Sustainable Cooling with Thermal Energy Storage

From IEA ECES Annex 14 to IEA ECES Annex 20

Halime Paksoy
Cukurova University, Turkey

Masaya Okumiya
Nagoya University, Japan

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Background
Sustainable Cooling with TES

- Global warming
  - heat waves
  - urban heat islands
- Increasing demand on cooling evolving comfort expectations
  - technological development
  - increased office automation
- Challenges to meet the peak electricity demand in summer
  - black-outs
  - electricity-cuts
- Changes in industrial picture
  - Shift from manufacturing type to assembly-type production in industry
  - Improvement of in-door climate to increase productivity
Increasing Cooling Demand Decreases Load Factor for Power Generation

Change of annual load factor in Japan

Load factor of 70% in the 1960's declined to 55% in 1994 in Japan

In European countries like Germany, England and France the load factor is around 65% for the same period of time
Improvement of Load Factor with TES

- Energy Conservation
- Reduction of CO₂ Emission
- Reduction of Cost of Power Supply

1% improvement of Load factor $\rightarrow$ 1% reduction of cost (METI, Japan)
Short Term (Diurnal) Storage for Peak Shaving

Strong peaks in electricity load curve can be shaved with diurnal storage.

[Graph showing electricity load curve with 100% peak at 1996 Jul., and 44% reduction with diurnal storage.]
Long Term (Seasonal) Storage for Cooling Load Shifting

- Closing the gap between supply of cold sources and demand for cooling
- Utilization of cold from
  - Renewable energy sources
  - Natural energy sources
  - Waste heat/ cold
- Summer electricity consumption for cooling can be shifted to winter
Subtasks of Annex 14

Phase 1 (June 1999 - May 2003)

- **Subtask 1.** Conduct a general review of existing and emerging cooling with TES applications in different climates
- **Subtask 2.** Evaluation of Feasible Boundary Conditions and System Configurations for Cooling with TES
- **Subtask 3.** Design and Analysis User-friendly Tools
- **Subtask 4.** Determining potential cooling with TES applications in different climates
Participating Countries (Annex 14)

- **Canada**
  Environment Canada
  Public Works Canada

- **Japan**
  The Heat Pump and Thermal Storage Technology Centre of Japan

- **Sweden**
  Luleå University of Technology
  VBB Viak AB
  Lund University
  Royal Institute of Technology

- **Turkey**
  Çukurova University Center for Environmental Research
  (Operating Agent)

- **USA**
  Richard Stockton College, New Jersey
Activities

Experts’ Meetings

1. Sundsvall, Sweden November 5-6, 1999 Lulea Technical University
2. Halifax, Canada April 7, 2000, Environment Canada
4. Tokyo, Japan November 11-12, 2000, Heat Pump Center of Japan
5. Istanbul, Turkey April 20, 2001, Cukurova University & ENERJISA
6. Adana, Turkey November 25-26, 2001, Cukurova University
9. Lleida, Spain, April 8-10, 2003, Lleida University
10. Warsaw, Poland, August 31, 2003, during Futurestock’2003

Minutes for the experts’ meetings can be found at: (http://cevre.cu.edu.tr/annex14/reports/)
## Activities

**Workshops**

<table>
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<tr>
<th>Workshops</th>
<th>Number of Participating Countries</th>
<th>Number of Participants</th>
<th>Number of Presentations</th>
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<td>Antalya, Turkey, June 4, 1999</td>
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<td>Halifax, Canada, April 7, 2000</td>
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<td>Tokyo, Japan, November 8, 2000</td>
<td>8</td>
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<td>15</td>
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<td>Istanbul, Turkey, April 19, 2001</td>
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<td>Shanghai, China, September 26, 2001</td>
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<td>60</td>
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<td>Pomona, NJ, USA, October 25, 2002</td>
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<td>75</td>
<td>9</td>
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<tr>
<td>Lleida, Spain, April 11, 2003</td>
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<td>13</td>
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**Subtask 1**

**Subtask Leader: Turkey**

1. Country specific state-of-the-art report prepared by each Annex 14 participating country
   

2. General report with a global perspective
   
   (Paksoy and Turgut, 2003)

3. Brochure with a CD-ROM containing the reports and Annex 14 workshop proceedings

4. Homepage (http://cevre.cu.edu.tr/annex14)
Subtask 2

Subtask Leader: Canada

Subtask 2 Final Report includes chapters on:

- Classification of boundary conditions
  - Natural
  - System
  - Social and political
  - Environmental
- Tools for choosing feasible boundary conditions
- Relevant boundary conditions for TES options
- Classification of available cold sources for TES

(Report is included in Appendix 4 of the Annex 14 final report.)
Subtask 3

Subtask Leader: Japan

Subtask 3 Final Report includes
- Evaluation and inventory of design and analysis tools
- Database for environmental calculations

Other Deliverables
- User-friendly ice storage systems program “Ice Club” was translated from Japanese
- Decision tree that can be used as a pre-design tool was developed for quick analysis of TES options for Japan

(Report is included in Appendix 5 of the Annex 14 final report)
Subtask 4

Subtask Leader: Sweden

Purpose of the Subtask

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

Subtask 4 program will be included in Phase II of Annex 14 or new annex.
Case Studies

Given in Subtask 1 General State-of-the-art-report

- Aquifer Thermal Energy Storage
  - Bo01 local district heating and cooling in Västra Hamnen, Malmö, Sweden
  - District cooling in city of Stockholm, Brunkebergs Torg, Sweden
- Borehole Thermal Energy Storage
  - Institution for Astronomy at the University of Lund in Sweden
  - Richard Stockton College, NJ, USA
  - Convenience store in Skunk Creek Conoco Station in Sandstone, Minnesota, USA
  - Esperanza del Sol, a small (twelve unit) development of low-cost homes in Dallas, Texas, USA
  - Northwest Louisiana Juvenile Detentions Facility, USA
  - Single family house in Zekeriyakoy, Istanbul, Turkey
Case Studies (cont’d)
Given in Subtask 1 General State-of-the-art-report

