

Newsletter of the
International Energy
Agency Solar Heating
and Cooling Programme



#SolarThermal
#SolarProcessHeat
#SolarCooling
#SolarDistrictHeating

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ISES Joins IEA SHC!

The IEA Solar Heating and Cooling Programme welcomes the International Solar Energy Society (ISES) as its newest Sponsor member. This development offers expanded opportunities for ISES members to participate in technical activities under the IEA SHC, and places ISES at the IEA SHC table as a member of its Executive Committee.



“As a sponsor, ISES aims to offer expanded opportunities for our members to participate in technical activities under the IEA SHC Programme and to have a seat at the table of one of the longest running IEA Technology Collaboration Programmes (TCPs),” remarks Jenny McIntosh, the ISES Executive Secretary. Many ISES members and Board of Directors participate in, and have been active in, IEA SHC Tasks. For the past ten years, ISES President Dr. Dave Renné has been serving as the Operating Agent for IEA SHC’s two solar resource assessment Tasks. As many as 80 solar resource experts from 17 countries around the world have been coming together to work on these tasks, and many important publications, seminars, handbooks, and conference presentations that advance the state of science in solar resource assessments and forecasting methodologies to support the solar industry have been produced. Task participants, such as Dr. Richard Perez of the State University of New York, this year’s ISES Farrington Daniels Award recipient, are well-known world experts in this field.

McIntosh notes, “Becoming a sponsor of IEA SHC is a natural fit within ISES’ expanded mission to partner and cooperate with the other leading renewable energy organizations and institutions. A mix of solar and other energy efficiency and renewable energy technologies, will be crucial to meet global goals to combat climate change; solar thermal technologies, including passive and active building designs, are and will continue to be part of that mix. Thus the role of the IEA SHC Programme remains as important today as it was in 1977 to continue to research, develop, demonstrate and exchange information on these important technologies and applications.”

ISES strives for 100% renewable energy for everyone used wisely and efficiently. It is the longest standing solar organization in the world, with its roots dating back to 1954.

ISES headquarters, located in Freiburg, Germany since 1995.



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SHC Members

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- Sweden
- Switzerland
- Turkey
- United Kingdom

New member from page 1

In 1963 ISES became accredited with the United Nations and has been working with UN entities and programs since, taking part in important events like the UNFCCC Climate Change Conferences and the UN Commission on Sustainable Development meetings.

The Society provides objective, scientific advice to governments and the public at a global level. ISES' strong research and academic foundations bring credibility to its advise on technical and policy issues related towards achieving 100% renewable energy worldwide. ISES has a track record of strongly supporting the solar industry, helping shape public opinion through education and outreach activities and providing informed comment on global issues.

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part in important events like the UNFCCC Climate Change Conferences and the UN Commission on Sustainable Development meetings.

The main pillars of work carried out by ISES are evident through the reputable Solar Energy journal, the successful Solar World Congresses and Euro Sun conferences as well as high quality webinars and publications.

The next big event for ISES is the upcoming ISES EuroSun 2016 conference to be held on 11-14 October in Palma, Spain. The conference theme is "Solar Energy for Buildings and Industry" with a focus on solar heating and cooling. Please visit the EuroSun website: www.eurosun2016.org to see the list of conference topics, keynote speakers and the preliminary program.

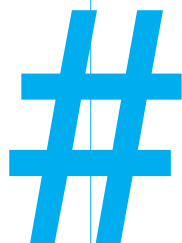
A new service, which is sure to be of interest for IEA SHC Task members in particular, is the International Experts Network (IEN). IEN is a platform for ISES members to present their expertise and knowledge to a broader community through a publicly accessible and searchable database. The platform allows users to search for the best experts for their projects, studies, market evaluations and other purposes. The network brings together those who offer expertise with those who are searching for experts in the renewable energy fields. The network is available at join.ises.org/ien.

“We look forward to a fruitful and successful partnership with the IEA SHC Programme”

JENNY MCINTOSH
ISES Executive Secretary
and IEA SHC ExCo member



▲ Together with the Spanish section of ISES, AEDES, and the University of the Balearic Islands, ISES will organize the 11th EuroSun Conference in Palma, Spain on October 11-14.



Harmonizing #tags

Three major solar heating and cooling institutions – the European Solar Thermal Industry Federation (ESTIF), the IEA Solar Heating and Cooling Programme (IEA SHC) and solarthermalworld.org – have started a campaign to harmonize SHC hashtags on social media.

Please join us in increasing the visibility of the solar heating and cooling (SHC) sector by using these hashtags in your posts!



#SolarThermal
#SolarProcessHeat
#SolarCooling
#SolarDistrictHeating



2016 Solar Thermal Trends

With 2016 underway, it's important to stop for a moment and think about where solar thermal is headed in the short-term and how current work can support or be adjusted to keep pace with technological advances. Several SHC Task Operating Agents have weighed in on trends in their areas of expertise.

Compact Thermal Energy Storage

- Continued improvement of compact thermal energy storage materials and better methods for characterizing the materials properties.
- Targeted development of critical components for compact thermal energy storage, e.g. heat exchangers and thermal reactors.
- Industry and automotive industries will get more attention from developers of compact thermal storage technologies.

Rating & Certification Procedures

- New revision of ISO 9806 standard for solar collector testing is expected to be approved and published before the end of 2016. This version takes into account issues raised by countries not adopting the present version thus the new version is expected to be more widely accepted.
- The "Global Solar Certification Network" is expected to start operating during 2016. New website: www.gscn.solar.

Large Scale Solar Heating and Cooling Systems

- Large scale applications feeding into the district heating systems of cities or provinces continue to experience steady growth, with Denmark leading the way.
- Increase in the number of systems that combine renewable heat and renewable electricity and seasonal heat storage to manage the mismatch between production and load.

