OECD/IEA
COMMITTEE ON ENERGY RESEARCH AND TECHNOLOGY
END-USE WORKING PARTY

Implementing Agreement on Energy Conservation Through Energy Storage

Annual Report 2003

March 2004

CONTENTS

CHAIRMAN'S REPORT

The Executive Committee (XC) was committed to expand its activities in 2003. Let me summarize the activities and achievements very briefly. From my point of view we have been very successful to increase the awareness of energy storage in general and to promote the IEA-Programme on "Energy Conservation Through Energy Storage" (ECES) to the public by the representation at different events. New activities have been put forward which will constitute the basis for ECES Programme in the next years.

Public Representation and Promotion
An important event was the Energy Technology Fair which took place in Paris late April during the Ministerial Meeting. The main objective of the Fair was to show-case the work of the Implementing Agreements and to present and highlight selected areas of the activities, results and successes. The Energy Storage Programme was very well represented by Halime Paksoy (Vice-Chairman, Turkey) and the ECES secretary Andreas Hauer (Germany). The exhibition of a small prototype thermo-chemical storage facility attracted the interest and attention of the delegates. The Fair was an excellent opportunity to increase the visibility of the ECES Programme and bring it to the attention of Energy Ministers of Member Countries, their advisors and to the press.

The **9th International Conference on Thermal Energy Storage FUTURESTOCK 2003** September 1-4, 2003 was another opportunity to show the work and results of the Programme to the "outside". The Conference organized and hosted by the Technical University of Warsaw took place in Warsaw, Poland with more than 180 participants from 22 countries. The Conference has been co-sponsored by the Executive Committee. The XC-Members were involved in the International Scientific Committee. Many papers presented at the Conference resulted from R&D carried out in the Annexes of the Programme. The ECES Programme covers the main topics "Underground Thermal Energy Storage" and "Phase Change Materials and Thermo-chemical Energy Storage" of the Conference. In conjunction with the Conference most Committee members were able to convene in an extra-ordinary Executive Committee Meeting. The Executive Committee agreed upon to review the papers and presentations of the comprehensive Conference programme and to publish the results as a "State of the Art review" in the ECES internet homepage.

Management of the ECES-Programme by the Executive Committee.
The Executive Committee managed both the **ongoing Annexes** and proposals for **new activities**:

- **Annex 12** has been finished by the end of 2003. The Final Report will be accomplished and published early in 2004.
- **Annex 13** is close to completion. An extension until June 2004 was approved to finalize and publish several technical reports and the Final Report.
- **Annex 14** (Phase I) will be completed in summer 2004 with a final symposium and the publication of the Final Annex 14 Report. The ExCo agreed to continue the work on the topic cooling in a new Annex.

- **Annex 17** will finish its work 2005. Knowledge transfer to the industry is of high priority. A closer co-operation was established with the IEA-Task: "Advanced Storage Systems for Low Energy Buildings" of the Solar Heating and Cooling Programme.

New activities were put forward to the Committee and have been intensively discussed at the ExCo meetings. Substantial interest was manifested to develop several new Annexes:

- **Deployment of Energy Storage Technologies** (interim Lead: Aart Snijders, IF Technology**)**
- **Transportation of Thermal Energy by TES** (designated O.A. Viktoria Martin, KTH Stockholm)
- **High Temperature Thermal Energy Storage Technology** (designated O.A. Rainer Tamme, DLR Stuttgart)
- **Cooling (**lead: Halime Paksoy**):** Follow up of Annex 14**.**

Unfortunately no progress could so far be achieved to start the proposed **Annex 15** on Electrical Energy Storage Systems.
More detailed information on ongoing Annexes and new Annexes is included in the attachments.

Administration, legal issues and participation
The legal office of the Secretariat recommended necessary amendments of the legal text of the Energy Storage Programme in order to comply with regulations of the IEA Framework adopted by the Governing board on April 3, 2003. A revised draft version of the Implementing Agreement was discussed at the XC meeting December 4-5, 2003 and will be approved in 2004.
The participation of IF Technologies as a Sponsor of the Implementing Agreement was eventually approved by CERT in 2003.
Contacts have been renewed with other interested but not yet officially participating countries: New Zealand and Slovenia and with the "dormant" countries: Denmark and Spain. Switzerland which has withdrawn several years ago from ECES will reconsider its participation.

Executive Committee meetings:
54th ExCo meeting in Bergen, Norway: May 11-14, hosted by the Geological Survey of Norway (Kirsti Midttomme).
55th ExCo meeting in Warsaw, September 4, hosted by the Technical University Warsaw (Roman Domanski)
56th meeting at IEA-Headquarters in Paris: December 4-5 (hosted by Carry Pottinger).

At the 54th ExCo meeting in Bergen Norway May 11-12, 2003 Volkmar Lottner was re-elected as Chairman and Halime Paksoy and Franck Cruickshanks as Vice-Chairs for another year. At the 56th ExCo meeting in Paris Andreas Hauer, ZAE-Bayern was re-elected as ECES-Secretary. At its meeting in Paris the Executive Committee celebrated the **25 Anniversary of the IEA-Energy Storage Programme** which was signed in September 1978.

The working group of the ExCo chaired by Frank Cruickshanks developed a new draft of the **Strategy Plan**. It will serve as the basis for the next term after 2005. The application for an

extension of the ECES for the following term 2006-2010 has to be submitted to the EUWP and CERT in the year 2005.

New Internet Homepage
The new Internet homepage was established at ZAE-Bayern after it was transferred in 2002 from the former Secretariat, Cukurova University Adana, Turkey to the new Secretariat with the new address www.iea-eces.org. Regularly updated information about the IEA-Programme activities and meetings is provided to the participants and public.

Co-operation within the IEA
A joint Meeting with the ExCo DHC was successfully organized in conjunction with the regular ExCo ECES meeting on May 14, 2003 in Bergen Norway. It was agreed to co-operate very closely together and to organize a joint workshop in 2004 which deals with the implementation of thermal energy storage systems in district heating systems. A joint meeting was also agreed with the Heat Pump Committee. This will be arranged in conjunction with the next regular ExCo meeting in May 2004, Montreal, Canada.
The Chairman together with the Operating Agents Halime Paksoy and Fredrik Setterwall participated at the Future Building Forum (FBF) preparatory meeting in Paris, December 2: "Global warming - a challenge for buildings". The Chairman attended the IEA Workshop "Ground Coupled Heat Pumps" (Vienna September 22). Together with the Operating Agents Halime Paksoy and Olof Andersson he also attended the IEA-workshop "Process Integration" (Manchester October 21) to offer the possibilities of future co-operation.

Support by the IEA-Secretariat.
I would like to take the opportunity to thank all colleagues in the ExCo for their engagement and in particular the representatives of the IEA Secretariat: Ms Carrie Pottinger (desk officer) and Ms Manuela Caruso (Legal office) for their strong support.

ENERGY CONSERVATION THROUGH ENERGY STORAGE IMPLEMENTING AGREEMENT

The Implementing Agreement (IA) started in 1978. Its present term ends by the end of 2005. At present Contracting Parties from the following countries have signed the Implementing Agreement: Belgium, Canada, CEC, Denmark, Finland, Germany, Italy, Japan, Norway, Spain, Sweden, Turkey, United Kingdom, USA and in 2003 the Sponsor IF Technologies from The Netherlands. The Executive Committee is working intensively to attract more countries to join the activities and to sign the Implementing Agreement in particular Poland, New Zealand and Slovenia. Australia, Bulgaria, China, France, India, Israel, Korea, Malaysia, South Africa. Switzerland has indicated to reconsider the participation in the Implementing Agreement. Experts from several countries do already participate in the Annex work as observers.

