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Newsletter of the International Energy Agency Solar Heating and Cooling Programme

IEA SHC & IEA ECES Collaboration Makes Advances in Thermal Energy Storage

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#SolarThermal
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In This Issue

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Thermal energy storage is key for integrating renewable heat sources into an energy system --from domestic applications to district heating and from industrial applications to the power sector. The flexibility storage provides is necessary for the coupling of energy sectors. When higher temperatures, volume restrictions or very long storage periods come into play, new compact thermal storage technologies are needed, but so is more work on their development for the different energy sectors. It is this need that was the motivation for SHC Task 58/ECES Annex 33: Material and Component Development for Thermal Energy Storage – to further improve the storage materials and components based on a better knowledge of the underlying physics and chemistry.

The joint project, SHC Task 58/ECES (Energy Conservation through Energy Storage) Annex 33 on Material and Component Development for Thermal Energy Storage, achieved something remarkable – it drew experts from the fields of materials development, thermal storage component development, and system integration to work together for the past three years on thermal energy storage (TES) materials and components development.

The Task participants conducted work in four main fields 1) the definition of the proper boundary conditions for the development and integration of thermal energy storage technologies for different applications, 2) the development and characterization of novel thermal storage materials, 3) the definition and testing of reliable testing procedures to determine the performance of materials and components under application conditions and 4) the analysis of design aspects for thermal energy storage components.

Below are selected achievements from the four main fields of work, along with some key messages extracted from the activities.

General key messages from the work are:

- The collaboration in SHC Task58/ECES Annex33 between materials experts and application experts led to an improved understanding and therefore, accelerated development.
- Standards for measurement and reporting are prerequisites for constructive discussions and rapidly addressing challenges and advancing TES technologies.

Energy Relevant Applications

Part of the project's work aimed to define sets of boundary conditions for a number of applications, for instance the use of TES for domestic hot water. The challenge was to find the proper balance between having a small set of more general boundary conditions

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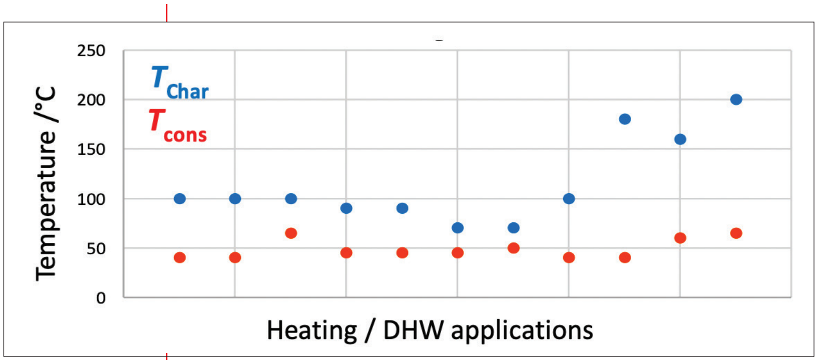
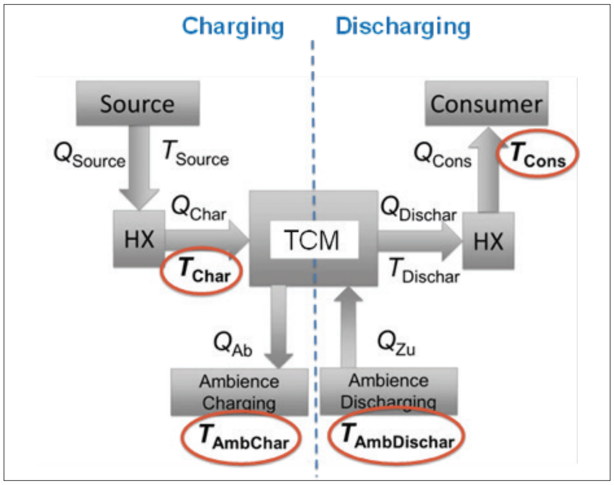
Thermal Energy Storage *from page 1*

that still reflect the details of individual technologies and having a larger set that better reflects the technologies but complicates the process of improving the materials and components for the technologies in an application. This problem was encountered especially in the field of industrial applications, as these show a very large variation. The most defining boundary conditions are the temperatures at which the storage is charged and discharged. In practice, this translates into a temperature that is available for charging, for instance from a solar thermal collector, and a temperature that is needed by the consumer, for instance for hot tap water. Figure 1 shows that these two temperatures have a variation over the different technological solutions applied by the experts.



▲ **Figure 1. Typical charging and consumption temperatures defined for 11 different compact thermal energy storage technologies, mostly using solar thermal collectors as the source.**

For thermochemical storage technologies, two other temperatures need to be specified. When charging, this is the temperature at which the sorbent is condensed. And when discharging, it is the temperature for evaporating the sorbent (see Figure 2.). This is particularly the case for seasonal storage, as these two temperatures will have very different values and need to be specified depending on the geographic location of the storage.



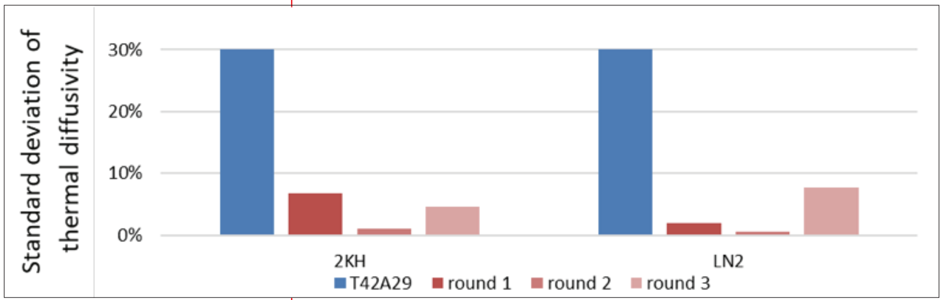
▲ **Figure 2. 4-Temperature Approach for thermochemical storage technologies. Besides the charging and consumption temperature, also the temperatures at which the sorbent is condensed and evaporated determine the storage performance and have to be specified.**

The key messages for this main field are:

- A large number of relevant applications exist for compact thermal energy storage.
- Standardized reference conditions can be defined for the building sector. For industrial applications, however, the diversity of processes makes it very difficult!

Development and Characterization of Improved Phase Change Materials and Thermochemical Materials

Compact thermal energy storage technologies are based on either Phase Change Materials (PCM) or on Thermochemical Materials (TCM). PCM has been under development for a much longer time and already are applied in a large number of applications. As a result, the PCM development work in this project focused on improving the methods with which material characteristics can be determined. These characteristics, like thermal conductivity or viscosity, are needed for a better numerical simulation of the technologies, leading to better component design and improved component performance. Part of the work was to improve the quality of determining the thermal diffusivity of PCM. A number of laboratories performed measurements on samples of the same material, leading to a standard deviation between the results of the measurements that was considerable, see Figure 3. The experts then analyzed the possible causes for these deviations, both in the way the samples were prepared and in the measurement procedure. The



▲ **Figure 3. Standard deviations of the differences between measured thermal diffusivity of a number of laboratories, for two different PCMs. The bars in blue show the values before the improvement of sample preparation and measurement procedure, the other colors the results after the improvements were implemented. The series on the left (with 2KH) were performed under cooling with 2 Kelvin per hour, while the series on the right underwent fast cooling with liquid nitrogen (LN2).**

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improved sample preparation and measurement procedure were then tested and led to much lower deviations between the results from the different laboratories.

In the field of TCM, a large number of experts are working on the development of improved thermochemical materials. One TCM class is the combination of a salt hydrate with a porous material. Combining these materials leads to improved energy densities and better long-term performance. Salt hydrates, when taking up too much water vapor, can liquify, leading to a very poor performance. If the salt hydrate is impregnated into a porous material the liquefying is prevented, while the thermal storage capacity of the porous material is increased by the addition of the salt hydrate. Figures 4 and 5 show microscopic images of some sample materials and a graph of the energy densities of porous materials and novel developed composite materials. It can be clearly seen that the latter have a higher energy density.

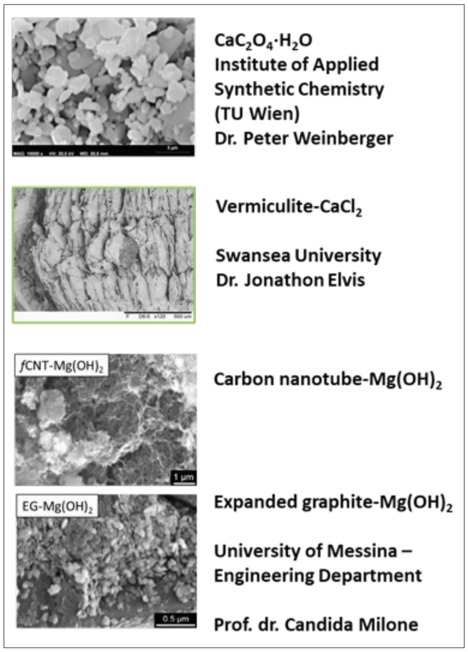
Work was also performed on the setting up of a materials database[2] with data on a number of materials for both PCM and TCM. This database will be expanded upon within the proposed follow-on SHC/ECES project.

Here, the key messages are:

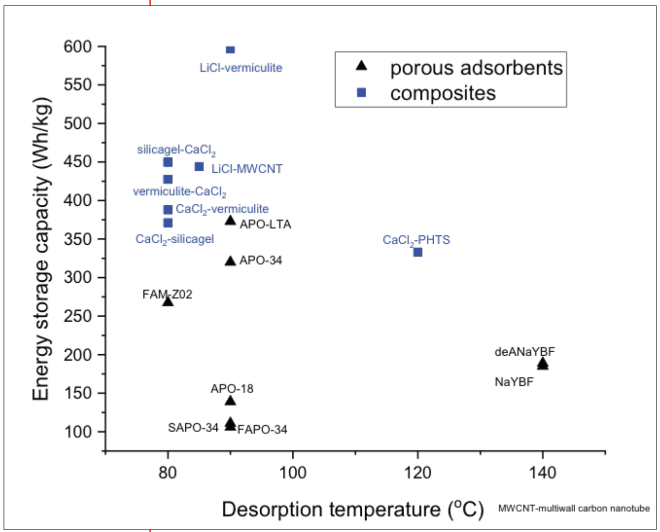
- A number of innovative and improved materials were developed and are continuously being developed, tested and introduced into storage components.
- Developed characterization methods are the basis for material evaluation and comparison and are the basis for the database inputs.
- The material properties not only cover the technical performance, but also questions like stability and compatibility.