Advanced Lighting Solutions for Retrofitting Buildings

- Lighting Systems and SSL (Solid State Lighting):
 - LED systems represent more than 30% of light sources sold worldwide, in central Europe more than 50%.
 - "More for less" – still increasing efficiency and added functionality (e.g., "tunable white", "tunable candle power distributions") which means falling prices.
 - "More than light" – luminaires becoming network points in ceilings (i.e., adding functionality to spaces like indoor locating /positioning, bulbs with loudspeakers, optical data transmission).
 - Context sensitive lighting controls – the user interacts with light and space.
 - Integrated "hybrid components" bringing daylight and electric light out of the façade into indoor spaces.
- Standards, Regulation and Certification:
 - New and enhanced methods and approaches. Adapting to rapidly changing technologies (SSL, lighting controls).
 - Increasing relevance of certification systems. In parts updates required.
- Retrofit of lighting installations:
 - Replacing existing solutions by SSL becomes more and more economical.
 - Increased focus in countries with rising electricity costs
 - Increasing interest due to the above mentioned aspects

Solar Resource Assessment and Forecasting

- High quality, reliable, and long-term solar resource data products, derived either from satellite imagery or numerical weather prediction models, are now available primarily through private data providers.

- Public/private relationships among data providers continues to evolve. National research institutes continue to offer publicly available data sets, and organizations, such as the World Bank, are contracting private data providers to offer free country or region-specific data sets to the public. In addition, on occasion small, independent companies are being acquired by larger, more mature companies interested in adding to their renewable energy services portfolio.
- Governments continue to support R&D activities to improve the solar resource models, but overall government funding support in resource assessment R&D is going down. Governments have recently focused on the data requirements for effective integration of large amounts of solar technologies into grid systems, including research on improving the accuracy of solar forecasts to support solar electric "fleet" management strategies.
- Collection of low-cost yet very high quality bankable data from ground measurement stations is a priority of the industry in order to gain financing for specific projects. Significant efforts are underway to design improved and cost-effective instrumentation and data collection and processing procedures, following agreed upon international best practices. Through support of national programs and international funding organizations like the World Bank, several new country-wide solar monitoring networks are being installed.
- IRENA's Global Atlas will continue to serve as a "one stop shop" for allowing practitioners, planners, and researchers to have ready access to quality and reliable resource data, even if the atlas leads the users to private-sector data providers. Other multilateral activities such as the World Bank's ESMAP

solar and wind resource mapping program have also gained prominence in providing country-specific resource atlases, especially in developing countries.

- Overall, the relationship between public research institutes and private-sector data providers is an evolving process, where governments now mainly support high risk R&D and provide data for public good, while the private sector provides the value added services required for effective solar energy deployments.

Solar Thermal Cooling

- Broadening reach to new markets in the Middle East and China where there is large market potential while the European solar cooling market remains very small.
- PV cooling, especially in the small power range, is pushing solar thermal cooling to adapt to the competition – new cost competitive sorption chillers are entering the market and solar thermal cooling costs are going down significantly.

- More than ever, peak load shaving is driving solar cooling (and heating), which means the link between grid operators and the future development and growth of the solar cooling sector is critical.

INTERVIEW

Solar Rating & Certification

Interview with Jan Erik Nielsen



The IEA SHC Programme wrapped up its work on Solar Rating & Certification (Task 43) in 2015, and in 2016 started a new Task on Solar Standards and Certification (Task 57). To get a better understanding of the impact of Task 43, we asked Jan Erik Nielsen, the Operating Agent, a few questions.

Solar Update (SU): Why was this work needed?

Jan Erik Nielsen (JEN): Task 43: Solar Rating & Certification was initiated to address some of the challenges facing solar thermal – new market entry costs for industry, promotion of quality products, support of ISO TC 180 work, and forum for exchanging experiences.

SU: What were the benefits of doing it thru IEA SHC?

JEN: The IEA SHC provided a good network for experts.

SU: What, if any, result surprised you?

JEN: It proved to be not so easy to convince certification bodies to participate in a common certification scheme.

SU: What is the most important deliverable of the Task and why?

JEN: There are two. The first is the establishment of the Global Solar Certification Network. The second is the new ISO/EN collector test standard that has now been approved.

SU: Do you have a success story about a Task deliverable being used by an end-user/industry?

JEN: Yes, the new standard, ISO 9806: Solar Energy - Solar Thermal Collectors - Test Methods, for solar collectors is being used/adopted in more countries (and by more manufacturers).

SU: How has your Task work supported capacity and skill building?

JEN: No specific capacity building was done – but the exchange of experience with respect to how certification works around

the world has been very valuable for the participants.

SU: Will we see more work in this area in IEA SHC?

JEN: We already are! A follow-up Task started this year and the kick-off meeting was held in March in Berlin. IEA SHC member Countries and Sponsors are welcome.

SU: Did the Task work on/support any standards?

JEN: Yes indeed – especially collector test methods (new ISO 9806).

Visit the SHC Task 43 [webpage](#) to learn more and download reports, or contact Jan Erik Nielsen, jen@solarkey.dk.

Promoting Solar Energy While Preserving Urban Context

Task 51

New energy regulations, together with mandatory solar fractions for electricity and Domestic Hot Water are introducing new materialities and geometries in buildings, resulting in new forms of architectural expression that are slowly modifying our city landscapes. The increased use of active solar collectors in buildings is clearly necessary and welcome, but brings major challenges in already existing environments. The large size of solar systems at the building scale asks for thoughtful planning, as these systems may end up compromising the quality of the building, threatening the identity of entire contexts.



▲ Figure 1. Quality evaluation steps and resulting graphic representation.

The LESO-QSV (QUALITY SITE VISIBILITY) Method

The question is no longer whether to be for or against the use of solar systems in cities, but is how to define minimal local levels of integration quality and to identify the factors needed to set smart solar energy policies that are able to preserve the quality of existing urban contexts while promoting solar energy use.

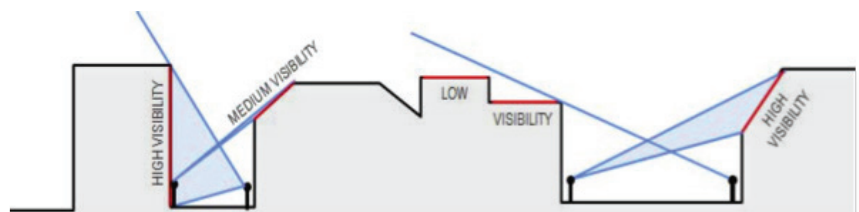
The vision underlining this approach is that solar integration is possible even in delicate contexts, if appropriate design efforts and adequate cost investments are made. If these investments cannot be afforded it may be better to postpone the operation, as poor integrations usually end up just discouraging new users. By contrast, if well designed, such examples can be among the strongest driving forces for solar change, repaying by far their extra cost.

