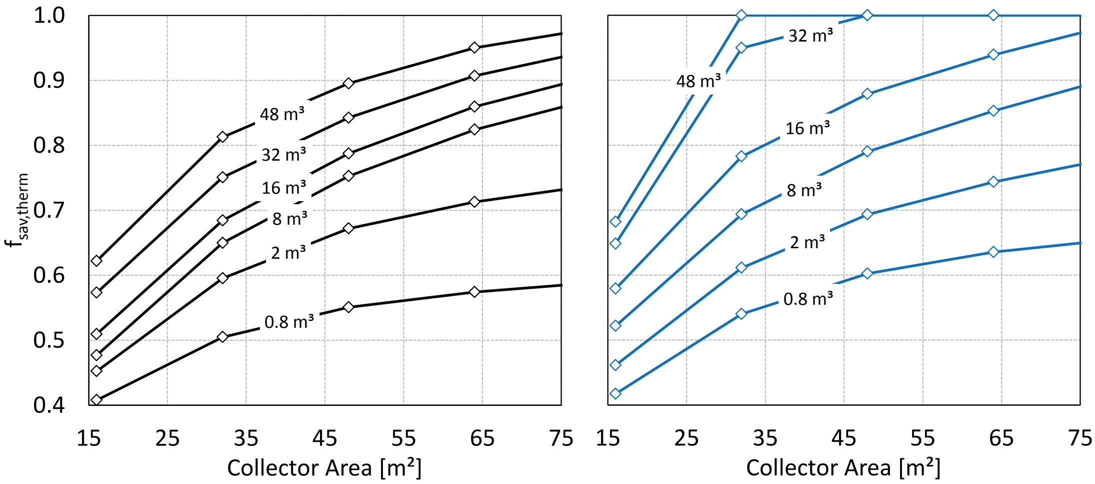

Figure 19. Fractional thermal energy savings as a function of the collector area for Water storage (left) and Water&PCM (right) for six different storage sizes, both using flat plate collectors.

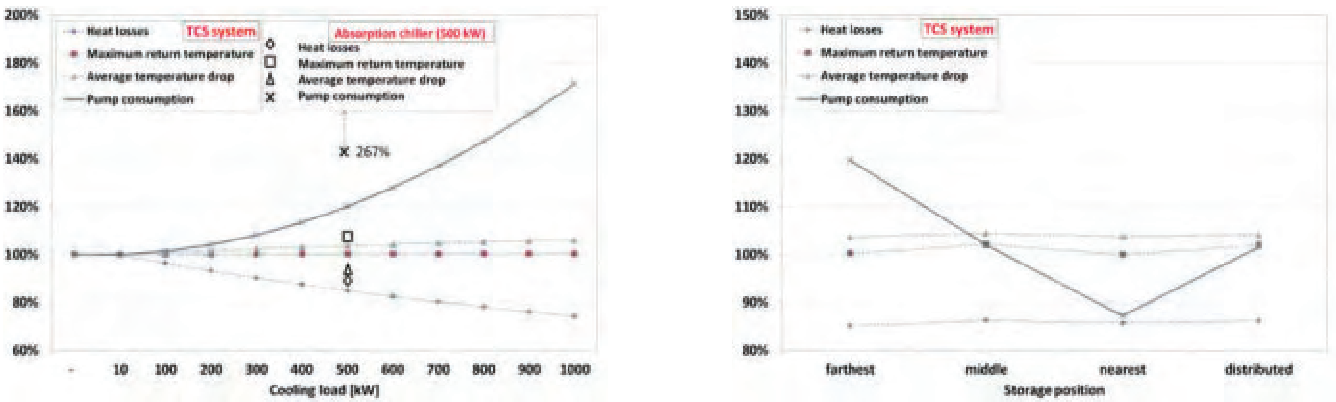

Figure 20. Assessment of key indicators with respect to the cooling load variation (left) and to the position variation (right).

Theoretical Limits

In order to improve estimates of the different storage materials and systems, work was done on finding the limits to these technologies on two different levels: the physical limits and the technical limits. For the physical limits, the search is for the connection between the type of material or reaction and the energy storage density that can be achieved. Figure 21 gives an example of proportionality rules that can be found from gathering the enthalpy of reactions in comparison to the melting and evaporation.

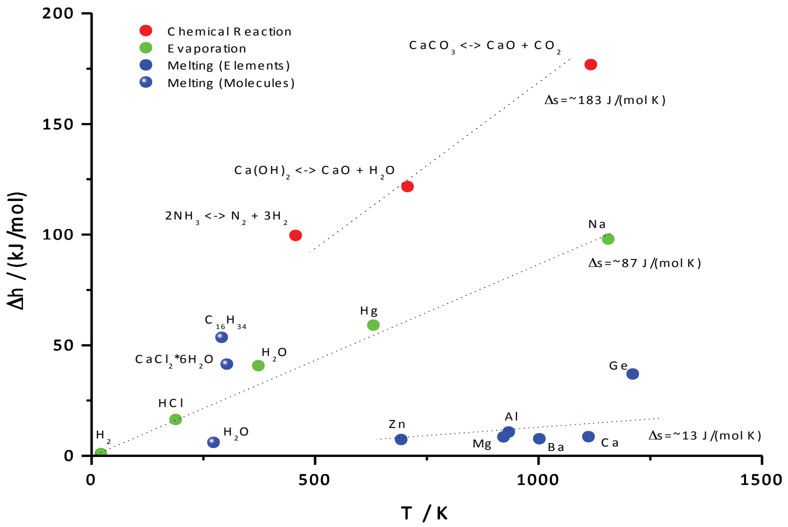

Figure 21. Reaction enthalpy for melting, evaporation and some selected reactions, as function of the temperature.

Acknowledgements

The Operating Agents would like to thank all the SHC/ECES Task participants for their invaluable contributions to the Task work. Authors from University of Zaragoza would like to thank Spanish government for partially funding this work, within the framework of research project: ENE2011-28269-C03-01 and ENE2011-22722.

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Task 39

Polymeric Materials for Solar Thermal Applications

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TASK DESCRIPTION

The objective of Task 39 is the assessment of the applicability and the cost-reduction potential by using polymeric materials and polymer based novel designs of suitable solar thermal systems and to promote increased confidence in the use of these products by developing and applying appropriate methods for assessment of durability and reliability. These goals will be achieved by either less expensive materials or less expensive manufacturing processes.

The Task's objectives are being achieved in the following Subtasks:

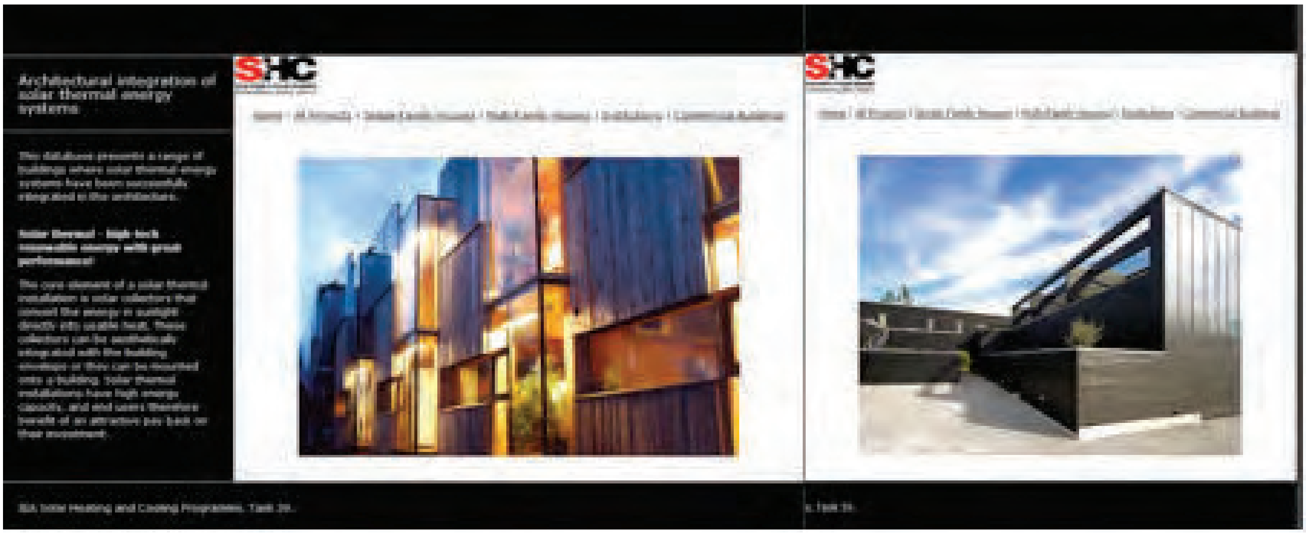
Subtask A: Information (Norway)
Subtask B: Collectors (Germany)
Subtask C: Materials (Austria)

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 penetration of good applications into the market.

Activities

- Updating of the state-of-the-art overview of existing applications of polymeric materials in solar thermal systems and other relevant industry sectors.
- Performance of two case studies, where a total cost accounting approach is adopted, for assessment of suitability of using polymeric materials in solar thermal applications.
- Investigation of standards, regulations and guidelines with regard to the applications of polymeric materials in solar thermal systems and building integration.
- Extension of the database consisting of showcases where solar collectors using mostly polymeric materials have been successfully integrated into the architecture.
- Dissemination of information of the work and results in all Subtasks 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 are focused on the development of:

- new collectors, made completely or partly with polymeric materials, with a profitable cost of ownerships,
- 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 from Subtask A, studies and development of new collectors, systems and components will be produced in order to show the feasibility, performance, durability and cost savings.

Subtask C: Materials

As shown in Phase I of Task 39, polymer engineering and science offer great potential for new products in solar thermal systems, which simultaneously fulfill technological and environmental objectives as well as social needs. The major achievements within Phase I of task 39 concerned the significant improvement in the long-term stability of an extruded polymer collector as well as the realization of a polypropylene based modular storage tank. Furthermore, a variety of novel polymeric material grades and components for solar-thermal systems (e.g., spectrally selective coatings with improved performance and commercial availability, 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, 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 in solar thermal systems have to fulfill a complex material property profile which can be provided only 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 development and investigation of multi-functional polymeric materials for various components in solar thermal systems considering different plant types and climate zones.
- Evaluation of polymer processing methods for the production of specimen and components with special focus up to the sub-component level (e.g., multi-layer films and sheets). Full components will be developed in Subtask B.
- Development of testing and characterization methods and modeling tools for the application-oriented assessment of the performance and durability.

Activities

- Formulation of 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).
- Compounding of polymeric materials considering a variety of functional fillers and additives allowing for improved processability and enhanced performance.
- Production of specimen and sub-components by applying various mass production processing technologies (e.g., injection molding, compression molding, extrusion, coating technologies, lamination and joining technologies).
- Establishment of 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.
- Implementation and application of analytical and technical methods for the characterization of properties, long-term behaviour and relevant aging and degradation phenomena.
- Establishment of micro-structure/ property/processing/performance relationships.

Duration

The SHC Executive Committee agreed on a 4-year Task extension. The Task was initiated on October 1, 2006 and will be completed on September 30, 2014.

Participating Countries

Austria, 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)

ACTIVITIES DURING 2012

Subtask A

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

A manuscript on results from the LCA performed in case study for publication in the Journal for Energy Materials and Solar Cells was submitted by B. Carlsson, H. Persson, J. Rekstad and M. Meir in July 2012. Acceptance is expected in 2013.

The handbook with compiled results of phase I was published on October 17, 2012. It is available from Wiley-VCH. ISBN: 978-3-527-33246-5.

Newsletters
- Task 39 Newsletter No. 10, June 2012
- Task 39 Newsletter No. 11, November 2012

Task 39 Workshop
- Chancen und Anforderungen für Kunststoffe in der Solarthermie, IEA-SHC Task 39 Workshop, Berlin, Germany, May 16, 2012

Subtask B

In September 2012, ITW from University of Stuttgart (Dr. Stephan Fischer) took over the Subtask B leadership. In order to speed up the progress in Subtask B an expert's workshop for the development of polymeric collector designs is planned for March 2013.

Subtask C

Multi-Functional Polymeric Materials

Polymeric Materials

SABIC joined Task 39 within the reporting period. Representatives attended the 14th Experts Meetings and gave an overview on PC sheets and SABIC-IP Solar Thermal Demo Collector Program. A new project on polymeric materials for solar facades was presented by AIT. A wall concept with phase change materials and thermotropic layers was developed and evaluated in order to improve the thermal comfort in rooms behind solar thermal facades.

Solar Absorber Compounds

Polypropylene exhibits 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. An objective within the research project SolPol-2 “Solar-thermal systems based on polymeric materials” is the identification and polymer-physical characterization of black pigmented PP grades. Recent research worked focused on two commercially available PP-Block-Copolymer grades (PP-B) and one PP-RCT (Polypropylene-Random Copolymer, Crystalline, Temperature resistance) development grade. The supplied materials were characterized on specimen level in the unaged state by UV-Vis-NIR spectroscopy, differential scanning calorimetry (DSC) and tensile testing at ambient temperature. The results revealed that pigmentation with carbon black is a suitable technique to fulfill high absorbance requirements (solar absorbance > 95%). Depending on the copolymer type and the additive package melting peak temperatures ranging from 135 to 170°C were obtained. Regarding the mechanical properties significant differences in the ultimate properties (e.g. strain-at-break) were detected. Due to the fact that PP-RCT is adopted for pressurized pipe applications, this grade was selected for further material development and optimization in SolPol-2.

Thermotropic Materials

PCCL reported on current achievements in the development of polymer based thermotropic materials for the collector glazing. By theoretical modeling it was shown that the switching potential of thermotropic materials with spherical fixed domains is from about 90% to 50% in hemispheric transmittance. The model materials developed and the experimental characterization revealed that these theoretical limits are not fully achieved due to imperfect phase formation. Further work focusses on the stabilization of spherical domains in the nm-range by surface modification.

Spectrally Selective and Photo-catalytic Coatings

The spectrally selective coatings developed by NIC (Slovenia) are now commercially used for the coating of metal and polymer substrates by Alanod (Germany). The polymer based coatings are commercialized under the brand-name Mirosol TS®. Compared to conventional PVD coatings significant cost reductions could be achieved. Current research work at NIC is focused on photo-catalytic clear coatings. The TiO_2 based coatings exhibited haze, yet their efficacy was up to 10 times higher compared to that of Pilkington TM commercial coatings on glass.

Liner Materials

In the reporting period the thermo-mechanical properties of polymeric liner materials for long-term heat storages were reported. At JKU-IPMT selected polyolefin materials were characterized by tensile testing and dynamic mechanical analysis (DMA). The stiffness (modulus) of the investigated polymeric materials is in the operating temperature range up to 90°C significantly dependent on temperature. The elastic moduli decreased by up to 85 % with an increase from 30°C to 95°C (i.e., maximum service temperature). DMA revealed a decrease of the storage modulus of up to 40 % from 5°C to 30°C, which are the ambient temperatures during the installation of heat storages in the field. Thus, the flexibility required for proper laying and welding is significantly dependent on temperature. It was emphasized, that stiffness characterization by tensile testing (single-point data) should be combined with thermo-mechanical stiffness characterization by DMA in order to thoroughly describe the material stiffness properties.

Methods for Testing and Characterization of Polymeric Materials

Methods for Aging Characterization

In addition to Fraunhofer-ISE, HU Berlin, JKU Linz one further partner (JKU-IAC) joined Task 39. The special expertise of JKU-IAC is on analytical test methods for the identification and quantification of stabilizers in polymeric compounds. JKU-IAC reported on novel wet-chemical methods for sample preparation and stabilizer analysis. The portfolio of identified stabilizers was presented along with relevant degradation products due to aging under service relevant conditions. Fraunhofer-ISE provided an overview of the EU-FP7 project SCOOP (Solar COllectors made Of Polymers) with special emphasis on accelerated aging and analysis methods, which are currently adopted for fiber-reinforced materials.

PUBLICATIONS & PRESENTATIONS IN 2012

Book

Koehl et al. Polymeric Materials for Solar Thermal Applications. Weinheim: Wiley-VCH, 2012. ISBN: 978-3-527-33246-5

Conferences and Seminars with contributions from Task 39

Fachforum Kunststoffe: Einsatz in der Solarthermie, OTTI Technologie Kolleg, R gensburg, Germany, February 13-14.

DVS-Forschungsseminar „Kunststofffügetechnik in Leichtbau und erneuerbaren Energien", March 6, Erlangen, Germany.

22nd Symposium Thermische Solarenergie, Bad Staffelstein, Germany, May 9-11, 2012.
SHC 2012 – International Conference on Solar Heating and Cooling for Buildings and Industry, San Francisco, USA, July 9-11.

International Conference Gleisdorf Solar 2012, Gleisdorf Austria, September 12-14.

Task 39 Workshop

Chancen und Anforderungen für Kunststoffe in der Solarthermie, IEA SHC Task 39 Workshop, Berlin, Germany, May 16, 2012.

Publications in Journals and Conference Proceedings

Stefan Brunold, 2012. Kollektorverglasung aus Kunststoff – Chancen und Risiken. Proceedigs: Fachforum Kunststoffe: Einsatz in der Solarthermie, OTTI Technologie Kolleg, Regensburg, Germany, Feb. 13-14, 2012.

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MEETINGS IN 2012

13th Experts Meeting & Open Industry Workshop

May 15-16
Berlin, Germany
42 participants from the plastics industry and research and/or the solar thermal sector participated in the event.

14th Experts Meeting

October 15-17
Pozo Izquierdo, Gran Canaria, Spain
6 experts participated in the meeting, among them new experts from industrial companies and research institutes from the Netherlands and Sweden.

MEETINGS PLANNED FOR 2013

15th Experts Meeting & Subtask B Workshop

March 13-15
Palma, Mallorca, Spain

16th Experts Meeting

October 9-11
Blumau, Austria

Funded Projects

Overview of funded projects of Task 39 Partners (November 2012, http://www.iea-shc.org/task39/fundedprojects/).

Project	Period	Funding Agency	Partner Countries
Poly2Facade – Innovative thermal self-regulating solar facades by means of functional polymers Coordinator: University of Leoben; Partners: PCCL, ÖFPZ Arsenal GesmbH, Forschungszentrum für integrales Bauwesen AG	2012-15	Forschungsförderungsgesell-schaft (FFG), Programmlinie Haus der Zukunft	AT
Untersuchungen zur Fertigungstechnik und Kollektorkonstruktion für Voll-kunststoff-Kollektoren Partners: HAW Ingolstadt, Roth Werke GmbH	2012-15	Bundesministerium für Umwelt, Naturschutz und Reaktorsi-cherheit	DE
SCOOP - Solar Collectors of Polymers Coordinator: Fraunhofer Institute for Solar Energy Systems - ISE Partners: http://eu-scoop.org/partners.html Website: http://eu-scoop.org/	2011-15	EU FP7-ENERGY-2011-1	DE, AT, FR, NO, CH
Exkoll - Konzeption von extrudierten Polymerkollektoren und Komponenten Coordinator: Fraunhofer Institute for Solar Energy Systems – ISE	2012-2014	Bundesministerium für Umwelt, Naturschutz und Reaktorsi-cherheit	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 Ver-kehr, Innovation und Techno-logie; 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/actions/project?id=C16/2011/21507&search=global&actionbean=actions/project	2011-14	Portuguese Agency for Deve-lopment and Innovation	PT, NO
POLYSOL - Development of a modular, all-POLYmer SOLarthermal collec-tor 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, Zukunfts-fonds 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 per-spective - Participation in IEA SHC Task 39 Coordinator: Linnæus University; Partners: Aventa AS, University of Oslo	2009-12	Swedish Energy Agency	SE, NO

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Task 40

Towards Net Zero Energy Solar Buildings

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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, programmes and industry adoption around the world.

Objective

The objective of this joint Task with the IEA ECBCS Programme (Annex 52) is 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 is to document and propose practical NZEB demonstration projects, with convincing architectural quality. These exemplars and the supporting sourcebook, guidelines and tools are viewed as keys to industry adoption. These projects aim to equalize their small annual energy needs, cost-effectively, through building integrated heating/cooling systems, power generation and interactions with utilities.

The Task will build 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 will address concerns of comparability of performance calculations between building types and communities for different climates in participating countries. The goal is solution sets that are attractive for broad industry adoption.

Scope

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

Subtask A: Definitions & Implications

(Subtask Leaders: Karsten Voss, Germany and Assunta Napolitano, Italy)

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

- The 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.
- A study of grid interaction (power/ heating/cooling) and time dependent energy mismatch analysis.
- The development of a harmonized international definition framework for the NZEB concept considering large-scale implications, exergy and credits for grid interaction (power/heating /cooling).
- The 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 aims to identify and refine design approaches and tools to support industry adoption. The Participants shall achieve this objective by the following activities:

- Documenting processes and tools currently being used to design NZEBs and under development by participating countries.
- Assessing 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.
- The 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 are 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 shall achieve these objectives by the following activities:

- Documenting and analyzing 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).
- Developing and assessing case studies and demonstration projects in close cooperation with practitioners.
- Investigating advanced integrated design concepts and technologies in support of the case studies, demonstration projects and solution sets.
- Developing 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 is to support knowledge transfer and market adoption of NZEBs on a national and international level. Subtask leaders will be responsible for the coordination of the individual contributions of Subtask participants and for coordination with the other Subtasks where a combined output is planned. The Participants shall achieve the objectives by the following activities:

- Establishing an 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.
- Producing a NZEB source book including example buildings for investigated building types and climates.
- Transferring the Task outputs to national policy groups, industry associations, utilities, academia and funding programs.
- Establishing 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.

Duration

This Task was initiated on October 1, 2008 and remains in force until September 30, 2013.

