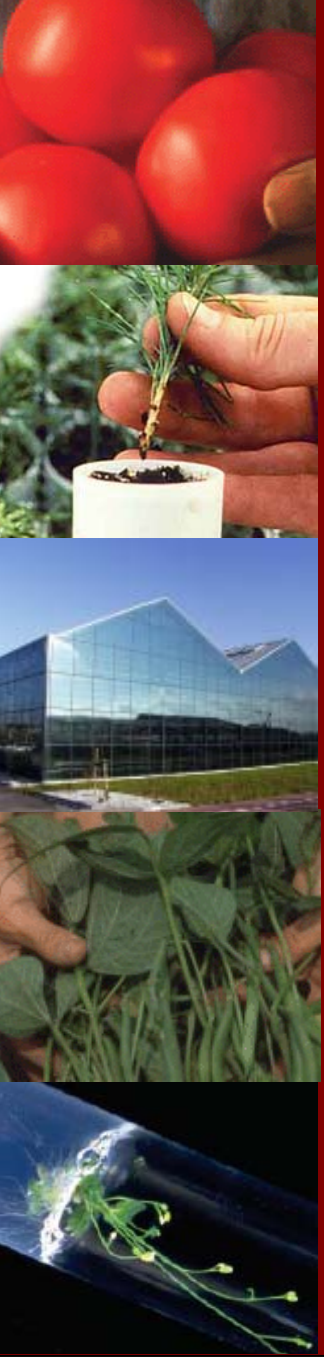


IEA ECES Concept Paper on

Energy Storage Applications in Closed Greenhouses

Frank Cruickshanks
Energy Applications Specialist
Environment Canada
June 2006

Features of a closed greenhouse:

- No ventilation windows
- Cooling and dehumidification
- Heat storage in summer
- Use of stored heat in winter

Jop Kipp, Wageningen, *Applied Plant Research, Greenhouse Horticulture*, June 2005

Benefits of a closed greenhouse:

- 20% increase in production
- Favorable levels of CO_2 maintained ($1000ppm^2$)
- Improved efficiency of water use – reduced consumption 40-50%
- Reduced pesticide use – 80%
- Quality control of product
- Opportunity to define delivery date

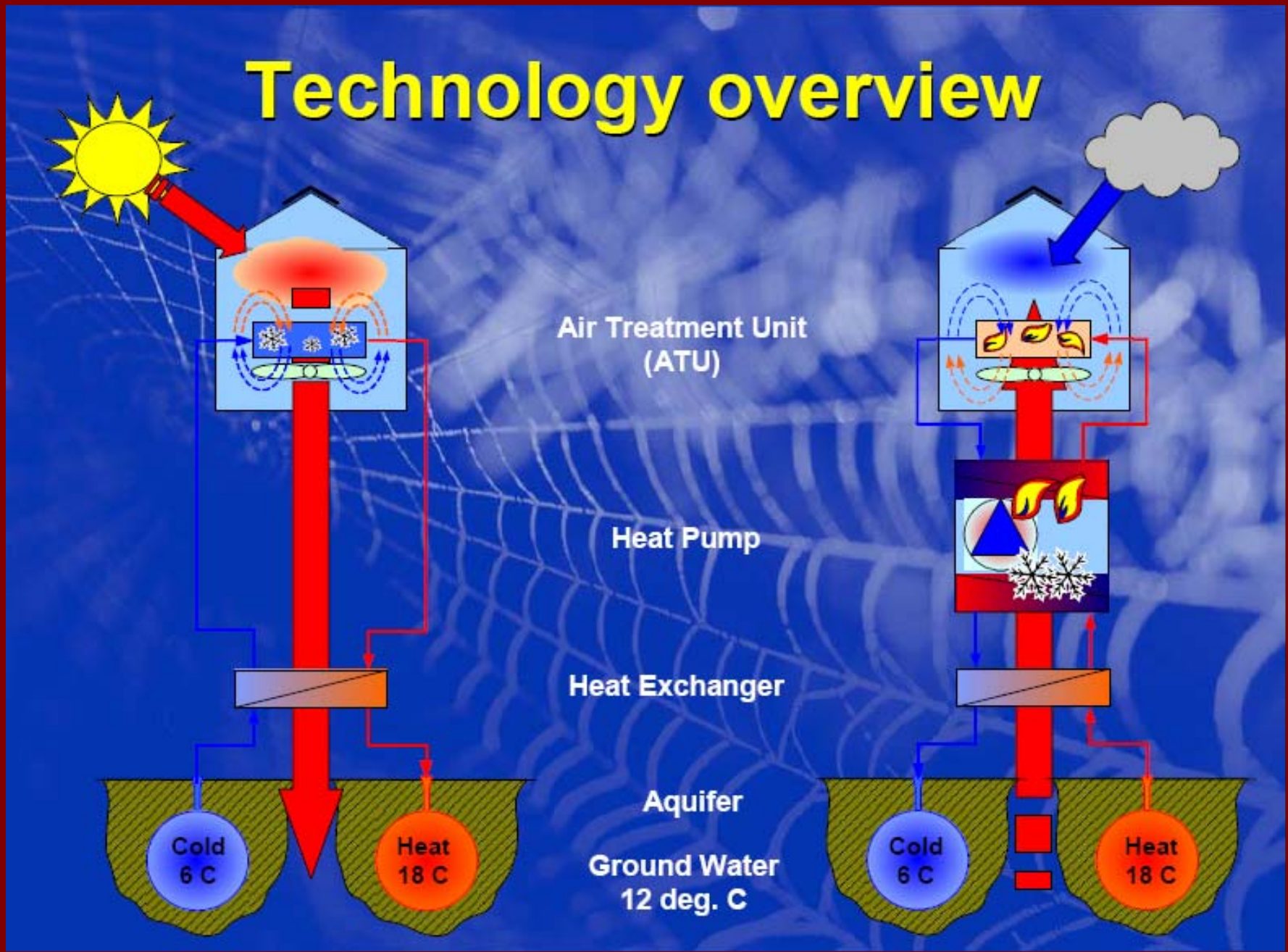
Jop Kipp, Wageningen, *Applied Plant Research, Greenhouse Horticulture*, June 2005