The LESO-QSV method gives clear and objective answers in this debate.

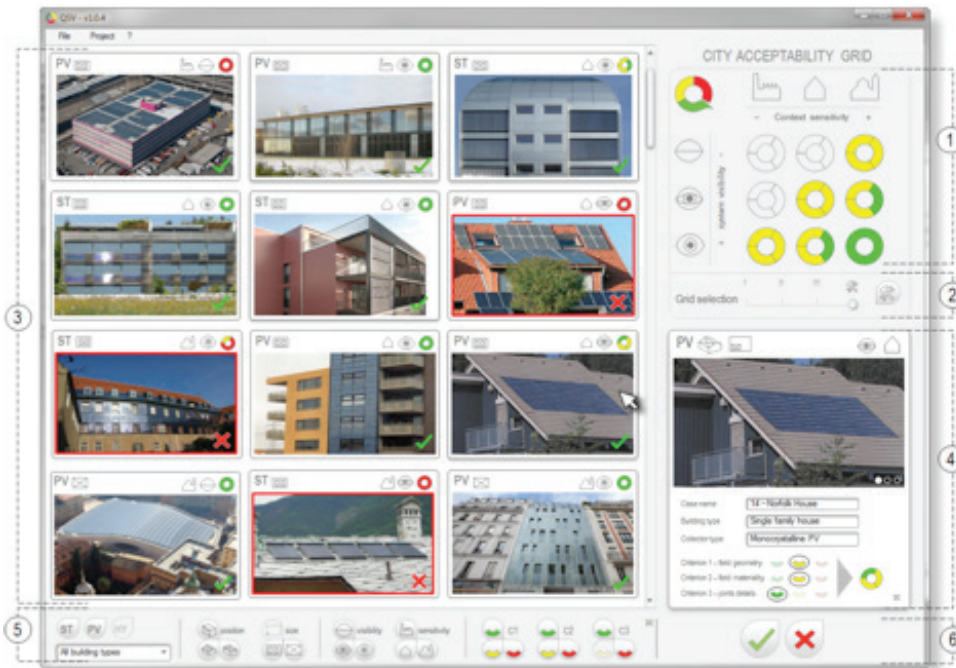
First, it clarifies the notion of architectural integration quality and proposes a simple quality evaluation method, based on a set of three criteria derived from pre-existing literature [2].

▼ Figure 2. Left: “Criticity” grid, crossing urban context sensitivity with building surfaces visibility. Right (top): Different context sensitivities (high; medium; low). Right (bottom): different levels of close visibilities.

CRITICITY	- context sensitivity +		
	low	medium	high
-	low		
system visibility		moderate	
+			high



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◀ **Figure 3. Main screen of the LESO-QSV GRID program.**

- 1 - Acceptability grid of the specific city:** i.e. required integration quality for each criticality level *f* (system visibility; context sensitivity). These are the criteria to be met for the installation to be accepted.
- 2 - Acceptability grid setting bar (for Municipality use only):** Integration requirements can be selected by using pre-established grids (more or less severe) or built to measure.
- 3 - Integration examples showcase:** A database of more than 100 cases is shown according to the selected filters setting (5). This showcase is meant to help Municipalities set a convenient acceptability grid by showing the impact in acceptancy of pre-defined sets of quality requirements; work as a model for authorities on how to objectively evaluate integration quality; and inspire architects, installers, building owners, etc.
- 4 - Case details window:** The window appears while clicking on a specific case. The detailed evaluation of quality becomes visible together with other more precise information and additional pictures of the case.
- 5 - Filter bar:** The case studies can be filtered according to solar system type, position, dimension, context sensitivity, system visibility, and integration quality.
- 6 - Accepted / not accepted cases button filters**

Second, it helps authorities set and implement local acceptability requirements, based on the notion of architectural “criticality” of city surfaces (LESO-QSV acceptability). The concept of “criticality” is at the basis of the whole approach. The “criticality” is defined by the Sensitivity of the urban context where the solar system is planned and by its Visibility (close and remote) (see Figure 2 left) from the public domain. The more sensitive the urban area and visible the system, the higher the needed quality.

In practice, authorities will be in charge to set the desired integration quality levels for each of the 9 “criticality” situations, considering geographic and social specificities (political orientation, available energy sources, city identity image, etc.).

To help the authorities setting these quality expectations, a specific software (LESO-QSV Grid, see Figure 3) was developed to show the impact in acceptancy of predefined sets of quality requirements over a large number of integration examples (100+ emblematic cases). These documented installations also serve as a model for authorities on how to objectively evaluate integration quality and provide a large set of inspirational examples for architects/installers/building owners.

Finally, the method proposes a way to adapt solar energy policies to local urban specificities by mapping the architectural “criticality” of city surfaces, and crossing this information with the city solar irradiation map (LESO-QSV cross-mapping). The obtained cross-mapping weights the irradiation on a given surface with its architectural criticality, evaluating the interest/difficulty to use this surface for solar energy production, helping setting priorities of intervention, planning oriented subsidies, etc. An ongoing PhD study is exploring ways to use GIS (Geographic Information System) information to automatically assess city surfaces visibility in order to facilitate the elaboration of the mentioned “criticality maps.”

An “application package” for municipalities willing to use the method to set and implement local acceptability requirements in their environment will be proposed by the end of August 2016.

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Currently, the LESO-QSV method is being used by:

- IEA SHC Task 51: Solar Energy in Urban Planning as a tool to assess the quality and acceptability of the different solar integration approaches proposed in the case studies and as one of the theoretical methods identified to be promising.
- EPFL (Switzerland) and IUAV (Italy) in three courses for master students in architecture and bachelor students in environment, civil engineering and architecture.

This article was contributed by Maria Cristina Munari Probst and Christian Roecker of Laboratoire d'Energie Solaire (LESO), EPFL, Switzerland, SHC Task 51 experts. For more information visit the Task 51 [webpage](#).

