

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

**Implementing Agreement on
Energy Conservation Through Energy Storage**



Annual Report 2004

April 2005

CONTENTS

CONTENTS	2
CHAIRMAN'S REPORT	3
ENERGY CONSERVATION THROUGH ENERGY STORAGE IMPLEMENTING AGREEMENT	5
ACTIVITIES OF THE EXECUTIVE COMMITTEE.....	8
ON-GOING ANNEXES	9
ANNEX 12. HIGH TEMPERATURE UNDERGROUND THERMAL ENERGY STORAGE.....	9
ANNEX 13. DESIGN, CONSTRUCTION AND MAINTENANCE OF UTES WELLS AND BOREHOLES.....	11
ANNEX 14. COOLING IN ALL CLIMATES WITH THERMAL ENERGY STORAGE.	13
ANNEX 17. ADVANCED THERMAL ENERGY STORAGE THROUGH APPLICATION OF PHASE CHANGE MATERIALS AND CHEMICAL REACTIONS – FEASIBILITY STUDIES AND DEMONSTRATION PROJECTS.....	15
PROPOSED ANNEXES.....	19
ANNEX 15. ELECTRICAL ENERGY STORAGE AND THE INTEGRATION OF RENEWABLES	19
ANNEX 16. MARKET DEPLOYMENT OF ENERGY STORAGE SYSTEMS	21
ANNEX 18. TRANSPORTATION OF ENERGY BY UTILIZATION OF THERMAL ENERGY STORAGE TECHNOLOGY.....	25
ANNEX 19. OPTIMIZED INDUSTRIAL PROCESS HEAT AND POWER GENERATION WITH THERMAL ENERGY STORAGE	28
PROPOSED ANNEX: COOLING WITH THERMAL ENERGY STORAGE	32
APPENDIX 1 - PARTICIPANTS OF ECES IA	39
APPENDIX 2 -LIST OF PUBLICATIONS.....	40

CHAIRMAN'S REPORT

After the unusually hot summer 2003 in many parts of the world and especially in Europe the public attention has focused once more to the dramatic environmental and health problems associated with a possible long term climate change due to greenhouse gas emissions into the atmosphere. A main progress is expected from the Kiyoto Protocol which became effective early in 2005 after Russia has just decided to join. However the growing energy demand especially of the Third World still leads to a rising fossil energy consumption and CO₂ emissions.

Recently rising temperatures and especially the need for higher living comfort have lead to a fast increase of electric driven air conditioning installations. Besides other detrimental consequences electric peak power demand of electric chillers and of air conditioning installations has already caused shortages of the electricity supply and even the total break down of electric local grids. Energy efficient cooling of buildings has become a subject of high priority also within the IEA. Politicians, technicians and building designers have to find adequate solutions.

A strategy to mitigate the problems is the development and implementation of new energy saving technologies. In the IEA-Programme: "Energy Conservation Through Energy Storage" thermal energy storage concepts and technologies have been developed which can be used for energy efficient cooling. The electricity demand can be substituted completely or to a large extent using the ambient cold stored in groundwater and aquifers or in the subsoil directly or via heat pumps. Other innovative concepts include the use of Phase Change Materials (PCM) in building materials and thermo-chemical reactions to generate cold by waste heat from cogeneration plants or industrial processes as well as from solar energy.

IEA Future Building Forum: Cooling Buildings in a Warmer Climate

The conference arranged in June 21-22 by the IEA and ADEME reviewed the present status of technologies and the different options to reduce the electric energy demand. Among the 140 participants with different expertise many delegates of ECES attended. Thermal energy storage was recognized important and suitable to contribute to sustainable air conditioning of buildings. Several technologies and concepts like cold storage in shallow aquifers and subsoil have been developed and are ready for implementation. The deployment can be facilitated with easy to use design tools and overcoming the existing legal barriers. On the other hand much progress can still be achieved to improve the cost-effectiveness and performance of the concepts.

IEA-Implementing Agreement: Programme and Activities

The Executive Committee managed several **ongoing Annexes** and **new activities**.

Present Annexes:

- **Annex 12** has been formally completed by the end of 2003. The Final Report has not yet been accomplished. We expect the publication in 2005.
- **Annex 13** will be completed 2005 with the publication of several technical reports and the Final Report.

- **Annex 14** has been completed in summer 2004 with the publication of the Final Annex 14 Report. The ExCo agreed to continue the work on cooling in a new Annex 20 (see below).
- **Annex 17:** will be completed 2005 after the last expert meeting with the publication of the final report.

New Annexes in preparation:

- **Annex 15: Distributed Generation and Electrical Energy Storage** (lead: Phil Baker/John Baker)
- **Annex 16: Deployment of Energy Storage Technologies** (interim lead: Aart Snijders, IF Technology)
- **Annex 18: Transportation of Thermal Energy by TES** (interim lead: Fredrik Setterwall and Andreas Hauer)
- **Annex 19: High Temperature Thermal Energy Storage Technology** (designated O.A. Rainer Tamme, DLR Stuttgart)
- **Annex 20: Sustainable Cooling with Thermal Energy Storage** (lead: Halime Paksoy and Masaya Okumiya)

Unfortunately no progress was achieved in 2004 launching the proposed **Annex 15**. It is not yet decided whether Annex 15 will be transferred to the recently proposed Implementing Agreement “Electricity Transmission and Distribution”.