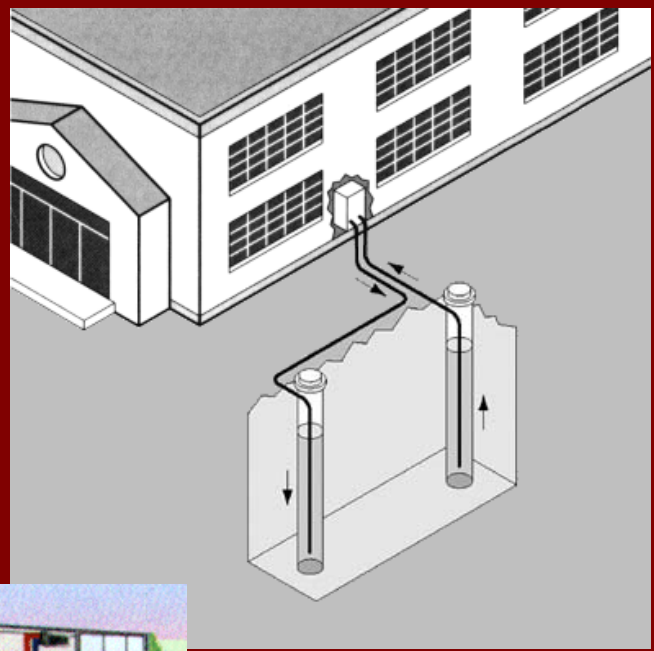
Aart Snijders, IF Technology, *Underground Thermal Energy Storage: A Source of RenewableEnergy? Applications and future Developments,* 2005

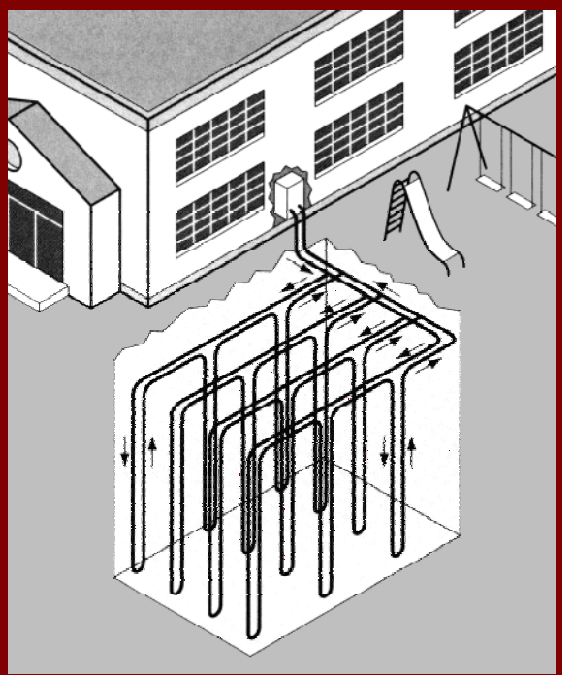
Joep van den Bosch, Priva Computers Incoroporated, *Technology Overview; Closed Greenhouses*

