



**Minutes from the
Kick-Off Workshop of Annex 18
“Transportation of energy by utilization of Thermal Energy
Storage Technology”**

**November 14. - 15. 2005
Bad Tölz, Germany**

A key component in a sustainable energy system is to be able to use thermal energy from various sources at a consumer located at a distance from these sources. For this purpose, the thermal energy has to be transported from one place to another. This could be achieved by using thermal energy storage technology. Depending on the distance, the storage medium could either be pumped through pipelines or for longer distances the TES itself could be transported on a truck or a train. The crucial properties of the TES for the technical and economical feasibility are the storage capacity per volume and weight, and the charging and discharging power, which affects the possible number of storage cycles per time.

The purpose of this workshop was to show that this field of thermal energy storage is active and to establish that there is enough interest from industry and academia from various countries to start the annex 18 officially.

General

In mid November 2005, 25+ participants from seven countries participated in the kick-off event in Bad Tölz, Germany (see Table 1). Among these, we had representatives from industry (materials, as well as systems), research institutes, municipalities, as well as universities. The chairperson Dr. Lottner, the secretary, Dr. Hauer, and Canada's representative Ed Morofsky represented the IEA/ECES executive committee. The two-day event covered fifteen presentations, thus providing a nice jump-start to defining state-of-the-art for the task of energy transport through advanced energy storage technology. Examples of topics covered in the presentations are:

- National activities of relevance for Annex 18
- Feasibility study on thermochemical storage in Netherlands
- Feasibility study of mobile TES in Belgium coupled to CHP.
- Feasibility study of mobile TES in Germany
- Description of a pilot project in Germany
- Presentations from companies marketing mobile TES
- Update on slurry technologies
- Possibilities for mobile TES using chemical reaction

Table 1 List of Participants, kick-off workshop in Bad Tölz 2005.

	Name		Institution	Country
1	Herdin	Günther	GE Jenbacher	Austria
2	Bardsley	James	Earth Source Energy Systems	Canada
3	Boyle	Julian	Halifax Regional Municipality	Canada
4	Morofsky	Ed	Public Works and Government Services	Canada
5	Altgeld	Horst	Institut für ZukunftsEnergieSysteme IZES	Germany
6	Brühl	Johannes	GfA Fürstenfeldbruck	Germany
7	Budach	Jan Hendrik	SI GmbH	Germany
8	Gschwandner	Stefan	Fraunhofer-Institut für Solare Energiesysteme ISE	Germany
9	Hauer	Andreas	ZAE Bayern	Germany
10	Hublitz	Astrid	ZAE Bayern	Germany
11	Jänchen	Jochen	ZeoSys GmbH	Germany
12	Kolf	Alfred	Promaco GmbH	Germany
13	Lottner	Volkmar	PTJ Projektträger Forschungszentrum Jülich GmbH	Germany
14	Mehling	Harald	ZAE Bayern	Germany
15	Raab	Udo	ZAE Bayern	Germany
16	Schossig	Peter	Fraunhofer-Institut für Solare Energiesysteme ISE	Germany
17	Steinle	Klaus	ZAE Bayern	Germany
18	Storch	Georg	ZAE Bayern	Germany
19	Strasser	Ronald	Transheat GmbH	Germany
20	Toufar	Helge	Tricat Zeolites GmbH	Germany
21	Unger	Baldur	Chemiewerk Bad Köstritz GmbH	Germany
22	Mori	Hiroshi	Mitsubishi Chemical Engineering Corporation	Japan
23	Shikata	Ichiro	Kurimoto Ltd.	Japan
24	Yukitaka	Kato	Tokyo Institute of Technology	Japan
25	Martin	Victoria	Royal Institute of Technology, Stockholm	Sweden
26	Setterwall	Fredrik	Konsult AB	Sweden
27	Egolf	Peter	University of Applied Sciences of Western Switzerland	Switzerland
28	Bach	Pieter	ECN / EEI	The Netherlands

National activities

Japan

In Japan's preparation to participate in Annex 18, a pre-requisite questionnaire was prepared and sent out to about 110 companies. They were asked to indicate special focus areas, or areas of interest with regards to heat transfer conditions (source temperature and power, storage method, means, density, temperature), transportation (means, distance, container specification), usage (demand and scale), storage method (temperature, power, density, temperature, scale).

Some indication had so-far been obtained from this questionnaire although only a few companies answered.

In general in Japan, ice slurries are very popular one reason being the very nice heat transfer characteristics.