Several kick-off meetings were held to initiate new Annexes 18, 19 and 20. Experts from several countries have shown their interest to participate, however the main problem is still the lack of financial support for participation.

More detailed information on ongoing and proposed new Annexes is provided in the attachments.

Revised legal text of the IA adopted

At the ExCo meeting in Montreal in May 2004 the revised legal text has been approved by the ExCo. The new text complies with the regulations of the IEA Framework adopted by the Governing board on April 3, 2003. Another amendment of the legal text (Article 10(c)) was suggested by the secretariat was adopted by the ExCo at the meeting in Lleida, December 9-10, 2004.

Technology Transfer and Participation

Technology transfer and information dissemination from the Annexes to the outside world is considered an important issue in the Programme. Therefore industrial workshops have been arranged in conjunction with the expert meetings. A highlight was the workshop by Annex 17 participants in Beijing, P.R. China in October 2004.

ITC Warsaw (Institute of Heat Engineering of the University of Technology) has submitted the formal application to join ECES as SPONSOR. After approval by CERT in 2005 ITC Warsaw will become a new participant of ECES.

Contacts have been renewed with other interested parties in New Zealand, Slovenia, Switzerland and France. It is hoped that the participation can be arranged in the near future.

Executive Committee meetings:

Two regular ExCo meetings took place:

- 14-15 May in Montreal (host: Frank Cruickshanks and Ed Morowsky)
- 9-10 December, University of Lleida, Spain (host: Luiza Cabeza, University of Lleida)

Co-operation within the IEA (BRIA's)

A joint meeting with the ExCo Heat Pumping Technologies was organized in conjunction with the regular ExCo meetings on May 13, 2004 in Montreal Canada. The common interest was affirmed to cooperate closely together in particular in the topic of ground coupled heat pump systems.

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 IF Technologies from The Netherlands and the Institute of Heat Engineering (ITC) of the University of Technology, Warsaw, Poland as sponsors. The Executive Committee is working intensively to attract more countries to join the activities and to sign the Implementing Agreement in particular New Zealand and Slovenia. Australia, Bulgaria, China, France, India, Israel, Korea, Malaysia, South Africa are also interested. 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 – 2004) 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, USA

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 two meetings during the year 2004 and a joint meeting with the Executive Committee of the Heat Pump Programme. The 57th XC meeting was held in Montreal, Canada on May 14-15 and 58th XC meeting in Lleida, Spain on December 9-10. The joint meeting was held on May 13 before the Executive Committee meeting in Montreal.

The most important items and decisions of the XC meetings in 2004 are outlined below.

The Montreal Meeting, May 14-15, 2004

- Approval of the minutes of the 56th XC meeting
- Volkmar Lottner was unanimously re-elected as Chairman, Halime Paksoy and Franck Cruickshanks as Vice Chairs.
- Annual Report 2003 was approved
- Financial statement from October 1st 2003 until May 1st 2004 of the secretariat was approved
- Approval of the revised legal text of the Implementing Agreement
- Approval of the progress reports of ongoing Annexes (12, 13 and 17).
- Approval of the final report from Annex 14.
- Extensions of Annex 12, 13 and 17 were approved.
- Evaluation of new Annex proposals Annex 15, 16, 18, 19 and 20.

The Lleida Meeting, December 9-10 2004

- Minutes of the 57th XC meeting were adopted
- Andreas Hauer was re-elected as the secretary and the budget until the end of 2005 was unanimously approved.
- The new strategy plan (2006-2010) and the end-of-term-report (due in 2005) were discussed.
- Approval of progress reports of the ongoing Annex 12, 13 and 17 and an extension of Annex 12 and 13
- The new Annexes 18 and 19 should continue in their task-definition-phase.
- Kick-off workshops are planned for Annex 16 and 20 in Spring 2005
- A Joint workshop with the DHC IA will be held in June 2005 in Berlin, Germany, in conjunction with the DHC-Conference "Euro-Power"
- The International Summer School on Thermal Energy Storage will take place in Izmir, Turkey in June 2005

ACTIVITIES OF THE EXECUTIVE COMMITTEE

Executive Committee Meetings

- 57th XC meeting, Montreal, Canada, May 14-15
- Joint meeting of both ExCos ECES and Heat Pumps in Montreal, Canada, May 13th before the 57th XC
- 58th XC meeting, Lleida, Spain, December 9-10

Expert Meetings and Workshops 2004

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

- 6th Experts Meeting (Joint Meeting with the Task 32 of the Solar Heating and Cooling Implementing Agreement), June 7 , Arvika, Sweden
- Workshop, June 8-9 , Arvika, Sweden
- 7th Experts Meeting, October 8, Beijing, China
- Workshop, October 11-12, Beijing, China

Annex 18: Transportation of Thermal Energy by Thermal Energy Storage

- 1st preparatory meeting, June 10 , Arvika, Sweden

Annex 19: Optimised Industrial Process Heat and Power Generation with Thermal Energy Storage

- 1st preparatory meeting, June 10 , Arvika, Sweden
- 1st Kick-Off Workshop, November 25-26, Bordeaux, France

Annex 20: Cooling in All Climates With Thermal Energy Storage

- 1st preparatory meeting, June 23, Nice, France

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

- BCG Meeting, June 22 2004, Nice, France
- IEA Future Building Forum: Cooling Buildings in a Warmer Climate, June 21-22 2004, Nice, France

Participation in IEA-Workshops

- IEA-workshop “Seeking Frontiers on Highly Efficient Energy Utilisation in Factories and Buildings”, Tokyo, Japan, January 19th , 2004.