According to the present Strategy Plan (1998 – 2003) the objectives for the IA are as follows*:*

'' The overall objective of the IA on ECES is to develop and demonstrate various energy storage technologies for applications within a variety of energy systems and to encourage their use as a standard design option. Energy storage technologies can improve the utilization of renewable energies, in particular solar and wind and the greater utilization of waste heat energy storage technologies should be implemented in all countries with significant energy storage market potential''

The Executive Committee co-ordinates and leads the collaborative work in the Annexes and the Committee also takes an active part in various information activities such as workshops, seminars and conferences.

List of annexes and participating countries:

Annex 12, High-Temperature Underground Thermal Energy Storage (HT UTES)
Objectives of this task are to demonstrate that HT-UTES can be attractive to achieve more efficient economical and environmentally benign energy systems, and to disclose requirements and find problem solutions for reliable long-term operation. The type of UTES-systems concerned shall be confined to Aquifer Storage (ATES) and Duct/Borehole Storage (DTES). This annex was started at the end 1997 with Germany as Operating Agent.

Participating Countries: Belgium, Canada, Germany, Netherlands, Sweden

Annex 13, Design, Construction and Maintenance of UTES Wells and Boreholes
Annex 13 is a result of the Energy Storage Strategy Workshop held in Montreal during January 1995. The Annex was approved by the ECES IA at the end of 1997 with Sweden as Operating Agent.

- Participating Countries: Belgium, Canada, Germany, Japan, Netherlands, Norway, Sweden, Turkey, USA

Annex 14. Cooling with TES in all Climates
Annex 14 was approved at XC46 in Luleå (14-15 June 1999) as a result of the Antalya kick-off Workshop (4-5 June 1999) and years of discussions within the Executive Committee. The

overall objective of Annex 14 is to employ research, development and feasibility studies to advance the prospects of cooling with TES technologies for applications within a variety of energy systems and climate conditions and to encourage their use as a standard design option. Operating Agent: Turkey.

Participating Countries: Canada, Japan, Netherlands, Sweden, Turkey

Annex 17, Advanced Thermal Energy Storage Techniques - Feasibility Studies and Demonstration Projects
The objectives of this Annex is to overcome technical and market barriers for introduction of long- (seasonal) or short-term phase change and chemical reaction thermal energy storage for energy savings and for reduction of peak demand of energy in buildings, agricultural and industrial applications.

Operating Agent: Sweden.

Participating Countries: Germany, Japan, Sweden

Executive Committee Meetings
The Executive Committee had three meetings during the year 2003 and a joint meeting with the Executive Committee District Heating and Cooling. The 54th XC meeting was held in Bergen, Norway on May 12-13, 55th XC meeting in Warsaw on September 4th and 56th XC meeting in Paris, France on December 4-5. The joint meeting was held on May 14 after the Executive Committee meeting in Bergen

The most important items and decisions of the XC meetings in 2003 are outlined below.

The Bergen Meeting, May 12-13, 2003
- Approval of the minutes of the 53rd XC meeting
- Volkmar Lottner was unanimously re-elected as Chairman, Halime Paksoy and Franck Cruickshanks as Vice Chair.
- Annual Report 2002 was approved
- Financial statement from October 1st 2002 until April 1st 2003 of the secretariat was approved
- Report of the secretary on the representation of the ECES IA at the Technology Fair of the IEA Ministerial Meeting April 2003
- Approval of the progress reports of ongoing Annexes (12, 13, 14, 17).
- Extensions of Annex 12, 13, 14, 17 were approved.
- Evaluation of new Annex proposals (Annex 15, Transportation of Thermal Energy Storage by Thermal Energy Storage, High Temperature Thermal Energy Storage for Industrial and Power Applications)

The Warsaw Meeting, September 4th 2003
- Information from the IEA Secretariat about the approval of IF Technology by the CERT as a sponsor
- Offer to host the next "Stock"-conference on thermal energy storage 2006 in New Jersey, USA by Prof. Lynn Stiles

- Side discussion meetings for the new Annexes "Transportation of Thermal Energy Storage by Thermal Energy Storage" and "High Temperature Thermal Energy Storage for Industrial and Power Applications" during the Futurestock Conference

The Paris Meeting, December 4-5 2003

- Minutes of the 54th and 55th XC meeting were adopted
- Approval of Andreas Hauer as the secretary and the budget until the end of 2004
- A Joint workshop with the DHC IA should be held in the second half of 2004 in Germany, preferably in conjunction with the task-definition-workshop of the new "Transportation"-Annex
- Approval of progress reports of the ongoing Annexes12, 13, 14, 17 and an extension of Annex 13
- Discussion on the new Annex proposal Annex 15 "Electrical Energy Storage and the Integration of Renewables"
- Beginning of the task-definition-phase for the new Annexes "Market Deployment of Energy Storage Systems" Annex 16, "Transportation of Thermal Energy Storage by Thermal Energy Storage" Annex 18, "High Temperature Thermal Energy Storage for Industrial and Power Applications" Annex 19
- Kick-off workshops are planned for Annex 16, 18, 19

ACTIVITIES OF THE EXECUTIVE COMMITTEE

Executive Committee Meetings

- **54th XC meeting, Bergen, Norway, May 12-13**
- **Joint meeting of both ExCos ECES and District Heating And Cooling in Bergen Norway, May 14th after the XC meeting in Bergen**
- **55th XC meeting, Warsaw, Poland, September 4th**
- **56th XC meeting, Paris, France, December 4-5**

Expert Meetings and Workshops 2003

Annex 14: Cooling in All Climates With Thermal Energy Storage

- **9th Expert meeting April 9th, 2003, Lleida, Spain**
- **6th Workshop, April 10-11, 2003, Lleida, Spain**
- **10th experts meeting, August 31, 2003 Warsaw, Poland**

Annex 17: **Advanced Thermal Energy Storage Through Application of Phase Change Materials and Chemical Reactions-Feasibility Studies and Demonstration Projects**

- **4th Experts Meeting, March 21st , 2003, Indore, India**
- **Workshop, March 22-23, 2003, Indore, India**
- **5th Experts Meeting, August 31st, 2003, Warsaw, Poland**

Participation in the meetings of the Building Coordination Group (BCG)

- **BCG Meeting, March 5, 2003 and December 1, 2003 IEA HQ Paris**
- **Future Building Forum (FBF) preparatory meeting "Global warming - a challenge for buildings", December 2, 2003, Paris**

Participation in IEA-Workshops

- **IEA Workshop "Ground Coupled Heat Pumps", September 22, 2003, Vienna**
- **IEA-workshop "Process Integration", October 21, 2003, Manchester**

Conferences 2003

Conference on Thermal Energy Storage Technologies (in conjunction with Annex 17 meeting), March 21-24, 2003, Indore, India

Futurestock´2003: 9th International Conference on Thermal Energy Storage in Warsaw, Poland, September 1-4, 2003

ON-GOING ANNEXES

Annex 12. High Temperature Underground Thermal Energy Storage

Operating Agent; Burkhard Sanner, Giessen University, Germany

Introduction
The Annex 12 "High Temperature Underground Thermal Energy Storage (HT UTES)" was approved at XC43, December 1997.

Participating Countries: Belgium, Canada, Germany, Netherlands, Sweden

Based upon the results from previous IEA activities and ongoing R&D, the objectives of Annex 12 are to demonstrate that HT-UTES can be attractive to achieve more efficient economical and environmentally benign energy systems, and to disclose requirements and find problem solutions for reliable long-term operation. The type of UTES-system concerned is confined to Aquifer Storage (ATES) and Duct/Borehole Storage (BTES). High temperature in this annex refers to a minimum storage loading temperature in the order of 50 °C.