Measuring Procedures and Testing Under Application Conditions

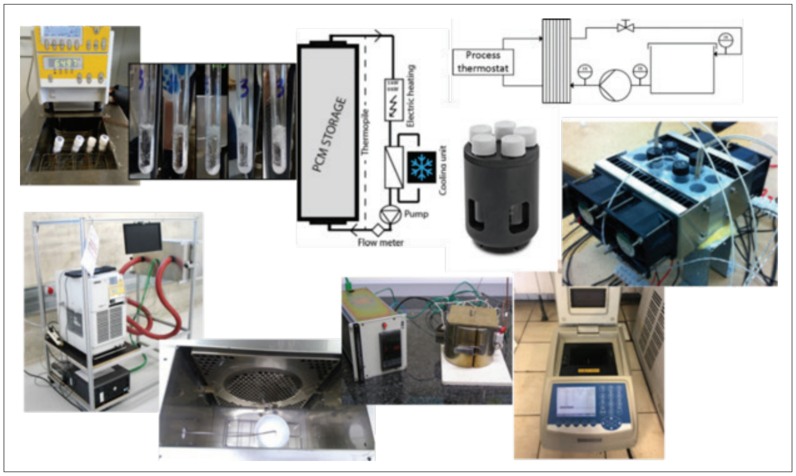
Ultimately, the performance of a thermal storage material is determined by it functioning in a component, in a system. So, when doing measurements on the storage material, one should apply the conditions imposed by the application. These are not only the temperature, pressure, humidity, etc. but also the geometry of a heat exchanger or the presence of other materials, for instance.



▲ **Figure 4. Microscopic images of different composite materials developed and tested by the project experts[1].**



▲ **Figure 5. Energy density of a number of materials. In black, the pure porous sorption materials and in blue novel developed composite materials.**



◄ **Figure 6. Experimental devices to investigate the long-term stability of PCM.**

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Thermal Energy Storage *from page 3*

Material scientists characterize materials by performing measurements on a very small amount of material. This measured performance is mostly not identical to the materials' performance in a storage device. One would like to be able to connect the small-scale material characteristics with its performance on a larger scale, and the experts in this project worked on the first steps of this connection.

For PCMs, a vast amount of knowledge has been gathered on determining material performance on a small scale, and SHC Task 58/ECES Annex 33 started the work on defining measurement methods with which the bulk-scale behavior of PCM can be determined, like the degree of supercooling, phase separation and long term stability. For long-term stability, the different measurement devices and methods have been identified and described. In the proposed follow-on project, these will be compared to find out the weaknesses and strengths of the different methods and to improve the methods (see Figure 6).

For TCM, even the characterization on the small-scale level is leading to different results between different measurement methods. To find out what the causes are for the differences, a series of round-robin tests were designed and performed, both with a sorption material (zeolite 13X) and a salt hydrate (Strontium bromide hexahydrate). Both the conditioning procedure for the samples and the measuring protocol have been analyzed and proposal for improvement made. These will be used in a following round-robin to see whether the differences will decrease. For sorption enthalpy measurements on zeolite, this procedure has already led to smaller deviations in the results while the process for the salt hydrate is a bit more tedious and needs more work.

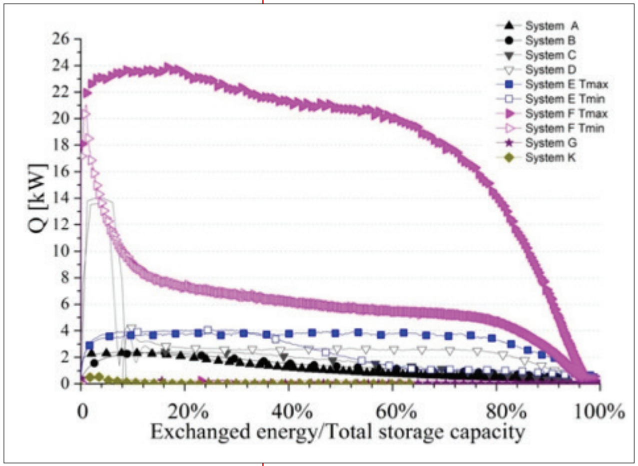
The key messages derived from this main field are:

- Only testing under application conditions helps in identifying the appropriate material for an actual application.
- Actual storage capacity and material stability have to be tested under real conditions and requirements.

Component Design for Innovative TES Materials

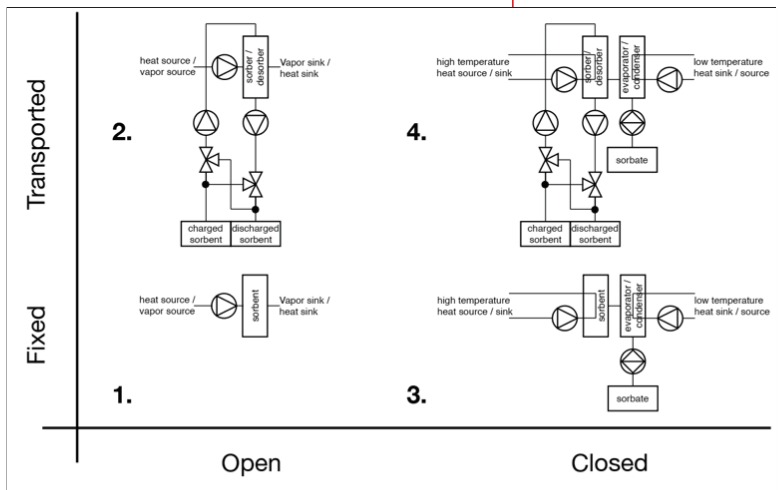
The main component for a PCM storage is the vessel/heat exchanger. The challenge in designing the heat exchanger is achieving the required thermal power in combination to a suitable energy storage density. In practice, there are many designs of heat exchangers for PCM. In this project, an inventory was made of PCM heat exchangers and then a method designed to determine the performance of the PCM in a uniform way, independent of design-specific aspects, see Figure 7. The aim is to compare different heat exchanger designs for a given application, helping to find the best design and a better understanding of interaction between thermal behavior of the PCM component and the material properties. A first set of normalized performance parameter was proposed[3], however further work will continue to explore most suitable normalization.

For TCM systems, the variety of component designs is very high, due to the difference in thermochemical storage principles. For low temperatures, for instance, there are sorption systems with solid material, salt hydrates systems with possible change from solid to liquid and liquid sorption systems that show crystallization under certain conditions. At higher temperatures, the variety is even stronger, with solid-gas reactions in which the solids also can melt or conglomerate. A first inventory of the different heat exchangers and reactors and the design of a classification method was completed, see Figure 8. These will form the basis for further component design and optimization in the proposed follow-on project.



▲ **Figure 7. Normalized power/capacity curve of a number of PCM storage devices.**

To date, the evaluation and comparison between systems is practically impossible. Even when focusing on a single application, such as seasonal heat storage for space heating. The large variety of testing conditions hinders comparison. To resolve this issue, a literature study was performed, looking into the required temperature lift for desorption (GTLD), the resulting temperature lift in sorption (GTLS) and its ratio GTLS/GTLD, defined as temperature effectiveness (TE). This method describes how well the system takes advantage of the full potential of the employed storage material and enables a basic comparison between the systems as well as the basic process designs[4]. Further work will follow to define standardized testing conditions to evaluate progress in the field.



▲ **Figure 8. Basic description of investigated TCM storage processes.**

From this field, the following key messages are:

- Identification of component parameters is necessary to enable the comparison of compact storage concepts.
- The attainable charging/discharging power is strongly influenced by the component design, where the interaction of the storage material with the component is crucial.

Outlook

In the three years of the joint SHC Task 58/ECES Annex 33 project, important steps were made in improving the materials and testing methods for compact thermal energy storage technologies. And, first steps were made in understanding the interaction between storage material and the heat exchanger or reactor. But the challenges in using and improving the gained knowledge for a better designed component are big. In order to arrive at well performing, reliable and affordable compact thermal energy storage systems, these challenges will have to be tackled in a coordinated way and thus form the reason for the new proposed new project to further improve the test and characterization methods and the link between material performance on the lab scale and component scale by studying the material-component interaction in more detail. The adoption of novel techniques from the field of digitalization will be explored to help the materials development process and better determine the state-of-charge of a compact thermal energy storage device. All this though is dependent on the continuation of the very successful formula – close collaboration between material scientists and component and system design engineers.

This article was contributed by Wim van Helden, AEE INTEC, Austria, Alenka Ristic, NIC, Slovenia, Stefan Gschwander, FhG-ISE, Germany, Christoph Rathgeber, ZAE Bayern, Germany, Daniel Lager, AIT, Austria, Ana Lazaro, University of Zaragoza, Spain, Benjamin Fumey, EMPA, Switzerland.

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INTERVIEW

Material and Component Development for Thermal Energy Storage

Interview with Wim van Helden

The IEA SHC Programme concluded its joint project with the IEA Energy Conservation through Energy Storage (ECES) Programme on Material and Component Development for Thermal Energy Storage (SHC Task 58/ECES Annex 33). To learn first-hand how this Task supported thermal energy storage market development, we asked Wim van Helden, the SHC Task Operating Agent, to share some of his thoughts on this 3-year project.

Why is a project like this needed?

Wim van Helden (Wim): Thermal energy storage (TES) is an enabling technology. It enables better and more efficient use of intermittent renewable heat sources, like solar thermal, and makes thermal systems more flexible. And not insignificant, thermal energy storage can help to stabilize the electricity grid by power-to-heat. We need the full range of TES technologies as the very different applications ask for tailor-made solutions. The most used technology is sensible water heat storage, but this technology cannot serve those applications that need high temperatures or have volume restrictions or need storage over a long period. For these cases, compact thermal energy storage technologies need to be further developed.

What is the current status of the technology?

Wim: Compact thermal energy storage can be subdivided into technologies using phase change materials, PCM, or thermochemical materials, TCM. For PCM, there are already a number of applications on the market, especially in the built environment. For TCM, there is at the moment only one mass-market application, namely in the zeolite dishwasher. Here, the zeolite technology has the double function of lowering electricity consumption and improving the drying quality of the dishwasher.

