MATERIALS FOR COMPACT THERMAL ENERGY STORAGE: A NEW IEA JOINT SHC/ECES TASK

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ABSTRACT

A new IEA Task has recently been initiated to develop new storage materials. This Task is implemented as a Joint Task between the Solar Heating and Cooling (SHC) and Energy Conservation through Energy Storage (ECES) Implementing Agreements, and is entitled "IEA SHC/ECES 42/24: Compact thermal energy storage: material development for system integration".

The objective of this Task is to develop advanced materials for compact storage systems, suitable not only for solar thermal systems, but also for other renewable heating and cooling applications such as solar cooling, micro-cogeneration, biomass, or heat pumps. The Task will cover phase change materials, thermochemical and sorption materials, and composite materials and nanostructures, and will include activities such as material development, analysis, and engineering, numerical modelling of materials and systems, development of storage components and systems, and development of standards and test methods.

The main added value of this Task is to combine the knowledge of experts from materials science as well as solar/renewable heating and energy conservation. The Task has officially started on January 1, 2009, and will last for four years.

At the conference, the results of the kick-off meeting will be presented. In addition, an overview will be given of the activities planned within the task, and of the first results of the projects that have already started.

1. BACKGROUND

Thermal energy storage is an important technology for renewable energy systems. By improving the effectiveness of thermal storage, the effectiveness of all renewable energy technologies that supply heat can be improved.

Particularly for solar thermal systems, thermal energy storage is essential. To reach high solar fractions, it is necessary to store heat (or cold) efficiently for longer periods of time. Until now, no cost-effective compact storage technologies are available to do this. For high solar fraction systems, hot water stores are expensive and require very large volumes of space. Alternative storage technologies, such as phase change materials (PCMs) and thermochemical materials (TCMs) are available on a laboratory scale. However, more research and development is needed before these technologies can be developed into commercial solutions.

In several IEA Annexes, both ongoing and completed, it was concluded that materials are the main bottleneck for finding effective solutions for compact thermal energy storage, and that there is a need for new storage materials with a higher specific energy storage density and lower material cost.

Around the world, several groups are working on either thermal energy storage materials or applications. However, these activities are not sufficiently linked. The current activities are either limited to specific applications, or to specific materials. What is needed is a way to bring the ongoing work on materials and applications together. This is one of the most important motivations behind the new Joint IEA SHC/ECES Task/Annex 42/24, that has started officially on January 1, 2009.

2. KICK-OFF

After two expert meetings, one in October 2007 in Zürich, Switzerland, and another in April 2008 in Petten, the Netherlands, a proposal for the Task was presented to both the ECES and SHC ExCos in November and December 2007, respectively. Both ExCos were very positive on the scope and topic of this task, and have approved the start of this Task as of January 1, 2009. The task will last four years, i.e. until December 2012. The main challenge for this task is to bring together material experts and application experts (particularly solar applications, given the primary scope of the task). Because of this, it was decided that this task should take the form of a joint task between these two Implementing Agreements. The Task's will be coordinated by two Operating Agents: Wim van Helden of ECN, The Netherlands, and Andreas Hauer of ZAE Bayern, Germany.

The official kick-off of the task was held in Bad Tölz, Germany, from February 11-13, 2009. The results of this kick-off meeting, as well as the first progress of the work within the Task, will be presented at the conference.

3. OBJECTIVE AND SCOPE

The overall objective of this Task is to develop advanced materials and systems for the compact storage of thermal energy. This can be subdivided into eight specific objectives:

- to identify material requirements for relevant applications by means of numerical simulation of currently known storage technologies,
- to identify, design and develop new materials and composites for compact thermal energy storage,
- to develop measuring and testing procedures to characterise new storage materials reliably and reproducibly,
- to improve the performance, stability, and cost-effectiveness of new storage materials,
- to develop multi-scale numerical models, describing and predicting the performance of new materials in thermal storage systems, and to compare them to conventional storage systems,
- to develop and demonstrate novel compact thermal energy storage systems employing the advanced materials,
- to assess the impact of new materials on the performance of thermal energy storage in the different applications considered, and
- to disseminate the knowledge and experience acquired in this Task.

