IEA ECES IA Annex 22
Thermal Energy Storage in Horticultural Greenhouses
Report to ExCo

November 18-19, 2009
Mie, Japan

Objectives

• To define the challenges of energy efficient greenhouse systems requiring thermal energy storage techniques and determine methods for overcoming the challenges.
• To determine the most effective storage technologies for greenhouse applications, including seasonal storage, and short-term storage.
• To develop deployment strategies for these prospective technologies as integrated components of greenhouse systems.
Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Institution(s)</th>
<th>First Experts' Meeting</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>VITO</td>
<td>-</td>
<td>Confirmed</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Technical University of Sofia</td>
<td>-</td>
<td>Not Confirmed</td>
</tr>
<tr>
<td>Canada</td>
<td>Environment Canada</td>
<td>✓</td>
<td>Withdrawn</td>
</tr>
<tr>
<td>France</td>
<td>BRGM Service EAU/RMD</td>
<td>-</td>
<td>Confirmed</td>
</tr>
<tr>
<td>Netherlands</td>
<td>IF Technology</td>
<td>✓</td>
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<tr>
<td>Norway</td>
<td>NIVA Veksthusringen NTNU</td>
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<tr>
<td>Spain</td>
<td>Universidad Politecnica de Valencia</td>
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<td>Not Confirmed</td>
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<tr>
<td>Sweden</td>
<td>Royal Institute of Technology</td>
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<tr>
<td>Turkey</td>
<td>Çukurova University</td>
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</tbody>
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First Experts Meeting and Workshop October 22-23, 2009

- Total of 17 participants from Canada (9), Netherlands (1), Norway (3), Sweden (1), Turkey (1), USA (2)
- Presentations from:
  - Companies 2
  - Universities 2
  - Government 1
- Belgium and France sent short information on their projects
- Video clip from Rubitherm, Germany on PCM project in greenhouse of botanical garden in Berlin
- RETScreen training session
State-of the-art

Greenhouse production

- Total greenhouse area
  - 50,000 - 10,000 - 300 ha
- Energy consumption
  - 55,000 m³ of oil - 450,000 m³ gas/y ha...
- Sources of energy
  - Oil, gas, coal, electricity
- Share of energy in total cost of production
- Standard greenhouse
  - Heating and cooling systems
  - CO₂ control mechanisms
  - Lighting

“for greener greenhouse production”

State-of the-art

Previous projects

- Short term storage
  - Water tank, PCM
- Long term storage
  - Paraffin, ATES, BTES
- System integration
  - Distribution systems
- Energy savings
  - 20 - 60 % increase
- Increase in product yields
  - 10 - 40 % increase
- Economics
  - Semi vs closed, $/kWh

“lessons learned...”
Boundary conditions

- Climate data
- Energy requirement
- Plant varieties
  - Temperature, humidity, evapo-transpiration, growth parameters,...
- Air exchange
- CO₂
- Dehumidification
- Control algorithms

"if you can handle a greenhouse you can handle any building"

Technology: ATES

- Pre-investigations
  - Aquifer properties
- Sources of energy
- Design
  - Wells
  - With or without heat pump
- Control strategies

"First ATES greenhouse project in Netherlands is 10 years old"
Technology : BTES

• Pre-investigations
  – Thermal response test
• Design
  – Ground heat exchanger
  – Borehole configuration
  – ....
• Control strategies

“stratified thermal borehole storage”

Technology : PCM

• Short term storage
  – Buffer tank
  – Peak shaving
  – Enhancing stratification in water tanks
  – Temperature control
• PCM choices and criteria
  – Organics & inorganics
  – melting range, latent heat, ...
• Containers
  – Various size, shape, material
• Structures
  – PCM towers in the greenhouse

“material may be very cheap, but with container and preparation cost increases”
Technology: Water tank

- Short and long term
- Buffer tank
- Storing heat from $CO_2$ production in summer
- Stratification
- Cost
  - 100 Euro/m3

“cheapest storage”

Technology: Short term + Long term

- BTES + Water tank and/or PCM
- ATES + Water tank and/or PCM
- Control strategies
- Optimization

“smart strategies for optimization”
Distribution systems

- Centralized air distribution
- Water distribution
  - Pipes, channels
- Fan coils
- AHUs

“increased air movement in the greenhouse having a positive effect on product yield”

Models

- Developing simulation models
  - Using TRYNSYS, ...
- Models for ground coupled systems
  - EED, ...
- RETScreen
  - include projects in RETScreen database
- Models validation and evaluation
Presented Projects

<table>
<thead>
<tr>
<th>Country</th>
<th>Previous projects</th>
<th>Anex 22 demo project(s)</th>
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</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>ATES, BTES, PCM, ground coupled gas absorption HP</td>
<td>ATES+HP for strawberry greenhouse</td>
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<tr>
<td>France</td>
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<td>ATES for tomatoes</td>
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<td>NL</td>
<td>ATES, ATES+water</td>
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<tr>
<td>Norway</td>
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<td>BTES+water for tomatoes</td>
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<tr>
<td>Sweden</td>
<td>-</td>
<td>ATES or BTES +short term storage for ?</td>
</tr>
<tr>
<td>Turkey</td>
<td>ATES, PCM</td>
<td>PCM for temperature control in root zone of zucchinis</td>
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Organization of Activities
Four Working Groups

- WG1: State-of-the-art
- WG2: Modeling
- WG3: Systems
- WG4: Optimization
WG1
Leader: (Canada), Belgium

- Greenhouse information (potential, production, design, plants, boundary conditions)
- Survey of modeling climate in greenhouses (who, how,..)
- Standard systems for greenhouses
- Existing systems for low energy greenhouses
- Literature survey on countries not participating in the Annex

WG2
Leader: Netherlands, (Canada)

- Identify TRYNSYS Greenhouse Modelers (TGM) and create a platform for information exchange
- Define and develop missing routines for existing models like TRYNSYS
- Collection of data on greenhouse construction materials
- Validation of the model for a standard greenhouse and (semi-) closed greenhouse
WG3
Leader: Norway, Netherlands
• Climate requirements and energy demand for traditional system
• Develop HVAC schematics
• Include/exclude lighting
• Sector feedback
• Optimal system configurations

WG4
Leader: Sweden, Turkey
• Define reference greenhouses
• System modeling
• Economical and environmental impact
Workplan

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Deliverables

- **D1**: State of the art report from each country (12M)
- **D2**: Report from modeling – including developed models and validation (24M)
- **D3**: Optimal system configurations (18M)
- **D4**: Final report (30M)
- **D5**: Web page (already started)

http://www.fskab.com/annex%2022/
# Workplan until next meeting

<table>
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<th>Actions</th>
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<td>Identification of TGMs</td>
<td>Dec 1, 2009</td>
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<td>Webpage</td>
<td>Next Experts’ Meeting</td>
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<tr>
<td>Country state-of-the-art report presentations</td>
<td>Next Experts’ Meeting</td>
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<tr>
<td>Information exchange platform possibilities</td>
<td>Next Experts’ Meeting</td>
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Next meeting will be hosted by IF Technologies in the Netherlands on April 26-28, 2010.