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- [2] Munari Probst, MC., Roecker, C., editors, Solar energy systems in architecture - integration criteria and guidelines, IEA SHC Task 41, 2012.
- [3] Krippner, R., Herzog, T., Architectural aspects of solar techniques – Studies on the integration of solar energy systems, in Proceedings Eurosun 2000, Copenhagen, 2000.
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“NEWS ALERT”

Upcoming Horizon 2020 Calls on SHC

The European Union (EU) is committed to reducing its greenhouse gas emissions and has also set binding targets on the final energy consumption from renewable sources. A crucial aspect to achieve these targets is the advancement in terms of renewable energy technologies. In this regard, the EU supports research activities to address the Societal Challenge “Secure, clean and efficient energy” through the Framework Programme for Research and Innovation “Horizon 2020”.

On behalf of the EU, the European Commission will soon publish on the [Participant Portal](#) the Horizon 2020 “COMPETITIVE LOW-CARBON ENERGY” (LCE) Calls of 2017. In particular, the Calls will include a specific challenge on “Development of components for residential single-family solar-active houses” (expected deadline for submission of proposals: January 2017) and a topic on “Near-to-market solutions for the use of solar heat in industrial processes” (expected deadline for submission of proposals: September 2017).



HORIZON 2020

Compact Thermal Energy Storage– Collaboration Leads to Groundbreaking Work

For the first time international teams of materials experts and application experts collaborated to tackle together issues confronting thermal energy storage. This one of a kind research platform was created jointly by the IEA Solar Heating and Cooling Programme (IEA SHC) and the IEA Energy Conservation through Energy Storage Programme (IEA ECES).

Current thermal energy storage technologies, mainly based on water tanks, perform well for short-term storage. Due to heat losses, long-term thermal storage with water is not efficient for small and medium sized systems while for very large water storage systems, mostly connected to district heating networks, long-term storage efficiency is good. However, conventional storage systems based on hot water tanks are limited and thermal energy storage needs new materials and system technologies.

Innovative compact thermal energy storage technologies are based on the physical principles and properties of phase change materials (PCM) and on thermochemical materials (TCM). With these materials, heat can be stored in a more dense form and with fewer losses than with hot water storage tanks.

Storage is a huge issue for renewables so IEA SHC joined with IEA Energy Conservation through Energy Storage Programme (IEA ECES) to support IEA SHC Task 42/IEA ECES Annex 24 on Compact Thermal Energy Storage. The Task covered phase change materials (PCMs), thermochemical materials (TCMs), and composite materials and nanostructures. And, included activities on material development, analysis, and engineering, numerical modeling of materials and systems, development of storage components and systems, and development of standards and test methods. This Task was completed the end of 2015, but not to worry as a new Task on this topic is being developed under the leadership of Wim van Helden of AEE INTEC of Austria.

WHAT'S BEEN ACHIEVED?

Key results of IEA SHC Task 42/IEA ECES Annex 24 on Compact Thermal Energy Storage are described briefly below. To learn more and find reports on specific topics visit the IEA SHC Task webpage, <http://task42.iea-shc.org/>.

Materials Engineering and Processing

Lead country: Slovenia, Alenka Ristic, NIC National Institute of Chemistry

More than 20 institutions from more than 12 countries collaborated on the engineering and processing of TES materials and results include:

New and improved materials for compact TES

Different new and improved PCMs were investigated – eutectic binary mixtures of sugar alcohols, low cost paraffin, cement mortar + microencapsulated PCM, polystyrene (PS)/n-heptadecane micro/nano-capsules, inorganic PCM ternary mixtures, PEG 10,000, microencapsulated n-octadecane, binary mixtures of linear alkanes and saturated fatty acids, new sugar alcohol eutectic mixtures and others.

What's Needed to Drive Market Deployment

- 1. Strong support of R&D work by governmental and international research programs as described above. Compact thermal energy storage systems based on phase-change and thermo-chemical material technologies are to a large extent still in their development stage. Single research groups cannot address the challenges and singularly achieved research results, but need a broad and internationally collaborative approach.**
- 2. Companies involved in the development of compact thermal storage systems are often relatively small and highly innovative. They need strong support by governments to be able to apply their technology in the building and industrial processes sectors, in spite of the economic disadvantage they still may have.**
- 3. Strong support of a growing number of demonstration projects is needed in order to gather operational experiences, to monitor and evaluate performance and to improve the performance of systems step-by-step. A much better basis for the further development and deployment of the huge potential of compact thermal energy storage systems will be established if these actions are taken.**

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And, new and improved TCM materials were synthesized and investigated – binder-free zeolite Y, activated carbon, composites of salt hydrates within porous matrices, etc.

Promising PCMs for different temperature ranges and applications

New PCMs with potential for solar thermal regulation of buildings and food storage containers are polymethylmethacrylate (PMMA)/capric-stearic eutectic mixture (C-SEM) micro/nano capsules can be integrated with conventional building materials polystyrene (PS)/n-heptadecane micro/nano-capsules.

With respect to solar heating and domestic hot water applications new binary mixtures of sugar alcohols comprising erythritol, sorbitol and xylitol were studied.

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

Material properties investigated and the role of material containers

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

Methods for TES-materials processing

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

This research ended up being mainly conducted in the field of PCMs, while only few research projects were performed in the field of thermochemical materials.

Test and Characterization of Phase Change Materials

Lead country: Germany, Stefan Gschwander, Fraunhofer ISE Institute for Solar Energy

Seven scientific institutions worked on the development of measurement standards for PCM characterization. Key results include:

New procedure for DSC measurement of PCMs

This procedure can be downloaded from <http://task42.iea-shc.org/data/sites/1/publications/Task4224-Standard-to-determine-the-heat-storage-capacity-of-PCM-vers150326.pdf>. It consists of five elements:

1. Heating and cooling rate test to determine suitable heating and cooling rates for the PCM to be measured. This is done by using the PCM to be characterized and applying heating and cooling rates starting from fast rates (e.g. 10 K/min) and slowing down the heating and cooling rates of consecutive cycles by halve the previous.
2. Calibration of the DSC by using 3 different calibration materials covering the desired temperature range (e.g. water, gallium and indium). The calibration has to be done with the determined heating rate.


