INTERNATIONAL ENERGY AGENCY

Working Party on Energy End-Use Technologies

Annual Report 1997

Implementing Agreement on
Energy Conservation through Energy Storage

November 1998

EXECUTIVE SUMMARY

The activities of the Implementing Agreement on Energy Conservation through Energy Storage during 1997 were focused on the MEGASTOCK '97 Conference in Sapporo, Japan; the performance of ongoing annexes - Annex 8: Implementing Underground Energy Storage, Annex 9: Electrical Energy Storage for Utility Network Optimisation - and to start new annexes as well as attracting new member countries to the Implementing Agreement. The prime strategy was to start new annexes and to attract new member countries to the Implementing Agreement. This was been performed through various information activities; Conferences, Workshops and Seminars as well as encouraging people to work with ideas for new annexes.

The MEGASTOCK '97 Conference at Sapporo, Japan, in June 1997, attracted over 450 participants from 23 countries. The main topics of the Conference were:

- Borehole/Duct Systems
- Aquifer Systems
- PCM/ Ice Storage
- Water Storage

The interest in Electrical Storage was expressed in several presentations. Next Conference - TERRASTOCK2000 will be held in Stuttgart/Munich, Germany in September 2000.

Annex 8 and annex 9 have been very active during the year with workshops, expert meetings and seminars.

Annex 8: There are presently eight participating countries and another three countries have shown interest to join. The activities are at a high level with seminars, workshops and demonstration projects. New ideas and activities have resulted in new annexes, for example High Temperature Underground Storage and Design, Construction and Maintenance of Wells and Boreholes.

The preparation work for the 2nd Stockton Geothermal Conference, March 1998, has been intensive during the year. Annex 8 and the ExCo have been involved. The main themes of the Conference were: Current Technology, Innovations, Engineering Design, Environmental Issues, Financing and Marketing. A Computer Workshop and a Technical Tour followed the conference.

Annex 9: Phase 1 of the annex was completed in December 1997 and resulted in significant progress in the basic understanding of the various applications of electrical storage systems, the principal storage technologies and the quantification of both their financial and environmental benefits. Collaboration with other Implementing Agreements has been initiated by this annex. Plans are now well in hand to build on this with experts' meeting and the Conference EESAT '98, as the major event, associated with the annex, in June 1998. The Conference aims to stimulate practical interest in electrical energy storage technologies and will focus towards future development and demonstration schemes. Discussions with Japan on participation in have been undertaken during the year.

The preparation work for the Conference EESAT 98 (Electrical Energy Storage Applications & Technology), June 1998 has been in focus for and also for the ExCo during the year. The Conference will serve as a major dissemination event upon the first phase of . There will be twelve technical sessions and key-note speakers. The Conference aims to stimulate practical interest in electrical energy storage technologies and will focus towards future developments and demonstration schemes.
During the year several workshops and seminars within annex 8 and 9 work were organised. Preparatory workshops with experts have also been performed for annex 10 - 13. Three new annexes have been prepared during 1997 and these were formally started at the Executive Committee Meeting in December 1997. These new annexes are:

- Annex 10 - PCM and Chemical Reactions for Thermal Energy Storage.
- Annex 12 - High Temperature Energy Storage
- Annex 13 - Design, Construction and Maintenance of UTES Wells and Boreholes

The Governing Board approved the Executive Committee's application of a three-year extension of the IA at their September meeting.

The activities during the year have attracted new countries to participate in the Implementing Agreement and passive member countries (Finland, Denmark and CEC) have activated their membership. Japan, Bulgaria and Poland became new member countries during 1997:. In addition to that, Australia, China, France, India, South Africa, Spain and Switzerland have expressed interest to participate in the annexes and the Implementing Agreement

The Energy Conservation through Energy Storage Implementing Agreement has collaboration and contacts with several other Implementing Agreements. The committee and/or the annexes conduct this collaboration.

The Executive Committee and Annex 8 collaborate and have contacts with the following Implementing Agreements:

- Demand-Side Management,
- Heat Pumping Technologies
- Geothermal Energy Systems.

The Executive Committee and Annex 9 have collaborative contacts with the following Implementing Agreements:

- Advanced Fuel Cells
- High Temperature Conductivity
- Hydrogen
- Hydropower Technologies
- Photo-Voltaic Power Systems.

The Executive Committee and Annex 10 have collaborative contacts with the following Implementing Agreements:

- Buildings and Community Systems
- CADDET/EETIC
- Solar Heating and Cooling

IEA ECES IA - Executive Committee

Introduction
The Implementing Agreement (IA) started in 1978 and was recently extended to the year 2000. It has now (1998) 14 members: Belgium, Bulgaria, Canada, CEC, Finland, Germany, Italy, Japan, the Netherlands, Poland, Sweden, Turkey, United Kingdom, and USA. During the past year the Executive Committee has worked intensively to attract more countries to join the activities and to sign the Implementing Agreement. As a consequence Japan, Poland and Bulgaria are new members of the year and Australia, China, India, South Africa, Spain and Switzerland have expressed interest to participate in the activities of the Implementing Agreement.

The Executive Committee is working on the Strategy Plan for the period 1998 - 2000, which mainly will be an update of the present Strategy Plan (1994-1997).

According to the present Strategy Plan the objectives for the IA are:

”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 utilisation of renewable energies, in particular solar and wind and the greater utilisation 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. Recently, the following major conferences are worth mentioning.

- MEGASTOCK ’97 Conference in Sapporo, Japan 1997 on Underground Storage,
- EESAT’98 in Chester, UK (June 1998) on Electrical Storage
- 2nd International Stockton Geothermal Conference, March 1998
- Energy Storage for Meeting Power Crisis: A Futuristic Option, February 1999, Indore, India
- TERRASTOCK 2000 September 2000 in Stuttgart, Germany

During the year the Executive Committee was engaged in the planning, and performing of these conferences.