A secondary but equally important objective of this Task is to create an active and effective research network in which researchers and industry working in the field of thermal energy storage can collaborate.

Task 42/24 deals with advanced materials for latent and chemical thermal energy storage, and excludes materials related to sensible heat storage. However, the latter category is used as reference. The Task deals with these materials on three different scales:

- material scale, focused on the behaviour of materials from the molecular to the 'few particles' scale, including e.g. material synthesis, micro-scale mass transport, and sorption reactions,
- bulk scale, focused on bulk behaviour of materials and the performance of the storage in itself, including e.g. heat, mass, and vapour transport, wall-wall and wall-material interactions, and reactor design, and
- system scale, focused on the performance of a storage within a heating or cooling system, including e.g. economical feasibility studies, case studies, and system tests.

Because seasonal storage of solar heat for solar assisted heating of buildings is the main focus of the IEA SHC Implementing Agreement, this will be one of the primary topics of Task 42/24. However, because there are many more relevant applications for thermal energy storage, and because materials research is not and can not be limited to one application only, this task will include multiple application areas.

Applications that will be included from the start of this Task are:

- seasonal solar thermal storage,
- cogeneration, trigeneration and heat pumps,
- building cooling,
- district heating,
- industrial waste heat, and
- concentrated solar power.

Temperature control, e.g. for medical applications, will be taken into account as an interesting spin-off. The above subdivision will be treated with flexibility. If, during the Task's four-year operation, new promising applications are revealed, they can be included in the Task's scope at a later point.

4. MAIN ACTIVITIES

The Task will be organised around several main activities, organised in the following Working Groups:

- materials engineering,
- materials processing,
- tests and characterisation,
- numerical modelling,
- system integration, and
- applications.

Materials engineering
The activities in this Working Group focus on engineering new materials or composites, i.e. changing the properties of existing materials and developing new materials with better performance, lower cost, and improved stability. Eventually, this should lead to the ability to design new materials tailor-made to specification.

This Working Group includes the following activities:

- synthesis of new materials,
- determination of material characteristics such as phase diagrams,
- determination of the relation between material performance and material structure and composition, in order to direct the search for improved materials,
- create material safety data sheets, and
- determination of the role and importance of material containers.

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

This Working Group includes the following activities:

- finding optimal methods for micro- and macro encapsulation of phase change materials,
- processing of phase-change slurries, and
- finding new combinations of materials.

Tests and characterisation
The performance characteristics of novel thermal energy storage materials, like phase-change materials or thermochemical materials, often cannot be determined as straightforward as with sensible heat storage materials. In order to have proper comparison possibilities appropriate testing and characterisation procedures should be developed and assessed. The activities of this Working Group are aimed at developing these new procedures and include:

- comparative testing of materials and their required methods,
- long-term stability determination, and
- (pre-)standardisation of testing methods.

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

The Working Group includes the following activities:

- molecular dynamics,
- multiscale modelling,
- thermomechanical modelling, and
- storage (system) modelling.

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

This Working Group includes the following activities:

- improve heat transfer from material to reactor wall or heat exchanger wall,
- develop and apply test and validation methods for storages,
- system performance assessment,
- container and reactor design,
- storage system design,
- assessment of durability of components.

Applications

There are several applications for compact thermal energy storage technologies, each with a different set of boundary conditions for the technology. The activities for every application, however, are similar and are given for all Application Working Groups. The activities are serving the underlying principle of guidance of the materials development within the limitations of the application. The materials development will be directed by the desired system performance. A constant assessment of performance criteria for a given application will be used to determine the chances for a given material/system combination. These criteria can come from economic, environmental, production technology or market considerations.

Activities in the Application Working Groups include:

- storage testing and validation,
- performance assessment,
- numerical modelling on application system level,
- perform case studies,
- economical modelling,
- feasibility studies, and
- market potential evaluations.

5. JOIN THE TASK

Experts from industries and research organisations worldwide, that are active in this field, are cordially invited to join Task 42/24. If you are interested, please contact the authors of this paper or your national ECES or SHC ExCo member.

More information on this task can be found on the Task websites at *www.iea-shc.org/task42* or on *www.iea-eces.org*.