Participating Countries

Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, South Korea, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, United Kingdom, United States

SHC Task 40 / ECBCS Annex 52nd National Experts and observers attending the 8th Experts Group Meeting, October 1 – 3, 2012, Barcelona, Spain.

WORK DURING 2012

Subtasks work is proceeding as per work plans. Highlights of accomplishments include:

- Conducted the 2nd PhD summer workshop to be hosted by France at the l'Institut des Rechereches Scientifique des Carsege, in conjunction with the 8th Task Experts Meeting in the 3rd quarter of 2012.
- Two Technical Reports completed posted on website.
- Negotiated with Wiley & Sons the publications of Volumes 2 and 3 of the sourcebook.
- National experts participated in the 1st Annual Solar Heating and Cooling Conference, June 2012 in San Francisco, USA.
- Discussions with China to join Task.
- Continually upgrading the Task File Sharing System and the Task public website.

WORK PLANNED FOR 2013

- Final drafts of Volumes 2 and 3.
- Final work on NZEB Tool framework.
- Wikipedia entries on Task 40 NZEB.
- Final Monitoring report.
- Fact Sheet of 3 case studies.

REPORTS PUBLISHED IN 2012

Technical Reports

"Survey of Current Practices for checking balances in Net ZEB Projects" by Assunta Napolitano and Roberto Lollini. A Report of Subtask A (A2).

"Zero Energy Building definition - A Literature Review" by Anna Joanna Marszal and Per Heiselberg. A Report of Subtask A (A1).

"LCA and embodied energy for NZEBs" by National Experts from Sweden (Björn Berggren) and Switzerland (Monika Hall).

Over 25 papers of these papers are posted for free downloading from the Task website, http://www.iea-shc.org/task40/

MEETINGS IN 2012

7th Experts Meeting
May 8 - 11
Naples, Italy

8th Experts Meeting
October 1 - 3
Barcelona, Spain
(In conjunctions with 2nd PhD workshop, September 25-29 Carsège Corsica, France)

MEETINGS PLANNED FOR 2013

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

10th Experts Meeting
October 1 - 3
Montreal, Canada

SHC TASK 40/ECBCS ANNEX 52 NATIONAL CONTACTS

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Task 41

Solar Energy and Architecture

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TASK DESCRIPTION

It is clear that solar energy use can be an important part of the building design and the building's energy balance to a much higher extent than it is today. Cleverly used, active and passive solar energy can both contribute to the energy supply and to a higher quality of the architecture.

Despite all the available solar technologies and the opportunity to reduce the energy demand, solar energy systems are in most cases not used in buildings today. This has several causes:

- Economical factors such as investment costs and maintenance costs.
- Technical knowledge factors, such as lack of knowledge among decision makers and architects, as well as a general reluctance to "new" technologies.
- Architectural (aesthetic) factors: solar technologies for building use have an important impact on the building's architecture. Due to the large size of solar systems in relation to the scale of the building envelope, the architectural quality of their integration has a major impact on the final architectural quality of the building. In this respect, the limit to the spread of solar technologies lies in the generally poor architectural quality of their integration into the building envelope.

Task 41 focused on the architectural factors and was intended to support promoting the use of solar technologies as a complement to promotion policies focusing on subsidies and technical information spread.

The main goals of the Task were to help achieve high quality architecture for buildings integrating solar energy systems, as well as improving the qualifications of the architects, their communications and interactions with engineers, manufactures and clients. Increased user acceptance of solar designs and technologies will accelerate the market penetration. The overall benefit will be an increased use of solar energy in buildings, thus reducing the non-renewable energy demand and greenhouse gas emissions.

The scope of the Task covered residential and non-residential buildings. Both new and existing buildings were included, for the climatic zones represented by the participating countries. The work was linked to national activities and focused on individual buildings or groups of buildings, with a special focus on the building envelope.

Subtask A: Criteria for Architectural Integration

(Lead Country: Switzerland)

This Subtask focused on architectural integration of *active* solar energy collector systems (solar thermal, PV and hybrids technologies) that offer an important potential for improvement regarding architectural integration. The objectives were to:

- Establish and communicate architectural criteria for the integration of active solar energy systems in the building envelope.
- Give recommendations to the industry to improve the architectural integration quality and flexibility of active solar products and systems (integrabability).
- Bring together architects and product/system developers to understand each other's needs.
- Educate/inform architects on integration characteristics for various technologies and on state of the art of innovative products.

Subtask B: Methods and Tools

(Lead Country: Canada)

This Subtask focused on methods and tools for architects, to use in the early design stage (EDS). The objectives were to:

- Achieve a comprehensive review of existing methods and tools (state-of-the-art) that architects currently use at EDS when designing buildings which integrate active/passive solar components.
- Identify current barriers that prevent architects from using the existing methods and tools for solar building design.
- Identify important needs and criteria for new or adapted methods and tools to support architectural design and integration of solar components at EDS.
- Provide clear recommendations for developers of methods and tools used by architects designing solar buildings.
- Initiate communication with tool developers (industry) in order to stimulate the development of tools based on the recommendations written.
- In collaboration with Subtask C, describe the significant role that tools for solar design play for architects besides aiding them in solar design during the early design phase, to be included in the Communication Guidelines.

Subtask C: Concepts, Case Studies and Guidelines
(Lead Country: Denmark, with support from Norway)

This Subtask focused on concepts for architectural integration as well as case studies, with a whole building perspective. The Subtask also condensed the results into communication guidelines, with support from Subtask A and B. The objectives of this Subtask were to:

- Present concepts and principles for high quality architectural integration of solar systems, based on analyses of existing systems as well as proposals for future systems through national and international architectural evaluations.
- Case studies were used to illustrate building concepts that utilize active and passive solar energy, achieving high quality architecture, sustainable solutions, attractive indoor climate and high energy performance. The case studies should aim at reducing the energy demand in buildings and increasing the fraction of renewable energy use such as solar energy.
- Develop knowledge and strategies to promote and implement high quality architecture using solar energy.

Duration

The Task commenced in May 2009 and ended in 2012.

Participation

Overall 30 organisations (6 research institutes, 15 universities and 9 companies) from the following 14 countries participated in Task 41: Australia, Austria, Belgium, Canada, Denmark, Germany, Italy, Norway, Portugal, Republic of Korea, Singapore, Spain, Sweden, and Switzerland.

TASK ACCOMPLISHMENTS

The main objectives of Task 41 were to help achieving high quality architecture for buildings integrating solar energy systems, as well as to improve the qualifications of the architects and their communications and interactions with engineers, manufactures and clients.

The following is a brief report on the accomplishments of each single work activity within the Subtasks. The main authors and/or editors are listed, but many more contributed and are listed in each specific report. All the main deliverables will be available on the SHC Task 41 website.

Subtask A: Criteria for Architectural Integration

Building Integration of Solar Thermal and Photovoltaics – Barriers, Needs and Strategies
Authors: Farkas, K. & Horvat, M.
This first report of Subtask A describes the results of a large international survey on the reasons why architects do not use or rarely use solar technologies, and gives proposals to help overcome these barriers by identifying the architect's needs in this area.

Solar Energy systems in Architecture - integration criteria and guidelines
Authors: Munari Probst MC & Roecker C.
This document was developed for architects, and written with a practical approach. It summarizes the knowledge needed to integrate active solar technologies (solar thermal and photovoltaics) into buildings, handling at the same time architectural integration issues and energy production requirements. Solar thermal and photovoltaics are treated separately, but the information is given following the same structure: 1) Main technical information; 2) Constructive/functional integration possibilities in the envelope layers; 3) System sizing and positioning criteria; 4) Good integration examples; 5) Formal flexibility offered by standard products; and 6) Innovative market products. To complete the information, the manual ends with a short section describing the differences and similarities between solar thermal and photovoltaic systems, which should help architects make an energetic and architecturally optimized use of the sun exposed surfaces of their buildings.

Designing solar thermal systems for architectural integration: Criteria and guidelines for product and system developers
Authors: Munari Probst M C & Roecker C.
Designing photovoltaic systems for architectural integration: Criteria and guidelines for product and system developers
Authors: Farkas K, Frontini F, Maturi L, Munari Probst MC, Roecker C & Scognamiglio A.
This deliverable is comprised of two separate publications addressed respectively to manufacturers of photovoltaic and solar thermal systems. These two documents follow the same structure and are based on a common theoretical work. They describe the main criteria for a successful integration of solar systems in buildings and propose a methodology for the design of systems specifically conceived for building integration. For each specific solar technology and sub-technology, they provide a comprehensive set of practical recommendations that should lead to the production of new systems appealing to architects. These two documents will be published in February/March 2013.

Website: Innovative solar products for architectural integration
Authors: Munari Probst MC, Roecker C., Deschamps, L. et al.
This website shows in an attractive way the innovative/inspiring solar products for building integration presently available on the market. The website is developed for architects and has three sections: photovoltaic, solar thermal and hybrid systems. By choosing a specific technology and integration approach (roof integration, façade integration, balcony etc) the user receives a selection of appropriate products, presented in the form of virtual A4 sheets. These sheets include dedicated information, contact details and pictures, both of the product alone and in situation on buildings. See http://solarintegrationsolutions.org/.

Innovative products – patents

The National University of Singapore (NUS) developed solar modules for building integration, with the following patents:

1. Title: Photovoltaic Module for Integration in Buildings
   US Provisional Application No. : 61/494,546
   Inventors: S. Wittkopf, H. Yixiang, T. Walsh
2. Title: Building Integrated Photovoltaic Blinds with Anidolic Daylight Redirection
   US Provisional Patent Application No. 61/540,064
   Inventor: S. Wittkopf
3. Title: Microstructure for Vertical Building Integrated Photovoltaic Facades
   US Provisional Application No.: 61/577,759
   Inventor: S. Wittkopf

IEA SHC Task 41 Product developments and dissemination activities

Editors: Lobaccari, G & Wall, M.

A document was compiled showing product developments and dissemination activities carried out within the framework of, or in close relation to, Task 41. It is not a complete list, but shows the different types of activities to share the findings from Task 41 and to initiate product developments in participating countries. This contains activities across subtasks.

Subtask B: Subtask B: Methods and Tools

State-of-the-art of digital tools used by architects for solar design

Editors: Dubois M-C & Horvat M.

The first stage of work in Subtask B was to review and analyze the current software landscape available for architects, with a focus on early design phase (EDP) decisions of building projects, and to identify missing software tools and/or missing functionalities required for encouraging and enhancing solar design of buildings and the integration of solar systems and technologies. This report includes 56 software packages, which were classified in three categories: CAAD (computer-aided architectural design) tools, visualization tools and simulation tools.

International survey about digital tools used by architects for solar design

Editors: Horvat M, Dubois M-C, Snow M & Wall M.

The second stage of the project aimed at learning from users (i.e., architects) about their satisfaction with currently available tools and methods for solar design, as well as to identify obstacles that they are facing especially during the early design phase. An international survey was carried out in 14 participating countries during 2010. This deliverable is the full survey report, with a description of the survey and a detailed discussion of the results.

Solar Design of Buildings for Architects: Review of Solar Design Tools

Editors: Horvat M & Wall, M.

The third report of subtask B presents the capabilities of 19 CAAD and Building Performance Simulation (BPS) digital tools for solar design, in order to increase overall awareness, and provide inspiration and incentive for the future choice of tool(s). The review was carried out by using the same building model as input for all tools, as far as possible. In addition, the second part of the report presents three exemplary case stories that intend to convey valuable experience as they describe different design approaches, which tools were used and how the use of solar design tools affected the design process and final architectural design.

Needs of architects regarding digital tools for solar building design

Authors: The Subtask B expert group.

This important outcome of Subtask B is a reach-out to the industry and digital tool developers in the form of a letter, clearly stating the perceived needs of professional architects, as they had been identified through the international survey and by Task 41 experts through experience and research reviews.

Solar components 3D parametric CAAD objects

- **Switzerland:** Solar objects were developed, compatible with both Graphisoft ArchiCAD and Autodesk AutoCAD. The main goals of the new tool are to speed up the rendering procedure when integrating PV systems in building design, to facilitate and stimulate the use of BiPV (Building integrated Photovoltaic) systems by architects and designers and to improve the architectural quality of BiPV systems. It was developed by the Institute for Applied Sustainability to the Built Environment (ISAAC) in collaboration with IDC AG, the Swiss national Graphisoft distributor (responsible for CAD object programming), as a part of a national Swiss project: BiPV Tools, Interactive tools and instruments supporting the design of building integrated PV installations. The modules were tested by Task 41 participants. The modules are available for free downloads from the following website: www.bipv.ch/index.php?option=com_content&view=article&id=338&Itemid=306&lang=en

- **Singapore:** 17 BIPV modules were prepared and presented as software libraries in 8 parametric Revit families and export formats compatible with AutoCAD and IFC. They are available for all Task 41 participants. Contact person: Stephen Wittkopf (former SERIS, NUS), Lucerne University of Applied Sciences and Arts, Switzerland.

Chapter 7 "Tools" in T.41.C.1 Communication Guideline

Authors: Horvat M, Lechner A & Kanters, J.

Chapter 7 in the report T.41.C.1 describes a significant role that tools for solar design play for architects besides aiding them in solar design during the early design phase. Proper tools can be a powerful means of communication between actors throughout the entire design and construction process: from negotiations with the client and client's advisors to dialogue with engineers, solar consultants, component manufacturers and installers at later stages. See also Subtask C.

Subtask C: Concepts, Case Studies and Guidelines

Communication Guideline – The Communication Process

Editors: Hagen R, & Jørgensen O B.

In order to stimulate an increased use of solar in energy conscious building design, the Task 41 participants developed a Communication Guideline as a tool to support architects in their communication process with especially clients, authorities and contractors. Today the energy performance of solar solutions is well documented and well known especially in the "technical environment". This knowledge, however, needs to be communicated in a convincing way to the decision makers in order to ensure a broad implementation of sustainable solar solutions in future building design. The Communication Guideline includes convincing arguments and facts supporting the implementation of solar based design solutions. The Communication Guideline is divided in three main parts:

- Part 1: Convincing clients to request and commission solar buildings
- Part 2: Communication strategies at the design/ construction team level
- Part 3: Tools and References.

Website: Collection of Case Studies of architecturally attractive solar buildings

Jørgensen O B & Kappel K (editors) and the Subtask C expert group.

A collection of case studies demonstrating architecturally attractive energy efficient solar buildings has been developed. The case study collection includes a wide range of new built or retrofitted building types. The solar technologies include passive elements and active elements (PV and Solar Thermal). More than 250 case studies have been proposed and evaluated by a broad range of trained architects from universities, research institutes, dissemination organisations and professional practices. Around 50 projects from 11 countries are included in the Collection of Case Studies. The evaluation process focused on criteria of specific importance with respect to architecture and energy:

- The overall global composition: How solar energy is integrated in the whole concept of the building and contributes to high architectural quality
- Detailed description of surface and materials: How solar energy is used in considerations of design, which contributes to architectural quality
- Added value and functions: How solar energy contributes to spatial experiences or other added values, which contribute to architectural quality.

The Collection of Case Studies will be available on the IEA SHC Task 41 website (http://task41.iea-shc.org/) in February/March 2013. Case studies can be downloaded based on own choices from the available various categories: Solar Technology, Project Type (new build or retrofit), Country, Architectural Typologies, Building Type and Construction Year. These selected innovative examples show that already today appealing and energy-efficient architecture can be achieved using solar energy in buildings.

Workshops and Conferences

The following are workshops and conferences Task participants contributed to with results of their work achieved within the frame of the Task or with results of the Task work. It also includes workshops and seminars organized to discuss and get input to the Task.

Workshop/Conference	Place	Date
Facilitate the acceptance of solar installations in the built environment	Luzern, Switzerland	23-24 March 2009
Interactive tools and assistance for the architectural integration of solar installations	Lugano, Switzerland	16-17 Nov. 2009
Workshop: Opportunities of collaboration between the building and solar sectors	Trübbach (Oerlikon), Switzerland	1-2 Feb. 2010
Architectural Workshop: Certification and Quality of Building Integrated PV and thermal collectors	Bolzano, Italy	19 March 2010
Conference ACFAS	Montreal, Canada	May 2010
Seminar: Forms of Energy	Rome, Italy	10 June 2010
EuroSun 2010; International Conference on Solar Heating, Cooling and Buildings	Graz, Austria	Sept. 2010
Workshop: A new generation facades providing cooling and heating	Stockholm, Sweden	16 Sept. 2010
The 2nd symposium on active solar building, OTTI	Luzern, Switzerland	22-23 Sept. 2010
Architectural Workshop linked to Klimaenergy Fair	Bolzano, Italy	23 Sept. 2010
Workshops (5): Formal characteristics of Photovoltaics	Trondheim (3), Norway Oslo (2), Norway	March, Sept. 2010 Sept., Oct. 2010
Conference Color and Light in Architecture	Venice, Italy	11-12 Nov. 2010

Workshop/Conference	Place	Date
Integrating Solar Technologies, Continuum Program and National Seminar Series, Australian Institute of Architects	Australia: on web	Dec. 2010-Jan. 2011
Bau Z congress, IBO	Vienna, Austria	17-18 Feb. 2011
Seminar: Solar Energy and Architecture – Knowledge and Inspiration	Oslo, Norway	1 April 2011
OTTI Symposium; Active solar systems	Bad Staffelstein, Germany	May 2011
Workshop Futurebase: Architectural integration of PV and solar thermal panels- best practice examples	Vienna, Austria	2 May 2011
CRSEEL 2011; conference on sustainable construction including solar technologies.	Caparica/Lisbon, Portugal	18 May 2011
The PhD Workshop Net-Zero Energy Solar Buildings: Theory, modelling, and Design. Concordia University. IEA SHC Task 40/41.	Montreal, Canada	20-25 June 2011
Modern – Construction Workshop	Vienna, Austria	5 July 2011
PLEA Conference 2011	Louvain, Belgium	13-15 July 2011
ISES Solar World Congress 2011	Kassel, Germany	28 Aug - 2 Sept. 2011
The 26th European Photovoltaic Solar Energy Conference and Exhibition	Hamburg, Germany	5-9 Sept. 2011
CISBAT Conference	Lausanne, Switzerland	14-16 Sept. 2011
Klima Energy	Bolzano, Italy	23 Sept. 2011
Seminar: Forms of Energy. A side event of the26th EUPVSEC	Hamburg, Germany	26 Sept. 2011
Melbourne Forum. Seminar: Solar Energy and Architecture	Melbourne, Australia	28 Sept. 2011
Joint IEA SHC, APVA and Sustainability Victoria Latest International Solar Technologies for Buildings Seminar	Melbourne, Australia	29 Sept. 2011
9th Photovoltaic Conference	Vienna, Austria	20-21 Oct. 2011
Seminar at Natural Resources Canada (NRCan) for Professional and researchers	Calgary, Canada	Oct. 2011
Seminar: Arkitektur & Solenergi	Stockholm, Sweden	17 Nov. 2011
6th Energy Forum Seminar for the building actors	Bressanone, Italy	6-7 Dec. 2011
Workshop for master students	Vienna, Austria	Autumn 2011

Workshop/Conference	Place	Date
Workshop/course: Innovation School – ENERBUILD 2011	Bolzano, Italy	Sept. – Dec. 2011
Architectural dissemination workshop: Klimahouse 2012: "Fotovoltaico integrato: la sfida per gli edifici del futuro"	Bolzano, Italy	26 Jan. 2012
Seminar at Illinois Institute of Technology, IIT	Chicago	Jan. 2012
Seminar at Dawson College, Montreal	Montreal, Canada	Feb. 2012
Architectural workshop: Energy MED. „Fotovoltaico e Preesistente. Spunti di discussione sull'impiego del fotovoltaico nelle città e nel paesaggio"	Naples, Italy	22 March 2012
IAHS World Congress	Istanbul, Turkey	16-19 April 2012
Architectural Workshop: Bread and Environment	Oslo, Norway	2 May 2012
22nd symposium Solar Thermal Energy	Bad Staffelstein, Germany	9-11 May 2012
The annual conference of Ontario Association of Architects	Ottawa, Canada	10-12 May 2012
The annual conference of L'Ordre des architectes du Québec	Montreal, Canada	31 May - 2 June 2012
Cities in transformation – Research & Design Conference	Milano, Italy	7-10 June 2012
SHC 2012; International Conference on Solar Heating and Cooling for Buildings and Industry	San Francisco, USA	9-11 July 2012

Journal Articles and Conference Papers/Presentations

In total, the participants reported more than 90 journal articles and conference papers and/or oral presentations that were carried out.

LINKS WITH INDUSTRY

The collaboration with industry included different types of industry. In Task 41 only minor direct participation came from the product/system industry (mainly from Norway and Switzerland). However, some of the Task participants collaborated with companies locally within their country, thus indirectly participating. The communication with the solar product industry and tool developers was organized by workshops and seminars and by direct contact with companies/employees. When including architect firms and consultants as industry, there was active (official) participation from 9 companies within 5 countries.

CONCLUSIONS/RECOMMENDATIONS

Task 41 focused on three main components related to architectural barriers 1) limitations of active solar products for building integration, 2) architects' limited knowledge regarding the possibilities offered by available solar technologies and products, and 3) a lack of tools to quantify, visualize and communicate the effect of solar systems at the EDP.

The work within Task 41 showed that although good examples of solar components and architecturally appealing solar buildings exist, there is still need for further developments in terms of products, design tools, and skills. More solar products are needed with improved flexibility in sizes, surface textures and colours, jointing etc, as well as dummy elements (with the same appearance as active elements), which could be used on parts of facades and roofs not suitable for active elements. On the other hand, thanks to the growing interest of architects for solar use, manufacturers are becoming increasingly aware of the need for new products specially adapted to architectural integration, or at least for an increased flexibility in their existing products, leading to novel development activities also in the less developed field of solar thermal integration.

