



Implementing Agreement  
Energy Conservation Through Energy Storage

Annex 12

**High-Temperature Underground Thermal Energy Storage**

1. Technical Sector, Definitions

Since energy demand and energy supply from renewable sources, waste etc. often do not coincide in time, storage of energy is a key issue to improve all such energy systems. The underground offers a huge potential for storage of thermal energy by various means. For heating purposes, thermal energy is the better suited the higher it's temperature is. In consequence, storage systems at elevated temperature levels are a promising technique

Definitions:

- Underground Thermal Energy Storage comprises all storage of heat, cold, or both in the natural underground (i.e. rock, soil, groundwater, caverns, pits etc.). Not included are artificial structures built below ground, like buried tanks.
- High Temperature in this proposal 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. Background

Thermal energy storage is a very versatile tool to improve heating systems or to create the necessary conditions for use of some renewable energies for heating. Short-term storage (water tank) is an integral part of every solar thermal water heater, and hot water accumulators are frequently used in district heating systems or in waste heat recovery in industrial environment. The underground is used as heat source and sink for heat pumps since the late 40s, and real underground heat storage is considered since the early 70s and practically demonstrated in the beginning of the 80s. UTES on a low temperature level, for space cooling or for combined heating and cooling (with or without heat pumps), today is in some



countries a standard design option and finds increasing application, not the least also due to previous IEA-activities. HT-UTES still is not widely used, but might allow further applications e.g. in district heating, in waste heat recovery, in solar heating etc.

The higher the temperature level of the energy supplied by the store is above ambient temperature (i.e. the higher its "exergy"), the better it can be used for heating purposes and in consequence the more valuable it is. With low temperature heat, advanced heating systems with very low supply temperature are required, or the temperature has to be increased by use of a heat pump (and the additional energy input required with this technique). With sufficiently high supply temperatures from the store, standard heating systems can be fed directly, or heat pumps, if still necessary, will sport excellent performance factors due to the high temperature heat source.

In the IEA-framework HT-UTES and related problems have been studied earlier:

IA Solar Heating and Cooling (Renewable Energy WP):

- Task VII: Central Solar Heating Plants with Seasonal Storage (CSHPSS), 1979-89

IA Energy Conservation through Energy Storage (Energy End Use WP):

- Annex I: Large Scale Thermal Storage Systems Evaluation, 1979-81
- Annex III: Aquifer Storage Demonstration Plant in Lausanne-Dorigny and associated projects, 1981-1989
- Annex VI: Environmental and chemical aspects of thermal energy storage in aquifers, 1987-93
- Annex VIII: Implementing Underground Thermal Energy Storage Systems (UTES), 1994-ongoing

Based upon the results from these activities and ongoing R&D, future work can be focussed on fields where the necessity is obvious and thus an optimum of results may be obtained with the smallest effort possible.

A first discussion on continuing co-operative R&D within the IEA framework took place at a HT-UTES-workshop on June 12, 1996, during the IEA ECES Annex 8 expert's meeting in Halifax, Canada. On April 28/29, 1997, a dedicated workshop on HT-UTES within IEA ECES was conducted in Berlin, Germany, with international attendance. This workshop was a platform for a first review of the state-of-the-art and the future opportunities, and resulted in the recommendation to proceed in establishing a relevant annex.



### 3. Objectives

The 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).

### 4. Benefits

Various benefits will be achieved with HT-UTES:

- Energy conservation (as stated in the title of the IA)  
HT-UTES will allow to use renewable energies like solar thermal energies, which otherwise have bad characteristics in matching time of heat load and supply, and to make use of waste heat in times where no heat load exists. In consequence, other (fossil) primary energies can be saved. Using HT-UTES, also the energy necessary for recovering the heat can be minimized.
- Environmental benefits (reduction of emissions)  
In unison with energy conservation the emission of carbondioxid and noxious gases will be reduced substantially. If waste heat can be used for storage, then also thermal pollution caused by dumping this heat into the environment can be mitigated. HT-UTES might here play a double role with reducing flue gas emissions and decreasing thermal emissions simultaneously.
- Economic benefits and improved reliability  
It is expected to achieve eventually a good economic basis for HT-UTES, at least in plants making use of otherwise wasted thermal energy. Reliability can be very high, provided the relevant techniques (e.g. water treatment) will successfully be demonstrated in this work.