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, apartment 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 2005.

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 2004

During 2004 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 2004 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.

Work plan for 2005

For the coming year 2005, 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)
- Canada, Frank Cruickshanks (frank.cruickshanks@ec.gc.ca)
- Germany, Burkhard Sanner (burkhard.sanner@geo-uni-giessen.de)
- Japan, Xiaomei Li (li@host2.hptej-unet.ocn.ne.jp)
- Netherlands, Guido Bakema (office@if-tech.nl)
- Norway, Helge Skarphagen (helge.skarphagen@ngu.no)
- Sweden, Olof Andersson (olof.andersson@sweco.se)
- Turkey, Halime Paksoy (hopaksoy@mail.cu.edu.tr)
- USA, Jeff Spitler (spitler@osuunx.ucc.okstate.edu)

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”

Final Report

The final report was approved by the executive committee at the 57th XC meeting, which was held in Montreal, Canada on May 14-15 2005. It can be downloaded from the Annex 14 homepage <http://cevre.cu.edu.tr/annex14/>. A brochure and a CD containing the report and the presentations at the Annex 14 work shops can be ordered from Bekir Turgut (annex14@mail.cu.edu.tr).

National Contacts

Sweden

Bo Nordell, Bo.Nordell@sb.luth.se
Kjell Skogsberg, Kjell.Skogsberg@sb.luth.se
Fredrik Setterwall, setter@chemeng.kth.se
Olof Andersson, OLOF.ANDERSSON@sweco.se
Bo He, bohe@ket.kth.se
Göran Hellström, neo.energy@swipnet.se

Japan

Motoi Yamaha, yamaha@isc.chubu.ac.jp
Tadahiko Ibamoto, ibamoto@env.a.dendai.ac.jp

Canada

Frank Cruickshanks, Frank.Cruickshanks@ec.gc.ca
Edward Morofsky, MOROFSKE@PWGSC.GC.CA

Turkey

Bekir Turgut, annex14@mail.cu.edu.tr
Derya Dikici, ddikici@mail.cu.edu.tr
Halime Paksoy, hopaksoy@mail.cu.edu.tr
Hunay Evliya, hevliya@mail.cu.edu.tr

USA

Lynn Stiles, Lynn.Stiles@stockton.edu

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

Annex 17 “Advanced Thermal Energy Storage through 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.

Expert meetings and work shops

Officially the Annex has three members, Germany, Japan and Sweden. Countries that have been interested in the work of the annex are Australia, Austria, 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 one or more of the work shops arranged in Leida (Spain), Benediktbeuern (Germany), Ljubljana (Slovenia), Tokyo (Japan), Indore (India), Warsaw (Poland), Arvika (Sweden) or Beijing (China). Details of these meetings are given below.

EM/WS	Location	Host	Date	Number of participants in the work shop	Participating countries	Observer countries
Kick-off	Lleida, Spain	University of Lleida	5-6 April 2001	13	Germany Japan Sweden	The Netherlands Spain Switzerland
1	Benediktbeuern / Munich, Germany	ZAE Bayern	3-4 October 2001	Together with ZAE-Bayern	Germany Japan Sweden	The Netherlands Turkey Australia Spain
2	Ljubljana, Slovenia	University of Ljubljana	3-5 April 2002	16	Germany Japan Sweden	China Slovenia Spain Switzerland
3	Tokyo, Japan	Heat Pump & Thermal Storage Technology Centre of Japan	30 Sept. – 2 October 2002	38	Germany Japan Sweden	China India Spain Turkey
4	Indore, India	Devi Ahilya University	21-24 March 2003	56	Germany Japan Sweden	India
5	Warsaw, Poland	Warsaw Technical University	31 August 2003	In connection to Futurestock conference	Germany Japan Sweden	Spain Switzerland Turkey
6	Arvika, Sweden		7-9 June 2004	50	Germany Japan Sweden	India The Netherlands Slovenia Spain Turkey
7	Beijing,	Tsinghua	8-12 October	48	Germany	Canada

The work in the Annex has been divided into three subtasks:

- Heating and cooling of buildings
 - Building materials and components
 - Sorption processes
 - Peak shaving
- Temperature control
- Utilization of natural and waste energy sources

New materials and physical properties

The interest has been focused on storage of cold energy. The reason is that phase change materials are more competitive in this area since the temperature range for storage is smaller and thus the energy density for sensible heat storage is low. Commercially available materials for this area are based on salt hydrates or mixture of paraffin hydrocarbons. The former usually have a low heat of fusion whereas the later exhibit a melting temperature range leading to that in some applications the total heat of fusion can not be utilized. New materials based on other organic or inorganic compounds have been presented during then annex.

Measurement and presentation of PCM physical properties differs between different suppliers. Reliable data for among others melting temperature, heat of fusion and heat conductivity are essential to a correct design of a storage based on theses materials. This has clearly been shown in presentations given during the annex work shops. In Germany has been decided to standardize measurement and presentation of such data. The suggested standard was presented during the latest work shop in Beijing.