Subtask A also showed the need for dissemination of existing knowledge regarding solar energy applications, innovative products and solutions. Seminars and courses for practising architects and students in architecture and engineering are needed. Fortunately, one of the important deliverables of this Task is production of workshops and seminars for architects in the participating countries. Some of these workshops have already been held with positive outcomes. However, the current curriculum within schools of architecture offers a limited range of courses regarding energy-efficient buildings in general and solar energy issues in particular. Increasing the offer of courses in these key areas would certainly contribute to accelerate the development of solar architecture around the world.

Subtask B showed that many digital tools can handle solar energy issues but these tools are mainly suitable for engineers and for an advanced design phase. Tools for the EDP, when key formal building decisions are taken, are still very limited or not integrated in the normal workflow of architects. Such tools are needed to support the architects in their work and also to support their communication with the client, consultants, the municipality for building permits, etc. Tool developments as well as development of CAAD objects for solar components are therefore urgently needed.

As part of the Subtask C activities, a considerable amount of architecturally inspiring solar buildings were identified. This is encouraging since good examples of buildings and architecturally well-integrated solar systems are important, both to convince architects and clients and to make the buildings welcome in the built environment. However, architecturally inspiring examples of energy-efficient building renovation with solar are few and need to be encouraged further. Our vision – and the opportunity – is to make architectural design a driving force for the use of solar energy!

Good examples of urban areas with a conscious planning of solar energy use and energy-efficient buildings were originally planned to be part of Task 41. However, one important conclusion was that only few good examples on solar energy in urban planning exist today and a vast development is needed regarding strategies, methods, tools and case studies on the urban level. This could not be handled within the short time frame and scope of Task 41. Therefore, the new Task 51 “Solar Energy in Urban Planning” will start in May 2013.

More buildings with integrated solar systems are needed. Photo: Maria Wall.

KEY REPORTS/PUBLICATIONS (expected publication dates included)

All reports will be available on the SHC website

ReportNo.	Report Title	Publication Date	Access (PUblic, REstricted)	Web or Print
T.41.A.1	Building Integration of Solar Thermal and Photovoltaics – Barriers, Needs and Strategies	June 2012	PU	Web
T.41.A.2	Solar Energy systems in Architecture - integration criteria and guidelines	July 2012	PU	Web
T.41.A.3/1	Designing solar thermal systems for architectural integration: Criteria and guidelines for product and system developers	Feb 2013	PU	Web
T.41.A.3/2	Designing photovoltaic systems for architectural integration: Criteria and guidelines for product and system developers	Feb 2013	PU	Web
Website	Innovative solar products for architectural integration	July 2012	PU	Web
List of activities	IEA SHC Task 41 Product developments and dissemination activities	July 2012	PU	Web
T.41.B.1	State-of-the-art of digital tools used by architects for solar design	July 2010	PU	Web
T.41.B.2	International survey about digital tools used by architects for solar design	August 2011	PU	Web
CAAD objects	Solar components 3D parametric CAAD objects	November 2011	PU	Web
T.41.B.3	Solar Design of Buildings for Architects: Review of Solar Design Tools	June 2012*	PU	Web
T.41.B.4	Needs of architects regarding digital tools for solar building design	June 2012	PU	Web
T.41.C.1	Communication Guideline – The Communication Process	July 2012	PU	Web
Website	Collection of Case Studies of architecturally attractive solar buildings	Feb 2013*	PU	Web

MEETINGS HELD IN 2012

7th Expert Meeting (final meeting)
March 27-30
Lisbon, Portugal

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Task 42

Compact Thermal Energy Storage: Material Development for System Integration

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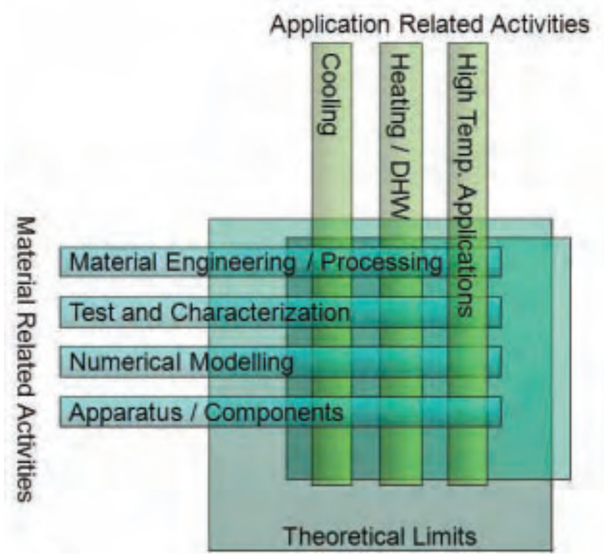
TASK DESCRIPTION

The objective of this Task is to develop advanced materials for compact storage systems, suitable not only for solar thermal systems, but also for other renewable heating and cooling applications such as solar cooling, micro-cogeneration, biomass, or heat pumps. The Task covers phase change materials, 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. The main added value of this Task is to combine the knowledge of experts from materials science as well as solar/renewable heating and energy conservation.



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.

The work in the Task is structured in materials oriented, application oriented, and crosscutting working groups.

Subtask A: Materials

Working Group A1: Material Engineering and Processing

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.

With respect to materials processing, the work focuses 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 needs to be processed into a slurry, encapsulated, or otherwise processed.

This Working Group includes the following activities:

- 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.
- Creating material safety data sheets.
- Determining the role and importance of material containers.
- 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: Tests 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 activities of this Working Group are aimed at developing these new procedures and include:

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

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 help to lay the foundation for such models.

The Working Group includes the following activities:

- Micro-scale modelling.
- Meso-scale modelling.
- Macro-scale modelling.
- Multi-scale approach.
- Thermo-mechanical modelling.
- Reactor models.

Working Group A4: Apparatus/ Components

The storage apparatus is composed of the storage material and the equipment necessary to charge and discharge the storage material in a controlled and optimal way. This includes heat and mass transfer equipment like heat exchangers and pumps or fans and (chemical) reactors. Methods for the design and optimisation of components and apparatus should be developed, together with appropriate testing methods and procedures to assess the long-term behaviour of an apparatus:

- Storage container and reactor design.
- Storage apparatus design, based on the selected storage materials.
- Improve heat transfer from material to reactor wall or heat exchanger wall.
- Apparatus performance assessment.
- Assessment of durability of components.
- Develop and apply test and validation methods for storages.

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 guidance 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:

- Inventory and analysis of existing store types, their theoretical and practical energy and power density, their possible application and their costs (if available) following the results of IEA SHC Task 32 and IEA ECES Tasks.
- Definition of application boundary conditions, such as load, demand, environment, dimensions, etc.
- Definition of required thermophysical properties for each application.
- Selection of relevant candidate materials and system technologies.
- Storage system design, based on the selected storage materials (link to A2) and applications.
- Assessment of durability of components.
- System performance assessment and validation.
- Numerical modelling on the application level.
- Case studies.
- Economical modelling.
- Feasibility studies.
- Market potential evaluations.

This subtask is subdivided in three Working Groups, each representing a particular application or group of similar applications:

- Working Group B1: Cooling
- Working Group B2: Heating / DHW
- Working Group B3: High Temperature Applications

Subtask C: Cross-Cutting

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 economical constraints of storage systems shall be evaluated.

Duration

This is a fully Joint Task with the IEA Energy Conservation through Energy Storage Programme (ECES Annex 24). The Task started on January 1, 2009 and will end on

December 31, 2012.

Participating Countries

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

WORK DURING 2012

The Task activities in the subsequent working groups were as follows:

Materials Engineering and Processing

Work was done on the overview of new or improved compact thermal energy storage materials. The information material will be put together in a main deliverable. In 9 chapters, the most important developments in CTES materials will be described. The chapters will cover sensible (high temperature) storage materials, phase change and thermochemical materials. The development work of several participating groups was published. Amongst others, it concerned the development of mesoporous silicates impregnated with a salt hydrate, solid-solid polymer phase change materials and novel metal organic framework materials.

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

Materials Testing and Characterization

Reports were prepared 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

Experimental data sets were assembled 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 4 configurations with phase change materials and 5 with thermochemical materials. The sets are all described in a report, to be published in the spring of next year.

Apparatus and Components

There was very little progress in this working group. The finalisation of the work on design process descriptions and on the performance test protocol is to be done in the spring of next year.

Application Working Groups

The cooling application working group drafted the final report. It describes two cooling applications as case studies for their boundary conditions for storage materials. A reporting template for 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, a first draft of the final report was made, including the material for the three deliverables: Description of systems and materials, Laboratory prototype development and testing and Simulated technical potential.
In the High temperatures application working group, the report for the State of the art

overview was finalised.

Theoretical Limits

The study into the economical limits of thermal storage was drafted and discussed. The part on top-down economic approach is finalised and will be reported in the deliverable.

Other

During 2012, four large EU funded R&D projects were launched. Three are aimed at development of novel compact thermal energy storage systems and one on research into novel low to medium temperature phase change materials. These projects give the R&D into CTES a boost and will contribute to the activities in the follow-up of this Task 42.

WORK PLANNED FOR 2013

2012 was the last year of Task 42. Next year, the Task will have a continuation of three years. Key activities for this continuation, planned for 2013 include:

- Gathering of experimental data for the materials database.
- 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 2012

Report on the state-of-the-art modeling techniques of PCM/TCM materials

REPORTS PLANNED FOR 2013

A series of reports are planned, with topics:

- Description of experimental data for numerical tools validation
- Description of thermal energy storage reactor designs
- Storage apparatus performance test protocol
- Boundary conditions for cold storage applications
- State of the art of high temperature storage applications
- State of the art on numerical modeling of high temperature TES applications
- Laboratory scale application of process heat at 200 °C
- Physical limits of thermal energy storage
- Technical limits and constraints of thermal energy storage

MEETINGS IN 2012

7th Experts Meeting

March 27-29
Tokyo, Japan

8th Experts Meeting

October 18-19
Petten, The Netherlands

MEETINGS PLANNED FOR 2013

9th Experts Meeting

April 19-21
Location to be confirmed

10th Experts Meeting

September
Details to be decided

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Task 43

Advanced Solar Thermal Testing and Characterization for Certification of Collectors and Systems

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TASK DESCRIPTION

Task 43 was an international collaboration focusing on research and development, where needed, of new test and certification procedures for conventional and advanced solar thermal products, at both the collector and system levels. Task activities drew on the knowledge of industry, testing laboratories, standard-setting authorities and certification bodies in the areas of solar collector and system performance and durability to ensure wide-ranging involvement of affected stakeholders. By researching testing issues and investigating innovative approaches, the outputs of this Task will help optimize the time and resources industry, laboratories and certification bodies expend on testing and certification. Consumer protection and the development and dissemination of credible information on solar heating and cooling benefits are guiding principles of this Task.

Stakeholders in Task 43 activities worked on methods to be used to apply the Task research results to specific products, standards and certifications, including global certification schemes now under discussion and development. Task products continue to be communicated to those legal authorities that define how certification shall be conducted, for use as they see fit.

The ultimate objective is a single global certification scheme.

One test, one certification → Access to all markets

Scope

The scope of Task 43 included performance testing and characterization, qualification testing, environmental impact assessment, accelerated aging tests, numerical and analytical modelling, component substitution procedures, and entire system design assessment.

Means

Task 43 was divided into the following Subtasks.

Subtask A: Collectors
(Leader: Enric Mateu Serrats, Spain)

The objective of this subtask is to examine existing testing and certification procedures for low-temperature evacuated tube and flat-plate collectors, air heating collectors, and medium- to high-temperature concentrating collectors in order to identify weaknesses, inconsistencies in application and significant gaps.

The activities in this Subtask produced research results to inform participants, industry, testing labs and certification bodies with new information to support lthe goal of harmonized testing and certification.

Subtask B: Systems Testing and Characterization
(Leader: Harald Drück, Germany)

The objective of this subtask was to examine existing testing procedures for entire systems and identify weaknesses, inconsistencies in application, and significant gaps, and to investigate component/material substitution issues, including implications for qualification and safety testing. System performance characterization, testing, simulation and modeling and extrapolation work has helped to clarify key issues regarding system design and applicability in various geographic areas.

Duration

This Task began in July 2009 and Phase 1 ended in June 2012. A proposal to extend the Task will be discussed at the June 2013 Executive Committee meeting.

Participation

A total of 11 countries participated in the Task: Australia, Austria, Canada, Denmark, Germany, Italy, Portugal, Spain, Sweden, Switzerland and the United States.

TASK ACCOMPLISHMENTS

Subtask A: Collectors

Roadmap of Collector Testing and Certification Issues

A comprehensive roadmap on existing collector testing processes was completed, which serves several purposes:

- A comprehensive guide to how tests and standards are applied and how they relate to certification.
- Identifies gaps, inconsistencies and weaknesses along with approaches to addressing problems.
- Makes recommendations for improving procedures in order to accommodate emerging technologies where standards and testing approaches are under development.

Low-to-Medium Temperate Collector Test Procedures, Standards and Simulation

Based on priorities and issue identification developed in the Roadmap Activity and work on the White Paper on Low-Medium Temperature Collectors, experts analyzed current issues in flat plate and evacuated tube collector testing and certification. Worldwide round-robin tests carried out through the QUAiST project helped to inform this effort by investigating the nature of any variations and problems in testing procedures. Topics of note that the experts identified include:

Flat Plate Collectors

- Issues surrounding the ability to maintain uniform test conditions around Europe have been the cause for considerable debate, however the QAiST Round Robin tests have diminished concern in this area due to the relatively good outcome of the testing results comparison.
- Rain penetration test procedures conducted under the European Standard have 3 different pass/fail criteria, so uniformity of results are not assured.
- For certain types of collectors, existing performance test procedures do not assure accurate performance characterizations when “non-typical” flow rates are used.

Evacuated Tube Collectors

- Gaps remain in the definitions and specifications of the various types of ETCs.
- Calculation of efficiency curves for ETCs are problematic due to the difficulty of measuring absorber temperature and the inaccuracies, which occur when applying existing efficiency models to double-glazed ETCs.
- Thermal capacitance measurement of ETCs using existing calculation methods is inconsistent among test methods.
- Mechanical load testing is not performed consistently across Europe.
- Impact resistance testing is not well-defined due to a number of factors, including:
    - Inconsistency in ice ball property definition
    - Low correlation between ice ball and steel ball impact results
    - Inconsistencies between individual glass tubes from the same manufacturer
- Vacuum loss characterization has not been addressed within testing procedures.

Polymeric Material Collectors

- Protection of polymer absorber plates in glazed collectors from the effects of the elevated operating temperatures expected in medium-temperature collectors remains a barrier to polymer substitution for metal absorbers.
- Protection of polymer glazings from damage due to sunlight exposure remains a barrier to necessary glazing transparency and durability.
- The challenge of determining polymeric formulations, which preserve the necessary ageing and operational characteristics at a price, which is sufficiently lower than metal-based products, has not yet been solved.

White Paper on Low-Medium Temperature Collectors

A draft white paper was written on this topic and will be completed in 2013.

Air Heating Collector Test Procedures, Standards and Simulation

Based on priority and issue identification work developed in the Roadmap Activity, and work completed in the Draft White Paper for Air Heating Collectors, the following points are made:

- Most issues identified in the Subtask A Roadmap regarding air collectors revolve around limitations in existing test procedures. The white paper notes:
    - ANSI-ASHRAE 93, published in 1977 and most recently updated in 2010, is the oldest and most well-known air heating collector testing standard, however it does not address durability and reliability.
    - EN 12975-2006 does not cover solar air collector testing, but some parts are used for establishing energy production values in order to establish eligibility for subsidies. Not all air heating technologies can be so tested, creating a marketplace problem. A draft extension of EN 12975 developed by Fraunhofer ISE to include air heating collector testing is nearing approval, and will include durability and reliability tests, but not “uncovered” collectors.
    - The Canadian CSA F378.2 for air heating collectors has become effective in 2012, and includes provisions for both “covered” and “uncovered” air heating collectors, although certain durability/reliability tests are not addressed.
    - A CEN-ISO unified standard is under development, and would include performance and reliability tests for both “covered” and “uncovered” products.
    - The EU-sponsored NEGST has developed a draft standard for air heating collectors, however is not applicable to “site-built” products such as transpired collectors, but only for modular products.
    - More work on the effect of wind on air heating collector performance, particularly for uncovered collectors, is needed.
- Building façade-integrated, transpired air-type “uncovered” collectors are gradually gaining market acceptance (particularly in Canada) for ambient air pre-heating applications.
- Combined photovoltaic/air heating collectors/systems are becoming available, but in some configurations pose difficulties in testing performance.

White Paper on Air Heating Collectors

A draft white paper was written and will be completed in 2013.

Concentrator Collector Test Procedures, Standards and Simulation

The Subtask A Roadmap section on concentrating collectors focuses on an assessment of current standards and certification procedures for concentrating collectors, an assessment of concentrating collector durability test methods, concentrating collector component durability test methods, and testing approaches for concentrating collector products. The following conclusions are reached:

Current Standards and Certification Procedures

- ANSI ASHRAE 93 addresses efficiency models for a limited number of concentrating collector configurations, and defines some parameters for incidence angle modifier testing.
- ISO 9806-1 is not applicable to tracking concentrating collectors, but contributes some information on parabolic trough incidence angle modifier testing.
- ANSI ASTM E 905-87 gives a method for determining thermal performance of tracking concentrating collectors using outdoor testing only, with some other limitations.
- UNE-EN 12975-2 contributes a quasi-dynamic thermal performance test procedure applicable to most concentrating collector designs, but is otherwise not applicable to tracking concentrating designs.

Collector Durability Test Procedures

- ISO 9806-1 is generally not applicable to concentrating collectors.
- EN 12975-2 does not provide a durability test applicable to concentrating collectors.
- Several IEC Standards, while not specifically written for concentrating thermal collectors, may provide useful language for a more specifically applicable standard, including IEC 60721 (Stress severity classification), IEC 61215 (PV module UV degradation, thermal cycling, humidity and hail impact), and IEC 62108 (concentrating PV durability).
- SRCC Standard 600 addresses criteria for collector and component overheat protection.

Component Durability Test Procedures

- ISO 9050 Light transmission and reflectance can inform mirror reflectance
- ISO 9845-1 Direct normal and hemispherical irradiance reference
- ASTM G173-03 Direct normal and hemispherical irradiance reference
- EN 12975-2:2011 Informative annex addresses reliability testing of concentrating and/or tracking collectors
- ISO 9806 Revision: Will include requirements modeled on EN 12975-2 annex designed to establish general requirements for collector/system self-protection against stagnation damage, including:
    - Exposure testing procedures
    - Active and passive overheat protection controls
    - High temperature resistance testing
    - Internal thermal shock testing (where applicable)
    - Mechanical load testing

White Paper on Concentrating Collectors

A draft white paper was written and will be completed in 2013.

Communication and Adoption of Results

Efforts to ensure that industry and other stakeholders are informed about the activities of this effort have been conducted over the course of the Task, including the following:

- In 2010, the formation in the US of a Solar Heating & Cooling Program US National Team, which met at the Solar Power International Conference and Exhibition in Los Angeles in October 2010, and again at the ASES Solar 2011 Conference in Raleigh, NC, USA, in May 2011. The Team was formed of numerous US SHC stakeholders, and details about progress on Task activities were communicated.
- In Europe, Industry Workshops have been held in conjunction with conferences, meetings of the SHC Executive Committee and Solar Keymark meetings.

Subtask B Systems Testing and Characterization

Roadmap of Systems Issues

Convened a meeting of experts to discuss issues and define research needs in more detail. Conduct research to define the limits/boundaries of solar thermal systems within the context of building integration, what is the solar thermal system in the contexts of storage, cooling, heating. Work considered how systems should be defined for incentive programs; characterizing quantity and quality of heat; and appropriate parameters for due diligence assessments for larger custom systems. Investigated ranges of tolerance/acceptable uncertainty in performance and/or define bands of acceptability for performance. Examined existing performance testing and research applied to systems and promoted round robin tests to investigate variations in practices and procedures and their impact on test results, for example for passive systems where there are problems in producing comparable results for separable thermosiphon systems versus ICS and non-separable thermosiphon systems.

Workshops and Conferences

The following are workshops and conferences Task participants contributed to by outlining progress, results and obstacles regarding their work associated with the Task.

Workshop/Conference	Place	Date
ISO/TC 180 Meeting	Johannesburg, S. Africa	October 16-17, 2009
ITW Solar Thermal & Hot Water Testing & Certification	Stuttgart, Germany	February 8, 2010
EN TC312/WG1 & Solar Keymark	Graz, Austria	October 5-6, 2010
Solar Power International National SH&C Team Meeting	Los Angeles	October 12, 2010
ASES 2011 National SH&C Team Meeting	Raleigh, NC, USA	May 17-18, 2011
ISES Solar World Congress	Kassel, Germany	September 3, 2011
SHC 2012 & Intersolar USA	San Francisco, CA, USA	July 10, 2012

CONCLUSIONS/RECOMMENDATIONS

Task 43 activities have resulted in a number of advances in the effort to move forward the goal of “One Test, One Certification, Access to all Markets.” At the same time, the realities of individual country-level, and region-level financial constraints should not be ignored. It is heartening to learn of solar heating programs in developing countries, which embrace the use of, and advocacy for, solar water heating products. It would be a mistake to ignore these growing markets. At the same time, many of these markets are located in geographic areas where advanced solar water heating system designs which can accommodate extreme operating conditions are not affordable or technologically feasible given local market realities.

One goal of ongoing efforts to harmonize solar product standards globally should be to recognize the value of a system where solar products are evaluated based on their intrinsic design capabilities to operate under one or more geographic and climate-specific operating conditions. The concept of product “classes,” where a testing regime establishes the ability of a given product to function as per design under varying/escalating levels of insolation/climatic duress would seem to allow for selection of products based on geographic/climatic need.