Work plan
To achieve the objectives, several activities will be carried out in two Phases:

The work is divided into two phases:

Phase 1	Review of the state-of-the-art, investigations into system opportunities and further R&D-need; completed with report end of 1999
Phase 2	Monitoring of existing plants (demo projects), design tools, improvement in water treatment and development of test equipment, choice of materials suited for high temperatures, economic analysis, design guidelines. Phase 2 was approved at XM 47, November 1999; ongoing

The work is done on a task-sharing basis, with experts meetings twice a year.

Results

The state-of-the-art report within Phase 1 was published as:

SANNER, B. (ed.) (1999): High Temperature Underground Thermal Energy Storage, State-of-the-art and Prospects. - Giessener Geologische Schriften 67, 158 p., Giessen

There are a small number of HT-UTES plants in operation, where monitoring programs allow to evaluate system performance, reliability, operational experiences, etc. within Phase 2. Monitoring is done within national programmes, and the results should be shared and compared within Annex 12:

Amorbach	Neckarsulm, D	BTES, residential area with solar heat (meanwhile enlarged to >500 BHE)
Anneberg	Solna, S	BTES, residential area with solar heat
Brinckmannshöhe	Rostock, D	ATES, appartment houses with solar heat

Hooge Burch	near Gouda, NL	ATES with heat from heat-and-power-cogeneration
Reichstag building	Berlin, D	ATES with heat from heat-and-power-cogeneration

Two other projects became operational during 2002, and first operational results could be obtained:

Attenkirchen	near Freising, D	BTES with water tank, residential area with solar heat	spring 2002
TESSAS	Mol, B	BTES, test plant	summer 2002

In Neckarsulm, the work for enlargement of the total system had an impact of the operation of the existing store and on the monitoring. For Annex 12, only the existing part as of late 2000 is considered. The full extent of the Reichstag ATES in Berlin has been reached in the year 2002, with the finalization of the surrounding building and the connections of the heating and cooling network. The full thermal capacity of the co-generation plants was available for loading of the store for the first time.

Some other HT-UTES projects have been discussed or planned in 2002:

Malmö, S	Huge system for 50 MW thermal output and about 100 °C, 2x19 wells 450-500 m deep, for the district heating system
Mahone Bay, NS, CAN	Hawthorn Village, HT-BTES with ca. 80 houses, medical center, etc., with solar thermal for loading; total system should have at least 50 % solar fraction
Halifax, NS, CAN	Quinpool Towers, residential complex, flats/apartments; 1100 m^3 pilot store, 4 holes, 3 m distance 120 m depth, storage operated at 50 °C. Planned to be enlarged to ca. 32 boreholes. Solar collectors and/or waste heat as heat source

Test methods for both BTES and ATES have been successfully demonstrated:

- Thermal Response Test (TRT), used in mobile equipment since ca. 1995, was used for design of the Attenkirchen BTES and also for the enlargement of Neckarsulm BTES. This technology meanwhile can be considered commercial for the low-temperature applications (mainly ground source heat pumps), and proved to be well adapted also for the higher temperature range. Because TRT does not determine the thermal conductivity of the solid ground only, but gives a value for apparent thermal conductivity comprising also other components like convection, the results are temperature-dependent and measurements have to be done at the desired operational temperature of the BTES.
- Test equipment for ATES to investigate groundwater behavior in situ (scaling, corrosion, etc.) has been improved and tested at several locations in 2002. A standard procedure to assess the suitable temperature range for ATES was developed, using step-wise increase of loading temperature with given flow and test duration. Tests at sites with different groundwater chemistry allowed to study the different behaviour, however, more tests are required to understand the processes better and to allow for the comparison with results obtained from computer models of groundwater chemical behaviour.

Status of work: preparation of the Final Report by the Operating Agent.

Annex 13. Design, Construction and Maintenance of UTES Wells and Boreholes

Operating Agent: Olof Andersson, Lund Institute of Technology, Sweden

Scope and objectives

Annex 13 cover aspects of test drilling, well and borehole design, construction and maintenance of wells and boreholes for UTES applications especially concerning ATES and BTES systems.

The final goal of the Annex is to work out a set of guidelines covering the following subtasks.

- How to gain information of the underground properties by test drilling (Subtask A)
- How to design well or borehole systems properly (Subtask B)
- How to construct wells or boreholes cost effective, safe and properly (Subtask C)
- How to keep the storage systems functional during operation (Subtask D)

A second goal is to identify items or areas that need further research and development.

Work plan

The Annex was planned during 1997 and eventually approved by the 43rd EXCO Meeting in Paris 4-5 of December 1997.

The work plan takes into consideration that a number of participating countries will contribute to the development of the Annex following the task shearing principle. The target was set to close the Annex during 2003. However, the Annex has been extended and is now expected to be finalized during 2004.

Participating countries

Over the years the following countries have formally or as observers participated in the development and progress of the Annex.

- Belgium Formal
- Canada Formal
- Germany Formal
- Japan Formal
- Netherlands Formal
- Norway Formal
- Switzerland Observer
- Sweden Formal
- Turkey Formal
- USA Formal

During 2003 Norway has become a formal member. Further more, Japan has announced that they can not participate at the finalization of the Annex due to financial problems.

Activities in 2003

During 2003 there have been no activities but further work on the Annex reports. There are seven reports to be written and approved by the ExCo. At the end of 2003 four reports were finalized. These are

- Subtask A:1. Test Drilling for UTES Applications*, by F.Michel, B.Andersson*
- Subtask A:2. Thermal Response Tests for BTES Applications*, by J.Spitler, S.Gehlin*
- Subtask B:2. Borehole Heat Exchangers Configurations and Thermal Efficiency, *by G.Hellström*
- Subtask D. Well and Borehole Failures and Cures in UTES Systems, *by G. Bakema*

These reports are to be found on the homepage of ECES and will later be published separately.

Publications

During 2003 the following publications directly related to the activities of Annex 13 have been published

- Andersson, B, 2003. Geodata Collection for UTES Applications by the Use of Test Drillings. Dept. of Engineering Geology, Lund Inst. Of Tech. Licentiate Thesis 2003.

- Gehlin, S and Spitler J, 3003. Thermal Response Test for BTES Applications-State of the Art 2001. Proceedings of the 9th Internat. Conf. On Thermal Energy Storage, Vol. 1. Warsaw, September 1-4, 2003.

Work plan for 2004

For the coming year 2004, the Annex is expected to be closed by submitting two more subtask reports and a final report with guidelines within the first half year.

Contacts

Country co-ordinators for countries still active in Annex 13 are:

- Belgium, Bert Gysen (gysenb@vito.be)
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Annex 14. Cooling in All Climates with Thermal Energy Storage.

Operating Agent: Halime Paksoy, Çukurova University, Adana, Turkey.

Introduction

Annex 14 has started operation after being approved by the Executive Committee at the 46th Executive Committee Meeting of ECES IA in Lulea, Sweden on June 14-16, 1999. Cukurova University Center for Environmental Research Adana, Turkey acts as the Operating Agent.

The scope of the work is to improve the efficiency of energy usage (energy conservation) which is valuable for the global environment and economies in both developed and developing countries. Moreover, Thermal Energy Storage (TES), which provides the matching of energy supply and demand, has been shown to contribute significantly in improving energy efficiency when compared to conventional energy systems. Such systems can also increase the potential of utilizing renewable energy sources such as ambient cold air or waste heat.

The overall objective of Annex 14 is to employ research, development and feasibility studies to advance the prospects of cooling with TES technologies for applications within a variety of energy systems and climate conditions and to encourage their use as a standard design option. The Annex will rely heavily on the activities and results of Annexes 6, 7, 8, 10 and 13 to encourage energy efficiency and increased sustainability of the global energy resources by stimulating the expanded use of TES in innovative, energy efficient and cost-effective projects in participating countries.