In order for both classes of technology to be wider applicable, development work both on materials and on components is needed. In this Task, both material and component experts collaborated to develop new materials, improve testing and characterization methods, and improve compact TES components and system performance.

Is there one result or outcome that really surprised you?

Wim: One surprising result is that there are so many ways materials can be improved. We found that combining materials led to new classes of materials that have better storage capacity on the one hand and are more stable with a longer lifetime on the other hand. And we are probably only just beginning to understand what the possibilities for materials improvement are.

Do you have a Task success story from an end-user or industry to share?

Wim: The zeolite dishwasher is a success story from industry. By using zeolite, which has a very good water vapor uptake while generating heat at the same time, a perfect combination was found between a storage material and a specific application. The material can provide the drying plus heating functionality. The use of this 'strange' material in the dishwasher generated some big design problems for the dishwasher manufacturer, but in the end, they solved all the challenges, and the product has found its way into the mass consumer market.

How has the Task's work supported capacity and skill-building?

Wim: We see that the collaboration between international experts for now over 10 years and in two Tasks with the ECES Programme has led to good professional and personal relations, which were and are the basis for a large number of project collaborations. Over the last five years, there's been an increase in the number of expert groups with young scientists and engineers, initiating a new phase in the collaborations.

What is the future of the technology – new developments, markets, policies, etc.?

Wim: In the past and at the moment, policymakers are strongly oriented towards the electricity part of the energy system, although I see a growing awareness of the importance of heating and cooling for the global energy system. Compact thermal energy storage technologies are best for high-temperature, high volume constraint, long storage period markets. Of these markets, we see that industrial heat and power-to-heat will be the first to be entered by compact TES. One of our Tasks in the near future will be to raise awareness of the potential of compact TES for these applications with the policymakers and decision-makers.

What were the benefits of running this as an IEA SHC Task?

Wim: The grand benefit is definitely the international cooperation of experts. They share their results and experiences on a broad range of technologies and applications, generating a lot of cross-fertilization in the research and development

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COUNTRY HIGHLIGHT

The Netherland's Solar Heat Roadmap Looks Towards 2050

Being a northwestern European country with a temperate maritime climate, the Netherlands spends a considerable share of its energy to heat buildings. Of the 6,000 PJ consumed overall on a yearly basis, 500 PJ is used as heat for the built environment, most of which is produced using natural gas. As part of the commitments made in the Paris Climate Agreement, the Dutch government plans to phase out the use of natural gas in the built environment by 2050. This ambitious target creates ample opportunities for other, cleaner energy sources, one of which may be solar heat. Solar heat production in the Netherlands currently amounts to just over 1 PJ, or just 0.2% of total heat demand in the built environment. Still, there seems to be an enormous potential to increase its use and develop it into a competitive technology, particularly for low-temperature applications such as hot water heating and space heating in the building sector.

To determine this potential, as well as the obstacles facing solar thermal energy, the Dutch Ministry of Economic Affairs and Climate and the Netherlands Enterprise Energy (RVO) in the summer of 2020 commissioned the Initiative for a Solar Heat Roadmap. Researchers at TNO, the Netherlands Organization for Applied Scientific Research, carried out the study and concluded that in 2050, solar heat would be a competitive standard technology for hot water and space heating in the built environment. This preliminary study was carried out in close cooperation with the solar trade association, Holland Solar, which plans to produce a solar heat roadmap together with the government and the business community at the beginning of 2021. This roadmap will include a comprehensive strategy for realizing the full potential of solar heat.

According to TNO, solar heat's potential is considerable across all sectors – buildings (residential and non-residential), agriculture and industry. The potential solar heat contribution for 2050 is projected to be 80 PJs, or 10% of the estimated total Dutch heat demand.

'The potential solar heat contribution for 2050 is projected to be 80 PJs, or 10% of the estimated total Dutch heat demand.'

▲ **The largest solar thermal system in the Netherlands is for heating the Tesselaar Freesia Heerhugowaard greenhouse. The system has 9,300 m² of collectors with two storages, a 30 m³ basement return vessel and a 1,400 m³ storage tank. The overproduction of heat during summer is stored in the soil.** (Source: G2 Energy)

To reach this target will take significant effort and change in focus. In the Netherlands, solar thermal hasn't seen the rapid growth of PV, biomass and offshore wind over recent years. In the Regional Energy Strategies defined by 30 regions in the Netherlands, solar heat is only mentioned in the margin.

Based on the preliminary study, the researchers make a series of recommendations:

- It is expected that solar heat can become a cost-effective part of the heat transition.
- Entrepreneurs should take responsibility for preparing and implementing the roadmap.
- A unified strategy for the development of solar is needed, including a timeline with clear milestones.
- Solar heat will need to contribute cost-effectively to sustainable energy production and natural gas-free neighborhoods.
- The roadmap should look closely at costs compared to other sustainable technologies.

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Potential for solar thermal in 2050, with and without heat storage		Potential (PJ) in 2050	
		without heat storage	with heat storage
Dwellings	Individual systems	25.1	34.3
	In existing heat networks	0.4	0.9
	In new heat networks	9.5	18.8
	Subtotal dwellings	35	54
	Share solar thermal in total heat demand	*17%*	*26%*
Services	Swimming pools, nursing homes, hotels	10	10
Agriculture	Horticulture, cattle breeding	3	3
Industry	Food industry	12	12
All Sectors	Total (rounded figures)	60	80
	Share solar thermal in total heat demand	*8%*	*10%*

According to TNO, a strong commitment is required from industry in the solar heating sector, but also the government. Long-term cooperation between these two parties, complemented by research institutes and civil society organizations, is necessary to initiate change and achieve the targets.

The TNO researchers also identified various bottlenecks to the further development of solar heat.

- **Communication strategies.** Solar heat is often unknown to the public and absent in communication about the energy transition.
- **R&D at the producer level.** Technological innovation is necessary for price reduction and new concept development.
- **R&D at the scientific level.** Technical challenges with seasonal heat storage, integration into heat networks and building integration at the system level.
- **Strategies at the economic, political and market level.** Cost reduction to make competitive with natural gas. Comparison with other energy concepts for fossil-free neighborhoods should take place within comparable system boundaries. Solar heat is supported by subsidy schemes, but the overall effectiveness is insufficient. Integration of solar heat into heat networks requires the right regulation and policy.

▲ **The 7,000 m2 solar thermal collector field on Zoneiland Almere (Almere Solar Island) is one of the largest of its kind in the world.** (Source is Nuon Vattenfall)

According to the TNO researchers, three product-market combinations have the greatest potential in the built environment:

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The Netherlands *from page 8*

- Solar heat for domestic hot water,
- Solar heat from uncovered collectors (solar thermal or PVT) as a source for heat pumps, ground-coupled heat exchangers, or low-temperature heat networks, and
- Solar heat for medium temperature district heating.

Most present-day heat networks in the Netherlands operate at temperatures too high for a suitable solar heat application. In the framework of the phase-out of natural gas, current and future heat networks are being designed more and more for medium and low-temperature heat. This provides ample opportunity for direct application of solar heat. Combinations with heat pumps or storage may prove useful for higher temperature district heating.

The TNO researchers provide a preliminary outlook for 2025, 2030 and 2050, regarding solar thermal's possible status in those years and the developments required for that purpose: 'By implementing multi-megawatt systems, growth can increase significantly in the short term. Meanwhile, the industry needs to focus on improving domestic systems. By 2025, the industry will have to ensure that solar heat is a serious option for natural gas free neighborhoods, both for individual homes and apartment buildings. After 2025, further cost reductions need to be achieved through targeted innovation, increased efficiency and economies of scale. This will pave the way for the roll-out after 2030, for which integral solar thermal system concepts must become standard. The sector needs to continue to focus on cost reduction and innovation for seasonal heat storage and needs to be active in both the new-build and renovation markets. The image of solar heat will then improve rapidly, and by 2050 solar heat will be a competitive standard technology for domestic hot water and space heating. Other sectors, such as industry, agriculture and horticulture, will also make widespread use of solar thermal'.

Overall, the report provides an optimistic message for solar heat in the Netherlands, as well as in general. The energy transition as a whole needs innovation and new concepts, and so does solar thermal. If the industry manages to decrease solar thermal system prices, then the competitive position of solar heat will continue to improve towards 2050, possibly helped by increasing prices for conventional energy and CO2 pricing. In the long term, solar heat can thus become a standard and subsidy-free technology. This will require a shared vision on solar heating, in which all parties involved, nationally and preferably also internationally, are serious about achieving its potential.

This article was contributed by Tomas Olejniczak of RVO and the new Dutch Executive Committee member.

NEW

SHC Task Starting in 2021

Harald Drück of the University of Stuggart will be leading our newest project, Task 66: Solar Energy in Buildings starting July 1, 2021.

Background

On the global level, buildings account for around 40% of the primary energy consumption and approximately 25% of the greenhouse gas emissions. Additionally, large amounts of energy are embodied in building construction materials.

Solar thermal and solar electric (photovoltaic) energy can significantly reduce fossil fuel energy demand in buildings. Numerous research projects have shown that 100% solar fractions of the electricity and heat requirements for individual buildings (mostly single-family homes) are feasible. However, these demonstrators were all in economic terms not nearly competitive with conventional energy supply solutions and were characterized much more by a high degree of self-sufficiency.

Task Scope

Participants will focus on developing economical energy supply concepts for high solar fractions of single-family buildings, multi-story residential buildings and building blocks or distinguished parts of a city (communities) for both new buildings and the comprehensive refurbishment of existing buildings.

Key Aspects

- Overall energy supply of the building: this means heat, cooling and power
- Synergetic consideration of the interaction with grid infrastructures (electricity and heat) in the sense of bidirectional flexibility

Subtasks

- Subtask A: Boundary Conditions, KPIs, Definitions and Dissemination
- Subtask B: Single Buildings – New and Existing
- Subtask C: Communities / Building Blocks – New and Existing
- Subtask D: Current and Future Technologies and Components

To learn more about this Task or inquire about how to participate, please contact Harald Drück, harald.drueck@igte.uni-stuttgart.de.

OPINION

The Curators of Social Capital

Dr. Richard Hall, a Vice Chair of the Solar Heating and Cooling TCP, discusses the role that IEA TCPs play in curating sectoral social capital and how this elusive form of capital is used by governments to efficiently deploy resources in times of crisis.