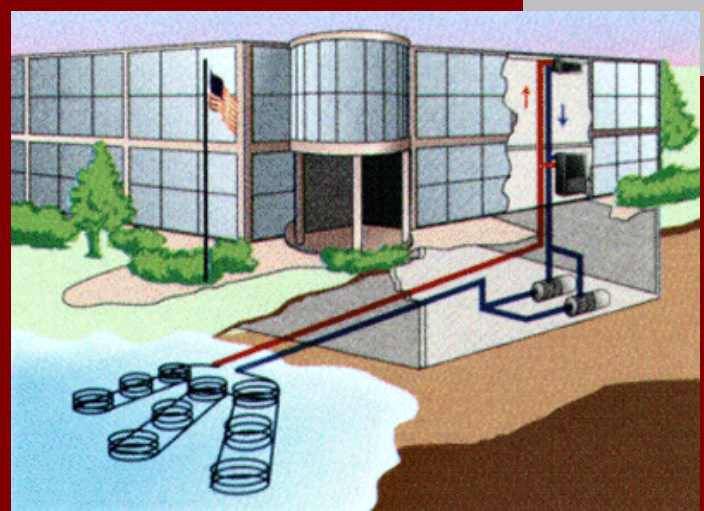
System components of a closed greenhouse:

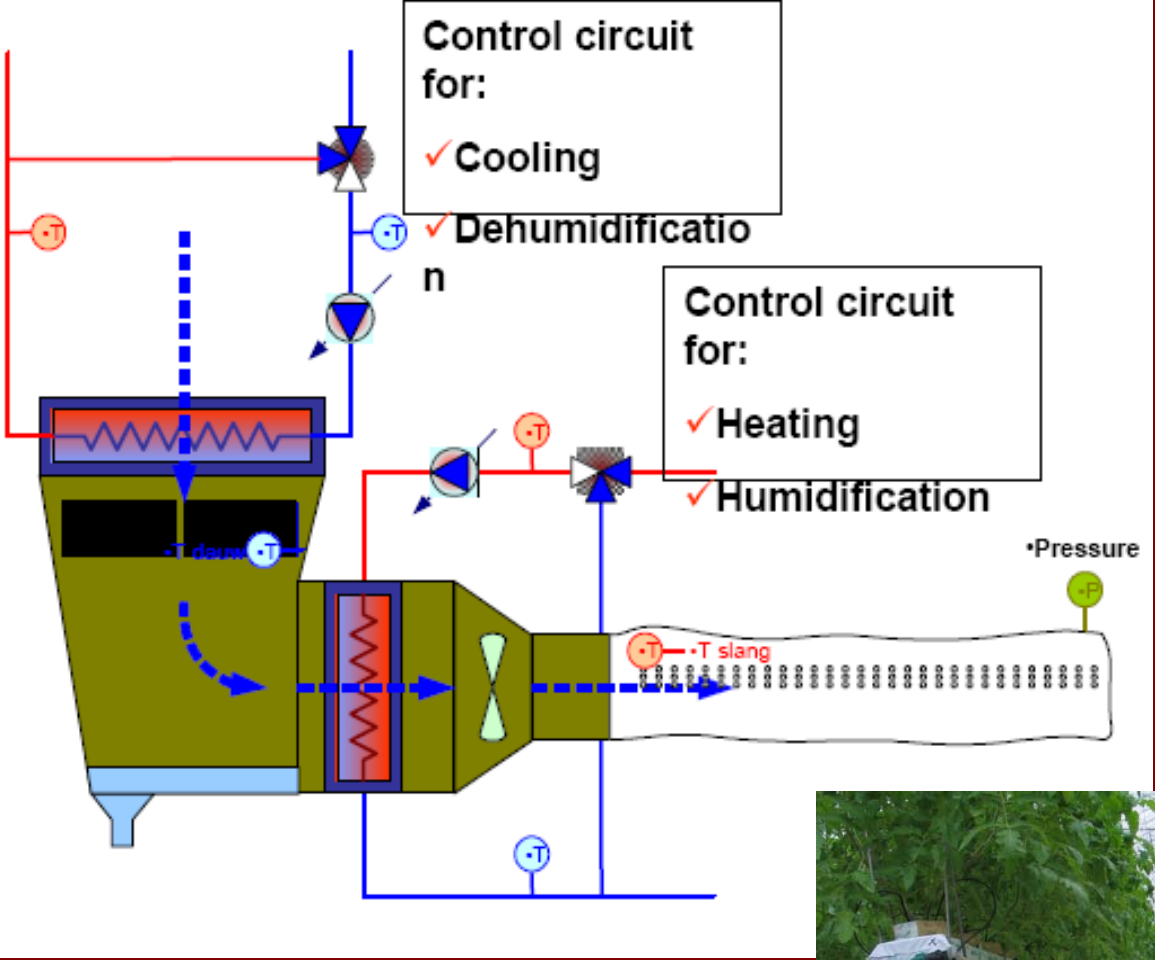
- (Thus Far) Aquifers and heat exchanger
  - Could be Phase Change
- Heat Pumps
- Air treatment units
- Water storage/buffer in cold and hot water
- Solar energy management
- Evaporative Cooling
- Cogeneration


