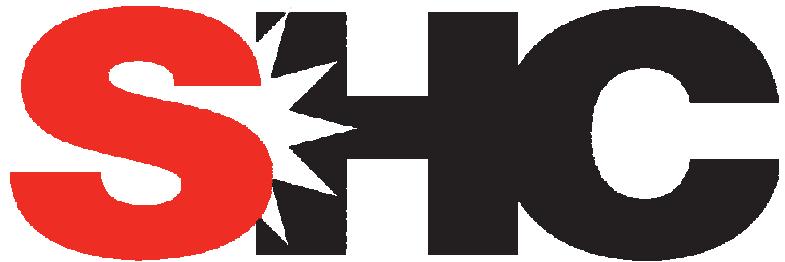


**SOLAR HEATING & COOLING PROGRAMME  
INTERNATIONAL ENERGY AGENCY**

# **2007 Annual Report**

**IEA Solar Heating & Cooling Programme**



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INTERNATIONAL ENERGY AGENCY**

# IEA Solar Heating & Cooling Programme

## 2007 Annual Report

Edited by  
Pamela Murphy  
Executive Secretary  
IEA Solar Heating and Cooling  
Programme  
Morse Associates, Inc.  
236 Massachusetts Ave. NE  
Suite 605  
Washington, DC 20002  
USA

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# Implementing Agreement

## IEA

The *International Energy Agency (IEA)* is an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD) based in Paris. Established in 1974 after the first “oil shock,” the IEA is committed to carrying out a comprehensive program of energy cooperation among its members and the Commission of the European Communities. The IEA provides a legal framework, through IEA Implementing Agreements such as the *Solar Heating and Cooling Agreement*, for international collaboration in energy technology research and development (R&D) and deployment. This IEA experience has proved that such collaboration contributes significantly to faster technological progress, while reducing costs; to eliminating technological risks and duplication of efforts; and to creating numerous other benefits, such as swifter expansion of the knowledge base and easier harmonization of standards.

## SHC PROGRAMME

The Solar Heating and Cooling Programme (SHC) was established in 1977, as one of the first programmes of the International Energy Agency (IEA). The Programme’s work is unique in that it is accomplished through the international collaborative effort of experts from Member countries and the European Commission. The benefits of such an approach are numerous, namely, it accelerates the pace of technology development, promotes standardization, enhances national R&D programmes, permits national specialization, and saves time and money.

The Programme is headed by an Executive Committee composed of one representative from each Member country and Sponsor organizations, while the management of the individual projects is the responsibility of project managers (Operating Agents) who are selected by the Executive Committee. Thirty-nine Tasks had been imitated since the beginning of the Programme. And, by the end of 2007, four Tasks were completed and three new Tasks proposed.

The Programme’s work is augmented through collaboration with other IEA Programmes, such as the Energy Conservation in Buildings and Community Systems Programme, the Photovoltaic Power Systems Programme, and the SolarPACES Programme, as well as solar trade associations in Europe, North America, and Australia.

### SHC MEMBER COUNTRIES

Australia  
Austria  
Belgium  
Canada  
Denmark  
European Commission  
Finland  
France  
Germany  
Italy  
Mexico  
New Zealand  
Netherlands  
Norway  
Portugal  
Spain  
Sweden  
Switzerland  
United States

## SHC MISSION

To continue to be the preeminent international collaborative programme in solar heating and cooling technologies and designs.

Based on this mission, the Programme will continue to take a whole building perspective, and success is to be measured by how well the Programme facilitates the greater use of solar design and technologies.

## **SHC OBJECTIVES**

To fulfill its mission, the SHC Executive Committee has agreed upon the following objectives and associated strategies. These objectives complement the objectives of the IEA CERT. Acknowledging the importance of coordinated efforts by IEA Implementing Agreements, the SHC objectives also support those of the IEA Renewable Energy Working Party.

- 1. To help achieve a significant increase in the performance of solar heating and cooling technologies and designs by:**
  - Increasing user acceptance of solar designs and technologies.
  - Continuing to develop cost-effective designs and technologies in collaboration with appropriate intermediary industries.
  - Identifying and prioritizing R&D needs for solar heating and cooling that will lead to expanded markets.
- 2. To help industry and government increase the market share of solar heating and cooling technologies and designs by:**
  - Working with appropriate intermediary industries and end users to accelerate the market penetration of solar designs and technologies.
  - Working with governments to promote and expand favorable policies to increase the market share.
  - Working towards or support the greater use of solar designs and technologies in developing countries.
  - Working to address issues regarding building design, aesthetics and its architectural value.
- 3. To be the primary source of technical information and analysis on solar heating and cooling technologies, designs and applications by:**
  - Assuring that technical information and analysis developed in this programme is available and disseminated to the target audiences in useful formats.
  - Working through relevant international standards organizations, support the development and harmonization of standards necessary for the widespread use of solar designs and technologies in the building, agricultural and industrial sectors.
- 4. To help educate decision makers and the public on the status and value of solar heating and cooling by:**
  - Communicating the value of solar heating and cooling designs and technologies in publications, conferences, workshops and seminars to the public and relevant stakeholders.
  - Providing analysis that links solar heating and cooling designs and technologies to energy security concerns, environmental and economic goals.
  - Quantifying and publicizing the environmental, economic and climate change benefits of solar heating and cooling and supporting policy measures solar design and

- technologies in meeting environmental targets and addressing policies and energy, supply security.
- Reviewing our products in relation to our objectives Annual Reports, Solar Update Newsletters, National Programme Review Reports, "Solar Heating Worldwide: Markets and Contributions to the Energy Supply report." Presenting the SHC Solar Award annually. Maintaining the Programme web site.

## HOW TO PARTICIPATE

Visit the SHC Programme web site at [www.iea-shc.org](http://www.iea-shc.org) to learn more about the Programme's work and publications and to find contact information for the Executive Committee members and Operating Agents.

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

If your country is not a Member, but a government agency or an organization is interested in joining, please contact the SHC Executive Secretary for information.

If you represent an international industry association or international non-profit organization and are interested in joining as a Sponsor, please contact the SHC Executive Secretary, who will provide the required information.

# Chairman's Report

Doug McClenahan  
CANMET – Natural Resources Canada

*I am pleased to present the 2007 annual report of the Solar Heating and Cooling Programme. 2007 was another year of steady growth in the global market for solar thermal. The SHC Programme celebrated its 30<sup>th</sup> year by taking on new work and continuing to collaborate with other organizations to support our vision of increasing the use of solar designs and technologies in the built environment, and for agricultural and industrial process heat.*

## SHC TASKS

Four Tasks came to an end in 2007 – Task 32: Advanced Storage Concepts for Solar and Low Energy Buildings (led by Switzerland), Task 33: Solar Heat for Industrial Processes (led by Austria), Task 34: Testing and Validation of Building Energy Simulation Tools (led by the United States), and Task 35: PV/Thermal Systems (led by Denmark). The results of these activities will be finalized in 2008 and presented at conferences and workshops. The Executive Committee extends a well deserved “thank you” to the Operating Agents – Task 32, Mr. Jean-Christophe Hadorn; Task 33, Mr. Werner Weiss; Task 34, Mr. Ron Judkoff; and Task 35, Mr. Henrik Sørenson.

As these Tasks came to an end, three new Tasks were initiated with start dates expected in 2008. These Tasks will focus on three key areas – storage materials, solar architecture and zero energy buildings.

## SOLAR THERMAL STATISTICS

The SHC Programme produced its 5<sup>th</sup> edition of the report, Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2005. This year's edition reported that the solar thermal sector has become a market leader in the past five years, growing 10 times faster than the overall economy. The annual collector yield (energy produced) in 2005 was 66,406 GWh – an oil equivalent of 10.7 billion liters and annual avoidance of 29.3 million tons of CO<sub>2</sub> emissions.

Data showed:

- Installed capacity in 2005 was 111.0 GW<sub>th</sub> (159 million square meters)
- Market penetration (installed capacity per 100,000 inhabitants) leading countries:
  - Cyprus 657 kW<sub>th</sub>; Israel 497 kW<sub>th</sub>; Austria 205 kW<sub>th</sub>; Barbados 200 kW<sub>th</sub>
- Most dynamic markets:
  - China and Taiwan were the leader with an average growth rate of 22% annually between 1999 and 2005 and representing 44% of the world market.
  - Followed by Australia and New Zealand at 18% and Europe at 15%.
- Initial 2006 data estimates an annual collector yield of 70 TWh<sub>th</sub>, second only to wind.

## **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** collaborated in SHC Task 34: Testing and Validation of Building energy Simulation Tools at a maximum level of collaboration as outlined in our Policy & Procedures Handbook.

In addition, joint meetings are held every 2-3 years. The next joint meeting will be held June 2008 in Austria.

**IEA Energy Conservation through Energy Storage Programme** and our Programme continued to share information on relevant Tasks and collaborated in SHC Task 32: Advanced Storage Concepts for Solar and Low Energy Buildings at a minimum level of collaboration as outlined in our Policy & Procedures Handbook.

The Swedish ExCo representative from the ECES Programme also attended our December Executive Committee meeting in Sweden.

**IEA Photovoltaic Power Systems Programme** collaborated in Task 36: Solar Resource Knowledge Management and Task 35: PV/Thermal Solar Systems at a minimum level of collaboration as outlined in our Policy & Procedures Handbook.

**SolarPACES Programme** collaborated in Task 36: Solar Resource Knowledge Management at a minimum level of collaboration as outlined in our Policy & Procedures Handbook and Task 33: Solar Heat for Industrial Processes at a moderate level of collaboration as outlined in our Policy & Procedures Handbook.

### **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, a SHC/Trade Association meeting was held in Germany in conjunction with ESTIF's June annual meeting. Another meeting is planned for 2008.

**EU ThERRA (Thermal Energy from Renewables – References and Assessment)**, the SHC Programme is represented on the Advisory board by Mr. Werner Weiss. The objective of this group is to develop and disseminate a methodology for monitoring the total amount of renewable heat produced in the EU.

**ESTTP (European Solar Thermal Technology Platform)**, the SHC Programme, represented by Mr. Michael Rantil and then Mr. Lex Bosselaar, continued to serve on the ESTTP Steering Group and to support the Platform's objectives.

## **PROGRAMME PARTICIPATION – BENEFITS & HOW TO JOIN**

Participation in the Programme remains strong with 18 Member countries and the European Commission actively involved in the Programme's management and the work of the Tasks. Communication with five target countries that have already been invited to join the Programme—Brazil, China, India, Japan and South Africa—continued. The ExCo approved a 2-year waiver of the Common Fund fee for these countries.

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 and include:

- 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.

The steps to take to join the Programme are:

- If your country is a Member and you are interested in participating in a current Task then contact the Executive Committee member from your country or the Operating Agent of the specific Task you are interested in joining.
- If your country is not a Member and your government agency or organization is interested in joining, please contact the SHC Executive Secretary.
- If you represent an international industry association or international non-profit organization and are interested in joining as a Sponsor, please contact the SHC Executive Secretary.

## **TO ANOTHER SUCCESSFUL YEAR**

It is with pleasure to serve my 2<sup>nd</sup> year as Chairman. It has been an active year with work ending, new work starting, steps towards a SHC Road Map, and farewells to old friends.

I would like to take this opportunity to thank the following Executive Committee members—Michael Rantil as the Swedish member, Paolo Zampetti as the Italian member, Urs Wolfer as the Swiss member, and Yves Boileau as the French member. Their contributions to the success of the Programme and their years of dedicated service have had a visibly positive impact on our work.

2008 will see new faces at the table, and to begin I would like to welcome Simonette Fumagalli who will now represent Italy on the Committee. In addition, I would like to thank the Operating Agents who completed their Tasks in 2007— Jean-Christophe Hadorn, Werner Weiss, Ron Judkoff and Henrik Sørenson.

I look forward to our collaboration as we expand the work and impact of the SHC Programme. It is an exciting time as national and international interest in and markets for solar heating, cooling, and daylighting technologies continue to grow.

# Highlights of 2007

## TASKS

### **Task 32: Advanced Storage Concepts for Solar and low Energy Buildings**

This Task was completed in 2007.

A complete framework to simulate solar combisystem with heating and cooling capabilities has been developed which includes TRNSYS files and a methodology to compare systems. Also a new FSC method for characterizing solar combisystems with one curve only was finalized and tested. This new method differs from the earlier version as it is able to accommodate for seasonal storage and cooling loads.

Final results of this Task will be presented at the joint ISES/SHC conference, EuroSun 2008: 1<sup>st</sup> International Conference on Solar Heating, Cooling and Buildings, on October 7-10 in Lisbon, Portugal.

*This was a collaborative Task with the IEA Energy Conservation through Energy Storage Implementing Agreement.*

### **Task 33: solar Heat for Industrial Processes**

This Task was completed in 2007.

Within the framework of the Task, nine pilot systems were designed in close cooperation with industry. All of these systems have been installed and most of them are equipped with monitoring devices. A total of 15 companies from Austria, Germany, Italy, Portugal and Spain participated in the Task.

Final results of this Task will be presented at the joint ISES/SHC conference, EuroSun 2008: 1<sup>st</sup> International Conference on Solar Heating, Cooling and Buildings, on October 7-10 in Lisbon, Portugal.

*This was a collaborative Task with the IEA SolarPACES Implementing Agreement.*

### **Task 34: Testing and Validation of Building energy Simulation Tools**

This Task was completed in 2007.

The work has led directly to improvements in software tools used for evaluating the impacts of energy efficiency and solar energy technologies commonly applied in innovative low-energy buildings. So far among all projects, the work has identified 63 results disagreements that have led to 58 software fixes.

*This was a collaborative Task with the IEA Energy Conservation in Buildings & Community Systems Implementing Agreement.*

### **Task 35: PV/Thermal Solar Systems**

This Task was completed in 2007.

About 65 market survey interviews of architects and solar dealers have been conducted in Canada, Denmark, Germany, Italy, Spain, Sweden, and the USA to obtain information from market actors on what affects or influences the purchase design, supply and installation of PV/T projects. The main conclusions of the survey are that both architects and solar companies are very interested in PV/T (e.g., for generating publicity and additional business) and that the key advantages of a PV/T system is that it can be used when limited roof space is available, can provide possible cost reductions (e.g., due to lower installation costs), can be integrated into a building, and provides a more uniform appearance than a side-by-side system.

Final results of this Task will be presented at the joint ISES/SHC conference, EuroSun 2008: 1<sup>st</sup> International Conference on Solar Heating, Cooling and Buildings, on October 7-10 in Lisbon, Portugal. Final reports will be completed in 2008.

*This was a collaborative Task with the IEA Photovoltaic Power Systems Implementing Agreement.*

### **Task 36: Solar Resource knowledge Management**

Successful efforts were made at a high political level to have the Task 36 activities recognized in the Group for Earth Observation (GEO), an initiative of the G8, that includes an energy component. Members of the Task contributed to the GEOSS strategic document on energy management. A video showing four case studies of solar energy systems in Africa was developed by Ecole des Mines de Paris/Armines, with the help of NASA, JRC, DLR, and the companies involved in the design of these systems. This was one of the success stories presented during the ministerial meeting held November 2007 in Cape Town, South Africa. The video is available on the web site of the GEO Community of Practice “Energy” (<http://www.geoss-ecp.org/img/video2/GEOSS-ECP.html>).

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

### **Task 37: Advanced Housing Renovation with Solar & Conservation**

A workshop on exemplary housing renovation projects was held in connection the Experts meeting in Switzerland. The workshop was attended by a film team contracted by the Norwegian State Housing Bank to make a film about exemplary European housing renovation projects. Task 37 demonstration projects will be included in this film. The Task plans to use the English version of the film to present and promote its work during 2008.

### **Task 38: Solar Air Conditioning and Refrigeration**

Two “Solar Air-Conditioning and Refrigeration” workshops were held in conjunction with the Experts meetings in France and Spain. The French workshop focused on the first results of Task 38—new developments, market status and experiences from various installations and design studies. Thirty-five external participants, mainly from France, and about 40 Task experts attended. The Spanish workshop focused on technologies and recent experiences

with installed systems as well as presentations on costs, economic analysis and market. Forty-two external participants from Spain attended.

### **Task 39: Polymeric Materials for Solar Thermal Applications**

The existing test standards and the problems for polymer-based systems are under discussion in the Task. These discussions are enhanced by the involvement of Task 39 participants from several central collector test institutions, such as Arsenal Research, Fraunhofer ISE, INETI, ITW-Stuttgart and SPF Switzerland. This is an excellent starting point for influencing the revisions of norms which disfavor polymeric collectors/ materials. A Task Force on 'Standards, regulations and guidelines' was formed at the September Experts meeting and they will hold separate meeting sessions starting with the next Experts meeting in Norway.

### **Daylight Roadmap Working Group**

This Working Group was formed to develop a digital roadmap for the daylight design of buildings. It is an extension of the Task 31 web site into a wiki-based interactive site that contributes to the understanding of the multiple criteria upon which good daylight design must be based and to the knowledge of the design tools available to evaluate building designs against these criteria. The objective is to ensure that the different audiences interested in good daylight design—architects, engineers, students, code writers and researchers—have access to up-to-date information.

## **EXECUTIVE COMMITTEE MEETINGS**

### **2007 Meetings**

The Executive Committee held two meetings:

- June in Haarlem, Netherlands
- December in Malmö, Sweden

### **2008 Meetings**

The Executive Committee will hold two meetings:

- June in Graz, Austria.  
*This meeting will include a 30th anniversary celebration for the Programme and a joint meeting with the Energy Conservation in Buildings and Community Systems Implementing Agreement*
- November/December, location to be finalized.

## **INTERNET SITE**

The web site has been completely redesigned. This user-friendly site is a key dissemination tool for the Programme as all of the Programme's outputs and contact information are available from here. The web address is [www.iea-shc.org](http://www.iea-shc.org).

# Feature Article

## ADVANCED STORAGE CONCEPTS FOR ACTIVE SOLAR ENERGY

Jean-Christophe Hadorn, Operating Agent SHC Task 32  
Groupe Berney - BASE Consultants SA, Geneva, Switzerland

### THE NEED FOR STORAGE

Storing solar energy is a must if we want to meet more than 50% of the heating needs of housing using solar. Even for cooling, storage is necessary for houses in climates where cooling is needed during the day and night.

Much effort is devoted to designing and building low energy houses—houses that require less than one third to one quarter of the energy of a 1970s house to maintain its interior comfortable in all seasons. If active solar energy is to cover a significant portion of the heating load and domestic hot water load in low energy houses then storage is needed to deliver the solar input at night and during winter months.

### THE PREVAILING SITUATION

For space heating, it is most efficient to collect solar energy at low to medium temperatures, between 20-80°C. Solar energy at these temperatures has been stored this way using water for centuries. And, it is still the most developed and cost effective way to store solar heat for space heating.

Water is an efficient heat storage medium—one m<sup>3</sup> of water can store 70 kWh between 20-80°C produced by about 20 m<sup>2</sup> of good quality flat plate solar collectors on a sunny day. Keeping this energy in a water tank for a few days can easily be achieved by insulating the container with standard insulation material 10-12 cm thick.

The sensible heat capacity (ability to store heat in a sensible form) of water is one of the highest. On top of this interesting physical property, water has four other very important advantages over other material—it is non toxic, ubiquitous, cheap, and fluid.

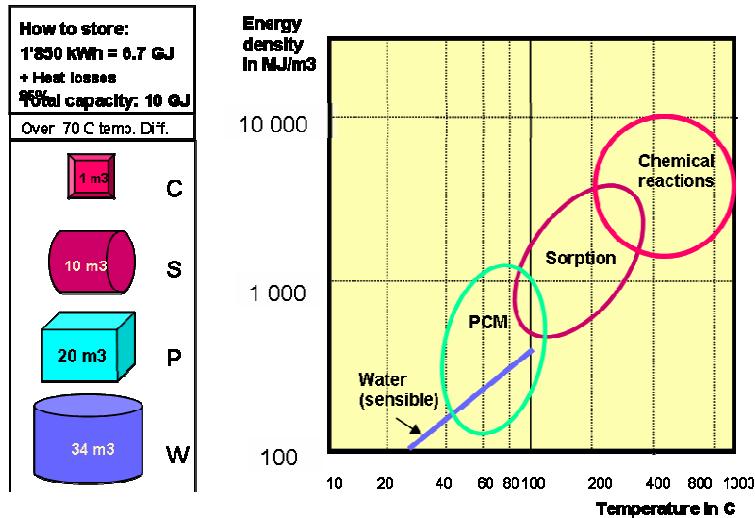
To store cold energy, say around 0°C, water is also a very good storage material. Using its latent heat from liquid to solid (ice), water can store 91.6 kWh per m<sup>3</sup>. This, combined with the total reversibility of the process, makes water clearly the first choice when cold storage is needed for cooling purposes in a building.

### ADVANCED CONCEPTS

Do we know all we need to about water tank storage? The answer is clearly no. Is there an alternative to water for storing solar energy for space heating or domestic hot water? The answer is yes, at least theoretically.

Figure 1 shows four ranges of solutions to store heat: water over 70°C, phase change materials (PCM), reactions based on sorption principles, and chemical reactions. The density that can be theoretically achieved is shown on the vertical axis and the horizontal axis shows the temperature needed.

Water, the best option as of today, is still a low density material compared to the other solutions. What this means is that more of it is needed. For example, some chemical reactions require theoretically a storage volume no larger than one m<sup>3</sup> for seasonal storage in a low energy house compared to 34 m<sup>3</sup> of water.



**Figure 1. Energy density vs. temperature (log scale) and comparison of theoretical volume needed to store 10 GJ of heat based on four different principles [1].**

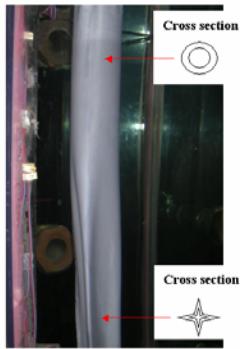
The IEA Solar Heating and Cooling Programme decided to investigate these four alternatives and initiated Task 32: Advanced Storage Concepts for Solar and Low Energy Buildings in 2003.

## WATER TANK STORAGE

For solar combisystems, water tank storage is the state-of-the-art choice [2]. However, there are ways to improve the efficiency of water tank stores and the overall performance of a water-based combisystem.

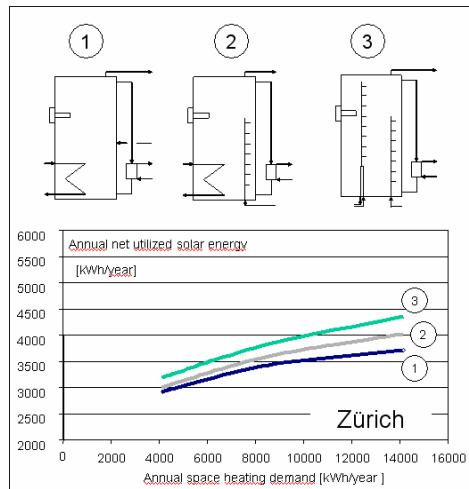
Several areas require additional R&D and SHC Task 32 has addressed the most important ones: stratification devices, heat losses, and system integration.

**Stratification devices** improve the stratification of hot water in a tank so that less auxiliary is needed to meet the peak load during DHW draw-off for example. There are several solutions on the market, but all are fairly complicated and expensive. The use of fabrics has been investigated in Denmark and exhibits promising results compared to the current devices. It is a two concentric layer system where water can leave at any level depending on its temperature relative to that of the tank levels.



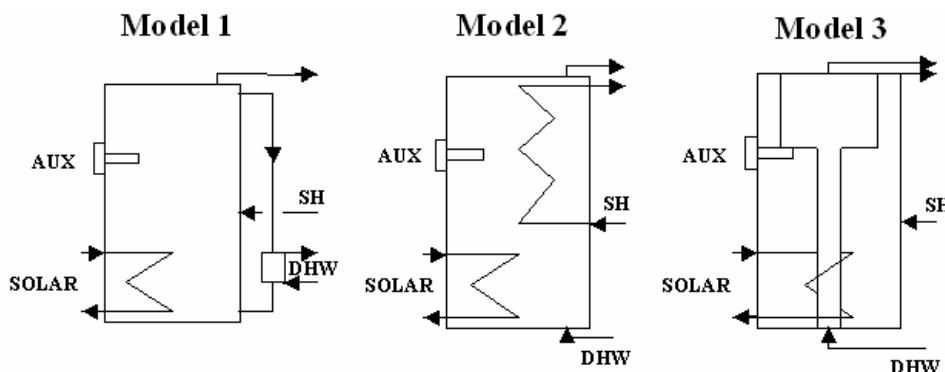
**Figure 2. A fabric stratifier for water tank storage from DTU Denmark.**

Is a stratifier worth it? Denmark investigated three configurations of combisystems whose only variation was the stratification scheme in the water tank (Figure 3). The alternative with two stratification devices, one for the solar loop and one for the return loop performed best, with a 20% improvement of the annual solar energy delivered to the load in the best case compared to the no stratification device case.



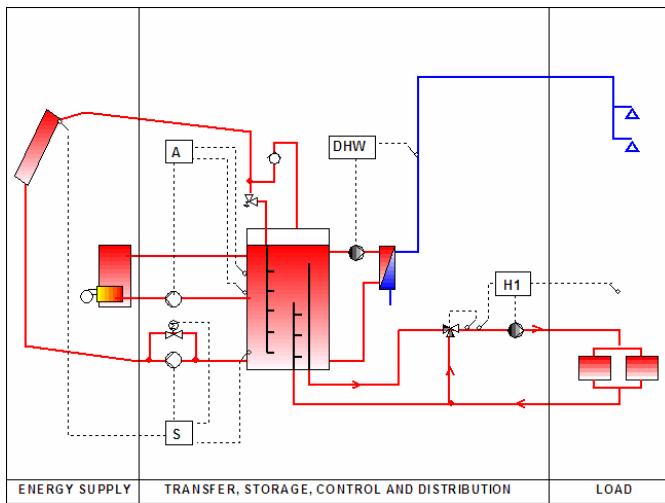
**Figure 3. In these detailed simulations from DTU, Denmark, the best performer in Zürich climate is clearly the double stratifier solution.**

When there is no stratifier (Figure 4), the internal heat exchanger solution performs best.



**Figure 4. Detailed simulation from DTU Denmark showed that Model 2 showed slightly better annual performance than the two others.**

Improving system integration in a solar combisystem to reduce the investment cost and to enhance annual performances was shown to be possible using the “Maxlean” system from Switzerland (Figure 5).

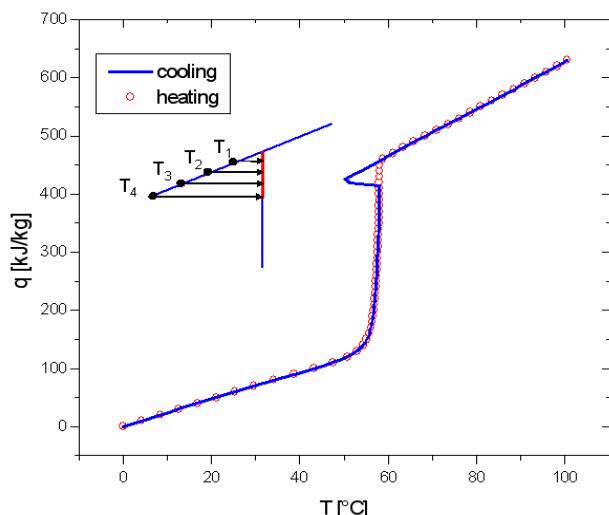


**Figure 5. The “Maxlean” system from SPF Switzerland with variable flow in heating loop, double stratifier, external DHW preparation, and a pressure-less tank.**

### STORAGE WITH PHASE CHANGE MATERIALS (PCM)

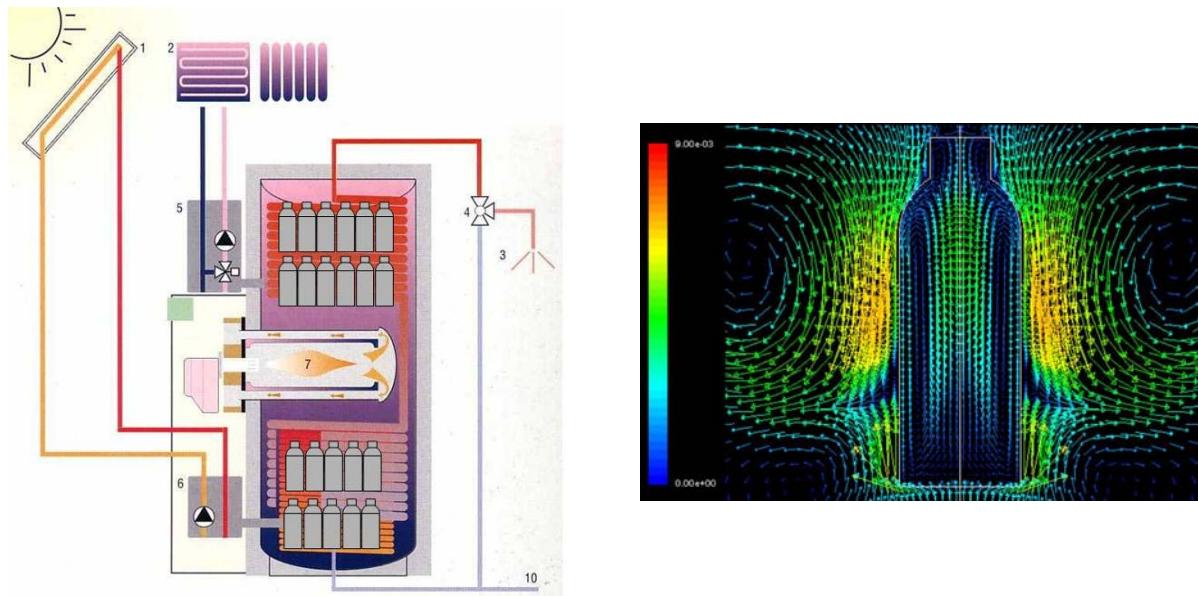
One way to improve storage is to use a material that is more energy dense than water. If the transition temperature is adequately chosen, such materials do exist. SHC Task 32 worked with sodium acetate, which exhibits a theoretical transition point at 58°C making it ideally suited for solar combisystems.

Material characterization is a topic in itself and SHC Task 32 developed a method to assess the thermal properties of the material (Figure 6).



**Figure 6. Thermal properties of sodium acetate trihydrate with graphite, measured at IWT, Austria. The material supercooling effect is clearly visible. Hysteresis (not shown on the graph) must also be precisely measured.**

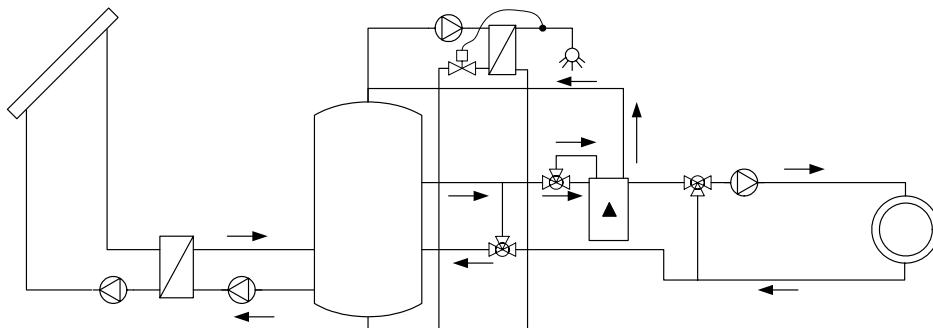
Modeling PCM in storage tanks is another area addressed in SHC Task 32. The Task successfully developed models for sodium acetate in different configurations that can be used to predict the behavior of solar combisystems with PCM storages (Figure 7).



**Figure 7. Modeling a combisystem with a water tank store filled with bottles full of PCM at HEIG, Switzerland. Thermal diffusion and convection inside the bottle is modeled and a new TRNSYS unit is available.**

Simulations of several combisystems with PCM storage revealed that PCM storage had two unforeseen limitations—the volume of PCM that can be introduced into a water tank is limited to 20-30% of the whole storage volume and due to the necessary containment of the material, the heat extraction power from the PCM to water is limited by the diffusion process inside the material.

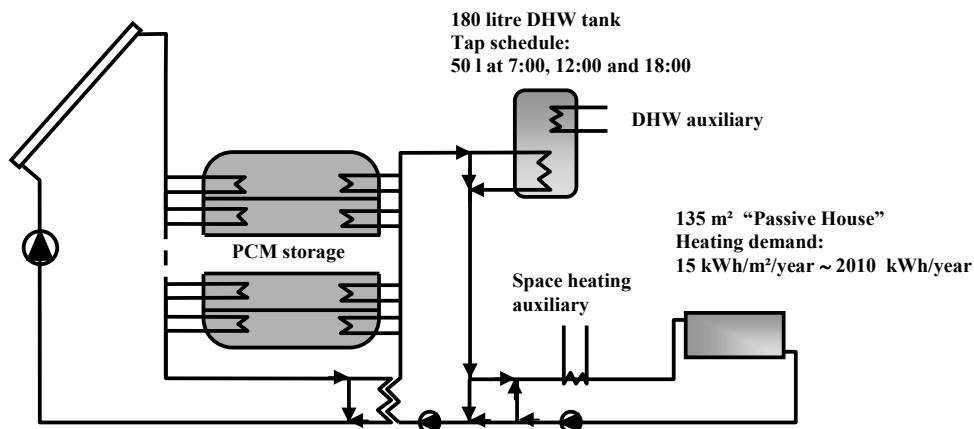
Sodium acetate did not show a decisive advantage over water in a combitank even if its density of energy is higher and its heat conductivity enhanced with graphite. Based on the Task 32 group's cumulative experience, special system designs were developed (such as the one shown in Figure 8) that showed improvements, but with a 35°C transition temperature material.



**Figure 8.** A combisystem design ( $22 \text{ m}^2$  of solar collectors with  $830 \text{ l}$  of storage with 50% PCM with a  $35^\circ\text{C}$  transition point) suited to PCM storage was shown to improve the fractional saving from a value of 54% to a higher value of 59% with a detailed validated simulation model at HEIG Switzerland.

Fine tuning of the adequate PCM and the proper way to build an efficient heat exchange should remain on the agenda of international solar research.

A new idea under investigation in Denmark is to use the supercooling effect of sodium acetate to build a seasonal store with limited heat losses. Future work will tell more about the concept that has been developed in Task 32.



**Figure 9.** A PCM seasonal store could be reduced to  $12 \text{ m}^3$  for a low energy Danish house with  $12 \text{ m}^2$  collector for a 90% annual solar fraction according to DTU Denmark.

## SORPTION STORAGE

There are different sorption principles that can be used for heat storage.

Sweden's Climatewell has developed the TCA machine which uses an absorption technique to provide 20 kW of heat and 10 kW of cooling from a solar source. This machine was extensively monitored in SHC Task 32, and results show that it functions more as a

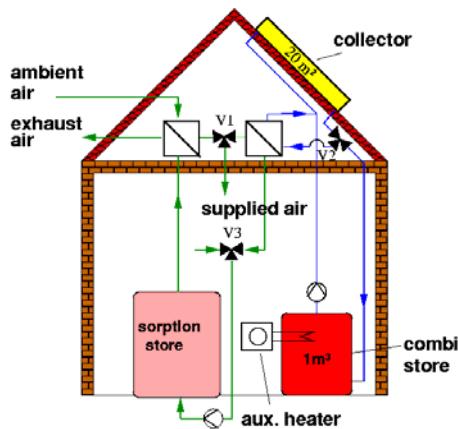
chemical heat pump than a true storage. However, it can store energy for a few hours and convert hot water to cooling and heating.