A “Global” harmonization approach which incorporates a capability to measure product performance and durability metrics, and assign product ratings based on those metrics, could meet the apparent need for a range of product performance, durability, and price ranges.

KEY REPORTS/PUBLICATIONS

Research and Standardization on Solar Collector Testing and Towards a Global Certification Scheme *(authors: Serrats, Kovacs, Kramer, Nielsen, Nelson)*
This document includes an excellent description of the numerous objectives, outcomes, and inter-related activities associated with Task 43.

Subtask A Roadmap

Draft White Papers on Low-Medium Temperature Collectors, **Air Heating Collectors and Concentrating Collectors**

MEETINGS HELD IN 2012

6th Task Experts Meeting
July 10
San Francisco, California, USA
(in conjunction with the SHC 2012 Conference and Intersolar USA)

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Task 44

Solar and Heat Pump Systems

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TASK DESCRIPTION

The objective of this Task is to assess performances and relevance of combined systems using solar thermal 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 considers solar thermal systems in combination with heat pumps, applied for the supply of domestic hot water and heating in family houses. It is thus dedicated to small systems in the range of 5 to 20 kW.

Any type of solar collector can be considered: using a liquid heat transfer fluid, air, hybrid collectors, or even hybrid thermal and photovoltaic or “PVT” collectors. All of them can be glazed or unglazed.

Any type of source of heat for the heat pump can be considered: air, water or ground source. The main focus will be on heat pumps driven by electricity, as the market is so oriented. However during the course of the Task it might be become relevant to consider thermally driven heat pumps since 100% solar could then be achieved.

To limit the scope, comfort cooling of buildings is not directly addressed in the Task common work, although it is not forbidden for a heat pump to be used for cooling purposes besides its main heating objective, for example in reverse mode.

The Task covers market available solutions as well as advanced solutions, which may be still in the laboratory stage or still to be developed during the course of the Task.

The Task is organized in the following Subtasks:

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

The objective of Subtask A is to collect, create and disseminate information about the current and future solutions for combining solar thermal and heat pump to meet heat requirements of a one family house. Subtask A deals 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 is to reach a common definition of the figures of merits of solar + heat pump systems and how to assess them.This work can lead to prenormative definition on how to test and report the performance of a combined solar and heat pump system.

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

The objective of subtask C is to provide modelling 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. Sizing of systems will also be possible using the output of this Subtask, either with the computing tools developed or with general or system specific tables.

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

The objective of this subtask is to provide information to the external world of Task 44 during the course of the Task so that value added created by the participants can be transferred as fast as possible to a growing market. A second objective is to deliver the final book of Task 44 aimed as a reference document in the field of solar heat and heat pumps.

Main Deliverables

- Technical reports on existing and monitored systems
- Map of generic systems with pros and cons
- New set of performance indicators
- Procedure to test combined solar and heat pump systems
- Technical reports on systems tested in laboratory with this procedure
- New reference framework for simulating solar and heat pumps systems
- New components models or compiled existing ones
- Website with all major reports and papers
- Educational material on the website
- Support to national workshops about the topic “solar and heat pump”
- Papers at international conferences
- Newsletters during Task’s duration
- Final handbook with all methods developed and results found

Duration

The Task started on 1 January 2010 and will end on 31 December 2013.

This Task is a joint Task with the IEA Heat Pump Programme (HPP). It is referred to as Task 44 in the SHC Programme and Annex 38 in the HPP.

ACTIVITIES DURING 2012

- The Subtasks have been working without disruption.
- The 5th and 6th Experts meetings were held in Povoar do Varzim, Portugal in May, and in Copenhagen in October. Two local industry workshops have been held the day prior the Task meeting.
- Task participants presented their work at the SHC2012 conference in San Francisco USA.

RESULTS IN 2012

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” is available since December 2012. More than 70 companies have been contacted and more than 120 systems reported. The analysis showed that most systems are designed or both heating and DHW and most use flat plate collectors. The great majority of systems on the market is a combination in parallel for solar and heat pump.

Reporting field test results
During 2012 still thirty projects combining solar and heat pumps and being monitored were reported on by participants. Some have already been completed and the results presented during Task meetings. These projects will also produce interesting material for simulation

and models validation for Subtask C.

A template for reporting field results was used by most of the projects that are being monitoring installations in the field.
Some projects have been terminated and results are available. For instance a solar and heat pump system worming with a central ice storage project has 2 years of monitoring and show good seasonal performances.

Dissemination and information
Several projects were presented at the SHC Programme’s SHC 2012 conference, the papers are available for all in the Task work area on the SHC website.

Using the square view representations derived in this Task, most of the solar and heat pump combinations have been sketched up (Figure 1).

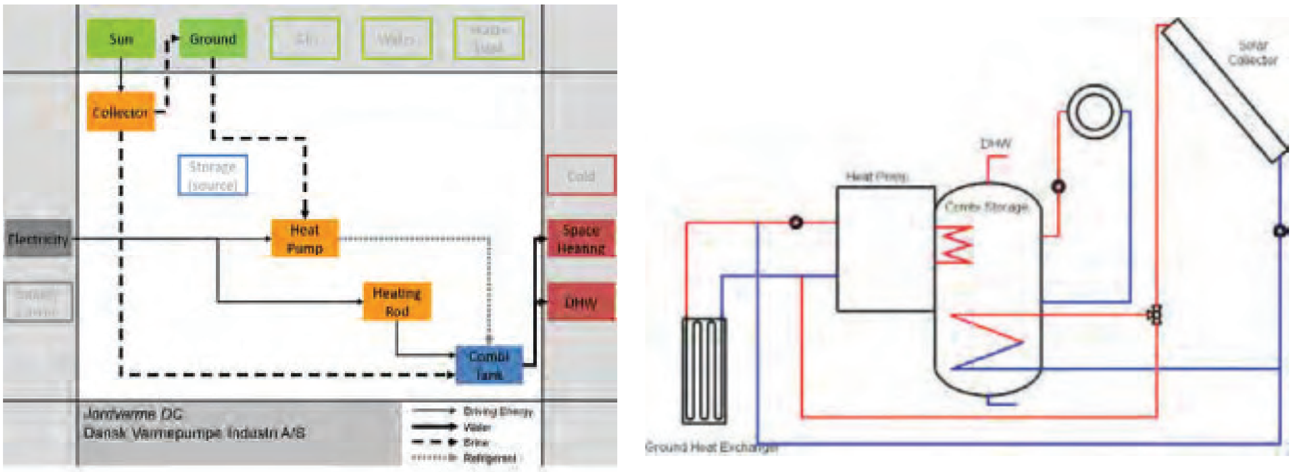

Figure 1. The "square view" representation of a so-called "regenerative system" and its usual hydraulic schematic.

Work on the final hanbdook of Task 44 was started in 2012 and Subtask A contributions for the theoretical chapters are available.

Subtask B: Performance Assessment

Definition of performance indicators
This deliverable is under internal review. SPF (seasonal performance factors have been defined for all necessary boundaries) and environmental indicators have been agreed upon. As far as environmental factors are considered, Task 44 participants decided to use the Primary Energy Ratio and the Global Warming Potential as indicators (see Figure 2).

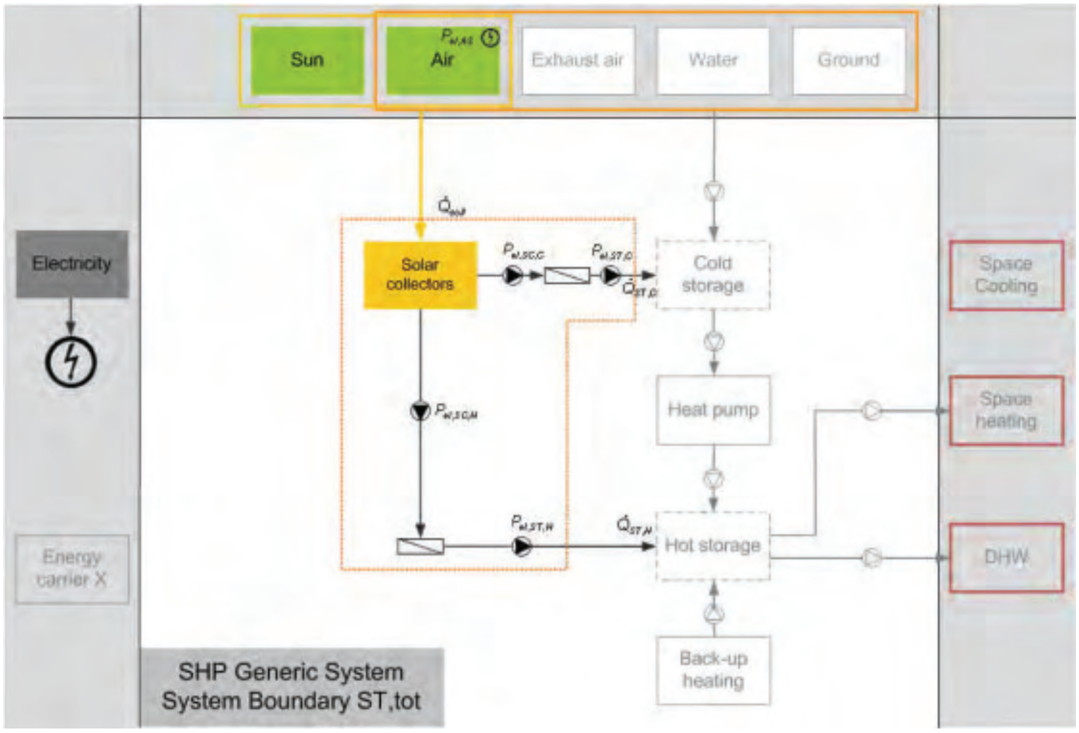

Figure 2. Definition of SPFs in Task 44 according to boundaries. Example of the solar SPF.

Testing on stands - procedure and results

Five institutes are testing solar and heat pump systems on bench stands. A common procedure of testing is not yet available. Institutes report on their test methods using a common template provided by the Task.

Standard test definition - prenormative

A template to report testing procedure has been issued.

Dissemination and information

Papers were presented at the SHC Programme's SHC 2012 conference.

Subtask C: Modelling and Simulation

Reference framework

The report defining the common framework for simulations has already been approved by the SHC Executive Committee, however, technical amendments are always necessary in this matter and are added as needed.

Models of sub component and validation

The four working groups—solar collector, ground heat exchanger, heat pump, and heat storage—finished their contributions to "Models of sub components and validation". It was a great shared effort to describe the available models in the world and their features. The report is currently in draft form. Some new components need special models, such as ice storage, heat pump with desuperheater, uncovered collectors that can freeze both sides, PVT collectors, etc. Development of such models are done by the teams that need them.

System simulations and validation

"System simulation and validation" is not yet completed. Two templates to describe systems simulation methods and results have been set up and distributed.

Five simulation platforms are being used in the Task (Trnsys, Polysun, Rdmes, Mathlab, and IDA), which makes comparison difficult.

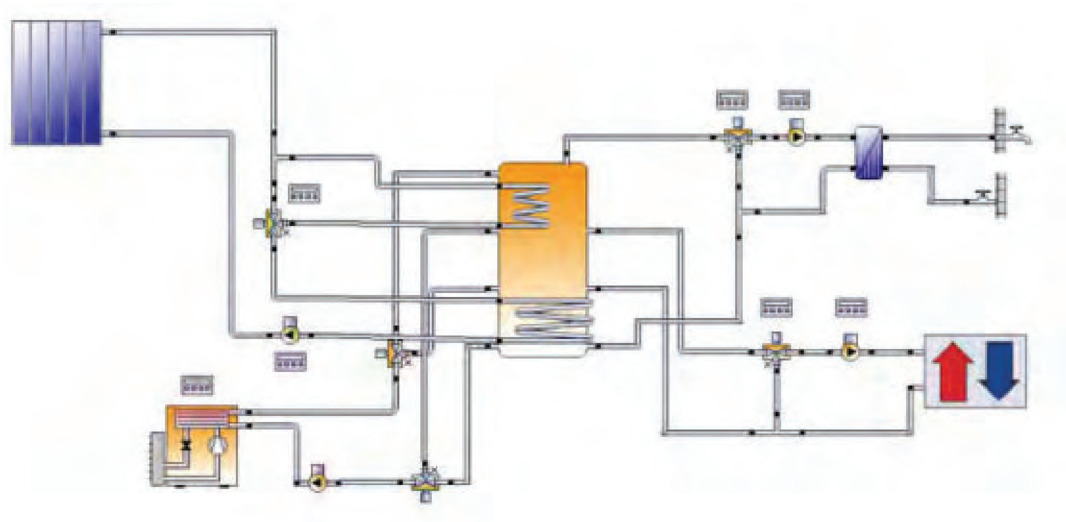

Figure 3. A one storage tank parallel solar and air heat pump systems in simulation

System intercomparison data

This activity has not begun as not many simulation results are available. Some teams are conducting simulations without using the common boundary conditions since their national project requires other conditions.

Subtask D: Dissemination and market support

Webpage and educational material

The Task webpage is continuously updated with publications. A Wikipedia page was created: http://en.wikipedia.org/wiki/Solar_and_heat_pump_systems

Newsletter and guideline for planners

The second electronic newsletter was issued in June 2012. It is available as PDF file at: http://www.iea-shc.org/publications/task.aspx?Task=44 with all the other Task publications.

Workshops and Conferences

A workshop was organized in Tastrup, Denmark before the 6th Experts meeting with 20 Danish attendees. The Danish market is more oriented towards large-scale systems, but there are some industries delivering S+HP systems and their system configurations were shared with the Task 44 experts. These presentations are posted on the Task work area.

System intercomparison report

It was decided that this report will be the C4 report as the content will be identical. Subtask D will promote the C4 report when available probably with a special Newsletter.

Postion Paper: Solar and heat pump systems: This paper will be published at the end of the Task.

Handbook

This book will be completed in 2013.

WORK PLANNED FOR 2013

Key activities planned for 2013 include:

- Activities as planned in each subtask.
- Meetings in Belgium and Switzerland (final Task meeting).
- Articles for conferences and publications.
- Newsletter for the industry.

LINKS WITH INDUSTRY

Several solar or heat pump manufacturers or system installers collaborate with university labs in our Task.

REPORTS PUBLISHED IN 2012

Subtask A

- A Review of Market-Available Solar Heat Pump Systems, October 2012

Subtask B

- Definition of Main System Boundaries and Performance Figures for Reporting on SHP Systems, October 2012

Subtask C

- The Reference Framework for System Simulations of the IEA SHC Task 44 / HPP Annex 38
  - Part A: General Simulation Boundary Conditions – April 2012
  - Part B: Buildings and Space Heat Load – April 2012

Subtask D

- Teaching material 1: Collection of S+HP examples in slides – revision 2012
- Task newsletter 2, June 2012

REPORTS PLANNED FOR 2013

Subtask A

- Reporting field test results

Subtask B

- Definition of performance indicators
- Testing on stands – procedures and results
- Standard test definition

Subtask C

- T44A38 reference framework for simulation
- Models of Sub components and validation
- System simulations and validation
- System intercomparison

Subtask D

- Teaching material on monitored systems
- Task newsletter 3
- Position paper
- Task Handbook

MEETINGS IN 2012

5th Experts Meeting
May 3-4
Povoa do Varzim, Portugal

6th Experts Meeting
October 9-10
Lyngby,Denmark

MEETINGS PLANNED FOR 2012

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

8th Experts Meeting
October 23-24-25
Switzerland

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Task 45

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

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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, which system type and size to choose 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 sought 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 a "Handbook for large solar systems" with the following content:

- Guidelines for design, installation and operation of large collector fields
- Guidelines for design, installation and operation of large scale thermal storages
- Guidelines for design, installation and operation of large scale solar heating and cooling thermal systems with seasonal storage and/or heat pumps

Duration

The Task started on January 1, 2011 and will remain in force until December 31, 2013.

RESULTS IN 2012

Subtask A: Collectors and Collector Fields

Subtask A is more or less advancing according to work plan.

- First draft of the report on models for correction of collector efficiency parameters depending on collector type, flow rate, tilt and fluid type is expected in June 2013.
- Deliverable of a proposal for an informal annex to be included in EN 12975/ISO 9806-1 regarding the corrections determined in the Task will be carried out in the second half of 2013.
- Proposal for requirements and test methods for collector loop pipes (safety, durability, heat loss, thermal expansion) - pre-normative work - to be proposed to the relevant ISO/CEN TC's is a little delayed. The report is expected in June 2013.
- Report on Guidelines for requirements for collector loop installation, hydraulic scheme including precautions for safety and expansion including checklist for checking installation accordingly is expected in June 2013.
- Detailed simulation models for solar collector fields (thermal performance) has been put on stand-by as nobody yet committed themselves to work with this due to the lack of funding.
- Control and operation strategies for solar collector fields might be merged with A-D4 (Guidelines for requirements for collector loop installation, hydraulic scheme including precautions for safety and expansion including check list for checking installation accordingly)
- Procedure for guaranteeing performance of collector field installation - including how to check the guarantee - and including validation on existing fields is ahead of schedule - first initial draft for the procedure is already made.
- Procedure for guaranteeing performance of solar loop heat exchanger - including how to check the guarantee - and including validation on existing fields is ahead of schedule - first initial draft for the procedure is already made.
- Input to Design Handbook is ahead of schedule - first initial draft for the handbook is finished.

Subtask B: Storages

Subtask B is in general behind original schedule due to late start of the subtask leader. Start of Subtask B was June 2011. The first meeting with a Subtask presentation was at the 2rd Experts Meeting in Canada in October 2011. The Subtask B leader attended for the first time at the 3rd Experts Meeting in Braedstrup in May 2012.

Subtask C: Systems

- Final overview of system categories.

- Extensive database for large solar system established – including systems outside Europe.
- ESCo compendium with models and guidelines.
- First draft of “Guidelines for planning, installation, commissioning, operation”.
- Significant input to design handbook made .

Dissemination/Presentations

- Erneuerbare Energie, AEE-INTEC, Austria, June 2012. Article by Jan Erik Nielsen
- MIICS2012, Mikkeli, Finland, March 2012. Presentation by Jan Erik Nielsen/Jan-Olof Dalenbäck.
- SHC2012, San Francisco, USA, Keynote by Jan Erik Nielsen, presentation by Jan Erik Nielsen.
- Gleisdorf Solar 2012, Gleisdorf, Austria, presentations by Jan Erik Nielsen, Doug McClenahan, Leo Holm, Rolf Meissner, Johann Breidler, and Philip Ohnewein.
- ASTTP (Austrian solar thermal technology platform), presentation by Sabine Putz, April 2012.
- KlimaEnergy Congress, presentation by Sabine Putz, September 2012.

Workshops

- IEA DHC/IEA SHC T45 workshop, Braedstrup, Denmark, May 2012
- IEA SHC Task 45/Task 48/Task 49 workshop, Graz, Austria, September 2012

WORK PLANNED FOR 2013

Subtask A: Collectors and Collector Fields

- Draft and final report on “Models for correction of collector efficiency parameters depending on collector type, flow rate, tilt and fluid type”.
- Proposal for 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.
- Make final report on “Guidelines for requirements for collector loop installation”.
- Final report on collector field performance guarantee procedure.
- Final report on heat exchanger performance guarantee procedure.
- Inputs to Handbook.
- Subtask A summary report.

Subtask B: Storages

- Final “state of the art report with best practise examples”.
- Final report on “identification of necessary R&D”.
- Inputs to Handbook.
- Subtask B summary report

Subtask C: Systems

- Update of data base for large systems (C-D1)
- Final report on “Guidelines for planning, installation, commissioning, operation” made (C-6)
- Inputs to Handbook
- Subtask B summary report

REPORTS PUBLISHED IN 2012

No publically available reports were published in 2012.

REPORTS PLANNED FOR 2013

The following reports/documents will be available on the SHC website.

- Report on models for correction of collector efficiency parameters depending on collector type, flow rate, tilt and fluid type,
- Report on work on requirements and test methods for collector loop pipes: list of standards, collect experience on operating conditions,
- Report on guidelines for requirements for collector loop installation,
- Report on collector field performance guarantee procedure,
- Report on heat exchanger performance guarantee procedure,
- State of the art report with best practise examples for large storages,
- Report on identification of necessary R&D" for large storages,
- Compendium for ESCO services,
- Report on guidelines for planning, installation, commissioning, operation, and
- A design handbook.

MEETINGS IN 2012

3rd Task Meeting
May
Braedstrup, Denmark

4th Task Meeting
September
Graz, Austria

MEETINGS PLANNED FOR 2013

5th Experts Meeting
May 21-22
Stuttgart, Germany

6th Experts Meeting
3rd FY quarter

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Task 46

Solar Resource Assessment and Forecasting

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TASK DESCRIPTION

Task 46 “Solar Resource Assessment and Forecasting” continues with the work accomplished under Task 36 “Solar Resource Knowledge Management”. Task 36, which was completed on 30 June 2011, achieved three major objectives: 1) 1st order and 2nd order methods for benchmarking of solar resource products with quality data sets; 2) a prototype design of a web portal for accessing both public and private data sets following basic protocols of the Global Earth Observational System of Systems (GEOSS), and 3) improved methods for developing data sets, including short-term and long term solar resource forecasting techniques. During 2010 and 2011 a concept paper and work plan for a new Task was submitted to the SHC Executive Committee and approved as Task 46, commencing on 1 July 2011.

Goal and Objectives

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

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 addresses four basic objectives in improving our understanding of solar resources: 1) evaluation of solar resource variability that impacts large penetrations of solar technologies; 2) standardization and integrating procedures for data bankability; 3) improving procedures for short-term solar resource forecasting, and 4) advanced solar resource modeling procedures based on physical principles.

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.

Means

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: SUNY/Albany, USA)*

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 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.

Subtask B: Standardization and Integration Procedures for Data Bankability *(Lead: DLR, Germany)*

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: DLR, Germany): 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.

