INTERNATIONAL ENERGY AGENCY

Working Party on Energy End-Use Technologies

Strategy Plan

(1999 - 2003)

Implementing Agreement

Energy Conservation Through Energy Storage

Executive Committee

March 1999

Preface

This strategic plan of the Executive Committee outlines the scope and goals of the IEA-Energy Storage Programme for the next 5 years (1999-2003). The paper has been compiled after intensive discussions at two workshops arranged in conjunction with the regular Executive Committee Meetings in 1998. The final document was approved by the Executive Committee in Spring 1999.

The strategy plan will serve as the basic working document to guide the future work of the Executive Committee and will also provide a comprehensive summary for other Committees of the IEA and for the IEA-secretariat. More detailed information on the Storage Programme, especially for a public audience is published in Conference Proceedings /1/, annual reports and Annex status reports of the Executive Committee, Annex brochures and on the Internet-Website of the IEA-Energy Storage Programme /2/.

Structure

1. Introduction

Energy storage technologies are a strategic and necessary component for the efficient utilization of renewable energy sources and energy conservation. There is a great technical potential to substitute for burning fossil fuels by using stored heat that would otherwise be wasted and by using renewable generation resources. These energy sources can be used more effectively through the addition of short and long term energy storage. Thermal and electrical energy storage systems enable greater and more efficient use of these fluctuating energy sources by matching the energy supply with demand. Thermal energy storage can also be used for cooling to reduce or eliminate the demand for electricity, including the most expensive electrical energy that is generated during periods of peak power demand.

The Implementing Agreement on Energy Conservation through Energy Storage was established in 1978 with the objective to facilitate international cooperation on research, development and demonstration (RD&D) of new, innovative energy storage technologies. Energy storage technologies are relevant in many IEAImplementing Agreements, especially in the building and transport sectors related to the Working Parties Renewable Energies and End Use Energy. Cooperation with these IEA Executive Committees is becoming more and more important in order to achieve the system integration and implementation of storage technologies.

2. Motivation

In 1973, after the first oil crisis, highest priority was given to improving the **energy security** of highly industrialized countries. At that time, many countries were completely dependent on imported oil. Today the situation has changed. The dependence on imported oil continues, but the rate of growth of petroleum products is slowing, and cheap fossil fuels are currently available. However, the further unlimited use of fossil fuels is causing a steady increase of energy-related CO_2-emissions into the earth`s atmosphere. This may lead to changes in the world climate in the medium and long term. Additionally, the use of conventional mechanical cooling utilizing ozone depleting substances (ODS), such as CFC and HCFC refrigerants, is also a major concern.

In December 1997, the Parties to the UN Framework **Convention on Climate Change** agreed to the terms of the **Kyoto Protocol**. This historic agreement sets legally-binding greenhouse gas emission objectives over the period 2008-2012 for industrialized countries. The energy sector, from supply to end use, is responsible for the majority of greenhouse gas emissions in the developed world, through the combustion of fossil fuels and the emissions of CO_2, N_2O and CH_4, three of the six gases covered by the Protocol.

Many governments have committed to reduce CO_2 emissions into the atmosphere. They have decided to strengthen their national efforts to increase the deployment of energy conservation technologies and utilization of renewable energy sources. So far in most industrialized countries, renewable energy sources contribute only marginally to satisfy energy demand. This is due to several reasons, in particular because new energy systems are not yet economically competitive with the combustion of fossil fuels, long term reliability is not yet proven, and there are still some regulatory and market barriers which have to be overcome. Therefore, further attempts have to be made to resolve these issues. This is especially true for many new energy storage technologies and concepts that have not yet been implemented on a large scale in the market.

The Executive Committee on Energy Storage has the following mission and vision for the Programme:

3. Mission

To research, develop, implement, and integrate energy storage technologies to optimize energy utilization by improving overall energy efficiency and economic growth while benefiting the local and global environments.