The Executive Committee had two meetings during the year. The first meeting was held in Sapporo, Japan in June and in Paris, France in December.

<u>The Sapporo Meeting, June 1997</u>
The most important items and decisions of the Sapporo meeting are outlined below. At the meeting the Executive Committee had the pleasure to welcome and unanimously approve Japan as a new member state of the Implementing Agreement.

We also concluded that the IEA EUWP and CERT endorsed an extension of the Implementing Agreement to the end of 2000. The possible extension of the Annex on Electrical Energy Storage, was suggested by the Operating Agent who would bring a full proposal to the next meeting.

The new annexes on Phase Change Materials and Chemical Reactions for Thermal Energy Storage (Annex 10), the annexes on High Temperature Underground Thermal Energy Storage (Annex 12), Design, Construction and Maintenance (Annex 13) and Low Temperature Underground Thermal Energy Storage (Annex 14) were well in preparation and the designated Operating Agents were endorsed to make the final preparation for the Executive Committee's decision at the next meeting.

A proposal for seed money on Underground Thermal Energy Storage to Developing Countries was tabled and a group was designated to investigate possible financial sources.

The Paris Meeting, December 1997

The most important discussions and decisions are outlined below.

The IEA Governing Board has confirmed the extension of the Implementing Agreement to the end of year 2000.

At the Meeting the Executive Committee had the pleasure to welcome and unanimously approve Bulgaria and Poland as new member states of the Implementing Agreement.

The European Commission has revitalised their participation, which the Executive Committee welcomed.

The Annex on Implementing Underground Thermal Energy Storage (Annex 8) and the Annex on Electrical Energy Storage for Utility Network Optimisation (Annex 9) are very active and important for the Implementing Agreement. Both the annexes were extended to 1999, Annex 9 will be operated in a 2nd phase.

Annex 10, 12 and 13 (see above, Sapporo meeting) were approved and formally started the work in December 1997.

The discussion on Underground Thermal Energy Storage (UTES) transfer to developing countries continued and action will be prepared to 1998 meetings. It will be called 'International Programme to Implementing UTES to Developing Countries and

The Executive Committee will collaborate with the IEA Future Building Forum in its activities and a contact group was designated.

IEA GENERAL INFORMATION

Framework of the International Energy Agency (IEA)

Established in 1974 with headquarters in Paris, the IEA is the energy forum for 24 industrial countries - Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, The Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Union also participates in the work.

The IEA, based in Paris, is an autonomous agency linked with the Organisation for Economic Co-operation and Development (OECD). The IEA's main decision-making body is the Governing Board, composed of senior energy officials from each Member country. Under normal circumstances, the Governing Board holds regular meetings several times a year. Meetings at Ministerial level are held every two years.

The Governing Board directs the activities and makes the major policy decisions of the IEA. It regularly reviews the world energy situation as well as domestic energy policies to assess future energy supply and demand patterns and to determine policies to meet changing energy and economic conditions.

A Secretariat, with a staff of energy experts drawn from Member Countries, supports the work of the Governing Board, the Standing Groups and Committees. The IEA Secretariat collects and analyses energy data, assesses Member countries' domestic energy policies and programmes, makes projections based on differing scenarios and prepares studies and recommendations on specialised energy topics. An Executive Director appointed by the Governing Board heads the IEA Secretariat.

The countries participate in the IEA to safeguard the members' collective energy security, and thereby reduce the economic risks, associated with energy shortages. Steps to safeguarding from economic risks has included reducing dependency on oil imports, the sharing of oil supplies in emergencies, the promotion of more stable world oil markets and the initiation of collaborative research on new and efficient energy technologies.

The future promises fundamental changes in the global energy balance. Higher economic growth rates will result in non-industrialised nations accounting for more than 60% of the world energy demand by the end of the century. The growing concern for environmental issues also having a strong influence on the nature of national and global energy priorities. IT appears that the need for international collaboration in energy strategy continuing to increase in importance.

Objectives

- To maintain and improve systems for coping with oil supply disruptions;
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations;
- To operate a permanent information system on the international oil market;

- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
- To assist in the integration of environmental and energy policies.

Shared Goals

The 24 Member countries of the International Energy Agency (IEA) seek to create the conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments.

IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants. In order to secure their objectives they therefore aim to create a policy framework consistent with the following goals:

- Diversity, efficiency and flexibility within the energy sector are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydropower, make a substantial contribution to the energy supply diversity of IEA countries as a group.
- Energy systems should have the ability to respond promptly and flexibly to energy emergencies. In some cases this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.
- The environmentally sustainable provision and use of energy is central to the achievement of these shared goals. Decision-makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should where practicable have regard to the Polluter Pays Principle.
- More environmentally acceptable energy sources need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA members wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.
- Improved energy efficiency can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by Governments and all energy users are needed to realise these opportunities.
- Continued research, development and market deployment of new and improved energy technologies make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member

countries, should be encouraged.

- Undistorted energy prices enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.
- Free and open trade and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.
- Co-operation among all energy market participants helps to improve information and understanding, and encourage the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

The IEA Ministers adopted the "Shared Goals" at their 4 June 1993 meeting in Paris.

Committee on Energy Research and Technology (CERT)

Fostering energy technology innovation is a central aspect of the IEA's work. Development of safer, more efficient technologies is imperative for energy security, environmental protection and economic growth. Equally essential is the widespread deployment of these more economical, environmentally benign technologies. But progress in energy technology research, development, demonstration and deployment implies investment. Two decades of IEA experience have shown that international collaboration on these activities avoids duplication of effort, cuts costs and speeds progress.