PCM usually has a low thermal conductivity which has been considered a drawback for the technology. By additives to the material or introduction of PCM into a matrix of conductive material the conductivity has been drastically improved. One such matrix is expended carbon which by the high porosity of the matrix leads to a high energy density with a very high thermal conductivity.

Building materials and components

Introduction of PCM into building materials increases the thermal mass of the building without changing the physical mass. By the increased thermal mass the external temperature variations will to a lesser extent be transferred to the interior of the building thereby creating a more comfortable indoor climate. The relative temperature constancy of the building also leads to a smaller moisture precipitation thereby avoiding damage to the building.

Building materials for different applications are now commercially available as presented during the latest work shop in Beijing. Plaster, fiber- and gypsum boards as well as introduction of PCM into concrete are examples of available materials. Also different building components as windows have been introduced to the market.

Passive cooling of buildings

The coldness of the night could be stored in PCM for air conditioning in day time. Such systems were presented during the work shop in Indore, India. The electrical power for the fans introducing the cold night air into the building corresponds to an electrical COP (Ratio between the produced cold and the required electrical energy) of approximately 20. The most important result however is not the energy savings but the reduced cost for installation compared to a conventional system. The air handling units will be substantially simpler with the passive cooling system.

Systems for passive cooling of buildings have been demonstrated in Germany, Sweden and in the United Kingdom.

Sorption processes

Demonstration projects in Germany show the feasibility of both cooling and heating of buildings utilizing district heating water for storage. In the project for heating low prized heat during the week ends is stored to heat a school building during the week. The cooling project concerns a jazz club with practically no cooling load during day time but high cooling power demand during show hours in the club.

Temperature control

Temperature control is needed in many cases

- Transportation of temperature sensitive goods
- Electronic equipment
- Personal comfort during extreme temperature conditions
- Medical applications

Presentations during the annex of products in this area are for instance

- LapTopCooler for keeping low temperature of the computer for avoiding burning and for safer running of the computer
- CoolWest for athletics in the Olympic Games. The west has also been used by fire man to prolong the stay in the fire area and by personal working with the light in theatres.
- Garment for medical doctors working with SARS-patients in order to keep a comfortable temperature even when dressed to avoid direct contact with the patients
- Cooling of new-borns for decreasing the risk of brain damage when subjected to oxygen deficiency.

Waste heat utilization

The Swedish project in the annex is about thermal energy storage in connection with absorption chillers. Especially in the case of district heating based on waste incineration it is important to be able to utilize the heat even in summer time when the heat load is small. Since absorption chillers are expensive, especially using low temperature energy as driving energy, the importance of thermal storage is obvious; by constant high load the peak power of the chiller could be held lower than the peak demand, thus decreasing the investment cost.

Further, an absorption chiller in a trigeneration system (producing simultaneously cold, heat and power) will, if operated continuously, lead to an increased electrical energy production and thus a more economical system.

Another project presented during the annex concerns utilization of high temperature energy but low duration from the steel industry. When the steel is cooled down in a batch process the energy is difficult to utilize for production of electricity without storage. When stored the energy could be used for a continuous production of electricity although the supply of thermal energy is intermittent.

New annexes

Discussions during the course of the annex show the need of more information in high temperature thermal energy storage and in the field of energy transportation.

Dr Rainer Tamme from Germany have taken the task to prepare for a new annex in the field of high temperature thermal energy storage.

Transportation by trucks, railways or ships of PCM as well as pumping high density energy carriers is a way to transport energy from the place where it is available to a place where it is needed. Two discussion meetings have been held during the annex. Dr Viktoria Martin took on the responsibility to arrange those meetings. However due to the financial and political situation in Sweden the situation about the future of this work at the moment is unclear.

Information

The web site of the annex, www.fskab.com/annex17 is visited by more than 700 visitors each month originating from around 60 different countries.

On the website information from all the experts meetings and work shops are given. Thus more than one hundred presentations are found on the web site and also found are addresses and names of more than one hundred persons working in the field of thermal energy storage utilizing PCM or chemical reactions.

Also found are data sheets of the physical properties of commercially available PCM as well as of more than three hundred compounds used by and suggested by researchers for use for thermal energy storage.

Upcoming meetings

The final expert meeting and work shop will be held on the 18th to 20th of April 2005 in Kizkalesi, Turkey. The intention is to present the outcome of the annex by having enterprises and researchers presenting new materials, products and systems based on phase change materials or chemical reactions for thermal energy storage.

National contacts

Germany	Andreas Hauer hauer@muc.zae-bayern.de
Japan	Motoi Yamaha yamaha@isc.chubu.ac.jp
Spain	Luisa Cabeza lcabeza@diei.udl.es
Sweden	Viktoria Martin vmartin@kth.se Fredrik Setterwall fredrik.setterwall@comhem.se

PROPOSED ANNEXES

Annex 15. Distributed Generation and Electrical Energy Storage

Remark: The following proposal has been submitted at the XC meeting in Turnhout, November 2002. It has not been updated since then as there was no progress towards the implementation and start of the Annex.