Subtasks

Phase I

- Subtask 1. Conduct a general review of existing and emerging cooling with TES applications in different climates
- Subtask 2. Evaluation of Feasible Boundary Conditions and System Configurations for Cooling with TES
- Subtask 3. Design and Analysis User-friendly Tools
- Subtask 4. Determining potential cooling with TES applications in different climates

Phase II

- Subtask 5. Feasibility study and design of practical demonstration of viable TES in representative cooling applications
- Subtask 6. Construction of practical demonstration of viable TES in representative cooling applications

Duration of Phase I

July 1999 – June 2004

Participating Countries

Canada, Japan, Sweden and Turkey are the participating countries from the beginning of the Annex. USA joined the Annex in 2002. Andorra, China, Germany, Israel, Korea, Malaysia, Netherlands, Portugal and Spain have participated in a number of Annex 14 workshops. Information exchange between experts from these countries is also established.

Collaboration with other Cooling Activities in IEA

- Presentation at the IEA BRIA Workshop "Global warming – a challenge for buildings", December 2, 2003
- Information exchange with IEA ECBCS Annex 37 "Low Exergy Systems for Heating and Cooling in Buildings"

Status of Subtasks in 2003

Subtask 1

- Final country-specific state-of-the-art reports - completed.
- General state-of-the-art report - completed
- Annex 14 brochure with a CD-ROM including final reports and workshop proceedings-completed

Subtask 2

- List of boundary conditions – on-going
- Cold sources – on going
- System configurations – on going

Subtask 3

- Ice storage early decision tool program translated from Japanese to English - completed
- Survey on existing models and tools – completed
- Database for environmental calculations – completed

Subtask 4

- *General description of system configurations – on going*
- Classification and characterization – on going
- Feasibility study of the most promising choices – on going
- Proposal for demo plants (Phase II) – on going

Activities in 2003

- Ninth Experts' Meeting of Annex 14 was held on April 8-10, 2003 in Lleida, Spain hosted by University of Lleida. Experts from Japan, Spain, Sweden and Turkey participated at the meeting. Sixth Workshop was held on April 11, 2003 in Lleida, following the experts' meeting. There were 30 participants joining the workshop from Andorra, Japan, Portugal, Spain, Sweden, USA and Turkey. Table 1 shows the papers presented and contribution to Annex work. Proceedings of the workshop was prepared on CD ROM and was distributed to the participants.

- Tenth Experts' Meeting of Annex 14 was held on August 31, 2003 in Warsaw, Poland before the Futurestock'2003 Conference. Experts from Canada, Japan, Spain, Sweden, USA and Turkey participated at the meeting.

Table 1. Input from Annex 14 Sixth Workshop

Presentations	**Subtask 1**	**Subtask 2**	**Subtask 3**	**Subtask 4**
Cooling in all climates with thermal energy storage - Even in Mediterranean *Halime PAKSOY, Çukurova University, Turkey*	x	X		
Cooling with UTES in Sweden *Olof ANDERSSON, VBB Viak AB, Sweden*	x	X		x
TES and Electric Deregulation *Rui FERRAZ, REAT SA, Portugal*	x			x
Possibility of natural cooling of a local library in Hokkaido by natural ventilation and utilization of underground cold energy through foundation piles *Katsunori NAGANO, Hokkaido University, Japan*		X	x	x
Ground-Coupled heat exchanger-based heat pump system to evaluate the use of Geothermal residual heat to improve cooling-and heating energy efficiency in the Mediterranean area *Javier Urchueguía SCHÖLZEL, Institute of Energy, Spain*	x	X		
Reduction of diurnal air conditioner load by cold energy storage during night in floor supply air conditioning system applied granulated PCM *Sayaka TAKEDA, Hokkaido University, Japan*		X	x	X
Study to profit the residual cooling capacity of the regassing plant of Barcelona's Port *Gustavo RODRIGUEZ and Aleksandrar IVANCIC, Barcelona Regional Agency, Spain*		X		

Publications in 2003

- Annex 14 brochure and CD including final reports and workshop proceedings
- Sixth Workshop Proceedings, April 11, 2003, Lleida, Spain (CD-ROM)
- Halime Paksoy, Bekir Turgut, Hunay Evliya, Muhsin Mazman, IEA ECES Annex14 Cooling in all climates with thermal energy storage, Futurestock'2003, 9th International Thermal Energy Storage Conference, 1-4 September, 2003, Warsaw.

Up-Coming Meetings

- Annex 14 Phase I Final Workshop – June 2004

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Annex 17. Advanced Thermal Energy Storage trough Application of Phase Change Materials and Chemical Reactions – Feasibility Studies and Demonstration Projects

Operating Agent: Professor (emeritus) Fredrik Setterwall, Fredrik Setterwall Konsult AB, Bäckvägen 7c, SE 192 54 Sollentuna, Sweden

Annex 17 "Advanced Thermal Energy Storage trough Application of Phase Change Materials and Chemical Reactions – Feasibility Studies and Demonstration Projects" was approved at the meeting of the Executive Committee of the Implementing Agreement on Energy Conservation through Energy Storage in Hull, Canada, 2001-05-16—18.

Officially the Annex has three members, Germany, Japan and Sweden. Countries that have been interested in the work of the annex are Australia, Canada, China, Finland, France, India, Ireland, the Netherlands, New Zealand, Poland, Slovenia, Switzerland, Turkey, Russia, Spain, United Kingdom and the United States. This interest is shown by having participated in previous meetings in Lleida (Spain), Benediktbeuern (Germany), Ljubljana (Slovenia), Tokyo (Japan).

The 4th Expert Meeting was held in Indore, India on the 21st of March 2003 followed by a Work Shop perfectly organized by Devi Ahilya Vishwa Vidyalaya University. 25 papers were received for the Work Shop. More than 50 persons attended the Work Shop. The industrial participation was large as well as representation from local government, governmental research institutes and universities.

The expert meeting was attended by three member countries (Germany, Japan and Sweden) and one observing country (India). During the expert meeting the progress of the projects of the Annex was discussed and new projects that will be presented during the time frame of the Annex were introduced.

The 5th Expert Meeting was held in Warsaw, Poland on the 31st of August 2003. After the expert meeting the Futurestock conference was arranged. A large number of papers concerning the field of the Annex were presented. Some of the presentations at the conference constituted report on Annex projects (see further below)

The expert meeting was attended by three member countries (Germany, Japan and Sweden) and three observing countries (Spain, Switzerland and Turkey). During the expert meeting the progress of the projects of the Annex was discussed. Activities for formation of new annexes on High Temperature Energy Storage and Energy Transportation Utilizing Thermal Energy Storage Technology were reported.

It was suggested to encourage cooperation with other organizations namely

> Solar and Heating Program within the International Energy Agency (SHC). It was decided to try to arrange a joint meeting between Annex 17 in the Storage Implementing Agreement and Task 32 of the SHC Implementing Agreement in connection with next annex meeting in Arvika, Sweden 2004-06-07—09.
>
> The application for a co-ordination action (CA) on Energy Storage and Transportation (ESTNET) within the 6th Frame Work Program did not receive any funding. It was

however decided to continue to find opportunities for formation of larger net works. In order to make decision makers aware of the importance of thermal energy storage not only for saving of thermal energy but also for conservation and safety of electrical energy systems it was decided that Andreas Hauer and Fredrik Setterwall together should write an article on the subject. It is important to point out that Energy Storage is equally important for thermal and for electrical energy purposes. .

Invitations to planned activities in Annex 17 and information will continuously be sent to the chairman of the Working Party on Ice-Slurries within IIR.

Co-operation with other Implementing Agreements like District Heating and Cooling (DHC), Heat Pumping Technologies, Fuel Cells is foreseen in the future. The Executive Committee had a joint meeting with DHC in their meeting in Bergen 2003-05-12—14 and will on their spring meeting 2004 meet with the Heat Pumping Technologies Executive Committee.