The IEA's Energy Technology Collaboration Programme operates under the guidance of the Agency's Committee on Energy Research and Technology (CERT) and its subsidiary bodies dealing with technologies for fossil fuels, renewable energy, efficient energy end-use and fusion power, as well as its expert groups on electric power technologies and technology assessment methodologies. The Programme enables experts from different countries to work collectively and share results, which are usually published. The Programme's objectives are

- improved energy efficiency and technology reliability;
- enhanced access to up-to-date assessments of energy technology performance;
- reduced environmental impact of energy-sector activities;
- Co-operation with non-member countries.

Practical elements of the Programme include:

- policy analysis through reviews of energy technology and R&D programmes in Member and selected non-member countries, thereby encouraging common approaches;
- sharing of practical experience and exchange of information through joint studies, conferences and workshops that monitor technological advances in key areas and enhance visibility for leading-edge techniques; and
- collaborative research projects. IEA Implementing Agreements offer the framework for these collaborative research projects.

The projects aim to:

- expand basic understanding of existing technical processes and reduce their costs;

- remove barriers to market deployment;
- foster sharing of operating experience and expand general awareness of technological capabilities.

The Implementing Agreements provide the legal mechanism for establishing participants' commitments and the project's management structure, and for ensuring distribution of benefits from the co-operative work while protecting participants' intellectual property. Activities are managed jointly by experts from IEA Member and non-member countries (representing government bodies, industry, academia and other international organisations). Resources come from participants. Benefits include not only pooled resources and shared costs, but also harmonisation of standards and hedging of technical risks. The IEA programme places emphasis on expanding co-operation with industry.

More than 30 countries are involved in Europe, America, Asia, Australia and Africa. Flexible and dynamic, the programme is expanding steadily as the advantages of international collaboration secure wider recognition. Some forty Agreements operate currently, involving a total of some US$100 million. They cover the full range of technologies used in the production, transformation, distribution and end-use of energy. Among the many areas covered by Agreements are bio-energy, solar heating and cooling, wind turbine systems, advanced fuel cells and electric vehicles. Energy technology information centres have also been set up under the programme. Concern for the protection of the environment is reflected strongly in the mandates of both long-standing and more recent Implementing Agreements.

Working Parties

The four Working Parties are the Working Party on **Energy end-Use Technologies**, the Working Party on **Fossil Fuels**, the Working Party on **Renewable Energy Technologies** and the **Fusion Power Co-ordinating Committee**. Working parties are composed of government officials from member countries who have a broad knowledge of their countries' activities in those particular areas. They help focus research and development initiatives and review the status of technology development and deployment. Working Parties identify areas of mutual interest among countries and, if warranted, initiate Implementing Agreements, which they then review and guide on a regular basis. Working Parties also exchange information on the status of national programs and on the development of technologies.

Working Party on Energy End Use Technologies

Infrastructure energy systems, buildings, industry, agriculture and food, electricity end-uses and crosscutting technologies are the current thrust areas of this Working Party. The following lists the active Implementing Agreements of the IEA which are guided by the Working Party on Energy End-Use Technologies.

Implementing Agreements

- Advanced Fuel Cells
- Alternative Motor Fuels
- Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET)
- District Heating and Cooling
- Electric Vehicle Technologies and Programs
- Energy Conservation and Emissions Reduction in Combustion

- Energy Conservation in Buildings and Community Systems
- Energy Conservation through Energy Storage
- Energy Technology Data Exchange (EITDE)
- Impacts of High-Temperature Superconductivity in the Electric Power
- Program of Energy Technology Systems Analysis (ETSAP)
- Pulp and Paper

An **Implementing Agreement**: is a framework, which facilitates the initiation, implementation monitoring and review of international collaborative efforts. Implementing Agreements can encompass any phase of the technology cycle research and development demonstration, validation of technical environmental and economic performance: market deployment or information: exchange: Member countries choose to participate in those-Implementing Agreements which best meet their needs.

Implementing Agreements are flexible and are set up to meet the requirements of those countries that wish to take part. Participants can be member country government organisations, semi-private entities (including universities) and private organisations when formally designated by the national government. Non-member countries may also join a given Implementing Agreement under a mechanism termed **Associate Participation**, provided **they obtain prior consent** from the IEA Governing Board. Private organisations not formally designated by their government, and non-intergovernmental international entities may also join the Implementing Agreement under a special designation termed **Sponsor Participation** provided they obtain prior approval from the Committee on Energy Research and Technology.

The initiative for an Implementing Agreement is usually taken by interested countries, which work with the IEA Secretariat and the Working Parties to draft a program of work. The proposed Implementing Agreement is first considered by CERT and then by the IEA Governing Board. Once approved, an **Executive Committee**, made up of one representative from each country, which joins the Agreement, develops a strategy for carrying out the research and development. If an implementing Agreement involves sizeable or varied work, it may be broken down into Annexes. Interested countries may choose to join all the Annexes, or only those which fulfil their requirements. An **Operating Agent** is elected for each Annex to act as project manager;

The IEA has no central funds to finance the Implementing Agreements, thus all resources are supplied by the participating countries. Two methods exist for financing an Implementing Agreement:

1. <u>Cost-sharing</u>: the participating countries contributing monetary resources to a common fund for equipment purchase or the operation of test facilities or information processing centres, and

2. <u>Task-sharing</u>: each participating country undertakes to devote specific resources and personnel to carry out part of a common work program.

Implementing Agreements are legal documents signed at a senior level such as the ambassador to the OECD.

IEA IA Energy Conservation Through Energy Storage Activities

Workshops

Annex 9.

- Experts' Meeting on Power Conversion, Heidelberg, Germany, 13 Feb 1997.
- Experts' Meeting on Utilities & Batteries, Chicago, 4th - 7th March 1997.
- Experts' Meeting on Superconducting Magnetic Energy Storage Systems, Gelsenkirchen, Germany, 20th-21st March 1997.
- Modelling Requirements Experts' Meeting, Chester UK, 10th -11th June 1997
- Modelling Requirements Experts' Meeting, Arnhem, The Netherlands, 29th September 1997.