### 5. Scope of work

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

#### **Phase I**

##### **1. State-of-the-art-review**

In this study the technical, environmental and economical feasibility and environmental advantages of high temperature thermal energy storage in aquifers and duct/boreholes will be investigated. The technical problems encountered in the construction and operation of the first generation pilot and demonstration



plants will be analyzed. Suggestions will be made how to overcome these problems and barriers.

A report summarizing the results of previous IEA-activities, describing ongoing R&D in the member countries, and collecting experiences from existing HT-UTES-plants will be a starting point for the new annex. This work will summarize, evaluate and compile documents of the previous IEA-activities and non-IEA literature, and will identify ongoing activities in the field. On that basis specific need and opportunities for further R&D-work will be defined, allowing a sound decision for phase II.

A special workshop is planned in spring 1998, bringing together experts from the previous IEA-activities, investigators in related ongoing R&D-projects, and engineers from HT-UTES-plants currently in operation.

2. System opportunities (from energy system side)

A study will join UTES-experts and HVAC engineers to describe and evaluate the most promising applications and system concepts for HT-UTES. The results will allow to assess the expected benefit of HT-UTES and will justify a decision on phase II.

## Phase II

3. Long-term perspective and scenarios

Based on the study in Phase I, the possibilities of HT-UTES will be forecast for a longer time period, and some exemplary application scenarios will be sketched and a life-cycle analysis (LCA) performed.

4. Environmental impact/benefits

The advantages of HT-UTES application for the environment and the impact of underground installations will be estimated, leading to a kind of "ecobalance".

5. Development of design tools

Existing design tools as reviewed in Annex 8 will be evaluated, the need for improved or new tools investigated (e.g. dealing with substantial buoyancy flow), and the according program development and validation will be done.

6. Improvement in water treatment, choice of material suited for high temperatures, and development of test equipment

Based on the results of Annex 6 and ongoing R&D, need for further research in water treatment (in aquifer storage) and environmental behaviour of all HT-UTES-concepts will be investigated. Theoretical and laboratory work will be done to find acceptable solutions. Materials used for low temperature applications may not prove applicable for temperatures above 50 °C, which requires search for and choice of suitable materials. Mobile test equipment will be improved ("TED" for borehole heat exchangers) or developed if necessary (for aquifer storage).



## 7. HT demo projects

In demonstration projects the use of design tools will be shown, the effectiveness of system concepts verified, and, where applicable, water treatment methods tested.

## 8. Design guide-lines

As a final outcome design guide-lines will be compiled, covering promising system concepts, assessment of subsurface conditions, use of design tools for system layout, suitable ground coupling or water treatment methods, etc.

## 6. Organisation

The individual steps of the annex work will be done in six subtasks, each led by a subtask leader from one of the participating countries. The total workplan is divided in two phases:

### **Phase I:**

Subtask A: State of the Art Review  
Activities 1 and 2, lead country: Germany

A milestone after phase I should allow to discuss the state-of-the-art and the identified R&D-needs and -opportunities at the June 1998 meeting of the IEA ECES Executive Committee, and to decide whether to proceed with phase II or to close the annex.

### **Phase II: \***

Subtask B: Theoretical work on long-term perspective and environmental impact  
Activities 3-4, lead country:

Subtask C: Design tools  
Activity 5, lead country:

Subtask D: Water treatment  
Activity 6, lead country:

Subtask E: Demo projects  
Activity 7, lead country:

Subtask F: Design guide-lines  
Activity 8, lead country:

The subtask leader shall be a participant which provides to the subtask a high level of expertise and undertakes substantial research and development in the

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\* Lead countries for Phase II will be identified at the end of Phase I.



field of the subtask. The subtask leader shall be proposed by the operating agent, and designated by the Executive Committee acting by unanimity. Changes in the subtask leaders may be agreed to by the Executive Committee, acting by unanimity of the participants.