**Figure 10.** The TCA machine from Climatewell Sweden is now on the market.

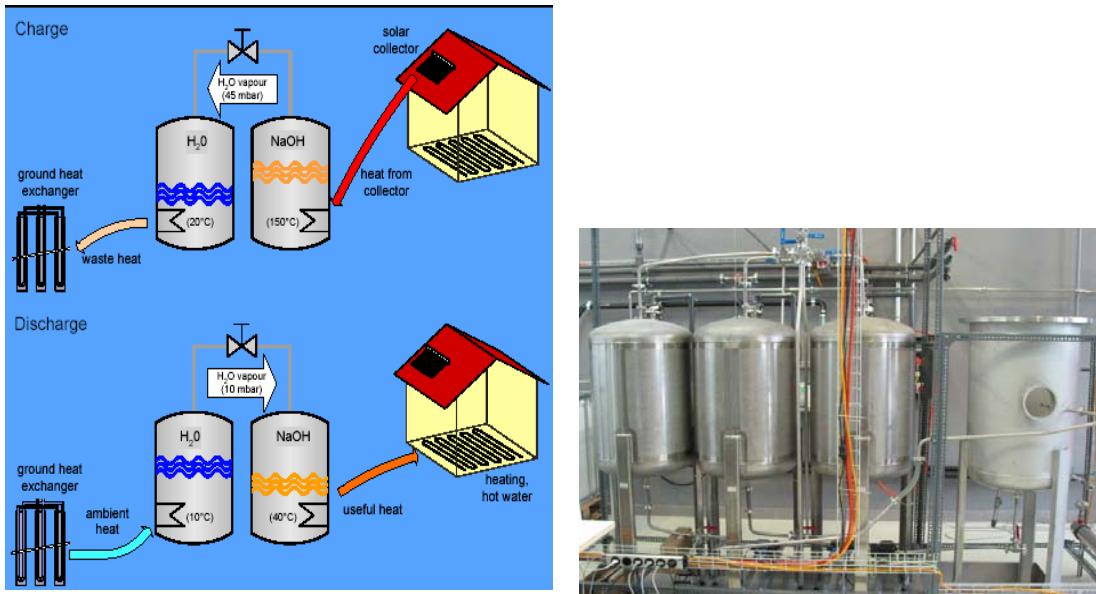
Other techniques based on adsorption principles have been experimented with silicagel or zeolite as a storage medium. After extensive research in a Swiss laboratory and in an experimental house in Austria, both media showed limitations when used as particles in beds.

A new method for using zeolite has therefore been developed in Germany within SHC Task 32. It is an extruded solid zeolite with air channels. This method has shown interesting properties at the laboratory level—simulation showed that an 8 m<sup>3</sup> storage volume would be enough for 70% of the heating load of a low energy house. A laboratory prototype will deliver more information soon.



**Figure 11.** The Monosorp storage concept from ITW, Germany is still a laboratory prototype but could lead to a dense seasonal storage solution for one family house.

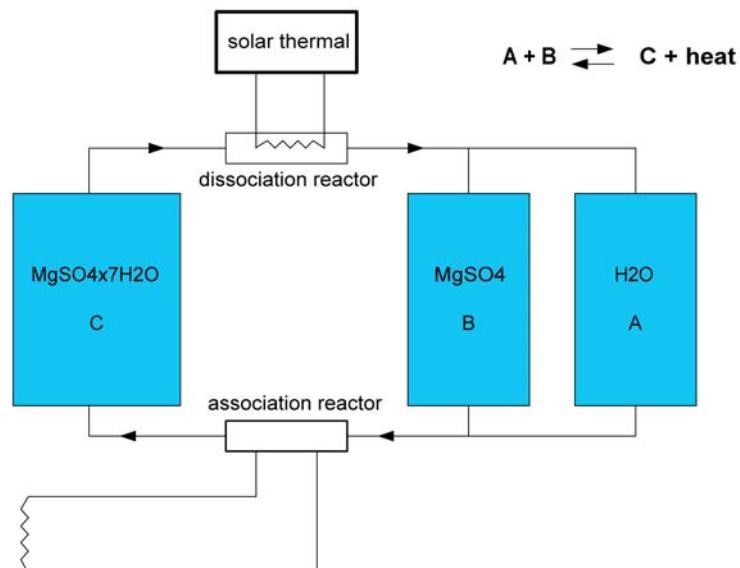
At EMPA in Switzerland, a storage unit prototype based on the NaOH desorption at 150°C principle (Figure 12) has been set up. First results show that the material can dry in the summer even better than anticipated (65% concentration reached) reducing the needed charging temperature to 120°C. The pilot installation will be monitored over two years and the modeling will enlarge the scope of the results.



**Figure 12. Principle of a NaOH/H<sub>2</sub>O storage system tested at EMPA Switzerland.**

The high density of storage with chemical reactions makes the topic attractive. However, many difficulties must be overcome before a commercial solution is reached.

The choice of an adequate reaction has kept the attention of ECN in the Netherlands. A promising material is magnesium hydroxide seven hydrates ( $MgSO_4 \cdot 7H_2O$ ) which could theoretically store 777 kWh/m<sup>3</sup> at 122°C. This is a temperature that high performance solar collectors can achieve during the summer. The principle is to dry the material in summer with solar heat and in winter re-hydrate the material to deliver back the energy (Figure 13). Work on this material and its ability to de-hydrate and re-hydrate has just started.



**Figure 13. Sketch of a future chemical heat store system with its three vessels at ECN in the Netherlands (for a 12.2 MWh capacity, tanks volume could be: A=14 m<sup>3</sup>, B=5 m<sup>3</sup>, C=16 m<sup>3</sup>).**

## HOW TO COMPARE VARIOUS STORAGE TECHNOLOGIES

SHC Task 32 developed a list of criteria that should be considered when comparing storage technologies (Table 1).

The first indicator concerns the energy performance of a combisystem with the storage technology. The value of  $F_{sav}$ , the fractional energy saving, has been selected as the best indicator and can be derived from the parameter  $FSC'$ .

$FSC'$  is a dimensionless quantity simultaneously taking into account the climate, the building (space heating and domestic hot water loads) and the size of the collector area, in a way that doesn't depend on the studied combisystem. First developed within SHC Task 26 [2], the  $FSC$  (Fractional Solar Consumption) has been improved in SHC Task 32. The improved  $FSC'$  takes into account the possible cooling load and seasonal storage. This means that it is now possible to show that  $F_{sav}$  is a function of  $FSC'$  even if  $FSC'$  is greater than 1.

**Table 1. Criteria considered for comparison of heat storage units within Task 32**

### Energy performance indicators

- NRJ1 Fractional energy savings  $F_{sav}$  as a function of  $FSC'$
- NRJ2 Comfort for heating and DHW load met without penalties
- NRJ3 Comfort in cooling conditions
- NRJ4.1 Heat storage material energy density kWh/m<sup>3</sup>
- NRJ4.2 Bulk storage density kWh/m<sup>3</sup>
- NRJ4.3 Storage efficiency

### Economical indicators

- ECON1 Investment cost per kWh stored
- ECON2 Operational costs per kWh discharged

### Market introduction

- MKT1 1 if on the market, 2 if within 3 years, 3 in more than 3 years

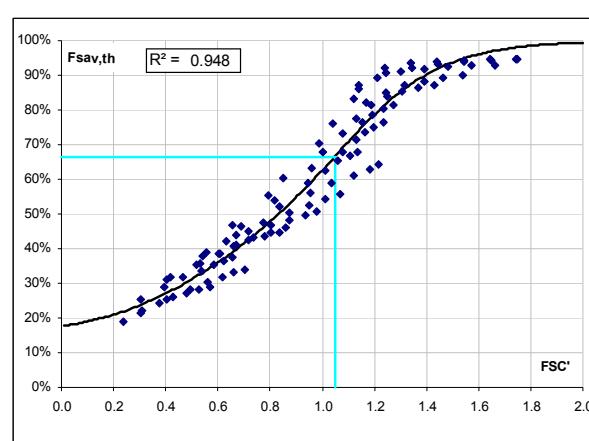
### Environmental indicators

- ENV1 Storage material risk (corrosion + toxicity + safety)
- ENV2 CO<sub>2</sub> saved by the system compared to a reference

### System integration

- INT1 weight of material for the storage unit kg/kWh capacity
- INT2 number of separate pieces
- INT3 level of skills required to install the storage unit
- INT4 need for technical maintenance

**Figure 14.  $F_{sav}$  (Fractional savings) is a function of  $FSC'$  that can be fitted with 4 parameters. This graph shows the characteristic curve of a combisystem based on a thermochemical heat store (TCM) from ECN (NL), based on reversible reaction  $A+2H_2O \leftrightarrow Ax_2H_2O + \text{heat}$ , in which hydration of material A has  $DH = 61 \text{ kJ/mol}$  and  $DS = 150 \text{ J/mol/K}$ .**



In order to assess  $F_{sav}$  in comparable conditions, it is necessary to set up a standard simulation framework that is applicable for many different systems. SHC Task 32 has defined a complete set of parameters for TRNSYS simulations for three different reference houses (low energy house with  $30 \text{ kWh/m}^2$ ,  $60 \text{ kWh/m}^2$  and  $100 \text{ kWh/m}^2$  for space heating) in four different climates (Stockholm, Zürich, Barcelona and Madrid). The entire deck of parameters is available from the SHC Programme.

Storage technologies integrated into a solar combisystem can be compared using this new method.

## WHAT NEXT?

Water will remain the storage of choice for solar combisystems in the years to come. But, some important findings regarding the use of other materials have been discovered in SHC Task 32. Also, models are now available for additional optimization analysis and for defining the best material a combisystem would need.

Table 2 summarizes the technologies for advanced storage concepts tested within SHC Task 32.

As for future work, the SHC Programme is committed to further work in this important area. Solar energy needs a long-term storage solution if the technology is to be used extensively for heating home, and therefore the Programme will begin a new Task on material research in 2008.

## References

- [1] **Hadorn J.-C. editor**, (June 2005), Thermal energy storage for solar and low energy buildings - State of the Art, a IEA SHC Task 32 book, Printed by Servei de Publicacions Universidad Lleida, Spain, 170 pages ISBN 84-8409-877-X, available through Internet [www.iea-shc.org](http://www.iea-shc.org) Task32
- [2] **IEA SHC Task 26** (2004): Solar Heating Systems for Houses - A Design Handbook for Solar Combisystems, W. Weiss and al., James & James, 2004, 313 pages
- [3] Task 32 reports are available at <http://www.iea-shc.org/task32/publications/index.html>

**Table 2. Storage technologies investigated by SHC Task 32 in 2003-2007**

Principle	Material	Institute	Status 2007
<b>Chemical reactions</b>			
Closed 2 phase absorption	Mg SO <sub>4</sub> 7H <sub>2</sub> O	ECN The Netherlands	Material investigation
<b>Sorption</b>			
Open adsorption	Zeolite solid	ITW Germany	Laboratory unit
Closed adsorption	Silica gel particles in bed	AEE Austria	System in a house tested - stopped
Closed adsorption	Silica gel and Zeolite beds	SPF Switzerland	Material and bed tested - stopped
Closed 2 phase absorption	NaOH / H <sub>2</sub> O	EMPA Switzerland	Laboratory unit running
Closed 3 phase absorption	LiCl	SERC Sweden	commercial
<b>PCM</b>			
PCM seasonal storage using subcooling	Na(CH <sub>3</sub> COO) · 3 H <sub>2</sub> O	DTU Denmark	Simulation of concept – Prototype 135 liters
Macroencapsulated PCM in storage tank	Na(CH <sub>3</sub> COO) · 3 H <sub>2</sub> O + graphite	Univ. Lleida, Spain	Lab prototype
Macroencapsulated PCM in storage tank with integrated burner	Na(CH <sub>3</sub> COO) · 3 H <sub>2</sub> O + graphite	HEIG-VD Switzerland	Complete combisystem tested
Microencapsulated PCM slurry	Paraffin,	IWT-TUGraz Austria	Lab prototypes- Stopped for storage
Macroencapsulated PCM in storage tank	Paraffin, Na(CH <sub>3</sub> COO) · 3 H <sub>2</sub> O with/without graphite	IWT-TUGraz Austria	Lab prototypes
Immersed heat exchanger in PCM	Na(CH <sub>3</sub> COO) · 3 H <sub>2</sub> O without graphite	IWT-TUGraz Austria	Lab prototypes
<b>Water</b>			
Simplified combisystem Maxlean system	Water	SPF Switzerland	Simulation proved
Water Stratifier	Fabrics immersed in water	DTU Denmark	Laboratory proved

# Task Reports

## **SHC TASK 32: ADVANCED STORAGE CONCEPTS FOR SOLAR AND LOW ENERGY BUILDINGS**

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

### **TASK DESCRIPTION**

The scope of this Task was to investigate new or advanced solutions for storing heat in systems providing heating or cooling for low energy buildings.

The main objective was to contribute to the development of advanced storage solutions in thermal solar systems for buildings that lead to high solar fraction up to 100% in a typical 45N latitude climate. The focus of the Task was on the integration of advanced storage concepts in a thermal system (solar, heat pump or boiler) for low energy housing.

The objective was reached in several projects. It was proven that storage with Phase change material ideally chosen can enhance solar fraction of a combisystem, absorption storage solution for both heating and cooling is available on the market. Advanced devices for stratification in water tanks were also developed and tested. New configurations of solar combisystem were also studied and proven to be both cost effective and with better performances than state-of-the-art solution.

It is also now anticipated that chemical storage based on sodium hydroxide or magnesium sulfate can yield to reduced seasonal storage volumes. Another promising technique was developed based on extruded zeolite.

The Subtasks were:

- Subtask A: Evaluation and Dissemination (Subtask Leader in 2006: Switzerland)
- Subtask B: Chemical and Sorption (Subtask Leader: Chris Bales, Sweden)
- Subtask C: Phase Change Materials (Subtask Leader: Wolfgang Streicher, Austria)
- Subtask D: Water (Subtask Leader: Harald Drueck, Germany)

The teams within Subtasks B, C and D were asked to set up a TRNSYS model of their system based on experimental work in order for Subtask A to compare all the options for a reference case of a single family house. Simulations have been made for several different storage technologies but trying to meet the same load. Results will be published in 2008 using an improved version of the FSC method originally developed within Task 26.

### **Duration**

The Task was initiated in July 2003 and was completed in December 2007. Final reporting will take place during early 2008.

## **ACTIVITIES DURING 2007**

### **General**

In 2007, two meetings gathered 25 experts from 7 participating countries (Austria, Denmark, Germany, Netherlands, Spain, Sweden and Switzerland) and the input from 1 other country (France).

#### ***Subtask A: Evaluation Method and Dissemination of Results***

Subtask A issued a book on heat storage in June 2005 which is on sale on the Task web site.

A complete framework to simulate solar combisystem with heating and cooling capabilities was developed by Subtask A. All TRNSYS files are available and a methodology to compare systems was derived. A new method for characterizing solar combisystems with one curve only was finalized and tested. It is called FSC' and can accommodate for seasonal storage and cooling loads compared to what was done with FSC in a previous SHC Task.

Simulation results from various teams are available and being compared for the final report of the Subtask.

The Task web site can be found at <http://www.iea-shc.org/task32/index.html>. The final reports are being posted here for public download as they become available.

The final presentation of all Task 32 results will take place during EuroSun 2008 in October in Lisbon, Portugal.

#### ***Subtask B: Chemical and Sorption Storage***

Six projects were investigated.

In Sweden, the Thermo Chemical Accumulator (TCA) is a machine to provide both heating (20 kW) and cooling (10 kW). The process is a 3 phase absorption system. The machine was tested and simulated and further optimized within the Task. The machine is available commercially in Spain since 2007.

In Austria, the Modestore project tested a silical store in a one family solar house. Results showed that the material is inadequate for solar storage. Simulations still carried on, based on a validated model for the storage, try to show the range of use of such a technique.

In Switzerland, zeolite beds have been deeply studied. Kinetics of such an adsorption bed is now known, and it was shown that the temperature lift during discharging will not be enough for a solar combisystem. Other material is needed. This opens the way to a future SHC Task that we have initiated.

In Germany, the Monosorp idea is progressing with a laboratory experiment that shows that seasonal storage for a house with 8 m<sup>3</sup> of extruded zeolite is possible!

In the Netherlands, work on characterizing magnesium sulfate started in 2007 and methods to evaluate the storage capacity of powders are being developed. A similar work started in France also on the same material.

In Switzerland, a new concept for thermochemical storage has been set up in laboratory. A 200 l tank filled with sodium hydroxide has been built and is being tested. Material knowledge is of primary importance and further investigation is needed.

#### **Subtask C: Phase Change Materials**

Six projects were developed. After a first round of material search, it was decided to focus on a material that the Spanish team had already experimented with, sodium acetate which shows a theoretical transition point at 58°C.

In Switzerland, a solar combisystem was equipped with a water tank enhanced by PCM. It was first shown that it was not easy to install enough PCM in a tank without expanding the total volume of the tank. Gains were found marginal on an average year due to the limitation of power that the PCM unit could absorb. Nevertheless a simulation model was validated against measurement and yield to further optimization, showing that in good conditions a PCM + water tank combination could be cost effective compared to a water tank only solution.

Spanish team and Austrian team developed a methodology to measure the thermal properties of a PCM such as Sodium Acetate, and tried several heat exchange method to find a good solution for this PCM.

The Danish project showed that a 10 m<sup>3</sup> only PCM seasonal storage using the super cooling effect of sodium acetate is theoretically possible. An experimental setup was set up to test the triggering of a PCM in bulk.

Early in the Task, Austria showed that slurries with microcapsules of PCM, aimed at transporting heat, were not suited to storage.

#### **Subtask D: Water Tanks**

Four projects have been presented by participants.

In Denmark, the team analyzed the best performer combisystem to prepare domestic hot water. It was found that an internal heat exchanger with a stratification enhancer can yield better.



**Testing of several fabric stratifiers at DTU in Denmark.**

In Spain, a theoretical analysis showed important dimensionless numbers for the evaluation of stratification effects.

In Switzerland, a new concept called the “Maxlean” was developed for solar combisystem and optimized with TRNSYS. It showed theoretically that the 3 principles of the Maxlean concept can yield to better performance and lower cost. This will open the way to a pilot installation in 2008.

In Germany, two new concepts of combisystems with water tank storage follow a similar path and were built during 2006-2007. Monitoring results were however not available during the Task schedule.

## **WORKED PLANNED FOR 2008**

Task 32 was completed in 2007. Final reports will be published in 2008, and at EuroSun in October 2008, all Task 32 results will be presented at a dedicated session on heat storage.

## **LINKS WITH INDUSTRY**

One participant from Germany is a representative of a big solar industry. An industry one day seminar was held in Germany during our 9th meeting. 25 participants outside Task 32 were present. During 2007, we have kept industry informed of Task 32 work at national meetings.

## **REPORTS/PAPERS PUBLISHED IN 2007 and before**

- December 2007: A1, The extended FSC procedure for larger storage sizes, Editor: Thomas Letz, 19 pages
- May 2007, A2: The Reference Heating System, the Template Solar System, Richard Heimrath, Michel Haller, 55 pages
- May 2005, B1: Chemical and sorption storage - Selection of concepts, Editor: Chris Bales, 23 pages
- May 2005, B2: Thermal Properties of Materials for Thermo-chemical Storage of Solar Heat, Editor: Chris Bales, 18 pages
- June 2007, B3: Laboratory Prototypes of Thermo-Chemical and Sorption Storage Units, Editor: Chris Bales, 34 pages
- February 2005, C1: Storage based on Phase Change Materials (PCM) - Selection of concepts, Editor: Wolfgang Streicher, 13 pages
- February 2005, C2: Inventory of Phase Change Materials (PCM), Editor: Wolfgang Streicher, 32 pages
- May 2007, C3: Laboratory Prototypes of PCM Storage Units, Editor: Wolfgang Streicher, 42 pages
- May 2005: Legionella in combisystem tanks, Editor: Luisa F. Cabeza, 16 pages
- September 2007: Simulation and Optimization of the Maxlean System, Robert Haberl, Peter Vogelsanger, Thomas Letz, 71 pages

## **REPORTS PLANNED FOR 2008**

### **Subtask A**

- Method of comparison and criteria assessment for advanced combisystems with new storage designs
- Comparison of system designs and best systems recommendation
- Subtask A report and Final task management report

### **Subtask B**

- Laboratory testing of storage units
- Simulation models
- Systems simulations results with ref conditions and improved designs
- Subtask B report

### **Subtask C**

- Laboratory testing of storage units
- Simulation models
- Systems simulations results with ref conditions and improved designs
- Subtask C report

### **Subtask D**

- Review of advanced concepts and dream systems for tank storage
- Laboratory testing of advanced or new devices
- Laboratory tests or field tests of advanced storage units
- Simulation models
- System simulation with reference conditions and improved designs
- Subtask D report

## **MEETINGS IN 2007**

### **9th Experts Meeting**

April 18-20, in conjunction with a German industry day on April 17th  
Stuttgart, Germany

### **10th Experts Meeting**

October 3-5  
Zürich, Switzerland

## TASK 32 NATIONAL CONTACTS

### **Operating Agent**

Jean-Christophe Hadorn  
BASE Consultants SA  
51 Chemin du Devin  
CH-1012 Lausanne, Switzerland  
[jchadorn@baseconsultants.com](mailto:jchadorn@baseconsultants.com)

Site des Renardières

F – 77818 Moret/Loing  
[Laurent.barthel@edf.fr](mailto:Laurent.barthel@edf.fr)  
[Philippe.stevens@edf.fr](mailto:Philippe.stevens@edf.fr)

### **Austria**

Wolfgang Streicher, Andreas Heinz,  
Richard Heimrath, and Peter Puschnig  
Institute of Thermal Engineering  
Graz University of Technology  
Inffeldgasse 25 B  
A-8010 Graz  
[w.streicher@tugraz.at](mailto:w.streicher@tugraz.at)  
[andreas.heinz@tugraz.at](mailto:andreas.heinz@tugraz.at)  
[michel.haller@tugraz.at](mailto:michel.haller@tugraz.at)

### **Germany**

Harald Drueck, Henner Kerskes, and  
Karola Sommer  
Institut fuer Thermodynamik und  
Waermetechnik (ITW)  
Paffenwaldring 6  
D-70550 Stuttgart  
[drueck@itw.uni-stuttgart.de](mailto:drueck@itw.uni-stuttgart.de)  
[kerskes@itw.uni-stuttgart.de](mailto:kerskes@itw.uni-stuttgart.de)  
[sommer@itw.uni-stuttgart.de](mailto:sommer@itw.uni-stuttgart.de)

Hans-Martin Henning, Thomas Nunez  
Thermal Systems and Components  
Fraunhofer Institute for Solar Energy  
Systems ISE  
Heidenhofstr. 2  
D - 79110 Freiburg  
[hansm@ise.fhg.de](mailto:hansm@ise.fhg.de)  
[nunez@ise.fraunhofer.de](mailto:nunez@ise.fraunhofer.de)

### Dagmar Jaehnig

AEE INTEC  
Arbeitsgemeinschaft ERNEUERBARE  
ENERGIE  
Feldgasse 19  
A-8200 Gleisdorf  
[d.jaehnig@aee.at](mailto:d.jaehnig@aee.at)

Klaus Vajen, Ulrike Jordan, Claudius  
Wilhelms, and Katrin Zass  
Universitaet Kassel  
Institut fuer Thermische Energietechnik,  
D-34109 Kassel  
[vajen@uni-kassel.de](mailto:vajen@uni-kassel.de)  
[jordan@uni-kassel.de](mailto:jordan@uni-kassel.de)  
[wilhelms@uni-kassel.de](mailto:wilhelms@uni-kassel.de)  
[katrinzass@uni-kassel.de](mailto:katrinzass@uni-kassel.de)

### **Denmark**

Simon Furbo, Elsa Andersen, and  
Jorgen Schultz  
Department of Civil Engineering  
Technical University of Denmark  
Building 118, Brovej  
DK-2800 Kgs. Lyngby  
[sf@byg.dtu.dk](mailto:sf@byg.dtu.dk)

### **France**

Thomas Letz  
INES - Education  
Parc Technologique de Savoie Technolac  
50 avenue du Léman BP 258  
F - 73 375 LE BOURGET DU LAC Cedex  
T. +33 (0)4 79 26 44 32  
F. +33 (0)4 79 25 36 90  
[letz@ines-solaire.fr](mailto:letz@ines-solaire.fr)

### **Observer :**

Laurent Barthel, Philippe Stevens  
EDF R&D

Dietmar Gross  
ISFH  
Institut für Solarenergieforschung GmbH  
Am Ohrberg I  
D-31860 Emmerthal  
[d.gross@isfh.de](mailto:d.gross@isfh.de)

**Spain**

Luisa F. Cabeza, Cristian Solé  
Escola Politècnica Superior  
Universitat de Lleida  
Jaume II, 69  
SP - 25001 Lleida  
[l.cabeza@diei.udl.es](mailto:l.cabeza@diei.udl.es)  
[csole@diei.udl.es](mailto:csole@diei.udl.es)

Robert Weber  
EMPA Duebendorf  
Abteilung Energiesysteme/Haustechnik  
Überlandstrasse 129  
CH-8600 Duebendorf  
[robert.weber@empa.ch](mailto:robert.weber@empa.ch)

**Sweden**

Chris Bales  
Solar Energy Research Center (SERC)  
Dept. of Mathematics, Natural Sciences  
and Technology  
Högskolan Dalarna  
S-78188 Borlänge  
[cba@du.se](mailto:cba@du.se)

**The Netherlands**

Wim van Helden, Marco Bakker, Martijn  
Vanessen, Herbet Zondag, and Zeming He  
Energy Research Centre of the  
Netherlands (ECN)  
P.O. Box 1  
NL - 1755 ZG Petten  
[vanhelden@ecn.nl](mailto:vanhelden@ecn.nl)  
[m.bakker@ecn.nl](mailto:m.bakker@ecn.nl)  
[V.vanessen@ecn.nl](mailto:V.vanessen@ecn.nl)  
[zondag@ecn.nl](mailto:zondag@ecn.nl)  
[z.he@tue.nl](mailto:z.he@tue.nl)

**Switzerland**

Stéphane Citherlet, Jacques Bony  
Applied University of West Switzerland  
Laboratory of Solar Energetics and  
Building Physics  
Route de Cheseaux 1  
CH - 1401 Yverdon-les-Bains  
[stephane.citherlet@heig-vd.ch](mailto:stephane.citherlet@heig-vd.ch)  
[jacques.bony@heig-vd.ch](mailto:jacques.bony@heig-vd.ch)

Lucienne Krosse, Huib Visser  
TNO Delft  
P.O. Box 49  
NL-2600 AA Delft  
[huib.visser@ecn.nl](mailto:huib.visser@ecn.nl)

Peter Vogelsanger, Paul Gantenbein,  
Heinz Marty, Frank Elimar, and Robert Haberl  
SPF Hochschul fur Technik  
Oberseestr. 10  
CH-8640 Rapperswil  
[heinz.marty@solarenergy.ch](mailto:heinz.marty@solarenergy.ch)  
[peter.vogelsanger@solarenergy.ch](mailto:peter.vogelsanger@solarenergy.ch)  
[paul.gantenbein@solarenergy.ch](mailto:paul.gantenbein@solarenergy.ch)  
[elimar.frank@solarenergy.ch](mailto:elimar.frank@solarenergy.ch)  
[robert.haberl@solarenergy.ch](mailto:robert.haberl@solarenergy.ch)

## **TASK 33: SOLAR HEAT FOR INDUSTRIAL PROCESSES**

Werner Weiss

AEE - Institute for Sustainable Technologies

Operating Agent for the Austrian Ministry of Transport, Innovation and Technology



### **TASK DESCRIPTION**

Around 168 million square meters of solar thermal collectors, corresponding to an installed capacity of 118 GW<sub>th</sub>, were installed by the year 2006 worldwide. Until now, the widespread use of solar thermal plants has focused almost exclusively on swimming pools, domestic hot water preparation and space heating in the residential sector.

The use of solar energy in commercial and industrial companies is currently insignificant compared to the use in swimming pools and the household sector. Most solar applications for industrial processes have been used on a relatively small scale and are mostly experimental in nature. Only a few large systems are in use worldwide. However, if one compares the energy consumption of the industrial, transportation, household and service sectors in OECD countries, the industrial sector has the highest energy consumption at approximately 30%, followed closely by the transportation and household sectors.

The major share of the energy, which is needed in commercial and industrial companies for production processes and for heating production halls, is below 250°C. The low temperature level (<80°C) complies with the temperature level that can easily be reached using solar thermal collectors already on the market. The principles of operation of the components and systems apply directly to industrial process heat applications. The unique features of these applications lie on the scale on which they are used, system configurations, controls needed to meet industrial requirements, and the integration of the solar energy supply system with the auxiliary energy source and the industrial process. For applications where temperatures up to 250°C are needed, the experiences are rather limited and suitable components and systems are missing. Therefore, for these applications the development of high performance solar collectors and system components is needed.

To be able to make use of the huge potential for solar heat in industry and to open a new market sector for the solar thermal industry, SHC Task 33 carried out potential studies, investigated the most promising applications and industrial sectors for solar heat, and optimized, developed and tested solar collectors for medium temperature applications (up to approximately 250°C). The development of integral solutions for solar thermal energy applications for given industrial processes (based on the “PINCH-concept”) was also one of the main topics of this Task. In addition also the design and the erection of 9 pilot plants in co-operation with industry was carried out.

### **Scope of the Task**

The scope of the Task was on solar thermal technologies for converting the solar radiation into heat, (i.e., starting with the solar radiation reaching the collector and ending with the hot air, water or steam transferred to the application). The distribution system, the production process and/or the optimization of the production process were not the main topics of the Task. However, influences on the production process and the distribution system arising from the character of the solar heat source were studied in the framework of the Task.

Applications, systems and technologies, which were included in the scope of this task, are:

- All industrial processes where heat up to a temperature level of approx. 250°C is needed.
- Space heating of production or other industry halls is addressed, but not space heating of dwellings.
- Solar thermal systems using air, water, low pressure steam or oil as a heat carrier, i.e. not limited to a certain heat transfer medium in the solar loop.
- All types of solar thermal collectors for an operating temperature level up to 250°C are addressed: uncovered collectors, flat-plate collectors, improved flat-plate collectors - for example hermetically sealed collectors with inert gas fillings, evacuated tube collectors with and without reflectors, CPC collectors and small parabolic trough collectors.

To accomplish the objectives of the Task, the participants were carrying out research and development in the framework of the following four Subtasks:

- Subtask A: Solar Process Heat Survey and Dissemination of Task Results  
(Lead Country: Italy)
- Subtask B: Investigation of Industrial Energy Systems  
(Lead Country: Austria)
- Subtask C: Collectors and Components  
(Lead Country: Germany)
- Subtask D: System Integration and Demonstration  
(Lead Country: Germany)

### **Collaboration with other IEA Programmes**

Due to the complementary background and know-how of the participants of the SHC and the SolarPACES Programmes, significant synergies were expected from collaboration.

Therefore, it was agreed to co-operate with the SolarPACES Program on a “moderate level” according to the SHC “Guidelines for Co-ordination with other Programs.”

## ACTIVITIES DURING 2007

### **Subtask A: Solar Process Heat Survey and Dissemination of Task Results**

#### ***Existing Plants and Potential Studies***

Currently about 90 solar thermal plants for process heat are reported worldwide, with a total installed capacity of about 25 MW<sub>th</sub> (35,000 m<sup>2</sup>). These plants are located in 21 countries and cover many different industrial sectors, highlighting that solar thermal could be fruitfully used for several applications in industry.

A summary table, reporting information about Solar Heat Plants for Industrial Processes (SHIP) worldwide, was developed and uploaded on the internal part of SHIP web site. This matrix collects several technical and economic data about the plants.

Regarding the potential for SHIP applications, the analysis carried out shows that, in spite of the small reported operating capacity of solar thermal plants in industry (25 MW<sub>th</sub> out of 118 GW<sub>th</sub> of solar thermal installed worldwide), the potential at EU level is quite high and equals 100÷125 GW<sub>th</sub> (143÷180 millions of m<sup>2</sup>), which represents 3.8% of the industrial heat demand in EU 25.

This analysis will be described in a specific booklet on potential studies, which will be published in 2008. The main outcome of this work, carried out is the harmonization of the results of the SHIP potential studies in several EU and non EU countries and their extrapolation at EU level.

#### ***Case Studies and Economic Analysis***

In 2007, nineteen case studies on solar thermal plants for industrial applications were carried out, covering different industrial sectors and several countries: 13 from Austria, 2 from Germany, 2 from Nicaragua and 2 from Spain.

As for the economic analysis, questionnaires have been collected from Austria, Germany, Italy, Portugal and Spain, including qualitative and quantitative information about the currently existing incentive schemes for SHIP plants and about energy and solar thermal plants prices.

The results will be uploaded on the internal part of Task 33/IV web site.

#### ***Dissemination Activities***

##### ***Industry Workshops***

In 2007, two industry workshops were carried out in Cologne and in Graz.

The first workshop, held in Cologne (Germany) on March, 30<sup>th</sup> 2007, was attended by 48 participants, mainly from the industry and research sectors, the German Federal Ministry of Environment Nature and Reactor Safety, the funding agencies.

The Austrian workshop, attended by 112 participants, was held on September, 12<sup>th</sup> 2007 in Graz, Austria. Besides industry and researchers, the participants included also

representatives from the Austrian Federal Ministry for Transport, Innovation and Technology as well as representatives from funding agencies.

#### *Industry Newsletter*

The 3<sup>rd</sup> Industry Newsletter was finalised and distributed in January 2007. The topics included are:

- Updated statistics on plant survey
- Monitoring results of CONTANK plant
- Design guidelines for space heating of factory buildings
- Solar heat for breweries
- Linear Fresnel process heat collector
- Outcomes of the Industry Workshops in Roma and Lisbon

The newsletter is available on the Task website in the following languages: English, German, Italian, Portuguese and Spanish. The 4<sup>th</sup> edition of the Industry Newsletter will be published in February 2008.

### **Subtask B: Investigation of Industrial Energy Systems**

#### ***Matrix of Indicators***

A “Matrix of indicators”, which is a comprehensive database on industrial processes, was developed in Subtask B as a decision support tool for solar experts. With this matrix the work with industry and the identification of suitable solar applications will be facilitated. With the MATRIX it should be possible to investigate and calculate the installation of solar heat in production processes without detailed knowledge of the relevant unit operations.

Some industry sectors such as food, chemistry, plastic processing, textile industry and surface treatment industry can be identified as very promising sectors for solar thermal applications. For these industries detailed information like general benchmark data, temperature levels of the processes, flow sheets of production lines and generic hydraulic schemes for solar integration can be found in specific Sub-MATRICES.

The investigation of these relevant industries has to focus on an integrated analysis of cooling and heating demands taking into account competitive technologies, when assessing the (economic) feasibility of solar thermal energy. Among those competing technologies are heat integration, co-generation, new technologies and heat pumps, which also have been described in the relevant parts of the MATRIX.