Annex 10. Proceedings from PCM and Chemical Reaction for Thermal Energy Storage, Kick-off Workshop. September 1997, Stockholm, Sweden.

Annex 12. Workshop on High Temperature Thermal Energy Storage in Aquifers and Duct Stores. *BEO-office in Berlin, 28-29 April 1997.*

IEA Annex 13. Preparatory Workshop. Design, construction and maintenance of UTES wells and boreholes, 2 Dec 1997, Paris.

Ongoing Annexes

Annex 8. Implementing Underground Thermal Energy Storage

Operating Agent: B. Nordell, Luleå University of Technology, Sweden.

1. Introduction
The general objective of Annex 8 is to conserve energy and improve the environment by speeding the introduction of Underground Thermal Energy Storage Systems (UTESS) into the building, industrial, agricultural and aqua-culture sectors. Originally Annex 8 was planned for five years (from May 1994). Later we had to change the time plan to follow the time plan of ECES IA. When the IA was extended also Annex 8 goes back to its original time schedule. At the start the annex had four participants Canada, Germany, Netherlands and Sweden. Later on Belgium, Turkey, USA and Japan joined the collaboration. Several more countries have shown their interest (Australia, Poland, and Finland) by attending the experts meetings as observers.

The seventh experts meeting (XM7) was held during the year in Sapporo, Japan, 13-14 June 1997. Eighteen experts from the eight participating countries + Poland, Australia attended the meeting. This meeting was held in conjunction with Megastock´97

The next Experts' Meeting (XM8) will take place at the Richard Stockton College of New Jersey, Pomona, NJ, USA. The XM8 will be held in connection to the second International Stockton Geothermal Conference. A computer workshop will be organised. Annex 8 experts will contribute by presenting papers at the conference and to the computer workshop by teaching on the use of different UTES simulation models and tools.

As a result of Annex 8 discussions on necessary UTES R&D new Annexes have been suggested. Experts of the group have made the preparatory work for the new annex proposals:

- Annex 12, High Temperature UTES (HT UTES)
- Annex 13, Design, Construction and Maintenance of UTES Wells and Boreholes
- Annex 14, Low Temperature UTES (LT UTES)

2. Present situation in participating countries.
Belgium: Rapid development of ATES systems. Continues with the Potential Study to include DTES also. Canada: Slow UTES development. Germany: Many UTES projects planned, both ATES and DTES. Work plan: The IEA Demo UTES Projects will be completed. Japan: Interesting development. The Heat Pump and Thermal Storage Centre of Japan (HPTSCJ) sent a survey delegation of 10 persons to Europe at the end of October. Some of facilities they visited were related to UTES. Most UTES interest in snow melting applications. Netherlands: Growing market for cold storage. About 40 ATES plants today and 500 ATES plants estimated by 2020. Average capacity 800 kW cooling. For smaller systems - DTES. Has distributed the final report (Phase II) "Applications and cost-effectiveness of energy storage in the Netherlands". Poland: Experience of deep geothermal energy Some UTES experience. Sweden: Increasing interest in UTES cooling applications in connection with District Cooling. Large number of BTES for direct cooling of telephone switching stations.

Study on a solar heated high temperature DTES in Rock for LT Heating of 100 Single-family Houses (Pre-Study). New DTES drilling equipment developed - enables much deeper DTES. Turkey: Increasing UTES interest as a result of seminars, radio and TV programs, papers etc. General awareness of UTES is low but green-house producers and architects have expressed interest. The Turkish Potential study is now in a draft version for review by the experts. Work plan till the end of 1999. USA: GHPC implementation. Training centres for engineers and architects. Mobile training equipment. Totally installed 1.6 GW geothermal cooling power > 1000 commercial projects. Plans to start up a project on Technology Transfer to Developing Countries. Introduction of electronic journal. Continues on implementation of non-HP cold storage project in US.

Annex 8 Work plan

The Annex 8 Work plan for the time period - January 1998 to May 1999 - has been discussed among the experts. There are only three more Experts’Meeting “planned”- March 98 (USA) - Autumn Meeting 1998 and Spring Meeting 1999 and the remaining work must be completed within this period.

Annex 8 Work Plan - January 1998 to May 1999.

Activities	Aus	Bel	Can	Ger	Jap	Neth	Swe	Tur	USA
UTES Potential studies	←→	←→						←→	
UTES Demonstration									
• State of Art						←→			←→
• Spec. Demo Plants				←→					
• New Demo Plants					←→			←→	
Environmental Screening			←→						
Model evaluation							←→		
Tech. Development									
• TED Applications and			←→				←→		
• Borehole HEX improvement							←→		
• Engineering Models							←→		
• Industrial Cooling		←→							
• Non-HP Heat Storage and Cold							←→		←→
• LT UTES (field test)							←→		
Implementation/Marketing									
• Electronic Journal									←→
• HP Newsletter (Summer 98 Issue)		←→	←→	←→	←→	←→	←→	←→	←→
• Impl. UTES in Developing		←→					←→	←→	←→
• General Marketing Efforts (not			←→		←→				
• 2nd Int. Stockton Geothermal		←→	←→	←→	←→	←→	←→	←→	←→
Workshops/Seminars							←→	←→	←→
• UTES Information Folder				←→			←→		
• Attracting New Participants							←→		

More participants are expected to contribute in some of the activities.

Annex 9. Electrical Energy Storage Technologies for Utility Network Optimization.
Operating Agent: J.N.Baker, EA Technology, United Kingdom

1. Introduction
The impetus for a major new initiative in the area of electrical energy storage followed from discussions at the IEA Energy Storage Strategy workshop, held Montreal, Canada, January 1995. The initiative was worked up into a draft Annex proposal, over the following 12 months, and presented as such to the 39th Executive Committee meeting, held Utrecht, the Netherlands, January 1996. The decision was made at this meeting for EA Technology, as Operating Agent (designate) to organise and deliver a workshop on the subject, April 1996, at Chester, in the United Kingdom. The success of this workshop led directly to the formal presentation of the Annex proposal at the 40th ExecCo. Meeting , held Halifax, Canada, June 1996, and to the initiation of the new Annex.