• Ice storage
  ★ Tokyo R&D building in Yokohama Kanagawa, Japan
  ★ Dairy industry in Japan
  ★ Gin-nai Farm21 Vegetable Factory in Urausu-cho, Hokkaido, Japan
  ★ Rice Factory in Numata-cho, Hokkaido
  ★ Kraft Building, Durst Building in NY and Centrex Building in Dallas, Texas, USA

• Snow storage
  ★ Hospital in Sundsvall, Sweden

• Chilled water tank storage
  ★ Residential applications in Japan
**Conclusions (ANNEX14)**

- First annex on cooling covering all types of TES technologies and considering different climates.
- Information exchange with other related IEA implementing agreements (SHC and ECBCS).
- State-of-the-art reports prepared helped to determine the current status of R&D and areas of further research.
- Information dissemination through workshops and publications (homepage, brochure and CD-ROM's).
- Workshops brought together experts with different backgrounds leading to new ideas of integrating TES.
- Network of 300 experts from 13 countries was formed as a result of workshops and other activities.
- TES concept was introduced for the first time to some new countries and awareness was increased in other countries with less experience in this field.
Conclusions (cont’d) (ANNEX 14)

- Increased TES activities in more experienced countries like Sweden resulted in a boost in some side-sectors, mainly the drilling sector.
- Annex also influenced the research activities at the universities. The following thesis’ were completed during Annex 14:
  - Seasonal Snow Storage for Cooling Applications – Licentiate Thesis, Lulea University of Technology
  - Utilization of Natural Cold Sources with Borehole Thermal Energy Storage – PhD Thesis, Cukurova University
  - Potential of Borehole Systems in Portugal – Master Thesis, Lulea University of Technology
Annex 14
Follow-up Activities

- Phase II of Annex 14 or a new annex??
  - Concept of a new annex prepared and approved by IEA ECES ExCo

- Scope Definition Workshop for Annex 20
  - Parallel to IEA FBF Workshop on Cooling in Nice, June 23 2004

- NATO Advanced Study Institute on Thermal Energy Storage for Sustainable Energy Consumption, June 6-19, 2005, Cesme, Turkey
  - 65 participants from 18 countries
  - 24 lecturers from 9 countries
From Annex 14 to Annex 20
Areas for Further R&D

- Feasibility study, design and construction of practical demonstration of viable TES in representative cooling applications in different climates
- Development of design and analysis tools for optimising cooling with TES applications, taking into consideration the size of the application and environmental benefits and energy savings of cooling with TES compared with conventional alternatives
- New TES alternatives combining seasonal storage with short term (diurnal) storage for peak shaving
- Humidity control in combination with TES
Integration of TES system

Short term

Daily Load Leveling
Peak Shifting

Water, Ice, PCM, Thermochemical, Building Structure

Long term

Annual / Seasonal Load Leveling

Renewable and natural energy sources

ATES
BTES
CTES
Benefits

- Reduction in CO₂ emissions
- Efficient utilization of energy sources
- Reduction in use of conventional mechanical cooling and assisting to phase out Ozone Depleting Substances (ODS) such as CFC and HCFC refrigerants
- Reduction in peak electrical power demand
- Better working environment that increases the productivity in industry
Sustainable Cooling

Performance Index for Optimization

- Energy Consumption
- CO₂ Reduction
  for cooling season
  for heating season → Annual

- Life Cycle Cost (LCC)
- Life Cycle Energy (LCE)
- Life Cycle CO₂ (LCCO₂)
Sustainable Cooling

Design tools (Existing)

Short Term Storage

| HVACSIM (USA) | Water TES |
| TRNSYS (USA) | Water TES (Solar) |
| ICE CLUB (JAPAN) | Ice TES |
| HASP/ ACLD/ ACSS (J APAN) | Water TES |
Other Tools (from China .....

Long Term Storage (???)

Developed by Olof Andersson
Frank Cruickshanks
Lynn Stiles

.....
Scope

A project oriented approach for optimized integration of TES in cooling system

by demonstrating and evaluating the sustainability of cooling system with TES

energy saving

CO2 emission reduction
Objectives

Advance the prospects of cooling with TES systems.
2. Establishment of design method (evaluation of design tools)
3. Feasibility studies
4. Demonstration projects

Information Dissemination and Technology Transfer within participating countries and to other countries (including non-Member countries).
Subtask A:

Demonstration projects/ System performance evaluation for an actual project

- demonstrate the prospects of sustainable cooling using short-term, long-term and alternative combinations of short-term with long-term thermal energy storage.
- short-term
  - water, ice, phase change materials (PCM), building structure etc.
- long term
  - underground options including soil, aquifer, cavities/ pits
- applied to
  - commercial and institutional buildings, residential, district heating and cooling, etc.
Subtask B:

Design Procedure and System Performance Evaluation Tools

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

Information Dissemination and Technology Transfer

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

- Workshops and international conferences held in various countries including a non-Member countries
Potential Participants

ECES members
- Germany
- Canada
- Japan
- Sweden
- The Netherlands
- USA
- Turkey
- Italy
- Spain

Non-ECES members
- China
- Iran
- Thailand
- Malta
- France
- Malaysia
Annex 20 Expert Meeting

Annex 20 Expert Meeting will be held in the morning on 3rd Jun 2006 at Townsend Residential Center (TRLC)

Room: will be notified at reception desk

Time: 9 to 12 am
(Also check the notice board)

Thank you for your attention