The budget of the work in the annex was discussed. The cost of the research and development foreseen to be presented within the Annex exceeds 10 million Euro whereas the cost for the actual work in the annex (25% of the expert time plus traveling cost) in total is less than 400 000 €. The budget will be updated and presented as an argument for countries to join the international cooperation in IEA.

The extension of the Annex until 2005-06-30 has been approved by the Executive Committee on their meeting in Bergen 2003-05-12—14.

In order to facilitate the spreading of information from the annex work it was suggested to form national teams for thermal energy storage in the way that Japan is presently doing. Dr D. Buddhi volunteered to start such a group in India. It was decided to bring up the question for discussion in the Executive Committee meeting in order to formalize an organization for this purpose. Also countries not members of the Implementing Agreement are welcome to form such groups in order to make the spreading of information more effective also to those countries. The formation of a group might be the first step for non-member countries to join IEA and their different IAs.

Report on ongoing projects

- **Heating and cooling of buildings (Germany and Japan)**

  - "Energy storage in the CREA building (Lleida)"
    The building will be finished in December 2003

  - "PCM module to improve stratified water tanks"
    Reported in the 1st Work Shop in Benediktbeuern in Germany. The technique is now commercially available in Japan. During Futurestock conference two papers were presented on the technology.

    One utilizes a mixture of $Mg(NO_3)_2.6H_2O$ and $MgCl.6H_2O$ as PCM in a hot water tank charged by solar energy. The melting point of the mixture is 60 ^oC and the water tank operates between 50 and 70 ^oC. (26. Katsunori NAGANO, Kenji OGAWA, Takashi HASHIMOTO, Kazumi SHIMAKURA, Tohru MOCHIDA, Atsushi OKAMOTO,

Kanetoshi HAYASHI: High efficient solar hot water supply system using evacuated solar collectors with a PCM/water hybrid thermal energy storage)

The second paper deals with $NaAc.3H_2O$ encapsulated in a carbon fiber matrix. The melting point of 58 ^oC enables an operating range of 50 to 65 ^oC. (41. Luisa F. CABEZA, Miquel NOGUÉS, Joan ROCA, Josep ILLA, Stefan HIEBLER, Harald MEHLING: PCM-module to improve hot water heat stores with stratification: first tests in a complete solar system)

A diploma thesis from the university in Lleida, Spain will be finished December 2003

- **Building materials:(Harald Mehling)**

  A report was given during the 3rd Work Shop in Tokyo, Japan. In short it is reported about a new PCM with a melting range of 20 – 24 ^oC, PCM in building materials and on PCM in windows and shadings

  - "Encapsulated PCM in building technology"

    Reported during the 2nd Work Shop in Ljubljana, Slovenia
    Testing of two rooms phasing south was reported during Futurestock conference. One room had gypsum plasterboard with microencapsulated PCM whereas the other had no PCM in the plasterboard.
    (47. Peter SCHOSSIG, Hans-Martin HENNING, Thomas HAUSSMAN, Alexandandra RAICU: Encapsulated Phase-Change Materials integrated into construction materials)
    Final report 2003/2004
    A study on PCM encapsulated into plasterboards used in the ceiling of an office for cooling the air from the air handling unit during peak hours was also presented during the Futurestock conference. The PCM, a mixture of octa- and hexadecane with a melting point of 22 ^oC, was encapsulated into crosslinked polyethylene. Both experimental and simulated results were shown. (83. Takeshi KONDO, Tadahiko IBAMOTO: Research on using the PCM for ceiling board)

  - "Mixture of wood, PCM and concrete"

    Reported during the 2nd Work Shop in Ljubljana, Slovenia. Will be finished 2003/2004

  - "PCM wallboards"

  - "PCM in concrete"

    Started April 2003 for two years.
    During Futurestock conference preliminary results were presented on microencapsulated Rubitherm RT 20 into concrete. The heat capacity increased 300% over plain concrete with a storage capacity of 43 MJ/m^3 (12 kWh/m^3) (77. Luisa F. CABEZA, Miquel NOGUÉS, Joan ROCA, Paco ALONSO, Ohiana ZUBILLAGA, Jesús MARCOS: First results on the development of smart microencapsulated organic PCMs to be applied on concrete)

- **Sorption systems: (Andreas Hauer)**

  - "Air conditioning and cold storage in an open sorption system using Lithium Chloride."

    Reported during the 4th Work Shop in Indore. A demonstration building in Amberg, Germany with 5700 m2 floor area is being built. Solar storage system for air dehumidification. The system will be demonstrated during the cooling season 2003. Presentation at Futurestock

  - "Heating and Cooling with Zeolites"

    The project was presented at the 3rd Work Shop in Tokyo, Japan. A sorption storage system using Zeolite was installed in a school building in Munich, Germany. Connected to the district heating net for peak shaving. The district heat is used in summer time for the air conditioning of a nearby jazz club. The Zeolite storage is used as a desiccant cooling system and cold storage. Heating and cooling leads to economical advantages. Payback time about 6 –7 years. Project finished.

  - "Silica gel in a Closed System"

    This is a commercial project run by the company Sortech AG. The company is invited to present their work at the next workshop spring 2004.

    HYDES is an EU project. The Fraunhofer Institute for Solar Energy Technology, ISE, is dealing with sorption storages for long term TES. Demonstration plants will be erected in the Netherlands, Austria and in Germany. Andreas Hauer has visited a demonstration plant in Austria and will report during the next Expert Meeting.

- **Peak shaving:(Motoi Yamaha)**

  - "HVAC with PCM storage in it"

    A report was given during the 2nd Work Shop in Ljubljana, Slovenia.
    Presentation of different applications of PCM for air conditioning has been given at the 3rd Work Shop in Tokyo, Japan. This includes ventilation systems for energy savings, thermal storage in ceiling systems, floor supply air conditioning systems. No new funding. Was presented during Futurestock

  - "Simulation of PCM storage system"

  - "City hall with PCM heater"

    Is working.

  - Stevenage Borough Council's offices

    Passive cooling utilizing cold night time air for comfort cooling. A joint English/Swedish project was reported during the 4th Work Shop in Indore. The cost for installation of the passive system for night time ventilation was estimated to 40£/m^2 as compared to 180 £/m^2 for a conventional air conditioning system. The project was

presented during Futurestock conference. (17. Nick BARNARD: Thermal Mass and Night Ventilation - Utilizing "Hidden" Thermal Mass)

- "Peak Shaving combination UTES and PCM" (Annex 14 project)

  The project was presented during Futurestock (59. Bo HE, Viktoria MARTIN, Olof ANDERSSON, Fredrik SETTERWALL: Borehole Thermal Energy Storage Coupled to Peak Load PCM Storage for Efficient Free Cooling System)

- **Temperature sensitive goods :(Spain, Luisa Cabeza)**

  Report on the state-of the art on PCM for temperature sensitive materials given during the 2nd Work Shop in Ljubljana, Slovenia.

  A project was reported on transportation of fine art performed at ZAE-Bayern in cooperation with the German company Va-Q-Tec

  - "Blood transportation"

    This is a project of Rubitherm GmbH. Results will be given at the end of the year 2003.

- **Waste heat utilization: (Sweden, Viktoria Martin)**

  - "Absorption chillers and energy storage"

    A first report was given during the 2nd Work Shop in Ljubljana, Slovenia. Now work is performed on a system study and on erecting experimental equipment. The project was presented at Futurestock conference (67. Magnus RYDSTRAND, Viktoria MARTIN, Fredrik SETTERWALL: Absorption Cooling Systems with Integrated Cool Thermal Storage)

  - "Cold transportation in PCM "

  A system utilizing sodium acetate tri hydrate for increasing the energy density in transportation of heat has been introduced by the company TransHeat. More information could be found on www.eurecaag.de/Trans/index.htm

  - "PCM applications in industry"

    A report on this project is available, but only in the German language.
  - "Thermal management of solid oxide fuel cell systems"

    This project is finished and a report will be given later

  - "PCM slurry systems"

    A system utilizing tertiary ammonium salts forming a slurry with high energy density was presented during the 5th Work Shop of Annex 10 in Sue, Japan. A demonstration of

this system was shown during the technical visit following the 3rd Work Shop of Annex 17 in Tokyo, Japan.