2. Work Programme and Time-scales
Five countries voted to participate in Annex IX from the outset, namely the UK, US, Canada, Germany and the Netherlands. The Annex became effective July 1996, with an 18 month work programme, through to December 1997. The principal outputs from the Annex from this time period are as follows:-

- a comprehensive state of the art review of electrical energy storage technologies worldwide, including comprehensive information from the various participating countries
- a comprehensive and updated directory of storage systems developers, manufacturers and suppliers
- a critical examination of utility requirements for electrical energy storage systems
- a techno-economic cost/benefit model, to enable authoritative assessments of different storage/applications matches to be performed
- an energy/emissions model, to enable the energy/emissions benefits of different storage systems/ applications matches to be assessed
- a major international workshop on the subject

3. Progress to December 1996
The main achievements in the year ending 31st December 1996 may be summarised as follows:
- the inauguration of national team networks within the United Kingdom, Germany and the Netherlands, together with direct contact with the designated national participating agents in the US and Canada
- the establishment of the communications and administrative procedures, to service the above
- the organization and delivery of the first series of experts' meetings, covering flywheel energy storage systems, fuel cell/electrolyser systems and utility requirements
- the collation of initial data sets, in relation to the above
- the preparation and issue of an initial series of technical questionnaires, relating to different storage systems and applications

- the publication of the first draft technical report, for the Annex participants
- the initiation of the planning for EESAT '98 (electrical energy storage systems, applications and technologies), as the major dissemination workshop, for June 1998

4. Future Plans

Planned activities for 1997 include the delivery of the remaining experts' meetings addressing power electronics and power conversion, utilities requirements (II) and super-conducting magnetic energy storage systems. The work will then proceed towards the development of quantitative models, addressing the cost/benefit ratios of different storage systems and also their energy/emissions savings benefits. It is anticipated that initial plans for collaborative hardware demonstration schemes, will evolve from this modelling work, possibly suitable for consideration under a future Annex. It is also intended to invite other countries to participate in the Annex, with a view to extending its lifetime, beyond December 1997.

The planning for EESAT '98 will also develop during the year, preparatory to its delivery in June 1998.

Annex 10. Phase Change Materials and Chemical Reactions for Thermal Energy Storage.

Operating Agent: F. Setterwall, Royal Institute of Technology, Stockholm, Sweden.

1. Introduction

The new annex on "Phase Change Materials and Chemical Reactions for Thermal Energy Storage" was approved at XC43, December 1997. The Department of Chemical Engineering and Technology at the Royal Institute of Technology in Stockholm should act as Operating Agent for this Annex 10. Participants in this annex are Bulgaria, Canada, China, Finland, Germany, Japan, Poland, Sweden, Switzerland, Turkey och United Kingdom. Further members could be USA and Australia.

The first workshop of the Annex will be held in Adana, Turkey on the 16th and 17th of April 1997. We believe that the workshop should attract interest from manufacturers of thermal energy storages, manufacturers of compounds (as paraffines and salts), manufacturers of heat pumps/chillers, energy companies and different kinds of users.

2. Objectives

The objectives are in general to solve technical and market problems for a better market opportunity for thermal energy storage systems utilizing PCM or chemical reactions and to broaden the knowledgebase and disseminate information. The field of application for the technology will be in the building, the agricultural and industrial sector.

The scope of the work undertaken in this annex include thermal energy storage by solid-solid, solid-liquid, liquid -vapor and solid-vapor phase transfer, for instance melting/solidification, crystallization/solubilization, vaporization/liquifaction and solid sorption processes as well as by chemical reactions.

Research will be carried out to find solutions to the difficulties in using PCM or chemical reactions for thermal energy storage. These difficulties includes:

to find a suitable material for the required temperature range

mass and heat transfer limitations

reversibility of the phase change

system integration

Annex 12. High Temperature Underground Thermal Energy Storage.

Operating Agent; Burkhard Sanner, Giessen University, Germany

1. Introduction

The new annex on " High Temperature Underground Thermal Energy Storage (HT UTES)" Phase 1, was approved at XC43, December 1997.

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-systems concerned shall be confined to Aquifer Storage (ATES) and Duct/Borehole Storage (DTES).

High Temperature in this annex refers to minimum storage loading temperatures on the order of 50 °C. Storage may be from short term (diurnal) to long term (seasonal), whereas "seasonal" requires the store to yield energy recovery at least three month after end of the loading period.

2. Workplan

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

<u>Phase I</u> (1.1.1998 - 31.12.1998)

State-of-the-art-review, system opportunities (from energy system side)

<u>Phase II</u> (1.1.1999 - 31.12.2000)

Long-term perspective and scenarios, environmental impact/benefits, development of design tools, improvement in water treatment, choice of material suited for high temperatures, and development of test equipment, HT demo projects, design guidelines.

The results shall be:

<u>Phase I:</u>

Evaluation and summary report of previous activities (state-of-the-art-report) and a report on R&D needs and opportunities and recommendations for Phase II

<u>Phase II:</u>

Ecobalance, annual reports, workshops, test equipment, design guide-lines / tools

Participating Countries are Belgium, Canada, Germany, Netherlands, Sweden, Turkey (not all yet confirmed); Operating Agent is Germany.

The work started in January 1998, a first Expert's Meeting was held in Giessen, Germany, on June 17, 1998; a workshop and the second expert's meeting is scheduled for October 14-16, 1998, in Lund, Sweden. Report to XC45 in USA, December 1998

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

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

1. Introduction

Most UTES concepts incorporate drilling one way another. Drilling activities or evaluation of older drillings are of fundamental importance already during the planing stage. The knowledge and understanding of drilling technology and parameters obtained from drilling will then increase during the stages of design, construction and operation.