Want to learn more?

The final Task results are available in one document and include:

- **Technology Position Paper: Compact Thermal Energy Storage (Matthias Rommel and Wim van Helden)**
- **Overview of the Task Compact Thermal Energy Storage (Matthias Rommel, Wim van Helden, Andreas Hauer)**
- **Engineering and Processing of PDMs, TCMs and Sorption Materials (Alenka Ristic et al.)**
- **Standardization of PCM Characterization via DSC (Stefan Gschwander et al.)**
- **Advanced Numerical Modelling Techniques to Tune the Properties of Heat Storage Materials for Optimal Reactor Performance (S.V. Gaastra-Nedea, C.C.M. Rindt et al.)**
- **Applications of Compact Thermal Energy Storage (Wim van Helden, Motoi Yamaha et al.)**
- **A Simple Tool for the Economic Evaluation of Thermal Energy Storages (Christoph Rathgeber et al.)**

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HDPE natur NT D960/6	Fraunhofer ISE	Oct 13, 2015	128.0	219.0			
Octadecan Parafol 18-97	Fraunhofer ISE	Dec 03, 2015	27.35	231.3			
RT 70 HC	Fraunhofer ISE	Oct 13, 2015	70.1	256.4			

▲ **Figure 1. Overview table of the PCM database.**

- Measurement of the empty crucible using the determined heating and cooling rates.
- Sample measurements by applying the sample to the crucible (apply the same sample mass as for the heating rate test) using the determined heating rate. Four measurement cycles have to be applied and three samples have to be measured.
- Analysis of data, and if necessary, baseline correction (displacement to zero heat flow) has to be applied. Carry out subtraction of heat flow signal measured with empty crucible from the sample measurement. Final data evaluation and computation of enthalpy curves.

PCM database

PCM data measured according to the new standard was collected. The database provides an overview table of all stored PCMs (see Figure 1). By choosing a PCM all relevant measurement parameters are available (onset temperature, integration limits for the given heat of fusion, sample mass, heating rate, etc.) as well as the measured data, which is provided as an ASCII table for download. The database is still less detailed for TCMs, but will be extended in the future.

Numerical Modeling

Lead country: The Netherlands, Camilo Rindt, Eindhoven University of Technology

The activities in this area focused on the different level modeling and simulations. The experts investigated MgCl₂ hydrates as

an example for developing and testing numerical models to understand and optimize material behavior.

Molecular models were used to check the effect of water vapor pressure on hydrolysis and dehydration reaction. The experts further used the results of the water diffusivity in the crystalline structure in higher-level models.

From the numerical results of material and thermophysical properties of PCM storage systems, it is clear that some deviation may occur if the enthalpy function does not perfectly fit the real behavior of the material. This may occur if the thermophysical characterization of the PCM is not correctly conducted. It is clear that further research work is necessary and material measurements have to be further improved so as to define reliable numerical and simulation methods.

Applications

Lead country: Japan, Motoi Yamaha, Chubu University

Experts from more than 20 research organizations worked on applications of compact thermal energy storage technologies. Application fields included cooling, room heating/domestic hot water and thermal storage for industry. The main challenges in the development of applications are in finding an optimal connection between the storage material and the other materials, the components and the system configuration. The problems to be solved are in the area of materials compatibility, like corrosion protection, prevention of side reactions and cycling stability; in the area of component design, with heat and mass transfer optimization; and in the area of system design with control strategies and cost reduction.

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

Most application developments in this IEA SHC Task 42/IEA ECES Annex 24 were in the area of thermal energy storage for room heating and domestic hot water preparation. Here, there is a broad collection of storage technologies and system concepts being developed and tested. Phase change materials and thermochemical materials are applied as active material in open and closed systems.

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

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

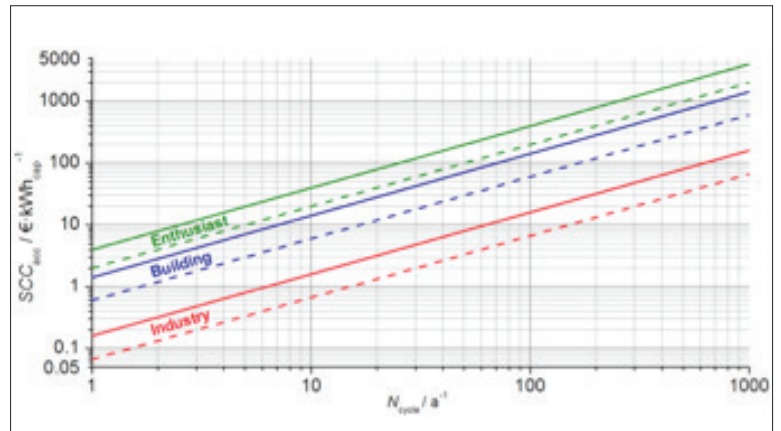
Theoretical Limits

Lead country: Germany, Subtask leader: Christoph Rathgeber, ZAE Bavarian Centre for Applied Energy Research

A tool for the economic evaluation of thermal energy storages was developed and tested on various existing storages. The storage capacity costs (i.e., the costs per installed storage capacity) of thermal energy storages were evaluated using a Top-down and a Bottom-up approach.

The Top-down approach

This approach is based on the assumption that the costs of energy supplied by the storage should not exceed the costs of energy from the market. The maximum acceptable storage capacity costs depend on the interest rate assigned to the capital



▲ **Figure 2. Maximum acceptable storage capacity costs (SCCacc) as a function of storage cycles per year N_{cycle} , determined for the three user classes: industry, building sector and enthusiast.**

costs, the intended payback period of the user class (e.g. industry or building), the reference energy costs, and the annual number of storage cycles.

Figure 2 shows the maximum acceptable storage capacity costs (SCCacc) as a function of storage cycles per year N_{cycle} , determined for the three user classes (industry, building sector and “enthusiast”, which denominates an investor group that accepts long payback periods and low interest rates, for example motivated by political or ecological reasons). A double-logarithmic scale was chosen to visualize both SCCacc of long-term storages with only few cycles per year and short-term storages with several hundred cycles per year. These results indicate that, for a fixed cycle period N_{cycle} , SCCacc depend on the user's economic environment. The low case of the industry sector and the high case of enthusiasts differ by a factor of about 60 in costs. Short-term storage with several hundred storage cycles per year, however, allows several hundred times higher storage costs because of the larger energy turnover.