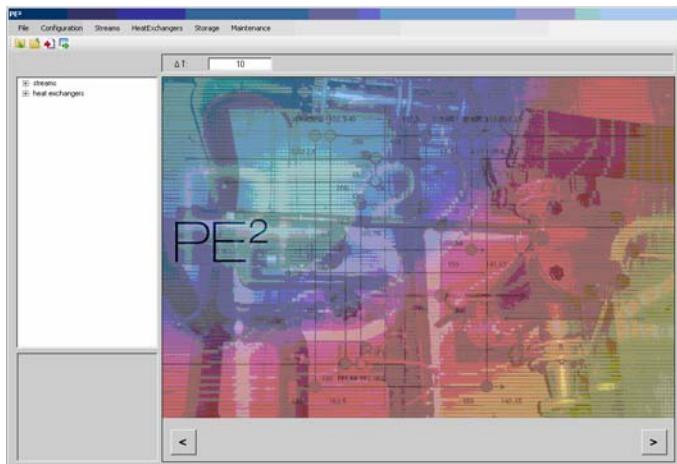
#### **Expansion of the Existing Heat Integration Models**

Most industries have a heat demand in the production and at the same time a lot of waste heat. The use of this waste heat has the advantage of being in competition with the heat demand of other processes. The reuse of this waste heat has to be done at as a high temperature as possible. The most promising methodology to identify the maximum heat recovery in a defined system (for a defined industrial company) is the pinch analysis. With this tool the minimal external heating demand and the minimal external cooling demand can also be identified.

Within the work of Subtask B, a computer program (Pinch Energy Efficiency – PE<sup>2</sup>), which calculates the heat recovery potential and designs a technically and economically feasible

heat exchanger network for given processes, has been developed. The new software PE<sup>2</sup> fulfils the needs of heat integration calculations in the promising industries. The automatic calculation of an ideal heat exchanger network (based on mathematical criteria and aiming at maximum savings in terms of energy savings in kWh per year) is one of the main advantages of this developed tool. Further the possibility to calculate heat exchanger surfaces and the calculation of a dynamic cost calculation resulting in the pay back period of a given heat exchanger network based on user defined economic data and the visualization of energy savings with the Sankey Editor afford a fast energy optimization of a whole company.

The analysis with this tool shows the remaining energy demand at the corresponding temperature levels after the optimization of the processes by heat recovery. It gives the information in which temperature demand external heat/cold is necessary – important information for a possible solar process heat plant.



**Front page of the PE<sup>2</sup> software, which was developed within Task 33/IV by JOINTS from Austria**

### **Subtask C: Collectors and Components**

#### **Medium Temperature Collector Developments**

The two final experts meetings of the Task in Köln, Germany and Graz, Austria in 2007 showed that various development works on Medium Temperature Collectors still continue. It can be expected that even after the end of the Task in the next years new developments will come up.

For example, there is a new development of an improved CPC-collector with evacuated casing, carried out at ZAE Bayern, Germany. Almost all components of the prototype are ready by now and the first collector will soon be assembled. Then experimental investigations on the collector will be carried out. It is expected that first testing results will be available in 2008.

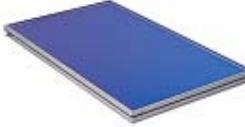
The redesign of the CCSTAR collector is almost finished now. It is an activity of the Universitat de les Illes Balears. The collector follows the principle of a fixed reflector and a tracking receiver. A 25 m<sup>2</sup> prototype reflector was built. The idea to construct a stepped

geometry of the reflector is not followed any more. The investigations carried out so far showed that a reflector with a parabolic shape will be exact enough as long as the concentration factor is not chosen too high. A continuous surface reflector is more easily produced than a reflector with a stepped geometry. Therefore, it is also more cost-effective. First optical investigations showed quite good results of the new reflector construction. The geometric concentration factor will be in the range of 11. The prototype reflector was built using reflector material from two different producers. It is planned to have the prototype available up to spring of 2008.

Interesting results were also achieved concerning the PSE-Fresnel collector for medium temperature applications. Measurement results were presented which were taken from the first prototype collector set up in Freiburg, as well as on the second prototype which is set up in Bergamo, Italy. During the summer of 2007 already the third prototype of this collector technology was installed (in Seville, Spain).

These examples and the other presentations in the meetings of the last operating year of the Task showed two facts: on the one hand, there is continued interest in new developments and still new technical possibilities for different development lines of process heat collectors come up.

**Table 1: Collectors developed and investigated within SHC Task 33/IV**

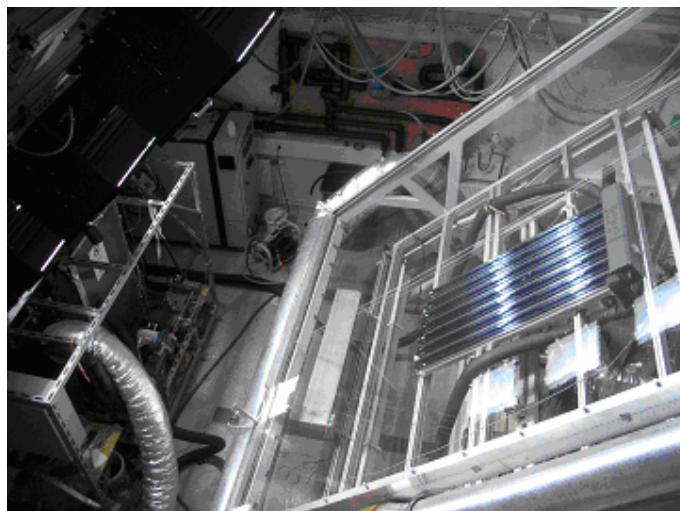
	Collector type	Working temperature [°C]	Heat transfer media	Contact Task 33/IV
<b>Optimised flat plate collectors</b>				
	<b>2AR flat-plate collector</b> Double Glazed Flat-Plate Collector with Anti-Reflective Glasses	80 – 150	Water-Glycol	Fraunhofer Institut für Solare Energiesysteme Heidenhofstrasse 2 79110 Freiburg Germany
	<b>SCHÜCO</b> Double-Glazed Flat-Plate Collector	80 - 150	Water-Glycol	Schüco International KG Karolinestrasse 1-15 33615 Bielefeld Germany
<b>CPC-collectors</b>				
	<b>AoSol</b> Stationary CPC Collector	80 - 110	Water-Glycol	DER/INETI, Edificio H, Estrada do Paço do Lumiar, 22, 1649-038 Lisboa Portugal
	<b>Solarfocus</b> Stationary CPC Collector	80 - 120	Water-Glycol	SOLARFOCUS GmbH 4451 St.Ulrich / Steyr Austria
	<b>ZEA</b> Evacuated stationary CPC collector	120 - 180	Water-Glycol	ZAE Bayern Walther-Meißner-Str. 6, 85748 Garching Germany
<b>Small parabolic trough collectors</b>				
	<b>PARASOL</b> Parabolic Trough Collector	100 – 200	Water or steam	AEE INTEC Feldgasse 19 8200 Gleisdorf Austria

	<b>SOLITEM PTC 1800</b> Parabolic Trough Collector	100 – 200	Water	DLR Institut für Technische Thermodynamik 51170 Köln Germany
	<b>NEP SOLAR</b> Polymer Carrier PTC	150 – 250	Water	New Energy Partners Pty Ltd Level 2 Suite 1a 802 Pacific Highway Gordon NSW 2072 Australia
	<b>PTC 1000</b> Modular parabolic trough collector	80 – 300	Water	Solar-Institut Jülich Heinrich-Mußmann-Str. 5 52428 Jülich Germany
	<b>CHAPS</b> Combined Heat and Power Solar collector	80 - 150	Water	Australian National University Centre for Sustainable Energy Systems Department of Engineering, Canberra ACT 0200 Australia
<b>Fresnel collector</b>				
	<b>PSE</b> linear Fresnel collector	100 – 400	Water, steam or Thermo oil	PSE Solar Info Center 79072 Freiburg Germany
<b>CCStaR – Concentrating collector with stationary reflector</b>				
	<b>CCStaR</b> Concentrating Collector with Stationary Reflector	80 - 140	Water	Universitat de les Illes Balears Palma de Mallorca Spain

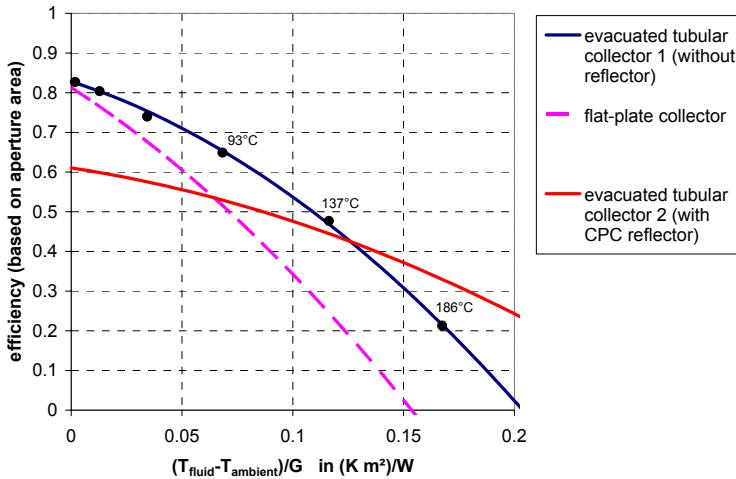
### **Process Heat Collector Testing**

The work on collector testing and recommendations for testing procedures was continued and finalized. The work on the Round Robin test (which rather was an inter-comparison test) was continued and finalized. Three institutions were involved in this activity of Task 33/IV: ITW, Germany, INETI, Portugal and Fraunhofer ISE. The tests were carried out on an evacuated tubular collector with CPC reflector. Three collectors of the same type were first tested at ISE. Due to these measurements it was checked that the efficiency curves of the three different collectors did not differ by more than 1%.

The results show that to a certain extent there is an agreement of the measured efficiency curves within the temperature range in which the efficiency point measurements were actually carried out by all three testing institutions. But it has to be admitted that not all tests were really carried out in the temperature range up to 200°C. In fact, the highest collector temperatures during the tests were only about 98°C (ITW) and 114°C (INETI). ISE tested up to 183°C. The results show that the differences in the measured efficiency values increase very much outside the measurement range. This again shows the unconditional necessity to measure the efficiency and performance of medium temperature collectors really at temperatures up to 200°C. The figure below shows the indoor simulator testing facility of Fraunhofer ISE with the new medium temperature testing facility. The diagram shows three efficiency curves which all were measured up to collector inlet-temperatures near to 200°C during the tests. The results of the Task also show that more experimental experiences are needed with respect to the determination of 2D-Incidence Angle Modifiers in order to achieve a better and more reliably characterisation of Medium Temperature Collectors.



**Figure 1. Efficiency curve measurement at Fraunhofer ISE for the evacuated tubular collector with a CPC reflector in the inter-comparison test. The medium temperature testing unit allows accurate measurements up to 200 °C (bottom left in the picture).**



**Figure 2. Measured efficiency curves of three different collectors (Fraunhofer ISE measurements, highest mean collector temperatures about  $185^{\circ}$  -  $190^{\circ}\text{C}$  for all three measured curves). The dots show the actually measured efficiency points for collector 1 and the mean collector temperature in the measurement. The collector which was used for the inter-comparison tests in the Task is denoted "evacuated tubular collector 2 (with CPC reflector)".**

### **Reliability of Collectors for Industrial Processes**

In this final year of the Task, the work on development considerations of solar absorbers for Medium Temperature Collectors was finalized. Suggestions for the definition of performance criteria for different medium temperature collectors (improved flat plate collectors, stationary CPC collectors with low concentration and highly concentrating collectors) were made. The base case for comparison is a non-selective coating. Samples of absorber coatings were measured with respect to accelerated degradation. The new suggested performance criteria were applied. The results show that due to the Task a first step has been taken now but more work has to be carried out to support the further development activities of medium temperature collectors.

### **Subtask D: System Integration and Demonstration**

In the framework of the Task nine pilot systems were designed in close cooperation with the industry. All of the plants are installed and most of them were equipped with monitoring devices.

The following table gives an overview of the pilot systems.

<b>Plant, Country</b>	<b>Application</b>	<b>Installed capacity Collector type</b>	<b>Monitoring data available</b>
Contank Spain	Container washing	357 kW <sub>th</sub> flat plate collector	YES
ROBUR Italy	cooling	65.5 kW <sub>th</sub> (132 m <sup>2</sup> ) 132 m <sup>2</sup> fresnel collector	YES
Seawater desalination Gran Canaria, Spain	Seawater desalination	70 kW <sub>th</sub> anti-reflective double glazed flat plate collector	YES
Seawater desalination plant, <u>Aqaba</u> , Jordan	Sea water desalination	50.4 kW <sub>th</sub> flat plate collector	YES
Fruit juices Gangl, Austria	Pasteurizing bottle washing	42 kW <sub>th</sub> flat plate collector	YES
Sunwash, Köflach, Austria	Car wash	30 kW <sub>th</sub> flat plate collector	NO
Moguntia Spices, Austria	Cleaning and washing processes	152 kW <sub>th</sub> flat plate collector	NO
Brewery Neuwirth Austria	Brewing process	14 kW <sub>th</sub> anti-reflective double glazed flat plate collector	YES
New Energy Partners Australia	cooling	50 m <sup>2</sup> PTC	YES



**Sea water desalination Gran Canaria, Spain (Fraunhofer ISE, Germany)**

## **REPORTS TO BE PUBLISHED IN 2008**

In general all work within Task 33/IV is completed. In 2008 the main results will be summarized by four specific booklets, dealing with the following topics:

1. Potential studies
2. Process heat collectors
3. Design guidelines for space heating of factory buildings
4. Pilot projects for solar thermal plants in industry

Furthermore a CD will be published with the following content:

- Demo version of the Pinch program PE<sup>2</sup> (energy efficiency in industrial processes)
- Matrix of industrial process indicators

The booklets will be available in a printed version and it will be available for download in PDF format from the IEA SHC web site.

## **LINKS WITH INDUSTRY**

The Task defined two levels of participation for the solar industry:

- **Level 1.** An industrial participant at this level participated at least in an annual workshop organized by SHC Task 33 and received at least once during the task duration a visit from a task participant to answer technical and marketing questions on solar heat for industrial applications.
- **Level 2.** An industrial participant at this level was expected to participate in all task meetings and to bring information and feedback from the market. Level 2 participation was seen in close connection with the main participant of the country of origin of the industry.

A total of 15 companies from Austria, Germany, Italy, Portugal and Spain participated in the Task.

**MEETINGS IN 2003**  
**First Experts Meeting**  
December 4 – 6  
Gleisdorf, Austria

**MEETINGS IN 2004**  
**Second Experts Meeting**  
March 29 – 30  
Brussels, Belgium

**Third Experts Meeting**  
October 3 – 5  
Oaxaca, Mexico

**MEETINGS IN 2005**  
**Fourth Experts Meeting**  
February 23 – 25  
Madrid, Spain

**Fifth Experts Meeting**  
October 3 – 8  
Kassel, Germany

**MEETINGS IN 2006**  
**Sixth Experts Meeting**  
March 29 – 31  
Rome, Italy

**Seventh Experts Meeting**  
October 11 – 13  
Lisbon, Portugal

**MEETINGS IN 2007**  
**Eighth Experts Meeting**  
March 28 – 30  
Cologne, Germany

**Ninth Experts Meeting**  
September 10 – 12  
Graz, Austria

## **TASK 33 NATIONAL CONTACTS**

### **Australia**

Wes Stein  
Lucas Heights Science & Technology  
Centre  
New Illawarra Rd, Lucas Heights NSW,  
PMB 7  
Bangor NSW 2234

Andreas Häberle

PSE GmbH  
Emmy-Noether Str. 2  
D-79110 Freiburg

### **Austria**

Werner Weiss, Dagmar Jähnig and  
Thomas Müller  
AEE INTEC  
AEE - Institute for Sustainable  
Technologies  
Feldgasse 19  
A-8200 Gleisdorf

Hans Schnitzer and Christoph Brunner  
Joanneum Research  
Elisabethstrasse 16/I  
A-8010 Graz

Gernot Gwehenberger  
Technical University of Graz  
RNS  
Inffeldgasse 25c  
A-8010 Graz

### **Italy**

Riccardo Battisti, Annalisa Corrado  
Claudia Vannoni, Serena Drigo  
University of Rome "La Sapienza"  
Department of Mechanical and  
Aeronautical Engineering  
Via Eudossiana  
18 00184 Rome

### **Germany**

Klaus Vajen and Elimar Frank  
Kassel University  
Department of Mechanical Engineering  
Solar and System Technology  
D-34109 Kassel

Klaus Hennecke  
DLR

Institut für Technische Thermodynamik  
D-51170 Köln

Matthias Rommel  
Fraunhofer ISE  
Heidenhofstrasse 2  
D-79110 Freiburg

Stephan Fischer  
ITW, Stuttgart University  
Pfaffenwaldring 6  
D-70550 Stuttgart

Markus Peter  
dp2 - Energienutzung mit Verstand  
Michelsweg 29  
D- 59494 Soest

### **Mexico**

Claudio Estrada  
CIE-UNAM  
Privada Xochicalco, S/N, Col. Centro  
Cuernavaca, Mor., Mexico

### **Portugal**

Maria Joao Carvalho  
INETI  
Edificio H, Estrada do Paço do Lumiar, 22  
1649-038 Lisboa

### **Spain**

Esther Rojas Bravo  
CIEMAT-PSA  
Avda. Complutense, 22, Edificio 42  
28040 Madrid

Gonzalez i Castellví  
AIGUASOL Engineering  
C/ Roger de Llúria, 29 3er 2a  
08009 Barcelona

Hans Schweiger  
Ingeniería Termo-energética y Energías Renovables  
Creu dels Molers, 15, 2o 1a  
08004 Barcelona

## **SHC TASK 34: TESTING AND VALIDATION OF BUILDING ENERGY SIMULATION TOOLS**

*Ron Judkoff  
National Renewable Energy Laboratory  
Operating Agent for the U.S. Department of Energy*

### **TASK DESCRIPTION**

The goal of this Task was to undertake pre-normative research to develop a comprehensive and integrated suite of building energy analysis tool tests involving analytical, comparative, and empirical methods. These methods provide for quality assurance of software, and some of the methods will be enacted by codes and standards bodies or other regulatory agencies to certify software used for showing compliance with building energy standards, tax credits, or other building energy incentive programs. This goal was pursued by accomplishing the following objectives:

- Create and make widely available a comprehensive and integrated suite of IEA Building Energy Simulation Test (BESTEST) cases for evaluating, diagnosing, and correcting building energy simulation software. Tests address modeling of the building thermal fabric and building mechanical equipment systems in the context of innovative low-energy buildings.
- Maintain and expand as appropriate analytical solutions for building energy analysis tool evaluation.
- Create and make widely available high quality empirical validation data sets, including detailed and unambiguous documentation of the input data required for validating software, for a selected number of representative design conditions.

This work was the combined effort of SHC Task 34 and the Energy Conservation in Buildings and Community Systems (ECBCS) Annex 43.

### **Scope**

This Task investigated the availability and accuracy of building energy analysis tools and engineering models to evaluate the performance of innovative low-energy buildings. Innovative low-energy buildings attempt to be highly energy efficient through use of innovative energy-efficiency technologies or a combination of innovative energy efficiency and solar energy technologies. To be useful in a practical sense such tools must also be capable of modeling conventional buildings. The scope of the Task was limited to building energy simulation tools, including emerging modular type tools, and widely used innovative low-energy design concepts. Activities include development of analytical, comparative and empirical methods for evaluating, diagnosing, and correcting errors in building energy simulation software. The audience for the results of the Task/Annex is building energy simulation tool developers, and codes and standards (normes) organizations that need methods for certifying software. However, tool users, such as architects, engineers, energy consultants, product manufacturers, and building owners and managers, are the ultimate beneficiaries of the research, and will be informed through targeted reports and articles.

## **Means**

A number of projects were defined. For the purpose of describing the work, it is useful to define the terms “comparative tests” and “empirical validation.” In comparative testing, a BESTEST-type comparative/diagnostic evaluation test procedure is written and software programs are compared to each other. Advantages of comparative tests include ease of testing many parameters, and that simple building descriptions may be used; the major disadvantage is lack of any truth standard for cases where analytical solutions are not possible. In empirical validation, software is compared with carefully obtained experimental data. The advantage of empirical tests is that true validation of the models may be accomplished within the uncertainty of the experimental data; disadvantages are that gathering high quality experimental data is expensive and time consuming, making it difficult to test the individual effects of many parameters.

Comparative tests included:

- BESTEST ground-coupled heat transfer with respect to floor slab construction
- BESTEST multi-zone heat transfer and shading
- BESTEST airflow, including multi-zone airflow
- Chilled-water and hot-water mechanical systems and components
- Buildings with double-skin facades.

Within the comparative test cases, analytical verification tests for evaluating basic heat transfer and mathematical processes in building energy analysis tools were included where possible. Analytical verification tests are comparisons with closed-form analytical solutions or with generally accepted numerical methods solutions performed outside of the environment of whole-building energy simulation software. Such closed-form analytical solutions and numerical solutions represent a “mathematical truth standard” and “secondary mathematical truth standard”, respectively, based on the underlying physical assumptions given in the test specifications.

Empirical validation tests include:

- Shading/daylighting/load interaction
- Chilled-water and hot-water mechanical systems and components
- Buildings with double-skin facades.

When a number of building energy simulation programs are tested against the same empirical data set, comparative tests are also possible. Such comparative tests can help identify deficiencies in the empirical experiment if they exist, or broad-based deficiencies in the current modeling state of the art.

To effectively disseminate the results of the Task a single web site consolidates IEA tool evaluation tests from SHC Task 12 / ECBCS Annex 21, SHC Task 22, and SHC Task 34 / ECBCS Annex 43.

## **Duration**

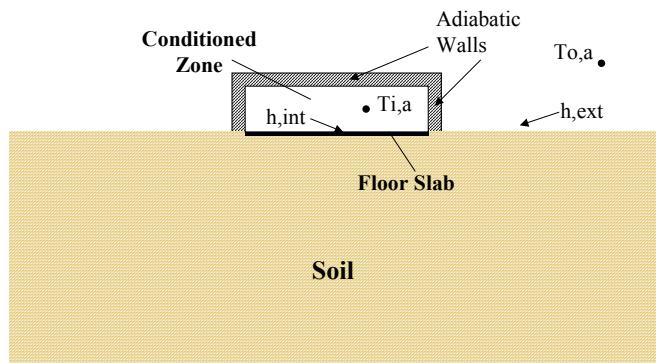
The Task was initiated in September 2003 and completed in December 2007.

## Participation

A total of 35 participants from 23 organizations in 13 countries participated in this Task. The participating countries are: Australia, Belgium, Canada, Denmark, France, Germany, Ireland, Japan, Netherlands, Sweden, Switzerland, United Kingdom, and the United States. More than 33 person-years of effort were expended by the participants over the course of the task. The work of Task 34 was organized into six projects:

### Project A: Ground Coupled Floor Slab and Basement Comparative Tests

The objective of these in-depth test cases is to determine the causes for disagreements among detailed ground heat transfer model results found in preliminary test cases developed during SHC Task 22. The cases are divided into “a”-series, “b”-series and “c”-series cases. The “a”-series test cases are for checking proper implementation of detailed 3-d numerical-methods ground heat transfer models run independently of whole-building simulations. They include a steady-state 3-d analytical verification test case, and two other idealized steady-state and periodically-varying comparative test cases. The less idealized “b”-series and “c”-series cases compare ground heat transfer models integrated with whole-building simulations to the independent numerical models. Parametric variations in these cases include: periodic ground surface temperature variation (versus steady-state), floor slab aspect ratio, slab size, deep ground temperature depth, and interior and exterior convective coefficients (realistic versus high values to test the effect of surface temperature uniformity).



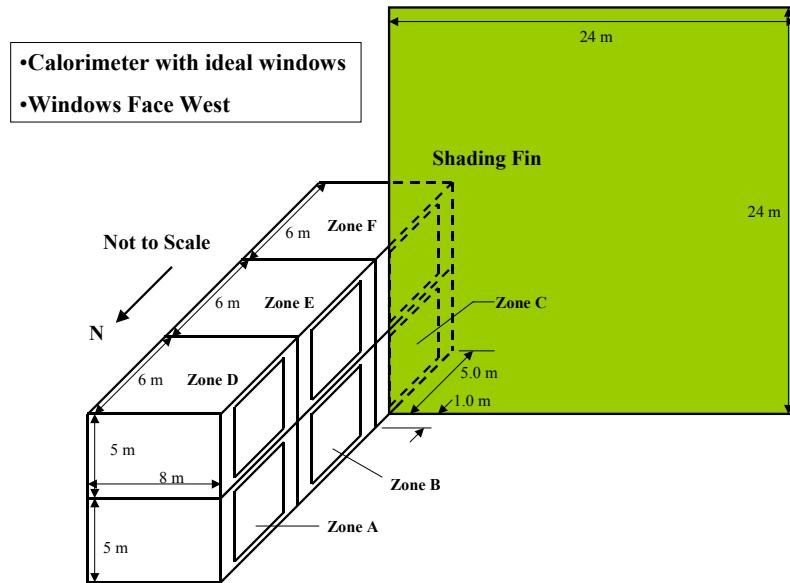
**Ground Coupling Test Case Schematic Diagram, Case GC30.**

### Project B: Multi-Zone and Airflow Comparative Tests

#### Project B1: Non-Airflow Tests

(Leader: US/NREL)

The objectives of the test cases are to test: a) models’ ability to correctly keep account of inter-zonal conduction heat transfer and to help define a starting point for multi-zone airflow cases; b) the ability of programs to account for multi-zone shading by a single shading object (see Figure 2) and self-shading of the building by zones that shade other zones; and c) the ability to model internal windows between zones. Shading and internal window test cases employ idealized glazing and building zones designed as calorimeters for testing shading and solar gains effects.

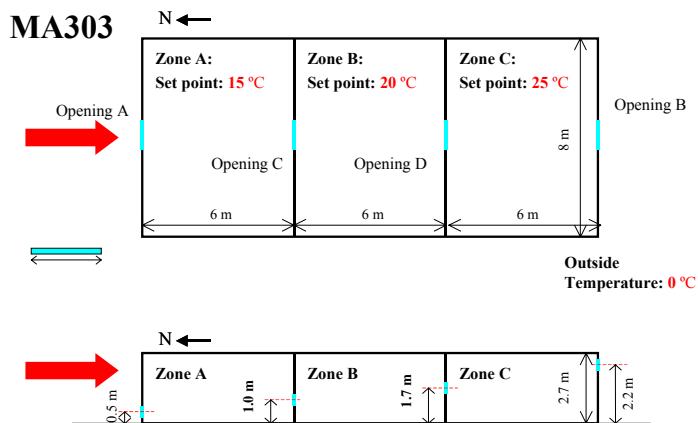


**Multi-Zone Shading Test Case Schematic Diagram.**

### **Project B2: Airflow Tests including Multi-Zone Airflow**

(Leader: Japan/INCT)

The airflow cases emphasize flows driven by natural ventilation, buoyancy, wind, temperature-difference, and mechanical fan. Cases have been developed in 1-zone and 3-zone configurations (see Figure 3). The test cases are based on the geometry of the multi-zone non-airflow cases, are simpler (potentially more diagnostic) than the ECBCS Annex 23 (COMIS airflow) cases, and allow use of nodal, zonal, and CFD models (not possible with COMIS cases).



**Combined Wind and Temperature Driven Airflow Test Case (MA303) Schematic.**

## **Project C: Shading/Daylighting/Load Interaction Empirical Tests**

### **Project C1: EMPA Shading/Daylighting/Load Interaction (Leader: Switzerland/EMPA)**

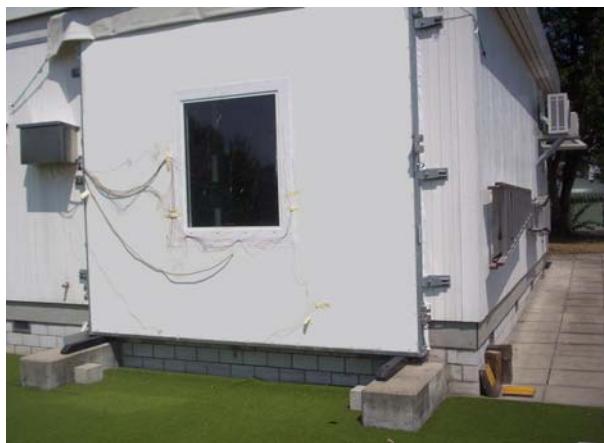
The goals of the project are:

- Collection of empirical data in Swiss Federal Laboratory for Materials Testing and Research (EMPA) test cells (see Figure 4) for the validation of thermal performance models of windows with/without shading devices in building energy simulation codes
- Comparison of simulation results with empirical data.

The suite of eight experiments includes: 1) Overall test cell conductance, 2) Overall test cell internal capacitance, 3) Glazing only, 4) Glazing with external textile shading screen, 5) Glazing with internal textile shading screen, 6) Glazing with external Venetian blinds, 7) Glazing with internal mini-blinds, and 8) Window, i.e. glazing with frame. The simulations for the solar gain experiments were designed to predict the cooling power required to maintain the constant zone temperature.

### **Project C2: ERS Shading/Daylighting/Load Interaction (Leader: US/Iowa)**

The purpose of the work done at Iowa Energy Resource Station (ERS) in the United States is to create an empirical validation data set for daylighting controls. Equipment used includes: dimmable ballasts, fabric shades, mini-blinds, exterior shading fins, and equipment for scheduled internal gains. Electric lights are controlled to maintain a minimum illuminance level; when enough natural daylight is available electric lighting is reduced. Daylighting tests were performed at ERS.



**EMPA Test Cells in Duebendorf, Switzerland.**

## **Project D: Mechanical Equipment and Controls Empirical Validation Tests**

This work is for testing and validating energy simulation software related to chilled- and hot-water building energy systems. The tests are separated into several sub-exercises to focus on single components as shown in Table I below. Beside a set of comparative tests, the experimental and measurement facilities at the Iowa Energy Resource Station/US are used for empirical studies.

The work includes comparative test cases for the coils (both cooling and heating coil) and the hot water boiler. The coil comparative tests are designed to predict coil performance to maintain a given leaving air temperature when temperature and humidity of entering air and water are given. Two different types of coil control strategies (variable water mass flow vs. variable water inlet temperature) are used for comparative test cases.

**Table 1: Components of the building systems related to Project D**

Test case	Simulation Exercises
Chilled water system	<ul style="list-style-type: none"> <li>- Chiller (two scroll compressors)</li> <li>- cooling coil (dry / wet regime with condensing water flow rate measurement)</li> <li>- hydronic network (pipes, pump, valve)</li> </ul>
Hot water system	<ul style="list-style-type: none"> <li>- Boiler (Condensing atmospheric natural gas boiler with variable firing rate)</li> <li>- Heat exchanger (terminal re-heat)</li> <li>- hydronic network (pipes, pump, valve)</li> </ul>

### **Project E: Double-Facade Empirical Tests**

The objective for this project is to assess suitability and awareness of building energy analysis tools for predicting heat transfer, ventilation flow rates, cavity air and surface temperatures and solar protection effect and interaction with building services systems in buildings with double facade.

#### **Project E1: Double-Skin Buildings Literature Survey (Leader: Sweden/Lund University)**

The objective for this sub-project is collection of available literature on typologies, modeling approaches, measurements, tools, etc.

#### **Project E2: Double-Façade Empirical Tests (Leader: Denmark/Aalborg University)**

The objective for this sub-project is to develop an empirical validation test procedure for DSF models including description of test facility (see Figure 5) and test cases, and documentation of the empirical data sets and simulation results. Test cases include the following configurations:

- DSF100\_e. All façade openings closed
- DSF200\_e. Openings are open to the outside
- DSF400\_e. Bottom opening open to outside; top opening open to inside

Within the test cases are a number of variations to check the influence of various parameters, including:

- Driving force of airflow (buoyancy, wind, mechanical fan, combined forces)
- Internal (thermal)/External (thermal, solar, wind) boundary conditions
- Opening area (fully opened, opening area controlled by temperature and/or airflow rate)



**Aalborg University Double-Skin Façade Test Facility in Aalborg, Denmark.**

**Project E3: Double-Façade Comparative Tests** (Leader: Denmark/Aalborg University)

The objective for this sub-project is to develop a comparative validation test procedure for DSF models.

Three comparative test cases have been defined. Comparative test weather data is 2 weeks (from April 2002) of the Danish reference weather year. The test cases are:

- DSF100. All façade openings closed
- DSF200. Openings are open to the outside
- DSF400. Bottom opening open to outside; top opening open to inside

**Project G: Web Site for Consolidation of Tool Evaluation Tests (Leader: Operating Agent)**

The objective of this project is to consolidate the tool evaluation tests from IEA SHC Task 12 / ECBCS Annex 21, SHC Task 22, and SHC Task 34 / ECBCS Annex 43 to a single web site.

## **ACHIEVEMENTS OF TASK 34**

The work has led directly to improvements in software tools used for evaluating the impacts of energy efficiency and solar energy technologies commonly applied in innovative low-energy buildings. **So far among all projects, the work has identified 63 results disagreements that have led to 58 software fixes.** Table 2 indicates by project the number of model errors that were identified and fixed. Table 3 indicates by project the 24 computer models that were tested. Individual achievements of each project are further discussed below.

**Table 2. Model Fixes Attributable IEA SHC 34/ECBCS Annex 43**

<b>Project</b>	<b>Leader</b>	<i>Disagreements</i>		<b>Models</b>
		<b>Fixed</b>	<b>Identified</b>	
<b>A. Ground Coupled Slab-on-Grade</b> , US/NREL	US/NREL	<b>19</b>	24	9
<b>B1. Multi-Zone Non-Airflow</b>	US/NREL	<b>25</b>	25	9
<b>B2. Airflow</b>	Japan	?*	?*	6
<b>C. Shading/Daylighting/Load Interaction</b>	Switz., US/Iowa	<b>14</b>	14	7
<b>D. Mechanical Equipment and Controls</b>	Germany	?*	?*	5
<b>E2/E3. Double-Skin Facade</b>	Denmark	?*	?*	5

\* "?" indicates the number is not yet reported by the project leader.

**Table 3. Models Tested during IEA SHC Task 34/ECBCS Annex 43**

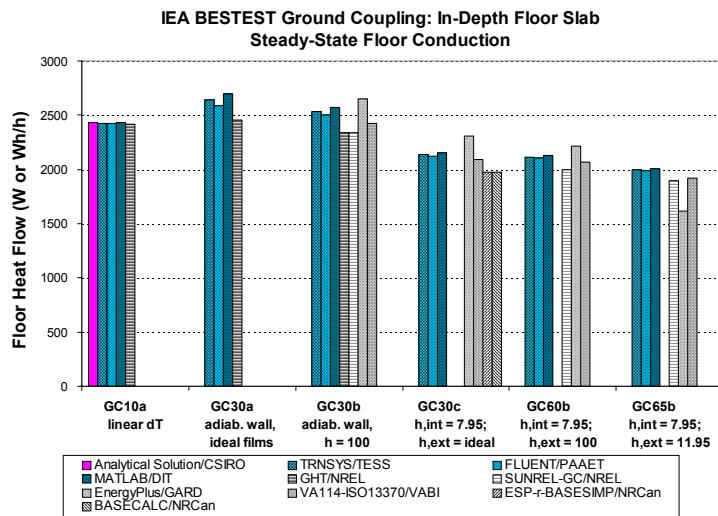
<b>Model Tested</b>	<b>Participating Country</b>	<b>Project</b>
BASECALC	Canada	A
BSim	Denmark	E
CODYRUN	France	B1 (MZ320 only),B2
COMFIE	France	B1 (MZ320 only)
COMIS 3.2	Japan	B2
DOE-2.1E	Switzerland	C
EES	Belgium	D
EnergyPlus	Switzerland	C
EnergyPlus	United States	A,B1,D
ESP-r	United Kingdom	B1,B2,C,E
ESP-r/BASESIMP	Canada	A
FLUENT*	Kuwait	A
HELIOS	Switzerland	C
HTB2	United Kingdom	B1,B2
IDA-ICE	Sweden	E
IDA-ICE	Switzerland	C
KoZiBu	France	B1 (MZ320 only)
MATLAB*	Ireland	A
MATLAB-Simulink	Germany	D
SUNREL-GC/GHT	United States	A
TRNSYS-TUD	Germany	B1,B2,C,D,E
TRNSYS-16*	United States	A
TRNSYS-16	Belgium	B1,C
VAI14	Netherlands	B1,D,E
VAI14/ISO-13370	Netherlands	A
VentSim	Japan	B2

\* Used as platform for developing detailed 3-D numerical model

## Project A: Ground Coupled Floor Slab and Basement Comparative Tests

The IEA BESTEST cases have been extended to include in-depth analytical verification test cases for slab-on-grade heat transfer models. An important achievement of this project was the development of a formal methodology to facilitate using and verifying numerical models to develop quasi-analytical solutions. This allows for greatly enhanced diagnostic capability when comparing results of other simplified and mid-level-detailed modeling methods that are typically used with whole-building energy simulation programs, because the range of disagreement among quasi-analytical solutions is typically much narrower than the range of disagreement among simulation results that may be applying a variety of less rigorous modeling methods. This also allows quasi-analytical solutions to be developed for more realistic (less constrained) cases than exact analytical solutions allow. The methodology applies to both the development of the test cases as well as to implementation of the numerical models.