4. Vision

Energy storage technologies are able to contribute significantly to energy efficiency, the global environment, and economic growth. Therefore it is envisioned that over the next decade the IEAProgramme on Energy Storage will continually broaden the scope of its activities by undertaking research and technology development, technology transfer activities and the prototyping and deployment of near-market ready and market ready technologies. Moreover, the effective matching of energy supply with energy demand through systems integration will be emphasized, as will the expansion of collaborative actions with all interested countries and other Implementing Agreements.

5. Objectives and Strategies of the Programme

The Energy Storage Programme is technology, environment and market oriented. The main objectives are:

TECHNOLOGY: Advance the development of thermal energy storage technologies utilizing waste, renewable or ambient energy sources to supply space heating, space cooling and process cooling to achieve significantly improved energy efficiency and cost-effectiveness. Research and develop electrical energy storage technologies and systems that integrate batteries, flywheels, and other storage media with power electronics and controls to enhance energy security and facilitate increased use of renewable energy sources. We will provide a forum to facilitate the international exchange of information and experience on energy storage research, development, project applications, field trials and products. We will advocate that adequate design information on innovative energy storage technologies is made available to interested groups in industry, government, and academia.

ENVIRONMENT: Evaluate and document the many environmental benefits of energy storage and ensure that potential environmental problems are directly addressed and avoided by sound technical analysis and design techniques. We will involve national and regional environmental agencies in our work to ensure that energy storage meets the present and future requirements of these agencies. We will raise the level of awareness and understanding of energy storage technologies, especially their environmental benefits, and advocate that impartial technical information is made available to all stakeholders involved in the implementation of energy storage.

MARKET: Encourage the required steps be taken to achieve the proper application of proven energy storage technologies world-wide in the commercial, industrial and agricultural sectors. We will focus our communications efforts on the world market players including design engineers, architects, building owners, developers, governments, regulatory agencies, electric utilities, and community leaders. We will encourage the use of renewable energy sources to

cool non-residential buildings in a post-CFC world; develop methods to integrate energy storage technologies into community-based systems; and develop effective residential cold storage techniques that avoid the use of conventional chillers in moderate climates. Heating and cooling applications are part of the market, but economic and technical limitations indicate that cooling is the first priority, followed by combined cooling and heating, and lastly heating. We will develop and encourage deployment of electrical storage with renewable generation technologies where market conditions favor off-grid implementation (many developing countries and remote locations world-wide). Short-term electrical storage will be investigated to improve power quality and reliability in all types of commercial endeavors. Longer duration electrical storage will be considered for peak shaving, system stability, and improved asset utilization in utility networks.

In general, we will establish and strengthen new and existing internal and external international networks that may result in increased implementation world-wide of many energy storage technologies.

6. Market Opportunities and Barriers to Deployment

As with many other renewable energy and energy saving technologies, energy storage technologies offer great market potential in the long term, but the present implementation is impeded by significant barriers.

The most important factors have been identified by the Executive Committee:

Market Opportunities

- Great energy saving and fossil fuel substitution potential.
- Opportunity to assist in meeting CO_2 emissions targets.
- Market deployment will create new jobs.
- Enhanced energy security through the use of storage technologies.

Threats and Challenges

- Energy storage technologies are not always cost-effective based on energy savings.
- High initial costs.
- Availability of cheap fossil fuels.
- National regulations of groundwater protection often impede the implementation of aquifer thermal energy storage.
- Perceived high technical and financial risks for the owner.
- Lack of knowledge and the need for education.

Strengths and Weaknesses

The most important factors are:

Strengths

- Direct and immediate technology transfer between the participating countries.
- Increased research capacity by combining research efforts.
- International network of experts.

Weaknesses

- Lack of sufficient funding for RD&D of thermal and electrical energy storage systems.
- Early demonstration plants had overly optimistic expectations and were not highly reliable.
- Cooperation is mainly research-oriented, there has been poor or insufficient involvement of industry.