Whenever I read that the objective of the Solar Heating and Cooling Technology Collaboration Programme (SHC TCP) is to 'advance research and development activities,' I can't help but feel that something is missing. The description fails to capture some very valuable aspects of what this TCP achieves in working with participating governments. But it's not easy to find the words to describe this 'other' work that we do in the SHC TCP, and this is a real problem when trying to justify the not insignificant financial resources required for the programme.

I'm going to argue that alongside lots of great research and development activities, the members of the SHC TCP also play vital roles as curators of social capital in the solar heating and cooling sector. This sectoral social capital is much more than simply 'networking.' Although elusive and difficult to quantify, social capital is vital to the effective deployment of financial capital, especially in times of crisis.

The things which make up social capital… are are not physical, but intangible, such as interpersonal connections, trust and sectoral knowledge.

What is Social Capital?

Since the introduction of the concept in the mid-1800s, there have been many attempts to settle on a definition of social capital. For me, one of the best definitions is provided by Lin (2001), who defined social capital as the "resources embedded in a social structure that are accessed and/or mobilized in purposive actions." These resources that Lin refers to include many forms of social relations, including norms (standards and rules), information channels and symbols of prestige. For governments, the building of social capital is vital in improving the effectiveness and efficiency of coordinated actions.

One important aspect of social capital is that it is something that can be accessed and activated when needed. But unlike financial capital (money), there is no single place where you can store and retrieve social capital. The things which make up social capital are distributed throughout the society, and many of these things are not physical, but intangible, such as interpersonal connections, trust and sectoral knowledge. Given the highly distributed nature of social capital, it requires continuous maintenance to ensure that each component can function when called upon. Because it is so elusive, there is a real danger that you do not realize your social capital has disintegrated until you really need it.

Social Capital, the International Energy Agency and the TCPs

What does social capital have to do with the TCPs, I hear you ask. TCPs are closely affiliated with the International Energy Agency (IEA), and they provide valuable input into the agency's work. The IEA was born during the first oil shock (1973-1974), when members of OAPEC initiated an oil embargo, causing the price of oil to triple. To protect themselves from this weaponization of the oil supply, several oil-consuming counties came together to coordinate a range of protection measures. This included the holding of 90 days of the previous year's net import of oil and the ability to activate a demand restraint programme to reduce national oil consumption by up to 10%.

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Social Capital *from page 10*

Within the construct of social capital, the IEA can be thought of as an organization set up to enhance sectoral (energy) social capital: Resources (oil reserves) were embedded within a social structure (multilateral co-operation with pre-determined rules) so that they could be accessed in purposive actions (protection against future oil shocks). The creation of the TCPs by the IEA Governing Board in 1975 was also part of the effort to strengthen social capital within the oil-consuming countries. As solar energy is usually local (within a country's territory), then promoting the greater use of solar energy is one tool a government can use to reduce oil imports; thereby enhancing energy security. At the time, the use of active solar energy was relatively novel and expensive, so the SHC TCP was set up to 'coordinate and promote the development, demonstration and deployment of technologies to meet challenges in the energy sector.'

It is undoubtedly true that the early work of the TCPs focused on advancing research and development activities. For the SHC TCP, trying to get forced circulation solar thermal systems to work efficiently and reliably was no easy task. But piece by piece, many of the technical challenges that prevented the use of solar energy have now been overcome. We are almost at the point where solar is the dominant form of new capacity worldwide.

Social Capital and Economic Shocks

Whilst we are hopefully nearing the end of the era of oil shocks, this is not the only type of crisis governments face where action from the energy sector plays an important role. In my last Solar Update article, Optimism for Solar Beyond the Great Lockdown, I talked about the connection between the economic recovery from recessions and the solar sector.

In the crisis caused by COVID-19, governments have been forced to control the pandemic and restart their economies using economic stimuli. Given the urgent need for action on the climate crisis, large elements of these stimulus plans have been directed towards decarbonizing the economy. We see this in the EU's 'Renovation Wave' and the UK's 'Green Homes Grant,' which are both largely dealing with the decarbonization of heating and cooling.

Just like during an oil shock, the COVID-19 pandemic has presented governments with a crisis in which resources embedded in a social structure have to be mobilized in purposive actions. We know what the principle purposive action is (the economic recovery), but what embedded resources are needed to get the financial capital working to support jobs and economic growth? In the case of responding to this crisis, governments need an understanding of solar deployment, a well-functioning installer certification system, up-to-date training courses that can easily be rolled out, an effective surveillance system to prevent scheme fraud and efficient information channels to communicate the right information to the right people.

Governments Need Objective Curators of Social Capital

Whist the SHC TCP cannot yet be described as the curators of social capital in the solar heating and cooling sector, I think the SHC TCP may be the closest thing to such an organization; and certainly, the closest if you consider our objectivity. Consider our work collecting deployment data for the report, Solar Heat Worldwide, our critique of solar standards and certification, our building of information channels and strengthening of interpersonal relationships via the Tasks and National Teams, our training work via the Solar Academy, or even our mapping of the sector via the Country Reports.

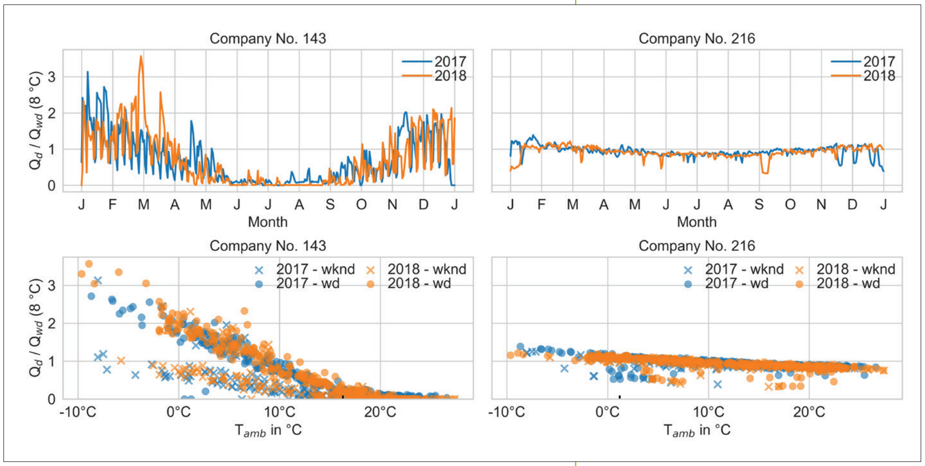
As the world moves towards net-zero carbon and oil shocks become less relevant, governments may need to give serious thought to how they respond to an entirely new set of non-oil shocks. We have just seen one type of shock in the form of an economic recession, where solar has been instrumental in getting people back to work. But there certainly will also be future 'renewable shocks'. Just as with oil shocks, having the social capital in place before they occur will be key in determining the effectiveness of governmental responses.

The SHC TCP is already playing a critical role in building social capital in the solar heating and cooling sector, and this has certainly supported governments in their economic recovery plans. But if the SHC wants to further increase its value to the IEA and its member governments, we may wish to explore this element of our work further.

Heat Load Profiles – A Key for Unlocking Renewable Heating Systems Potential

In the context of IEA SHC Task 64: Solar Process Heat, researchers developed a method to estimate the heat load profiles of companies in industry and commerce to facilitate preliminary designs, feasibility assessments and potential studies on renewable heating systems.

When planning a conventional heating system, the knowledge of the expected peak load alone is sufficient in many cases. However, since the availability of renewable energy varies during a year, the need for detailed information on the shifting heat demand in line with the targeted share of renewable heat is essential for preliminary design, feasibility assessment or potential studies on renewable heating systems. While there are several methods available to estimate the expected load profiles of residential buildings, little is known about the load profiles in the industrial and commercial sectors, especially when they have a higher share of industrial process heat to overall heat demand. To fill this knowledge gap, German utilities provided almost 1,000 profiles in hourly resolution of natural gas consumption from industrial and large commercial, residential and public consumers (> 1.5 GWh/a). Using this database, the overall goal is to develop a method to predict the load profile, depending on the ambient temperature, for large companies from industry and commerce, as well as large public facilities like schools, gyms and swimming pools.



▲ Figure 1. Yearly profiles of daily gas consumption and daily gas consumption depending on ambient temperature for two consumers. Heat demand is normalized to mean heat demand on days with an average ambient temperature of 8 °C. (wknd: weekend or official holiday; wd: working day).

Ambient temperature has a major influence on space heating demand, and the heat demand of many industrial processes is dependent on the ambient temperature. For instance, drying processes or surface treatment processes often use heated ambient air. Several other parameters like holidays, degree of capacity utilization and type and operation of heat generators also influence the heat demand, but predicting them is difficult. Nevertheless, for most of the gathered profiles, the influence of parameters, besides the ambient temperature, seems minor, especially when the daily heat demand is considered separately for working days, weekends and holidays.

The load profiles are clustered by their dependency on ambient temperature using a machine learning algorithm (K-Means). With four clusters, the analysis shows a good compromise between accuracy and a manageable small number of clusters. From cluster 0 to cluster 3, the dependency on ambient temperature continuously increases. For consumers in cluster 0, gas consumption is roughly the same on every working day of the year, making this cluster especially appropriate for a high share of solar thermal heat supply. In the case of the ambient temperature dependent clusters, the summer load decreases from cluster 1 to 3. While for cluster 1, a significant amount of heat could still be supplied by a solar thermal system with a storage capacity ranging from hours to a maximum of one day, solar heat generation without seasonal storage can only have a minor impact in clusters 2 and 3.