- 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.
- 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.

Subtask C: Solar Irradiance Forecasting
(Lead: U-Oldenburg, 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) (lead: U-Oldenburg, Germany): 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, e.g. 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: GeoModel s.r.o., Slovakia): 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 (lead: 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 was initiated July 1, 2011 and will be completed June 30, 2016.

This is a collaborative Task with the SolarPACES Implementing Agreement, and is referred to as Task 5 and the Photovoltaic Power Systems (PVPS) Implementing Agreement's Task 14 High Penetration of PV Systems in Electricity Grids

ACTIVITIES DURING 2012

Overall Task Activities

Although progress on Task 46 was initially slowed by the need to develop a revised work plan and line up funding resources and Task participants, activities in 2012 were quite extensive, including publication of research results, participation in conferences and symposia, and field activities. Three Task Expert Meetings have now been held. The first meeting was a 1-day event held immediately following the Solar World Congress 2011 in Kassel, Germany on 2 September 2011, with a focus on making refinements to the draft work plan and discussing key technical issues. This Task meeting was followed by a small meeting of several participants engaged in both Task 46 and PVPS Task 14, which was held in conjunction with the 26th PVSec in Hamburg on 5 September 2011. The second meeting was a 1-day review of progress conducted immediately after the World Renewable Energy Forum in Denver on 19 May 2012. The meeting was hosted by the U.S. National Renewable Energy Laboratory, and included about 25 participants, including some connecting in via telephone conference call. At this meeting two new researchers from Reúnion Island joined the task. The meeting included a facilitated discussion on measurement best practices, especially for DNI, and a discussion on the definition of DNI. Results of forecasting and solar variability studies that had also been presented at the WREF were presented at the Expert Meeting as well.

The third meeting was recently held in Sophia Antipolis, France, hosted by MINES ParisTech, on 21-23 January 2013. This meeting included extensive discussion and refinement of the scope and deliverables of the work plan, a review of progress in all tasks, and a special 1-day workshop on best practices in solar measurement activities, with an emphasis on DNI.

In addition to these Task Expert meetings, the Task liaison to SolarPACES, Dr. Richard Meyer of SunTrace GmbH (Germany) participated in the SolarPACES Conference in Marrakesh, Morocco in September 2012. Summaries of Task 46 activities are also provided to the semi-annual PVPS ExCo meetings, and our Task Liaison to PVPS, Jan Remund of Meteotest (Switzerland) is participating in PVPS Task 14 activities.

Several participants are involved in the International Renewable Energy Agency's (IRENA's) Global Solar and Wind Energy Atlas development. Work that had been achieved as a result of Task 36's "Common Structure for Archiving and Accessing Data Products" has been directly incorporated into the Global Atlas web site. Work will continue with IRENA by several Task 46 participants in the area of solar resource data provision to the Atlas.

Specific Technical Achievements in the Subtasks

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

Activity A1: Short Term Variability.

In the context of the DiGASP project, supported by the European PV ERANET/PV+Grid program, Oldenburg University is developing a method to generate synthetic irradiance data with a 1-min resolution. The generator is based on the method proposed in Skartveit et Olseth (1992)[1], which was adapted to use hourly satellite data as input to generate 1-min data, rather than the original 5-min data, as output. The irradiance generator is applied in a Monte-Carlo simulation of low-voltage grids to investigate which PV-penetration levels are acceptable to the grid. First project results have been presented at the EU-PVSEC 2012 [Bucher et al, 2012].

Ciemat has proposed a simple method for generating 10-min synthetic data of global and direct irradiance from hourly means. The method has two boundary conditions imposed: the energy is conserved at a daily level and the dynamics of the observed pattern are well reproduced in the synthetic data. Figure 1 shows examples of the synthetic irradiance compared to the original measured for four different daily patterns. Future works on the assessment of this method in the context of a solar thermal system simulation are expected.

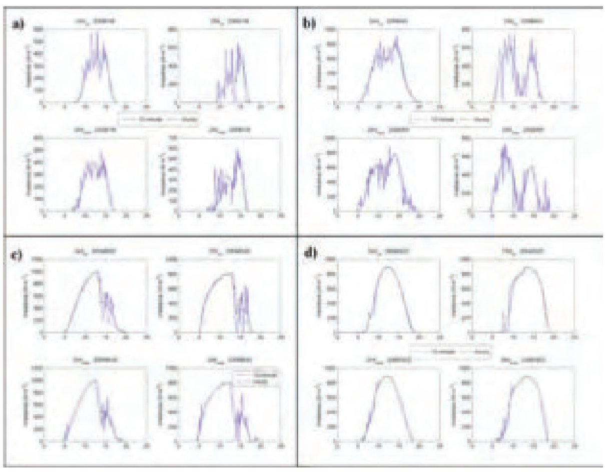

Figure 1. Examples of GHI and DNI 10-minute data generated synthetically compared with the original measurements for four different days.

[1] Skartveit, A. and J.A. Olseth,1992. The probability density of autocorrelation of short-term global and beam irradiance. Solar Energy 46 (9), 477–488.

Activity A2: Integration of Solar with Other RE Technologies.
Work on this activity has not yet commenced.

Activity A3: Spatial and Temporal Balancing Studies of the Solar and Wind Energy Resource.
The University of Jaén has been working on the analysis of the balancing between solar and wind energy resources in southern Spain. Notably, the balancing between the wind energy and the solar energy (associate with the GHI) has been explored using canonical correlation analysis (CCA) based on solar and wind energy estimates derived with a numerical weather prediction model. The CCA method allows optimal locations for wind farms and PV solar plants in terms of reducing the aggregated power fluctuations to be obtained. Results of this research, recently published in an international journal (Santos-Alamillos et al., 2012), show the existence of valuable balancing between the solar and wind energy resources in the region, but with a marked seasonality. In particular, during winter (Figure 2), a noteworthy balancing was observed between the solar energy resources over almost the entire study region and the wind energy resources near the Strait of Gibraltar. During spring, weak balancing was observed between solar energy near the eastern Strait of Gibraltar and wind energy in the central strait area and mountainous interior of the region, and between solar energy in the southwestern Iberian Peninsula and wind energy in the central and eastern peninsula. Important balancing was evident in summer between the solar energy over almost the entire region and wind energy in the south and east. Atmospheric circulations associated with these coupled patterns showed a marked seasonal dependence. Synoptic scale variability greatly influenced the balancing, but so did topography, especially near the Strait of Gibraltar.

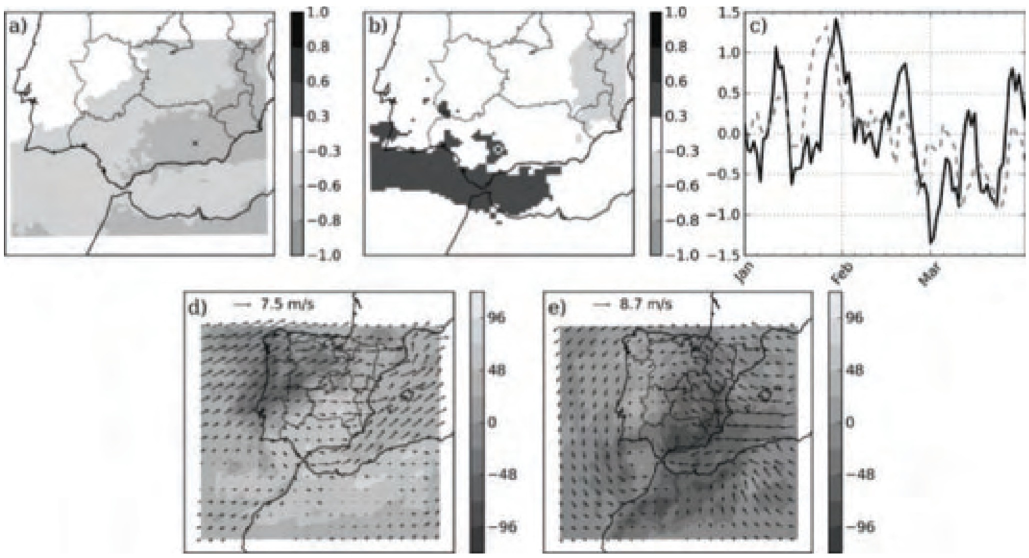

Figure 2. Second mode of the CCA resulting from the winter analysis. a) Homogeneous correlation (canonical loadings) map for the solar energy and b) for the wind energy. c) Canonical time series, filtered with a 3-day moving average filter. Solid black and dotted grey lines are canonical series for solar and wind energy, respectively. d) Composite of daily-mean horizontal wind components at 30 m AGL, and solar radiation anomaly values at the surface corresponding to the 15 highest positive anomalies of the wind energy canonical time series. e) As in d), but for the lowest 15 negative values. Solar radiation data units are W/m^2 and the scale represents the range of the anomalies. Wind speeds are scaled according to the reference at top of Figs. d) and e), which indicates maximum wind speed in m/s.

Based on the CCA analysis, Uni-Jaén further analyzed time series of the wind and solar energy resources at locations of the greatest balancing (Figure 3). The most important results were found for the second mode during autumn. Wind and solar energy time series representative of this mode showed a correlation of -0.56, and 71% of the time, the sign of the anomalies was opposite. Finally, 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.

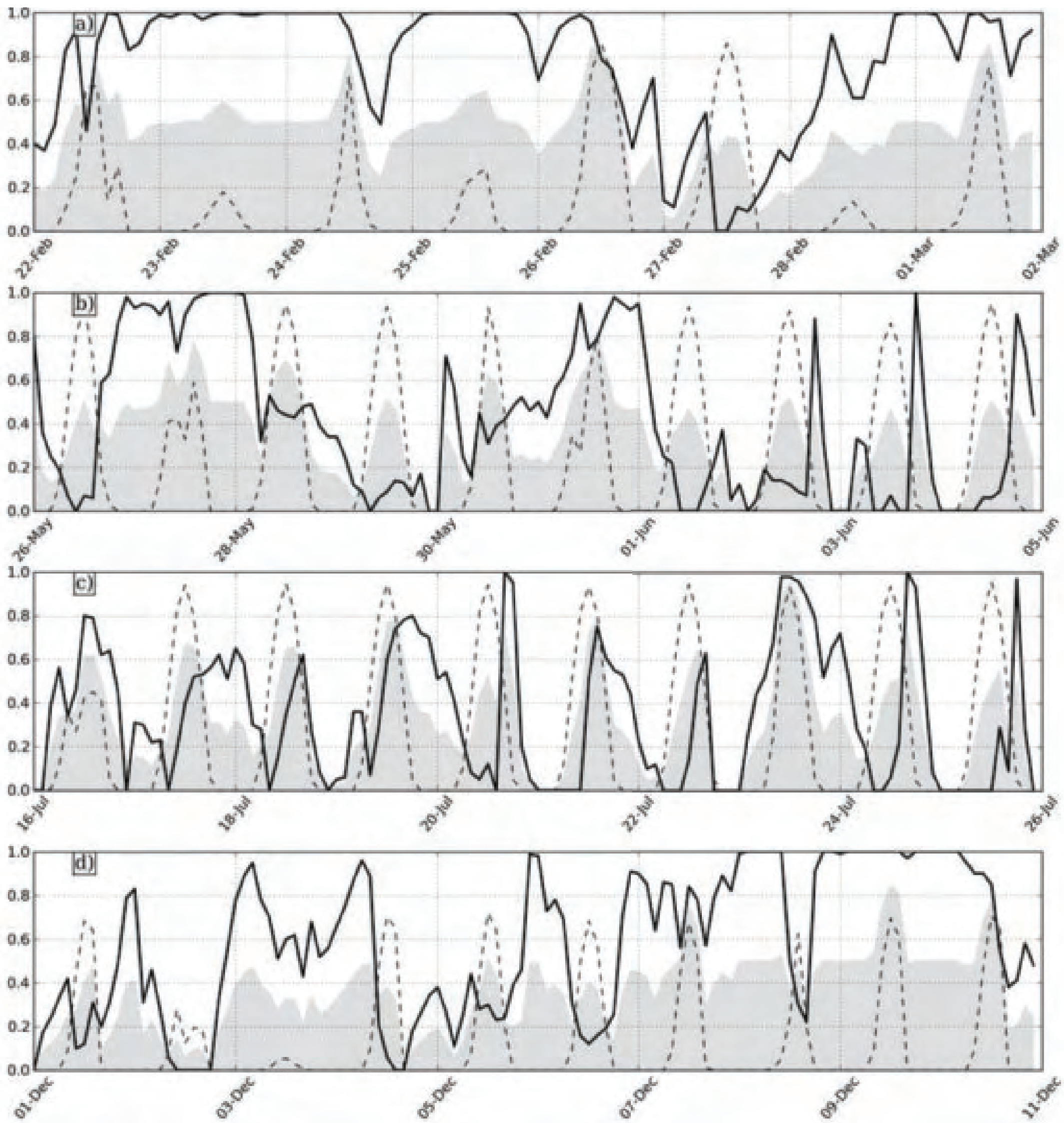

Figure 3. Capacity factor time series for a PV plant (dashed line), wind turbine (continuous line) and the combination of both (shaded areas) for selected period in the year 2007. Values were computed for a reference wind turbine and PV plant. Figures correspond to 10 days selected in each season. Particularly, February 22 through March 2 (a) was used as representative of the winter season, May 26 through June 6 for spring (b), July 16 through July 26 for summer (c) and December 1 through December 11 for autumn (d).

Subtask B: Standardization and Integration Procedures for Data Bankability
Activity B1: Measurement Best Practices.

In Activity B1 manuals on best practices for obtaining measured irradiance data sets that provide bankable data for financial institutions are being prepared. The standardization and characterization of commonly used instruments such as the Rotating Shadowband Irradiometers (RSIs) is directly connected to this objective.

In 2012 the first draft of the best practices for measurements with RSI instruments was distributed among all B1 participants for review. This manual was presented and discussed at the Task 46 meeting in Sophia Antipolis on 23 January 2013 with the objective to identify missing topics and information, text sections that must be removed, shortened, and re-worded, and assignment of responsibilities for the required changes. The manual will be a major deliverable of Task 46 in the next year.

Activity B2: Gap Filling, QC, Flagging and Data Formatting.
Within the framework of the FP-7 EU project ENDORSE (Energy Downstream Service for GMES, Grant Agreement no 262892), MINES ParisTech and DLR have set up a series of tools and procedures for an accurate and easy use of meteorological data. Figure 4 is a poster describing the tools and procedures.

Various surface meteorological parameters are handled: air temperature and relative humidity, wind speed and direction, and solar exposure. For a given parameter, measurements can be made over different integration periods, ranging from one minute to one day with different time references (e.g. legal time, including daylight saving time, universal time (UT), mean solar time (MST), true solar time (TST)).

A series of procedures and advanced mathematical tools have been developed to harmonize these data sets to support validation activities as well as the integration of data into product generation and services. Three generic types of problems have been addressed:

- the over-sampling of time series of meteorological data (e.g. from a 1-h time series of irradiance to a 1-min time series of irradiance);
- the sub-sampling time shift of time series of meteorological data (e.g. application of the sub-hourly time translation to a 1-h TST time series of irradiance to get a 1-h UT time series);
- the averaging, inducing a down sampling, of time series of meteorological data with missing data (e.g. from a sub-daily time series of irradiance with data gaps to daily, monthly or yearly time series of irradiance).

State-of-the-art techniques have been analyzed, benchmarked and discussed. In case of over-sampling none of them respect the consistency property. A correction is proposed of two standard techniques (linear and cubic spline interpolations) with respect to this consistency property and demonstrates that it improves the resulting quality.

As far as averaging time series with data gaps different approaches has been tested. It is shown that missing sub-daily data can have significant impact on the resulting daily average time series; this impact is quantified as a function of the percentage in missing data. A limit of acceptable percentage as a function of the foreseen exploitation of the sub-daily and daily data has been proposed.

Meteorological data measured by ground stations are often a key element in the development and validation of products and methods. Their quality is seldom known and the ground-based data should be qualified before entering a method or serving as reference for validation. A review of the state-of-the-art in quality checks of meteorological data has been performed. The published procedures were tested and their results were analyzed. Finally, a series of automatic procedures has been proposed for assessing the plausibility of the measurements of the meteorological variables under concern.

Figure 4. Poster on Quality Check of meteorological data (Espinar et al., 2012).

NASA developed a new updated set of quality control procedures that were applied to Baseline Surface Radiation Network (BSRN) measurements of solar global, direct and diffuse irradiances. These procedures were able to identify measurements (up to 10% at some sites) that were outside physical limits. It was also found that the removal of these measurements from the time series records led to improved comparisons between satellite-estimated fluxes from the NASA/GEWEX (Global Energy and Water Cycle Exchange Program) SRB project (and thus the Surface meteorology and Solar Energy web portal).

Activity B3: Integration of Data Sources.
Work has not yet commenced on this activity.

Activity B4: Evaluation of Meteorological Products.
Work has not yet commenced on this activity.

Activity B5: Data Variations over Various Temporal and Spatial Resolutions
Work has not yet commenced on this activity.

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 Activity C1. Task members involved in irradiance forecasting have been continuously working on further development of forecasting algorithms for both global horizontal and direct normal irradiance.

<u>C.1.1. Time series models based on ground-measured irradiance data</u>
The University of South Australia is working on short term forecasting of solar radiation, short term being hourly and intra hourly by using a combination of Fourier Series to estimate all cyclical components in the data, and then modeling the residuals formed from subtracting the Fourier series representation from the original data sets. This modeling is done with a coupled autoregressive and dynamical system (CARDS) approach. This work incorporates the construction of prediction intervals from a probabilistic approach. The work has resulted in two publications ([Huang et al, 2003] and [Boland et al, 2012]) and will be incorporated into an Australian Solar Institute project to design the Australian Solar Energy Forecasting System (ASEFS). The goal is to couple this short term forecasting model with longer term forecasting systems.

<u>C.1.2. Total sky imagers</u>
MINES ParisTech is working in collaboration with EDF R&D on a prototype of a low- cost fish-eye camera developed and set up by EDF R&D, meant to be an alternative to standard total sky imagers for local and very short term solar forecasting (Figure 5). This preliminary study has demonstrated a very important pre-requisite for using fish-eye cameras for solar forecasting purpose: the relationship between hemispheric sky images and the different components (global, diffuse and direct) of the surface solar irradiance (SSI). This study has been carried out with high quality "BSRN quality level" radiometric data and hemispheric sky images from a EDF R&D's test site on Reunion Island, in the Indian Ocean. This experimental study leads to very conclusive and promising results on sub-hourly estimation of diffuse, direct and global SSI from sky images provided by the fish-eye camera.

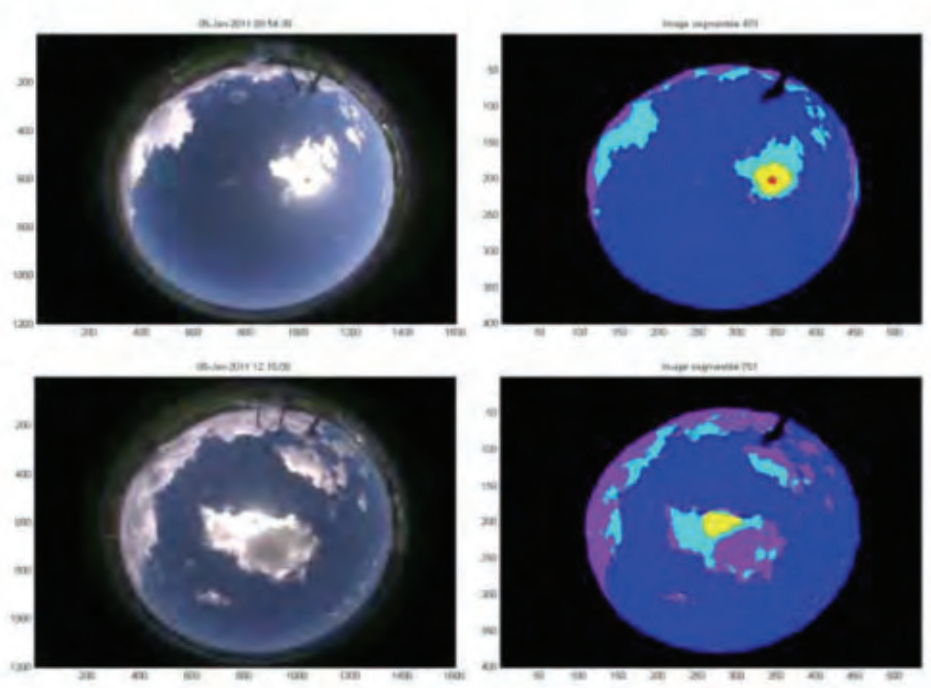

Figure 5.
Examples of clouds/clear sky segmentation result (right) for two hemi-spheric sky images (left) (Gauchet et al., 2012; see Reports and Papers Published in 2012).

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 (Figure 6). In [Ghonima et Kleissl, 2012] digital images of the sky obtained using a total sky imager (TSI) were classified pixel by pixel into clear sky, optically thin and optically thick clouds (Figure 6). A new classification algorithm was developed that compares the pixel red blue ratio (*RBR*) to the *RBR* of a clear sky library generated from images captured on clear days. The difference rather than the ratio between pixel *RBR* and *CSL RBR* resulted in more accurate cloud detection. High correlation between TSI image *RBR* and aerosol optical depth (AOD) measured by an AERONET photometer was observed and motivated the addition of a haze correction factor (*HCF*) to the classification model to account for variations in AOD. Misclassifications of clear and thick clouds into the opposite category were less than 1%. Thin clouds were classified with an accuracy of 60%. Accurate cloud detection and opacity classification techniques will improve the accuracy of short-term solar power forecasting.