The Bottom-up approach

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

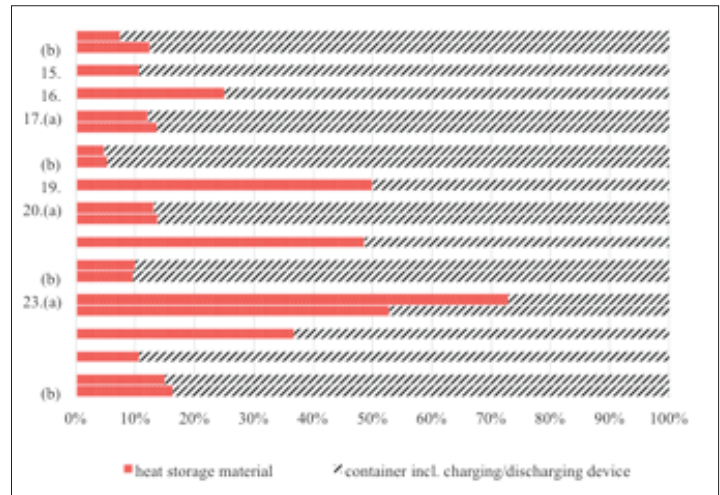
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Storage from page 11

term storage. It also means that the development of storage systems that allow a high annual number of storage cycles is economically favorable over seasonal storages.

In order to identify major cost drivers and, thereby, cost reduction potentials for the investigated storage systems, the composition of the investment costs has been analyzed. Figure 3 illustrates how the investment costs of thermal energy storages under investigation in SHC Task 42/ECES Annex 29 are divided into costs of the heat storage material itself and costs of the surrounding container or reactor including the charging/discharging device. So, the Bottom-up analysis showed that a major fraction of the investment costs of the investigated storages is not costs of the heat storage material itself, but costs of the storage container or reactor (including charging/discharging unit). Therefore, R&D activities on cost-effective Thermal Energy Storage systems have to consider both cost-effective heat storage materials and cost-effective storage container or reactor components.

This article was contributed by Matthias Rommel, SHC Task 42 Operating Agent. For more information visit the Task [webpage](#).



▲ **Figure 3. The breakdown of investment costs by material and container.**

INTERVIEW

Solar Heat in Industrial Processes

Interview with Christoph Brunner

The IEA SHC Programme wrapped up its work on Solar Heat Integration in Industrial Processes last December. This was a collaborative project with IEA SolarPACES. To get a better understanding of the impact of the Task, we asked Christoph Brunner, the SHC Task 49 Operating Agent, a few questions.

Solar Update (SU): Why was this project needed?

Christoph Brunner (CB): SHC Task 49/SolarPACES Annex IV: Solar Heat Integration in Industrial Processes was initiated to foster market penetration of this rather young technology that has large worldwide potential.

SU: What were the benefits of doing it thru the IEA?

CB: The IEA SHC provides an international network that allows the team of experts to take into account the perspectives from different countries. Participating countries benefit from the specific know-how of each

of the other participants. For example, an international project within the IEA SHC may be capable of bringing together a supplier of technology in one country with an interesting market in another country. In this new field of solar thermal application, international cooperation was needed to analyze the potential, to develop new high performance components and adapted system designs as well as to disseminate the results of the joint effort.

SU: What is the most important deliverable of the Task and why?

CB: The Integration Guideline is an important tool because it provides practical advice to a broad community

(solar planners, solar companies, process engineers, etc). They all now have access to a general procedure so that they can identify and rank suitable integration points and solar thermal system concepts when integrating solar heat into industrial processes.

SU: Do you have a success story about Task work being used by an end-user/industry?

Important conclusions from our work on stagnation have been directly applied and tested at the large-scale solar plant at the Göss brewery in Austria. This solar

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brewery produces over 4.5 million pints of beer per year using the power of the sun.

SU: How has your Task work supported capacity and skill building?

CB: Our Task documents and publications are highly relevant for solar thermal professionals, planners, energy consultants, energy auditors, energy managers in companies, researchers and strategic decision-makers. The available wiki-Web on Solar Process Heat is one example of an online information source that reaches people globally to support capacity and skill building. Trainings within international projects, such as Greenfoods, also benefited from our Task results and expertise.

And, our industry workshop in Montpellier, France served as a platform to promote solar process heat as well as the results of Task 49. Specific workshops on solar process heat were also held for the process engineering community to educate them on the process design for solar process heat.

SU: What is the current status of the technology?

CB: The technology is generally ready to be applied, but there are barriers still to overcome. Often, the available space is a bottleneck for the installation of large scale systems due limitations of space on the roof and the ground. This bottleneck can restrict the plant size, which in turn can limit the solar ratio reached by the solar plant. Industry usually likes to see a significant share of the energy demand covered by solar if they are going to decide on a solar thermal solution. Another barrier can be storage. Large-scale plants also need large storages. Here, investment is the issue as well as storage management. New storage technologies on the industrial scale still require a breakthrough and existing large-scale water storages require good management in order to function according to simulation predictions. This is especially important when storages are used for various energy supply sources and for covering various process energy demand. While a lot of different collectors

exist that can be used as process heat collectors, there is still an ongoing trend to develop targeted collectors for medium temperature collectors. In terms of the integration of solar process heat in the industrial processes, it is often not easy to make process modifications to allow for an easy integration. Traditional process technologies face the barrier that they are not designed for solar heat supply. In this context, a closer consideration of bringing processes and collectors together is important. And finally, in terms of market penetration, the economic barriers cannot yet be overcome. On the one hand a cost reduction in the production is necessary and on the other hand new approaches are necessary in order to make the financing of large plants possible.

SU: What is the future of the technology – new developments, market, research, policies, etc.?