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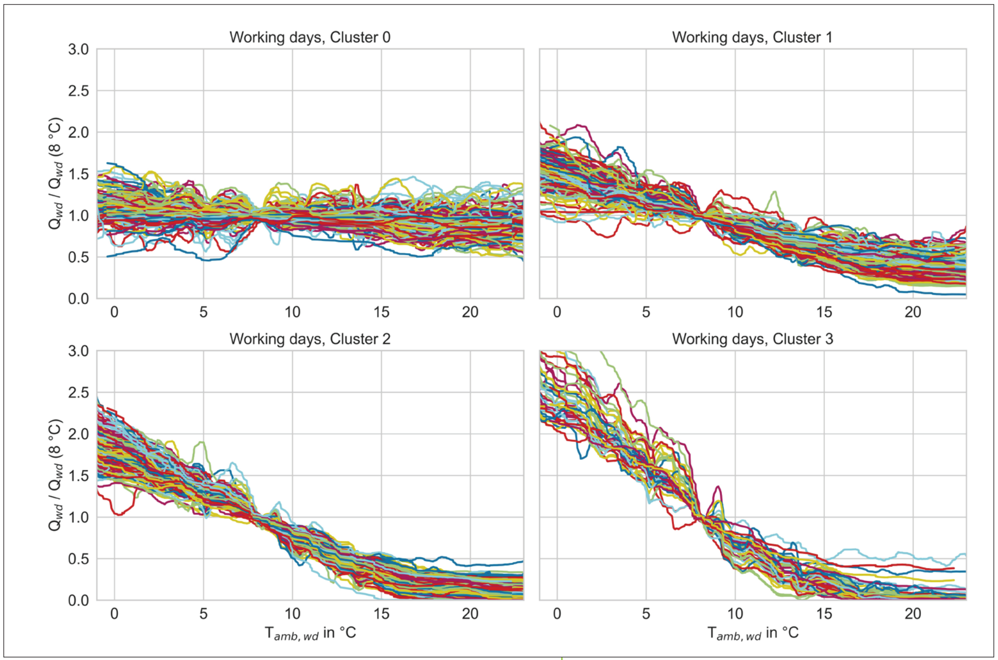
The share of the different clusters found within a specific industry sector shows that some subsectors like the production of food products or beverages are dominated by a process heat demand that is not dependent on the ambient temperature. For consumers within some other subsectors like the manufacturing of computer, electronic and optical products or the manufacturing of electrical equipment, almost all consumers show a dependency on the ambient temperature.

The correlation between ambient temperature and heat demand will be captured in a regression analysis. Finally, the hypothesis that the dependency on ambient temperature is similar for consumers within a particular subsector located all over the world will be tested using international heat demand profiles provided by IEA SHC Task 64 participants. In subsectors where this hypothesis can be verified, a transferability of the regressions to locations across the globe will be given.

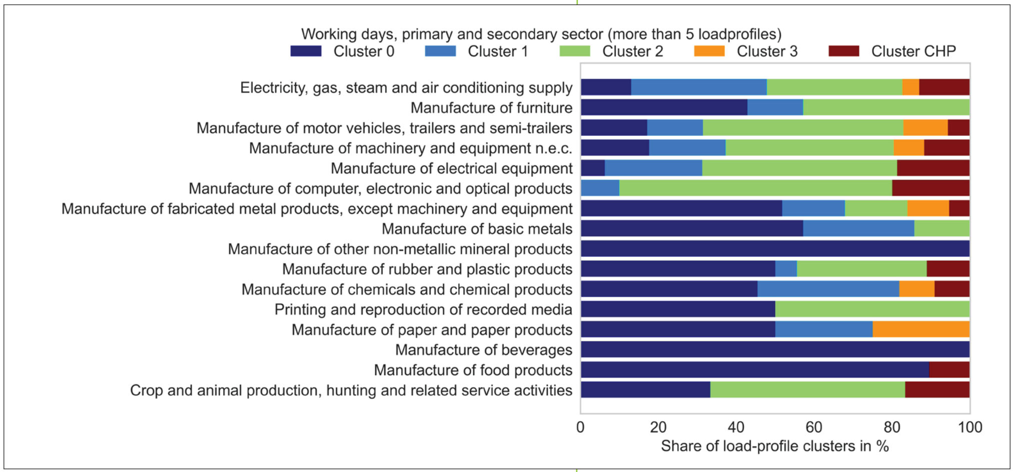
Within IEA SHC Task 64, the load profile regressions in conjunction with defined temperature levels will be used to define reference applications for integrated energy systems at various international locations. In a simulation study, the influence of the location on, for example, the system design or the economically achievable renewable energy share will be investigated for each of the defined reference applications at the beginning of 2021. Eventually, this will mark an important step towards facilitating global comparability and transferability of integrated energy systems.

This article was contributed by Mateo Jesper and Felix Pag of the University of Kassel, Germany. Felix Pag leads Subtask A of SHC Task 64: Integrated Energy Systems. For more information, visit the Task 64 webpage, https://task64.iea-shc.org, or contact pag@uni-kassel.de



▲ **Figure 2. All load profiles in the four working-day clusters. To keep the figure clean, only the moving average (and not the daily heat demand as a scatter plot) for each consumer is illustrated.**

▼ **Figure 3. Share of the four clusters within the primary and secondary sector for different subsectors (only subsectors with at least 5 consumers are illustrated). Some load profiles could be assigned to a CHP and were excluded from the cluster analysis.**



SOLAR ACADEMY SHC

FOR HEATING & COOLING IN BUILDINGS & INDUSTRY

Virtual Workshops Tackle Technical and Market Assessments of Solar Cooling in the Caribbean

About 30 consultants, researchers, manufacturers, grid operators and CCREEE staff joined a two-day training course organized by the Caribbean Centre for Renewable Energy and Energy Efficiency (CCREEE) as part of the SHC Solar Academy. CCREEE, the newest member of the SHC Programme, welcomed the opportunity to learn about Austria and Greece's solar thermal work and the new SHC project, Task 65 on Solar Cooling for the Sunbelt Regions.

The online workshop kicked off with Werner Weiss, of the Austrian company, AEE INTEC, and Vassiliki Drosou, of the Greek Centre for Renewable Energy Sources, first giving an overview of solar thermal applications used in homes, hotels, hospitals and manufacturing businesses before describing specific successful implementation strategies, support mechanisms and quality control methods.

On Day 2, the workshop participants learned about the work starting in the new SHC project, *Task 65: Solar Cooling for the Sunbelt Regions*, and state-of-the-art solar cooling. Daniel Neyer, of Neyer Brainworks based in Austria, and Uli Jakob, of German-based dr. jakob energy research, presented basic system functions and trends in solar cooling, economic and technical assessments and best practices.

"CCREEE did a great job of organizing the training. Despite the event being held online, attendees were very engaged, which prompted many in-depth discussions," said Jakob. One benefit of solar thermal cooling, as relayed during the sessions, is that it can reduce the strain on power grids, an especially important factor on islands with capacity problems. An attendee who works for a grid operator said, "If PV or wind generators are connected to the grid, weather conditions have an immediate impact on grid stability. As soon as a cloud covers one of the smaller islands, electricity demand can grow within seconds. Solar thermal cooling could help lessen the effect of that."

Of particular interest to attendees was a case study on the technical and economic aspects of installing a hybrid cooling system on the island of Barbados. The calculation showed a payback period of less than seven years at an internal rate of return (IRR) exceeding 13%. "For this study, we selected a 75 m^2 field of flat plate collectors that would drive a 15 kW ammonia-water absorption and a 15 kW ammonia vapor compression chiller in hybrid mode. The absorption chiller would deliver chilled water at 6°C as soon as the collector exceeded 200 W/m^2. And if needed, a vapor compression device would meet the remaining demand. This system could be used for small office or residential buildings," explained Neyer.

"One benefit of solar thermal cooling, as relayed during the sessions, is that it can reduce the strain on power grids, an especially important factor on islands with capacity problems."

— ULI JAKOB

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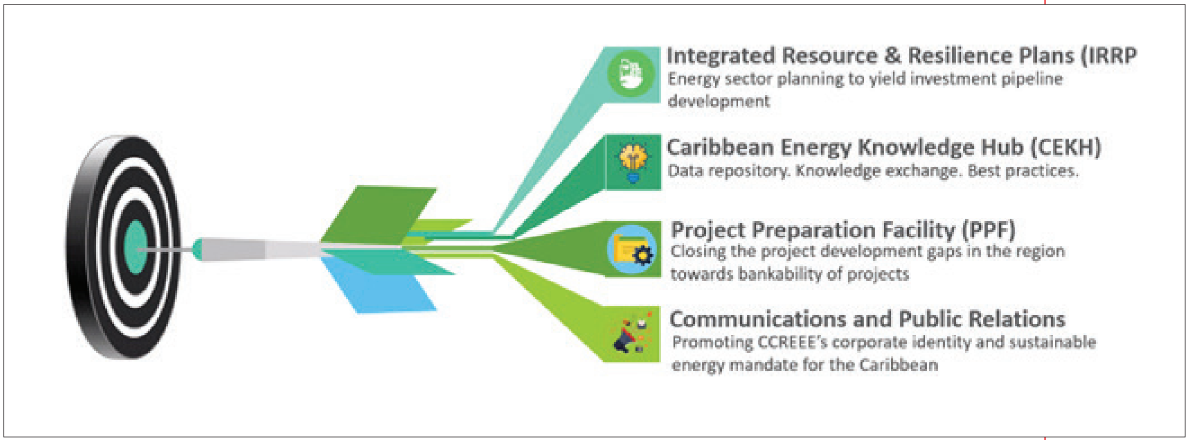
Solar Academy *from page 14*



CCREEE's work program.

Major Elements of CCREEE's Current Work Program

The addition of online training to the SHC Solar Academy's offerings will hopefully soon complement the Academy's pre-pandemic onsite training. Whether online or in-person, the trainings are creating a peer-to-peer bridge to exchange solar heating and cooling research work and experiences.

As Cornelia Schenk, CCREEE's Energy Efficiency Division Leader, noted, "We received a lot of positive feedback from attendees, so we are now exploring what other training opportunities we could make available in collaboration with the SHC Solar Academy." CCREEE is a relatively new but fast-growing organization that serves all 15 member states of the Caribbean Community, also known as Caricom. Founded in May 2018, it already employs ten staff as well as several interns.

A high point of CCREEE's current program is the Caribbean Energy Knowledge Hub (CEKH) that will provide a wide variety of data and information, including studies and reports. The CEKH is scheduled to come online this December.

Another notable activity is CCREEE's Project Preparation Facility (PPF) that aims to develop business models for clean energy or energy efficiency bankable projects. "A soft launch of the PPF is scheduled for 25 November with some initial seed projects. We are planning to go into full implementation in April 2021, following a validation period," explained Schenk.

CCREEE is part of GN-SEC, the Global Network of Regional Sustainable Energy Centres, and one of five GN-SEC members in the SHC Programme.

France Takes Solar to University

France's Solar Academy Graduate School is on course to become an international scientific reference on the integration of solar energy. Central to its work is integrating solar energy in the built environment by combining training and research at the highest level.