There is a number of potential failures that might occur if not a proper well or borehole design is put into practice. These could be related to poor documentation of geological and hydrogeological properties during the site investigation stage that will lead to a poor design. They might also be connected to hydrochemical or biochemical processes like scaling, corrosion and incrustation and in that case create severe operational problems.

Also environmental and legal issues could be seriously misjudged unless accurate geodata and operational features are being used. These items are normally studied by model simulations and, as well known, the assurance of simulations are strongly connected to the quality of data being used.

All together, avoidance of designing mistakes and failures of any kind related to wells and boreholes, will improve and strengthen the future usage of the UTES technology.

Based on the background described above the main goal with annex 13 will be to make UTES technically safer and more cost effective

2. Objectives

The objectives are to:

- describe national procedures for UTES drilling and to exchange experiences of different technologies
- identify well or borehole related problems in order to establish areas for further research and development
- work out guidelines connected to test drilling, well or borehole design and construction
- investigate the occurrences and arts of operational failures related to the well or borehole system and to work out preventive guidelines for monitoring, maintenance and rehabilitation measures.

A Preparatory Annex 13 Workshop was held in Paris, shortly before the Executive Committee Meeting (XC43) at which this annex was approved in December 1997.

Proposed Annex

Annex 14. Low Temperature Underground Thermal Energy Storage

- A proposal for future work

1. Background and Scope

Improvements in the efficiency of energy usage (energy conservation) is good for the global environment and economies in both developed and developing countries. Moreover, Underground Thermal Energy Storage (UTES) systems, which provide for the matching of energy supply and demand, have been shown to contribute significantly to improving energy efficiency when compared to conventional energy systems. UTES systems can also increase the potential of utilizing renewable energy sources such as ambient cold air or waste heat. In addition to direct cooling in a non-CFC world, UTES can also be used to reduce the demand for (expensive) electricity, including the most expensive electrical energy which is generated during periods of peak power demand.

UTES on low temperature level for cooling and/or heating is a standard design option in some countries like Sweden and The Netherlands. The number of these applications are increasing especially in countries in the Northern hemisphere,where there is a cold climate. However, little attention has been paid to the possible Low Temperature(LT)-UTES applications in warm climate areas. In warm climate, active storage of natural winter cold from rivers, seas, lake etc., has a large potential. During the short but cold periods occurring, also cold air (in the range -10-+10^{o}C) may be used as a cold source. Another area that has been neglected is LT-UTES applications at temperatures at/or below the freezing point of water in cold climate areas. Interesting applications in addition to"free cooling"in cold climates, like using snow deposits as cold source can be envisioned. Temperature levels for LT-UTES can be different for cold and warm climates. Therefore, given the larger global potential, both economically and environmentally, concerted international effort should be given to researching, developing and demonstrating (RD&D) efficient and environmentally benign cooling technologies such as LT-UTES.

2. Objectives

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

The Specific Objectives of Annex 14 are:

- To define, for the purpose of this Annex, Low Temperature UTES
- To conduct a general review and potential study of existing and emerging Low Temperature UTES technologies

- To develop computer models for optimising Low Temperature UTES
- To identify obstacles that need to be overcome to make Low Temperature UTES more economically viable
- To demonstrate the practical viability of Low Temperature UTES in a variety of system applications in different countries.
- To develop procedures for dissemination

3. Means

Countries participating in the IEA R&D Program perceive collective benefits from sharing R&D results from national programs and from collaborative international R&D. Therefore, the means employed to achieve Annex 14 objectives will be collaborative efforts based upon co-operation and task sharing arrangements with lead countries for each sub-task.

4. Activities

- Sub-task 1. Preparation of a definition for Low Temperature-UTES
- Sub-task 2. Conduct a general review of existing and emerging Low Temperature - UTES Requirements and Applications
- Sub-task 3. Evaluation of Feasible LT-UTES Boundary Conditions
- Sub-task 4. LT-UTES Design and Analysis Tools
- Sub-task 5. Identification and Characterisation of Technical Obstacles that could Impede the Implementation of LT -UTES
- Sub-task 6. Practical Demonstrations of Viable LT-UTES in Representative Applications
- Sub-task 7. Technology Transfer

APPENDICES

APPENDIX 1: LIST OF ANNEXES

Annex No.	Annex Name
	Closed Annexes
1	Large Scale Thermal Storage Systems Evaluation
2	Lake Storage Demonstration Plant in Mannheim
3	Aquifer Storage Demonstration Plant in Lausanne-Dorigny
4	Short-term Water Heat Storage Systems
5	Full-scale Latent Heat Storage Installations
6	Environmental and Chemical aspects of Thermal Energy Storage in Aquifers and Research and Development of Water Treatment Methods
7	Innovative and Cost-effective Seasonal Cold Storage Applications
	Ongoing Annexes
8	Implementing Underground Energy Storage Systems
9	Electrical Energy Storage Technologies for Utility Network Optimisation
10	Phase Change Materials and Chemical Reactions for Thermal Energy Storage
12	High Temperature UTES
13	Design, Construction and Maintenance of UTES Wells and Boreholes
	Planned Annex
14	Low Temperature UTES

Annex 1. Large Scale Thermal Storage Systems Evaluation
Annex 1 was a technical and economic evaluation of various storage concepts presented by the participating countries. The results of this work formed the basis for subsequent Annexes. The final report was published in October 1981.The Annex was formally closed at the Executive Committee Meeting in April 1983. Participating countries: Switzerland (OpA), Belgium, CEC, Denmark, Germany, Sweden, USA.

Annex 2. Lake Storage Demonstration Plant in Mannheim
Annex 2 had the objective of developing a seasonal lake storage and to demonstrate the feasibility by the construction of a large-scale pilot plant in Mannheim, Germany. Construction of the plant was cancelled after failing to achieve an economic design.