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 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 countries 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**

Phil Baker
Department of Trade and Industry (DTI)
1 Victoria Street
London SW1H 0ETUK

Tel. 020 7215 2675
Fax: 020 7215 2674

e-mail: Philip.Baker@dti.gsi.gov.uk

or subscribe to the Annex 15 egroup at:
<http://groups.yahoo.com/group/electricalenergystorage>

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 for energy conservation. The energy storage technologies developed and demonstrated involve underground thermal energy storage, thermal energy storage in phase change 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 large scale 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, as well as renewables like 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 responsibility for market deployment cannot be left to 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 one or more of the energy storage technologies developed in this Implementing Agreement:
Underground Thermal Energy Storage (UTES), Phase Change Material Storage

(PCMS) and Electrical Energy Storage (EES)¹.

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. As a minimum, each national team shall consist of one marketing expert and one specialist in energy storage.

3. Work programme.

A kick-off Workshop has been organized with the prospective participants to prepare the Annex work plan, including the specific tasks and responsibilities of the participants. The work in the framework of this Annex can be subdivided in four subsequent phases. For each phase an estimate is given of the time required to carry out the activities. The timeline for the subsequent phases is predicated on the assumption that all participants will be able to start their respective activities by September 2005.

Phase 1 Market segmentation

The major objectives of this phase are:

- Definition of the system concepts or products that include storage technologies that are already on the market or ready for the market;
- Assessment of the major market segments for these “embedded storage technologies”. This will result in a number of Product-Market Combinations (PMC’s).

The objective of this phase is not to complete a detailed market segmentation for each storage technology considered, but to focus on promising market segments. This implies that those market segments that are considered not interesting for the near future will be discarded (with reason) in an early stage. The promising market segments will be analysed into more detail. The analysis for these market segments includes the size of the market segment, existing technologies that will be replaced by the new technology, position of the storage technology, major stakeholders in this segment, as well as a preliminary SWOT analysis for the embedded storage technology.

Output Phase 1: A report on market segmentation for selected PMC’s for (and by) each participating country.

Timeline: September 2005 - April 2006.

Phase 2 Selection of one or two PMC’s per participating country

In this phase an Experts Meeting will be organized to select the most prospective PMC for each of the storage technologies. It is not expected that the most prospective market segments will coincide for the participating countries, so the PMC selection will be country specific.

Output Phase 2: The most prospective market segments for UTES, for PCMS, and for EES¹.

Timeline: May 2006.

¹ It will be decided by the participation countries which storage technologies will be included in this Annex.

Phase 3 PMC analysis and development of deployment strategies.

In this phase the PMC's selected in Phase 2 will be further analysed and deployment strategies will be developed for these PMC's. The PMC selection, and thus the further analysis will be country specific and will be performed for one or two PMC's by each participant.

The analysis of each of the PMC's will result in the deployment strategy and includes the answers to the following questions:

- what is the product (embedded storage technology)? *“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 with features they do care about”* (IEA, 2002)
- what is the position of this product in this market segment? This includes both the position of the product in the technology adoption life cycle and the position as compared to existing technologies (incremental first cost, energy saving, operational cost saving, etc.).
- what are the opportunities and threats for this storage technology in this specific market segment?
- who are the first adopters in the specific market segment and which clients will be the early majority?
- how does the value chain look like in this market segment?
- what is the best route 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 adoption, etc.) and the other stakeholders in the market deployment strategy?

An Experts Meeting will be held after completion of the PMC analyses to focus the next step: the development of the deployment strategies.

*Output Phase 3: Country specific deployment strategies for the PMC's selected in Phase 2.
Timeline: June - December 2006.*

Phase 4: Dissemination of results

The results of this Annex will be made available to stakeholders in the field of energy efficiency and renewables through:

- presentation of the (country specific) deployment strategies to the stakeholders in the participating countries.
- publication of the major results on the ECES website.
- preparation of a summary report and distribution of the summary 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.

Output phase 4: See above

Timeline: January - March 2007 (excl. Presentation Energy Storage Conference)

4. Costs involved.

To carry out the activities described in this Annex, the level of effort is estimated to be about six person months per participating country (four months marketing expert, two months energy storage specialist). In addition to this, about three person months are required for the specific tasks of the Operating Agent.

5. Operating Agent.

To be determined.

6. Participating countries.

To be determined.

An expression of interest was received from:

Belgium

Germany

The Netherlands

Norway

Turkey

Sweden.

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 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 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 too 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 an 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 processes 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: July 2005 - December 2005

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

Phase 1: January 2006 – June 2006 (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: July - December 2006

- 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: January 2007 - June 2007

- 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: July 2007 - December 2007

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

Phase 5: January 2008 - June 2008

- 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. Activities 2004

The definition of the scope and work program was further developed. Significant effort was made to distribute information and to raise interest of potential participants for participation. Two events to establish Annex 19 should be highlighted:

- Kick-off meeting: 10th of June 2004, Arvika, Sweden, in connection with Annex 17 expert meeting and Annex 17 workshop
- Workshop and expert meeting: 25-26th of November 2004, Bordeaux-Talence, France

The meeting in Arvika was attended by 14 participants from Germany, Japan, Netherlands, Spain, Sweden, and Turkey. In addition to technical presentations main emphasis was directed to get an overview of activities in the different countries which would fit to the work program and to identify interest and potential parties for joining this Annex. Participants from Germany, Netherlands, Japan, Spain and Sweden expressed high interest, but it turned out that due to currently **uncertain** funding no commitment for joining the Annex could be given. It was agreed to proceed with a “Non-official expert meeting” in France to get more information of the French HTP stock group.