Germany

In Germany, two main projects are of relevance for the Annex 18 work: one regarding PCM slurries lead by Fraunhofer-Institut für Solare Energiesysteme ISE; and one regarding mobile TES conducted by ZAE Bayern. In addition, there are many companies working on technol-

ogy issues and product development. Germany hope to form a national expert group around the work related to Annex 18.

Canada

Canada joined the workshop enthusiastically by representatives from the Halifax Regional Municipality, along with an engineering company specializing presently in underground thermal energy storage. An overview of the local energy situation was provided with the following issues highlighted:

- The present challenge of demand-shifting electricity consumption – Halifax area is greatly affected by the US east coast which has a large cooling load.
- There is a goal as a municipality to decrease the greenhouse gas emissions by 20%.
- Plans are under way for developing a district energy system for the downtown area (2 square miles) where there is a university, a large hospital, a naval base etc.

Sweden

Sweden is preparing to join the Annex 18, and in Bad Tölz a presentation was given on possibilities with *Energy Transportation using TES* in the Swedish District Energy System. Some examples were given of candidate systems that deserves further exploration:

1. The Stockholm, and Gothenburg district cooling systems where too low cooling capacity [$\text{MW}_{\text{cooling}}$] is threatening in the future due to steadily increasing demand for cooling. Shortage of space for storage make pumpable PCM slurries interesting, at least for local, small parts of the network. Then, the network will have a storage capacity in itself.
2. The Oxelösund steel making company (SSAB) where a large amount of heat is wasted every year due to lack of suitable heat demand in the nearby community. Could part of this waste heat be transported by railroad to the nearby city of Nyköping, utilizing mobile TES?

Sweden has participated in the now finished annex 10, annex 14, and annex17 dealing with cooling through TES, as well as advanced TES concepts. Knowledge on material characteristics, heat transfer, and experience in design with efficiency monitoring will be of great use for the potential applications studies of TES systems in district energy systems and in industry.

Switzerland

Switzerland conducts research on PCS slurries, and also on advanced storage concepts for solar applications (IEA/Solar Heating and Cooling Task 32). Switzerland highlighted the importance of annex 18 to collaborate with that Task 32. Switzerland has, through Professor Egolf of Univ. of Applied Sciences of Western Switzerland, been extensively involved with the IIR working party on ice slurries. Collaboration with this working party is also of interest for annex18. Nowadays, activities with PCS are also included (see below).

Phase Change Slurries

In a review by Professor Egolf from Switzerland, the many commercial-scale systems employing ice slurry technology for increased energy efficiency were summarized. Large-scale ice slurry systems are in place in e.g. Japan and Korea, while small to medium scale systems are increasing in number throughout Europe. Other emerging technologies are micro-encapsulated PCM slurries, micro-emulsions of PCM in heat transfer fluid, chlatrates (NKK's system in Japan), and shape-stabilized paraffins.

Peter Schossig from Fraunhofer ISE high-lighted the usefulness of PCS-technology for cooling applications. For these, there is the potential for an advanced storage concept to be competitive as compared to stratified water storage since the temperature range in which to operate the storage is small for a comfort cooling application. The need for storage is huge as cooling demand often follows the electrical power demand curve such that peak cooling load coincides with peak electricity demand. Also, the cooling demand is expected to increase throughout the world. When comparing slurry technology to the mobile TES-technology, Schossig pointed out the need to compare the primary energy demand for each system – one example of an important criteria for evaluation of all Annex 18 projects. For the same mass flow rate, using PCS (28% by weight PCM), can almost double the amount of energy transported as compared to water alone.

PCM-slurries with micro-encapsulated PCM is now ready for a demonstration plant. Micro-emulsions (which have many promising features including a potentially lower cost as compared to micro-encapsulation) are on the other hand just in the laboratory-scale innovative phase where the creation of a stabile emulsion is a critical task.

Mobile TES

Many interesting examples exist where a district energy network for distributing heating and cooling is not feasible. It could be situations where a heat surplus is generated too far from a heat demand sufficiently large to warrant a network. Heat generation and demand may be very local, and small by district energy standard.

One example presented by IZES (Germany) was that of a biogas plant on a farm in Belgium. There, the biogas was fired in a gas engine generating a total of 1.1 MWh_{el} and over 1.4 MWh_{heat} per year. The farm's heat demand was only 600 kWh_{heat}/year resulting in a large heat surplus. For this reason, a feasibility study had been conducted investigating the possibility of trucking the heat to a nearby home for elderly. Some results of economical system simulations were that heat transportation was only interesting above 500 MWh_{heat}/year and then for short distances (below 5 km). The positive effect of green certificates for the electricity production is offset by the diesel consumption of transportation.