The work resulted in diagnosis of 24 software issues resulting in 19 improvements to 7 of the simulation models, including: EnergyPlus, ESP-r/BASESIMP, BASECALC, SUNREL-GC, TRNSYS-GC, VA114, and DIT's model executed within MATLAB. The detailed 3-D numerical-methods models of TRNSYS-GC, FLUENT, and MATLAB are able to produce results in agreement within 1% for the analytical solution case, and within 4% of each other for the remaining cases. These models provide a secondary numerical mathematical truth standard for the other cases, and enhance the ability to diagnose disagreements of the models integrated with whole-building simulations. Figure 6 shows an example of Project A final results for six of the test cases, depicting the analytical solution (magenta background, one case only), verified numerical model results (blue background), and other simulation results (white background).



**Ground-Coupled Floor Slab Sample Results, Floor Conduction. Establishing Numerical Methods Results as Quasi-Analytical Solution using Steady State Analytical Verification (GC10a) Benchmark.**

## **Project B: Multi-Zone and Airflow Comparative Tests**

### **Project B1: Non-Airflow Tests**

The IEA BESTEST cases have been extended to include an in-depth analytical verification test case for multi-zone conduction and in-depth comparative test cases for multi-zone shading and internal window models.

This project has resulted in diagnosis of 25 modeling issues related to conduction, shading, and internal windows, resulting in 25 improvements to 6 of the simulation programs including: CODYRUN, EnergyPlus, ESP-r, HTB-2, TRNSYS-TUD, and VAI14.

For the multi-zone conduction case, all but one of the tested simulation programs agree within 1% of the analytical solution. For the shading cases, results indicate the programs are properly accounting for multi-zone and building-self shading after a number of disagreements have been diagnosed and fixed and that shading models for both direct beam and diffuse radiation are working in a multi-zone context. The improved shading diagnostics for the revised cases allowed identification of software errors that have reduced ranges of disagreement to about one third of the disagreement range evident at the beginning of the project. For the internal window cases, agreement among results has also improved substantially as a result of model improvements during the project.

### **Project B2: Airflow Tests including Multi-Zone Airflow**

IEA BESTEST has been extended to include analytical verification test cases for airflow models, including tests for the effects of natural ventilation, buoyancy, wind driven, and temperature-difference driven flows, and the effects of mechanical fan driven flows.

## **Project C: Shading/Daylighting/Load Interaction Empirical Tests**

### **Project C1: EMPA Shading/Daylighting/Load Interaction**

Empirical validation test cases were developed to test models related to shading, daylighting and load interaction related to shading of solar gains.

This project has resulted in diagnosis of 14 modeling issues related to conduction, shading, and internal windows, resulting in 14 improvements to 5 of the simulation programs including: HELIOS XP, EnergyPlus, ESP-r, TRNSYS-TUD and IDA-ICE.

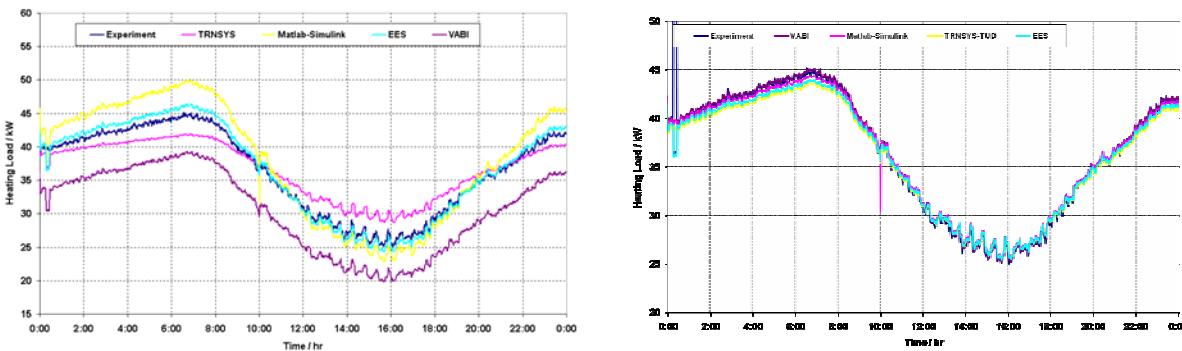
Overall uncertainty in various input parameters causes roughly  $\pm 3\%$  uncertainty in simulated cooling load results. Experimentally determined cooling loads have similar uncertainty. EnergyPlus simulations are within 95% credible limits of the empirical data and the propagated error for Experiment 7. It is therefore believed that the experiments are well suited for empirical validation.

### **Project C2: ERS Shading/Daylighting/Load Interaction**

Additional empirical validation test cases were developed to test models related to shading, daylighting and load interaction related to shading of solar gains. Simulation results were received from ISU/EMPA, US/Switzerland (EnergyPlus, DOE-2.1E). Conclusions are that overall predictions for daylighting performance were within acceptable ranges, and that uncertainty in the ERS – a real building – is greater than in a controlled laboratory experiment. This is a good exercise to see how accurate predictions can be for a real building.

## Project D: Mechanical Equipment and Controls Empirical Validation Tests

Empirical validation test cases were developed to test models related to hydronic mechanical system equipment and controls. Empirical data for both the hot-water and the chilled-water systems were obtained from several experiments conducted at the



**Results for predicted heating load and experimental data (averaged data); Blind test results (left) and Results after first iteration (right).**

ERS. After several iterations of test specification and model improvements, model agreement with experimental data has greatly improved as shown in the figure on the next page.

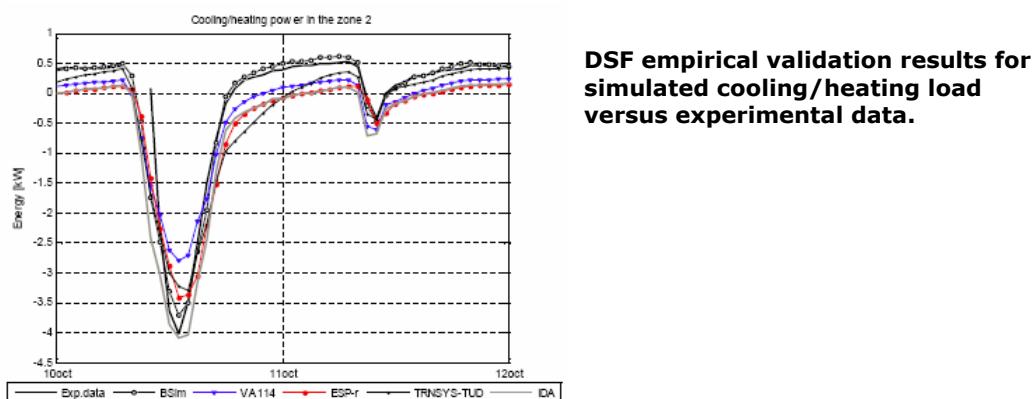
## Project E: Double-Facade Empirical Tests

### Project E1: Double-Skin Façade Buildings Literature Survey

Completion of a double-skin façade (DSF) building literature review final report covering: building energy consumption, thermal and visual comfort, acoustics, environmental impacts during construction and operation, application of new technologies, and modeling approaches and methods for DSF. The final report documents the study of several categories of double-skin building construction types; advantages and disadvantages of DSF; and modeling issues including airflow, thermal and daylighting simulations. The literature review found roughly 50 case studies.

### Project E2: Double-Facade Empirical Tests

Empirical validation test cases were developed to test models related for double-skin façade buildings.



### **Project E3: Double-Façade Comparative Tests**

Comparative test cases were developed to test models related for double-skin façade buildings.

### **Project G: Web Site for Consolidation of Tool Evaluation Tests (Leader: Operating Agent)**

Creation of a single location for obtaining all tool evaluation tests developed in IEA SHC Task 12 / ECBCS Annex 21, SHC Task 22, and SHC Task 34 / ECBCS Annex 43, including a note identifying IEA procedures that have been adapted into ANSI/ASHRAE Standard 140, and a link to the Standard-140 web page.

## **ACTIVITIES DURING 2007**

A summary of Subtask research and codes & standards activities completed is presented below.

Activities during 2007 consisted of finalizing test specifications, acquiring empirical test data, finishing simulations of test cases, and submittal of final reports for approval by the SHC and ECBCS Executive Committees.

### **Project A: Ground Coupled Floor Slab and Basement Comparative Tests**

Full sets of field-trial simulations were completed using: EnergyPlus (GARD Analytics, US), TRNSYS (TESS, US), VA114 using ISO 13370 calculation (VABI, Netherlands), ESP-r/Basesimp (NRCan, Canada) [only running “c”-series cases], Basecalc (NRCan, Canada) [only running “c”-series cases], FLUENT (PAAET, Kuwait), SUNREL-GC/GHT (NREL, US), MATLAB (DIT, Ireland). The draft final report was approved by the experts at the Glasgow Meeting (October 2007).

### **Project B: Multi-Zone and Airflow Comparative Tests**

#### **Project B1: Non-Airflow Tests**

Field-trial simulations were completed by 9 participants (submitting participant in parenthesis) using: CODYRUN (U. Reunion Island, France), COMFIE (Ecole des Mines de Paris, France), EnergyPlus (GARD, US), ESP-r (U. Strathclyde, UK), KoZiBu (JNLOG, France), HTB2 (Cardiff U., UK), TRNSYS-TUD (Dresden U. of Technology, Germany), TRNSYS 16 (University of Liege, Belgium), VA114 (VABI Software, The Netherlands).

#### **Project B2: Airflow Tests including Multi-Zone Airflow**

The test specification was modified according to comments from the March 2007 experts meeting. So far there are six calculated results from TUD (TRNSYS-TUD), Sumitomo-Mitsui Construction Co., Ltd., (VentSim), Welsh School of Architecture, (HTB2), Ashikaga Institute of Technology and Imagic Design, (COMIS3.2), University of Strathclyde (ESP-r), and University of Reunion (CODYRUN). In order to compare the results to the analytical solution, two analytical solutions are developed by Imagic Design Co. and INCT. Comparison of the results of two analytical solutions for each of the test cases indicates a maximum difference of 2.7% for the combination of wind and temperature driven flows; flows driven by wind only show exactly the same mass airflows.

### **Project C: Shading/Daylighting/Load Interaction Empirical Tests**

The final report was completed, and fully approved by both the Experts and the Executive Committee review teams. The final report, including test procedures and accompanying data files for combined EMPA/ERS works, was posted on the SHC web site, October 2007.

### **Project D: Mechanical Equipment and Controls Empirical Validation Tests**

Test specifications, empirical data collection and simulation results were completed. Simulation results were obtained using TRNSYS-TUD (TUD), MATLAB/Simulink (TUD), EES (U. Liege), VA114 (VABI Software), and EnergyPlus (Gard Analytics). Final report production is in progress.

### **Project E: Double-Facade Empirical Tests**

#### **Project E1: Double-Skin Façade Buildings Literature Survey**

The literature review final report was fully approved by both the Experts and the Executive Committee review teams, and was posted on the SHC web site, July 2007.

#### **Project E2: Double-Façade Empirical Tests**

Aalborg University experienced a 9-month construction delay on their test facility, which has caused this sub-project to run late. Empirical data collection for the project is complete. For DSF100\_e and DSF200\_e test case specifications have been provided to modelers. First-round results from all modelers have been compared to measurement results and were discussed at the October 2007 experts meeting. The measurement results for test case DSF400\_e are also available. Simulation results were obtained using BSim (Aalborg U., Denmark), ESP-r (U. Strathclyde, UK), IDA (Lund U., Sweden), TRNSYS-TUD (TUD, Germany), and VA114 (VABI, Netherlands).

#### **Project E3: Double-Façade Comparative Tests**

Test specifications for all cases have been provided. Simulation results for the comparative tests were received for BSim (Aalborg U., Denmark), VA114 (VABI, Netherlands) and TRNSYS-TUD (TUD, Germany). An initial draft final report was prepared for project participant review.

### **Project G: Web Site for Consolidation of Tool Evaluation Tests (Leader: Operating Agent)**

No activity for this project yet. This project to be completed at the joint ExCo meeting in June 2008.

## **WORK PLANNED FOR 2008**

### **Project A: Ground Coupled Floor Slab and Basement Comparative Tests**

Obtain ExCo approval of final report. Posting of final report, including test procedures and accompanying data, on web site Prepare project presentation for joint ExCo meeting, June 2008, Graz, Austria.

## **Project B: Multi-Zone and Airflow Comparative Tests**

### **Project B1: Non-Airflow Tests**

Finalize simulation results. Complete the draft final report, and submit it to project participants for comments and approval. Submit participant-approved final report to SHC and ECBCS review committees for approval. Post the final report including test procedures and accompanying data files on web site. Prepare project presentation for joint ExCo meeting, June 2008, Graz, Austria.

### **Project B2: Airflow Tests including Multi-Zone Airflow**

Finalization of test specification and results. Completion and approval of final report. Posting of final report including test procedures and accompanying data files on web site. Prepare project presentation for joint ExCo meeting, June 2008, Graz, Austria.

## **Project C: Shading/Daylighting/Load Interaction Empirical Tests**

Prepare project presentation for joint ExCo meeting, June 2008, Graz, Austria.

## **Project D: Mechanical Equipment and Controls Empirical Validation Tests**

Finish final report, to address comments from the project participants, and obtain required IEA approvals. Post the final report including test procedures and accompanying data files on web site. Project leader to prepare project presentation for joint ExCo meeting, June 2008, Graz, Austria.

## **Project E: Double-Facade Empirical Tests**

### **Project E1: Double-Skin Façade Buildings Literature Survey**

Prepare project presentation for joint ExCo meeting, June 2008, Graz, Austria.

### **Project E2: Double-Façade Empirical Tests**

Aalborg University experienced a 9-month construction delay on their test facility, which has caused this sub-project to run late. AAU will distribute updates of the optical properties of the glazing systems in the DSF. AAU will also distribute the details and conditions for running the intermediate steady state case, the task experts will run their simulations and send the results to AAU. AAU will summarize the results and distribute it to task experts by 14th of November 2007. Modelers will adjust their models and send the final results of simulations to AAU by January 1, 2008. AAU will process the results and distribute them by January 10, 2007.

AAU will prepare the final draft of the empirical test case report and distribute it for the review by February 15, 2008. Final draft is to be reviewed and comments will be sent to AAU by March 1, 2008. AAU will revise the report and submit it for the final approval by March 15, 2008. After experts' approval, report will be sent to Executive Committees for final approval about May 1. Posting of the final report on the SHC web site is expected soon after ExCo approval. Project leader to prepare project presentation for joint ExCo meeting, June 2008, Graz, Austria.

### **Project E3: Double-Façade Comparative Tests**

Comparative test case report is to be reviewed by modelers by November 15, 2007. AAU

will revise the report according to comments. Final comparative report will be distributed for the review by February 15, 2008. Project leader to prepare project presentation for joint ExCo meeting, June 2008, Graz, Austria.

### **Project G: Web Site for Consolidation of Tool Evaluation Tests (Leader: Operating Agent**

At the upcoming joint SHC/ECBCS meeting (June 2008, Graz, Austria), the Operating Agent will work with SHC and ECBCS Web Coordinators to develop the new web site, and explore adding a primary menu listing on both website cover pages labeled “Software Tests”.

Currently test procedures are posted or listed at:

- IEA SHC Task 22 website [www.iea-shc.org/task22/deliverables.htm](http://www.iea-shc.org/task22/deliverables.htm),
- SHC Task 12 website <http://www.iea-shc.org/publications/category.aspx?CategoryID=17> [also include “Task12-Lomas-et-al-Part4.zip”, which was not previously posted],
- ECBCS Annex 21 website [www.ecbcs.org/annexes/annex21.htm](http://www.ecbcs.org/annexes/annex21.htm), and
- SHC Task 34 website [www.iea-shc.org/task34/publications/index.html](http://www.iea-shc.org/task34/publications/index.html).

We will consolidate (with links) PDF reports and accompanying data files containing procedures currently listed at the Task 22 and Task 12 websites with the new procedures to come from IEA 34/43. Task 12, Task 22 and 34/43 reports that do not include test procedures (e.g., methodology studies, literature surveys, etc.) will not be included with the consolidated “Software Tests” page.

#### **Other (Operating Agent [US/NREL])**

Continue work outside the scope of this Task related to bringing evaluation test procedures developed under IEA research into codes and standards (normes). See below under “Links With Industry”, subheading “Codes and Standards Activities”.

## **LINKS WITH INDUSTRY**

The primary audiences for the IEA tool evaluation research are building energy analysis tool authors and national and international building energy standard (norme) making organizations. Activities of SHC/ECBCS Task 34/Annex 43 and previous related SHC Task 22 and SHC/ECBCS Task 12/Annex 21 research are linked to the needs and recommendations of the world's leading building energy analysis tool developers. For example, a recent study comparing 20 whole building energy simulation tools indicates that 19 of the 20 tools reviewed had been tested with at least one of the IEA BESTEST procedures; 10 of the tools had been tested with more than one of the BESTEST procedures. The study also indicates that test procedures developed by the IEA dominate the set of available tests.

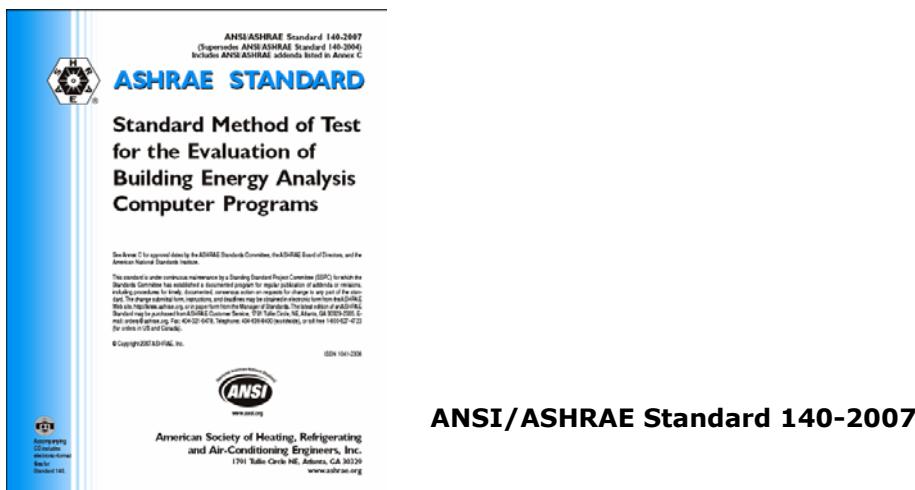
Industry links for this work are well founded. Activities related to the propagation and adoption of the IEA BESTEST procedures, described below, include codes and standards activities, non-English language translations of test procedures, publication of papers and news articles, and so forth.

## Codes and Standards Activities

A key audience for the research undertaken within this Task is national and international building energy standards organizations. These organizations can use the test cases developed in this task, along with those developed in previous IEA tasks, to create standard methods of tests for building energy analysis tools used for national building energy code compliance.

The American National Standards Institute (ANSI) and the American Society of Heating, Refrigeration, and Air Conditioning (ASHRAE) continue to adopt SHC work into their standards. **ANSI/ASHRAE Standard 140-2007** includes adaptations of earlier SHC work (posted at <http://www.iea-shc.org/task22/index.html>):

- **IEA Building Energy Simulation Test and Diagnostic Method (BESTEST)** – building thermal fabric comparative tests, developed by National Renewable Energy Laboratory (NREL), US, in joint *SHC/ECBCS Task 12/Annex 21, Solar Building Analysis Tools*
- **HVAC BESTEST Volume 1** – unitary cooling equipment analytical verification tests, developed by NREL in *SHC Task 22, Building Energy Analysis Tools*
- **Fuel-Fired Furnace BESTEST** – analytical verification tests, developed by Natural Resources Canada in *SHC Task 22*
- **HVAC BESTEST Volume 2** – unitary cooling equipment comparative tests, developed by NREL in *SHC Task 22*.



There is a several year time lag between development of new test suites and their incorporation into ASHRAE standards because of the ANSI/ASHRAE consensus standards process.

Future revisions of Standard 140 will consider adaptation of additional test suites, including those recently developed under joint *SHC/ECBCS Task 34/Annex 43, Testing and Validation of Building Energy Simulation Tools*.

Standard 140 will add HERS BESTEST next. HERS BESTEST, which is conceptually based on the IEA BESTEST building thermal fabric test cases, was developed by NREL in collaboration

with the U.S. HERS Council for testing simplified models commonly used with residential analysis and Home Energy Rating Systems. The Operating Agent has been acting as liaison with, and is the Chair of, ASHRAE SSPC 140 (the ASHRAE project committee responsible for ANSI/ASHRAE Standard 140). We anticipate that other work from IEA SHC Task 34/ ECBCS Annex 43, IEA SHC Task 22, ASHRAE, and elsewhere will be considered for addition to Standard 140 in the future.

Standard 140 and/or the reports that comprise the test suites contained therein are being referenced and used by a growing number of code promulgation authorities throughout the world. ASHRAE Standard 90.1-2004, which is used for regulating energy efficiency in commercial and non-low-rise residential buildings requires use of Standard 140-2004 for testing software used in building energy efficiency assessments. Software used for calculating energy savings for purposes of the energy-efficient commercial building tax deductions in the U.S. must be tested with Standard 140. The International Energy Conservation Code is also referencing Standard 140. These citations are important because they mandate software evaluation using test procedures developed under IEA research activities. For example, because of the ASHRAE Standard 90.1 requirement to test software using ASHRAE Standard 140, two of the largest suppliers of building HVAC equipment in the world, Carrier and Trane Corporations, regularly test their respective software packages HAP and TRACE with Standard 140. Also, EnergyPlus, the USDOE's most advanced simulation program for building energy analysis, maintains their Standard 140 validation results on their website.

The Netherlands (TNO) has developed their Energy Diagnosis Reference (EDR) based on BESTEST. TNO has developed the EDR to satisfy the European Performance Directive (EPD) of the European Union. The EPD emphasizes performance-based standards and requires certification of software used to show compliance with energy performance standards (normes). Portugal is also using BESTEST as their basis for software quality control under the EPD. As part of their building energy performance assessments under the EPD, Austria, Denmark, Greece and The Netherlands are using a new software tool that includes algorithms that have been checked with BESTEST. Also, CEN has utilized BESTEST to check their reference cooling load calculation general criteria of prEN ISO 13791 and simplified methods of prEN ISO 13792. Elsewhere, IEA BESTEST has been referenced in codes and standards in Australia and New Zealand. Furthermore, NREL's overall validation methodological framework has been included in the 2005 ASHRAE *Handbook of Fundamentals*. As a result of these and other activities, many major software providers worldwide are using BESTEST and ASHRAE Standard 140.

The UK's Chartered Institute of Building Services Engineers (CIBSE) is compiling tests (CIBSE TM33) for software accreditation and verification. The tests address "a need for UK regulators to have a mechanism for the technical accreditation of detailed thermal models as part of their formal approval for use in the [UK] National Calculation Methodology." CIBSE notes that the TM33 tests are primarily meant to instill confidence in users rather than to provide comprehensive validation of a program. For those intending more detailed program validation, CIBSE TM33 cites tests and benchmarks available from ASHRAE Standard 140, IEA, ASHRAE Research, and CEN. For example, papers recently published by U. Strathclyde, UK, describe how many of the BESTEST suites have been directly integrated within ESP-r for automated testing of revisions to the software.

## **Non-English Language Translations of IEA BESTEST**

The popularity and utility of the BESTEST procedures developed within various SHC Tasks is also evident from language translations undertaken within various countries using their own resources, including translations into Japanese, Dutch and German. Japan distributed a recently completed Japanese-language translation of HVAC BESTEST Volume 1 (NREL/SHC Task 22). This translation and an earlier translation of IEA BESTEST (NREL/SHC Task 12/ECBCS Annex 21) have been distributed to over 30 researchers and engineers in Japan. Several Japanese papers have already been published that refer to these BESTEST translations. Translations of HVAC BESTEST Volume 2 (NREL/SHC Task 22) and Fuel-Fired Furnace BESTEST (NRCan/SHC Task 22) into Japanese are planned for the future. The Netherlands (TNO) has developed their Energy Diagnosis Reference (EDR) based on the IEA BESTEST building thermal fabric test suite, which was revised for Netherlands-specific buildings, and is written in Dutch. A journal article on HVAC BESTEST Volume 1 was translated into German and published in a German HVAC engineering journal.

## **Conference Papers and News Articles**

Within the 2006 ESim conference proceedings, 5 of 32 papers cite BESTEST. Additional papers by software developers related to use of SHC Task 22 and SHC Task 12 test procedures have appeared regularly at ASHRAE meetings in the US. A number of papers previewing the work of Task 34 have already been published or are in progress. Conferences and meetings in 2006 and 2007 where the work of Task 34 was presented include TRNSYS User Day, organized by TRANSSOLAR in Stuttgart, Germany; the EPIC2006AIVC Conference in Lyon, France; the ASHRAE summer meeting in Quebec City, Canada; and the IAQVEC 2007 Conference in Sendai, Japan. For the future, the scientific committee for Building Simulation 2009 (IBPSA's bi-annual international conference to be held July 27-29, 2009 in Glasgow, UK) has invited a session on the IEA-34/43 work.

The Operating Agent has written regular news articles in the ECBCS Newsletter and SHC Solar Update to publicize SHC Task 34/ECBCS Annex 43 reports as they are published, and to provide updates on codes and standards activities related to this work. Additionally, the ECBCS Executive Secretary, with input from the Task 34 Operating Agent, is writing an article on the early ECBCS Annex I connection to BESTEST and Standard Methods of Test including Standard 140, ISO CEN tests, etc.

## **Other Activities**

The Operating Agent (Ron Judkoff) has written a proposal for dual collaborations among Denmark and the U.S. and Germany and the U.S. to continue the DSF and Mechanical Equipment model validation work under bilateral research agreements in the process of being established.

A Noteworthy Quote from a Participant/Software Developer Jeff Thornton, President of Thermal Energy System Specialists (TESS), Madison, Wisconsin, U.S. – a private-sector company that develops and sells TRNSYS and does consulting work using TRNSYS – published the following comment in his modeler report for Project A:

*“Without this IEA Subtask for ground coupling, we would have had no means to check the results from our model, nor had a reason to make improvements to our model. There should be no question that the IEA Subtask has improved the TRNSYS ground coupling model and, in doing so, has also provided energy modelers a greatly increased sense of confidence when modeling heat transfer to the ground.”*

## **REPORTS PUBLISHED IN 2007**

These are posted at <http://www.iea-shc.org/task34/publications/index.html>

- H Poirazis. (2006). *Double Skin Facades, A Literature Review*. Lund, Sweden: Department of Architecture and Built Environment, Division of Energy and Building Design, Lund University, Lund Institute of Technology.
- P. Loutzenhiser, H. Manz, G. Maxwell. (2007). *Empirical Validation of Shading/Daylighting/Load Interactions in Building Energy Simulation Tools*. Dubendorf, Switzerland: Swiss Federal Laboratories for Materials Testing and Research. Ankeny, Iowa: Iowa Energy Center.

## **REPORTS PLANNED FOR 2008**

- Slab-on-grade ground coupled heat transfer analytical verification and comparatives tests: test specification and results
- Multi-zone non-airflow analytical verification and comparative tests: test specification and results
- Airflow analytical verification and comparative tests: test specification and results
- Chilled water and hot water mechanical equipment and control comparative and empirical validation tests: test procedures, test apparatus specifications, empirical data sets, and simulation results.
- Double-skin buildings:
  - Comparative tests: test specification and results
  - Empirical Validation tests: test procedures, test cell specifications, empirical data sets, and simulation results.

## TASK 34 NATIONAL CONTACTS

### **Operating Agent**

Ron Judkoff  
National Renewable Energy Laboratory  
1617 Cole Boulevard  
Golden, Colorado 80401  
United States

### **Australia**

Angelo Delsante  
CSIRO Manufacturing & Infrastructure  
Technology  
PO Box 56, Highett. Vic. 3190

### **Belgium**

Jean Lebrun, Vincent Lemort  
University of Liege  
Thermodynamics Laboratory  
Building B49  
B4000 Liege

Phillipe Andre  
University of Liege  
Department of Environmental  
Management and Science  
Avenue de Longwy, 185  
B-6800 Arlon

### **Canada**

Hajo Ribberink, Ian Beausoleil-Morrison  
CANMET Energy Technology Centre  
Natural Resources Canada  
580 Booth Street, 13<sup>th</sup> Floor  
Ottawa, Ontario K1A 0E4

### **Denmark**

Per Heiselberg, Olena Kalyanova  
Aalborg University  
Hybrid Ventilation Centre  
Sohngaardshdmsvej 57  
9000 Aalborg

### **France**

Peter Riederer  
Centre Scientifique et Technique du  
Bâtiment  
CSTB - DDD/AGE  
84 Avenue Jean Jaurès, B.P. 2  
77447 Marne la Vallée cedex 02

Harry Boyer, Frederic Maranville  
Civil Engineering and Building Physics  
research Team  
University of Technology  
40, avenue de Soweto  
97410 Saint-Pierre

Bruno Peuportier  
Centre d'Energetique,  
Ecole des Mines de Paris  
60, Bd St Michel 75272 Paris cedex 06

Jean NOEL  
CETHIL - ETB  
INSA de Lyon - Bât. Freyssinet  
40 avenue des Arts  
F-69100 Villeurbanne  
France

### **Germany**

Clemens Felsmann  
Technische Universität Dresden  
Institut für Thermodynamik und Techn.  
Gebäudequusrüstung  
Helmholtzstr. 14  
01062 Dresden

Hans Erhorn  
Fraunhofer-Institut für Bauphysik  
Nobelstr. 12  
D-70569 Stuttgart

Herbert Sinnesbichler, Erwin Lindauer,  
Ingo Heusler  
Fraunhofer-Institut für Bauphysik  
Postfach 1152  
D-83601 Holzkirchen  
Fraunhoferstrasse 10

### **Ireland**

Michael Crowley  
Department of Building Sciences and  
Engineering  
Dublin Institute of Technology  
D.I.T, Bolton Street  
Dublin

**Japan**

Yasuo Utsumi  
Department of Architecture  
Institutes of National Colleges of  
Technology  
Natori, Miyagi, 981-1239

Teruaki Mitamura  
Ashikaga Institute of Technology  
268-1 Omae-Cho, Ashikaga City, Tochigi,  
326-8558

Yukiko Yoshida  
National Institute of Environment Studies  
16-2 Onogawa  
Tsakuba, Ibaraki

**Netherlands**

Aad Wijsman  
VABI Software  
Kleveringweg 12  
2616 LZ Delft  
P.O. Box 29 2600 AA Delft

**Sweden**

Harris Poirazis, Ake Blomsterberg, Maria  
Wall,  
EBD, LTH  
Lund University  
P.O. Box 118  
SE-221 00 Lund

**Switzerland**

Heinrich Manz, Thomas Frank, Peter  
Loutzenhiser  
EMPA  
Laboratory for Applied Physics in  
Buildings  
Uberlandstr. 129  
CH-8600 Duebendorf

Gerhard Zweifel  
Hochschule Technik + Architektur Luzern  
Abt. HLK  
CH-6048 Horw

**United Kingdom**

Donald Alexander  
Welsh School of Architecture  
Cardiff University  
Cardiff, Wales

Paul Strachan  
ESRU, Dept. of Mechanical Eng  
University of Strathclyde  
Glasgow G1 1XJ, Scotland

**United States**

Joel Neymark  
J. Neymark & Associates  
3000 Youngfield St., #163  
Lakewood, Colorado 80215

Gregory Maxwell, Som Shrestha  
Mechanical Engineering Department  
Iowa State University  
2025 Black Engineering Building  
Ames, Iowa 50011

Curtis J. Klaassen  
IEC Energy Resource Station  
DMACC, Building 23  
2006 S. Ankeny Boulevard  
Ankeny, Iowa 50021

Jeff Thornton, Tim McDowell  
Thermal Energy Systems Specialist  
2916 Marketplace Drive, Suite 104  
Madison, Wisconsin 53719

Mike Witte, Robert Henninger  
GARD Analytics  
1028 Busse Highway  
Park Ridge, Illinois 60068-1802

Michael Deru  
National Renewable Energy Laboratory  
1617 Cole Boulevard  
Golden, Colorado 80401

## **TASK 35: PV/THERMAL SOLAR SYSTEMS**

*Mr. Henrik Sørenson  
Esbensen Consulting Engineers Ltd.  
Operating Agent for the Danish Energy Authority*

### **TASK DESCRIPTION**

PV/Thermal Solar Systems combine photovoltaic technologies and solar thermal technologies into one system with both electricity and thermal energy output. The typical systems are solar collectors with photovoltaic systems integrated in the collector-surface or photovoltaic panels used as collector directly as solar air collector. Through combined production of electricity and heat, the overall efficiency can potentially be higher for a specific collector-area, than the efficiency of traditional "side-by-side" photovoltaic and solar thermal systems. The systems are typically integrated in the built environment.

The EU has set targets for 2010 of 100 million m<sup>2</sup> for solar thermal (corresponding to 70 GW<sub>p</sub> thermal) and 3 GW<sub>p</sub> for PV. The markets for both solar thermal and PV are growing rapidly globally, and PV/T has the potential to experience a similar growth since the technical potential of the technology is large, especially if the market for domestic applications can be reached. However, very few commercial PV/T manufacturers exist.

The objectives of Task 35 *PV/Thermal Solar Systems* are to catalyse the development and market introduction of high quality and commercial competitive PV/Thermal Solar Systems and to increase general understanding and contribute to internationally accepted standards on performance, testing, monitoring and commercial characteristics of PV/Thermal Solar Systems in the building sector.

The Task is organised in five subtasks, each focusing on the key issues identified being important to meet the overall objective of the Task.

- Subtask A: Market and Commercialisation of PV/T
- Subtask B: Energy Analysis and Modelling
- Subtask C: Product and System Development, Tests and Evaluation
- Subtask D: Demonstration Projects
- Subtask E: Dissemination

### **COLLABORATION WITH OTHER IEA PROGRAMMES**

It has been agreed to collaborate with the Photovoltaic Power Systems Programme at a "minimal level" according to the SHC guidelines for coordination with other programmes. The Task is fully defined and managed by ExCo SHC with appropriate input from ExCo PVPS. National experts can be assigned to participate in the Task from both IEA SHC and IEA PVPS Executive Committee members or the participants can be accepted by sponsors of either of the two programmes.

## **Duration**

The Task was initiated on January 1, 2005 and will be completed in the course of 2008.