Technology overview
Air Treatment Unit
(ATU)
Heat Pump
Heat Exchanger
Aquifer
Ground Water
12 deg. C
Cold
6 C
Heat
18 C
Cold
6 C
Heat
18 C



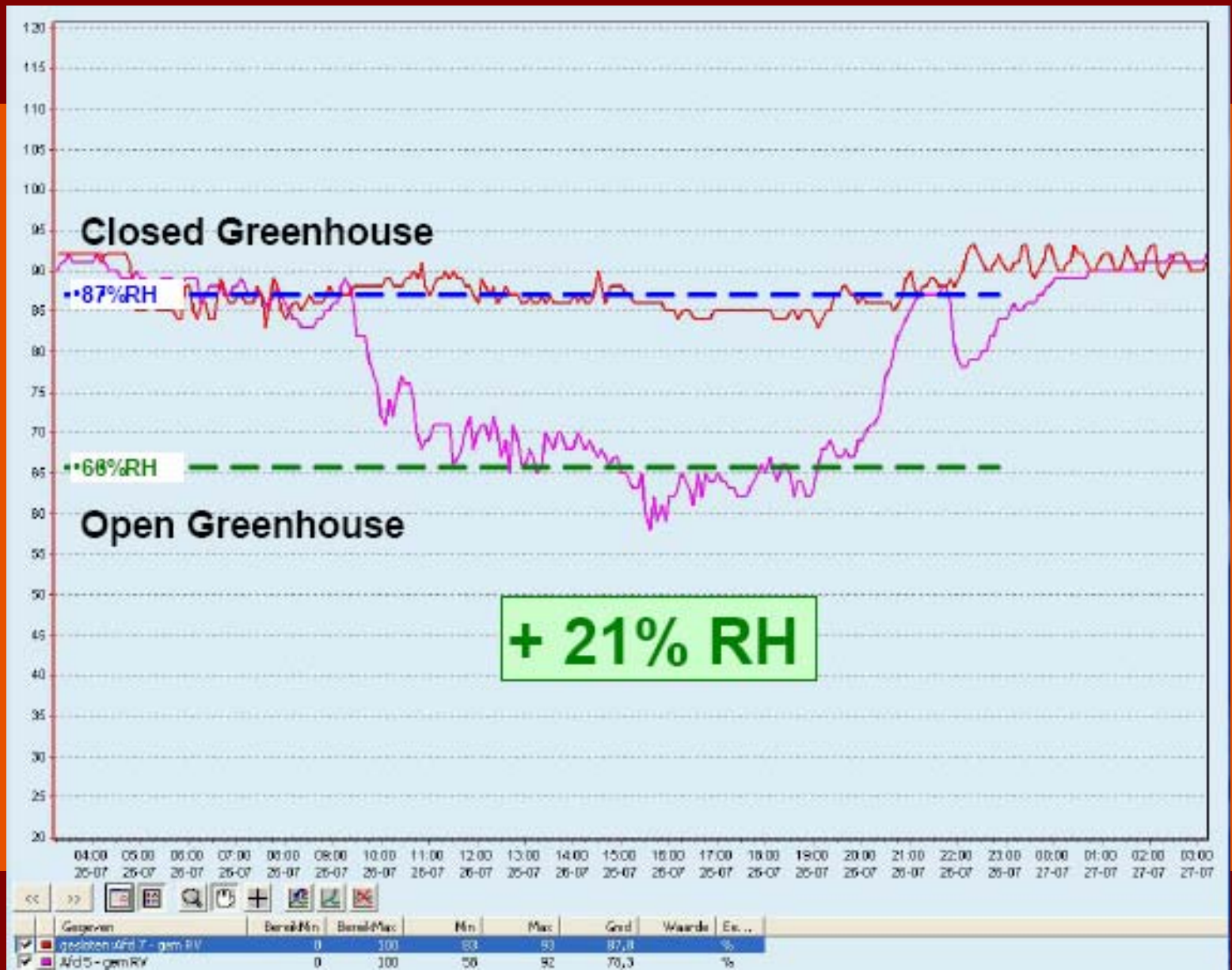





Control circuit for:
✓Cooling
✓Dehumidificatio n
Control circuit for:
✓Heating
✓Humidification
•Pressure
•T slang


GeslotenKas

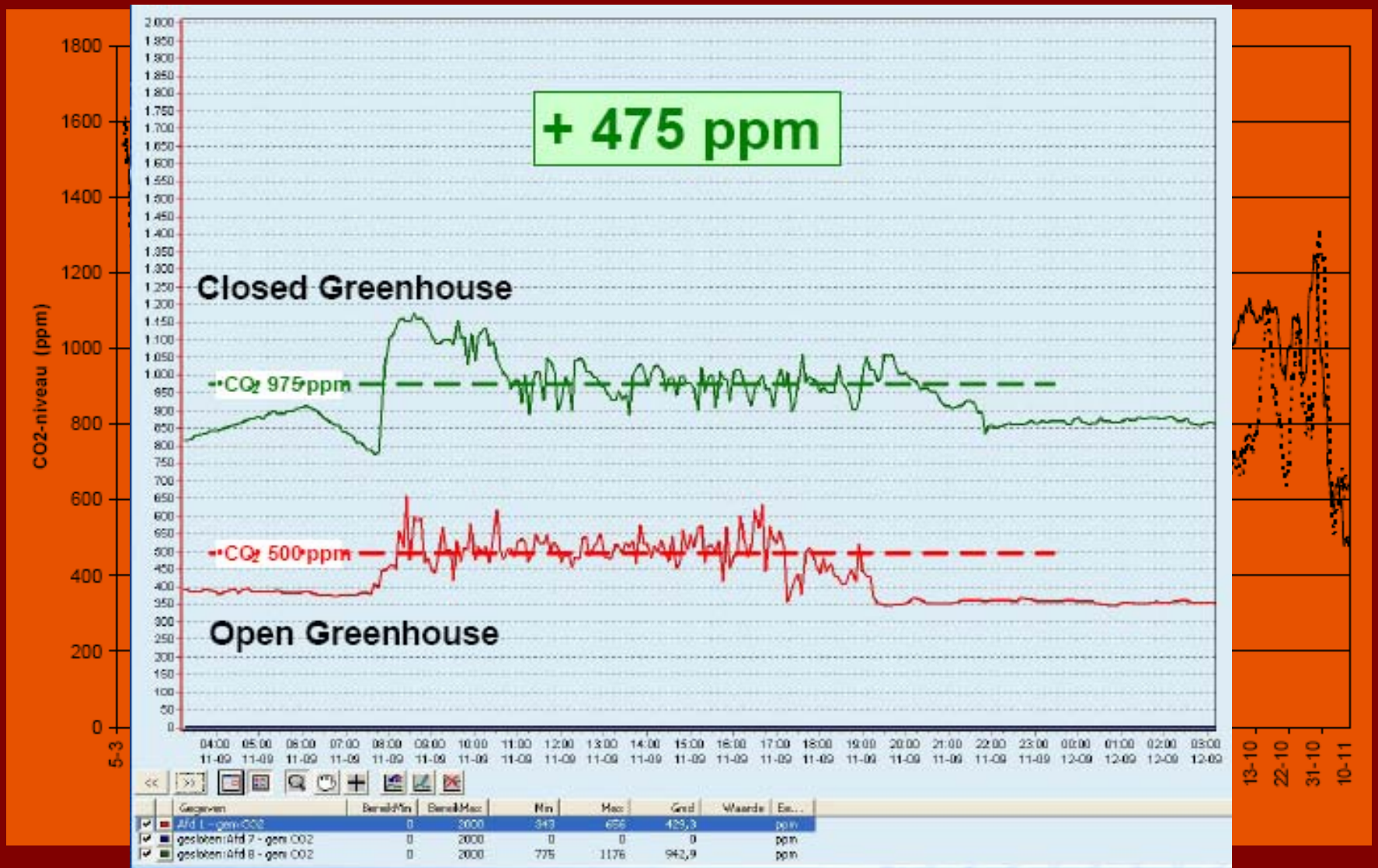
Relative humidity – results from Jop Kipp and Joep van den Bosch