CB: In the future, the industrial energy supply will be based on hybrid solutions and will be closely linked with regional structures (city, neighboring companies, etc.). If hybrid solutions using renewable energy are to completely meet the industrial supply then innovative and coordinated interaction between solar process heat, heat pumps, biomass and biogas and district is needed. At this point, research demand for tailor-made system solutions for industry sectors and locations is necessary.

To reach higher solar ratios in large-scale industrial projects, new storage technologies will continue to be an important research topic to achieve economically feasible large-scale storage capacities. New collector developments will further focus on the medium temperature level, with a focus on light weight collectors, simple installation procedures and economic potential.

Research on the integration of solar thermal energy in industrial process will focus on new process technologies. On the one hand, it will focus on new technologies for using low temperature heat (e.g., membrane distillation) and on the other hand a more integrated research approach

connecting collectors and process technologies. This could be on the direct use of solar radiation in industrial processes that require higher temperatures. This direct use of solar radiation can minimize transmission losses. In some processes the selective use of UV radiation can have positive effects on chemical transformation (photo chemistry). Further, a closer inter-linkage between the collector and process can be achieved on the low temperature level by combining collector and process fluid heating in one unit. On the medium temperature level, simple integration pathways for solar steam solutions will be important to enable an easy connection to the industrial steam supply.

An interesting topic for future work would be to develop new “solar process technologies” for one type of operation, such as drying, This would also meet the needs of the up and coming bio-based industry to find simple and renewable energy solutions for biomass drying.

Finally, as with everything, the economic barriers need to be overcome. Cost reduction and promising financing mechanisms are indispensable to enable further market penetration.

SU: Will we see more work in this area in IEA SHC?

CB: Definitely.

SU: Did the Task work on/support any standards?

CB: Yes, recommendations were developed for testing procedures for solar collectors used in solar process heat plants.

Visit the SHC Task 49 [webpage](#) to learn more and download reports or contact Christoph Brunner c.brunner@aee.at.

The Future of Solar Cooling

The increasing demand for refrigeration and air conditioning has led to a dramatic increase in peak electricity demand in many countries. With the increase in demand comes the increase in the cost of electricity and summer brownouts, which have been attributed to the large number of conventional air conditioning systems running on electricity. As the number of traditional vapor compression cooling machines grows (more than 100 million units sold in 2014) so do greenhouse gas emissions, both from direct leakage of high GWP refrigerant, such as HFCs, and from indirect emissions related to fossil fuel derived electricity consumption. An obvious counter to this trend is to use the same energy for generation of cooling that contributes to creating the cooling demand—solar energy.

The distinct advantage of cooling based on solar energy is the high coincidence of solar irradiation and cooling demand (i.e., the use of air conditioning is highest when sunlight is abundantly available). This coincidence reduces the need for energy storage, as the cooling produced from solar energy is almost immediately used.

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

Status of the Technology and Industry

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

Technical maturity

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

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

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



▲ **Figure 1: Solar cooling state-of-the-art (does not claim to be a complete list).**

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

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

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

Energy performance

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

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

- Keep the design as simple as possible in order to reduce risks of errors in implementation, operation, and maintenance.
- Carefully design and plan in order to define the optimal size of key components and an appropriate design fitting to the actual load profile, including strategies for efficient backup cooling when solar heat is not available.
- Auxiliary components (pumps and fans) should be highly energy-efficient.
- An operation and control strategy has to be developed that

leads to energy-efficient operation under both full and part load conditions.

- A careful commissioning phase of the system is necessary to ensure system operation as planned. An ongoing monitoring ("continuous commissioning") program is also helpful in order to enable long-term operation at highest possible performance.

Economic viability and environmental benefits

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

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

The cost saving during operation very much depends on the boundary conditions. Boundary conditions that favor a short payback time are:

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

Looking at the overall life cycle cost of a SAC system (excluding any incentives or funds) in comparison to a conventional standard solution the situation looks much better than in the case of cost. Depending on the particular conditions SAC systems will in many

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cases amortize within their lifetime. Under promising conditions payback times of ten years and less can be obtained. However, commercial companies often expect a payback time of five years or less in order to justify an investment. Such short payback times will only be achieved under very special conditions.

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

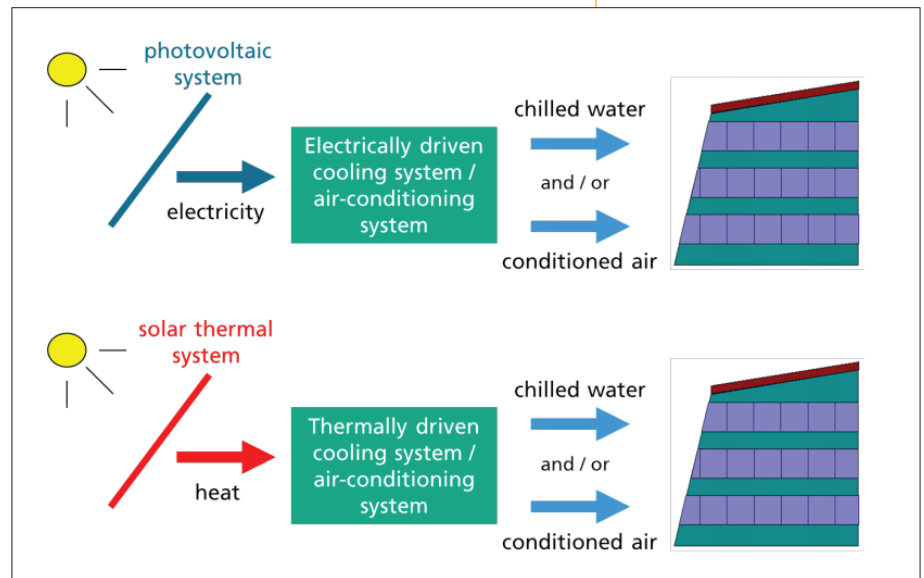
- SAC systems can contribute to reducing electricity infrastructure costs (and hence reduce electricity tariffs) in regions where a considerable share of peak electricity consumption from the grid is from air-conditioning with conventional techniques. Similarly, it may contribute to grid stability in regions where electricity infrastructure is insufficient to meet demand.

- Application of SAC systems may lead to (primary) energy savings and thus help to reduce the dependence of finite energy fuels, which have to be imported in many countries.