## **ACTIVITIES DURING 2007**

The 5<sup>th</sup> Task meeting was organised as a 3-day meeting and hosted by the University of Padova, Vicenza in Italy, 12-14 March 2007 with participation of 7 experts from Canada, Denmark, Israel, Italy, The Netherlands, and Sweden. Three PV/T collectors were tested here and the meeting in Italy was a good opportunity for the group to see the test stand and discuss various issues related to testing.

The Task meeting in Italy had intensive media coverage. The regional newspaper “Il Gazzettino” interviewed the Italian hosts and an article was published the following day. Furthermore the local TV channel “Canale 68” and the TV channel “Antenna 3” covering a larger area also filmed some of the meeting and interviewed the Italian hosts.

In October 2007, a web- and telephone meeting was held. The aim of the meeting was to discuss a possible extension of the Task duration period, to give a status for the work and deliverables and discuss and co-ordinate relevant issues.

During this period was necessary to cancel, reduce or change some of the originally planned deliverables and activities.

### **Subtask A: Market and Commercialization of PV/T**

About 65 market survey interviews of architects and solar dealers have been conducted in Canada, Denmark, Germany, Italy, Spain, Sweden, and the USA to obtain information from the market place about which things will affect or influence the purchase design, supply and installation of future PV/T projects.

An article under preparation for the magazine Sun & Wind Energy will present the analysis of the market survey interviews. The main conclusion of the survey is that both architects and solar companies are very interested in PV/T (e.g., for generating publicity and additional business). Opportunities for PV/T are generated by the limited roof space available, possible cost reduction (e.g., due to lower installation costs), building integration, and the fact that a PV/T system has a more uniform appearance than a side-by-side system.

A PDF file with an overview of commercially available PV/T collectors is available on the Task website.

Some work has been done internally to get an overview of the differences in grants and grants in various countries for PV and solar thermal systems.

### **Subtask B – Energy Analysis and Modeling**

A draft report on PV/T, PV, and Solar Thermal Models was completed. The report describes the available simulation models, TRNSYS components and theoretical models.

Work was done on modifications for existing TRNSYS models for Water/Air PV/T collectors (type 50d) and Concentrating PV/T collectors (type 50h). A new model for a transpired air PV/T collector is about to be completed—a prototype has been built and tested, and comparison to the model is in progress. The PV/T collector models that can be completed in time will be compiled into a standard downloadable package of models for researchers.

Originally, it was expected that the Task would use the models for a standard downloadable package(s) or simulation program(s) for non-researchers based on TRNSED. However, another approach will be used here.

Development of a standardized method for characterization and monitoring of PV/T-modules is on-going and a report on the work will be completed in 2008. This deals with a method by which the thermal and electrical output of PV/Thermal collectors can be quantified. Three ways of rating are being proposed as mentioned below. The first rating scheme is very detailed and complex, but there is a decrease in detail and complexity as one goes down in the list:

- “design rating scheme”
- “technical rating scheme”
- “marketing scheme”

The development of control strategies needed for PV/Thermal Systems was discussed, but due to time and resource limitations an investigation of control strategies will not be made.



**Figure 1. PV/T test stand at the University of Padova in Italy.**

### **Subtask C: Product and System Development, Test and Evaluation**

An MS Excel spreadsheet with an overview of PV/T components and projects has been completed and is available on the Task web site.

Flat plate glazed liquid PV/T collectors from the Dutch manufacturer PVTWINS, previously tested at the Danish Technological Institute, and a prototype, COGEN, from Ecosolar

Engineering, DTG in Italy have been tested at the University of Padova in Italy together with a unglazed liquid/air PV/T collector, MSS from Millennium Electric, Israel (see Figure 1).

Testing of a transpired air PV/T collector from Conserval Engineering, Canada, previously tested at the National Solar Test Facility in Canada, was performed at the Danish Technological Institute (see Figure 2).



**Figure 2. Front and back view of two SolarWall® PV/T transpired air collectors, one thermal reference and one PV reference in the test stand at the Danish Technological Institute .**

Testing of other categories of PV/T collectors have been carried out at Lund University in Sweden.

Different test methodologies based on the experiences from the participating laboratories and the PV Catapult deliverable D8-6: *PVT performance measurement guidelines* have been used. The aim of the activities is to achieve a much better understanding of the performance of already existing systems and to suggest standard methods for testing the characteristics and durability of PV/T collectors.

Regarding investigation of the need for development for PV/T components, industry, manufacturers, and designers have been asked and an overview of the R&D needs is being formulated.

#### **Subtask D: Demonstration Projects**

A combined report with experiences from interviews of stakeholders for realized PV/T systems and information on installed PV/T systems and monitoring is under preparation.

With regards to identifying potential new PV/T demonstration projects there have been enquiries from persons in different countries. However, it has not been feasible to offer help for planning, design and hosting of PV/T demonstration projects directly within the framework of Task 35. Individuals interested in realizing a PV/T system have been referred to manufacturers of PV/T collectors.

### **Subtask E: Dissemination**

A Task 35 flyer is available on the Task web site, and 1,300 copies were sent to all the Task 35 contributors for further distribution.

A paper, "Market, modeling, testing and demonstration in the framework of IEA SHC Task 35 on PV/Thermal Solar Systems", describing the aims and organization of Task 35, the PV/T technology and some preliminary results of the Task was presented at the 22<sup>nd</sup> European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC) in Milan, Italy on 3-7 September 2007.

The internal Task web site is a key tool in the Task work. All documents produced within the Task and all communication within the Task 35 project group is uploaded here to facilitate dialogue between the Task experts and to provide a hub for information exchange on PV/Thermal Solar Systems.

The public Task web site <http://www.iea-shc.org/task35> is continuously being updated to give access to Task results and information related to PV/T,

## **WORK PLANNED FOR 2008**

The work in 2008 will focus on completing the key deliverables.

### **Subtask A: Market and Commercialization of PV/T**

A market article on PV/T is under preparation and will be published in the magazine Sun & Wind Energy.

### **Subtask B: Energy Analysis and Modeling**

The available PV/T collector models will be compiled into a standard downloadable package of TRNSYS models for researchers. It is the expectation to complete a simulation program for PV/Thermal solar systems that can be used in both a simple version and a more detailed version.

### **Subtask E: Dissemination**

In the end of the Task period a Task brochure describing the aims and organisation of Task 35, the PV/T technology, and the final Task results will be made.

## **LINKS WITH INDUSTRY**

Manufacturers of PV/T components have joined meetings and been active in the performance of work.

## **REPORTS PUBLISHED IN 2007**

No reports were published in 2007, but a number of documents and papers were made available on the Task web site.

## **REPORTS PLANNED FOR 2008**

- DB1: Report on heat transfer and electric performance models in PV/Thermal Solar systems (*Title could be changed*)
- DB2: Report on recommended standard for characterisation and monitoring of PV/Thermal Solar systems. (*Title could be changed*)
- DC4: Tests of PV/T collectors and a suggestion for a method for performance measurements of PV/T collectors. (*Title could be changed*)
- DD2/DD3: Realized PV/T installations – experiences and monitoring results.

## **MEETINGS IN 2007**

### **Telephone meeting**

17 January 2007

### **5<sup>th</sup> Task expert meeting**

12-14 March 2007

University of Padova, Vicenza, Italy

### **Web- and telephone meeting**

5 October 2007

## **MEETINGS PLANNED FOR 2008**

No meetings are planned for 2008

## TASK 35 NATIONAL CONTACTS

### Operating Agent

Henrik Sørensen  
Esbensen Consulting Engineers Ltd.  
Carl Jacobsens Vej 25 D  
DK-2500 Valby, Denmark  
[h.soerensen@esbensen.dk](mailto:h.soerensen@esbensen.dk)

### Project Manager

Jan Hansen  
Esbensen Consulting Engineers Ltd.  
Carl Jacobsens Vej 25 D  
DK-2500 Valby, Denmark  
[j.hansen@esbensen.dk](mailto:j.hansen@esbensen.dk)

### Canada

Michael R. Collins  
University of Waterloo  
200 University Ave West Waterloo  
Ontario N2L 3G1  
[mcollins@mecheng1.uwaterloo.ca](mailto:mcollins@mecheng1.uwaterloo.ca)

John Hollick  
Conserval Engineering Inc  
200 Wildcat Road  
Toronto, Ontario  
[jhollick@solarwall.com](mailto:jhollick@solarwall.com)

### Denmark

Ivan Katic  
Danish Technological Institute  
Gregersensvej  
Postboks 141  
DK-2630 Taastrup  
[Ivan.Katic@teknologisk.dk](mailto:Ivan.Katic@teknologisk.dk)

### Hong Kong

T.T. Chow  
City University of Hong Kong  
Tat Chee Avenue  
Kowloon  
[bsttchow@cityu.edu.hk](mailto:bsttchow@cityu.edu.hk)

### Israel

Ami Elazari, Harel Nahmani  
Millennium Electric T.O.U. Ltd.  
8 Abba Eban Blvd.  
P.O. Box 12346 Herzelia Industrial Zone,  
46733  
[ami@millenniumsolar.com](mailto:ami@millenniumsolar.com)  
[solor@netvision.net.il](mailto:solor@netvision.net.il)  
[harel@millenniumsolar.com](mailto:harel@millenniumsolar.com)

### Netherlands

Herbert Zondag, Wim Van Helden, Marco  
Bakker  
ECN - Energy research Centre of the  
Netherlands  
P.O. Box 1  
1755 ZG PETTEN  
[zondag@ecn.nl](mailto:zondag@ecn.nl)  
[vanhelden@ecn.nl](mailto:vanhelden@ecn.nl)  
[m.bakker@ecn.nl](mailto:m.bakker@ecn.nl)

Marcel Elswijk  
PVTWINS  
P.O. Box 9308  
1800 GH Alkmaar  
[info@pvtwins.nl](mailto:info@pvtwins.nl)

### Sweden

Björn Karlsson, Bengt Perers  
Lund University  
Div. Energy and Building Design  
P.O. Box 118  
221 00 Lund  
[Bjorn.Karlsson@ebd.lth.se](mailto:Bjorn.Karlsson@ebd.lth.se)  
[Bengt.Perers@ebd.lth.se](mailto:Bengt.Perers@ebd.lth.se)

Joakim Byström  
Arontis Solar Concentrator AB  
Östanväcksgatan 16  
SE-871 31 Hägnösand  
[joakim@logosol.s](mailto:joakim@logosol.s)

**Thailand**

Thipjak Nualboonrueng

Institute of Solar Energy Technology

Development (ISET)

National Science and Technology

Development Agency (NSTDA)

111 Thailand Science Park

Paholyothin Rd.,

Klong 1, Klong Luang

Patumthani 12120

[thipjak@nstda.or.th](mailto:thipjak@nstda.or.th)

## **TASK 36: SOLAR RESOURCE KNOWLEDGE MANAGEMENT**

Dr. Dave Renné

National Renewable Energy Laboratory

Operating Agent for U.S. Department of Energy

### **TASK DESCRIPTION**

#### **Goal and Objectives**

The goal of SHC Task 36 "Solar Resource Knowledge Management" is to provide the solar energy industry, the electricity sector, governments, researchers, and renewable energy organizations and institutions with the most suitable and accurate information of the solar radiation resources at the Earth's surface in easily-accessible formats and understandable quality metrics. The scope of solar resource assessment information includes historic data sets and currently derived data products using satellite imagery and other means.

There are three main objectives of this Task to achieve this goal:

- To provide further standardization and benchmarking of international solar resource data sets to insure worldwide intercomparability and acceptance
- To provide improved data reliability, availability and accessibility in formats that address specific user needs, and
- To develop methods that improve the quality and the spatial and temporal coverage of solar resource products, including reliable solar radiation forecasts.

Achieving these objectives would reduce the cost of planning and deploying solar energy systems, improve efficiency of solar energy systems by more accurate and complete solar resource information, and increase the value of the solar energy produced by solar systems.

#### **Scope of the Task**

This Task focuses on the development, validation, and access to solar resource information derived from surface-based and satellite-based platforms. The Task will investigate benchmarking and data quality assessment procedures for data products and validation data sets, examine means by which the data can be made easily available to users through various web-based hosting schemes, and conduct studies on improving the input data sets and algorithms from which satellite-derived products are produced, including the investigation of short term forecasting and past and future climatic variability of the solar resource.

The audience for the results of the Task 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.

#### **Means**

Task 36 participants are addressing the objectives through sharing a co-coordinated work

plan encompassing three Subtasks.

#### **Subtask A: Standard Qualification for Solar Resource Products**

The objective of this Subtask is to provide the user community with benchmarked, standardized, validated worldwide solar resource data sets. Key Subtask activities to meet this objective are:

- Select and Qualify Ground Data Sets (lead: NASA, USA)): this activity will include a survey and documentation of existing data sources, and the production and reporting of validation data.
- Define Measures of Model Quality for Product Validation (lead: H2Magdeburg, Germany): besides defining measures of model quality, this activity includes the establishment and documentation of model intercomparison procedures.
- Develop Methodology for Establishing Coherent Benchmarking of Products (lead: NASA, USA)
- Apply Benchmarking Procedures to Subtask C Products (lead: H2Magdeburg, Germany): this activity includes a characterization of model performance as a function of input data sets.

#### **Subtask B: Common Structure for Archiving and Accessing Data Products**

The objective of this Subtask is to provide a user-oriented information system, such as a distributed data system, for archiving and accessing solar resource data. Key subtask activities to meet this objective are:

- Evaluate the Legal Aspects of Accessing Solar Resource Data (lead: Armines, France): this activity focuses on establishing copyright and proprietary rights of data that will be made available through the distributed data system, and to establish appropriate protocols with each participating institution for making the data generally available to the public.
- Identification of User Requirements (lead: SUNY/Albany, USA and JRC, EU): this activity captures and examines needs expressed by users of the data and the outcomes are specifications for the information system, list of customers serving later as testers of the prototypes and guidance to subtask A for selection of algorithms and methods
- Develop Data Exchange Protocols and Metadata (lead: Armines, France): various data exchange protocols will be examined, and one will be selected and documented.
- Develop Prototype (lead: Armines, France): a prototype web-based system will be developed whereby a user can request information of a certain type and format, and the information system provides the response or responses that most closely addresses the request.
- Develop Network of Resource Providers (lead: NASA, USA): a worldwide network of data providers will be established, and the techniques for data exchange among the providers will be investigated.
- Develop Use of Prototype by Users (lead: Armines, France): this activity defines the prototype that can be accessed by users, and raises the awareness of the data exchange system to external users.
- Define Automatic Access by Commercial Applications (lead: NASA, USA): This activity will enable automatic and fast access of resources through the information system by using commercial applications.
- Develop a Test Application (Solar Micrositing) (lead: JRC, EU): a case study in micro siting of a solar energy system will be developed to demonstrate the benefits of the information system.

### **Subtask C: Improved Techniques for Solar Resource Characterization and Forecasting**

The objective of this Subtask is to conduct essential R&D to improve the accuracy and the spatial and temporal coverage of current techniques, including the introduction of solar resource forecasting products. Key activities to meet this objective are:

- Improve Satellite Retrieval Methods for Solar Radiation Products (lead: SUNY/Albany, USA): This activity will focus on key model input parameters and methodologies, such as cloud indices, radiative transfer schemes, aerosol data retrievals, and treatment of snow and other surface albedo artifacts. The activity also addresses ways of improving the spatial resolution of satellite-derived broadband solar resource products.
- Conduct Climatological Analysis of Solar Resources (lead: NASA, USA): In order to ascertain future impacts on system performance due to climate variations, this activity includes the analysis of long-term surface and satellite-derived data sets and climate models; specifically addressing natural long-term fluctuations associated within the ocean-atmosphere system, such as the Southern Oscillation/El Nino.
- Evaluate Solar Radiation Forecasting Procedures (lead: EHF, Germany): This activity investigates different approaches for developing solar resource forecasts based on global numerical weather predictions and extrapolation of cloud motion vectors

### **Collaboration with other IEA Programmes**

Knowledge on solar resources is highly important for all forms of solar energy applications. Therefore Task 36 is conducted as a collaborative Task together with the IEA Implementing Agreements SolarPACES (Solar Power and Chemical Energy Systems), which has been adopted as Task V in their program, and PVPS (Photovoltaic Power Systems). It was agreed by both partnering Implementing Agreements, that SHC coordinates the Task. Cooperation is based on “minimum level” according to the SHC “Guidelines for Coordination with other Programmes.”

### **Duration**

The Task was initiated July 1, 2005 and will be completed June 30, 2010.

## **ACTIVITIES DURING 2007**

### **Third Experts Meeting**

Task 36 held its third Experts Meeting in Ispra, Italy on March 12-14, 2007, hosted by the Joint Research Center (JRC). Approximately 50 participants, guests, and observers attended the meeting, which also included a kick-off session of the European Union-funded MESoR (Management and Exploitation of Solar Resource Knowledge) project. Although non-European Task members do not participate in MESoR, much of the work conducted under MESoR will be relevant to the goals of Task 36. At the meeting Austria joined Task 36 through the participation of Blue Sky Wetteranalysen and the Austria Solar Innovation Center. There were technical presentations on a variety of task-related topics, including an update on using global surface solar radiation data sets for model validation, statistical measures to be used for benchmarking satellite-derived solar data sets and for validation of these data sets with surface data, the latest steps taken to create a worldwide data portal that allows users to access solar resource data from institutions around the world based on menu queries, results of recent studies of long-term (+20-year) trends in satellite-derived

solar resources and comparisons with ground measurement, recent breakthroughs in techniques for providing up to 3-days ahead solar resource and PV power output forecasts to assist utility dispatching of grid-connected solar energy, and new information on the world-wide distribution of aerosols, a critical input to the satellite-derived solar resource models. Task participants also discussed plans for the mid-term review to be held in the fall of 2007, and reviewed possible schedules for upcoming task expert meetings.

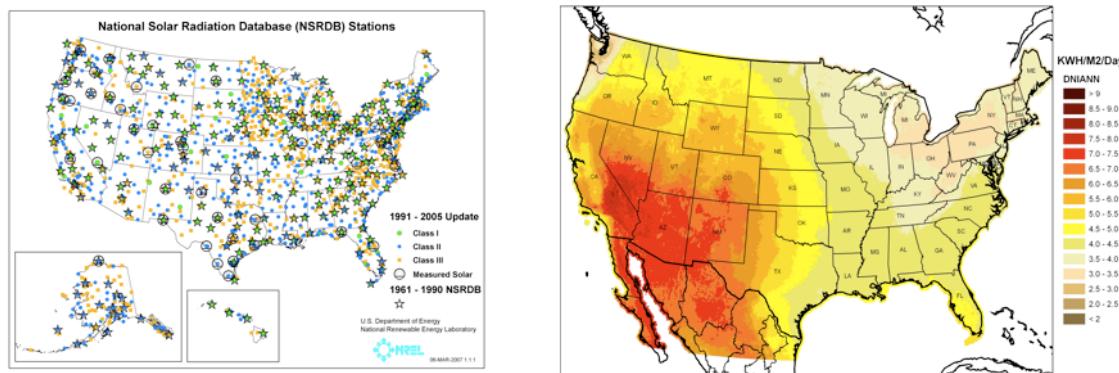
### **Fourth Experts Meeting**

The Task held its fourth Task Experts Meeting, hosted by SunTechnics GmbH in Hamburg, Germany on 23-25 October, followed by a Resource Assessment Symposium on 26 October. Much of the progress and future plans listed below were presented at the meeting. In addition, plans for a mid-term review to the SHC ExCo were developed.

Part of the mid-term review is based on a questionnaire filled out by a number of the task participants prior to and during the Experts Meeting. In general, the respondents showed satisfaction with the scope and progress of the Subtasks and activities. Task leadership is generally viewed as competent. In many cases, progress on individual activities appears to be delayed but tolerable. In addition, funding support is generally believed to be lower than required, but also tolerable. Technical input to the task as well as output is viewed as valuable and even excellent, and task participation is mostly seen as good. Relevance of the task outputs to industry overall is seen as good, and participation by industry is felt to be generally good. At this stage of the Task dissemination of results is only partially effective, but this is likely to improve over the next three years as more and more results are published and as the web portal becomes operational.

### **Release of the U.S. Updated National Solar Radiation Database**

The U.S. released the update to its National Solar Radiation Data Base this year. The database now contains modeled solar radiation and meteorological data values for over 1400 surface stations as well as seven years of 10-km resolution gridded satellite-derived solar data (see Figure 1). The solar data are available for free, and the meteorological data are available for a fee, all from the U.S. National Climatic Data Center.



**Figure 1. The U.S. 1991-2005 National Solar Radiation Data Base, released in 2007. The left panel shows the location of the 1454 ground stations for which hourly solar radiation were developed. The right panel shows hourly satellite-derived solar radiation data for the years 1998-2005 at a 10-km grid resolution.**

## **Coordination with Group of Earth Observations System of Systems (GEOSS)**

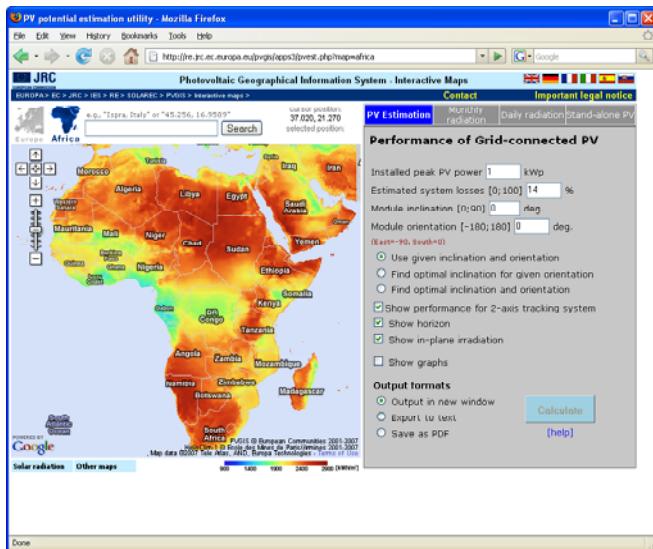
Successful efforts have been made at a high political level to make the Task 36 activities recognized in the Group for Earth Observation (GEO), an initiative of the G8, that includes an energy component. Members of the Task have provided contributions to the strategic document on energy management for the GEOSS community. A video showing four case studies in Africa exploiting solar energy achievements for solar energy systems has been developed by Ecole des Mines de Paris/Armines, with the help of NASA, JRC, DLR and the companies involved in the design of these systems. This was one of the success stories presented during the ministerial meeting held November 2007 in Cape Town, South Africa. The design of these systems was made by using the SoDa Service and the combined SSE and HelioClim datasets from NASA and Armines, respectively. The video is available on the web site of the GEO Community of Practice “Energy” (<http://www.geoss-ecp.org/img/video2/GEOSS-ECP.html>).

The proceedings of the IEEE IGARSS international conference devoted to Earth observation were published. They contain the following communication, depicting the principles of the information system: Stackhouse P., Renne D., Perez R., Meyer R., Wald L., Suri M., “Towards designing an integrated Earth observation system for the provision of solar energy resource and assessment”, Proceedings of the IEEE IGARSS Symposium, pp. 3517-3520, July 2006.

## **The PVGIS Web Site at the Joint Research Center**

At the 4th Experts Meeting the Joint Research Center reported on the PVGIS web site developed to provide users with an easy interactive application that provides free access to solar resource data for Europe, Africa, and southwestern Asia, as well as ambient temperature data for Europe. The PVGIS site also provides assessment tools that calculate solar radiation for fixed and sun-tracking systems, calculations of energy output for grid-connected photovoltaic systems, and the performance of stand-alone PV systems (Africa only). Tools on the web site provide the user with key overview information on investment decisions to support project developers and the manufacturing industry.

The applications are based on the Google Maps interface, and provide several different formats of information, including the estimated accuracy of the calculations. Web-based estimates for single sites can be accessed through the following URL: <http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php>. In addition, gridded data sets at approximately 10-km by 10-km resolution can also be accessed. An example of the PVGIS interface is shown in Figure 2.



**Figure 2. Example page from the PVGIS web site.**  
*(courtesy of Thomas Huld, Marcel Šuri, and Tomáš Cebecauer of the Joint Research Centre, Ispra, Italy)*

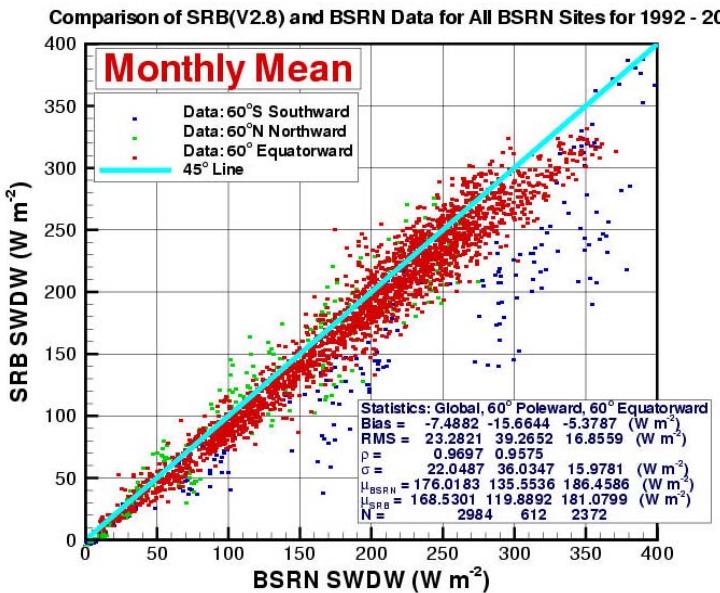
## Specific Technical Achievements

### Subtask A: Standard Qualification of Solar Resource Products

Key results presented at the Experts Meetings are summarized here:

- **Activity A1: Select and Qualify Ground Data Sets**

The BSRN and IDMP data sets will form the core of the ground data to be used for benchmarking. Preliminary results comparing BSRN data with the NASA SSE data set are shown in Figure 3. A common quality control (QC) procedure is under study for the ground data qualification. New input to this discussion has been provided through a study by CIEMAT (Spain) that focuses on problems caused by incorrect time labeling and problems associated with Direct Normal Insolation (DNI) measurements at low sum angles. Data from ground stations that pass the common QC may be used to supplement the BSRN and IDMP data sets for regions not covered by these data.



**Figure 3. Intercomparison of the NASA Surface Radiation Budget Products for total ground irradiance versus the BSRN precision measurements.** (Zhang & Stackhouse, NASA-LARC)

Dr. Enio Pereira (a guest participant in the 4<sup>th</sup> Experts Meeting from the Brazilian Spatial Institute) has reported on the installation of SONDAR, a new high quality, and Baseline Surface Radiation Network (BSRN) -equivalent ground station network in Brazil. Data access is give via an Internet portal.

A new spectrometer has been developed by Environment Canada to expand the database for spectral measurements. The qualification of this spectroradiometer is ongoing.

NASA has collected and processed hourly measurements from the BSRN. NASA is developing an inventory of other networks containing high quality measurements for algorithm assessment. These and other high quality surface observations will be selected in collaboration with the team for general evaluation of solar resource assessment methodologies.

- **Activity A2: Define Measures of Model Quality fro Product Validation**

A new set of error measures had been identified. Key measures are based on the Kolmogorov-Smirnov (K-S) scheme for the comparison of cumulative distribution functions.

These measures are applied to satellite-based irradiance data that could be compared to ground measured data for a set of 38 stations of the German weather service. The outcome indicates the complementarities of first- (mean bias error, root mean square) and second-order measures (based on the K-S scheme) of the model quality. A paper on this method has been submitted to the Solar Energy Journal (Analysis of different error parameters applied to solar radiation data from satellite and German radiometric stations, by Bella Espinar, Lourdes Ramírez, Anja Drews, Hans Georg Beyer, Luis F. Zarzalejo, Jesús Polo, and Luis Martín).

- **Activity A3: Develop Methodology for Establishing Coherent Benchmarking of Products**  
The exercise of the analysis of the METONORM database using high quality ground data from Geneva has been performed by the University of Geneva. A test concerning the end use accuracy has been finalized using the performance of grid connected PV systems. A report of this is in print in Solar Energy Journal (Quality of performance assessment of PV-plants based on irradiation maps, A. Drews, H.G. Beyer, U. Rindelhardt).

### **Subtask B: Common Structure for Archiving, Processing, and Accessing Resource**

The work plan, revised in February 2007, is being pursued in several areas, and highlights of accomplishments are summarized here:

- **Activity B1: Evaluate the Legal Aspects of Accessing Solar Resource Data**  
The object of Activity B1 is to produce a report containing sketches of the information system, describing the roles and responsibilities of the participants, including legal aspects, intellectual property, and ethical aspects (such as equal treatment of suppliers by a broker) in their relationships, including commercialization of data, and elements that support the belief that the outcomes of Subtask B will be exploited by the solar energy community for its benefits. The document will depict how IPR are taken into account in the architecture and exchange on information.

Legal aspects and property rights were analyzed in view of what is currently done in meteorology and on the web in general. ISO documentation on geographical information was taken into account. This activity is strongly linked to the design of the information system.

A first draft of this report was developed at the end of March 2007, and will be updated during the course of Task 36. Discussions are held in workshops or meetings of opportunity with potential providers, including companies, in order to accumulate case studies and various experiences. From this material, we will study the issue of a typical Service Agreement.

The knowledge acquired by the Task about IPR in the European Union with respect to meteorological and satellite data is extensive. The case where “public” data (e.g., from NASA or BOM) are sold by third parties arose. Effective links between the SoDa Service and the NASA-SSE database and the combination of the NASA-SSE database (free access) with the HelioClim database (for pay access) have been established. Presently, the access to these integrated services is free.

- **Activity B2: Identification of User Requirements**  
This activity captures and examines needs expressed by users of the data. The outcome provides specifications for the information system, list of customers serving later as testers of the prototypes, and guidance to subtask A for selection of algorithms and methods.

The user survey was conducted through a questionnaire. In addition, the feedbacks obtained by information systems managers (NASA-SSE, PV-GIS, Satel-Light, SoDa, etc.) were taken into account. A server at JRC hosted the on-line questionnaire through February 2007. Several servers of relevance, e.g., NASA, Satel-Light, SoDa, PV-GIS, were pointed to the JRC in order to create awareness and increase the number of responses. Approximately 110 answers were collected. Analysis was performed by JRC. The survey

reveals several interesting features that have been documented in a report. The document is now in its final form, available and published on the Task 36 website. This completes Activity B2.

- **Activity B3: Develop Data Exchange Protocols and Meta-Data**

This activity includes the close monitoring of standardization procedures, investigation of available tools, their limits and advantages, and participation in international working groups, such as INSPIRE (Europe) and GEOSS.

There are several levels in exchange protocols. The information system will rely on the most standard ones for the lowest levels. An example is the HTTP protocol commonly used to browse the Internet. These protocols are embedded in a satisfactory manner in the middleware tools selected in Activity B4 during the spring of 2007 (JBoss, open source). These issues should be considered as completely handled by the middleware and there is no need for development or augmentation.

During this reporting period, activities have concentrated on the exchange protocol at a semantic level (i.e., the “solar radiation” level). Information should be depicted by metadata, held in a thesaurus. This thesaurus should have a practical implementation on a computer, which is called an application schema or XML schema, since such schemes are often written in XML.

We analyzed the standards for metadata from a variety of meteorologically-oriented web servers. As the choice of metadata and schema has a strong impact on the architecture of the system and its functionalities, we also paid great attention to the exchange of information between the middleware and a web service. A standard, called WSDL (Web Service Description Language) was adopted. After a search and test of several tools, Armines has selected the Eclipse workshop (open source) to allow efficient exploitation of these schemes for developing and deploying web services.

In addition, we take into account the experience gained in the SoDa Service in the composition of web services. Though an efficient automatic and adaptive composition system is beyond the scope of Task 36, we took this functionality into account to analyze the proposed schemes. In particular, we had to understand the limitations of WSDL in invoking a web service.

Considering all these elements together, the conclusion was that none of these schemes were suited for the management of time-series of irradiance, one of the products most in demand by users. Consequently, we have developed a specific thesaurus for time-series of irradiance and its schema. The proposed schema takes into account the intellectual property rights of the providers. This thesaurus has been sent to the INSPIRE Implementation Group for comments and has been presented at an international conference: Gschwind Benoît, Lionel Ménard, Thierry Ranchin, Lucien Wald, Paul Stackhouse, 2007, “A proposal for a thesaurus for web services in solar radiation”, in Proceedings EnvirolInfo 2007, O. Hryniwicz, J. Studzinski and M. Romaniuk (Eds), Shaker Verlag, vol. 1, pp. 135-142.

As this domain of standardization is very prominent at this time, we made efforts to be involved in such activities in order to be aware of the outcomes and to raise awareness about our concerns in solar energy (e.g., management of time systems, composition of services). In particular, we have registered the SoDa Service as a SDIC (Spatial Data

Infrastructure Community) to the INSPIRE community and to the three candidate portals for GEOSS: The European Space Agency (ESA), OGC and Environmental Sciences and Research Institute (ESRI). In this case, the SoDa Service serves as a proxy for the not-yet existing information system of Task 36.

- **Activity B4: Develop Prototype**

A prototype web-based system will be developed whereby a user can request information of a certain type and format, and the information system provides the response or responses that most closely address the request.

The development of the prototype is on going. A first version is presently available (<http://project.mesor.org>). This prototype is a proof-of-concept as it implements all elements discussed above (web service installed on another web server, thesaurus, exchange protocols, etc.).

In order to ensure that the developments are made according to the state-of-the-art, Armines and NASA participate in the GEOSS group on System Architecture. We found that this group is promoting the JBoss middleware and the LifeRay portal that we selected in Spring 2007, which enforces the confidence we have in these open source tools and their communities of developers.

The revision of the PV-GIS web made by the JRC in the past months offered the opportunity to evaluate practical solutions for the selection of a given geographical site (Google tools). Meteotest has already exploited these tools for the product MeteoNorm. Consequently, they have been adopted in the prototype. Of interest to the GUI (graphical user interface) is the tool Ajax (open source). Analysis is on going.

The “use-cases” are under development. They depict several cases of usage of the information system by users. This is done in close relationship among Activities B3, architecture design and prototype development (Activity B4) and service providers (Activity B5), taking into account the expressed user needs and the experience gained by the managers of the existing information systems.

As discussed previously, this Subtask has identified the composition of the web services as a weak point. The composition defines a plan for calling services. Armines is working on concepts for composition, which can range from fully manual (the case of the SoDa Service) to fully automatic. Except for the manual case, all other concepts are relevant to activities that are beyond the scope of Task 36. However, as the SoDa Service offers an excellent opportunity for testing real cases, these research activities made at Ecole des Mines de Paris are closely linked to Task 36 and therefore may benefit the Task. A test bed has been devised and tested. It comprises 16 scenarios (use cases) that can be instantiated by services dealing with irradiance or temperature. This test bed will permit the test of the prototypes for composition. The test bed has been presented at an international conference: Gschwind Benoît, Lucien Wald, Robert Mahl, François Irigoin, Lionel Ménard, 2007, “Test of several approaches for the composition of web services in meteorology”, in Proceedings EnvirolInfo 2007, O. Hrynewicz, J. Studzinski and M. Romaniuk (Eds), Shaker Verlag, vol. I, pp. 127-134”.

- **Activity B5: Develop Network of Resource Providers**

This activity aims at establishing a worldwide network of data providers (through web services). Two different approaches were adopted during the reporting period. The first one is to proceed as planned with the analysis of available techniques for data exchange

between the web services and the middleware, including their adoption and possible augmentation. The second approach exploits opportunities to connect new web services to the SoDa Service. In that case, the SoDa Service serves as a proxy to the information system. The second approach permits the quick and efficient development of new services, to make them tested by a large number of customers very rapidly, and finally to make the provider better acquainted with the proposed collaborative system.