The spatial and temporal variability of solar radiation is the main cause of fluctuating photovoltaic power fed into the grid. Clouds are the dominant source of such variability and their velocity is a principal input to most short-term forecast and variability models. In [Bosch et al., 2012] two methods are presented to estimate cloud speed using radiometric measurements from eight global horizontal irradiance sensors at the UCSD Solar Energy test bed. The first method assigns the wind direction to the direction of the pair of sensors that exhibits the largest cross-correlation in the irradiance time series. The second method requires only a sensor triplet; cloud speed and the angle of the cloud front are determined from the time delays in two cloud front arrivals at the sensors. Both methods require high variability in the input radiation as provided only in partly cloudy skies.

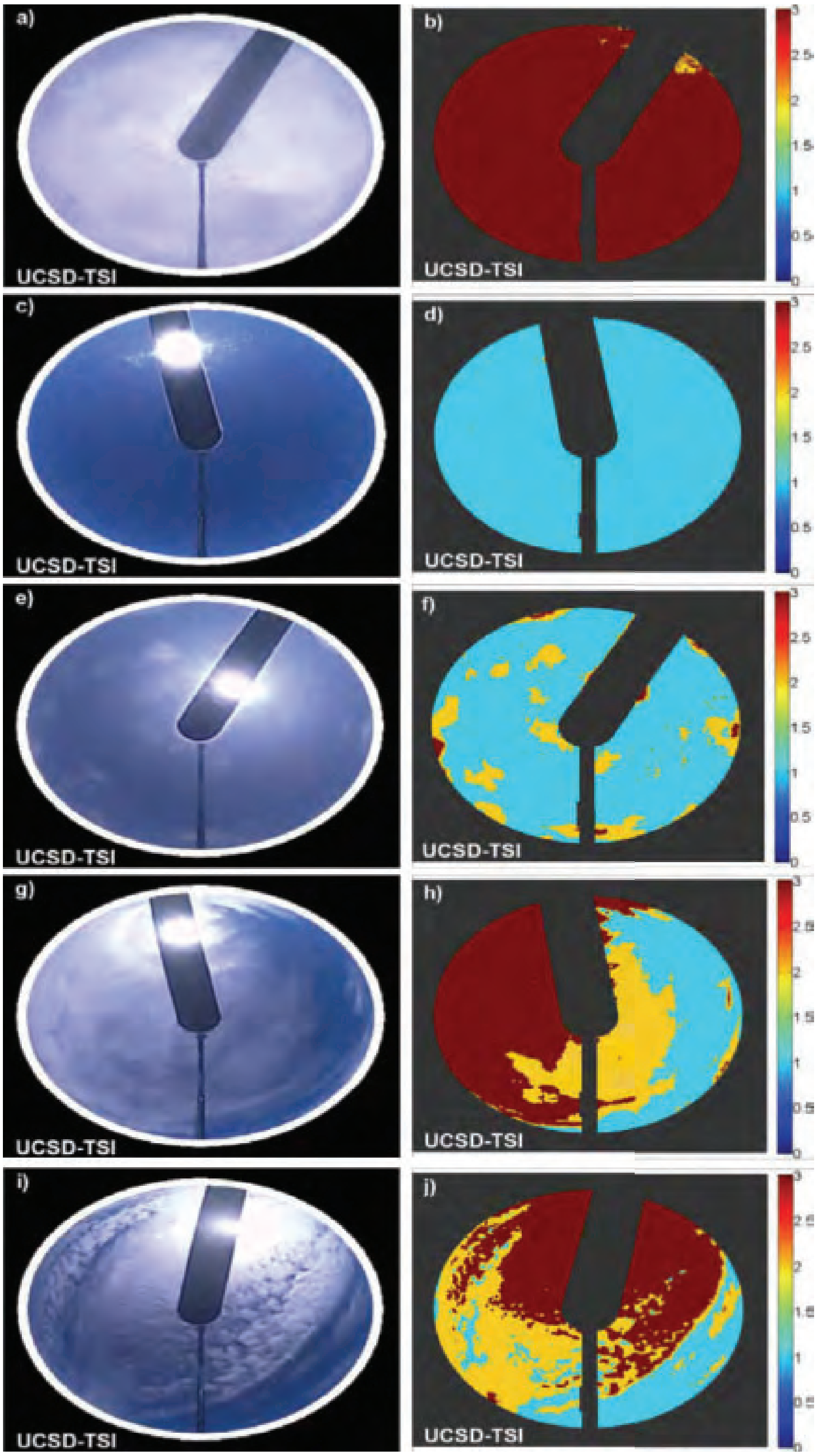

Figure 6. Total sky image (a, c, e, g, i) and CDOC (b, d, f, h, j) for: 1) overcast skies (a, b) taken on April 20, 2011; 2) clear skies (c, d) taken on Feb 12, 2011; 3) few thin clouds (e, f) taken on April 19 2011; 4) partly cloudy skies (g, h), (i, j) taken on Feb 13, 2011, and Feb 14, 2011. For the classification images, a value of 3 on the color scale represents thick clouds, 2 represents thin clouds, and 1 represents clear skies (Ghonima and Kleissl, 2012).

C.1.3. Motion vectors from satellite data

U of Oldenburg (Germany) is working on evaluation and further development of their cloud motion vector (CMV) forecasting algorithm based on Meteosat satellite images. Results of a one-year evaluation (July 2011- June 2012) for 270 stations in Germany presented in [Kühnert et al. 2012], reveal a superior performance of the CMV forecasts for up to 4 hours ahead compared to NWP based forecasts. A special focus has been on the evaluation of regional forecasts, which are of particular interest for grid operators. It was shown that for forecasts of the average irradiance for the area of Germany, root mean square error (RMSE) values are reduced to around one third of the corresponding values for single sites (see Figure 7).

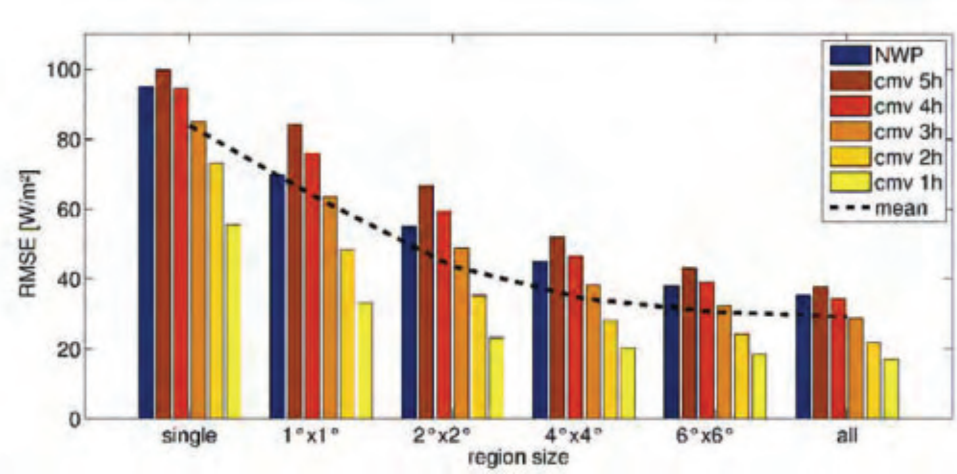

Figure 7. Evaluation of forecast accuracy in terms of RMSE compared to ground measurements for averaged forecasts in dependency on the regions size. NWP based forecasts as well as CMV forecast of different horizons are displayed.

Meteotest (Switzerland) developed a short term forecasting method combining cloud and radiation fields from Meteosat satellite images with wind fields from the numerical weather prediction (NWP) model known as the weather research and forecasting (WRF) model. An evaluation for lowland, alpine and high-alpine stations in Switzerland for July and August 2012 revealed a superior performance of the developed short term forecasting scheme to WRF forecasts up to 6 hours ahead. Figure 8 illustrates that short-term fluctuations are captured much better with the satellite based short-term prediction scheme than with the WRF. RMSE values of the short term forecasting scheme range between 20% (100 W/m^2) and 55% (250 W/m^2). Uncertainties are larger in alpine and high-alpine areas.

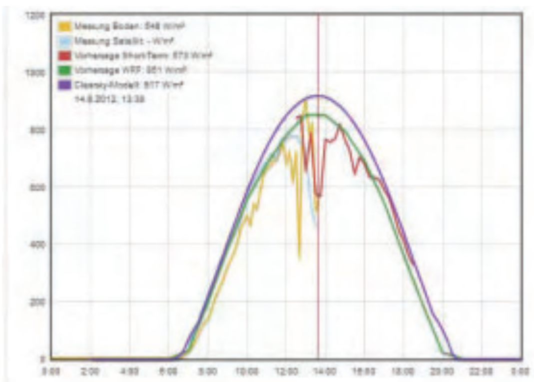

Figure 8: Comparison of forecasted and measured irradiances for 14.8.2012 for Muehleberg Stockeren. (yellow; measured; light blue: satellite-derived, Red: new short term forecast, green: WRF, pink; clear sky).

C.1.4 NWP forecast models

At the Danish Meteorological Institute (DMI) the HIRLAM 7.3 S05 ensemble model has been tested for the period from 2011-Aug-05 to 2011-Nov-12. The ensemble has 25 members (Figure 9). The GHI output data are tested against measurements from the 28 Danish pyranometer stations. The results based on forecast lead times of 2-54 hours show that RMSE is reduced by 15%-20% in the ensemble mean forecast as compared to the control forecast.

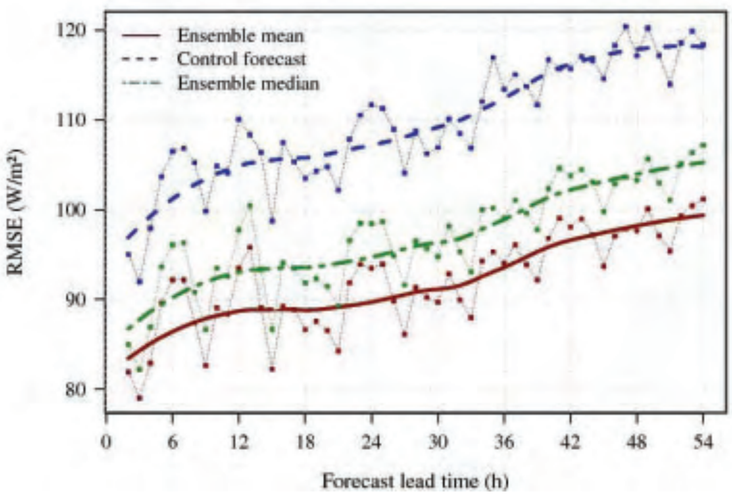

Figure 9. RMSE of Ensemble mean and median of the HIRLAM 7.3 S05 ensemble model in comparison to a control forecast.

DMI also contributes also with irradiance forecasts of their satellite & RADAR RUC model, which has a spatial resolution of 3 km and a temporal resolution of 10 min. The forecasts are updated hourly Figure 10 illustrates increasing agreement between RUC

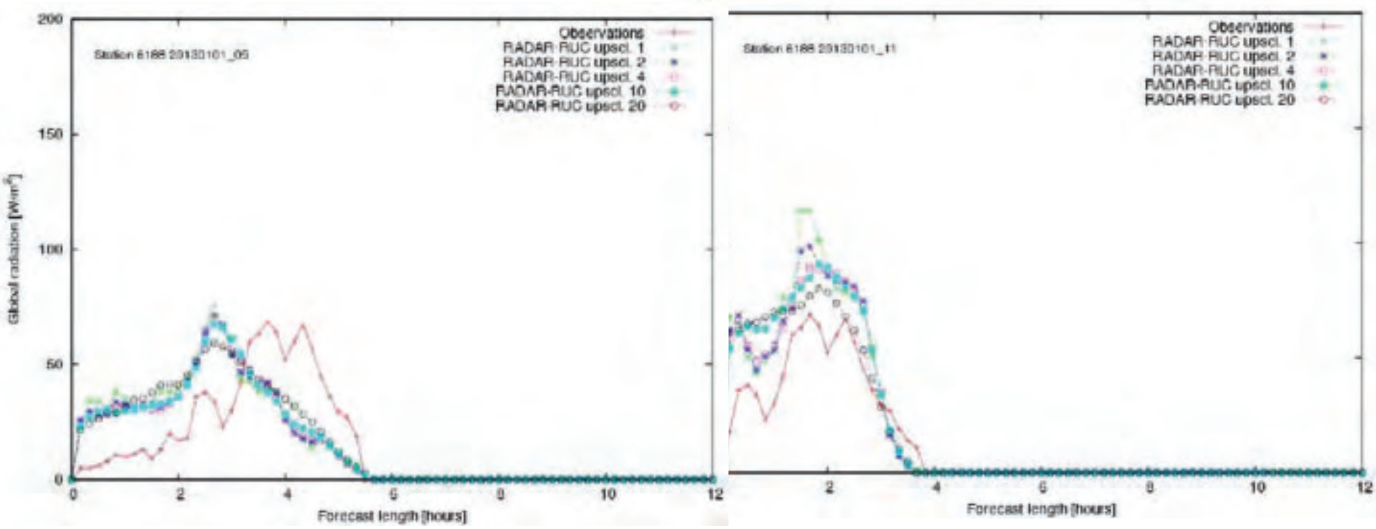

Figure 10. Comparison of forecasted (several RUC model runs) and measured irradiances for a Danish meteorological station.

model forecasts and measurements for decreasing forecast horizon.

C.1.5. Statistical models integrating different data sources

University of Oldenburg is investigating an approach based on linear regression to combine forecasts based on cloud motion vectors from satellite images and forecast data of two NWP models (Lorenz et al 2012). The NWP model data used in the study are operational forecasts of the integrated forecast system (IFS) run by the European Centre for Medium-Range Weather Forecasts (ECMWF) and the COSMO-EU model, operated by the German Weather Service. There is a strong potential for improving the forecast performance by combining different models (Figure 11). The combined forecasts outperform the single model forecasts for all forecast horizons investigated. For regional day-ahead predictions an improvement of 10% compared to the ECWMF based forecasts is found, when combining the two NWP model forecasts. For intra-day predictions with additional integration of satellite based CMV forecasts, the benefit is even much larger.

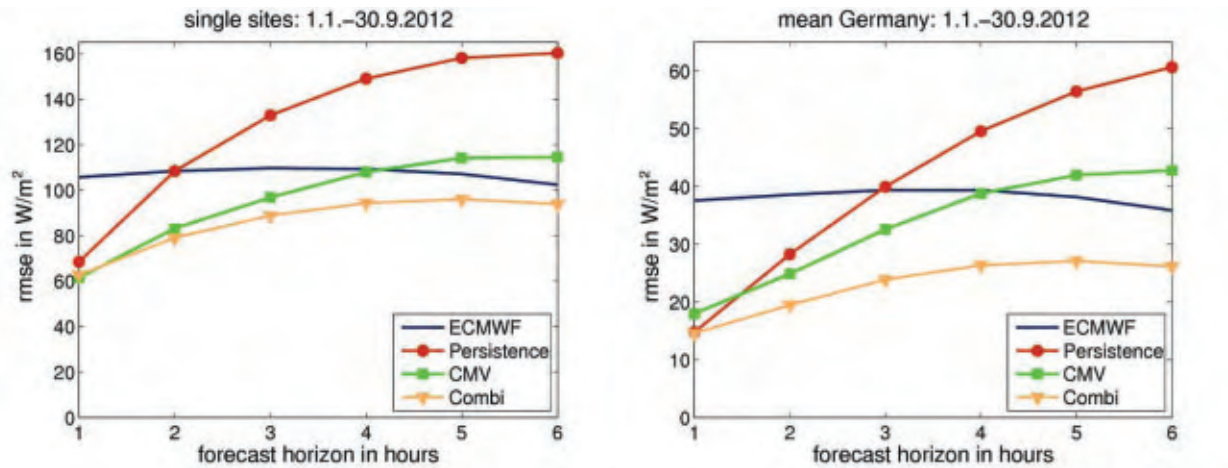

Figure 11. RMSE of ECMWF based, CMV and combined forecasts in comparison to persistence in dependence on the forecast horizon. For the ECMWF based forecast, the 12:00 UTC run of the previous day is evaluated independent of the forecast horizon and variations of the RMSE with the forecast horizon are due to the horizon dependent data sets Left: single sites, right: German mean.

DMI has provided NWP data as input to statistical models in the project: "Solar/electric heating systems in the future energy system". This project is lead by the Civil Engineering Department of the Danish Technical University (DTU). A statistical analysis has been published (Bacher 2012). Data from 2009 using the HIRLAM 6.2 S05 model is included in the study.

Activity C2: Integration of Solar Forecasts into Operations.

Work on this activity has not yet commenced.

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

- *Determination of Circumsolar Radiation from Meteosat Second Generation*

Progress has been made in determination of circumsolar radiation caused by cirrus clouds from the geostationary Meteosat Second Generation (MSG) satellites. This was achieved within the FP7 funded SFERA project (see project report). The circumsolar radiation is parameterized in terms of input parameters, optical depth and effective particle size which are retrievable from MSG. The retrieval of these input parameters was improved with special focus on translucent clouds.

- *Development of new transposition method to derive direct irradiance from global irradiance*

MINES ParisTech, in collaboration with TOTAL Gaz & Power R&D, has developed a general shape (sigmoid function) of the relationship between the clear sky index (Kc) and the ratio of the diffuse to global irradiance (fD), as shown in Figure 12, based on a literature review and analysis of several data sets of ground measurements. This analytical function needs two parameters. One is defined by the case of the overcast skies. The other parameter changes depending on the clear-sky conditions for the location and the instant. A clear-sky model provides the Kc and fD for the clear-sky conditions that can be used to estimate this second parameter. The proposed method is interesting because it is flexible, adaptive and does not rely on empirical parameters fitted from a set of ground-based measurements.

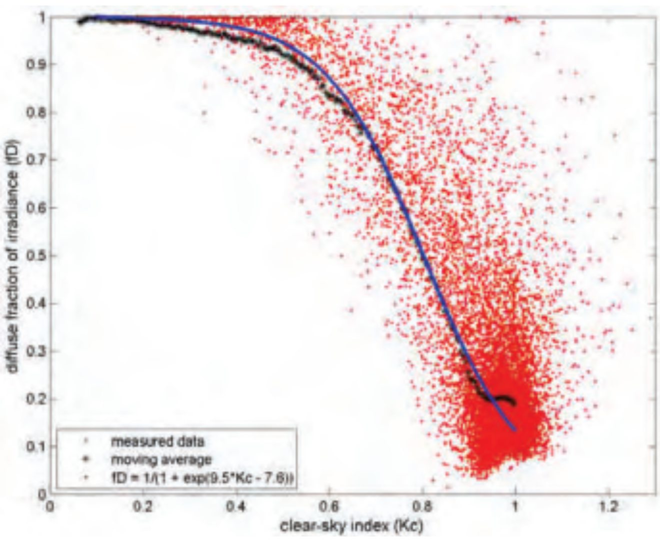

Figure 12. Example of the sigmoid function used to describe the relationship between the clear-sky index and the diffuse

- *MACC McClear: a model of clear-sky irradiance*

Within the framework of the FP7 funded MACC-II project (subproject radiation, MACC-RAD), MINES ParisTech has set up the clear-sky irradiance model McClear (spatial coverage: worldwide, time period: 2004 to 2011). Results of McClear are disseminated for free through a GEOSS-compliant web service (Web Processing Service, WPS). A web-based client using this WPS is available at http://www.soda-pro.com/web/guest/gmes-products and from the MACC portal (http://www.gmes-atmosphere.eu) (Figure 13).

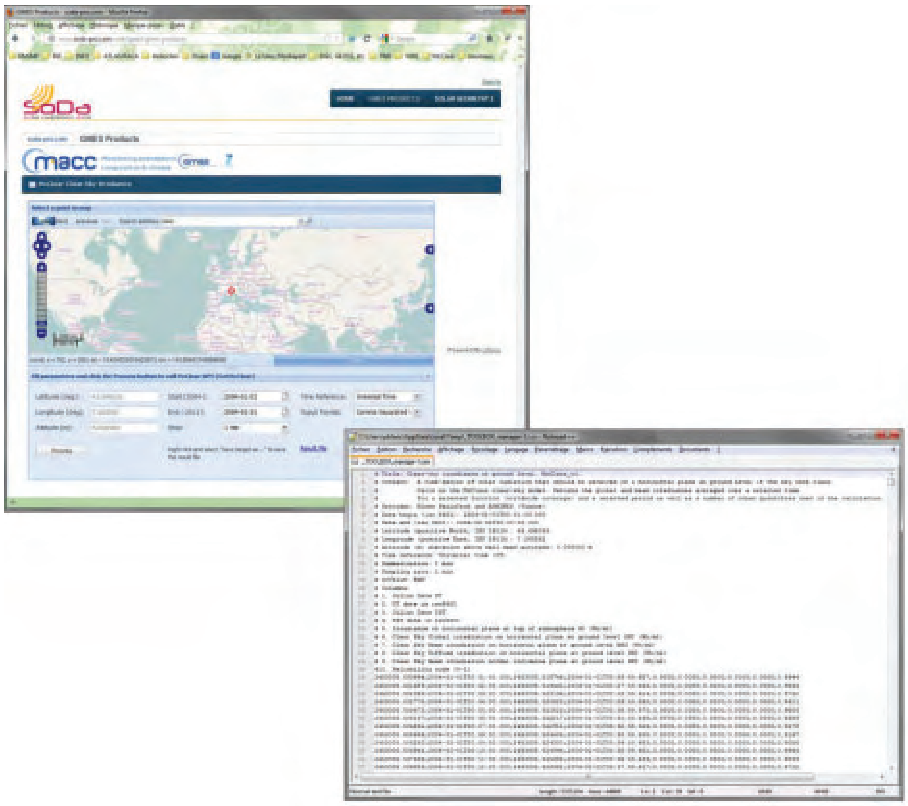

Figure 13. Snapshot of the web-based client (http://www.soda-pro.com/web/guest/gmes-products) delivering clear-sky irradiances from the McClear model developed in the framework of the FP7 funded MACC-II project.