- Correspondingly, application of SAC systems will lead to reduced CO₂ emissions and thereby contribute to a reduction of climate change and related effects.

- SAC systems using thermally driven cooling cycles show additional environmental benefits since they typically employ refrigerants with no ozone depletion potential and no or a very small global warming potential.

- SAC systems can be used also for all heating applications in a building or industry. The large solar collector field also provides heat for other purposes than cooling and thus helps to avoid consumption of fuel (or electricity) for heating applications.



Current Barriers

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

The second main shortcoming of SAC is the economics. The first cost of realized SAC installations is between 2 and 5 times higher than a conventional state-of-the-art system, and so must be reduced. The two major possibilities to overcome that barrier are 1) to focus on medium to large system sizes, which lead to economies of scale, and 2) to standardize as much as possible the systems to reduce on site efforts and risks. An important focus should also be on policy strategies that enable a cost reflective means of internalising electricity system costs into the upfront purchase price of solar cooling systems.

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Challenges for Solar Cooling

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

The following actions should lower this risk:

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

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

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

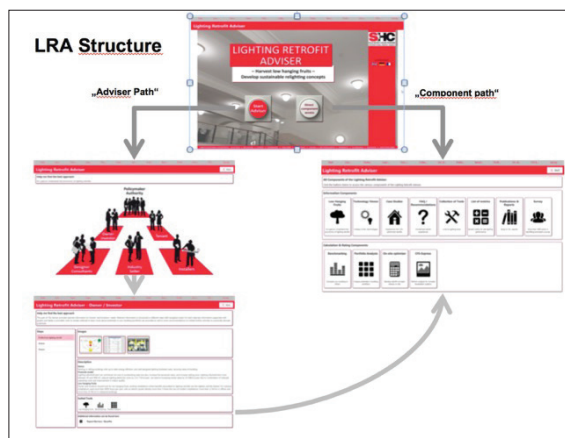
Quality procedures that cover all phases of a project are most critical in order to satisfy the expectations of all involved stakeholders. This work has been widely covered by the work of IEA SHC Task 48: Quality Assurance & Support Measures for Solar Cooling Systems of the IEA SHC Programme and these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

This article was contributed by Daniel Mugnier, the Operating Agent for SHC Task 48: Quality Assurance & Support Measures for Solar Cooling Systems and SHC Task 53: New Generation Solar Cooling and Heating. For more information visit the IEA SHC website, www.iea-shc.org or contact Daniel Mugnier, daniel.mugnier@tecsol.fr.

MarketPlace

The Solar Heating and Cooling Programme is making strides in R&D as well as impacting the solar market. This section of the newsletter highlights solar advancements developed or conceptualized in an IEA SHC Task that are being commercially manufactured, marketed or used.

Lighting Retrofit Adviser



The "Lighting Retrofit Adviser" is an integrative, comprehensive, multi-platform (desktop/ mobile) tool for stakeholders involved in lighting retrofits.

- Authorities can find information on regulation and certification approaches for lighting retrofits.
- Investors can inform themselves on the economic boundary conditions (and means to overcome barriers) of bringing new advanced lighting systems into practice.
- Designers / consultants can make use of an "On-Site Optimizer" that allows them to develop retrofit concepts directly on site, while drawing from a knowledge database of 45+ retrofit techniques (daylight, electric lighting and lighting controls) and 20+ case studies.

Better integration of daylighting and electric lighting solutions is a next big trend for increasing efficiency and better matching lighting to the user's needs. As many studies show, daylight is the user's favorite light source, and so must be protected from a simple substitution or mimicking by low priced electric lighting.

The Lighting Retrofit Adviser will be available starting June 2016 on the IEA SHC Task 50 [webpage](#). In the meantime, for more information contact Jan de Boer, the SHC Task 50 Operating Agent, Jan.deBoer@ibp.fraunhofer.de.

Solar Heat for Industrial Processes – Global Database Highlights Global Potential

A review of the potential use of solar heat for industrial processes (SHIP) in Australia, Austria, Chile, Cyprus, Egypt, Germany, Greece, India, Italy, Morocco, Netherlands, Pakistan, Portugal, South Africa, Spain, Sweden, Tunisia, and Wallonia (Belgium) plus European and worldwide shows:

- The total global process heat demand was approximately 98 EJ in 2008 [19]. Based on the evaluation within the potential study review, about 4% or 3.9 EJ global technical potential for solar process heat is a conservative estimate. To roughly calculate the order of magnitude of this, one could assume a mean useful annual solar irradiance (not specifying if global or beam) of 1,200 kWh/(m²a) and an annual solar thermal system efficiency of 40%. This would result in a solar collector area of close to 2,300 million m².
- For the year 2050, the estimated technical potential is 5.6 EJ, corresponding to about 3,200 million m². (source Taibi et al., 2012)
- In Europe a potential of 155 million m² of solar collectors has been identified, which can be compared with individual country studies:
 - Morocco – 2.4 million m²
 - Pakistan – 7.1 million m²
 - Egypt – 4.6 million m²
 - Germany – 35 million m²
 - Chile – 6 million m²



Visit the SHIP online database, a living platform, of solar thermal plants for production processes throughout the world. You as a user of the database have the possibility to share your SHIP application - <http://task49.iea-shc.org/related-sites>.

The International Energy Agency was formed in 1974 within the framework of the Organization for Economic Cooperation and Development (OECD) to implement a program of international energy cooperation among its member countries, including collaborative research, development and demonstration projects in new energy technologies. The members of the IEA Solar Heating and Cooling Agreement have initiated a total of 57 R&D projects (known as Tasks) to advance solar technologies for buildings. The overall Programme is managed by an Executive Committee while the individual Tasks are led by Operating Agents.

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SOLARUPDATE

The Newsletter of the IEA Solar Heating and Cooling Programme

Vol. 63, May 2016

Prepared for the IEA Solar Heating and Cooling Executive Committee

by
KMGroup, USA

Editor:
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This newsletter is intended to provide information to its readers on the activities of the IEA Solar Heating and Cooling Programme. Its contents do not necessarily reflect the viewpoints or policies of the International Energy Agency or its member countries, the IEA Solar Heating and Cooling Programme member countries or the participating researchers.

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