Another example presented by ZAE Bayern is that of a demonstration in a hydro aluminum plant. In this concept, zeolites will be used to store heat and the transportation will take place using standard containers. In the project, the economical feasibility was presented showing promising figures. In the next-coming phase, the project will include building a charging station at the plant, charging of conceptual zeolite storage, and then discharging to the aluminum plant's own storage hall where aluminum coils are stored. There, the dehumidification and heating is needed to prevent condensation on products.

Chemical Reactions – transportation of chemicals

Reversible chemical reactions can be used for energy storage, promising high storage densities when properly designed. One simple example is



With reactants being successfully separable, they can then be transported to a heat demand where they are brought together again and through the reaction heat is released. Typically

with chemical reactions, there is a heat pumping effect such that the heat is supplied (forward reaction) at a higher temperature than it is recovered (backward reaction).

The Energy Center of Netherlands discussed results from simulations of a system using chemical reactions as a step for transport of waste heat from the chemical industry to heat demands. The reversible reaction considered was the one involving isopropanol, acetone and hydrogen. No economic advantages over conventional energy transport were found at this stage. Also, small-scale experiments were conducted to test various catalytic materials.

In Japan, chemical reactions is considered a primary candidate for efficient energy transportation because of the potentially high energy density, and because of the potential for long-term energy storage since the thermal loss from reactants is negligible. Also, the temperature of the storage can be chosen by way of a suitable chemical reaction. High-lighted areas for development were e.g. reactor design (good heat and mass transfer characteristics), durable materials and catalysts.

Overall Discussion – a few notes

After almost two days of inspiring talks, there was still some energy stored within the participants and a vivid discussion took place. Some items that were brought forward include:

- The need for an economical comparisons with conventional DH&C systems

A comparison should be from both economic and energy point of view. Some pointed out that it is only economics that will "make or break" a technical solution. Someone else pointed out that the politicians may be interested in the energetic point of view because of CO₂ – commitment for example.

There is a need for demonstration projects.

- How to get High Capacity and High Power Storage Systems?

New materials, mixtures, chemical reactions – commercially available PCMs are gathered in a data base.

Perhaps one should not look for "the best energy density" but rather the ratio price/capacity. One example is if a new system or material increases the capacity by just a few percent, but at double the cost, then it may not be a good solution.

Also with regards to materials, rather than looking for new materials one should rather develop the overall systems for high ice packing factor and power.

- Reasonable investment cost per peak power shaved 100-300 € kW – how to reach it?
- Acceptable cost of "waste heat" – it is probably not always zero?
- Standardization of connections and components from the start?
Soon a German standardization of PCM measurements.
- Resistance to new technology?

Resistance to new technology may be due to lack of knowledge. Our responsibility is to disseminate information to various actors, thus providing a base from which to make better choices regarding technology.

Good examples and demonstration projects will result in acceptance in the end.

The Message from ExCo

At the meeting of the executive committee it was decided to extend the task-definition phase of Annex 18 until the next meeting, which will take place in conjunction with the "EcoStock" conference, the international conference on thermal energy storage. That means we can go on!

The work plan/legal text needs some revision such that it is crystal clear what can and will be handled within the proposed annex period of three years.

Confirmed participants are Japan and Germany – obviously they are eager to start. Technically, an annex can start with two countries. However, in this case the annex is missing an operating agent, hence the delay.

Sweden will continue to investigate a possible interest to participate.

ExCo-delegates from Canada, Belgium and Turkey will inquire with their industry regarding an interest to participate.

Join Annex 18 now to:

1. Get access to the combined experience of the international research community, system developers and business solutions for efficient energy transport. (parts of workshop presentations will be “closed” such that the documentation is only available to those countries, or other partners, who are officially members of Annex 18).
2. Get a chance to present your own, and your country's, projects within the field. Regular, biannual, workshops ensure informal discussions along with a constantly upgraded and expanding network of problem solving partners. No need to re-invent the wheel.
3. Get a proven leverage of invested capital for research¹ – in an IEA collaboration 1+1 is not 2, but closer to 3!

¹ See e.g., Westin, M., 2002, Aspects in Multi-Institutional International Collaboration as a Method for Technical Development, Licentiate Thesis, KTH – Dept. of Chemical Engineering and Technology, ISBN 91-7283-396-3, Stockholm, Sweden.