The participants shall establish a technical advisory committee consisting of the subtask leaders and the operating agent or their respective designees. The technical advisory committee shall assist the operating agent in the co-ordination of the task and advise the operating agent on the performance of the task.

The annex will be conducted on a task-sharing basis. Participants are expected to contribute equally to the completion of the task in terms of work sharing. The level of effort for Phase I should be at least one person-month per participating country. The estimated level of effort for Phase II is about 20 person-month per participating country.

If suitable, cost-sharing might be adopted for some activities exceeding the task-sharing effort, like development of mobile test equipment or common demonstration plants. The Executive Committee shall decide on establishing such cost-sharing activity and on the level of contribution, acting by unanimity.

All activities need to be documented. The subtask leaders will be responsible for the editing, printing and distribution of activity reports.

Expert meetings will be called by the operating agent with the advise of the technical advisory board so as to accomplish the objectives of the annex. Subtask meetings may be called by subtask leaders with the agreement of the operating agent. At least one expert meeting per year shall be held over the life of the annex.

## 7. Time Schedule

Timeframe is from 1.1.1998 until 31.12.2000 (or until 31.12.1998, if closed after phase I).

**Phase I:** 1.1.1998 - 31.12.1998

Subtask A: 1.1.1998 - 31.12.1998

Milestone: IEA ECES Executive Committee Meeting December 1998

**Phase II:** 1.1.1999 - 31.12.2000

Subtask B: 1.1.1999 - 31.12.1999

Subtask C: 1.1.1999 - 31.12.2000

Subtask D: 1.1.1999 - 31.12.2000



Subtask E: 1.1.1999 - 31.12.2000

Subtask F: 1.1.2000 - 31.12.2000

## 8. Results/Deliverables

The results of the task shall be:

### **Phase I:**

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

### **Phase II:**

- Ecobalance
- Annual reports
- Workshops
- Test equipment
- Design guide-lines / tools

## 9. Responsibilities

Responsibilities of participants:

Participants are expected to contribute equally to the completion of the annex in terms of collaborative effort. The Executive Committee may decide that one or more participants may contribute to the annex in part with budgetary resources in lieu of collaborative effort on certain tasks. Expert Meetings will be rotated among the participating countries to the extent feasible. A subtask leader will be responsible for each subtask as indicated under section 6.

Responsibilities of the Operating Agent:

The Operating Agent shall be responsible for overall management of the work under the terms of this annex and for implementing the decisions of the Executive Committee. To that end, the Operating Agent shall

- initiate and plan expert meetings to accomplish the objective of the annex;
- prepare work plans for the annex to accomplish its objective;
- co-ordinate the publication and dissemination of intermediate reports as required;
- report to the Executive Committee on the results and progress of the work under this annex, at least annually, or as required;
- on completion of the annex, compile and distribute to all participants a final report on the annex.

## 10. Information and Intellectual Property



- a) Executive Committee's Powers. The publication, distribution, handling, protection and ownership of information and intellectual property provided under or arising from activities conducted under this Annex shall be determined by the Executive Committee, acting by unanimity, in conformity with this Annex.
  
- b) Right to Publish. Subject only to the patents and copyright restrictions of this Annex, the Participants in this Annex (referred to in this Annex as the "Participants") shall have the right to publish all information provided to or arising from this Annex except proprietary information, but they shall not publish it with a view to a profit, except as agreed by the Executive Committee, acting by unanimity. Neither the Participants nor the personnel designated by them shall introduce into the Annex proprietary information unless such information is specifically identified and the terms and conditions for its introduction are agreed upon in writing by the Operating Agent and the concerned Participant.
  