- **Other projects**

  - Introduction of thermal energy storage in a district cooling net in existing built environment
    Usually in built environment space is as much a restriction as is money and technology. A feasibility study on introduction of thermal energy storage for increase of the capacity of an existing cooling net work is performed in Sweden with a case in Gothenburg

In order to facilitate the cooperation between industry and research institutes, two experts from each country will participate in experts meetings, one industrial and one from the research world.

A home page for the Annex could be found on www.fskab.com/Annex17. The website is sponsored by Rubitherm GmbH (Germany), Climator AB (Sweden) and TEAP (Australia). The website is active. 766 unique visitors from 69 different countries visited the website during August 2003.

In order to attract new countries the experts meetings and work shop will be located to countries that either have difficulties to attract enough attention on thermal energy storage within the country or are not members of IEA. In this way the cooperation and collection of information will be spread outside the members of the annex.

Upcoming meetings

- Sweden, Arvika 7th to 9th of June 2004.
- Beijing, China, fall 2004
- Turkey, spring 2005

National contacts

Germany: Andreas Hauer hauer@muc.zae-bayern.de
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PROPOSED ANNEXES

Annex 15. Electrical Energy Storage and the Integration of Renewables

Operating Agent: Alan Collinson, EA Technology, UK

Introduction

Electrical energy storage is widely recognized as a key emerging technology, likely to find widespread use within electricity generation, transmission, distribution and supply networks as well as other major industrial and commercial end user applications. The benefits of bulk energy storage applied to the increasing levels of embedded generation, especially from new and renewable sources, are being increasingly recognized. The Annex 15 proposal is focusing specifically on the issues of electrical energy storage and how it can be used to assist in the successful conservation of energy by the integration of new and renewable energy sources into existing electrical networks.

Key issues which will be addressed by Annex 15 include:

- the need for storage from a renewables perspective
- modeling of network/renewables/storage interaction
- implementation strategies for storage-based solutions
- the costs of storage
- the benefits of storage
- alternatives to storage

Annex 15 is seen as a key enabling mechanism in moving the application of energy storage to the integration of new and renewable energy sources significantly closer to market realization. Key elements of this strategy include the modeling of the interaction between the electricity network and the energy source as well as producing targeted educational and promotional material to increase awareness of the growing potential of energy storage-based solutions.

Discussions at the ECES Executive Committee

The first proposal of Annex 15 as a follow on of Annex 9 was submitted by EA-Technology to the ExCo at the meeting XC47, November 1999, Berlin.

Several issues had to be clarified including:

- Interest of participation: the suggested workshop and kickoff meeting to identify the topics and interest of possible participants never took not place.
- Requested common budget for the Operating Agent: cost sharing was hardly to finance.
- Overlap with other new activities: The Commission of EU established a network with research institutes and companies for the preparation of a joint European

Programme on Electrical Energy Storage. Information was presented by the Lead person Philippe Malbranche, CEA, France

- At the Turnhout ExCo meeting some member counties like UK and Finland pointed out that their main interest on participation in the IA is the topic Electrical Energy Storage. It was decided that Phil Baker reviews the present status of interest and possible overlap with the EU-Programme before the next XC meeting and submit a proposal how to proceed for the next ExCo meeting in Norway, May 2003

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Annex 16. Market Deployment of Energy Storage Systems

1. Background.

The IEA Implementing Agreement "Energy Conservation through Energy Storage" has contributed significantly to the development of energy storage technologies in the participating countries. These energy storage technologies are considered a strategic and necessary component for the efficient utilization of renewable energy sources and energy conservation. The energy storage technologies developed and demonstrated involve underground thermal energy storage, thermal energy storage in phase changed materials, and technologies for electrical energy storage.

To promote the implementation of thermal energy storage in building energy supply systems, the most energy and cost effective applications have been identified in the framework of Annex 8 to the Implementing Agreement. However, for the deployment of new, energy efficient technologies in the energy market a greater effort is required from all stakeholders. This conclusion is not typical to energy storage technologies, but also holds for other energy efficient technologies like heat pumps, solar and wind. This situation is recognized by the OECD/IEA and has resulted in the publication of two books:

- Enhancing the Market Deployment of Energy Technology - a survey of eight technologies (IEA, 1997);
- Creating Markets for Energy Technologies (IEA, 2002).

In both books it is concluded that the market deployment cannot be left the responsibility of private companies only, but is the responsibility of governments too.
"If new technologies are to deliver their potential, they must be commercially launched in a way that leads to effective penetration of the many and varied markets for energy equipment and services. The process of technology deployment can be long and complex and the rate at which it occurs is influenced by many variables, including government policies and programmes……" (IEA 1997).
"Deployment policy and programmes are critical for the rapid development of cleaner, more sustainable energy technologies and markets. While technology and market development is driven by the private sector, government has a key role to play in sending clear signals to the market about the public good outcomes it wishes to achieve" and *"In the end it is the combined effect of technology potential and customer acceptance that makes an impact on the market and hence on energy systems. Developing a deeper understanding of both, including how they are influenced by the actions of government, is an essential ingredient of effective deployment policy."* (IEA, 2002).

2. Objectives.

The objectives of the work to be performed under this Annex are:

1. To assess the most prospective applications (market segments) for the energy storage technologies developed in this Implementing Agreement: Underground Thermal

Energy Storage (UTES), Phase Change Material Storage (PCMS) and Electrical Energy Storage (EES).
2. To develop deployment strategies for these prospective market segments.

To achieve these objectives, it is considered essential that the activities in the framework of this Annex will be carried out by marketing experts, in close cooperation with specialists in energy storage, representatives of the private sector, and policy makers.

3. Work programme.

The work in the framework of this Annex can be subdivided in three subsequent phases. For each phase an indication is given of the time required to carry out the activities.

Phase 1 Start up. (time required six months)

In this phase a workshop will be organized with the prospective participants. This workshop is aimed at achieving the major objectives of this phase:

- Definition of the storage technologies that are already on the market or ready for the market;
- Assessment of the major market segments for each storage technology. This will result in a number of Product-Market Combinations (PMC's).
- Preparation of a detailed work plan for this annex including the specific tasks of the participants.

Phase 2 Comparison of PMC's. (time required nine months)

A comparison will be made between the Product-Market Combinations defined in phase 1. The criteria for this comparison still have to be defined, but include first cost, additional first cost compared with present energy system, energy saving compared with present energy system, energy saving potential in market segment, and potential competitive technologies. At the end of this phase a workshop will be organized to select the most prospective PMC's for each of the storage technologies. So, the result of this phase will be the most prospective market segments for UTES, for PCMS, and for EES, as well as a preliminary analysis of the opportunities and threats in these market segments.

Phase 3 Development of deployment strategies. (time required nine months)

In this phase a deployment strategy will be developed for the three most prospective PMC's. The deployment strategy for each of the PMC's includes the answers to the following questions:

- what are the opportunities and threats for this storage technology in this specific market segment?
- who are the potential clients for this product?
- who are the first adaptors in the specific market segment?
- what is the product? *"Most consumers have little interest in energy issues per se, but would gladly respond to energy efficiency measures or use renewable fuels as part of a package which features they do care about"* (IEA, 2002)
- what is the best way to approach the client?

- what type of documentation and promotion material is required?
- what is the role of the government (e.g. regulations, subsidies, early adaptation, etc.)?