7. Collaboration with other Executive Committees

Closer cooperation among the relevant Executive Committees is essential, especially for the Storage Programme. Storage technologies have to be integrated with the total system and have to meet the specific technical and economic requirements of the application. Integrated system concepts that include storage technologies have to be developed to achieve an optimal cost-effectiveness and energy saving potential. Therefore the Executive Committee will intensify the cooperation with other Executive Committees in the future. One way this will be done is by joint workshops to identify new cooperative joint activities. Close collaborations will be established in the Residential and Commercial Sectors especially with the following Programmes:

- Solar Heating and Cooling
- Energy Conservation in Buildings and Community Systems
- Heat Pumping Technologies
- District Heating and Cooling
- Demand Side Management (DSM)
- Photovoltaic Power Systems
- Superconductivity

8. Achievements of the Programme

So far, great progress has been made by the Programme to achieve its objectives. The main results are:

- A reliable data and information base on various energy storage technologies and concepts has been established by international reviews of the state of the art, assessment and market studies, and construction and monitoring of pilot and demonstration plants.
- The technical as well economic risks to implement new energy storage technologies have been reduced.
- National and international guidelines have been developed for the implementation of ground and aquifer storage systems to avoid environmental risks and to facilitate installation by local water authorities.
- Design tools and computer models have been developed and are being used now by engineers for the planning and design of new energy systems that include energy storage technologies.
- Technology transfer and information dissemination have continued with the sponsorship of workshops and international conferences, including the series of International Thermal Energy Storage Conferences (Enerstock’85, Jigastock´88, Thermastock´91, Calorstock´94, Megastock´97) and the Electrical Energy Storage Conference (EESAT´98).
- Deployment of low temperature aquifer storage facilities for heating and cooling on a large scale in various countries, e. g., The Netherlands, Sweden, the United States of America, Switzerland and Germany.
- Close cooperation with other Implementing Agreements (e. g., Solar Heating and Cooling, Buildings and Community Systems, Heat Pumping Technologies) has been established to

avoid duplication of effort and to align the Energy Storage Programme with the interest of other IEAProgrammes. Cooperation within the Future Building Forum has been initiated.
- Internet homepages of the IEA-Energy Storage Programme and various Tasks has been set up.
- New member countries (Japan, Spain, Turkey, UK) have been attracted. Other countries (Bulgaria, Poland, Switzerland) are interested in participating in the Programme.

9. Scope and Workplan

The Executive Committee constitutes a forum of Senior National Programme Managers and Experts. It fulfills the following tasks:

- Task Management (Appendix)
- Coordination of national activities among participating countries
- Information dissemination by electronic Journals and Internet Websites
- Organization of International Conferences and workshops
- Evaluation of the State-of-the-Art technologies.

Until recently, the Storage Programme was mainly focused on thermal energy storage technologies for the heating and cooling of buildings because this sector offers the largest energy saving and substitution potential in northern countries. However, electrical energy storage systems are also important for the stabilization and optimization of electrical energy systems as well as for the utilization of renewable energy sources, in particular in photovoltaic and wind energy systems. Therefore, the End Use Working Party recommended that the scope of the programme be broadened to include electrical and other energy storage technologies.

In January 1995 an IEAWorkshop on Energy Storage was held in Montreal to examine the opportunities and interest of cooperation in storage technologies that the IA had not previously covered in the Programme. As a result of the workshop, two new Annexes were initiated:
- Annex 9: Electrical Energy Storage Systems and Network Optimization.
- Annex 10: Phase Change Materials and Thermochemical Storage.

In 1998, the IA was extended by the Energy End-Use Working Party for 3 years until the end of the year 2000. So far twelve Annexes have been carried out, and seven of them have already been completed successfully (Appendix 1).
Special R&D activities on energy storage systems have been carried out in the context of other IEA programmes, e. g.,
- Solar PACES: (High temperature thermal storage systems for solar thermal power plants).
- Solar Heating and Cooling: Task 16 - Photovoltaics in Buildings (Survey: Battery Storage Systems), Task 14 and Task 26: Advanced Solar Heating Systems (hot water storage).
- Photovoltaic Power Systems.
- Heat Pumping Technologies.
- District Heating and Cooling.