- *Fast and accurate computation of the position of the Sun.*

The solar position algorithm (SPA) from NREL is a very accurate but slow algorithm for the computation of the Sun position with respect to an observer at ground surface. Within the FP-7 EU project ENDORSE, MINES ParisTech has proposed a new algorithm named SG2. Compared to existing fast algorithms, SG2 is faster and offers the same level of accuracy than the most accurate, i.e., maximum error in solar vector of order of 1000, for a multi-decadal time period, with an example of a 50-year period: 1980–2030. This performance is achieved by devising approximations of the original equations of the SPA to decrease the number of operations. This yields a decrease in accuracy that is controlled and bounded (Figure 14).

- *Heliosat-4: new satellite-based Surface Solar Irradiance estimation method with radiative transfer code*

Downwelling surface shortwave irradiance (SSI) is more and more often assessed by means of satellite-derived estimates of optical properties of the atmosphere. Performances are judged satisfactory for the time being but there is an increasing need for the assessment of the direct and diffuse components of the SSI. MINES ParisTech and the German Aerospace Center (DLR) are currently developing the Heliosat-4 method to assess the SSI and its components in a more accurate way than current practices. This method is composed of two parts: a clear sky module based on the

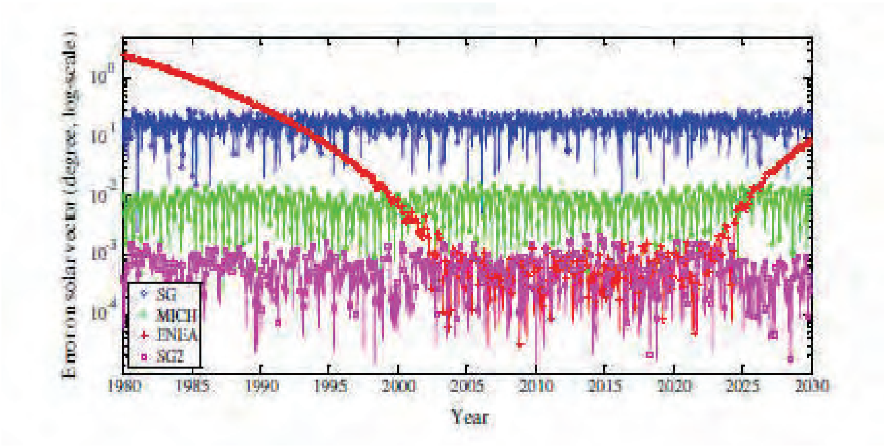

Figure 14. Errors on the solar vector predictions for the three fast algorithms (SG, MICH, and ENEA), compared to SG2, during the reference time period 1980–2030 (cf. Blanc and Wald, 2012).

radiative transfer model libRadtran, and a cloud-to-ground module using two-stream and delta-Eddington approximations for clouds and a database of ground albedo. Advanced products derived from geostationary satellites and recent Earth Observation missions are the inputs of the Heliosat-4 method. Such products are: cloud optical depth, cloud phase, cloud type and cloud coverage from APOLLO of DLR, aerosol optical depth, aerosol type, water vapor in clear-sky, ozone from MACC products (FP7), and ground albedo from MODIS of NASA. Figure 15 provides the general schema of the Heliosat-4 methodology.

- *Production of a new high-resolution global Surface Solar Energy Dataset*

The team at NASA, SUNY and NREL are collaborating with the US National Oceanic and Atmospheric Administration's National Climate Data Center (NCDC) to produce a new long-term solar irradiance data set. The project has progressed in the past year. The first version will be using the newly reprocessed ISCCP B1U/GridSat and using the SUNY model. This year SUNY tested the model on ISCCP B1U data and found

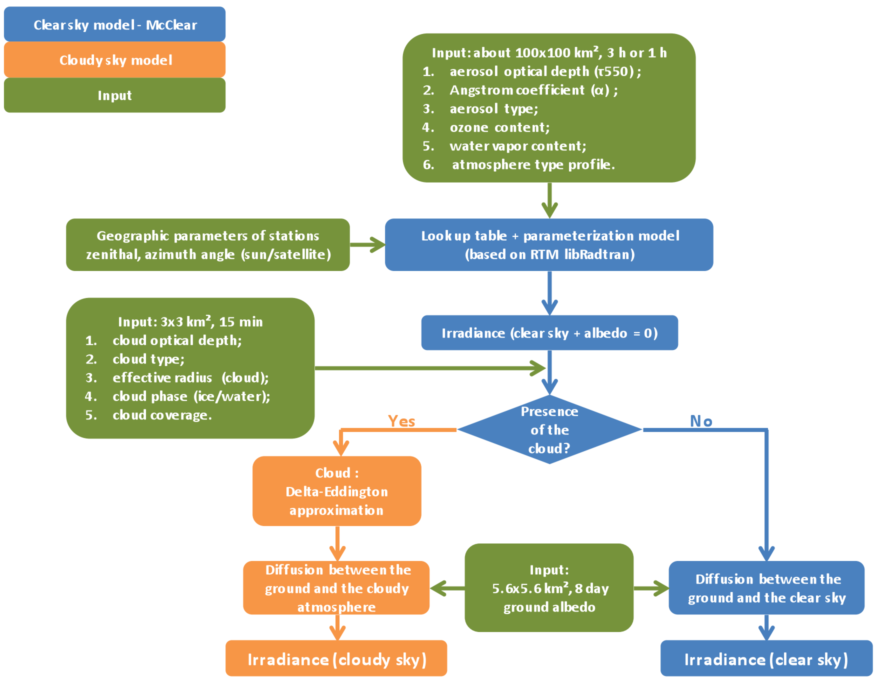

Figure 15. General schema for the Heliosat-4 method.

estimates comparable to its retrieval using the US GOES observations. SUNY has now delivered its model to NASA for incorporation into a production system that uses a variety of satellite-based and model inputs. New long-term aerosol data sets are also being incorporated into the production system. First samples of data products are expected to become available in the next 6 months. Subsequent versions of the data sets will be adapted from a newly reprocessed ISCCP version with both the SUNY model and a model containing full radiation physics.

- *"Modeling the distribution of radiances in the sky vault under clear-sky conditions for an accurate assessment of the beam and circumsolar radiation"* (PhD Thesis, 2012 - 2014)

Radiance is the density of power received on a plane from a given direction. Irradiance is the angular integral of radiances on the sky vault. Distribution of radiances is not uniform (see Figure 16). The radiance is the greatest in the direction of the sun and decreases towards the horizon; it varies very rapidly in the vicinity of the sun direction. Several systems exhibit limited angular aperture, such as pyrheliometers that measure the beam irradiance, or concentration-based systems for producing energy, e.g., CSP or CPV. The irradiance received by such systems is presently not well modeled. A more accurate description and modeling of the radiances should yield a better assessment of the solar radiation available for energy conversion.

The objectives of the thesis are first to define a method for the fast simulation of the distribution of radiances on the sky vault as a function of the optical state of the clear atmosphere, and then to develop and validate a model of this distribution. Emphasis is put on the beam radiation.

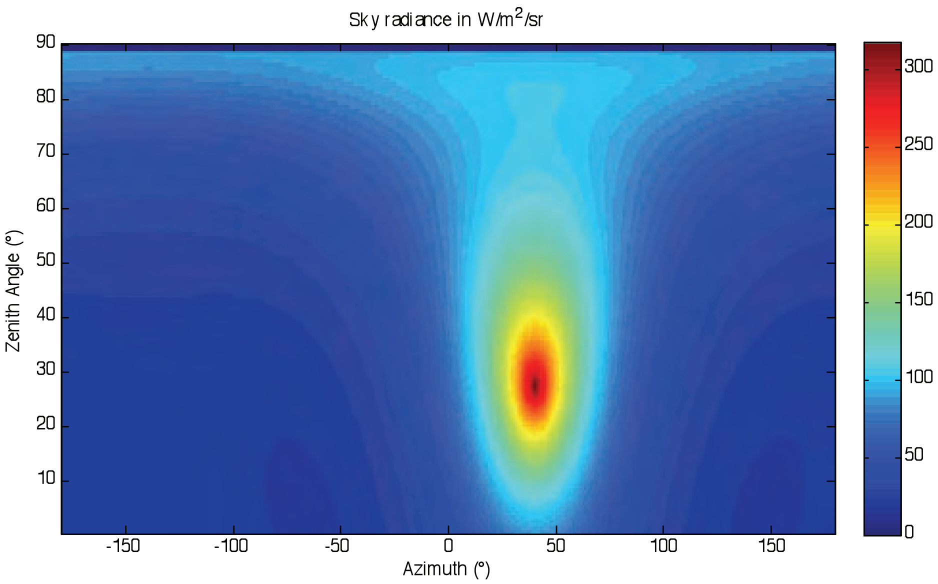

Figure 16. Example of diffuse sky radiance from the model proposed by Igawa et al. (2004).

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" (PhD Thesis, 2012-2014).*

The radiation emitted by the Sun has wavelengths comprised between 200 nm and 4 mm. Half of the energy lies in the visible band. The spectral distribution is modified by interactions with atmospheric constituents as the radiation travels downward. We are presently capable of producing fairly accurate assessments of the total radiation, i.e. integrated over the whole spectrum at any location and any instant, but not for spectral distribution. Such estimates would bring a better knowledge in the effective energy that can be used by a given photovoltaic (PV) system or in photo-catalysis, or in UV and its impact on human health, or material weathering, including organic cells for PV, or in photosynthesis (PAR) for plant growing, or in daylight, i.e. the light to which the eye is sensitive.

The objective of the research is the development of a numerical model for the assessment of the spectral distribution of the solar radiation for any place any time. Model inputs will be provided by existing models for atmospheric physics and results from processing of satellite images.

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

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

TOTAL Gaz & Power R&D and Masdar Institute of Science and Technology, in collaboration with MINES ParisTech, has carried out a validation of the aerosol optical depth dataset from MACC-ECMWF re-analysis in the United Arab Emirates. This validation has been done by comparing MACC-ECMWF AOD estimation with corresponding AERONET ground-based dataset in term of libRadTran-based estimation error of global horizontal and direct normal irradiances under clear-sky condition (Figure 17).

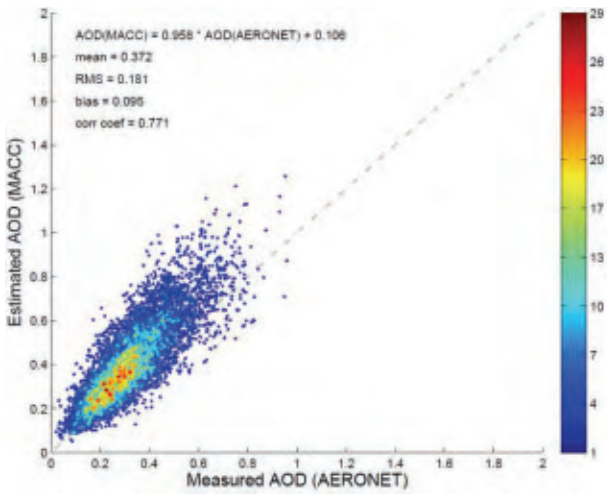

Figure 17. Comparison between measured (AERONET) and estimated (MACC) hourly AOD at 550 nm, for all AERONET stations in UAE.

Ciemat has reviewed the ground albedo estimation in satellite retrievals and has proposed a method for considering the dependence with the scattering angle that has to be applied dynamically on every pixel. The robustness of the methodology has been analyzed with different geostationary satellites (MSG, MFG IODC and GOES) showing good results for different reflective grounds as well. Figure 18 shows the ground albedo computed for Thesalonica with MSG and MFG IOCD images and the daily GHI retrieved compared to ground measurements.

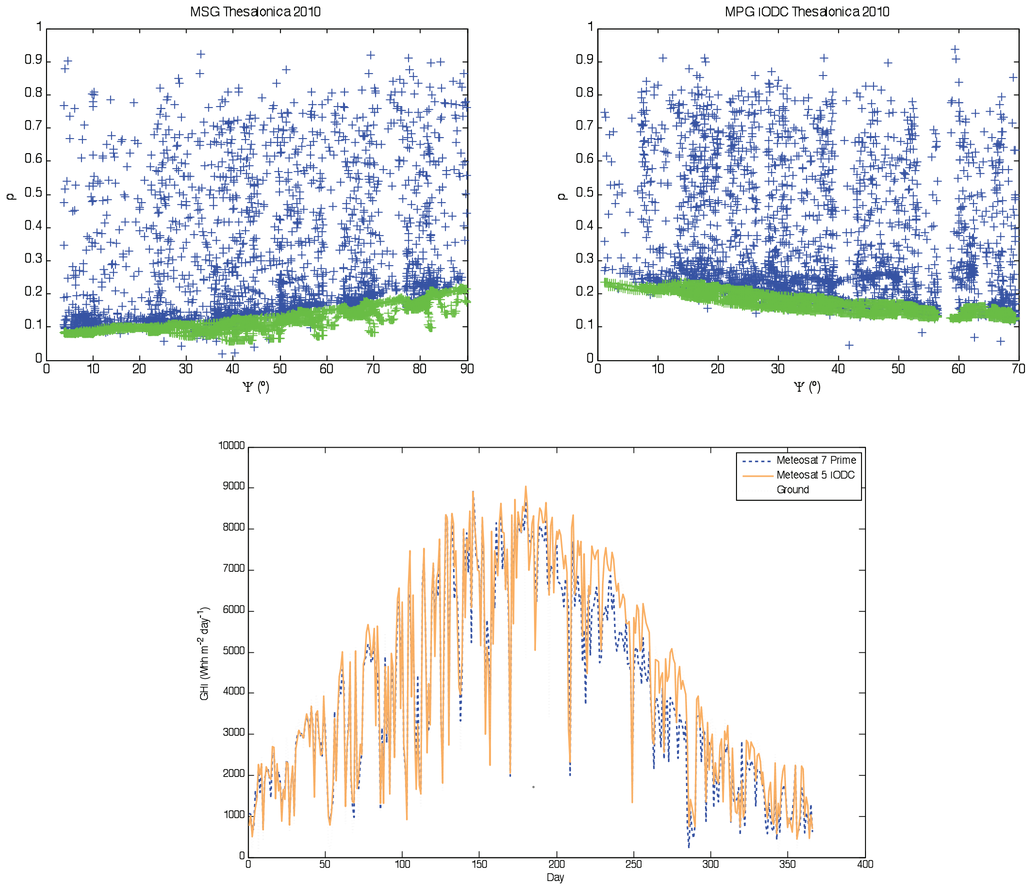

Figure 18. Ground albedo computed for Thesalonica using MSg and MFG IODC images for 2010 and GHI daily estimations.

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

The GEWEX radiative flux assessment report is now in last stages of preparation for publication. The report will be published on the Internet at the World Climate Research Programme (WCRP) web site. The major conclusion is that the current versions of the long-term solar fluxes from satellite-based estimates are not accurate enough to differentiate between physical changes and satellite calibration and data input uncertainties. Short-term and/or large regional changes due to clouds are more likely to be confirmed in long-term satellite estimates. Subtle changes in the current multi-decadal data sets due to aerosol effects are not yet detectible owing to the large uncertainties in the physical properties and variability of those aerosols. Work is underway to completely reprocess the older measurements starting around 1980 with new and improved satellite calibration and atmospheric inputs that should improve the ability to detect long-term variability.

WORK PLANNED FOR 2013

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

Work planned for 2013 is to:

1) Include the solar resources associated with the DNI in the balancing analysis.
2) Analyze the spatial balancing of the solar energy resources over wide regions.

Subtask B: Standardization and Integration Procedures for Data Bankability

Activity B1: Measurement Best Practices.
Although the work in B1 is on time the activity will be extended to five years instead of 3 years as previously planned.

In 2013 the best practices for RSI based resource assessment will be revised based on the discussions and reviews collected at the 23 January 2013 Task 46 workshop. The manual for ground based resource assessment with further instruments will be planned in detail. The option to update NREL's best practices handbook (Stoffel et al., 2010)[2] has been discussed and was identified as the best possible way to proceed. Thus, the work on this general manual can be started immediately after the publication of the RSI specific manual (beginning of 2014.

Activity B2: Gap Filling, QC, Flagging and Data Formatting.
<u>MINES ParisTech:</u>

- Publication of a peer-reviewed article on Quality Check procedure for meteorological data, and notably for ground-based irradiance data.

<u>NASA:</u>

- Evaluating gap filling procedures for new satellite based data products
- Applying new surface measurement procedures to surface measurements for validation of satellite estimate solar flux data products.

Activity B3: Integration of Data Sources.
<u>MINES ParisTech:</u>

- Publication of a peer-reviewed article[3] on the short-term calibration of monthly Global Horizontal Irradiance estimation from Helioclim-3 in collaboration with SOLAIS (a French consultant company on the field of PV engineering).

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[2] Stoffel, Tom, Dave Renné, Daryl Myers, Steve Wilcox, Manajit Sengupta, Ray George, Craig Turchi, 2010: Concentrating Solar Power: Best Practices Handbook for the Collection and Use of Solar Resource Data. NREL/TP-550-46475, National Renewable Energy Laboratory, Golden, Colorado USA 80401. September 2010. http://www.nrel.gov/docs/fy10osti/47465.pdf

[3] Vernay, C., P. Blanc, S. Pitaval, 2013. Characterizing measurement campaigns for an innovative calibration approach of the global horizontal irradiation estimated by HelioClim-3, Renewable Energy *(accepted, to be published).*

- Continuation of scientific activities on the short-term calibration with ground-based measurements of sub-daily irradiance long-term datasets (global, diffuse and direct) from HelioClim-3 (collaboration with Transvalor Innovation and Bertin Technologies, financial support of ADEME, the French agency for environment and energy management).

Activity B4: Evaluation of Meteorological Products.
NASA:

- Evaluation of new atmospheric water vapor and ozone data products for long-term production of satellite based solar fluxes
- Validation of NASA reanalysis and other near surface meteorological products including temperature, dew point, pressure and wind against global surface measurements networks.

Subtask C: Solar Irradiance Forecasting

MINES ParisTech:

- Continuation of scientific activities on low-cost fish-eye webcams (notably in collaboration with EDF R&D). Planned study on stereoscopic analysis of pair of fish-eye cameras for cloud height estimation.

Subtask D: Advanced Resource Modeling

Activity D1: Improvements to Existing Solar Resource Retrieval Methods
MINES ParisTech:

- Continuation and finalization of the PhD thesis on Heliosat-4 (Radiative transfer model for satellite-based surface solar irradiance estimation).
- Continuation (1st year) of the PhD thesis on the sky radiance (collaboration with the MIST and TOTAL)
- Continuation (1st year) of the PhD thesis on the spectral surface solar irradiance
- Continuation of activities related to AOD and surface solar irradiance retrievals in the United Arab Emirates (collaboration with the MIST and TOTAL).

Planned Joint Activities for Participants Involved in D1

- Publication of a collective peer-reviewed journal article on definitions and best practices for solar processing related to direct and circumsolar normal irradiance.
- Inventory of ground-based measurement available from the Task 46 participants (and observers) of interest for validation activities required for D1 (e.g. ground-based measurements of global, diffuse and direct normal irradiance, sunshape, circumsolar ratio, aerosol optical depth, cloud properties, etc.).

- Compilation of existing comparisons dedicated to surface solar irradiance retrieval of different sources of aerosol optical depth and other related relevant properties (satellite-based or meteorological re-analysis based) with ground based measurements (e.g. AERONET). Organization of a workshop with different providers of aerosol datasets (ECMWF, NASA, etc.).

NASA:

- Production and assessment of extended versions of new solar irradiance data products using NASA inputs and the SUNY algorithm.
- Evaluation of long-term AEROCOM based aerosols, with parameterizations aimed at accounting for variability for production of long-term solar flux data products.

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

<u>*Planned joint activities for participants involved in D2*</u>

- Comparison of long-term inter-annual variability estimated from different sources of long-term surface solar irradiance datasets.

<u>NASA:</u>

- Assessment of variability of most recent decade of solar measurements from surface and satellite based estimates with long-term climate prediction data products.

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), Irradiance Corp. (USA), Augustyn and Co. (USA), and Clean Power Research (USA). Additional participation is anticipated from Sun2Market Solutions (Spain), Peak Design (UK), and Solar Consulting Services (USA).

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

REPORTS/PAPERS PUBLISHED IN 2012

Journal Articles and Book Chapters

Blanc, P. and L. Wald, 2012. The SG2 algorithm for a fast and accurate computation of the position of the Sun for multi-decadal time period, Solar Energy. 86, 10, pp. 3072–3083 (related to activity D1).

Bosch JL, Y Zheng, J Kleissl, Deriving cloud velocity from an array of solar radiation measurements, *Solar Energy*, in press.

Espinar, B. and P. Blanc, 2012. Satellite images applied to surface solar radiation estimation, Chapter 4 of Solar Energy at Urban Scale, B. Beckers (Ed.), iSTE, Wiley, pp. 57–100 (related to activity D1).

Ghonima, M, J Kleissl, A Method for Cloud Classification Based on Ground Based Sky Imagery, *Atmospheric Measurement Technology*

Huang, Jing, Malgorzata Korolkiewicz, Manju Agrawal and John Boland, 2013. Forecasting solar radiation on an hourly time scale using a coupled autoregressive and dynamical system (CARDS) model, Solar Energy, (in press).

Luoma, J, J Kleissl, Determination of forecast value considering energy pricing in California, submitted to Applied Energy

Mathiesen, P, J Brown, J Kleissl, Regime-Based California NWP Probabilistic Irradiance Forecasts, *IEEE Transactions on Sustainable Energy*, 99, 2012 10.1109/TSTE.2012.2200704.