A first draft of a “how-to” document has been written to the attention of web service developers. This document has been sent to several partners for comments.

Several providers in the SoDa Service and others (e.g. Armines, ENTPE, JRC, Meteotest, NASA) have declared interest in offering their services in the new information system and show a high level of knowledge in information technologies. This is supporting our expectation of a rapid population of the system by services.

Regarding the second approach, an effort was made, under the common umbrella IEA and GEOSS, to connect NASA’s SSE database to the SoDa Service. In addition, a compound service was made that jointly exploits the SSE and HelioClim (Armines) databases and selects the information having the best spatial resolution. Since these two new services in SoDa have become available a large number of requests have made (more than 1500 anticipated from July to December 2007), clearly demonstrating the usefulness of such services.

Armines has revised a web service available through the SoDa Service that allows companies to create ASCII files that can be entered into GIS software for producing maps of irradiance (a common requirement specified by users). Here again, the rapid prototyping facility offered by the SoDa Service proves its efficiency. After a few months of testing, the service was revised for its GUI for outputs and an asynchronous capability was added. This functionality should exist in the final developed system.

An analysis was made on the possibility of accessing the information held in the SWERA web site by the SoDa Service. Currently, this is not possible at very low cost.

- **Activity B6: Define Automatic Access by Commercial Applications**

This activity will enable automatic and fast access of resources through the information system by using commercial applications.

Though the activity has not formally begun, preliminary results have already been obtained. A web service was developed by Armines to automatically connect to NCAR / NCEP forecasts, thus offering these forecasts through the SoDa Service. This connection worked for several months with a growing number of users, but has not been working properly since September 2007. A possible solution is the introduction of asynchronous capability of this service; it is still unclear if the solution adopted in the previous case (see Activity B5) is the most appropriate given the users expectations.

- **Activity B7: Example application using solar micro-siting in GIS**

This activity will be implemented from month 48 to month 60, i.e., the last year of the current Task 36 work plan.

### ***Subtask C: Improved Techniques for Solar Resource Characterization and Forecasting***

- *Activity C1: Improve Satellite Retrieval Methods for Solar Radiation Products*  
Task participants have been active with wide-ranging activities fitting into this category:

SUNY reported on their current investigation to augment the spatial resolution of NASA SSE data by observing that the relative distribution of mean monthly irradiances within a NASA SSE Cell (1 degree x 1 degree) remains stable over time. The methodology is designed to transfer the high-resolution irradiance distribution pattern derived from recent satellite data to older historical SSE data. An independent test of the method was presented.

SunTechnics presented the outline of a promising methodology to combine short term ground measurements and long term satellite data to provide accurate, site-specific long term information at a given site. This activity, as the one above, presented aspects related to activity C1 (new methodology), but also is closely linked to activity C2 (addressing long term variability issues) and Subtask A (benchmarking and validation). Thus its final attribution has yet to be established.

The JRC briefly reported on a new methodology to incorporate terrain effects into satellite derived estimates and are now working on incorporating these effects into the modeling of diffuse radiation in addition to direct.

Environment Canada reported on plans to deploy spectral radiometers in Canada. These instruments could be used to provide ground truth for the development/validation of satellite and other models capable of providing the spectral data needed for advanced PV simulation and other applications.

University of Navarra had started an effort to evaluate tilted irradiance and radiance distribution models and investigate their applicability to satellite derived data but was unable to attend the task meeting in Hamburg.

- *Activity C2: Conduct Climatological Analysis of Solar Resources*  
NASA is evaluating the 22-year global solar resource maps against surface and other satellite solar resource algorithms. This assessment is part of the World Climate Research Programme (WCRP) Global Energy and Water Cycle Experiment (GEWEX) Radiative Flux Assessment project thus connecting Task 36 to WCRP/GEWEX activities. The results to date are:
  - The year-to-year irradiance anomalies were evaluated against long-term surface measurements for a nineteen year, 12 year and 5 year set of surface measurements.
  - The agreement between the anomalies and satellite based gave correlations greater than 0.8.
  - New techniques of trend analysis that include the autocorrelation of the time series have been developed to better quantify the agreement between satellite and surface measurements and the uncertainty related to the detection of trends. These results show that the trend problem is very sensitive to the year-to-year variability and data gaps from the site measurements.
  - These results have been reported in several presentations and will become part of the GEWEX Radiative Flux Assessment Report.
- *Activity C3: Evaluate Solar Radiation Forecasting Procedures*

The participants involved in this activity have performed continuing evaluation and further development of the different forecasting algorithms. Their results have been presented at several conferences.

The processing of forecasts for the benchmarking of the different forecast algorithms was started. SUNY/A, Meteotest, Meteocontrol, Oldenburg University, DLR -DFD, Blue Sky Wetteranalysen and CIEMAT are contributing forecasts to the inter-comparison:

- SUNY/A completed the processing of forecasts for the benchmarking for the USA; test period: April – September 2007. DLR -DFD evaluated aerosol forecasts and cloud forecasts by the EURAD MADE system for an improved forecasting of clear-sky irradiances in comparison to the European Centre for Medium-range Weather Forecasting (ECMWF) based forecasts. Results were presented at the DACH 2007, 10-14 September 2007, Hamburg, Germany. A study on the use of irradiance forecasts for the management of solar thermal power plants has been performed in cooperation with DLR-TT.
- At Oldenburg University the analysis of cloud forecasts by the ECMWF global model with respect to irradiance forecasts in order to derive an enhanced irradiance forecast was continued. An approach to provide confidence intervals for PV power forecasts was developed and included in a paper on solar power prediction, presented at the 20th European PV Conference, 3-7 September 2007, Milan, Italy. Furthermore, a paper on solar power prediction has been presented at the DACH 2007, 10-14 September 2007, Hamburg, Germany.
- An analysis on irradiance predictions based on the mesoscale model WRF processed at the Forwind Institute, center of wind energy research of Oldenburg University and Hanover University, was performed as a joint project of Oldenburg University and Ciemat.
- At Meteotest, irradiance forecasts based on the MM5 model and GFS input data have been operationally processed and evaluated since June 2006.
- Ciemat has performed an analysis of the irradiance of ECMWF reanalysis data. The evaluation was done for Spanish radiometric stations operated by the Spanish National Weather Service (INM) for the period 1994-2003.
- Bluesky Wetteranalysen began to process operational irradiance forecasts in July 2007.

## WORK PLANNED FOR 2008

### **Subtask A: Standard Qualification of Solar Resource Products**

#### **Activity A1: Select and Qualify Ground Data Sets**

The definition and application of a common OC procedure for the qualification of the ground data sets will be completed. The procedure will be applied to the selected sets, which will include the BSRN and IDMP databases and data from selected other sources to be applied in regions with a sparse covering of by BSRN and IDMP (e.g. data from the SONDAR data set for Brasil.) Data quality procedures and information regarding these surface measurements and will be made available to the participants via the Internet.

#### **Activity A2: Define Measures of Model Quality fro Product Validation**

The newly defined measures for the model quality will be investigated for the end use

accuracy in data applications. The most appropriate measures to be used to qualify a certain data set for its application to model and analyze a given class of solar energy systems should be identified. A further extension of the set of measures will be evaluated for use in the analysis of spectral data.

**Activity A3: Develop Methodology for Establishing Coherent Benchmarking of Products**

Related to the respective outcome of activity A2, a comprehensive and application-specific benchmarking procedure will be established. First examples will concern the analysis of photovoltaic and domestic hot water systems.

**Subtask B: Common Structure for Archiving, Processing, and Accessing Resource**

**Activity B1: Evaluate the Legal Aspects of Accessing Solar Resource Data**

Case studies and experiences regarding web-based data dissemination will be gathered. Legal aspects about the usage of data delivered by NASA or NREL in the US and the Bureau of Meteorology in Australia will be examined.

**Activity B3: Develop Data Exchange Protocols and Meta-Data**

The thesaurus and related schema is one of the keys in a collaborative information system based on web services. Though already implemented and available, the proposed schemes will be presented and discussed in the forthcoming months in various meetings and workshops in order to raise awareness on our efforts and if possible, establish them as a de facto standard for radiation data. The thesaurus will need to be extended to time-series of meteorological data, including temperature and humidity (see user requirements).

A new language and thesaurus should be developed for additional description of services allowing tasks specific to our system: IPR, GUI, outputs (presentation, format). This will be done following the “use-cases” in close relationship between Activities B3, B4 and service providers (Activity B5) taking into account the expressed user needs and the experience gained by the managers of the existing information systems.

We will create new thesauri for other products, such as statistics on types of days, to facilitate the provision of services.

We will proceed with participation in international activities on standardization of data products, and will set up documentation for these thesauri. The thesauri will be put on a web server of public access.

**Activity B4: Develop Prototype**

We will proceed with the development of the prototype following the use-cases, with emphasis on the GUI and exchange of information between the middleware and a web service. We will also prepare assessments of the prototype by users.

**Activity B5: Develop Network of Resource Providers**

We will proceed with the development of services, with two major goals: better exploit the NASA/SSE database and assist other providers of web services. The NASA/SSE group anticipates release of a new version in the next six months.

### **Activity B6: Define Automatic Access by Commercial Applications**

Though not officially started, we will investigate the automatic connection of the prototype to the NCEP / NCAR forecasts to check the capability of the prototype.

### **Subtask C: Improved Techniques for Solar Resource Characterization and Forecasting**

#### **Activity C1: Improve Satellite Methods for Solar Radiation Products**

SUNY will continue the development of the methodology to augment the resolution of NASA-SSE by undertaking a “test run” of the method for the entire United States, creating three test years of hourly high resolution data synthesized from the mean irradiance distribution patterns and three-hourly low resolution NASA-SSE data. NASA also plans release of latest long-term solar irradiance data set that shows improvements relative to previous versions by changing angular properties, aerosol properties, and extraterrestrial solar irradiance.

SunTechnics has plans to develop a methodology to find the best estimate of the site-specific long-term solar irradiance conditions based on the combination of satellite data and measurements through 2008 and 2009. At this time however, the attribution of this activity has yet to be finalized among this activity (C1), activity C2 and subtask A.

JRC will implement terrain features into the assessment of direct and diffuse irradiance by the means of horizons calculated from SRTM-3 elevation data. For site assessments the possible shading of the direct normal irradiance is tested using the horizon outline. For the case of the diffuse component, in collaboration with SUNY, the Perez model for tilted surfaces will be modified to account for sky fraction (isotropic diffuse component) and the horizon outline (shading of the circumsolar diffuse component).

University of Navarra has plans to:

- Apply different radiance angular distribution models for the sky conditions of Pamplona.
- Analyze radiance data obtained by two different instruments (Sky Scanner EKO and Solar Igel).
- Continue to compare radiance distribution results obtained when applying Igawa model and Perez modified model with the measurements obtained with Solar Igel (already completed) and with Sky Scanner (nearing completion). The Brunger model will also be investigated in a similar fashion.

#### **Activity C2: Conduct Climatological Analysis of Solar Resources**

Long-term irradiance data sets assessments will be provided in conjunction with the GEWEX Radiation Flux Assessment project and including long-term satellite irradiance records from task participants. Methods developed above will also be applied for evaluation of uncertainties and trend detection.

#### **Activity C3: Evaluate Solar Radiation Forecasting Procedures**

The task participants will continue with evaluation and further development of the different forecasting algorithms.

The benchmarking for the USA for the April – September 2007 period will be completed during the next reporting period and a technical paper on the results will be prepared. SUNY/A, Meteotest, and Oldenburg University will contribute to this inter-comparison.

The processing of the forecasts for the benchmarking for European forecasting over the period July 2007 to June 2008 will be continued.

Three new projects on irradiance forecasting will start:

- Development of an energy management of a solar thermal power plant using solar irradiance forecasting by AsiC
- Joint project between Natural Resources Canada and the Canadian Meteorological Centre (Environment Canada) on solar and PV forecasting
- The new participant, University of Jaen in Spain, will work on solar radiation evaluation and forecasting using NWP models.

## **LINKS WITH INDUSTRY**

Several small companies are directly participating in the Task: Meteocontrol, GmbH, SunTechnics, GmbH, and Meteotest. Blueskywetter of Austria also joined the task at the end of 2006. The audience for the results of Task 36 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 2007**

- A number of papers were presented at the Solar 2007 Conference in Cleveland, Ohio (USA) July 11-14, 2007 by authors involved in Task 36, including the following:
  - S. Wilcox, M. Anderberg, R. George, W. Marion, D. Myers and D. Renne', National Renewable Energy Laboratory; N. Lott and T. Whitehurst, National Climatic Data Center; W. Beckman, University of Wisconsin; C. Gueymard, Solar Consulting Services; R. Perez, State University o New York at Albany; P. Stackhouse, National Aeronautics and Space Administration and F. Vignola, University of Oregon: Completing Production of the Updated National Solar Radiation Database for the United States
  - D. Myers, National Renewable Energy Laboratory: Relative Performance of Multiple Solar Radiation Resource Assessment Data Sources
  - R. Perez and M. Kmiecik, Atmospheric Sciences Research Center; S. Wilcox, NREL and P. Stackhouse, NASA Langley Research Center: Enhancing the Geographical and Time Resolution of NASA SSE Time Series Using Microstructure Patterning
  - R. Perez, M. Kmiecik, J. Schlemmer and L. Root, Atmospheric Sciences Research Center; K. Moore, Integrated Environmental Data and P. Stackhouse, NASA Langley Research Center: Evaluation of PV Generation Capacity Credit Forecast on Day-Ahead Utility Markets
  - R. George, S. Wilcox and M. Anderberg, National Renewable Energy Laboratory and R. Perez, State University of New York at Albany: National Solar Radiation Database (NSRDB) - 10 Km Gridded Hourly Solar Database
  - C. Whitlock, S. Gupta, T. Zhang and W. Chandler, Science Systems and Applications, Inc.; P. Stackhouse, NASA Langley Research Center; L. Hinkelman,

- National Institute of Aerospace and C. Long, DOE Pacific Northwest National Laboratory: Clear-Sky Shortwave Surface Radiation Intensities Over The Globe
- W. Chandler, Science Systems and Applications, Inc.; P. Stackhouse, NASA Langley Research Center and C. Whitlock, J. Hoell, D. Westberg and T. Zhang, Science Systems and Applications, Inc: NASA's Surface Meteorology and Solar Energy Web Portal (Release 6.0)
  - Lorenz E., Heinemann D., Wickramarathne H., Beyer H.G., Bofinger S. (2007): *Forecast of ensemble power production by grid-connected PV systems*. 20th European PV Conference, 3.9-7.9 2007, Milano, Italy. (Joint paper of Oldenburg University, H<sup>2</sup> Magdeburg, and Meteocontrol).
  - Lorenz E., J.Hurka , D. Heinemann , H. G. Beyer (2007): *Solarleistungsvorhersage für die Netzintegration von verteilten Photovoltaikanlagen*. DACH 2007, 10.9.-14.9.2007, Hamburg, Germany. (Joint paper of Oldenburg University and H<sup>2</sup> Magdeburg).
  - Bella Espinar, Lourdes Ramírez, Anja Drews, Hans Georg Beyer, Luis F. Zarzalejo, Jesús Polo, and Luis Martín: Analysis of different error parameters applied to solar radiation data from satellite and German radiometric stations. Submitted to the Solar Energy Journal.
  - Gschwind Benoît, Lionel Ménard, Thierry Ranchin, Lucien Wald, Paul Stackhouse, 2007, "A proposal for a thesaurus for web services in solar radiation", in Proceedings EnvirolInfo 2007, O. Hryniwicz, J. Studzinski and M. Romaniuk (Eds), Shaker Verlag, vol. I, pp. 135-142.
  - Drews, H.G. Beyer, U. Rindelhardt: Quality of performance assessment of PV-plants based on irradiation maps. To be published in Solar Energy Journal

## MEETINGS IN 2007

### Third Experts Meeting

13-15 March  
Ispra, Italy

### Fourth Experts Meeting

24-26 October  
Hamburg, Germany



## MEETINGS PLANNED FOR 2008

### Fifth Experts Meeting

9-10 June  
Austria

*This meeting will include a one-day session devoted to the MESoR (Management and Exploitation of Solar Resource Knowledge) Project. The EU-funded MESoR Project involves many of the Task 36 participants and will provide significant funding for the Task.*

### Sixth Experts Meeting

Date and location to be decided

## TASK 36 NATIONAL CONTACTS

### Operating Agent

Dave Renné  
National Renewable Energy  
Laboratory  
1617 Cole Boulevard  
Golden, Colorado 80401-3393  
USA  
[David\\_renne@nrel.gov](mailto:David_renne@nrel.gov)

### Austria

Klaus Reingruber and Wolfgang  
Traunmuller  
Bluesky Wetteranalyzen  
Steinhüblstr. 1, 4800 Attang-  
Puchheim  
[klaus.reingruber@blueskywetter.at](mailto:klaus.reingruber@blueskywetter.at)  
[wolfgang.traunmueller@blueskywetter.at](mailto:wolfgang.traunmueller@blueskywetter.at)

Gerald Steinmauer  
Austrian Solar Innovation Center  
Dursiolstr. 7 /Top50, 4600 Wels  
[steinmauer.gerald@asic.at](mailto:steinmauer.gerald@asic.at)

### Canada

L. J. Bruce McArthur  
Experimental Studies Division, Air  
Quality Research Branch  
Meteorological Service of Canada  
4905 Dufferin Street  
CAN-M3H 5T4 North York,  
Ontario  
[Bruce.McArthur@ec.gc.ca](mailto:Bruce.McArthur@ec.gc.ca)

### European Commission

Marcel Šuri  
European Commission - DG Joint  
Research Centre  
Institute for Environment and  
Sustainability  
I-21020 Ispra (VA)  
Italy  
[marcel.suri@jrc.it](mailto:marcel.suri@jrc.it)

### France

Lucien Wald (Subtask B Leader)  
Centre Energetique et Procedes  
Ecole des Mines de Paris / Armines  
/ CNRS (FRE 2861)  
BP 207  
F-06904 Sophia Antipolis cedex  
[lucien.wald@ensmp.fr](mailto:lucien.wald@ensmp.fr) or  
[lucien.wald@cep.cma.fr](mailto:lucien.wald@cep.cma.fr)

Dominique Dumortier  
LASH-ENTPE  
Rue Maurice Audin  
F-69518 Vaulx-en-Velin  
[dominique.dumortier@entpe.fr](mailto:dominique.dumortier@entpe.fr)

### Germany

Hans Georg Beyer (Subtask A  
Leader)  
Fachbereich Elektrotechnik  
Hochschule Magdeburg-Stendal  
(FH)  
Breitscheidstrasse 2  
D-39114 Magdeburg  
[hans-georg.beyer@et.hs-magdeburg.de](mailto:hans-georg.beyer@et.hs-magdeburg.de)

Richard Meyer  
Team Leader Technical Analysis  
Solar Energy  
SunTechnics GmbH  
Anckelmannsplatz 1  
20537 Hamburg  
[R.Meyer@suntechnics.de](mailto:R.Meyer@suntechnics.de)

Detlev Heinemann (Subtask C  
Leader) and Elke Lorenz  
Carl von Ossietzky Universität  
Oldenburg, EHF  
D-26111 Oldenburg  
[detlev.heinemann@uni-oldenburg.de](mailto:detlev.heinemann@uni-oldenburg.de)  
[elke.lorenz@uni-oldenburg.de](mailto:elke.lorenz@uni-oldenburg.de)

Gerd Heilscher  
meteocontrol GmbH  
Spicherer Str. 48  
D-86157 Augsburg  
[heilscher@meteocontrol.de](mailto:heilscher@meteocontrol.de)  
[bofinger@meteocontrol.de](mailto:bofinger@meteocontrol.de)

Carsten Hoyer-Kick  
DLR Institut für Technische  
Thermodanamik  
Pfaffenwaldring 38-40  
D-70503 Stuttgart  
[carsten.hoyer@dlr.de](mailto:carsten.hoyer@dlr.de)

Bernhard meyer and Marion  
Schroedeter-Homscheidt  
DLR-DFD  
Oberpfaffenhofen  
D-82234 Wessling  
[marion.schroedter-  
homscheidt@dlr.de](mailto:marion.schroedter-<br/>homscheidt@dlr.de)

Jan Remund  
Meteotest  
Fabrikstr. 14  
CH-3012 Bern  
[remund@meteotest.ch](mailto:remund@meteotest.ch)

**United States**  
Paul Stackhouse  
NASA Langley Research Center  
MS 420  
Hampton, VA 23681  
[Paul.w.stackhouse@nasa.gov](mailto:Paul.w.stackhouse@nasa.gov)

Richard Perez  
State University of New  
York/Albany  
Atmospheric Sciences Research  
Center  
251 Fuller Road  
Albany, NY 12203  
[perez@asrc.cestm.albany.edu](mailto:perez@asrc.cestm.albany.edu)

### **Spain**

Lourdes Ramirez, Jesús Polo, and  
Luis F. Zarzalejo  
Plataforma Solar de Almeria  
Departamento de Energia  
CIEMAT Avd  
Complutense  
E-2228040 Madrid  
[Lourdes.Ramirez@ciemat.es](mailto:Lourdes.Ramirez@ciemat.es)  
[jesus.polo@ciemat.es](mailto:jesus.polo@ciemat.es)  
[lf.zarzalejo@ciemat.es](mailto:lf.zarzalejo@ciemat.es)

José Louis Torres  
University of Navarro  
[jlte@unavarra.es](mailto:jlte@unavarra.es)

David Pozo Vazquez  
University of Jaen  
Campus Lagunillas, A3, 23071 Jaen  
[dpozo@ujaen.es](mailto:dpozo@ujaen.es)

### **Switzerland**

Pierre Ineichen  
University of Geneva, CUEPE  
7 rte de Drize  
CH-1227 Carouge Geneva  
[pierre.ineichen@cuepe.unige.ch](mailto:pierre.ineichen@cuepe.unige.ch)

## **TASK 37: ADVANCED HOUSING RENOVATION WITH SOLAR AND CONSERVATION**

*Mr. Fritjof Salvesen  
KanEnergi AS  
Operating Agent on behalf of Royal Norwegian Ministry of Industry and Energy*

### **TASK DESCRIPTION**

Buildings are responsible for up to 35 percent of the total energy consumption in many of the IEA participating countries. Housing accounts for the greatest part of the energy use in this sector. Renovating existing housing offers an enormous energy saving potential.

The Task objective is to develop a solid knowledge base on how to renovate housings to a very high energy standard and to develop strategies which support market penetrations of such renovations. Task 37 will include both technical R&D and market implementation as equal priority areas.

The Task will begin by analyzing the building stock in order to identify building segments with the greatest multiplication and energy saving potential. Examples of building segments are year of construction, type of buildings, type of envelope and components. Within these segments important topics for discussions are: - ownership and decision structures, inhabitants and their characteristics and actual groups of retrofit market players.

In parallel, exemplary renovation projects achieving substantial primary energy savings while creating superior living quality, will be analyzed. Important aspects are both energy performance and the owner's motivations behind the renovation. Drawing on this experience package of measures in combination with the most updated research front, new and innovative concepts and components will be developed.

Insights from this international collaboration will be conveyed to target national end users in a deliberate strategy to increase the market penetration of advanced housing renovations.

The Task is organized into four Subtasks.

#### **Subtask A: Marketing and Communication Strategies (Lead country: Norway)**

This Subtask is planned to be a cross-Task activity to:

- Focus national Task activities on building types and solutions with the greatest multiplication and energy saving potential.
- Develop concrete market strategies together with companies, authorities, research institutes or other market players participating in the Subtask.
- Develop communication plans in accordance with the strategies to maximize the impact of knowledge gained through the Task.

#### **Subtask B: Advanced Projects Analysis (Lead country: Switzerland)**

This Subtask's objectives are to:

- Systematically analyze and document projects meeting Task selection criteria in order to quantify which measures achieve the greatest energy savings or non energy benefits and at what costs.
- Identify innovative, promising concepts for detailed analysis in Subtask C.
- Provide guidance for national R&D activities by identifying weaknesses and opportunities in high-performance housing renovations.

### **Subtask C: Analysis and Concepts (Lead country: Germany)**

This Subtask will start with the analysis of advanced projects (in Subtask B) and then develop new concepts also using new components and systems. Accordingly, the objectives are to:

- Evaluate the performance of advanced housing renovation projects, characterizing performance using methods developed in SHC Task 28.
- Assess the adaptability of new energy supply systems, including renewable energy systems, as part of comprehensive renovation packages.
- Analyze new products and concepts for advanced housing renovations and provide manufacturers feedback to optimize products.
- Develop and publicize optimized renovation concept packages

### **Subtask D: Environmental Impact Assessment (Lead country: Belgium)**

The Subtask will piece together quantifiable and qualitative results to obtain a comprehensive picture of the effectiveness of housing renovation approaches. It will assess the impact of the approaches taken in a selection of advanced housing renovation projects on:

- the environment
- the (urban) infrastructure
- health, safety and quality of life.

### **Task Deliverables**

The results of the Task will be brochures and technical reports describing:

- Housing segments with the greatest multiplication and energy saving potentials [A].
- Design and performance of exemplary renovation projects, describing benefits, process and motivations [B]
- Packages of technically and economically robust concepts for housing renovation which could be applied in concrete projects [C]
- Innovative future solutions with great potential of primary energy reduction [C]
- A “basics” on sustainable renovation including principles for the design and realization of renovation projects, connecting the technical point of view at the project scale to factors of a larger scale (environment and resources, infrastructure and equipment, health and well-being) [D]
- Strategies for increased market penetration of housing renovation in selected market segments [A]

### **Duration**

The Task was initiated on July 1, 2006 and will be completed on December 31, 2009.

## **ACTIVITIES DURING 2007**

Two Task Expert meetings were held in 2007, April in Wallisellen Switzerland and November in Vienna. A workshop on exemplary housing renovation projects took place in connection with the Wallisellen meeting. Twelve demonstration projects were presented from Austria, Denmark, Netherlands, Norway, Sweden and Switzerland.

The workshop was also attended by a film team who is contracted by the Norwegian State Housing Bank to make a film about exemplary European housing renovation projects. Task 37 demonstration projects will be included. It is expected that the English version which should be used to present and promote the work of task 37, will be ready during the spring 2008.

A Task 37 flyer has been developed and can be downloaded from the web-site, [www.iea-shc.org/task37](http://www.iea-shc.org/task37)

The second version of the Task 37 glossary has been presented. This will include definitions (floor area etc.), primary energy factors, economics, life spans on the different technologies etc. The glossary is intended as a task 37 working document.

Twelve brochures of exemplary renovation projects have been made and will be available from the public web-site early 2008.

Four thematically topics regarding ventilation solutions, construction details, energy terminology and cross analysis methodology were addressed in Subtask C. First monitored projects are evaluated and results were presented. Most of the projects chosen are delayed, but still on the time frame of the task.

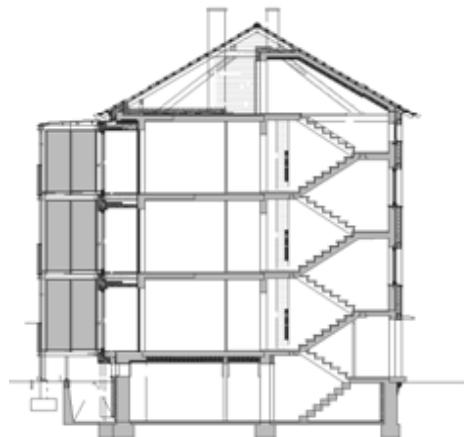
An intermediate Expert meeting dealing with thermal bridge solutions was held and a methodology and preliminary layout was presented by German experts. It was identified, that air tightness is linked strongly to the thermal bridges but should be treated separately.

Several realized ventilation solutions in the demonstration projects and new concepts were presented as well as new test procedures. A preliminary layout of the ventilation study and a proposal for a design guideline for ventilation in housing renovation was presented. A set of different solutions will be documented and published mid 2008. A study on integration of solar thermal systems in existing heating supply structures was presented.



### **Belgium Rowhouse Henz-Noirfalise**

This 150 year old house needed a thorough renovation. The exterior was insulated with cellulose, new triple glazed windows were installed, the building is heated with solar collectors and pellets stove. Energy reduction was 95%.



### **German Apartment Building in Freiburg**

Two apartment buildings were built in 1961. Renovations included additional insulation, new windows and solar water heating systems. Energy reductions achieved were 87% in one of the buildings and 80% in the other building.



### **Swiss Apartment Building in Staufen**

Apartment was renovated in two stages, 1. building envelope and 2. building services. An Air to water heat pump was installed, 110 m<sup>2</sup> PV array installed with a nominal output of 14,7 kWp, amortized within 20 years. Energy reduction was 65%.

## **WORK PLANNED FOR 2008**

Internet meetings will be organized early in 2008 to discuss similarities between the national building stock analyses, and the conclusions from the work will be presented at the April expert meeting.

The work on market strategies and communication plans will continue during 2008. The pace of the cooperation is dependent of the progress in the involved national strategy projects. Until the next expert meeting, analyses and selection of strategies will need to be completed for some of the projects in order to match the planned schedule. During the fall, Subtask A will invite industry representatives to a workshop in connection with the expert meeting in Norway.

Subtask B will start the cross analysis of the projects which have been documented as brochures. Skeleton for publishing the set of buildings, cross comparisons and lessons learned will be discussed at the next meetings. More exemplary renovation brochures will be made.

Subtask C will continue the work on producing web based publications on different building renovation techniques and concepts. A draft on whole building concept analysis and new technology assessment and a thermal bridge catalog will be presented at the spring meeting. A set of different ventilation solutions will be documented and published by mid 2008. Energy supply technologies and systems will be the main focus in the Fall 2008 meeting.

A web-based model for calculation of energy potential of different renovation levels for different typologies of buildings has been presented. This could be a basis for a more general task 37 model and will be further elaborated.

Subtask D is working on the sustainable renovation booklet. In connection with the April expert meeting, an afternoon workshop will be organized were the booklet will be presented and the expert team from Belgium will present an example of a renovation project where both energy savings as well as other sustainability principles (materials, water savings, waste management etc.) have been taken into account. The workshop will be open for interested experts outside task 37.

## **LINKS WITH INDUSTRY**

One third of the Task experts are representing companies and organizations working very close with the housing industry.

The Task will focus on marketable technical solutions, and the market strategies will help the market players to identify the most promising housing segments with the highest potential for renovation projects.

There are also links with the housing industry on the national level. As an example, Norway has established a national Task 37 project. This is organized as a collaborative effort with more than 15 stakeholders from the building sector working together with the Norwegian Task 37 experts. These stakeholders are both manufacturers, consultancies, building contractors, housing cooperatives and local authorities.

## **REPORTS PUBLISHED IN 2007**

A Task 37 flyer is available for downloading on the web-site.

## **REPORTS PLANNED FOR 2008**

- Several brochures of Task 37 demonstration projects will be available from the public web-site.
- The final results from the building stock analyses will be reported in the spring.
- First solution sets published on the web before summer.
- First draft of the booklet “Sustainable renovation basics” will be presented in April.

## **MEETINGS IN 2007**

### **2<sup>nd</sup> Experts Meeting**

17-18 April

Wallisellen, Switzerland

### **Subtask B workshop**

16. April

Wallisellen, Switzerland

### **3<sup>rd</sup> Experts Meeting**

17-18 October

Vienna, Austria

## **MEETINGS PLANNED FOR 2008**

### **4<sup>th</sup> Experts Meeting**

16-18 April

Rotterdam, The Netherlands

In connection to this meeting, a Subtask D workshop on sustainable renovation projects will be held on the 16<sup>th</sup> for invited architects and other key representatives from the building industry.

### **5<sup>th</sup> Experts Meeting**

September/October

Norway

A national renovation workshop with task 37 key experts will be organized in connection to the expert meeting.