The workshop in France was attended by 13 participants from France, Germany, and Netherlands. The French research group “High Temperature and Power Materials” - HTP-stock consist of the 4 research institutes: TREFLE – CERTES – PROMES – LaTEP and is coordinated by Prof. Elena Palomo from CNRS Bordeaux. At the workshop 6 presentations providing a survey on TES activities of institutes, 4 technical presentations on PCM and chemical storage, and 3 presentations on modeling and simulation of TES materials and systems were presented.

The HTP-stock expressed strong interest to collaborate with new annex 19. While funding of the HTP-stock project is provided by Ministry of Research, international cooperation needs to be approved by Ministry of Industry. The responsible person is Mr. Bruno Gremillot, director of the "International Strategy Department" of the French Minister of the Industry.

The status of negotiations (April 2005) with interested parties can be summarised as follows:

- Germany – represented by DLR – agreed to participate and to provide the OA
- France – represented by the HTP stock group – will participate but needs first to enter the ECES IA
- Netherlands – represented by ECN – is not a member of the ECES IA. ECN prefers to join ECES as a sponsor.
- Finland – represented by VTT – and Australia – represented by CSIRO – having not yet defined a specific project which would fit to the Annex.

- Sweden - represented by KTH – and Japan – represented by TII - need industrial support for project funding.

In addition there are request from interested parties from several other countries, but actually there is no official commitment available.

3. 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

4. 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

5. 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.

6. 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.

7. 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 mostly by fossil fuel based systems and still be able to meet the ever increasing and varying demand. Two important key points of efficient energy usage are demand leveling measures and finding the best mix of energy sources. Annual load factor for power generation, which is the ratio of annual average power supply to maximum power supply, is generally used to show the increasing demand on electricity. In countries where large cooling demand exists in summer, the load factor of electricity for power generation is decreasing. For example, load factor of 70% in the 1960's declined to 55% in 1994 for Japan. In European countries like Germany, England and France the load factor is kept more or less around 65% for the same period of time. However, load factor is expected to decline again not only in Japan but in other countries.

The short/long term load leveling and the peak shaving accomplish improvements in load factor. The electric load curve with strong peaks can be changed with diurnal (daily) thermal energy storage. Annual electric load curve shows large demand in summer and low demand in winter. If summer electric consumption can be shifted to winter, annual load profile can be smoothed even more. This can be achieved with Annual Cycle Energy System (ACES). The ACES utilizes renewable/natural and waste energy with TES for short and long term. ACES can be introduced to individual buildings and district heating/cooling systems.

Rapid growth of energy consumption is especially expected in Asian countries. Most of Asian countries have warm climate and increasing cooling demand. For example in China, the electric demand has increased immensely due to recent remarkable economic development and progress in living standards. Also number of air-conditioners sold has been increasing rapidly. In 2003 summer regional electric power failures were seen in China. It is a serious problem for Chinese economics and ventures that want to advance to China. Already China is the second country of the world in energy consumption and CO₂ emissions. In other Asian countries, same situation can occur in the near future. TES can be one of the solutions for this problem and TES technology has to be transferred properly to these countries.

Recent "black-out" instances in North America in August 2003, once again showed the urgent need to find a way to use less electricity for cooling. Even the nuclear power plants of France were not adequate to meet the peak demand of electricity for cooling during the heat wave in summer of 2003, killing 15000 people.

2. Scope and Objectives

The new Annex will follow a project oriented approach for optimized integration of TES in cooling systems by demonstrating and evaluating the sustainability (energy saving and CO₂ emission reduction) of cooling system with TES system.

Under the background described above, the objectives of the new Annex are:

- Advance the prospects of cooling with TES systems.
 - Technology development (short-term, long-term, alternative combinations of short-term with long-term TES utilizing renewable/natural energy).
 - Establishment of design method (evaluation of design tools)
 - Feasibility studies
 - Demonstration projects
- Information Dissemination and Technology Transfer within participating countries and to other countries (including non-Member countries).

3. Area of Activities

Subtask A : Demonstration projects/System performance evaluation for an actual project

This Annex aims to demonstrate the prospects of sustainable cooling using **short-term, long-term and alternative combinations of short-term with long-term** thermal energy storage. The thermal energy storage media that can be considered for short-term are water, ice, phase change materials (PCM), building structure etc., and for long term underground options including soil, aquifer, and cavities/pits are possible. Thermal storage systems can be applied to several sectors like commercial and institutional buildings, residential, district heating and cooling, etc.. In this subtask, demonstration projects for implementation of thermal energy storage in energy systems will be carried out in participating countries. The systems will be evaluated based on data from a monitoring programme of the actual thermal energy storage.

Subtask B: Design Procedure and System Performance Evaluation Tools

A good design is necessary to fully demonstrate energy-saving performance of a thermal storage system. For a good design, the manuals and design tools that were developed with the correct understanding of performance of a system are required. Another important issue is the proper operation of thermal storage system. For the optimal operation of thermal storage system, the appropriate operation tools and manuals are needed. So, in this subtask:

- Existing design manuals and tools for the short and long term thermal storage will be reviewed using inventory developed in Annex 14 or from other activities.
- Evaluation of design tools with respect to possibility of their use in various stages of design procedure will be examined.
- For a specific system, performance evaluation with two or more design tools will be performed, and the results will be compared.