Annex 3. Aquifer Storage Demonstration Plant in Lausanne-Dorigny
Annex 3 involved the design, construction and operation of a high-temperature aquifer storage in Lausanne-Dorigny. The storage consisted of a vertical well with horizontal drains. The project was commonly called SPEOS. Waste heat from a municipal facility was stored in summer and used for space heating and domestic hot water of a gymnasium. Collaboration involved seven countries and terminated in 1989. Participating countries: Switzerland (OpA), Denmark, USA, Sweden.

Annex 4. Short-term Water Heat Storage Systems
Annex 4 reviewed the theory, techniques and application of hot water storage systems and produced a state-of-the-art report. It focused on various measures to maintain thermal stratification. The Annex was closed in 1988. Participating countries: The Netherlands (OpA), Germany, Sweden, USA

Annex 5. Full-scale Latent Heat Storage Installations
Annex 5 involved the installation and monitoring of latent energy storage installations with the objective of evaluating their technical and economic feasibility. The Executive Committee recommended reviewing the state-of-the-art of latent heat stores and a

workshop was held in 1984 sponsored by the German Ministry for Research and Technology. As a result of the workshop recommendation to concentrate on monitoring pilot and demonstration plants to provide reliable performance data, an Annex on Full Scale Latent Heat Storage Installations was initiated in 1988. Germany has provided the Operating Agent. The Annex was terminated in 1992. Participating countries: Germany (Op. A), Sweden, USA.

Annex 6. Environmental and Chemical aspects of Thermal Energy Storage in *Aquifers and Research and Development of Water Treatment Methods*
Annex 6 dealt with the chemical and environmental aspects of thermal energy storage in aquifers. A major potential problem of aquifer energy storage is the scaling an clogging of wells and heat exchangers. To avoid these problems reliable and ecologically sound methods of water treatment are required. The development and testing of the chemical, micro-biological and environmental effects of ground-water treatment methods were the objectives of Annex 6. The work was initiated in 1987 and extended through twelve experts meetings into 1993. The Netherlands provided the Operating Agent and nine countries participated. The Annex was formally closed by the Executive Committee in 1996. Participating countries: The Netherlands (Op. A), Canada, Denmark, Finland, Germany, Sweden, Switzerland, USA.

Annex 7. Innovative and Cost-effective Seasonal Cold Storage Applications
Annex 7 aimed to demonstrate innovative, energy efficient and cost-effective cold storage design for a variety of building types and industrial applications to encourage the adoption of cold storage as a standard design option. More specifically, it evaluated effective storage control and operating strategies; evaluated combined hot and cold storage for increased energy efficiency and cost- effectiveness; and conducted national market studies for the developed technologies. A planning workshop in Sweden initiated the work in January 1989 and the activities extended through eight experts meeting into 1993. The Annex was formally closed by the Executive Committee in 1996. Participating countries: Canada (Op. A), Germany, Netherlands, Sweden.

<u>ONGOING ANNEXES, Annex 8 - Annex 13</u>

Annex 8. Implementing Underground Thermal Energy Storage Systems
Annex 8 aims to speed the introduction of Underground Thermal Energy Storage in the building, industrial and agricultural sectors. It will encourage the adoption of energy storage in standard project designs by developing procedures and tools based upon documented applications in different energy efficient systems. Screening and decision tools will be provided to ensure ecologically sensitive applications. The first experts' meeting was held May 1994 in Sweden. Participating countries: Sweden (Op. A), Belgium, Canada, Germany, Netherlands, Turkey, USA, Japan.

Annex 9. Electrical Energy Storage Technologies for Utility Network Optimisation
Annex 9 will examine the potential role of electrical storage technologies in optimising electricity supply and utilisation. It will identify and overcome barriers to widespread adoption of electrical energy storage technologies through successful demonstration projects. Annex 9 was proposed by EA Technology Limited of the UK as a result of

the recommendations of the Energy Storage Strategy Workshop held in Montreal during January 1995. The annex started in June 1996. Participating countries: Canada, Germany, Netherlands, Sweden, UK (OpA), and USA.

Annex 10. PCM and Chemical Reactions for Thermal Energy Storage.
Annex 10 will examine the role and accelerate the introduction of phase change materials into energy systems in residential, commercial, industrial and agricultural sectors. It has been proposed by the Concordia University, Centre of Building Studies in Montreal as a result of the recommendations of the Energy Storage Strategy Workshop held in Montreal during January 1995. The Annex was approved by XC43 on December 1997. Participating countries: Bulgaria, Canada, Finland, Germany, Japan, Poland, Sweden (OpA) and Turkey. China is preparing its participation and Australia, France, India, Italy, the Netherlands, United Kingdom, and USA have shown interest in participation.

Annex 12. High Temperature UTES
Germany initially suggested Annex 12. Phase 1 of the annex was approved by XC43. This stage starts with a State-of-the-art review of HT UTES applications. It will be followed by at study in which the most promising applications and system concepts for HT-UTES are evaluated. The results will allow assessing the expected benefit of HT-UTES and justify a decision on phase II. Participating countries are not yet clear but Canada, Germany (OpA), Belgium, Sweden and the Netherlands have shown interest in the annex.

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 XC43, December 1997. The objectives are to: Describe UTES drilling and exchange experiences of different technologies. Identify related problems in order to establish areas for further R&D. Work out guidelines connected to test drilling, well design and construction. Investigate the occurrences and arts of operational failures related to the well or borehole system and to work out preventive guidelines for monitoring, maintenance and rehabilitation measures. The following countries have shown interest in participation: Australia, Belgium, Canada, Germany, Italy, the Netherlands, Sweden, Switzerland, Turkey, and the U.S.

PROPOSED ANNEX

Annex 14. Low Temperature UTES
Canada initially suggested annex 14. The annex text was discussed at the XC Meetings in Sapporo and Paris. As a result a wider scope was suggested. The Annex will now include LT UTES in different climates i.e. what is LT in a warm region would not be considered LT in a colder region. Canada and Turkey continue the preparation of this annex.