To conclude this phase, the results of this Annex will be made available to stakeholders in the field of energy efficiency and renewables through:

- publication of the results on the ECES website
- distribution of the final report to EUWP members and EC members of Implementing Agreements in the fields of energy efficiency and renewable energy sources
- presentation of the results at the next International Conference on Energy Storage.

4. Costs involved.

To carry out the activities described in this Annex, the level of effort is estimated to be about 0,5 person years per participating country. In addition to this, about 0,3 person years is required for the specific tasks of the Operating Agent.

5. Operating Agent.

To be determined.

6. Participating countries.

To be determined.

Annex 18. Transportation of energy by utilization of Thermal Energy Storage Technology

Introduction

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 theses 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 possible charging and discharging power, which affects the possible number of storage cycles per time.

Phase Change Slurries for Energy Transportation

Recently, interest in multifunctional fluids for ***energy storage and transportation*** has gained much attention as they may be highly useful in re-locating e.g. industrial waste heat from source to demand. These fluids are often called Phase Change Slurries (PCS). With such fluids, the gap in time and distance between a heat source and a heat demand has the potential of being managed in a cost-effective way, a key issue that must be mastered before sustainability in the energy system can be fully obtained. Numerous future-oriented technologies may be supported by this technology like high-efficient cooling of fuel cells, electronic devices, and elementary particle detectors, etc.

Presently, the technology is tested for a few applications. For example, small quantities of phase change materials are created in industrial processes and immersed in carrier fluids. A new technique is to encapsulate PCM in microcapsules with diameters of only a few microns. Since 1996 the "Working Party on Ice Slurries of the International Institute of Refrigeration (IIF/IIR)" co-ordinates research and industrial activities in the field of water/ice suspensions, which define a subgroup of the PCS. They are used as secondary refrigerants and help to phase out chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs) and, therefore, contribute to a reduction of ozone depletion and global warming.

The recent increased interest in PCS technology, as compared to decades ago when the technology first emerged, is presumably due some important changes in "boundary conditions". Examples are:

- increased activities in combating global warming and establishing a sustainable energy system;
- increased number of commercially available storage systems;
- for air-conditioning and refrigeration, an increased concern for HFCs and a willingness to cut peak power demand;
- advances in available materials;
- improved knowledge on how to master sub-cooling.

Mobile Thermal Energy Storage – transporting by truck or train

If the distance between thermal energy source and the consumer is for economical reasons to long for pipelines, the TES itself has to be transported on the street or on the track. For applications like the utilization of waste heat from industrial processes at distances over a few kilometers up to about 50 km, activities have been discussed among research institutes and companies in Japan and Germany.

In Germany for example the company "Transheat" has installed a demonstration plant, where waste heat of about 180 °C is charged to a PCM storage, which is transported from the factory to a office building some 30 km away by truck. The system is economical interesting, because there is a high demand for heating and cooling (by absorption chillers), which allows a high number of charging and discharging cycles of the storage.

In Japan the transport of salt solutions concentrated by waste heat for liquid desiccant cooling systems is under discussion. The high prices for district heat in Japan could lead much faster to economical interesting systems compared to Europe.

Other thermal energy storage technologies, like solid or liquid sorption process are interesting due to their high possible storage capacity. The influences of the changed "boundary conditions" on these systems could be as positive as for the PCS systems. In this context a revitalized discussion on sensible heat storage systems could be valuable.

Scope and objectives

The general objectives of the proposed Annex on Transportation of Energy by Utilization of Thermal Energy Storage Technology are to identify state-of-the-art for using different technologies for energy storage and transportation, to broaden and co-ordinate the knowledge within the field, and to disseminate information. In particular, research on high capacity storage materials and high thermal power charging and discharging technologies that are easy to implement in an energy transport system will be encouraged, along with research on system aspects where heat sources are linked to the customer's need and where these links' impact on system design is assessed. Potential cost-effective applications must be identified.

At the end of the annex, present activities within the field are expected to be better co-ordinated, and initiatives for new activities have been taken.

Suggested Operating Agent

As operating agent for the proposed new annex Sweden, through KTH (Dr. Viktoria Martin) is suggested.

Work Program – Main Activities and Time Schedule

Phase 0: January – June 2004

- Invitation to participate
- Kick-off workshop in e.g. Japan – establishing participants and their combined goal with the annex

Phase 1: July-December 2004 (Task Definition Phase)

- Finalize Annex Objectives, Goals and Work Plan with ExCo
- Collecting information on ongoing activities in the area
- Finalizing Financing Plans for participants
- Establishing collaboration activities
- First Workshop and Expert Meeting

Phase 2: January-June 2005

- Compile State-of-the-Art high capacity TES technologies
- Identify potential applications, including heat/cold sources and "customers"
- 2nd Workshop and Expert Meeting

Phase 3: July-December 2005

- Applications' evaluations
- Candidate technologies – special material's issues for PCS systems, system issues for sorption systems, design of mobile TES.
- 3rd Workshop and Expert Meeting

Phase 4: January-June 2006

- Establishing desired feasibility studies and demonstration projects – a plan for future IEA activities
- 4th Workshop and Expert Meeting

Phase 5: July-December 2006

- Final Report
- Closing the Annex
- Dissemination of Results
- 5th Workshop and Expert Meeting

Activities

- Evaluation of presentation and findings
- Workshops and expert meetings
- Initiate projects related to:
    - classifying boundary conditions for the application of slurries or TES on trucks/trains
    - identifying cheap and reliable candidate PCS materials,
    - finding appropriate system designs for sorption storage systems
    - system technologies that are reliable for a large number of charging/discharging cycles
    - applications and potential

Major outcomes

The major outcomes of the proposed annex will be:

- increased awareness of the possibilities of efficient energy transportation using advanced thermal energy storage;
- increased activities in the area, e.g. initiation of feasibility studies and demonstration projects regarding energy transportation through TES.
- a solid work plan for continuing annex regarding feasibility studies and demonstration projects

Annex 19. Optimized Industrial Process Heat and Power Generation with Thermal Energy Storage

1. Background.

Previous activities in the IEA Implementing Agreement "Energy Conservation through Energy Storage" has achieved significant progress in thermal energy storage technologies for energy savings and for reduction of peak demand of energy in buildings and in advancing the prospects of cooling with TES technologies.

The potential for thermal energy storage and regenerative heat transfer for the industrial process heat sector for efficient energy utilization, heat recovery and storage of high temperature waste heat as well as the need for energy storage for power generation based on new conversion techniques and renewable energy resources (RES) is a concern of several national and international research strategies. Both areas are directed to applications and processes at high temperature. In this context "High Temperature" is defined to be higher than 120 °C as required for comfort heating and where water cannot be applied as heat transfer fluid.

Nevertheless, no or very few examples of commercial high temperature thermal energy storage (HTTES) are realized. Main reasons are the still too high investment costs of the existing HTTES technology which leads to non economic systems. In order to achieve the required cost reduction the realization of long-term stable, low cost storage materials with superior thermo physical properties, the development of a high efficient and economically optimized heat exchanger configuration and innovative storage design are required. In the same way, the development of optimized integration and operation strategies for the specific application are essential.

Currently, international research activities in the field of HTTES are fragmented with respect to the investigated storage technique and TES material development as well as to the considered power level, range of thermal capacity and temperature range.

Important applications for high temperature heat storage can be found in the industrial process heat sector. Depending on the temperature range and the dominating heat transfer fluids, two different areas are identified. A huge amount of energy in the temperature range of 100-300°C is needed to generate process steam at low or intermediate pressure for application in food processing, manufacturing of construction materials, production of cardboard and paper, in the textile industry, manufacturing of rubber and other commodities. For such applications improved PCM/steam storage systems could lead to economic TES solutions. For elevated temperatures above 500/600 °C flue gas and process air are the dominating heat transfer fluids. Due to the poor heat transfer characteristics of gas/air the development and design of high efficient heat transfer technique represent an additional important task for the realization of economic HTTES technology.