10. Proposed Future Activities

The proposed future activities are largely extensions of the previous and present work of the Programme. Various topics and activities will be continued in order to achieve successful implementation of storage technologies. The following list includes the activities that will be examined by the Executive Committee.
- Follow-on to Annex 8: Implementation of underground thermal energy storage.

- Follow-on to Annex 9: Pilot and demonstration electrical storage plants. Develop consortia and explore funding mechanisms to realise demonstration schemes within a reasonable time scale.
- Evaluation of electrical storage systems for use with renewable resources and demonstration of the environmental benefits of reduced greenhouse gas emissions.
- Research electrical energy storage for competitive electricity supply markets and determine the economic advantages of storage for peak shaving, capital equipment deferral and frequency regulation applications.
- Annex 14: Cooling in all climates with thermal energy storage systems (Task Definition Phase).
- Short term cold storage for DSM (demand side management)
- Comprehensive evaluation of the environmental and indoor consequences of energy storage by reviewing present national efforts and development of a validated methodology.
- Role of thermal energy storage in increasing the energy efficiency of building HVAC systems such as combined with closed-loop building heat pump systems and desiccant-based cooling systems. Cooperation with the IEA Building and Community Systems, Heat Pumping Technologies and Solar Heating and Cooling IAs will be useful.
- Evaluation of the benefits of hot and cold storage with heat pumps, especially the advanced generation of heat pumps, in collaboration with the Heat Pump IA.
- Study the potential for water remediation efforts using energy storage through community or aquifer-based planning of large-scale energy supply systems with the objective of assisting the implementation of energy storage in a systematic manner.
- Organisation of International Conferences, workshops and symposia:
    - TERRASTOCK-2000 (August 2000, Stuttgart, Germany)
    - EESAT 2000 (September 2000, Orlando, Florida, USA)
    - Workshop on Advanced Solar Thermal Energy Storage (October 1999, Freiburg, Germany) in collaboration with the Solar Heating and Cooling Programme.
- Publication of the electronic journal: Underground Thermal Storage and Utilization /2/.
- Publication of Programme and Annex brochures and reports on Internet /2/.
- Continuous evaluation and preparation of state-of-the-art reviews.
- Joint efforts should be initiated to implement new energy storage technologies in all countries with an interest in storage or with a significant energy storage market potential.

11. Participation

The following countries and corresponding organizations have signed the IEA Energy Storage Implementing Agreement:

Belgium, Ministry of Economical Affairs
Canada, Public Works Canada
Commission of the European Communities
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.
Spain, IBERDROLA
Sweden, The Swedish Council for Building Research
The Netherlands, The Netherlands Agency for Energy and the Environment (NOVEM)
Turkey, Çukurova University, Adana
United Kingdom, EA Technology
United States of America, Department of Energy.

Bulgaria, Poland and Switzerland presently participate in various Tasks and have sent representatives to the Executive Commitee meetings. These countries are expected to become signatory countries of the Implementing Agreement on Energy Storage.

12. References

/1/ CALORSTOCK`94: 6th International Conference on Thermal Energy Storage, August 22-25, 1994 Espoo, Finland, Proceedings pp. 303-339.

MEGASTOCK`97: 7th International Conference on Thermal Energy Storage, June 18-21, 1997, Sapporo, Japan, Proceedings pp. 1003-1026.

EESAT 98, Electrical Energy Storage Systems Applications & Technologies, June 16-18, 1998, Chester, UK, Proceedings.

/2/ Internet Website addresses:

http://www. sb.luth.se/vatten/projects/iea/ (general information, task and annual reports)
http://www.eatl.co.uk/annexIX/home.htm and http://www. eus.de/energy-storage/ (Annex9)
http://www.chemeng.kth.se/avdelningar/ts/annex10/index.htm (Annex10)
http://www.geo-journal.stockton.edu (electronic journal)
http://www.itw.uni-stuttgart/TERRASTOCK

Appendix: Current Annexes

Annex 8: Implementing Underground Thermal Energy Storage Systems.