Finally the comprehensive design/evaluation tool which leads to realization of the optimized integration of TES in cooling system is established.

Subtask C : Information Dissemination and Technology Transfer

Information dissemination and technology transfer are conducted in the following two ways.

1. The knowledge acquired by Subtask A and B will be summarized into the booklet with the title of "Design, operation and evaluation of cold storage system", and this is distributed to the participating countries.

2. Workshops and international conferences

Workshop will be held in various countries including a non-Member countries. It will be possible for the non-Member countries (NMCs) to participate in this workshop. This is developed to technology transfer to Asian countries, the Mediterranean coast countries where air conditioning load will increase in the future. Moreover, it leads to realization of Sustainable Cooling in a true meaning.

4. Means

The Participants shall share the coordinated work necessary to carry out this Annex. The objectives shall be achieved by demonstration projects, review of design/operation/evaluation tools and the information and technology transfer. The result of the projects should be distributed to the participating member countries in the Annex. If possible demonstration projects should be performed jointly between two or more of the participating member countries. Semi-annual meetings should be held for discussion of the results and for arrangement of workshops.

5. Results

The results of this Annex shall be

- periodic documents and interim progress reports on the results achieved under the Programme of Work
- recommendations for future case studies shall be given by priority by the Participants.
- final report describing the work carried out under this Annex. The final report should restate the scope and objectives of the Annex, its findings and documentation of case studies and demonstration projects
- Publication of the booklet: "Design, operation and evaluation of cold storage systems".

6. Time schedule

This Annex shall commence 1st of July 2005 and remain in force until 30th of June 2008. It may be extended by agreement of two or more Participants, acting in the Executive Committee, and taking into account any recommendations of the Agency's Committee on Energy Research and Technology concerning the term of this Annex. Extensions shall apply only to those Participants who agree to the extension or who notify the IEA Secretariat of their decision to continue to participate.

Phase 1: July – Dec 2005

- Collecting information on the advanced and sustainable cooling system with thermal energy storage
- Pickup applications of which performance will be evaluated

- Discuss the method for evaluations and the performance indexes
- Workshop and Expert Meeting

Phase 2: Jan – June 2006

- Evaluation of actual projects in participating countries
- Collecting information on the design manuals/tools and operating manuals
- Workshop and Expert Meeting (at new country)

Phase 3: July – Dec 2006

- Evaluation of actual projects in participating countries (continuation)
- Collecting information on the design manuals/tools and operating manual (continuation)
- Define the application and condition for investigating the design manual and tools
- Workshop and Expert Meeting (at new country)

Phase 4: Jan – June 2007

- Execution of several design tools for the defined application
- Making the summary for competition
- Final report and dissemination of results
- Final Workshop and Expert Meeting

7. Specific Obligations and Responsibilities of the Participants

Each Participant shall

- provide the Operating Agent with detailed reports on the results of the work carried out
- collect, assess and report to the Operating Agent data on ongoing projects in the field of thermal energy storage
- participate in the editing and review of draft reports on the Task
- be prepared to host semi-annual experts meetings and arrange work-shops
- participate in case studies or demonstration projects either nationally or in cooperation with other participating member countries
- cooperates positively on the technology transfer within participating and to non-participating countries
- participate in activities to enroll new members to the Annex by spreading information about the Annex and act in technology transfer to non-member countries where appropriate

8. Specific Obligations and Responsibilities of the Operating Agent

In addition to the obligations enumerated in Article 7 of this agreement the Operating Agent shall:

- Prepare and distribute the results mentioned in Article 5 above
- At the request of the Executive Committee organize workshops, seminars, conferences and other meetings
- Prepare the detailed program of work for the Task in consultation with the Participants and submit the programme of work for approval to the Executive Committee

- Propose and maintain a methodology and a format for the submission of information on data and results from case studies and demonstration projects and other on ongoing projects as described in Article 7
- Provide the semi-annually and other periodic reports to the Executive Committee on the progress and the results of the work performed under the programme of work
- Provide to the Executive Committee within six month after completion of all work under the Task a final report for its approval and transmittal to the Agency
- In coordination with the Participants use its best effort to avoid duplication with activities of other related programs and projects implemented by or under the auspices of the Agency or by other competent bodies
- Provide the Participants with the necessary guidelines for the work they carry out assuring minimum duplication effort
- Coordinate the efforts of all Participants and ensure the flow of information in the Task
- Perform such additional services and actions as may be decided by the Executive Committee acting by unanimity

9. Funding

(a) Semi-annual meetings. The Participants shall host the semi-annual meetings pursuant to Article 4 above in turn. The cost of organizing and hosting meetings shall be borne by the host Participant.

(b) Publications. The Operating Agent shall meet the cost of publishing the reports and summary assessments described in Article 5 above.

(c) Individual financial obligations. Each Participant shall bear all the costs it incurs in carrying out the Task activities, including reporting and travel expenses.

(d) Task-Sharing requirements. Apart from the participation in the demonstration projects, the review of tools and technology transfer which are anticipated to be financed outside of the Annex, the Operating Agent should devote 6 man-month per year to the work in the Annex. The Participants are expected to devote 3 man-month per year to the work in the Annex.