Polo, J., L. Martin, M. Cony, 2012. Revision of ground albedo estimation in Heliosat scheme for deriving solar radiation from SEVIRI HRV channel of Meteosat satellite Solar Energy 86, 275-282.

Santos-Alamillos F.J., Pozo-Vázquez D, Ruiz-Arias J, Lara-Fanego V and Tovar-Pescador J. 2012. Analysis of the spatio-temporal balancing between wind and solar energy resources in the southern Iberian Peninsula. Journal of applied meteorology and climatology. 51:2005-2024 DOI: 10.1175/JAMC-D-11-0189.1

Zhang T, P.W. Stackhouse, Jr., S. K. Gupta, S.J. Cox, J.C. Mikovitz, and L.M. Hinkelman, 2012. The validation of the GEWEX SRB surface shortwave flux data products using BSRN measurements: A systematic quality control, production and application approach. *J Quant. Spectrosc. Radiat. Transfer*, http://dx.doi.org/10.1016/j.jqsrt.2012.10.004

Conference Proceedings

Boland, John, Malgorzata Korolkiewicz, Manju Agrawal and Jing Huang (2012) Forecasting solar radiation on short time scales using a coupled autoregressive and dynamical system (CARDS) model, *Proceedings of the Australian Solar Energy Conference*, Melbourne, Dec 2012.

Bucher, C., Betcke, J., Andersson, G., Bletterie, B., Küng, L., Simulation of distribution grids with photovoltaics by means of stochastic load profiles and irradiance data, paper presented at the 27th EU-PVSEC, 24-28 Sept. 2012, Frankfurt Germany.

Espinar, B., P. Blanc, L. Wald, B. Gschwind, L. Ménard, E. Wey, C. Thomas, L. Saboret, 2012. HelioClim-3: a near-real time and long-term surface solar irradiance database, in: COST WIRE Workshop on “Remote Sensing Measurements for Renewable Energy” (related to activity D1).

Espinar B., P. Blanc, L. Wald, C. Hoyer-Klick, M. Schroedter-Homscheidt, T. Wanderer, 2012. Controlling the quality of measurements of meteorological variables and solar radiation. From sub-hourly to monthly average time periods", in: European Geosciences Union 2012, Vienna (Austria) (related to activity B2).

Gauchet, C., P. Blanc, B. Espinar, 2012. Surface solar irradiance estimation with low-cost fish-eye camera, in: COST WIRE Workshop on “Remote Sensing Measurements for Renewable Energy”, DTU Risoe (related to activity C1).

Kühnert J, Lorenz E, Hammer A and Heinemann D: Prediction of solar irradiance using METEOSAT images for the application in photovoltaic power prediction systems. EUMETSAT Meteorological Satellite Conference, Sopot, Poland, 3 - 7 September 2012.

Lorenz E, Kühnert J, and Heinemann, D: Short Term Forecasting of Solar Irradiance by Combining Satellite Data and Numerical Weather Predictions. Proc. of 27th EUPVSEC, p 4401 – 4405, Frankfurt, Germany, 25 – 27 September 2012.

Oumbe, A., Z. Qu, P. Blanc, H. Bru, L. Wald, 2012. An adaptive method to derive direct irradiance from global irradiance. In: SolarPACES 2012 (related to activity D1).

Oumbe, A., H. Bru, Z. Hassar, P. Blanc, L. Wald, A. Fournier, D. Goffe, M. Chiesa, H. Ghedira, 2012. Selection and implementation of aerosol data for the prediction of solar resource in United Arab Emirates. In: SolarPACES 2012 (related to activity D1).

Perez, Richard, J. Schlemmer, K. Hemker, P.W. Stackhouse, Jr., S.J. Cox, and J.C. Mikovitz, 2012: Towards a high resolution long-term solar resource database: applying the SUNY model to ISCCP B1U data stream. Proceedings of the Solar 2012 (American Solar Energy Society). Denver, Colorado, 13-17 May.

Qu, Z., A. Oumbe, P. Blanc, M. Lefèvre, L. Wald, M. Schroedter-Homscheidt, G. Gesell, 2012. A new method for assessing surface solar irradiance: Heliosat-4. In: European Geosciences Union 2012, Vienna (Austria) (related to activity D1).

Stackhouse, P.W., Jr., E. Raschke, T. Wong, L. Hinkelman, S. Kinne, W. Rossow, Y. Zhang, E. Dutton, C. Long, M. Wild, N. Loeb, W. Su, T. Zhang, S. J. Cox, and J. C. Mikovitz, 2012: An Overview of Results from the GEWEX Radiative Flux Assessment. International Radiation Symposium, Berlin, Germany, August 6-10.

Vernay, C., S. Pitaval and P. Blanc, 2012. Calibration of long-term global horizontal irradiation estimated by HelioClim-3 through short-term local measurement campaigns: extending of the results to European and African sites, in: WREF, 2012: pp. 1–8 (related to activity B3).

Wey, E., C. Thomas, P. Blanc, B. Espinar, M. Mouadine, 2012. A fusion method for creating sub-hourly DNI-based TMY from long-term satellite-based and short-term ground-based irradiation data, in: Solar Paces 2012 (related to activities A1 and B3).

Other Miscellaneous Reports

Espinar, B., L. Wald, P. Blanc, C. Hoyer-Klick, M. Schroedter-Homscheidt, T. Wanderer, 2012. Report on the harmonization and qualification of meteorological data. Technical report D3.2, ENDORSE FP-7 project, 81 pages. http://www.endorse-fp7.eu/public_deliverables (related to activity B2).

Reinhardt, B., Buras, R., Bugliaro, L., Mayer B., 2012, Report on the Determination of the Sunshape from Meteosat Second Generation, Technical Report SFERA Project Deliverable R13.4, http://sfera.sollab.eu/index.php?page=joint_wp13

MEETINGS IN 2012

Second Task 46 Experts Meeting
18 May 2012
Golden, Colorado USA

This meeting focused on a review of Task activities, including a special discussion on measurement of circumsolar radiation and definitions of Direct Normal Irradiance.

Third Task 46 Experts Meeting
21-23 January 2913
Sophia Antipolis, France

This meeting focused on revisions to the work plan to clarify schedule and deliverables, and review progress in all subtasks. The meeting included a special one-day workshop on best practices in solar resource (DNI) measurements.

MEETINGS PLANNED FOR 2013

Joint Task 46/PVPS Task 14 Expert Meeting
30 September 2013
Paris, France (in conjunction with 28th PVSEC)

Fourth Task 46 Experts Meeting
7-9 October
Oldenburg, Germany

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Task 47

Renovation of Non-Residential Buildings Towards Sustainable Standards

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TASK DESCRIPTION

Buildings are responsible for up to 35 % of the total energy consumption in many of the IEA participating 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 the 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.

This Task will start by analyzing highly successful renovations and develop innovative concepts for the most important market segments.

Equally important, local authorities, companies and planners also need the knowledge 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
- Super markets and shopping centers

Depending on available projects among the participating countries, the following types may also be recognized; 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, Asplan Viak AS, Fritjof Salvesen)

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, Segel AS, Trond Haavik)

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, Fraunhofer ISE, Doreen Kaltz)

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, University of Louvain La Neuve, Sophie Trachte).

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 available on the website by spring 2012. Target groups are designers, planners and building owners.
3. Two seminars in conjunction with expert meetings presenting 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 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 1 January 2011 and will end on 30 June 2014.

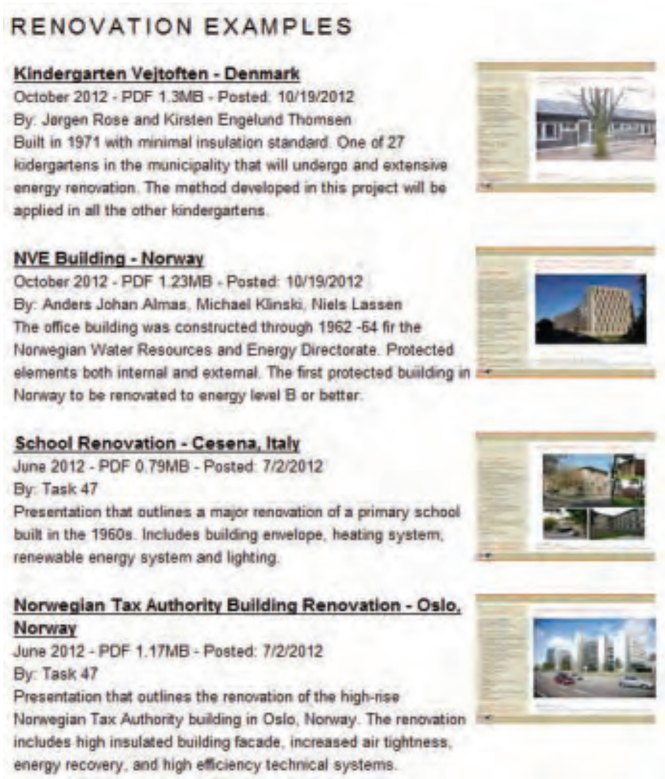
WORK DURING 2012

Information

A public Task 47 seminar was organized in Brussels on September 5. The seminar was in connection with the Passive House Fair in Brussels organized by the Passiefhuis-Platform vzw.

Subtask A: Exemplary Renovation Projects

For the public presentation of 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


RENOVATION EXAMPLES

Kindergarten Vejtoften - Denmark
October 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 kidergartens 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
October 2012 - PDF 1.23MB - Posted: 10/19/2012
By: Anders Johan Almas, Michael Klinski, Niels Lassen
The office building was constructed through 1962 -64 fir 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
June 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
June 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.

processes, the building envelope, the building services system, the energy and environmental performances and finally the costs.

Four exemplary project brochures were uploaded on the public website during 2012, two office buildings from Norway, one Kindergarten from Denmark and one school building from Italy. Due to differences in the energy calculation standards among the countries the energy numbers are not always comparable.

The projects show a reduction in heat consumption of 50-75% and 50-70% reduction in the overall energy demand.

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 have been accomplished. Some of 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

Preliminary conclusions from the building stock analysis show that the main energy saving potential are 1) Retail buildings, 2) Offices, and 3) Educational buildings.

Subtask C: Technical Solutions and Operational Management

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.

Subtask D: Environmental and Health

The work included the topic indoor comfort, which is of special importance for schools. Not all designers and planners are aware of the fact that children are not "small adults"; their metabolism, nervous system and respiratory system are not mature:

- Compare to their weight children drink and eat more, they also absorb a larger proportion of pollutants in their food.
- Children inhale twice as much air as adults compared to their weight. They breathe mainly through the mouth.
- Their metabolic elimination of toxic substances is weak
- They spend more time near the floor and put their fingers in their mouths, increasing their exposure to toxic agents in dust and soil.

WORK PLANNED FOR 2013

It is planned that more than ten additional renovation project brochures will be available from the Task website during 2013. A summary of national renovation guidelines also will be presented.

A seminar in connection with the spring meeting in Sydney, Australia will be organized.

The Task will be represented at the SHC 2013 Conference in Freiburg, Germany in September.

The building stock analysis in Subtask B will be completed and the work with decision-making processes and market strategies will be continued.

In Subtask C, numbers from the detailed database will be used to evaluate buildings and plant performance.

LINKS WITH INDUSTRY

Some of the Task participants are representing consulting companies. In some countries, as with Norway, a national Task 47 project is organized with several industry partners.

REPORTS PUBLISHED IN 2012

Four brochures were published and posted on the Task website.

REPORTS PLANNED FOR 2013

Ten more brochures will be available on the website.

MEETINGS IN 2012

3rd Experts Meeting
April 12 - 13
Rome, Italy

4th Experts Meeting
September 5 - 6
Louvain la Neuve, Belgium
(Task 47 Seminar, September 7 in Brussels).

MEETINGS PLANNED FOR 2012

5th Experts Meeting
April 3 - 4
Sydney, Australia
(Task 47 Seminar, September 5 in Sydney).

6th Experts Meeting
September 30 - October 2
Graz, Austria

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Task 48

Quality Assurance and Support Measures for Solar Cooling

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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 about 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, Belgium*, Canada, China, France, Germany, Italy, Japan, Singapore, United States
**Participation ended in 2012*

RESULTS IN 2012

The main organizational progress has been 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 & 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

The first SHC Task 48 Training Seminar was held at the AHR Fair in Chicago, Illinois in January. It was lead by Lucio Mesquita of Thermosol.

Workshop solar heating for air conditioning and industrial process heat at the Klimaenergy Fair in September in Bolzano, Italy. International experts compared their experiences to give life to a discussion that develop strategic visions for the solar thermal sector, with particular interest to solar heating & cooling - air conditioning of buildings. Task 48 OA Daniel Mugnier managed the workshop on solar cooling (both in German and Italian language) to share with 30 people the topic of solar cooling, especially in the Italian context.

Common internal workshop for SHC Task 45, SHC Task 48 and SHC Task 49 experts on Large solar systems (district heating and cooling) in Graz, Austria.

Conference Presentations and Articles

1st Saudi Arabia Renewable Energy Conference and Exhibition in February in Dahran, Saudi Arabia.

InterSolar Europe Conference in June in Munich, Germany.

SHC 2012 Conference in July in San Francisco, California.

EuroSun 2012 Conference in September in Rijeka, Croatia.

Gleisdorf Solar Conference in September in Gleisdorf, Austria.

7th International DERBI Conference on Renewable Energy
Place in October in Perpignan, France

Article on Solar Cooling & Task 48 in the International Airport Review & International Sustainable Energy Review, Issue 1, authors U. Jakob and D. Mugnier.

Press releases:

- Momentum in solar cooling growing: large industrial corporations entering the field
- Presentations of solar cooling session at Intersolar Europe now available for download

Ten draft reports were completed. These draft reports are only available internally at this time:

- ***Subtask A***
  - MA2-1 : creation of assemblies related to plant components & materials
  - MA6-1: Start extensive market overview on Conc. collectors.

- ***Subtask B***
  - MB2-1: 1st status on good practice for DÉC design & installation
  - MB7-1: method to collect criteria to qualify quality & cost competitiveness of SAC

- ***Subtask C***
  - MC1-1: template for review of relevant int. Standards rating & incentive schemes
  - MC4-1: draft of measurement and verification procedure
  - MC6-1: status on existing work in T45 on contraction models

- ***Subtask D***
  - MD1-1: existing websites on SAC
  - MD4-1: existing roadmaps
  - MD5-1: existing training material

WORK PLANNED FOR 2013

According to the Work Plan, the following deliverables should be available by the end of 2013:

- Subtask C: Report and database of existing inter-national standards, rating and incentive systems relevant to solar cooling.
- Subtask C: Report on the rating, measurement and verification of solar cooling performance and quality.
- Subtask C : Report on contracting models.
- Subtask D: Updated website.

LINKS WITH INDUSTRY

Industry representives participating in Task Experts Meeting as observers include: Shuangliang (China), Pink (Austria), Kawasaki (Japan), SOLEM (Australia), Sortech (Germany), Invensor (Germany). They represent primarily chiller 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 2012

2nd Experts Meeting
March 26-27
Milano, Italy
(38 experts from 9 countries (Germany, Austria, Australia, Italy, Japan, Spain, USA, Canada, France) attended).

3rd Experts Meeting
September 10-11
Graz, Austria
(In conjunction with Gleisdorf Solar. 33 experts from 8 countries (Germany, Austria, Australia, Italy, Japan, Spain, USA, France, China) attended).

MEETINGS PLANNED FOR 2013

4th Experts Meeting
April 09-10
Newcastle, Australia

5th Experts Meeting
September 30 – October 01
Freiburg, Germany

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Task 49

Solar Process Heat for Production and Advanced Applications

Christoph Brunner
Operating Agent for AEE INTEC Austria

TASK DESCRIPTION

The scope of the Task is on solar thermal technologies for converting the solar radiation into heat and the further integration of the produced heat into industrial processes (i.e., the subject which is covered by the Task starts with the solar radiation reaching the collector and ends with the hot air, water or steam being integrated into the application).
The Task 49 deals with all industrial processes that are thermal driven and have a temperature range up to 400°C.

The work in the Task is structured into four Subtasks.

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 life time. Based on the investigation of the dynamic behaviour 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:

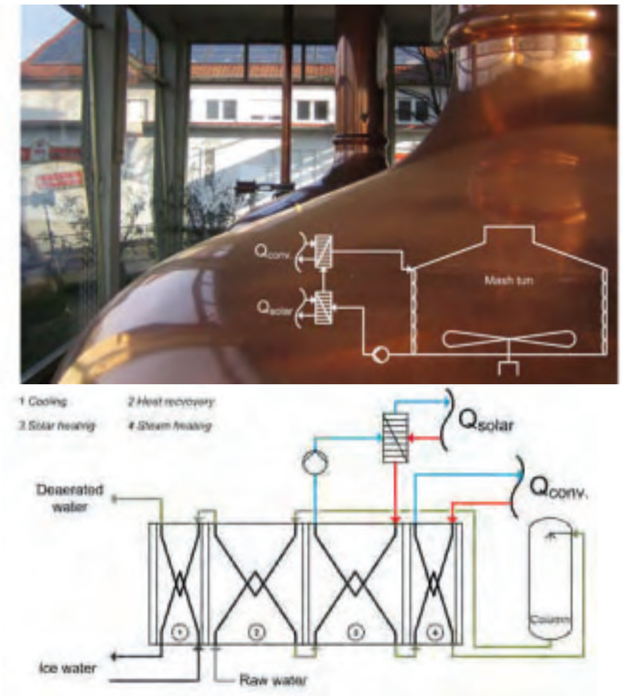
- Improving solar process heat collectors and collector loop components.
- Providing a basis for the comparison of collectors with respect to technical and economical conditions.
- Giving comprehensive recommendations for standardized testing procedures.

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 or 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.



Brewery concept in Kassel , Germany
Photo: *Bastian Schmitt*

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)

NEP application in Switzerland.
Photo: © ewz

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

The Task commenced in February 2012 and will end in January 2016.

This is a collaborative Task with the IEA SolarPaces Program on a “maximum level” according to the SHC Guidelines for Co-ordination with other Programs.

Participating Countries

Australia, Austria, China, Denmark, France, Germany, Hungary, India, Japan, Italy, Mexico, Netherlands, New Zealand, Poland, Portugal, Slovenia, Spain, South Africa, Sweden, Switzerland, Tunis, United Kingdom, USA

WORK DURING 2012

Comparison of Collectors with Respect to Technical and Economical Conditions

The overall aim is to develop criteria for application-based collector selection (options rather than restrictions). Specific application-based conditions could be:

- Required temperature level.
- Thermal output of a collector for a chosen operating temperature, location etc.
- Restricted installation space.
- Wind loads and/or other mechanical stresses by weather impacts (hail, snow, etc.).
- Restrictions regarding the heat carrier, the pressure, etc.

So far for the comparison of collectors, the use of standardized weather data has been discussed as it is necessary to define reference locations and reference data for comparing the thermal output of different collector types. Based on many locations, it was decided to start with some specific locations (Würzburg, Germany, Athens, Greece, Abu Dabi, UAE, Cairo, Egypt).

With the Solar Keymark Collector Output Tool (also referred to as "Scenocalc"), which was (further) developed in the QAiST project, collector data from Standard Testing (either QDT or SST) can be put in, a location can be chosen (out of four), and the gross heat gain for four different constants Tm,f-Ta calculated. Additional locations (that is, the respective weather data) can be added. Within Task 49, the participants (especially the manufacturers) started to also check if collectors with special challenges regarding the optical and/or thermal characterization could be properly assessed using this tool. So far, only comparisons of thermal benchmarks have been discussed.

Develop System Concepts and Integration Guideline

The integration guideline is being developed as a living document, and the final version will be available at the end of the Task. The integration guideline will provide guidance on how to integrate solar process heat in industry. There is a common understanding that there is not one general ideal integration point in industry, but that sensible integration points depend very much on sector, product variety, processing technology, infrastructure, etc.

Survey and Dedicated Workshop on New Process Technologies

On September 5th, the first workshop for "solar process heat and process intensification" with focus on the food industry took place in Graz, Austria. Approximately 25 participants with expertise in solar, process engineering and food technology attended. The workshop's objective was to bring together experts in Process Intensification and Solar Thermal Applications to discuss the potential of combining intensified processes with solar heat/direct radiation(UV), to identify promising technological solutions for specific unit operations and to define important research targets in this area.

Simulation Tools

Work on simulation tools began with an overview of tools being used by participants. The next step is to look into the tools' details and determine whether they meet all needs or whether critical points must be solved before their use in all systems. A round robin test will take place to cross-compare the tools and simulation approach. A definition of case studies covering the broad range of systems will be prepared for the selection process.

WORK PLANNED FOR 2013

Key activities planned for 2013 include:

- Discussion and decision on the design guidelines.
- Definition of the integration guidelines.
- Definition of general requirements and relevant parameters for process heat collectors (and specific collector loop components) and their improvement.
- An overview of collector output and key figures for defined conditions.
- Integration guideline (methodology for advanced integration, system concepts, guidelines on integration types, checklists, etc.).
- Start of a worldwide overview of results and experiences from solar heat in industrial systems (including completed and ongoing demonstration system installations using monitoring data, as well as carrying out economic analyses).

REPORTS PUBLISHED IN 2012

General Requirements for Process Heat Collectors and Loop Components

REPORTS PLANNED FOR 2012

An Overview of Collector Output and Key Figures for Defined Conditions

Integration Guideline (Methodology for Advanced Integration, System Concepts, Guidelines on Integration Types, Checklists etc.)

MEETINGS IN 2012

1st Experts Meeting
February 29 – March 1
Freiburg, Germany

2nd Expert Meeting
September 6 - 7
Graz, Austria

MEETINGS PLANNED FOR 2013

3rd Expert Meeting
March 5 - 6
Rapperswill, Switzerland

4th Expert Meeting
October 3 - 4
Tecnalia, Spain

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As of December 2012

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