APPENDIX 2: PARTICIPANTS OF ECES IA (DEC. 1997)

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 Centre of Finland
Germany	Forschungszentrum Jülich GmbH
Italy	ENEA , Governmental Energy Research Agency
Japan	The Heat Pump and Thermal Storage Centre of Japan
Sweden	The Swedish Council for Building Research
The Netherlands	NOVEM, The Netherlands Agency for Energy and the Environment
Turkey	Çukurova University
UK	EA Technology
USA	US Department of Energy

APPENDIX 3: LIST OF PUBLICATIONS

Annex 8

- Application and Cost-Effectiveness of Energy Storage in Aquifers in the Netherlands. Subtask A2, Annex 8. Draft. NOVEM and IF Technology bv. Arnhem, The Netherlands. Dec. 1995. Submitted to ExCo January 1996.
- Underground Thermal Energy Storage. State of the art 1994.IF Technology bv. PO Box 605.
- NL-6800 AP Arnhem, The Netherlands. Jan. 1995.
- Underground Thermal Energy Storage. Applications in Industry and Economy.
- Seminar November 16, 1995, Çukurova University, Adana, Turkey.
- Underground Thermal Energy Storage. Applications in Industry and Economy.
- Seminar June 13, 1996, Environment Canada, Halifax NS, Canada
- Aquifer Thermal Energy Storage. Applications in Industry and Economy.
- Seminar November 13, 1997, Leuven, Belgium

List of computer models

Annex 9

Draft Proposal. Electric Energy Storage Technologies for Utility Network Optimisation. June 1995. EA Technology, Capenhurst, Chester, UK.

Proceedings from the Chester Workshop, April 1996.

Baker John. Recommended Procedures for the Organisation of Annex Workshops. EA Technology Limited, 1996.

Annex 10

Setterwall, F.; Alexandersson, K.: Phase Change Materials and Chemical Reactions for Thermal Energy Storage. Dep. of Chemical Engineering and Technology, Royal Institute of Technology, Stockholm Sweden TRITA-KET R54, ISSN 1104-3466, ISRN KTH/KET/R-54-SE

Annex 10. Proceedings from PCM and Chemical Reaction for Thermal Energy Storage, Kick-off Workshop. September 1997, Stockholm, Sweden.

Annex 12

Bouma, J., Faninger, G., Knoblich, K., Reuss, M. & Sanner, B. (1997): Zusammenfassung der Berichte und Diskussionen des 3. Symposiums Erdgekoppelte Wärmepumpen. - Ber. Symp. Erdgek. Wärmepumpen 1997, Ber. IZW 2/97, S. 1-6, Karlsruhe

Andersson, O., Mirza, C. & Sanner, B. (1997): Relevance of geology, hydrogeology and geotechnique for UTES. - Proc. MEGASTOCK 97, S. 241-246, Sapporo

Hellström, G., Sanner, B., Klugescheid, M., Gonka, T. & Mårtensson, S. (1997): Experiences with the borehole heat exchanger software EED. - Proc. MEGASTOCK 97, S. 247-252, Sapporo

Katzenbach, R., Knoblich, K., Mands, E., Rückert, A. & Sanner, B. (1997): Energiepfähle - Verbindung von Geotechnik und Geothermie. - Ber. Symp. Erdgek. Wärmepumpen 1997, Ber. IZW 2/97, S. 91-98, Karlsruhe

Sanner, B. (1997): Neue Trends und Technologien bei Unterirdischer Thermischer Energiespeicherung (UTES). - Geothermische Energie 19-20/97, S. 32-37, Neubrandenburg

Sanner, B. (1997): New Trends and Technology for UTES. - Proc. MEGASTOCK 97, S. 677-684, Sapporo

Sanner, B. (1997): Oberflächennahe Geothermie, dezentrale Nutzung der Erdwärme im Wohn-, Gewerbe- und Industriebau. - Tagungsband Praktische Anwendungen der Geothermie im Wohn- und Gewerbebau, Ökozentrum Hamm, S. 21-46, GtV, Neubrandenburg

Sanner, B. (1997): Internationale Konferenz zur thermischen Energiespeicherung, MEGASTOCK 1997, Sapporo, Japan. - Geothermische Energie 19-20/97, S. 54-56, Neubrandenburg

Sanner, B., Hahne, E. & Konstantinidou, E. (1997): VDI-Richtlinie 4640 "Thermische Nutzung des Untergrundes". - - Ber. 3. Symp. Erdgek. Wärmepumpen 1997, Ber. IZW 2/97, S. 7-12, Karlsruhe

Sanner, B. & Hellström, G. (1997): Neue Entwicklungen und Erfahrungen mit EED. - Ber. Symp. Erdgek. Wärmepumpen 1997, Ber. IZW 2/97, S. 211, Karlsruhe

Sanner, B. & Rybach, L. (1997): Oberflächennahe Geothermie - Nutzung einer allgegenwärtigen Ressource. - Geowissenschaften 15/7, Juli 1997, S. 225-231, Berlin

Sanner, B., Rybach, L. & Eugster, W.J. (1997): Erdwärmesonden Burgdorf - ein Programm und viele Mißverständnisse. - Geothermie CH 1/97, S. 4-6, Zürich

Sanner, B. & Stiles, L. (1997): Status of seasonal cold storage in ground source heat pumps. - Proc. MEGASTOCK 97, S. 13-18, Sapporo

Sanner, B., Stiles, L. & Hellström, G. (1997): Världens största marklager för värme och kyla. - ByggForskning 3/97, S. 32-33, Stockholm

Sanner, B., Stiles, L. & Hellström, G. (1997): The world's largest underground storage facility for heat and cold. - Swedish Building Research 3/97, S. 10-11, Stockholm