With increasing amount of electricity generated by RES feeding into the interconnected grids, considerable grid stability problems come up. For solar thermal power plants the integration of thermal energy storage avoids such interconnection and frequency stability problems by stabilizing solar power generation within the fence of the solar thermal plant. For stand alone solar thermal plants in remote or island power parks, energy storage is the fundamental element to maximize capacity factor and to assure availability. In case of wind power,

electricity has to be stored to make up for the inherent variability of wind. As an alternative to storing electricity the "Advanced Adiabatic Compressed Air Energy Storage (CAES)" is being developed by a European consortium. The core component of the AA-CAES concept is an efficient high temperature heat storage device necessary to enable effective and economic adiabatic CAES technology. With respect to power generation with fuel cells there is considerable demand for thermal management and HTTES especially for the operation of high temperature solid oxide fuel cells.

2.Objectives.

The general objectives of the proposed Annex" Optimized Industrial Process Heat and Power Generation with Thermal Energy Storage" are to overcome the fragmented research and to achieve synergies from existing and new future HTTES activities.

The objectives of the work to be performed under this Annex are:

- To conduct a general review and assessment study of existing and emerging HTTES technologies
- To identify obstacles that need to be overcome to make industrial process heat and power generation with TES more economically and environmentally viable
- To identify efficient and economic storage materials
- To compare and assess different HTTES concepts and design
- To define strategies for efficient storage integration and operation
- Technology transfer

3.Work programme.

The work in the framework of this Annex is planned for a period of 3 years (with expected start after approval by the ExCo in late fall 2004) and subdivided in subsequent phases. For each phase an indication is given of the time required to carry out the activities.

Phase 0: Pre-definition Phase
January-October 2004

- Invitation to participate, clarification of interest and participation
- Kick-off workshop in June or July 2004 (organized by DLR) – establishing participants and their combined goal with the annex
- Collecting information on ongoing activities in this area, compiling State-of-the-Art of HTTES technologies

Phase 1: Start up and Task Definition Phase (time required 6 months)

- Finalizing Annex Objectives, Goals and Work Plan with ExCo
- Finalizing Financing Plans for participants
- Establishing collaboration activities
- State of the Art Reviews

- Workshop and Expert Meeting

Phase 2: Review and Assessment Phase (time required 15 months)

- State of the Art Reviews (continued)
- Technical and economic assessment of different HTTES concepts
- Identify of applications with high potential for economic HTTES integration
- Case Studies
- Evaluation of the concepts and applications
- Workshop and Expert Meetings

Phase 3: Development and Implementation Phase (time required 15 months)

- Case Studies and Pilot projects (continuation)
- Defining candidate technologies for power generation and process heat
- Establishing desired feasibility studies and demonstration projects – a plan for future IEA activities
- Initiation of energy storage projects related to industrial process and power generation
- Workshop and Expert Meetings
- Final Report and Dissemination of Results

4.Costs involved.

The work will be carried out on Task Sharing Basis.

To carry out the activities described in this Annex, the level of effort per participating country is estimated to be about 3 person months per year. In addition to this, about 4 person months per year is required for the specific tasks of the Operating Agent.

5.Operating Agent.

To be determined by the ExCo.

In case, Germany will contribute with a considerable project, DLR has the experience and capability to take over the role of the OA.

6.Participating countries.

To be determined.

1. Introduction

Renewable and natural energy sources, main components of sustainable energy systems, can only be made continuously available to users through thermal energy storage (TES). In addition to heating TES provides several flexible alternatives for cooling systems. Recent discussions on topics like global warming and heat waves have brought attention once again to energy efficient cooling systems utilizing renewable energy sources. Cooling demand has already been increasing due to the evolving comfort expectations and technological development around the world. Climate change has brought additional challenges for cooling systems designers. New cooling systems must use less and less electricity generated by fossil fuel based systems and still be able to meet the ever increasing and varying demand.

TES can be used in cooling systems to achieve following purposes:

- Energy conservation
- Increasing energy efficiency
- Peak shaving
- Load leveling

The following concepts of TES are used with cooling systems to replace and/or support conventional systems:

- Sensible Heat - Resulting from a change in the temperature of a material is utilized in storage.
- Latent Heat – Associated with a phase change (solid-solid, solid-liquid) of the material is used for storage.
- Chemical Reaction Heat - Stored as the energy of a chemical compound, and energy can be repeatedly stored and released in the same materials by reversible chemical reactions. This generally involves a reversible chemical reaction, absorption, adsorption or a hydration process.

The TES technologies using these concepts are:

- Underground Thermal Energy Storage(UTES)
- Phase Change Materials
- Thermochemical Reactions
- Chilled Water Storage
- Building Structure Storage

The expected benefits from implementation of TES in cooling systems are:

- Reduction in CO_2 emissions
- Efficient utilization of energy sources
- Reduction in use of conventional mechanical cooling and assisting to phase out Ozone Depleting Substances (ODS) such as CFC and HCFC refrigerants

- Reduction in peak electrical power demand
- Better working environment that increases the productivity in industry

Within IEA ECES IA previous Annexes 7, 8, 10, 13 and 14 have looked at various aspects of cooling with TES alternatives. The results of these Annexes have lead to an increase in awareness followed by initiation of TES activities. There is a need for a new annex to provide new combinations of TES for different energy systems in different climates and spread implementation of TES systems.

2. Applications

The current applications of cooling with TES can be grouped into following categories:

1. Commercial and institutional buildings
2. District cooling
3. Residential
4. Agriculture – Aquaculture
5. Industry
6. Telecommunication stations
7. Power generation

3. Objectives

The overall objective of the new Annex is to employ feasibility studies and demonstration projects to advance the prospect of cooling with TES technologies for applications within a variety of energy systems and to encourage their use as a standard design option.

APPENDIX 1 - PARTICIPANTS OF ECES IA

COUNTRY	CONTRACTING PARTY
Belgium	Ministry of Economical Affairs
Canada	Public Works Canada
CEC	Commission of the European Communities
Denmark	The Ministry of Energy
Finland	TEKES, Technology Development Center of Finland
Germany	Forschungszentrum Jülich GmbH
Italy	ENEA , Governmental Energy Research Agency
Japan	The Heat Pump and Thermal Storage Center of Japan
Norway	The Research Council of Norway
Spain	IBERDROLA, Madrid
Sweden	FORMAS
Turkey	Cukurova University
UK	Department of Trade and Industry (DTI)
USA	US Department of Energy
Sponsor	IF Technology
Poland	Present status: Observer

IEA-Secretariat:

Responsible desk officer: Carrie Pottinger

APPENDIX 2 -LIST OF PUBLICATIONS

Annex 14 :

- Annex 14 brochure and CD including final reports and workshop proceedings
- Sixth Workshop Proceedings, April 11, 2003, Lleida, Spain (CD-ROM)
- Halime Paksoy, Bekir Turgut, Hunay Evliya, Muhsin Mazman, IEA ECES Annex14 Cooling in all climates with thermal energy storage, Futurestock'2003, 9th International Thermal Energy Storage Conference, 1-4 September, 2003, Warsaw.

More info can be found at the Internet site: http://cevre.cu.edu.tr/annex14/

Annex 17:

Proceedings of Wokshops presented in internet of Annex 17 homepage:
http://www.fskab.com/Annex17

- Indore. March 22-23, 2003

Annex 12 / 13:

Final Reports and State of the Art Reports Annex 12 and Annex 13 are in preparation, will be published 2004

Futurestock Conference:

The proceedings of Futurestock´2003, 9th International Conference on Thermal Energy Storage held in Warsaw, Poland, September 1-4, 2003 can be asked for at:
Prof. Roman Domanski, **rdoma@itc.pw.edu.pl**