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 various energy efficient systems. Screening and decision tools will be provided to ensure ecologically sensitive applications. Sweden is providing the Operating Agent. The Annex has been extended into 1999.

Duration: 1996-1999, Operating Agent: Sweden.

Annex 9: Electrical Energy Storage Systems and Network Optimization.

The overall objective of Annex 9 is to encourage the greater uptake of electric energy storage systems on utility and associated distribution networks, thereby allowing the full energy savings, operational efficiency and environmental benefits to be realised. The priority areas to be addressed in the short and medium terms include the application of electrical energy storage systems in the following areas:-

- integration with renewables and non-despatchable power sources
- power quality/quality of supply
- asset management
- deferment of capacity additions

The scope of work includes the following elements:-

- retro-spective case studies
- forward looking project definitions
- network applications modelling
- information collation and dissemination
- formation of strategic R&D partnerships

Duration: 1996-1999, Operating Agent: UK

Annex 10: Phase Change Materials and Thermochemical Reaction Systems

The objectives of Annex 10 are to solve technical and market problems for increased market opportunities for thermal energy storage systems utilising phase change materials (PCM) or chemical reactions and to broaden the knowledge base and disseminate technical information.

Research will be carried out to find solutions to the difficulties in using PCM or chemical reactions for thermal energy storage. In particular, research into system analysis will be pursued in order to eliminate market barriers for implementing the technology in residential, commercial, industrial and agricultural sectors. The action will be executed in close co-operation with manufacturers, utilities, users, governmental representatives and organisations involved in the development of energy technologies.

Annex 10 will result in completed case studies and demonstration projects related to potential applications. Furthermore, it should produce general recommendations for the energy industry and more application-oriented R & D activities with increased participation by industry, manufacturers, and other stakeholders

Duration: 1998-2000, Operating Agent: Sweden

Annex 12: High-Temperature Underground Thermal Energy Storage (HT-UTES)

In contrast to Annex 8, this Task deals with the storage of heat at temperatures above 50 ^{o}C. The stored heat can be used without a heat pump. HT-UTES still is not yet widely used, but might allow further applications e.g., in district heating, in waste heat recovery, in solar heating, etc. The type of UTES-systems concerned shall be confined to Aquifer Storage (ATES) and Duct / Borehole Storage (DTES). The Annex is being carried out in two Phases.

Phase I (1.1.1998 - 30.06.1999)

Based upon the results from previous IEA activities and ongoing R&D, the objectives of Annex 12 are to demonstrate that HT-UTES can achieve more efficient, economical and environmentally benign energy systems, and to disclose requirements and find solutions for reliable, long-term operation. A state-of-the-art-review has been completed along with the identification of system opportunities.

Phase II (1.10.1999 - 31.12.2002)

Based on the conclusions and recommendations of the Phase I review, the necessary R&D efforts will be initiated and demonstration plants erected, monitored and evaluated. Long-term scenarios will be investigated; environmental impacts and benefits will be examined; design tools and guidelines will be developed; water treatment methods implemented; and material suited for high temperatures tested.

Duration: 1998-2001, Operating Agent: Germany.

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

Most UTES (Underground Thermal Energy Storage) concepts incorporate drilling one way another. Furthermore some concepts are highly dependent on a proper well or borehole efficiency to have an optimal operational performance.

This Annex will cover aspects of test drilling, well and borehole design, construction and monitoring and maintenance of UTES applications. The main target is set upon aquifer and borehole systems (in some countries refereed to as ”open” and ”closed or duct” systems).

The final goal of the task 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 effectively, safely and properly (Subtask C)
- How to keep the storage systems functional during operation (Subtask D)

Duration: 1998-2000, Operating Agent: Sweden

Annex 14: Cooling in All Climates with Thermal Energy Storage (Task Definition Phase).

The overall objective of Annex 14 is to employ research, development and demonstrations to advance the prospects of thermal energy storage (TES) technologies for applications within a variety of energy systems in various climate zones 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 TES in innovative, energy efficient and cost-effective projects in participating countries.

Duration: 1999 Start of the Task Definition Phase, Operating Agent: Turkey.