- c) Proprietary Information. The Participants shall take all necessary measures in accordance with this Annex, the laws of their respective countries, and international law to protect proprietary information. For the purposes of this sub-paragraph, proprietary information shall mean information of a confidential nature acquired prior to or outside the scope of this Annex, such as trade secrets and know-how (for example, computer programmes, design procedures and techniques, chemical composition of materials, or manufacturing methods, processes or treatments) which is appropriately marked, provided such information:
  - (1) Is not generally known or publicly available from other sources;
  - (2) Has not previously been made available by the owner to others without obligation concerning its confidentiality; and
  - (3) Is not already in the possession of the recipient Participant without obligation concerning its confidentiality.It shall be the responsibility of each Participant supplying proprietary information to identify the information as such and to ensure that it is appropriately marked.
  
- d) Production of Relevant Information. The Operating Agent should encourage the governments of all Agency Participating Countries to make available or to identify to the Operating Agent all published or otherwise freely available information known to them that is relevant to the Annex. The Participants should notify the Operating Agent of all pre-existing information and information developed independently of the Annex known to them which is relevant to the work



of the Annex and which can be made available to the Annex without contractual or legal limitations.

- e) Reports on Programme Work. Reports containing arising information and pre-existing information necessary for and used in the Annex, including proprietary information, shall be provided to the Operating Agent by each Participant performing the work. Each Participant agrees to provide to the Operating Agent all information which is utilised in the activities under this Annex. The Operating Agent shall provide such information to all Participants. The Operating Agent shall provide summary reports of work performed under this Annex and the results thereof (arising information), excluding proprietary information, to the Executive Committee.
- f) Arising Information. All information developed in connection with and during activities carried out under this Annex (arising information) shall be provided to each Participant by the Operating Agent, subject only to the need to retain information concerning patentable inventions in confidence until appropriate action can be taken to protect such inventions in accordance with sub-paragraph (h) below.
- g) Licensing of Pre-existing Inventions. Each Participant agreed to negotiate, to the extent permitted by law, licences to all pre-existing inventions, and will not unreasonably withhold such licences covered by patents owned or controlled by it which are necessary for and used in the Annex to the other Participants, their governments and the nationals of their respective countries designated by them on reasonable terms, for use in all countries and to the government of any Agency Participating Country for use in its own country of any such invention on reasonable terms and conditions, subject to the laws and regulations governing the patent holding country in order to meet its energy needs.
- h) Arising Inventions. Inventions made or conceived in the course of or under the Annex (arising inventions) shall be owned by the inventing Participant, subject to an irrevocable non-exclusive royalty-free licence to each of the other Participants, their governments, and the nationals of their respective countries designated by them. Information regarding inventions on which patent protection is to be obtained by the Participants shall not be published or publicly disclosed by the other Participants until a patent application has been filed, provided, however, that this restriction on publication or disclosure shall not extend beyond six months from the date of receipt of such information. It shall be the responsibility of the inventing Participant to appropriately mark reports which disclose inventions that have not been appropriately protected by the filing of a



patent application. In order that public disclosure of inventions shall not adversely affect the patent interest of the Participants, patent approval for release or publication of information generated by or made a part of the activities under this Annex shall be obtained from the Operating Agent prior to any release or publications. Each Participant agreed to license such arising inventions to the government of any Agency Participating Country for use in its own country on reasonable terms and conditions in order to meet its energy needs.

- i) Copyright. The Operating Agent or each Participant for its own work may take appropriate measures to protect copyrightable materials generated under the Annex. Copyrights obtained shall be the property of that Participant or the Operating Agent for the benefit of the Participants, provided, however, that Participants may reproduce and distribute such material, but shall not publish it with a view to profit.
- j) Inventors and Authors. Each Participant shall, without prejudice to any rights of inventors or authors under its national laws, take all necessary steps to provide the cooperation with its inventors and authors required to carry out the provisions of this paragraph. Each Participant will assume the responsibility to pay awards or compensation required to be paid to its employees according to the laws of its country.
- k) Definition of "National" The Executive Committee may establish guidelines to determine what constitutes a "national" of a Participant.

## 11. Operating Agent

Phase I: Forschungszentrum Jülich acting through Justus-Liebig-University,  
Giessen

Phase II: To be determined at the end of Phase I.

## 12. Contracting Parties