## **TASK 37 NATIONAL CONTACTS**

### **Operating Agent**

Fritjof Salvesen  
KanEnergi AS  
Hoffsveien 13  
0275 Oslo, Norway  
[fs@kanenergi.no](mailto:fs@kanenergi.no)

Herbert Greisberger  
Österreichische Gesellschaft fur Umwelt  
und Technik  
Hollandstrasse 10/46  
A-1020 Wien, Austria  
[office@oegut.at](mailto:office@oegut.at)

### **Subtask Leaders**

#### **Subtask A**

Are Rødsjø  
Norwegian State Housing Bank  
Peter Egges Plass 2  
7005 Trondheim, Norway  
[are.rodsjo@husbanken.no](mailto:are.rodsjo@husbanken.no)

Anita Preisler  
Arsenal Research  
A-1210 Wien, Austria  
[anita.preisler@arsenal.ac.at](mailto:anita.preisler@arsenal.ac.at)

#### **Subtask B**

Robert Hastings  
AEU GmbH  
Bahnhofstrasse 26  
CH 8304 Wallisellen, Switzerland  
[robert.hastings@aeu.ch](mailto:robert.hastings@aeu.ch)

Wolfgang Streicher  
Graz University of Technology  
Inffeldgasse 25B  
A-8010 Graz, Austria  
[w.streicher@tugraz.at](mailto:w.streicher@tugraz.at)  
Waldemar Wagner  
AEE INTEC  
Feldgasse 19  
A-8200 Gleisdorf, Austria  
[w.wagner@aee.at](mailto:w.wagner@aee.at)

#### **Subtask C**

Sebastian Herkel  
Fraunhofer - Inst. Solar Energy Systems  
Heidenhofstrasse 2  
79110 Freiburg, Germany  
[sebastian.herkel@ise.fraunhofer.de](mailto:sebastian.herkel@ise.fraunhofer.de)

**Belgium**  
Andre De Herde  
Université Catholique de Louvain  
Place du Levant. No.1 Bat. Vinci  
B-1348 Louvain-la-Neuve, Belgium  
[andre.deherde@uclouvain.be](mailto:andre.deherde@uclouvain.be)

#### **Subtask D**

Sophie Trachte  
Free-lance for Architecture et Climat  
Avenue Coghen, 140  
1180 Brussels, Belgium  
[trachte@arch.ucl.ac.be](mailto:trachte@arch.ucl.ac.be)

Wouter Hilderson  
Passiefhuis-Platform vzw  
Gitschotellei 138  
B-2600 Berchem, Belgium  
[wouter.hilderson@passiefhuisplatform.be](mailto:wouter.hilderson@passiefhuisplatform.be)

### **Participants**

#### **Austria**

Thomas Mach  
Graz University of Technology  
Inffeldgasse 25B  
A-8010 Graz, Austria  
[thomas.mach@tugraz.at](mailto:thomas.mach@tugraz.at)

Caroline Kints  
Université Catholique de Louvain  
Place du Levant. No.1 Bat. Vinci  
B-1348 Louvain-la-Neuve, Belgium  
[kints@arch.ucl.ac.be](mailto:kints@arch.ucl.ac.be)

Erwin Mlecnik  
Passiefhuis-Platform vzw  
Gitschotellei 138  
B-2600 Berchem, Belgium  
[erwin.mlecnik@passiefhuisplatform.be](mailto:erwin.mlecnik@passiefhuisplatform.be)

Sabrina Prieus  
Belgian Building Research Institute  
Department Building Physics and  
Equipments, Division Energy and Climate  
Avenue Pierre Holoffe 21  
1342 Limelette, Belgium  
[sabrina.prieus@bbri.be](mailto:sabrina.prieus@bbri.be)

Jeroen Vrijders  
Belgian Building Research Institute  
Department Building Physics and  
Equipments, Division Energy and Climate  
Avenue Pierre Holoffe 21  
1342 Limelette, Belgium  
[jeroen.vrijders@bbri.be](mailto:jeroen.vrijders@bbri.be)

**Canada**  
Anil Parekh  
CANMET Energy Technology Centre -  
Natural Resources Canada  
580 Booth Street, 13 A9  
Ottawa, Ontario, Canada, K1A 0E4  
[AParekh@NRCan.gc.ca](mailto:AParekh@NRCan.gc.ca)

Paul Parker  
University of Waterloo; Fac. of  
Environmental Studies  
200 University Avenue  
Waterloo ON, Canada N2T 1G3  
[pparker@uwaterloo.ca](mailto:pparker@uwaterloo.ca)

**Denmark**  
Olaf Bruun Jørgensen  
Esbensen Rådgivende Ingenører A/S  
Carl Jacobsens Vej 25D  
2500 Valby, Denmark  
[o.b.joergensen@esbensen.dk](mailto:o.b.joergensen@esbensen.dk)

**Finland**  
Mia Ala-Juusela  
VTT  
P.O.Box 1000  
FI 02044 VTT, Finland  
[mia.ala-juusela@vtt.fi](mailto:mia.ala-juusela@vtt.fi)

**Germany**  
Florian Kagerer  
Fraunhofer - Inst. Solar Energy Systems  
Heidenhofstrasse 2  
79110 Freiburg, Germany  
[florian.kagerer@ise.fraunhofer.de](mailto:florian.kagerer@ise.fraunhofer.de)

Berthold Kaufmann  
Passivhaus Institut  
Rheinstr. 44/46  
64283 Darmstadt, Germany  
[berthold.kaufmann@passiv.de](mailto:berthold.kaufmann@passiv.de)

Johann Reiss  
Fraunhofer - Inst. Bauphysik  
Nobelstrasse 12  
70569 Stuttgart, Germany  
[re@ibp.fraunhofer.de](mailto:re@ibp.fraunhofer.de)

**Italy**  
Valerio Calderaro  
University La Sapienza of Roma  
Via Flaminia 70  
Rome, Italy  
[valerio.calderaro@uniroma1.it](mailto:valerio.calderaro@uniroma1.it)

**Netherlands**  
Chiel Boonstra  
DHV B.V.  
P.O. Box 80007  
5600 JZ Eindhoven, Netherlands  
[chiel.boonstra@dhv.nl](mailto:chiel.boonstra@dhv.nl)

Erik Franke  
Franke Architekten B.V.+ Dutch  
PassiefHuis Holland  
Postbus 151  
3360 AD Sliedrecht, Netherlands  
[e.franke@frankearchitekten.nl](mailto:e.franke@frankearchitekten.nl)

Henk F. Kaan  
ECN Energy Research Centre of the  
Netherlands  
P.O. Box 1, Westerduinweg 3  
1755 ZG Petten, 1755 LE Petten,  
Netherlands  
[kaan@ecn.nl](mailto:kaan@ecn.nl)

Ivo J. Opstelten  
ECN Energy Research Centre of the  
Netherlands  
P.O. Box 1, Westerduinweg 4  
1756 ZG Petten, 1755 LE Petten,  
Netherlands  
[opstelten@ecn.nl](mailto:opstelten@ecn.nl)

Edward Prendergast  
moBius consult  
Diederichslaan 2  
3971 PC Driebergen, Netherlands  
[Edward@moBiusconsult.nl](mailto:Edward@moBiusconsult.nl)

### New Zealand

Albrecht Stoecklein  
Meridian Efficiency  
11-13 Walter Street  
Wellington, New Zealand  
[albrecht.stoecklein@meridianenergy.co.nz](mailto:albrecht.stoecklein@meridianenergy.co.nz)

### Norway

Tor Helge Dokka  
SINTEF Buildings and Infrastructure  
Budstikka 18  
3612 Kongsberg, Norway  
[Tor.H.Dokka@sintef.no](mailto:Tor.H.Dokka@sintef.no)

Trond Haavik  
Segel AS  
Box 284  
6770 Nordfjordeid, Norway  
[trond.haavik@segel.no](mailto:trond.haavik@segel.no)

Pål Guthorm Kavli  
Norwegian State Housing Bank  
Peter Egges Plass 2  
7005 Trondheim, Norway  
[pal.kavli@husbanken.no](mailto:pal.kavli@husbanken.no)

Michael Klinski  
Norwegian State Housing Bank  
P.O. Box 1243 Vika  
0110 Oslo, Norway  
[michael.klinski@husbanken.no](mailto:michael.klinski@husbanken.no)

Gry Kongslí  
Norwegian State Housing Bank  
Peter Egges Plass 2  
7005 Trondheim, Norway  
[gry.kongslí@husbanken.no](mailto:gry.kongslí@husbanken.no)

Trine Pettersen  
SINTEF Buildings and Infrastructure  
P.O. Box 124 Blindern  
0314 Oslo, Norway  
[trine.pettersen@sintef.no](mailto:trine.pettersen@sintef.no)

Marit Thyholt  
SINTEF Buildings and Infrastructure  
7465 Trondheim, Norway  
[marit.thyholt@sintef.no](mailto:marit.thyholt@sintef.no)

### Sweden

Ulla Janson  
Lund University - Energy and Building  
Design  
Box 118  
SE-221 00 Lund, Sweden  
[ulla.janson@ebd.lth.se](mailto:ulla.janson@ebd.lth.se)

Henrik Sundqvist  
Skanska Sweden AB/Skanska Technology  
Drottningtorget 14  
20533 Malmö, Sweden  
[henrik.sundqvist@skanska.se](mailto:henrik.sundqvist@skanska.se)

## **SHC TASK 38: SOLAR AIR-CONDITIONING AND REFRIGERATION**

*Hans-Martin Henning  
Fraunhofer Institute for Solar Energy Systems  
Operating Agent for Forschungszentrum Jülich GmbH*

### **TASK DESCRIPTION**

In many regions of the world room air-conditioning is responsible for the dominant part of electricity consumption of buildings. Electrically driven chillers cause high electricity peak loads in electricity grids, even if systems are used that reached a relatively high standard concerning energy consumption. This is becoming a growing problem in regions with cooling dominated climates.

The main objective of SHC Task 38, Solar Air-Conditioning and Refrigeration, is the implementation of measures for an accelerated market introduction of solar air conditioning and refrigeration with a major focus on improved components and system concepts. The market introduction will be supported through:

- Activities in development and testing of cooling equipment for the residential and small commercial sector.
- Development of pre-engineered system concepts for small and medium size systems and development of optimized and standardized schemes for custom made systems.
- Reports on the experiences with new pilot and demonstration plants and on the evaluation and performance assessment procedure.
- Provision of accompanying documents supporting the planning, installation and commissioning of solar cooling plants.
- Analysis of novel concepts and technologies with special emphasis on thermodynamic principles and a bibliographic review.
- Performance comparison of available simulation tools and applicability for planning and system analysis.
- Market transfer and market stimulation activities, which include information letters, workshops and training material as well as the 2<sup>nd</sup> edition of the Handbook for Solar Cooling for Planners.

The task is organized with four Subtasks:

- Subtask A: Pre-engineered systems for residential and small commercial applications  
*(Lead country: Austria)*

The objective of Subtask A is to support measures for the development of small and medium size pre-engineered systems, characterized by:

- Cooling capacity < 20 kW.
- A high degree of pre-fabrication of the entire system.
- No additional effort in planning is required for this type of systems.
- Pre-engineered systems, consisting in general of solar collector, storage, back-up system, chiller, heat rejection and control unit as the main components, can be connected directly to the room components by the installer.

- Subtask B: Custom-made systems for large non-residential buildings and industrial applications (*Lead Country: Italy*)

The objective of Subtask B is to overcome the main technology related barriers for a wider implementation of medium and large scale systems for solar assisted cooling, characterized by:

- cooling capacity > 20 kW.
- Individually planned systems for the particular application with involvement of planning engineers.
- Call for tender typically for single components and not for the system as a whole.

The target markets will be large air-conditioning and refrigeration end-users (large office and other non-residential buildings, hotels, industry etc.).

- Subtask C: Modeling and fundamental analysis (*Lead Country: France*)

The main objectives of Subtask C are:

- Further development and examination of new and already existing component models and simulation tools with special regards to their applicability to different stages of the layout process
- Evaluation of novel and advanced solar cooling concepts which are still in a state of R&D and not yet ready for installation and market introduction.

- Subtask D: Market transfer activities (*Lead Country: Italy*)

The main objectives of Subtask D are:

- To identify promising markets for solar air-conditioning and refrigeration technology and
- To ensure that the findings of the Task work are transferred to the important target audiences.

One of the major results with input from work of the entire Task will be a 2<sup>nd</sup> edition of the Handbook for Solar Cooling for Planners.

## Main Deliverables

The results of the Task will be technical reports and tools like the followings:

- State-of-the-art report describing market available cooling equipment in the desired capacity range in a comparative and standardized way
- Installation and maintenance guidelines for pre-engineered/package systems
- Overview of market available thermally driven cooling technologies and suitable new solar components
- Soft tool package for the fast pre-design assessment of successful projects
- Analysis tools for the theoretical and technical assessment of new concepts
- Technical report with developed certification and standardization schemes
- Second edition of the Solar Cooling Handbook for Planners

## Duration

The Task started September 1, 2006 and will be completed August 31, 2009.

## **ACTIVITIES DURING 2007**

- The second expert meeting was held April 23-25 in Aix-Les-Bains, hosted by INES. 63 experts attended the meeting at which the first intermediate results were presented and further work steps planned.
- A workshop “Solar Air-Conditioning and Refrigeration” was held after the second expert meeting on April 25 in Aix-les-Bains/France. Topics of the presentations based on the first results of Task 38 were new developments, market status and experiences from various installations and design studies. About 35 external participants, mainly from France, and about 40 members of the Task 38 attended the workshop.
- The third expert meeting was held on October 15-17 in Barcelona, hosted by AIGUASOL. 78 experts attended the meeting at which the intermediate results were presented and further work steps planned.
- A workshop “Solar Air-Conditioning and Refrigeration” was held before the third expert meeting on October 15. The workshop included presentations concerning technologies and recent experiences with installed systems as well as presentations on costs, economic analysis and market. 42 external participants from Spain attended the workshop.

## **WORK PLANNED FOR 2008**

### **In General**

In connection with the 4<sup>th</sup> Expert Meeting in Vienna/Austria in April 2007, a one-day IEA-SHC-Conference on Solar Cooling will be organized for local professionals and R&D experts. At this conference, the results of the ROCCOCO project will be presented.

The 5th expert meeting on October 6-7 in Lisbon, Portugal will be held before the EuroSun 2008. Task experts will contribute to the EuroSun 2008, held in Lisbon, Portugal from October 7-10.

The following work planned in the different Subtasks

### **Subtask A: Pre-Engineered Systems for Residential and Small Commercial Applications**

- Overview on Solar combisystems
- Draft report on generic system concepts
- Report list of monitored small systems
- Template and guideline for data collection of monitored systems and presenting of first monitoring results
- Report on evaluation procedures
- Draft template for installation and maintenance guidelines
- Survey on market available equipment suitable for small-scale systems.

## **Subtask B: Custom-Made Systems for Large Non-Residential Buildings and Industrial Applications**

- Draft guidelines for system design and control as well as for installation, commissioning and for call for tender
- Survey on market available equipment suitable for large-scale systems and overview on pilot installations.
- Outline of a common monitoring scheme in order to ensure that proper evaluation of systems and comparison
- Presentation of first monitoring results
- Presentation of application results of the fast pre design tool

## **Subtask C: Modeling and Fundamental Analysis**

- Technical review of new solar cooling developments
- Report "New developments in simulation tools" suitable for solar cooling and air-conditioning and first validation with experimental facilities
- Technical report explaining the methodology and advantages of the exergy analysis
- Presentation of new concepts of heat rejection.

## **Subtask D: Market Transfer Activities**

- Report on overall performance and cost assessment methodology
- Report on life cycle assessment
- Draft chapters of the second edition of Solar cooling handbook for planners
- Elaboration of training material for installers and planners
- Organization of industry workshops
- Newsletter for the industry

## **LINKS WITH INDUSTRY**

A number of the Task experts are representing companies active either on planning and installation of solar thermal systems or manufacture of key components such as thermally driven cooling systems. In addition, many involved R&D institutes are closely co-operating with companies, mainly start-up companies, active in developing new small-scale thermally driven cooling machines (water chillers, open cycle systems). The Task also contributes to workshops addressing professionals working in the design and installation of HVAC and solar systems for buildings.

## **REPORTS PUBLISHED IN 2007**

No reports have been finalized in 2007 which are available to the public.

## **REPORTS PLANNED FOR 2008**

- Report of selected systems schemes (generic systems)
- Report on system design and control for large scale systems

- Report on performance assessment methodology as well as on life cycle assessment

## **MEETINGS IN 2007**

### **2<sup>nd</sup> Experts Meeting**

April 23-24

Aix-les-bains, France.

*In connection with this meeting, a one-day workshop on Solar Air-Conditioning and Refrigeration and Summer Comfort was organized for local professionals and R&D experts on April 25.*

### **3<sup>rd</sup> Experts Meeting**

October 15-17

Barcelona, Spain.

*In connection with this meeting, a public workshop Solar Air-Conditioning and Refrigeration was organized on October 15.*

## **MEETINGS PLANNED FOR 2008**

### **4<sup>th</sup> Experts Meeting**

April 1-2

Vienna, Austria

*In connection with the ROCCOCO/IEA-SHC-Conference on Solar Cooling on March 31.*

### **5<sup>th</sup> Experts Meeting**

October 6-7

Lisbon, Portugal

Task experts will contribute to EuroSun 2008, in Lisbon, Portugal from October 7-10.

## TASK 38 NATIONAL CONTACTS

### Operating Agent

Hans-Martin Henning  
Fraunhofer Institut für Solare  
Energiesysteme  
Heidenhofstr.2  
79110 Freiburg, Germany  
[hans-martin.henning@ise.fraunhofer.de](mailto:hans-martin.henning@ise.fraunhofer.de)

### Leader Subtask A

Alexander Thür as deputy for Dagmar  
Jähnig  
AEE INTEC, AEE - Institute for  
Sustainable Technologies  
Feldgasse 19  
A-8200 Gleisdorf, Austria  
[a.thuer@aee.at](mailto:a.thuer@aee.at)

### Leader Subtask B

Wolfram Sparber  
EURAC research  
Viale Druso/Drususallee 1  
39100 Bolzano/Bozen, Italy  
[wolfram.sparber@eurac.edu](mailto:wolfram.sparber@eurac.edu)

### Leader Subtask C

Etienne Wurtz  
Institut National d'Energie Solaire  
50, avenue du lac Léman BP 332  
73375 Le Bourget du Lac Cedex, France  
[ewurt@univ-savoie.fr](mailto:ewurt@univ-savoie.fr)

### Leader Subtask D

Mario Motta  
Politecnico di Milano  
Dip. Energetica  
Piazza Leonardo da Vinci 32,  
20133, Milano, Italy  
[mario.motta@polimi.it](mailto:mario.motta@polimi.it)

### Australia

Paul Kohlenbach, Steven D. White  
CSIRO Division of Energy Technology  
PO Box 330  
Newcastle, NSW, 2300  
[paul.kohlenbach@csiro.au](mailto:paul.kohlenbach@csiro.au)  
[Stephen.D.White@csiro.au](mailto:Stephen.D.White@csiro.au)

### Wasim Saman

University of South Australia  
Division of Information Technology,  
Engineering and the Environment  
The Mawson Centre  
Mawson Lakes 5095  
[wasim.saman@unisa.edu.au](mailto:wasim.saman@unisa.edu.au)

### Warwick Johnston

ClimateManagers  
Melbourne  
PO Box 782  
Port Melbourne VIC 3207  
[warwick.johnston@climatemanagers.com](mailto:warwick.johnston@climatemanagers.com)

### Jean-Luc Godillion

Energy Conservation Systems  
209 Sandgate road  
Albion, QLD 4010  
[j.godillion@escaustralia.com](mailto:j.godillion@escaustralia.com)

### Austria

Dagmar Jähnig, Alexander Thür, Erich  
Podesser  
AEE INTEC, AEE - Institute for  
Sustainable Technologies  
Feldgasse 19  
A-8200 Gleisdorf  
[d.jaehnig@aee.at](mailto:d.jaehnig@aee.at)  
[a.thuer@aee.at](mailto:a.thuer@aee.at)  
[erich.podesser@utanet.at](mailto:erich.podesser@utanet.at)

### Tim Selke, Dong-Seon Kim

Arsenal Research  
Business Field Sustainable Energy Systems  
Giefinggasse 2  
1210 Wien  
[tim.selke@arsenal.ac.at](mailto:tim.selke@arsenal.ac.at)  
[don-seon.king@arsenal.ac.at](mailto:don-seon.king@arsenal.ac.at)

### Hilbert Focke, Gerald Steinmaurer

ASIC- Austria Solar Innovation Center  
Durisolstraße 7/Top 50  
4600 Wels  
[focke.hilbert@asic.at](mailto:focke.hilbert@asic.at)  
[steinmaurer.gerald@asic.at](mailto:steinmaurer.gerald@asic.at)

Horst Striessnig, Philip Ohnewein, and  
Christian Holter  
S.O.L.I.D. Gesellschaft für Solarinstallation  
und Design m.b.H.  
Puchstraße 85  
8020 Graz  
[p.ohnewein@solid.at](mailto:p.ohnewein@solid.at)  
[h.striessnig@solid.at](mailto:h.striessnig@solid.at)  
[c.holter@solid.at](mailto:c.holter@solid.at)

Wolfgang Streicher, Harald Moser  
Institute of Thermal Engineering  
Graz University of Technology  
Inffeldgasse 25, 8010 Graz, Austria  
[w.streicher@tugraz.at](mailto:w.streicher@tugraz.at)  
[harald.moser@tugraz.at](mailto:harald.moser@tugraz.at)

### **Canada**

Lúcio Mesquita, Steve Harrison, and  
Marcus Jones  
Queens University - Department of  
Mechanical and Material Engineering  
Kingston, ON  
[mesquita@me.queensu.ca](mailto:mesquita@me.queensu.ca)  
[harrison@me.queensu.ca](mailto:harrison@me.queensu.ca)  
[jones@me.queensu.ca](mailto:jones@me.queensu.ca)

### **Denmark**

Klaus Ellehauge  
Ellehauge & Kildemoes  
Vestergade 48H, 2.tv.  
8000 Århus C  
[klaus.ellehauge@elle-kilde.dk](mailto:klaus.ellehauge@elle-kilde.dk)

Søren Ø. Jensen, Claus S. Poulsen, and  
Lars Reinholdt  
Danish Technological Institute  
Refrigeration and Heat Pump Technology  
Teknologiparken  
Kongsvang Allé 29  
DK-8000 Aarhus C  
[soren.o.jensen@teknologisk.dk](mailto:soren.o.jensen@teknologisk.dk)  
[claus.s.poulsen@teknologisk.dk](mailto:claus.s.poulsen@teknologisk.dk)  
[lars.reinholdt@teknologisk.dk](mailto:lars.reinholdt@teknologisk.dk)

Søren Minds  
AC-Sun  
Rudolfsgaardsvej 19  
DK-8260 Viby J  
[smi@ac-sun.com](mailto:smi@ac-sun.com)

Ebbe Münster, Per Alex Sørensen  
PlanEnergi  
Jyllandsgade 1  
DK 9520 Skørping  
[em@planenergi.dk](mailto:em@planenergi.dk)  
[jen@planenergi.dk](mailto:jen@planenergi.dk)  
[pas@planenergi.dk](mailto:pas@planenergi.dk)

### **France**

Etienne Wurtz, Nolwenn Le Pierrès  
INES - Université de Savoie  
BP 332 - Savoie Technolac  
50 Avenue du Lac Léman  
F-73377 Le Bourget du Lac  
[Etienne.Wurtz@univ-savoie.fr](mailto:Etienne.Wurtz@univ-savoie.fr)  
[nolwenn.le-pierres@univ-savoie.fr](mailto:nolwenn.le-pierres@univ-savoie.fr)

Nadège Chatagnon  
EDF R&D  
Department EnerBat  
Site des Renardières - Ecuelles  
77 818 Moret-sur-Loing  
[nadege.chatagnon@edf.fr](mailto:nadege.chatagnon@edf.fr)

Daniel Mugnier, Amandine Le-Denn ,and  
Jean-Yves Quinette  
TECSOL SA.  
105 av Alfred Kastler - BP 90434  
66 004 PERPIGNAN Cedex  
[daniel@tecsol.fr](mailto:daniel@tecsol.fr)  
[amandine.le-denn@tecsol.fr](mailto:amandine.le-denn@tecsol.fr)  
[jyq@tecsol.fr](mailto:jyq@tecsol.fr)

Paul Bourdoukan  
LEPTAB - University of La Rochelle  
[paul.bourdoukan@univ-lr.fr](mailto:paul.bourdoukan@univ-lr.fr)

Thibaut Vitte, Monika Woloszyn  
CETHIL - UCBL/INSA Lyon/CNRS  
[thibaut.vitte@insa-lyon.fr](mailto:thibaut.vitte@insa-lyon.fr)  
[monika.woloszyn@insa-lyon.fr](mailto:monika.woloszyn@insa-lyon.fr)

### **Germany**

Alexander Morgenstern, Edo Wiemken  
Fraunhofer Institut für Solare  
Energiesysteme  
Heidenhofstr.2  
79110 Freiburg  
[alexander.morgenstern@ise.fraunhofer.de](mailto:alexander.morgenstern@ise.fraunhofer.de)  
[edo.wiemken@ise.fraunhofer.de](mailto:edo.wiemken@ise.fraunhofer.de)

Reiner Buchholz, Felix Ziegler  
Technische Universität Berlin  
Institut für Energietechnik  
Marchstraße 18  
D-10587 Berlin  
[reiner.buchholz@tu-berlin.de](mailto:reiner.buchholz@tu-berlin.de)  
[felix.ziegler@tu-berlin.de](mailto:felix.ziegler@tu-berlin.de)

Uli Jacob, Sven Saulich  
Solarnext AG  
Nordstr. 10  
83253 Rimsting  
[uli.jakob@solarnext.de](mailto:uli.jakob@solarnext.de)  
[sven.saulich@solarnext.de](mailto:sven.saulich@solarnext.de)

Roland Heinzen  
Institute of Thermal Engineering  
University of Kassel  
Kurt-Wolters-Str. 3  
34125 Kassel  
[heinzen@uni-kassel.de](mailto:heinzen@uni-kassel.de)

Christian Schweigler  
ZAE Bayern  
Walther-Meißner-Str. 6  
85748 Garching  
[schweigler@muc.zae-bayern.de](mailto:schweigler@muc.zae-bayern.de)

Peter Noeres  
Fraunhofer Umsicht  
Osterfelder Str. 3  
D-46047 Oberhausen  
[noe@umsicht.fhg.de](mailto:noe@umsicht.fhg.de)

Uwe Franzke  
ILK Dresden GmbH  
Bertolt-Brecht-Allee 20  
01309 Dresden  
[uwe.franzke@ilkdresden.de](mailto:uwe.franzke@ilkdresden.de)

Thomas Brendel, Marco Zetsche  
Universität Stuttgart, Institut für  
Thermodynamik und Wärmetechnik  
(ITW)  
[task38@itw.uni-stuttgart.de](mailto:task38@itw.uni-stuttgart.de)

**Italy**  
Marco Calderoni  
Ambiente Italia srl  
Via Carlo Poerio 39  
20129 Milano  
[marco.calderoni@ambienteitalia.it](mailto:marco.calderoni@ambienteitalia.it)

Wolfram Sparber, Francesco Besana, and  
Assunta Napolitano  
EURAC Research  
European Academy Bolzano  
Viale Druso/Drususallee 1  
39100 Bolzano/Bozen  
[wolfram.sparber@eurac.edu](mailto:wolfram.sparber@eurac.edu)  
[francesco.besana@eurac.edu](mailto:francesco.besana@eurac.edu)  
[assunta.napolitano@eurac.edu](mailto:assunta.napolitano@eurac.edu)

Mario Motta, Marcello Aprile, and Michele  
Liziero  
Politecnico di Milano  
Dip. Energetica  
Piazza Leonardo da Vinci 32,  
20133, Milano  
[mario.motta@polimi.it](mailto:mario.motta@polimi.it)  
[aprile.marcello@polimi.it](mailto:aprile.marcello@polimi.it)  
[michele.liziero@polimi.it](mailto:michele.liziero@polimi.it)

Marco Beccali, Pietro Finocchiaro and  
Bettina Nocke  
University of Palermo  
Viale delle Scienze 9  
90128 Palermo  
[marco.beccali@dream.unipa.it](mailto:marco.beccali@dream.unipa.it)  
[pietro.finocchiaro@dream.unipa.it](mailto:pietro.finocchiaro@dream.unipa.it)  
[bettina@dream.unipa.it](mailto:bettina@dream.unipa.it)

Sufia Jung, Andrea Cagni  
OLYMP ITALIA SRL  
Via Orbassano, 16  
10090 Bruino, Italy  
[olympitalia@olympitalia.it](mailto:olympitalia@olympitalia.it)  
[andrea.cagni@libero.it](mailto:andrea.cagni@libero.it)

Rajendra S. Adhikari  
Politecnico di Milano  
Dept. Building Environment Sciences &  
Technology (BEST)  
Via Garofalo 39  
20133 Milano, Italy  
[rajendra.adhikari@polimi.it](mailto:rajendra.adhikari@polimi.it)

Luigi Marletta, Gianpero Evola  
Universita di Catania  
Dipartimento di Ingegneria Industriale e  
Meccanica (DIIM)  
Viale A. Doria 6  
95125 Catania, Italy  
[luigi.marletta@diim.unict.it](mailto:luigi.marletta@diim.unict.it)  
[gevola@unict.it](mailto:gevola@unict.it)

Tullio Pagano  
AMG Energia SpA  
Via Ammiraglio Gravina 2e  
Palermo, Italy  
[tullio.pagano@amg.pa.it](mailto:tullio.pagano@amg.pa.it)

Maurizio De Lucia  
Universita di Firenze (CREAR)  
[delucia@unifi.it](mailto:delucia@unifi.it)

Serena Drigo, Claudia Vannoni  
University of Rome La Sapienza  
Dipartimento di Meccanica e aeronautica  
[serena.drigo@gmail.com](mailto:serena.drigo@gmail.com)  
[claudia.vannoni@gmail.com](mailto:claudia.vannoni@gmail.com)

**Mexico**  
Roberto Best y Brown, Camilo Alberto  
Arancibia Bulnes, Wilfrido Rivera Gomez  
Franco, and Octavio Garcia Valladares  
CIE-UNAM (Centro de Investigacion en  
Energia,  
Universidad Nacional Autonoma de  
Mexico  
[rbb@cie.unam.mx](mailto:rbb@cie.unam.mx)  
[caab@cie.unam.mx](mailto:caab@cie.unam.mx)  
[wrgf@cie.unam.mx](mailto:wrgf@cie.unam.mx)      [ogv@cie.unam.mx](mailto:ogv@cie.unam.mx)

**Portugal**  
João Farinha Mendes, Maria Joao Carvalho  
DER/INETI, Edificio G  
Estrada do Paço do Lumiar  
1649-038 Lisboa  
[farinha.mendes@ineti.pt](mailto:farinha.mendes@ineti.pt)  
[mjao.carvalho@ineti.pt](mailto:mjao.carvalho@ineti.pt)

**Spain**  
Juan Rodriguez Santiago, Luis Angel  
Bujedo  
Fundación CARTIF  
Energy Division, Renewable Energies Area

Parque Tecnológico de Boecillo, parcela  
205  
47151 Boecillo, Valladolid  
[juarod@cartif.es](mailto:juarod@cartif.es)  
[luibui@cartif.es](mailto:luibui@cartif.es)

Laura Sisó Miró, Dani Gonzales, and  
Jaume Salom  
AIGUASOL ENGINYERIA  
Sistemes Avançats d'Energia Solar Tèrmica  
SCCL  
C/ Roger de Llúria, 29 3r 2a 08009  
Barcelona  
[laura.siso@aiguasol.coop](mailto:laura.siso@aiguasol.coop)  
[dani.gonzales@aiguasol.coop](mailto:dani.gonzales@aiguasol.coop)  
[jaume.salom@aiguasol.coop](mailto:jaume.salom@aiguasol.coop)

Marcelo Izquierdo Millán  
Instituto de Ciencias de la Construcción  
Eduardo Torroja (CSIC)  
c/ Serrano Galvache N° 4  
28033 Madrid  
[mizquierdo@ietcc.csic.es](mailto:mizquierdo@ietcc.csic.es)

Pedro Juan Martínez Beltrán  
Universidad Miguel Hernández  
Área de Máquinas y Motores Térmicos  
Dpto. Ingeniería de Sistemas Industriales  
Avenida de la Universidad  
s/n /Edificio Torreblanca)  
03202 Elche – Alicante  
[pjuan.martinez@umh.es](mailto:pjuan.martinez@umh.es)

Antonio Lecuona Neumann, Pedro  
Acisclo Rodríguez Aumente, and Raquel  
Lizarte  
Universidad Carlos III de Madrid  
Dpto. de Ingeniería Térmica y de  
Fluidos  
Avda. de la Universidad 30  
28911 Leganés, Madrid  
[lecuona@ing.uc3m.es](mailto:lecuona@ing.uc3m.es)  
[aument@ing.uc3m.es](mailto:aument@ing.uc3m.es)  
[rlizarte@ing.uc3m.es](mailto:rlizarte@ing.uc3m.es)

Bakarne Egilegor, Maider Usabiaga  
IKERLAN - Centro de investigación  
tecnológicas  
Parque Tecnológico de Álava  
Juan de la Cierva I  
01510 Miñano  
[begilegor@ikerlan.es](mailto:begilegor@ikerlan.es)  
[musabiaga@ikerlan.es](mailto:musabiaga@ikerlan.es)

Susana López, Arrate Marcaide  
Centro Tecnológico Tekniker  
Renewable Energy Unit  
Apdo. 44  
Avda. Otaola 20  
20600 Eibar · Guipúzcoa  
[slopez@tekniker.es](mailto:slopez@tekniker.es)  
[amarcaide@tekniker.es](mailto:amarcaide@tekniker.es)

José A. Ferrer Tevar  
CIEMAT  
Unidad de Eficiencia Energética en la  
Edificación  
Avenida Complutense 22  
28040 Madrid  
[ja.ferrer@ciemat.es](mailto:ja.ferrer@ciemat.es)

Maria J. Jiménez Taboada  
CIEMAT  
Unidad de Eficiencia Energética en la  
Edificación  
Plataforma Solar de Almería  
04200 Tabernas, Almería  
[mjose.jimenez@psa.es](mailto:mjose.jimenez@psa.es)

Marcos Lucena Martin  
INTA  
Ctra. San Juan del Puerto-Matalascañas  
km. 34  
21130 Mazagón,Huelva  
[lucenamm@inta.es](mailto:lucenamm@inta.es)

Amandine Gal  
Acciona Infraestructuras  
Departamento de Investigación,  
Desarrollo e Innovación  
Polígono Industrial de Alcobendas  
C/Valportillo II, 8  
28108 Alcobendas (MADRID)  
[amandgal@accionae.es](mailto:amandgal@accionae.es)

**Switzerland**  
Jacques Bony, Catherine Hildbrand, and  
Stéphane Citherlet  
HEIG-VD - School of Business and  
Engineering  
Laboratory of Solar Energetics and  
Building Physics (LESBAT)  
Route de Cheseaux I  
CH - 1400 Yverdon-les-Bains  
[stephane.citherlet@heig-vd.ch](mailto:stephane.citherlet@heig-vd.ch)  
[catherine.hildbrand@heig-vd.ch](mailto:catherine.hildbrand@heig-vd.ch)  
[jacques.bony@heig-vd.ch](mailto:jacques.bony@heig-vd.ch)

Andreas Luzzi, Paul Gantenbein  
Institut für Solartechnik SPF  
Hochschule für Technik Rapperswil HSR  
Oberseestrasse 10  
CH-8640 Rapperswil  
[andreas.luzzi@solarenergy.ch](mailto:andreas.luzzi@solarenergy.ch)  
[paul.gantenbein@solarenergy.ch](mailto:paul.gantenbein@solarenergy.ch)

## **TASK 39: POLYMERIC MATERIALS FOR SOLAR THERMAL APPLICATIONS**

*Michael Köhl  
Fraunhofer ISE  
Operating Agent for the Projektträger Jülich*

### **TASK DESCRIPTION**

The objective of this Task 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 objectives shall be achieved in the following Subtasks:

Subtask A:	Information	(Norway, Michaela Meir)
Subtask B:	Collectors	(France, Philippe Papillon)
Subtask C:	Materials	(Austria, Gernot Wallner)

#### **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.

The production of a yearly newsletter, targeted at the solar- and polymer industry, a colored flyer for promotion of the Task and the preparation of an electronic or printed handbook on polymeric materials in solar thermal applications are to be main results of this Subtask.

#### **Activities**

- Provide a state-of-the-art overview of existing applications of polymeric materials in solar thermal systems and other relevant industry sectors.
- Investigate standards, regulations and guidelines with regard to the applications of polymeric materials in solar thermal systems and building integration.
- Analyze the challenges of polymeric materials in solar thermal applications from a market perspective
- Disseminate information of the work and results in all Subtasks to a wide audience

These activities will be carried out within 4 different projects:

- Project A1: State of the art: Polymeric materials in solar thermal applications  
Project A2: Standards, regulations and guidelines

- Project A3: Challenges of polymeric materials in solar thermal applications from a market perspective  
Project A4: Dissemination of information

### **Subtask B: Collectors**

As the full potential of polymeric materials can only be used when several product functions are integrated into a single component in a fundamentally new design (in contrary to the simple substitution of materials), the work in this Subtask is based on a review and a detailed definition of technical and economic parameters for collectors and the development of novel designs of collectors.

The concept development and the following verification phase with the demonstration of examples should therewith lead to different, polymeric material oriented, collector designs. The benefits of these could be the replacement of expensive materials (e.g. copper), enhanced freedom of design, realization of cost potentials or the integration of several functions into the collector structure.

Considering the prospects of the use of polymeric materials this Subtask will focus on the following areas:

- integrated collector structure
- collector absorber for new solar thermal system designs
- thermo-syphon and storage collector systems
- unglazed collectors

The objectives of this Subtask are:

- To analyze the state-of-the-art in polymer based solar collectors and to derive and define the requirements to collectors in given applications.
- To develop concepts for easy to handle, mass producible polymer based collectors with promising prospects regarding costs.

#### **Activities**

The main activities will include a comprehensive state of the art analysis of solar collectors made from plastics and the system requirements.

In a second step, novel designs are development based on both, new system designs and new materials, for absorbers and entire collectors. Design examples will be produced in order to show the feasibility, performance, durability and cost savings.

These activities will be carried out within 2 different projects:

- B1: Integrated Collector Structure  
B2: Absorber

### **Subtask C: Materials**

Polymer engineering and science offers great potential for new products and applications, which simultaneously fulfill technological and environmental objectives as well as social

needs. The main components of a solar thermal system are the collector (glazing and absorber), pipes, fittings and pumps, and a storage unit. Polymers are already widely in use for solar thermal systems with an operating temperature range up to 30°C (water preheating and swimming pool heating). For solar thermal domestic hot water systems with intended maximum service temperatures up to 90°C only few polymeric parts and components have been developed and introduced into the market. A main reason is that efficient, spectrally selective glazed flat plate collectors reach stagnation temperatures up to about 200°C, which are not in agreement with the nominal operating temperature range of solar thermal systems for domestic hot water applications. However, if the nominal operating temperature range is ascertained, nearly any component of a collector system can be realized by commodity and engineering plastics with material costs ranging from 1 to 10 €/kg. For a solar thermal system both structural and functional materials are needed. While the main requirement of structural materials is to carry mechanical loads, and thus the mechanical properties are of prime importance, functional materials are defined as solids with special mass and/or energy transfer properties.