The Solar Academy Graduate School is located at the INES (National Institute of Solar Energy) campus in Savoie, France. The ambition of the Solar Academy is to become a national and international leader in academic research, engineering, business, economy and law for a model of low-carbon distributed generation and consumption. The core of its organization is a multidisciplinary approach to enable the large-scale use of the solar energy resource. The Solar Academy combines practice and theory in the areas of solar and building physics, scientific computing, material science, business, law, sociology, architecture and urban planning.

The Solar Academy relies on a joint "Graduate Program" and "Research Center" between University Savoie Mont Blanc (USMB), CNRS and CEA.

Solar Academy Research Center

The Research Center draws on the skills of seven USMB scientific laboratories, joint CNRS (French National Centre for Scientific Research) units and CEA (French Alternative Energies and Atomic Energy Commission) laboratories grouped into three scientific poles: Solar resources for multi-scale energy needs (Engineering skills), Solar energy digitalization for better reliability (Data sciences and Mathematics skills) and Diffusion of solar energy use (Busines and Sociology skills). The research and training of master's students and researchers are reinforced by the chair CITEE -cross-border innovation chair on energy efficiency, a joint venture between USMB, the University of Geneva and HES- hepia), the partnerships and relationships developed since the launch of INES, and a strong international network of research centers, laboratories and universities.

Solar Academy Graduate Program

This high-level training program, through research and for research, will be composed of a 2-year master's and a 3-year Ph.D. program (with subjects in materials, mathematics, numerics and law). The Master's Program offers two courses. The first one is about engineering (solar resource exploitation, solar energy integration at building and city scales, digitalization and data sciences). The second is on economic, legal and social issues. The two master's programs share a common core – for every student shall be aware of and trained in the other course's themes (economic models and policies to encourage the spread of solar energy for some, and technological drivers and barriers for others). Solar Academy labels are also proposed within other USMB master's programs if students follow certain graduate program modules. A Scientific Solar Summer School is organized each year around these multidisciplinary themes. The master's program will open at the start of the 2021 academic year, and the application process is to come (the academy will post information on the website, https://www.univ-smb.fr/solaracademy/).

International Connections

Through INES, partners of the Solar Academy enjoy access to first-class international networks, including with the International Solar Alliance (ISA), which was launched during COP 21 as a

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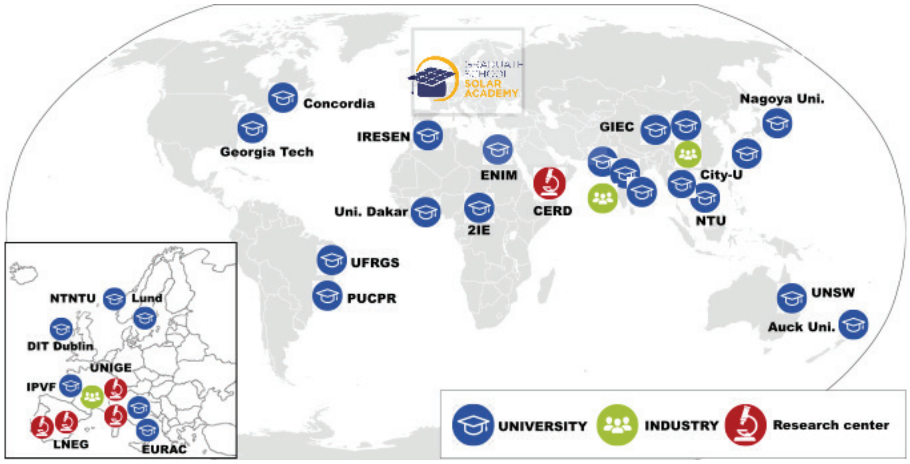
Member News *from page 16*

coalition of 121 solar-rich countries between the two Tropics to scale up the large-scale roll-out of solar energy and with SoMed!, a network of information and exchanges on solar energy in the Mediterranean region. The Solar Academy is positioned within a strong international network, including renowned universities and research centers in Africa, Asia, the Americas, Europe and Oceania.



The Solar Academy is directly connected to IEA SHC Task 63 on Solar Neighborhood Planning. As Maria Wall, the SHC Task 63 Operating Agent, notes, "experts and organizations participating in both SHC Task 63 and the academy will help to increase the dissemination of the work in Task 63, and hopefully develop an even stronger collaboration in the future. A real bonus is that the leading university of the Solar Academy, University Savoie Mont-Blanc, is also the co-leader of SHC Task 63 Subtask C on Solar Planning Tools."

This article was contributed by Prof. Monika Woloszyn, Director & Prof Christophe Ménézo, Deputy Director in charge of scientific and international partnerships. For more information please visit the website https://www.univ-smb.fr/solaracademy/ or email Prof. Ménézo, christophe.menezo@univ-smb.fr. For more information on SHC Task 63: Solar Neighborhood Planning visit the Task webpage, https://task63.iea-shc.org/ or contact the Task 63 Operating Agent, Maria Wall, maria.wall@ebd.lth.se.

Interview *from page 16*

work. This would not have been possible with national or even international projects, as these are more bound to pre-fixed goals and timelines and have fewer dynamics. Another benefit is that the mere fact that we have this IEA collaboration is a catalyst for national or international projects, as program owners and reviewers acknowledge the IEA collaboration as a very valuable asset and a marker of quality.

Will we see more work in this area in the IEA SHC Programme?

Wim: In the last year of the Task, we started discussing the why and how for continuing this IEA collaboration. We identified the most important R&D challenges that arose from our work, and at the moment, we are in the so-called definition phase for a follow-up Task. It will again be a joint project between the SHC Programme and the ECES Programme. We hope to get the green light from the two programmes in the first half of next year and start the second half. I am looking forward to the continued collaboration of this group of experts very much.

Lighting Solutions with People in Mind

The collaborative project, SHC Task 61 / EBC Annex 77 on Integrated Solutions for Daylight and Electric Lighting: From Component to User Centered System Efficiency, is wrapping up its work in June 2021 and results from these three and half year project are coming in. This article presents the first results of the Task's work on user requirements and design support for practitioners against the backdrop of integrating daylight and electric lighting. The Task experts joined forces to extensively investigate both user perspective and needs as well as state-of-the-art design workflows. The findings are documented in two Task reports, "Literature review of user needs, toward user requirements" and "Workflows and software for the design of integrated lighting solutions."

Literature Review of User Needs, Toward User Requirements

This report's main objective is to rethink and reformulate user requirements for lighting (daylighting and electric lighting) in public buildings based on a thorough literature study.

The concept of lighting quality is one among many lighting concepts that express the user perspective best. The following definition of lighting quality has been used for many years:

> Lighting quality is a concept that allows excellent vision while providing high comfort.
>
> *Kruisselbrink, Dangol and Rosemann, 2018*

In this article, the authors tried to find measures to use to describe lighting quality – quantity, glare, spectral power distribution, distribution of light, directionality and dynamics. The article also shows that mapping the luminance distribution is a suitable way to get useful information on the lighting quality. If the spectral distribution is added to these measurements, an even better description of the lighting quality is obtained.

The definition mentioned above for lighting quality focuses on humans. But, it does not consider aspects of light that have an indirect and profound impact on human health and well-being. These are the non-image forming aspects of light and some of the psychological elements as addressed in the report chapters:

- Visual perception
- Visual comfort
- Psychological aspects of lighting (view out, perceived quality of space, privacy, etc.)
- Non-image forming aspects of light (ipRGCs action spectrum, hormones, etc.)

By thoroughly reviewing literature dealing with these four basic aspects, the Task experts could revisit several lighting quality criteria, both image-forming and non-image forming. They also could compare between qualities of electric lighting and daylighting.

Based on the literature review, the experience of the Task experts involved, and the series of industry workshops coordinated with the Task's industry partners, the Task has identified a number of important measures for creating a better lighting environment, including both daylight and electric lighting (see Table 1). Included are most of the measures available now. The Task experts collected most of the measures from standards and others from ongoing projects and then specified the recommended threshold values.

Based on the many results from the literature review that showed a significant impact of daylight on people, we recommend daylight as a primary source supplemented by electrical light. As much as is practically affordable, electric light should be adjusted to individual needs, or at least differentiated between standard and visually demanding tasks.

The information in the table below should not be considered as absolute solutions but rather as guidelines. Revisions to these 'guidelines' will be done as scientific evidence calls for their updating. Below is a section of Table 1 on page 31 of the Task report summarizing the daylighting and electric lighting measures and recommended threshold values.

Workflows and Software for the Design of Integrated Lighting Solutions

Practitioners are using a wide variety of workflows, methods and tools in the planning of integrated solutions for daylighting, electric lighting and lighting controls. Lighting design projects cover a huge variety of applications with different requirements as well as project types and sizes. Within the Task's work in Subtask C: Design Support for Practitioners – Tools, Standards, Guidelines applied workflows in practical applications were reviewed and summarized in this report.

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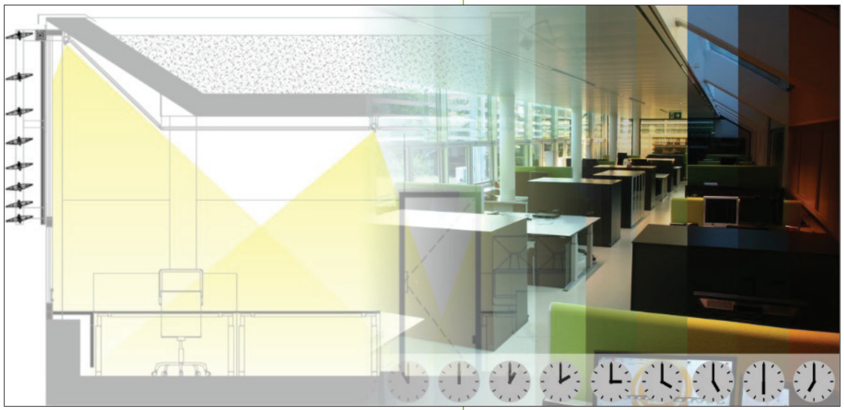
Lighting Solutions *from page 18*

The evaluation of planning workflows to design integrated solutions for daylighting, electric lighting, and lighting controls shows a broad spectrum of approaches. And reflects the variety and differences in real-world lighting design projects as illustrated in three office projects in Austria, China and Germany highlighted in the report. The described workflows can be seen as design processes representing well-working examples. All in all, they provide a toolbox of options and workflow steps to choose from and to assemble a specific workflow for a project.