10. Operating Agent

Heat Pump&Thermal Storage Technology Center, Japan , acting through the Department of [Environmental Engineering and Architecture](#) , Graduate School of Environmental Studies at Nagoya University, Nagoya, Japan is designated as Operating Agent.

11. Information and Intellectual Property

(a) Executive Committee's Powers.

The publication, distribution, handling, protection and ownership of information and intellectual property arising from this Annex shall be determined by the Executive Committee, acting by unanimity, in conformity with this Annex.

(b) Right to publish.

Subject only to copyright restriction described in Article 11(i) below, the Participants shall have the right to publish all information arising from this Task, except proprietary information, as defined in Article 11(c) below.

(c) Proprietary information.

The Participants and the Operating Agent shall take all necessary measures in accordance with this Article, the laws of their respective countries and international law to protect the proprietary information provided to, or arising from this Task. For the purpose of this Annex,

proprietary information shall mean information of a confidential nature such as trade secrets and know-how which is appropriately marked provided that such information:

- (1) Is not generally known or publicly available from other sources;
- (2) Has not previously been made available by its owner(s) to others without obligation concerning its confidentiality;
- (3) Is not already in the possession of the recipient Participant(s) without obligation concerning its confidentiality;

It shall be the responsibility of each Participant supplying such proprietary information and of the Operating Agent for developing proprietary information to identify each information as proprietary and to ensure that it is appropriately marked.

(d) Production of Relevant information by Governments.

The Operating Agent should encourage governments of all Agency Participating Countries to make available or identify to the Operating Agent all published or otherwise freely available information known to them that is relevant to the Task.

(e) Production of relevant information by Participants.

Each Participant agrees to provide to the Operating Agent all previously available information and information developed independently of the Task which can assist or is needed by the Operating Agent to carry out its function in this Task, which is freely at the disposal of the Participant and the transmission of which is not subject to nay contractual and/or legal limitations under the following conditions:

- (1) If no substantial cost is incurred by the Participant in making such information available at no cost to the Task therefore;
- (2) If substantial costs must be incurred by the Participant to make such information available at such charges to the Task as shall be agreed between the Operating Agent and the Participant with the approval of the Executive Committee;

(f) Use of confidential information.

If a Participant has access to confidential information which would be useful to the Operating Agent in carrying out the studies, assessments, analyses or evaluations called for in this Task, such information may be communicated to the Operating Agent but shall not become part of any report or other form of documentation issued as part of this Task, nor shall it be communicated to the Participants except as may be agreed between the Operating Agent and The Participant who supplies such information.

(g) Acquisition of Information for the Task.

Each Participant shall inform the Operating Agent of the existence of information that can be of value to the Task but which is not freely available and each Participant shall endeavor to make such information available to the Task under reasonable conditions in which event the Executive Committee may, acting by unanimity, decide to acquire each information.

(h) Reports on work performed under the Task.

The Operating Agent shall provide reports on all work performed under the Task and the result thereof including studies, assessments, analyses, evaluations and other documentation but excluding proprietary information in accordance with Article 10(c) above.

(i) Copyright.

The Operating Agent, or each Participant for its own result, may take appropriate measures necessary to protect copyrightable material generated under this Task. Copyrights obtained shall be the property of the Operating Agent, for the benefit of the Participants provided, however, that Participants may reproduce and distribute material, but shall not publish it with a view of profit, except as otherwise provided by the Executive Committee.

(j) Authors.

Each Participant shall, without prejudice to any rights of authors under its national laws, take necessary steps to provide the co-operation from its authors required to carry out the provisions of this Article. Each Participant shall assume the responsibility to pay awards or compensation required to be paid to its employees according to the laws of the country.

12. Participants in this Task

Participants in this task have to determined.

APPENDIX 1 - PARTICIPANTS OF ECES IA

Belgium, Ministry of Economical Affairs

Canada, Public Works and Government Services Canada

CEC, EC / Research Director-General, RTD Programme "Improvement of energy efficiency"

Denmark, The Ministry of Energy

Finland, Technology Development Centre TEKES

Germany, Forschungszentrum Jülich GmbH

Italy, Ente per le Nuove Tecnologie l' Energia e l' Ambiente (ENEA)

Japan, Heat Pump & Thermal Storage Technology Center of Japan

Norway, Geological Survey of Norway

Spain, IBERDROLA, Madrid

Sweden, The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, FORMAS

Turkey, Çukurova University, Adana

United Kingdom, Department of Trade and Industry (dti)

United States of America, Department of Energy

IF Technology (The Netherlands), as a sponsor

Institute of Heat Engineering (ITC) of the University of Technology Warsaw (Poland), as a sponsor (to be approved by CERT spring 2005)

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
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>

- **Workshop, June 8-9 , Arvika, Sweden**
- **Workshop, October 11-12, Beijing, China**

Annex 12 / 13:

Final Reports and State of the Art Reports Annex 12 and Annex 13 are in preparation, will be published 2005

IEA Future Building Forum: Cooling Buildings in a Warmer Climate

The proceedings of the IEA Future Building Forum: Cooling Buildings in a Warmer Climate, June 21-22 2004, Nice, France are available from the International Energy Agency IEA in Paris (<http://www.iea.org/>).