An important aspect of all research activities in this Subtask will be the strong focus on the performance, functionality and durability of polymer products with respect to the application in solar thermal systems. As with other materials, 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.

The objectives of this Subtask are:

- To identify appropriate products for existing commercial and novel polymeric materials with high potential (short-, mid-, and long-term) which fulfill sustainability, durability and performance requirements criteria.
- To develop, investigate and establish structure/property-correlation for both, functional polymeric materials and polymer surfaces for solar thermal applications as well as performance defined structural polymeric materials for solar thermal applications.
- To evaluate polymer processing methods for the prototype production and cost-efficient mass production for solar thermal components.

### **Activities**

- Providing information like specific property profiles of plastic materials, design approaches and processing routes to Subtasks A and B.
- Definition of parts and components of solar thermal systems to develop and investigate polymeric materials for (together with Subtasks A and B).
- Screening and evaluation of commercially available functional and structural materials for solar thermal applications.
- Formulation and preparation of novel functional and structural polymeric materials for solar thermal applications.
- Development and implementation of advanced characterization and test concepts and methods for assessment of the performance and durability that reflect the application and service relevant properties of polymeric materials in solar thermal applications.
- Investigation of the behavior of polymeric materials under service relevant loading and environmental conditions.
- Establishment of micro-structure/property/performance relationships and systematic further development and optimization of material formulations for solar thermal systems.

- Design and layout of polymeric components in solar thermal systems.
- Development and manufacturing of prototypes.
- Screening and evaluation of processing routes allowing for the mass-production of polymeric components in solar thermal systems.

Subtask C requires input from Subtasks A and B in terms of components to be developed and requirements to be fulfilled. Vice versa input to Subtasks A and B will be given to the specific properties and processing routes of plastics which are due to the macromolecular structure of polymers very different to inorganic materials, such as metal, ceramic or glass (e.g., time/temperature dependent behavior; functional properties; plastics processing).

According to the objectives the work will be carried out in the following three projects:

C1: Functional Polymeric Materials and Polymer Surfaces for Solar Thermal Applications

C2: Performance Defined Structural Polymeric Materials for Solar Thermal Applications

C3: Components and Polymer Processing

### **Duration**

The Task was initiated on October 1, 2006 and will be completed on September 30, 2010.

## **ACTIVITIES DURING 2007**

### **Subtask A: Information**

#### ***State of the Art Report: "Polymeric Materials in Solar Thermal Applications"***

Deliverable A1.1, the state of the art overview on polymeric materials in solar thermal applications was prepared in table format and is available on the password-protected Task 39 database. It includes: polymeric pool collectors, glazed collectors, small and medium sized heat stores, seasonal heat stores and advanced components. In connection with every Experts meeting, news is reported by all Task 39 partners and updates made in the database. The database also includes the product data sheets and general (review) articles. An amendment from Kassel University on elastomeric materials is available in table format. INETI provided a technical report on (polymeric) swimming-pool heating systems.

#### ***Standards, Regulations and Guidelines***

The existing test standards and the problems for polymer-based systems are under discussion. Task 39 has participants from several central collector test institutions, such as Arsenal Research, Fraunhofer ISE, INETI, ITW-Stuttgart and SPF Switzerland. Several experts have worked in 'norm committees' before. This is an excellent starting point for influencing in the revisions of norms which disfavor polymeric collectors/materials.

A task force group on 'Standards, regulations and guidelines' was formed at the Blumau Experts meeting in September 2007 and will have separate meetings starting with the next Task 39 meeting in Oslo.

Major contributions have been made by Arsenal Research on presenting the present collector test- and certification standards for all experts; further, the challenges for polymeric collectors to pass the tests procedures. Several Task 39 experts participated in

central meetings (e.g., the SolarKeymark II meeting in Vienna, and the 10th plenary meeting CEN/TC 312 Thermal Solar Systems and Components in Nicosia, Cyprus) and keep the Task 39 experts updated when actions should be taken.

### **Promising Market Sectors and Systems for the Application of Polymeric Materials**

A structure for the report of project A3 was worked out. Several Task 39 experts prepared presentations for the Task39 meeting in Blumau (see below and also newsletter 1-2007). These can be considered as valuable input for Subtasks B and C, too.

Presentations on systems, markets:

- Fraunhofer ISE: Solar thermal markets: General overview, actors and statistics
- Fraunhofer ISE: Feasibility study of polymeric solar thermal collectors with economical valuation (exists also as master thesis)
- University of Oslo: Polymers from a marked perspective, ideas for future developments
- École Polytechnique Fédérale de Lausanne: Building integrated solar thermal systems: Architectural integration issues

On polymeric collectors, components, applications (co-coordinated with Subtask B):

- University of Oslo: Life-cycle assessment of a polymeric collector compared to conventional collectors
- AEE-INTEC: Stagnation of solar heating systems a challenge for polymer materials
- Solartwin Ltd., Experiences with development of Solartwin system
- CLIPSOL/ CEA-INES: Polymeric components for solar applications
- Solar Diamant Systemtechnik GmbH: Experiences with development of BBT polymeric components
- AGRU Kunststofftechnik GmbH: Manufacturing and processing of polymeric materials for geomembranes and sheets in solar thermal applications

On materials and processing:

- Chevron Phillips Chemicals: PPS and PPS alloys: Plastics that take the heat
- University of Leoben, Injection molding of polymeric components
- EMS-Grivory: Polymer degradation under exposure of heat aging, weathering and hydrolysis

Abstracts from all presentations are included in the Task 39 newsletter 1/2007. These activities will be also supported by a new Task-force on 'Marketing and building integration' within Task 39, established at the Blumau Experts meeting.

### **Dissemination and Information**

A Glossary on 'solar thermal' and 'polymeric material' terms was prepared. After final reviews, the main parts of the glossary will be available on the public website, the complete glossary on the Task 39 database.

A Flyer was designed for emailing and will be distributed to contact lists provided by all Task 39 experts together with an electronic newsletter, which has been prepared from the presentations of Task 39 experts at the meeting in Blumau (09/2007). The IEA-SHCP-hosted public Web site is updated regularly by Subtask A.

The experts agreed to compile the results in a design handbook for polymeric solar-thermal systems. Next steps: The OA and the Subtask leaders will prepare a table of contents and

Subtask A will discuss with actual publisher(s). A first draft for the table of contents will be discussed the next Task 39 experts meeting in Oslo (04/2007).

## Subtask B: Solar Thermal Collectors

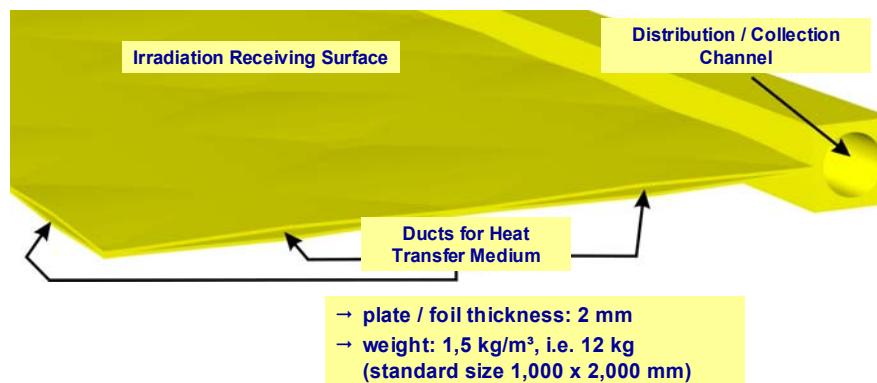
This Subtask has taken a long time to have significant results. The most dominant reasons are:

- Funding is missing,
- Confidentiality of some on-going projects,
- Difficulty to know the best way to proceed with polymeric collectors
  - low temperature, low efficiency, low prices <> high temperature, higher efficiency, higher prices
  - integrated collector structure, in order to use in the most efficient way polymeric processes <> replacement of metallic parts by polymeric parts in traditional flat plate collector

A brainstorming session during the fall meeting gave valuable inputs for the design of polymeric collectors, which will be further developed in order to define our target collectors and systems.

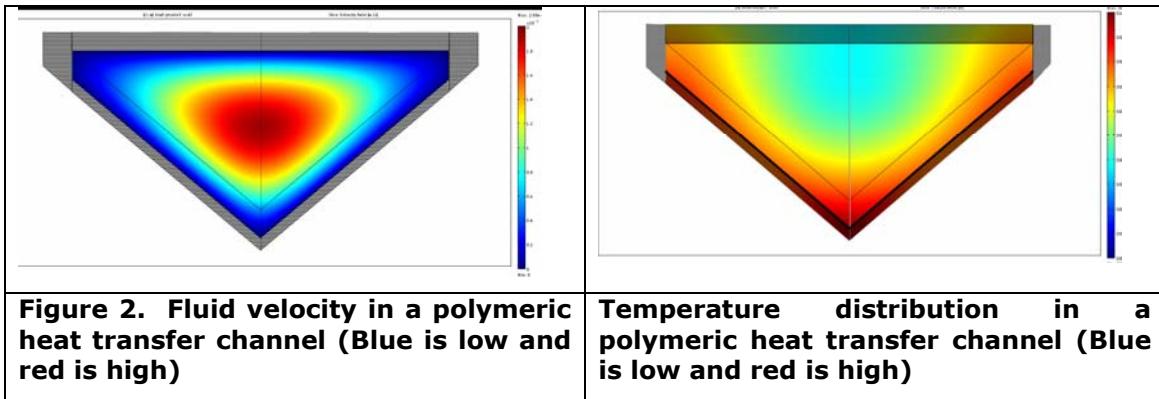
### ***Development of a Polymer Absorber***

The design principle of most of today's absorbers, the pipe/plate design using copper/copper or copper/aluminium for pipes and plates, requires a complete reengineering. There are still many thermodynamic weaknesses and problems associated with production that can be solved by using a completely different design principle, i.e. the so-called volumetric flow absorber as shown in Figure 1.



**Figure 1. Design example of polymer based volumetric flow absorber.**

Simulation tools based on Finite Elements Methods are developed in order to optimize the heat transfer channels for a partly compensation of the low heat conductivity of the polymers. Figure 2 shows the fluid velocity and the temperature distribution exemplarily for a triangular channel design.



### Subtask C: Materials

#### **Functional Polymeric Materials and Polymer Surfaces for Solar Thermal Applications**

An effective UV-protective coating is a prerequisite for the use of many polymeric materials, which are in the non-stabilized state susceptible to UV-induced degradation. The topic “UV-protected paints for unglazed absorbers” was discussed and have to be considered more comprehensively in future.

A review on thermotropic materials for overheating protection of solar-thermal collectors was provided. While in the past thermotropic hydrogels, polymer-blends and resin systems for overheating protection of passive solar-thermal systems (e.g. glazings and transparent insulation systems) were investigated, current studies are aiming on thermotropic materials based on polymer blends and resin systems with fixed domains for active solar-thermal collectors. Currently thermotropic materials with switching temperatures ranging from 55 to 100°C and hemispherical transmittance values of 85 and 55 % in the transparent and cloudy state, respectively, have been achieved. With such materials the stagnation temperature of a glazed collector with a black absorber can be limited to 120°C, which would allow for the use of cost-efficient commodity and engineering polymers.

Regarding spectrally selective absorber coatings with a polymeric matrix (binder) and a dispersed inorganic phase, the results of recent research work at NIC focusing on organic-inorganic-hybrid nanocomposite binders have been presented and discussed. Binders based on TiO<sub>2</sub> modified methacrylate substituted alkoxysilane (TiMEMO) exhibit low IR absorption, good abrasion resistance and good anti-soiling properties.

#### **Performance Defined Structural Polymeric Materials for Solar Thermal Applications**

One activity focusing on the ageing behavior of commodity and engineering polymeric materials for solar absorber applications is already ongoing at the Polymer Competence Center Leoben (PCCL, A), the University of Oslo (UiO, N) and Solarnor AS (Oslo, N). An overview on structural polymeric materials for solar absorber applications was provided. Furthermore, an introduction to polymer structure and thermal transitions and their correlation was given.

Regarding the ageing and long-term behavior special emphasis was given to polyamides. For an amorphous transparent polyamide grade excellent weathering behavior was ascertained,

thus being an interesting alternative to polycarbonate glazing materials. For blackened PA12 grades the procedure to generate time-temperature-limits was exhibited. For these grades a lifetime of 200.000 hours at 80°C in water was derived.

## REPORTS PUBLISHED IN 2007

### Publications

Munari-Probst, M.C., Roecker, C., 2007. Towards an improved architectural quality of building integrated solar thermal systems (BIST). *Solar Energy* (81) 9, 1104-1116.

Kahlen, S. , Wallner, G.M., 2007. Aging behavior of polymeric materials for solar thermal absorber applications, ISES Solar World Congress 2007, Beijing, China, Sept. 18-21, 2007.

Mendes, J.F., Horta, P., Carvalho, M.J., Silva, P., 2007. Solar thermal collectors in polymeric materials: A novel approach towards higher operating temperatures, ISES Solar World Congress 2007, Beijing, China, Sept. 18-21, 2007.

Resch, K., Wallner, G.M., Hausner, R., 2007. All polymeric flat-plate collector - Potential of thermotropic layers to prevent overheating, ISES Solar World Congress 2007, Beijing, China, Sept. 18-21, 2007.

Resch, K., Wallner, G.M., 2007. Thermotropic resin systems: Relationships between formulation parameters, material structure and optical properties, ISES Solar World Congress 2007, Beijing, China, Sept. 18-21, 2007.

Munari-Probst, M.C., Kosoric, V., Schueler, A., de Chambrier, E., Roecker, C., 2007. Facade integration of solar thermal collectors: Present and future. CISBAT 2007 - Int. Scientific Conference, École Polytechnique Fédérale (EPFL), Lausanne, Switzerland, Sept. 4-5, 2007.

Kahlen, S., Wallner, G.M., 2007. Degradation behavior of polymeric materials for solar thermal applications 27th PDDG Meeting, Aston University, Birmingham, England Sept. 5-7, 2007.

Martins, A.J., Nunes, C., Brites, M.J., Prates, M.L., Teixeira, V., Carvalho, M.J., 2007. Novel nanocomposite coating with dispersed organic nanoparticles for solar absorbers (poster), NanoSMat 2007 - International Conference on Surfaces, Coatings and Nanostructured Materials, Alvor, Algarve, Portugal, July 9-11, 2007.

Weiβ, K.-A., 2007. Polymeric materials for solar thermal collectors – a feasibility study. Proceedings of the 3rd European Solar Thermal Energy conference, Freiburg, Germany, June 19-20, 2007.

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Köhl, M., 2006, Polymere Materialien für Solarthermische Systeme, Erneuerbare Energie 4-2006, Austria.

Brites, M. J., Nunes, C., Vieira, S., Marinho, C., Quintino, D., Lopes Prates, M., Alexandre, J., Teixeira, V., Carvalho, M. J., 2007. Desenvolvimento de novos revestimentos espectralmente selectivos com pigmentos organicos para absorsores de colectores solares (Development of new spectrally selective coatings with organic pigments for solar collector absorbers), CIES 2006 - XIII Congresso Ibérico e VIII Congresso Ibero-Americano de Energia Solar, 9-10 Novembro 2006, Lisboa.

Wallner G.M. and Lang R. W., 2006. Kunststoffe-Neue Möglichkeiten in der Solarthermie. Erneuerbare Energie 2-2006, AEE-Intec, Austria.

## **MEETINGS IN 2007**

### **2<sup>nd</sup> Experts Meeting**

2-4 May

Aveiro, Portugal

### **3<sup>rd</sup> Experts Meeting**

24-26 September

Blumau/Leoben, Austria

## **MEETINGS PLANNED FOR 2008**

### **4<sup>th</sup> Experts Meeting**

April, 28-30

Oslo, Norway

### **5<sup>th</sup> Experts Meeting**

October 13-15

Chur or Rapperswil, Switzerland

## TASK 39 NATIONAL CONTACTS

### Operating Agent

Michael Köhl  
Fraunhofer Institute for Solar Energy Systems  
Dept. Thermal Systems and Buildings  
Fraunhofer-Institut für Solare Energiesysteme ISE  
Heidenhofstr. 2,  
79110 Freiburg, GERMANY  
[michael.koehl@ise.fraunhofer.de](mailto:michael.koehl@ise.fraunhofer.de)

### Austria

Robert Hausner  
AEE - Institut für Nachhaltige Technologien  
Feldgasse 19  
A-8200 Gleisdorf  
[r.hausner@aee.at](mailto:r.hausner@aee.at)  
<http://www.aee-intec.at>

Josef Buchinger  
Arsenal Research  
Österreichisches Forschungs- und Prüfzentrum Arsenal Ges.m.b.H.  
Giefinggasse 2  
A-1210 Wien  
[josef.buchinger@arsenal.ac.at](mailto:josef.buchinger@arsenal.ac.at)  
<http://www.arsenal.ac.at>

Susanne Kahlen and Katharina Resch  
Polymer Competence Center Leoben  
Parkstraße 11  
A-8700 Leoben  
[kahlen@pccl.at](mailto:kahlen@pccl.at)  
[resch@pccl.at](mailto:resch@pccl.at)  
<http://www.pccl.at>

Gernot Wallner  
Institute of Materials Science and Testing of Plastics  
University of Leoben  
Franz-Josef-Str. 18  
A-8700 Leoben  
[wallner@unileoben.ac.at](mailto:wallner@unileoben.ac.at)  
<http://www.unileoben.ac.at>

### France

Philippe Papillon  
CEA INES  
Recherche, Développement et Innovation Industrielle  
BP 332  
50, avenue du Lac Léman  
73377 Le Bourget du Lac  
[philippe.papillon@cea.fr](mailto:philippe.papillon@cea.fr)  
<http://www.cea.fr/>  
<http://www.ines-solaire.fr/>

### Germany

Zörner Wilfried, Trinkl Christoph and Treikauskas Franz-Dominik  
Fachhochschule Ingolstadt  
Kompetenzzentrum Solartechnik  
Esplanade 10  
D-85049 Ingolstadt  
[zoerner@fh-ingolstadt.de](mailto:zoerner@fh-ingolstadt.de)  
[trinkl@fh-ingolstadt.de](mailto:trinkl@fh-ingolstadt.de)  
[treikauskas@fh-ingolstadt.de](mailto:treikauskas@fh-ingolstadt.de)  
<http://www.solartechnik-ingolstadt.de>

Helmut Vogel  
University of Applied Sciences Osnabrück  
P.O. Box 1940  
D-49009 Osnabrück  
[h.vogel@fh-osnabrueck.de](mailto:h.vogel@fh-osnabrueck.de)  
<http://www.fh-osnabrueck.de/>

Mathias Rommel, Eva Stricker, Karl-Anders Weiss and Markus Heck  
Fraunhofer Institute for Solar Energy Systems  
Dept. Thermal Systems and Buildings  
Heidenhofstr. 2,  
79110 Freiburg  
[rommel@ise.fraunhofer.de](mailto:rommel@ise.fraunhofer.de)  
[eva.stricker@ise.fraunhofer.de](mailto:eva.stricker@ise.fraunhofer.de)  
[karl-anders.weiss@ise.fraunhofer.de](mailto:karl-anders.weiss@ise.fraunhofer.de)  
[markus.heck@ise.fraunhofer.de](mailto:markus.heck@ise.fraunhofer.de)  
<http://www.ise.fraunhofer.de>

Claudius Wilhelms and Klaus Vajen  
Universität Kassel  
Mönchebergstraße 19  
34109 Kassel  
[wilhelms@uni-kassel.de](mailto:wilhelms@uni-kassel.de)  
[vajen@uni-kassel.de](mailto:vajen@uni-kassel.de)  
[www.uni-kassel.de](http://www.uni-kassel.de)

Stephan Fischer and Fabian Ochs  
University Stuttgart, ITW  
Pfaffenwaldring 6  
D-70550 Stuttgart, GERMANY  
[fischer@itw-stuttgart.de](mailto:fischer@itw-stuttgart.de)  
[ochs@uni.itw-stuttgart.de](mailto:ochs@uni.itw-stuttgart.de)  
<http://www.itw.uni-stuttgart.de>

**Norway**  
Michaela Meir and John Rekstad  
University of Oslo  
Department of Physics  
PO Box 1048, Blindern  
N-0316 Oslo, NORWAY  
[mmeir@fys.uio.no](mailto:mmeir@fys.uio.no)  
[john.rekstad@fys.uio.no](mailto:john.rekstad@fys.uio.no)  
<http://www.physics.uio.no/energy>

**Portugal**  
Clarisse Nunes and Manuel Lopes Prates  
Instituto de Technologias Energeticas  
Department de Energias Renovaveis  
Estrada do Paço do Lumiar 22  
1649-038 Lisboa  
[lopes.prates@ineti.pt](mailto:lopes.prates@ineti.pt)  
[www.ineti.pt](http://www.ineti.pt)

**Slovenia (observer)**  
Boris Orel  
National Institute of Chemistry Slovenia  
Hajdrihova 19  
PO Box 660  
SI-1001 Ljubljana  
[boris.orel@ki.si](mailto:boris.orel@ki.si)  
<http://www.ki.si/>

**Sweden**  
Kenneth Moeller  
SP Swedish National Testing and Research  
Institute  
Box 857  
SE-501 15 Borås  
[kenneth.moller@sp.se](mailto:kenneth.moller@sp.se)  
<http://www.sp.se>

**Switzerland**  
Maria Cristina Munari Probst and  
Christian Roecker  
EPFL ENAC ICARE LESO-PB  
LE 0 04 (Bâtiment LE)  
Station 18  
CH-1015 Lausanne  
[mariacristina.munariprobst@epfl.ch](mailto:mariacristina.munariprobst@epfl.ch)  
[christian.roecker@epfl.ch](mailto:christian.roecker@epfl.ch)  
<http://www.epfl.ch>

Stefan Brunold  
Institut für Solartechnik SPF  
Hochschule für Technik Rapperswil HSR  
Oberseestrasse 10  
CH-8640 Rapperswil  
[stefan.brunold@solarenergy.ch](mailto:stefan.brunold@solarenergy.ch)  
<http://www.solarenergy.ch>

# Addresses

## EXECUTIVE COMMITTEE MEMBERS

### AUSTRALIA

Mr. Max Maffucci  
Standards Australia International  
GPO Box 5420  
Sydney, NSW 2001  
[max.maffucci@standards.org.au](mailto:max.maffucci@standards.org.au)

Alternate  
Mr. Ken Guthrie  
Sustainability Victoria  
Urban Workshop  
Level 28  
50 Lonsdale Street  
Melbourne 3000  
[Ken.Guthrie@sustainability.vic.gov.au](mailto:Ken.Guthrie@sustainability.vic.gov.au)

### AUSTRIA

Prof. Gerhard Faninger  
c/o Universität Klagenfurt, IFF  
Sterneckstraße 15  
A-9020 Klagenfurt  
[gerhard.faninger@uni-klu.ac.at](mailto:gerhard.faninger@uni-klu.ac.at)

### BELGIUM

Prof. André De Herde  
Architecture et Climat  
Université Catholique de Louvain  
Place du Levant, 1  
B-1348 Louvain-la-Neuve  
[deherde@arch.ucl.ac.be](mailto:deherde@arch.ucl.ac.be)

### CANADA

Mr. Doug McClenahan (*Chairman*)  
CANMET - Natural Resources  
Canada  
580 Booth Street  
Ottawa, Ontario K1A 0E4  
[dmcclena@nrcan.gc.ca](mailto:dmcclena@nrcan.gc.ca)

### DENMARK

Mr. Jens Windeleff  
Danish Energy Authority  
Amaliegade 44  
DK-1256 Copenhagen K  
[jew@ens.dk](mailto:jew@ens.dk)

Alternate  
Mr. Poul E. Kristensen  
IEN Consultants  
Hasselvej 30  
2830 Virum  
[poul@ien.dk](mailto:poul@ien.dk)

### EUROPEAN COMMISSION

Mr. Jose Riesgo  
European Commission  
DM24 3/1442  
B-1049 Brussels, BELGIUM  
[Jose.Riesgo@cec.eu.int](mailto:Jose.Riesgo@cec.eu.int)

### FINLAND

Mr. Jarkko Piirto  
TEKES, National Technology Agency  
Energy and Environment  
Employment & Economic  
Development Centre for  
Ostrobothnia  
FIN-00101 Helsinki  
[jarkko.piirto@tekes.fi](mailto:jarkko.piirto@tekes.fi)

### FRANCE

Mr. Yves Boileau  
French Agency for the Environment  
and Energy Management (ADEME)  
500 Route des Lucioles - Sophia  
Antipolis  
F-06565 Valbonne Cedex  
[yves.boileau@ademe.fr](mailto:yves.boileau@ademe.fr)

**GERMANY**

Mr. Markus Kratz  
Forschungszentrum Jülich - PTJ  
D-52425 Jülich  
[m.kratz@fz-juelich.de](mailto:m.kratz@fz-juelich.de)

Alternate

Mr. Tobias Petrovic  
Forschungszentrum Jülich GmbH  
D-52425 Jülich  
[t.petrovic@fz-juelich.de](mailto:t.petrovic@fz-juelich.de)

**ITALY**

Dr. Simonetta Fumagalli  
ENEA, C.R. Ispra  
via Enrico Fermi 2497  
21020 Ispra (VA)  
[simonetta.fumagalli@ispra.enea.it](mailto:simonetta.fumagalli@ispra.enea.it)

**MEXICO**

Dr. Wilfrido Rivera Gomez-Franco  
Center for Energy Research  
National University of Mexico  
Apdo. Postal #34  
62580 Temixco, Morelos  
[wrgf@cie.unam.mx](mailto:wrgf@cie.unam.mx)

Alternate

Dr. Camilo Arancibia Bulnes  
same address as above  
[caab@cie.unam.mx](mailto:caab@cie.unam.mx)

**NETHERLANDS**

Mr. Lex Bosselaar  
SenterNovem  
P.O. Box 8242  
3503 RE Utrecht  
[L.Bosselaar@SenterNovem.nl](mailto:L.Bosselaar@SenterNovem.nl)

**NEW ZEALAND**

Mr. Michael Donn  
School of Architecture  
Victoria University of Wellington  
P.O. Box 600  
Wellington 1  
[michael.donn@vuw.ac.nz](mailto:michael.donn@vuw.ac.nz)

**NORWAY**

Dr. Anne Gunnarshaug Lien (*Vice Chair*)  
Enova SF  
Abelsgate 5  
7030 Trondheim  
[anne.g.lien@enova.no](mailto:anne.g.lien@enova.no)

Alternate

Mr. Fritjof Salvesen  
KanEnergi AS  
Hoffsveien 13  
0275 Oslo  
[fs@kanenergi.no](mailto:fs@kanenergi.no)

**PORTUGAL**

Mr. Joao A. Farinha Mendes  
INETI – Edificio H  
Departamento de Energias  
Renovaveis  
Estrada do Paco do Lumiar, 22  
1649-038 Lisboa  
[farinha.mendes@ineti.pt](mailto:farinha.mendes@ineti.pt)

**SPAIN**

Dr. Manuel Romero  
Director Renewable Energy Division  
CIEMAT  
Avenida Complutense 22  
E-28040 Madrid, Spain  
[manuel.romero@ciemat.es](mailto:manuel.romero@ciemat.es)

Alternate

Dr. Esther Rojas  
Concentrating Solar Systems  
Plataforma Solar de Almería  
CIEMAT  
Avenida Complutense 22  
28040 Madrid  
[esther.rojas@ciemat.es](mailto:esther.rojas@ciemat.es)

**SWEDEN**

Mr. Michael Rantil  
Swedish Energy Agency  
Box 310  
631 04 Eskilstuna  
[Michael.Rantil@energimyndigheten.se](mailto:Michael.Rantil@energimyndigheten.se)

**SWITZERLAND**

Mr. Urs Wolfer  
Federal Office of Energy  
CH-3003 Bern  
[urs.wolfer@bfe.admin.ch](mailto:urs.wolfer@bfe.admin.ch)

**UNITED STATES**

Mr. Drury Crawley (*Vice Chair*)  
U.S. Department of Energy  
Energy Efficiency and Renewable  
Energy  
EE-2J, Office of Building Technologies  
1000 Independence Ave. S.W.  
Washington, D.C. 20585-0121  
[Drury.Crawley@ee.doe.gov](mailto:Drury.Crawley@ee.doe.gov)

**EXECUTIVE SECRETARY**

Ms. Pamela Murphy  
Morse Associates, Inc.  
9131 S. Lake Shore Dr.  
Cedar, MI 49621  
UNITED STATES  
[pmurphy@MorseAssociatesInc.com](mailto:pmurphy@MorseAssociatesInc.com)

**ADVISOR**

Dr. Frederick H. Morse  
Morse Associates, Inc.  
236 Massachusetts Ave., NE, Suite 605  
Washington, DC 20002  
UNITED STATES  
[fredmorse@MorseAssociatesInc.com](mailto:fredmorse@MorseAssociatesInc.com)

**IEA SECRETARIAT LIAISON**

Mr. Nobuyuki Hara  
International Energy Agency  
9 rue de la Fédération  
75739 Paris Cedex 15  
FRANCE  
[Nobuyuki.Hara@iea.org](mailto:Nobuyuki.Hara@iea.org)

**TASK OPERATING AGENTS****PERFORMANCE OF SOLAR  
FAÇADE COMPONENTS**

Mr. Michael Köhl  
Fraunhofer Institute for Solar Energy  
Systems  
Heidenhofstr. 2  
D-79 110 Freiburg  
GERMANY  
[michael.koehl@ise.fraunhofer.de](mailto:michael.koehl@ise.fraunhofer.de)

**ADVANCED STORAGE CONCEPTS  
FOR SOLAR AND LOW ENERGY  
BUILDINGS**

Mr. Jean-Christophe Hadorn  
BASE Consultants SA  
8 rue du Nant  
CH-1211 Geneva  
SWITZERLAND  
[jchadorn@baseconsultants.com](mailto:jchadorn@baseconsultants.com)

**SOLAR HEAT FOR INDUSTRIAL  
PROCESSES**

Mr. Werner Weiss  
AEE INTEC  
Feldgasse 19  
A-8200 Gleisdorf  
AUSTRIA  
[w.weiss@aee.at](mailto:w.weiss@aee.at)

**TESTING & VALIDATION OF  
BUILDING ENERGY SIMULATION  
TOOLS**

Mr. Ron Judkoff  
Buildings & Thermal Systems Center  
National Renewable Energy Lab  
1617 Cole Boulevard  
Golden, CO 80401  
UNITED STATES  
[ron\\_judkoff@nrel.gov](mailto:ron_judkoff@nrel.gov)

**PV/THERMAL SOLAR SYSTEMS**

Mr. Henrik Sørensen  
Esbensen Consulting Engineers Ltd.  
Carl Jacobsens Vej 25D  
Sukkertoppen - Copenhagen  
DK-2500 Valby  
DENMARK  
[h.soerensen@esbensen.dk](mailto:h.soerensen@esbensen.dk)

**SOLAR RESOURCE KNOWLEDGE  
MANAGEMENT**

Dr. Dave Renné  
National Renewable Energy  
Laboratory  
1617 Cole Boulevard  
Golden, Colorado 80401-3393  
UNITED STATES  
[david\\_renne@nrel.gov](mailto:david_renne@nrel.gov)

**ADVANCED HOUSING RENOVATION  
WITH SOLAR & CONSERVATION**

Mr. Fritjof Salvesen  
KanEnergi AS  
Hoffsveien 13  
0275 Oslo  
NORWAY  
[fs@kanenergi.no](mailto:fs@kanenergi.no)

**SOLAR AIR-CONDITIONING &  
REFRIGERATION**

Dr. Hans-Martin Henning  
Fraunhofer Institute for Solar Energy  
Systems  
Department of Thermal Systems and  
Buildings  
Heidenhofstr. 2  
D-79110 Freiburg  
GERMANY  
[hans-martin.henning@ise.fraunhofer.de](mailto:hans-martin.henning@ise.fraunhofer.de)

**POLYMERIC MATERIALS FOR  
SOLAR THERMAL APPLICATIONS**

Mr. Michael Köhl  
Fraunhofer Institute for Solar Energy  
Systems  
Heidenhofstr. 2  
D-79110 Freiburg  
GERMANY  
[michael.koehl@ise.fraunhofer.de](mailto:michael.koehl@ise.fraunhofer.de)

# SHC Projects & Lead Countries

- Task 1 Performance of Solar Heating and Cooling Systems, 1977-83 (Denmark)  
Task 2 National Solar R & D Programs & Projects, 1977-84 (Japan)  
Task 3 Solar Collector and System Testing, 1977-87 (Germany and United Kingdom)  
Task 4 Insolation Handbook and Instrumentation Package, 1977-80 (United States)  
Task 5 Existing Meteorological Information for Solar Applications, 1977-82 (Sweden)  
Task 6 Evacuated Tubular Collector Performance, 1979-87 (United States)  
Task 7 Central Solar Heating Plants with Seasonal Storage, 1979-89 (Sweden)  
Task 8 Passive Solar Low Energy Homes, 1982-89 (United States)  
Task 9 Solar Radiation and Pyranometry, 1982-91 (Canada and Germany)  
Task 10 Solar Materials R & D, 1985-91 (Japan)  
Task 11 Passive Solar Commercial Buildings, 1986-91 (Switzerland)  
Task 12 Solar Building Analysis Tools, 1989-94 (United States)  
Task 13 Advanced Solar Low Energy Buildings, 1989-94 (Norway)  
Task 14 Advanced Active Solar Systems, 1990-94 (Canada)  
Task 15 Advanced Central Solar Heating Plants, not initiated  
Task 16 Photovoltaics for Buildings, 1990-95 (Germany)  
Task 17 Measuring and Modeling Spectral Radiation, 1991-94 (Germany)  
Task 18 Advanced Glazing Materials, 1991-97 (United Kingdom)  
Task 19 Solar Air Systems, 1993-99 (Switzerland)  
Task 20 Solar Energy in Building Renovation, 1993-98 (Sweden)  
Task 21 Daylight in Buildings, 1995-99 (Denmark)  
Task 22 Building Energy Analysis Tools, 1996-00 (United States)  
Task 23 Optimization of Solar Energy Use in Large Buildings, 1997-02 (Norway)  
Task 24 Solar Procurement, 1998-03 (Sweden)  
Task 25 Solar Assisted Air Conditioning of Buildings, 1999-04 (Germany)  
Task 26 Solar Combisystems, 1998-02 (Austria)  
Task 27 Performance of Solar Facade Components, 2000-05 (Germany)  
Task 28 Solar Sustainable Housing, 2000-05 (Switzerland)  
Task 29 Solar Crop Drying, 2000-06 (Canada)  
Task 30 Solar Cities, not initiated  
Task 31 Daylighting Buildings in the 21<sup>st</sup> Century, 2001-05 (Australia)  
Task 32 Advanced Storage Concepts for Solar and Low Energy Buildings, 2003-07 (Switzerland)  
Task 33 Solar Heat for Industrial Processes, 2003-07 (Austria)  
Task 34 Testing and Validation of Building Energy Simulation Tools, 2003-07 (United States)  
Task 35 PV/Thermal Systems, 2005-07 (Denmark)  
Task 36 Solar Resource Knowledge Management, 2005-10 (United States)  
Task 37 Advanced Housing Renovation with Solar & Conservation, 2006-09 (Norway)  
Task 38 Solar Air Conditioning and Refrigeration, 2006-09 (Germany)  
Task 39 Polymeric Materials for Solar Thermal Applications, 2006-10 (Germany)