	Daylight		Electric light	
Parameter	Measure	Standard value	Measure	Standard value
Workplace illuminance General	Target illuminance of daylight provision from windows	≥ 300 lux on the working place level ≥ 50% of the yearly daylight hours ≥ 50% of the space area	Mean $E_{horizontal}$ on the desk	Together with daylight ≥ 500 lux
	Spaces with skylights	as for windows but ≥ 95% of the space area		
Workplace illuminance Visual demanding	daylight provision from windows	≥ 750 lux on the desk ≥ 50% of the yearly daylight hours	Mean $E_{horizontal}$ on the desk	1000 lux
Workplace illuminance homogeneity	Minimum Target illuminance of Daylight provision from windows	≥ 100 lux on the working level in room ≥ 50% of the yearly daylight hours ≥ 95% of the space area	Uniformity Uo (E_{min}:E_{mean}) on the desk	≥ 0.6
Workplace illuminance homogeneity Visual demanding	Minimum Target illuminance of Daylight provision from windows	≥ 200 lux on the working level in room ≥ 50% of the yearly daylight hours	Uniformity Uo (E_{min}:E_{mean}) on the desk	≥ 0.7

The investigated lighting design software tools provide the possibility for every checked feature. However, no single software can cover all the relevant aspects. Similar to the workflows, the tools are designed for specific applications with special focuses. For example, some are mainly developed for daylighting analysis, while others focus on electric lighting design or BIM (Building Information Modeling) functionality.



▲ **Schematic design of integrated daylighting and electric lighting solution, and example sequence of interior lighting conditions in the report's design project at the Bartenbach R&D office in Austria.**

As a general result, one can see that basic functionality, such as illuminance calculation, is covered by all tools. On the other side, databases for either luminaires or daylighting systems, glare evaluations and the functionality to use BSDF-data for daylighting systems are only available in selected tools. And, the relatively new field of non-visual effects of lighting is hardly covered in the software systems. For this, special tools are available but have not been considered in the Task's work due to their limited functionality to evaluate integrated solutions for daylighting, electric lighting and control.

Both Task reports are available on the SHC Task 61 webpage, publications.

This article was contributed by Barbara Matusiak, Department of Architecture and Technology, NTNU, Norway, leader of Subtask A (barbara.matusiak@ntnu.no) and David Geisler-Moroder, Bartenbach GmbH, Aldrans, Austria, leader of Subtask C (david.geisler-moroder@bartenbach.com).

2020 Solar Thermal Trends

As 2020 comes to an end and 2021 begins, our team of SHC Task managers want to share some trends they see in their fields of expertise. We hope that by taking the time to stop and think about where solar thermal is headed, we can stay one step ahead of the technological advances and market changes.

TECHNOLOGY

Solar Cooling

Hybrid systems. More and more hybrid system solutions of all kinds in the field of solar cooling will come onto the market. They will offer high CO2 savings in small to medium cooling capacity ranges with good economic efficiency. There will be solutions with better efficiency and profitability in the area of **medium-temperature systems** (solar collector temperatures around 160-180°C) and double-effect absorption chillers. And with their smaller solar fields and lower heat rejection capacities, these systems have an **investment advantage of up to 40%** compared to conventional solar cooling systems.

PV/Thermal Systems

Market trends. There is increasing recognition that PVT (PV and Solar Thermal collectors combined) systems can deliver heat and electricity to homes as well as commercial and industrial buildings. And with this recognition comes growth. An estimated **3 million square meters of PVT will be installed by the end of 2021** as more examples of the technology at work continue to bolster this growing solar application. It is expected that more companies will be displaying their innovative PVT solutions and that the certification and official testing of PVT collectors will be easier and less costly for manufacturers.

Viable solar option. PVT glazed collectors are well suited for providing domestic hot water year round and delivering lots of electricity during sunny days for onsite use. In combination with a heat pump, unglazed PVT collectors provide the source of heat and some part of the electricity to run the heat pump, increasing the total solar fraction covered. Planners and installers will be considering the use of PVT to maximize the use of a roof, at least at the offer level when clients ask for PV.

BUILDINGS

Lighting

Lighting solutions. An integrative approach to lighting solutions in an indoor environment is picking up speed. After the technology transition to LED lighting, "Ledification," and a better and new understanding of human lighting needs, the **integration of electric lighting and daylighting** will continue to be assessed and advances made.

New alliances. Market actors once on opposite sides are building new partnerships. Luminaire manufacturers are teaming up with façade (glare protection and sun shading) and building automation suppliers. They are striving for **better user-centered lighting** while at the same time focusing on **energy savings**. For instance, new control concepts will improve lighting by positioning lighting directly in the field of view in workplaces rather than at some remote spot on the façade ceiling.

Standardization and certification. In 2021, we will probably see revisions to the main documents on lighting requirements (e.g., EN 12464-1) that introduce more differentiated requirements. Broadly used lighting design tools are expected to enhance **daylight modeling capabilities**, thus supporting practitioners in implementing integrative lighting solutions.

INDUSTRY

Solar District Heating

Energy management system (EMS). The coupling of different heating grids or the (frequently decentral) integration of renewable energy systems often leads to cross-ownership of an energy system, which raises the question, "How can we operate these systems optimally?" One answer is an **optimization-based predictive supervisory control** and a specific simulation that investigates different operating strategies. For example, social optimum could reduce the overall operating costs of a renewable district heating system by 9% and the overall CO2 emissions by 45%.

Model predictive control for large-scale absorption heat pumps. Varying operating conditions, as typically occur in solar district heating and cooling systems throughout the day and the year, are challenging for absorption heat pump systems. They can result in persistent actuator saturation, which in turn reduces their control performance. One **advanced control strategy, the model predictive controller (MPC)**, could reduce these periods of actuator saturation and limit their negative effects on absorption heat pump systems. A MPC control strategy's advantages can be appreciated when compared to a conventional PI controller using an absorption heat pump system simulation model and a solar cooling configuration with similar load profiles.

Concentrating systems for district heating integration – new Task concept. One insight from SHC Task 55 is that, aside from Denmark, many district heating systems are still operated with supply temperatures over 80 - 100°C, thus making it hard to transfer Denmark's solar district heating (SDH) concepts worldwide. These high temperatures are needed by the connected consumers (e.g., radiator heating systems) and allow for high heat storage capacity while having small mass flows (high exergy networks). Unfortunately, high-temperature heat is

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still typically produced by caloric power plants (often driven by coal) and seldom by solar technologies directly or indirectly (e.g., by combining solar collectors with heat pumps). However, there is a range of mature high-temperature collector systems on the market to efficiently produce higher temperatures > 100°C together with innovative new storage concepts for efficiently storing heat at high temperatures. Furthermore, introducing high temperature for large-scale solar thermal systems would facilitate integration and industrial applications (e.g., SHIP) provide possibilities for sector coupling with the electrical grid (e.g., using steam turbines). With this in mind, one main objective of the follow-on Task to SHC Task 55 will be to **develop concepts, collect system requirements, provide reliable performance measures and develop optimal control strategies** for the most efficient production, integration/distribution and storage of high-temperature heat for large-scale SDH systems. Another focus will be on digitalization measures for SDH.

Digitalization measures allow for more efficient monitoring, automatic fault diagnosis, predictive maintenance and advanced process control (e.g., mixed-integer model predictive controllers). If you are from a SHC member country and are interested in participating in the new Task's definition phase, contact Viktor Unterberger, viktor.unterberger@best-research.eu.

Nexus Water-Energy-Industry

Opportunities. About 20% of the world's water is used by industry, and therefore is an essential economic good. Water shortages in specific regions worldwide, as well as the need for CO2 reduction and primary energy savings, underline the interdependence of water and energy. The efficient supply of energy, the best possible integration of renewable sources, and the recovery of resources must go hand in hand. Theoretically, a **100% solar energy supply ratio for water treatment technologies** is possible as it is common to work with large volumes and buffer storages, allowing production capacity variation and solar availability.

Industrial (waste) water treatment. The integration of solar process heat in industrial (waste) water treatment technologies is an application area and new market for solar thermal systems with enormous technical and economic potential. Technological combinations include thermally driven water separation technologies with the recovery of valuable resources, for example, integrating **solar-driven membrane distillation and thermally driven technologies** like diffusion dialysis, pervaporation or selective crystallization. There are also emerging technologies integrating solar into **water decontamination and disinfection systems**. The increased efficiency due to solar may affect the quality of the conversion process and help define new solar collector concepts to reduce manufacturing costs by maintaining high efficiency in collecting UV photons for better performing chemical oxidation reactions.

Solar Process Heat

System integration. Solar process heat is seen as a reliable component within the energy supply system for industry. The total energy supply system comprises various technologies (storages, boilers, heat pumps, solar thermal and other renewables) that complement each other with the aim of reliably delivering heat at required temperatures, power and time patterns with as **little GWP (Global Warming Potential) as possible and for an affordable price.**

Modularization. The trend is to move from individually engineered custom solutions towards **standardized modular concepts** that can more easily be replicated without high engineering demand and corresponding costs and risks.

Digitalization. System simulation is more and more moving from academic to standard engineering tools. Also, digitalization is becoming a **standard prerequisite for system integration** with optimum complementation/interaction of various technologies

Standardization. Specific aspects of solar process heat technologies will be recognized in **international standards.**

Market introduction. New **large demonstration projects** in various countries support the technical concepts of solar process heat systems (they work) and the attractiveness for investors (they make money) with innovative financing models.

Marketplace

The Solar Heating and Cooling Programme is not only making strides in R&D but also impacting the building sector. This section of the newsletter highlights trends and solar technologies developed, conceptualized, or part of the research in one of our Tasks and is now being tested/demonstrated or commercially manufactured, marketed, or used.

TODAY IN THE LAB – TOMORROW IN ENERGY?

This new IEA initiative is designed to shine a spotlight on research projects under development in the 38 Technology Collaboration Programmes. The second round highlights 24 projects, one of which showcases work done within SHC Task 60: Application of PVT Collectors.

Cheaper Heating and Cooling Using Innovative Heat Pumps and Solar

What is the aim of the project?

The SunHorizon project aims to unlock the potential for a user-friendly, cost-effective heating and cooling solution for residential and public-sector buildings. It combines heat pumps and solar appliances – among the most installed residential renewable energy systems – with thermal storage to form Technology Packages controlled by innovative software.

How could this technology be explained to a high school student?

Solar panels collect sunlight and turn it into electricity. Heat pumps are electrical devices that extract heat from one place and transfer it to another using a compressor pump and conductor coil. This project will connect advanced solar panels and heat pumps within homes and buildings to maximize consumers' use of solar energy that they generate themselves and to guarantee indoor comfort. The project will also develop software tools that reduce operating and capital costs by maximizing harvested solar energy and optimizing the design of new installations.

What is the value for society?

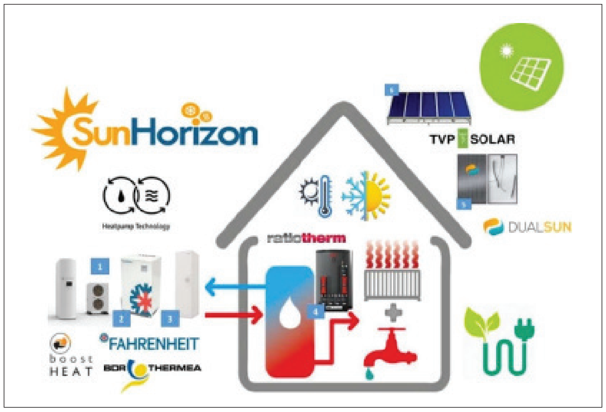
- saves primary energy
- lowers energy bills
- reduces fossil fuel dependency
- increases energy reliability in buildings

At what stage of development is this project?

The project was launched in November 2018 and is expected to run until September 2022. The sizing and layout of the Technology Packages are now defined, and eight demonstration sites are preparing all the necessary steps for installation, which will be finalized in 2021.

What government policies could bring this from the lab to the market?

- Making heat pump subsidies and incentives contingent upon integration of photovoltaic-thermal (PVT) and solar thermal plus photovoltaic technology (ST+PV).
- Advancing the European Strategic Energy Technology Plan (SET-Plan) heating and cooling policy at EU level.



Solar and heat pump technologies. Source: SunHorizon project, GA 818329

Partners

A consortium of 21 partners including research institutions, industrial companies, and public organizations.

Funder

HORIZON 2020 Research and Innovation Program (under Grant Agreement N. 818329)

This project's work was done within the framework of SHC Task 60: Application of PVT Collectors.

IEA (2020), Today in the Lab – Tomorrow in Energy?, IEA, Paris

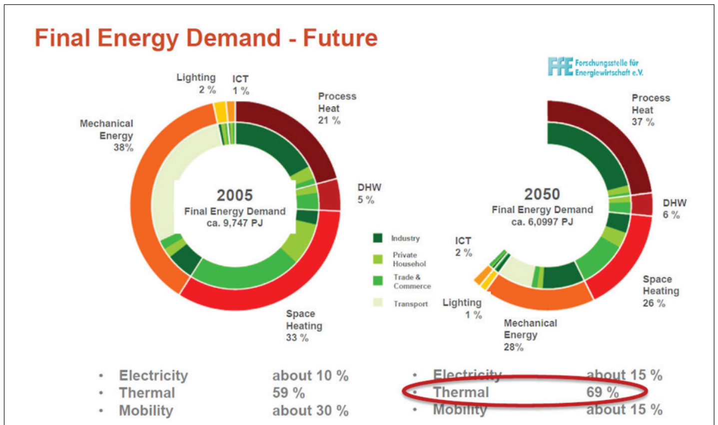
Learn more about the initiative, read the launch commentary, or explore the TCPs.

continued on page 23

Marketplace *from page 22*

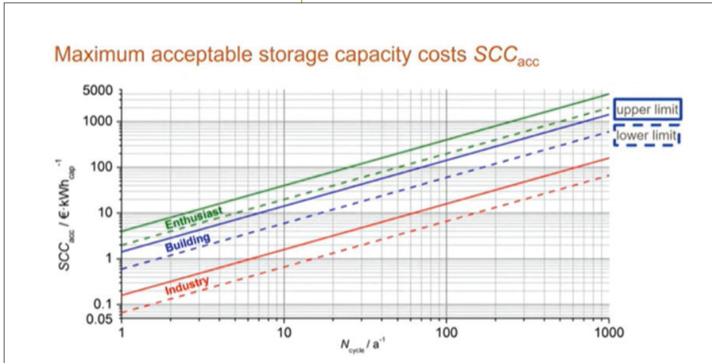
SIMPLE TOOL SHOWS ECONOMICS OF THERMAL ENERGY STORAGE

Andreas Hauer, the ECES Operating Agent for the joint IEA SHC/IEA ECES project, SHC Task 58/ECES Annex 33: Material & Components for Thermal Energy Storage notes that “The first thing you will see when looking at the estimates in the Final Energy Demand - Future graphs is a remarkable reduction in final energy demand from 9,747 PJ to 6,000 PJ. And yet, the share of heat will grow over the next 30 years.” Adding that in 2050, **demand for heat would be almost 5 times as high as for electricity**, creating an “urgent need to make use of all thermal energy storage technologies at our disposal.”



The share of heat in the final energy consumption will increase to 69 % by 2050
Source: FfE

A simple tool can be used to show the economics of thermal energy storage systems for three different types of users 1) enthusiasts (green), 2) building owners (blue), and 3) manufacturers (red). The requirement is that the cost of energy supplied by the storage system does not exceed the price for energy sold on the market. The y-axis shows the acceptable maximum storage capacity costs in EUR/kWh (calculated by using the interest rate on the cost of capital), the intended payback period for a given consumer, the reference energy costs, and the number of storage cycles a year. According to these calculations, the annual number of storage cycles (shown on the x-axis) has the largest impact on cost-effectiveness.



Maximum acceptable storage capacity costs for different consumers
Source: ZAE Bayern

How is this double-logarithmic chart to be read? “If a seasonal storage system with one cycle a year is used in the building sector, costs must be below 1 EUR/kWh of capacity – and, indeed, Denmark’s large sensible heat storage systems are in the range of 0.4 EUR/kWh,” explained Hauer. If the application is industrial and requires a daily storage cycle, costs range from 20 EUR/kWh to 30 EUR/kWh of capacity, according to the chart. Consequently, if the annual number of storage cycles is high enough, all thermal energy storage technologies will become cost competitive.

For more information:

- *https://task58.iea-shc.org/*
- *https://www.ffe.de/ (in German)*
- *https://www.aee-intec.at/index.php?params=&lang=en*
- *https://en.zae-bayern.de/*
- *https://www.solarthermalworld.org*

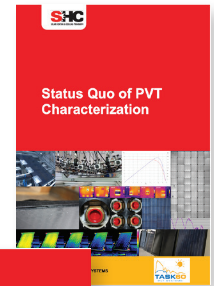
Note: *A follow-on Task is under development. To find out more or get involved, contact Andreas Hauer, ZAE Bayern, Germany, a.hauer@zae-bayern.de and Wim van Helden, AEE INTEC, Austria, w.vanhelden@aee.at*

Publications

New Publications Online!

You can find all our publications online and download them for free. Our complete library of reports, factsheets, case studies, photo galleries, online tools, databases and presentations goes back to the start of the SHC Programme. We invite you to explore all that is available by clicking on the "Publications' tab at the top of the SHC website.

Application of PVT Collectors



Status Quo of PVT Characterization

Achieving a sustainable PVT market development relies on product reliability and this can only be achieved by establishing functioning standards. This report covers the current situation of PVT characterization to support PVT development and application. The report should be of interest to researchers as well as public and private sector stakeholders.

Key Performance Indicators for PVT Systems

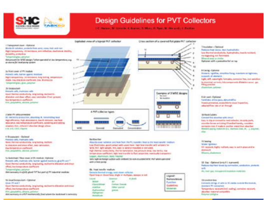
Provides precise definitions of useful KPI's for PVT systems. Where possible, these definitions correspond to those used in the technology fields of solar thermal systems and photovoltaic systems. In particular, the KPI's for the thermal performance of PVT systems are, to a considerable extent, based on the definitions adopted in SHC Task 44 (Hadorn 2015). The stipulation and use of standardized KPI's and notations will be essential for the comparability of different research results.

Basic Concepts of PVT Collector Technologies, Applications and Markets

Summarizes the current state of PVT collector technologies, applications and markets. The contents of this report have also been used to update a Wikipedia article on PVT.

2020 Subsidies for PVT Collectors in Selected Countries

Gives an overview of PVT subsidies in Austria, France, Germany, Italy, the Netherlands, Switzerland and the UK. The data for this overview was gathered through a survey on funding schemes for three solar technologies: Photovoltaics, Solar Thermal Systems and PVT Systems. The report presents the subsidy situation in each country and outlines recommendations for improvements.

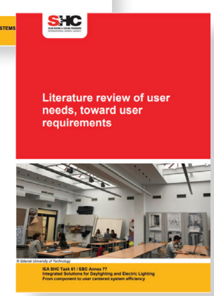


Design Guidelines for PVT Collectors

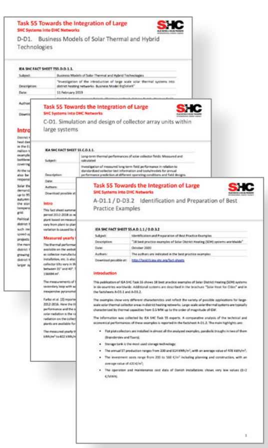
Quick 1-page reference on the different components of PVT collectors.

Integrated Solutions for Daylight & Electric Lighting

For information on the two reports below see the article, Lighting Solutions with People in Mind, on page 18.



Literature Review of User Needs, Toward User Requirements



Integration of Large SHC Systems into DHC Networks

Fact Sheets

- Identification and preparation of best practice examples
- Long-term thermal performances of solar collector fields: Measured and calculated
- Solar radiation modelling on tilted surfaces based on global radiation
- Collector types for large collector fields: Thermal performance
- CFD models of different collector types
- Business Models of Solar Thermal and Hybrid Technologies
- Business Models of Solar Thermal and Hybrid Technologies
- ENRSIM software

IEA SHC programme

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 66 R&D projects (known as Tasks) to advance solar technologies for buildings and industry. The overall Programme is managed by an Executive Committee while the individual Tasks are led by Operating Agents.

Follow IEA SHC on

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Technology Collaboration Programme
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