Jop Kipp, Wageningen, *Applied Plant Research, Greenhouse Horticulture*, June 2005
Joep van den Bosch, Priva Computers Incoroporated, *Technology Overview; Closed Greenhouses*

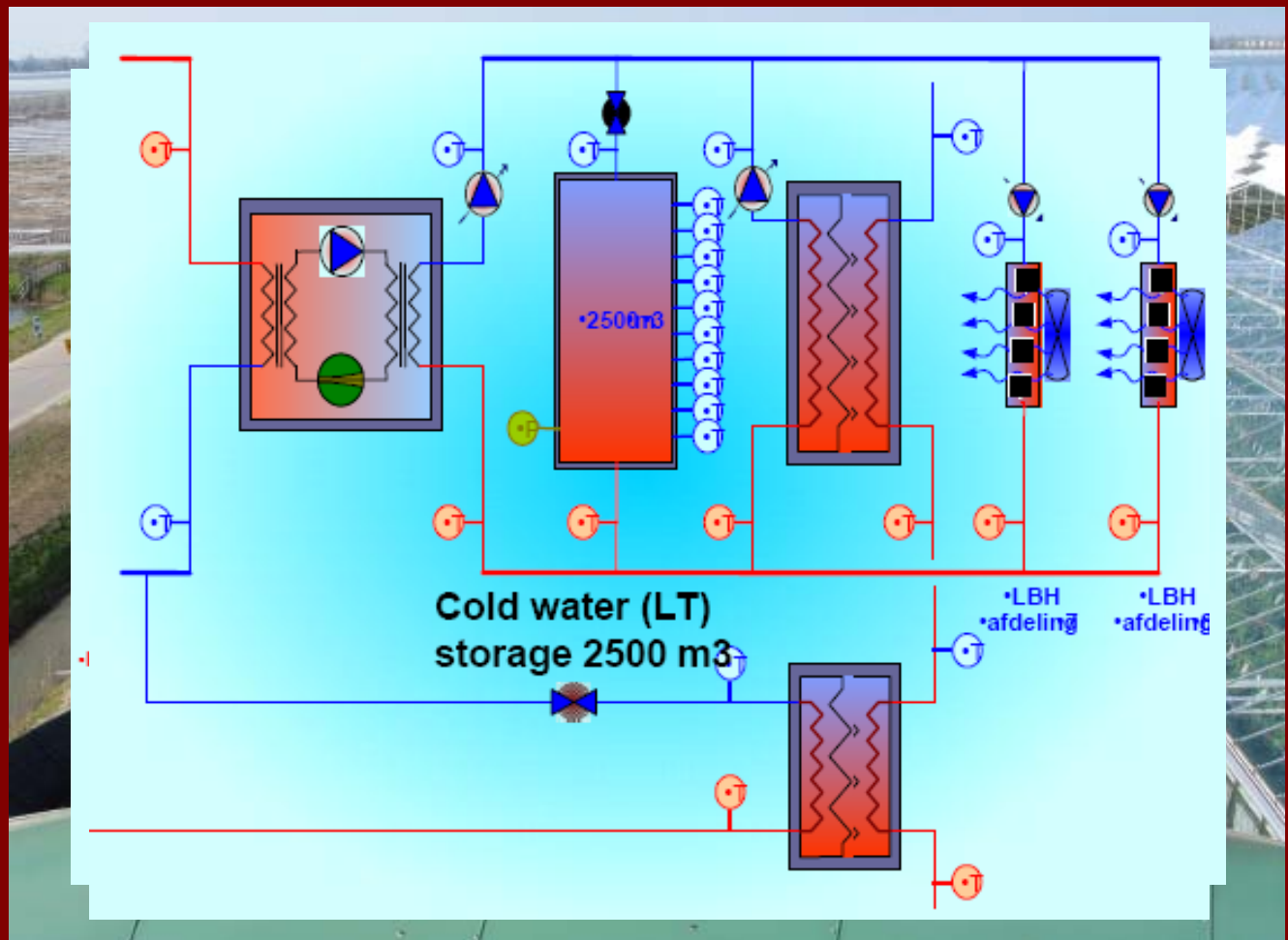
Environment Canada Environnement Canada

Daytime CO_2 concentration – results from Jop Kipp and Joep van den Bosch



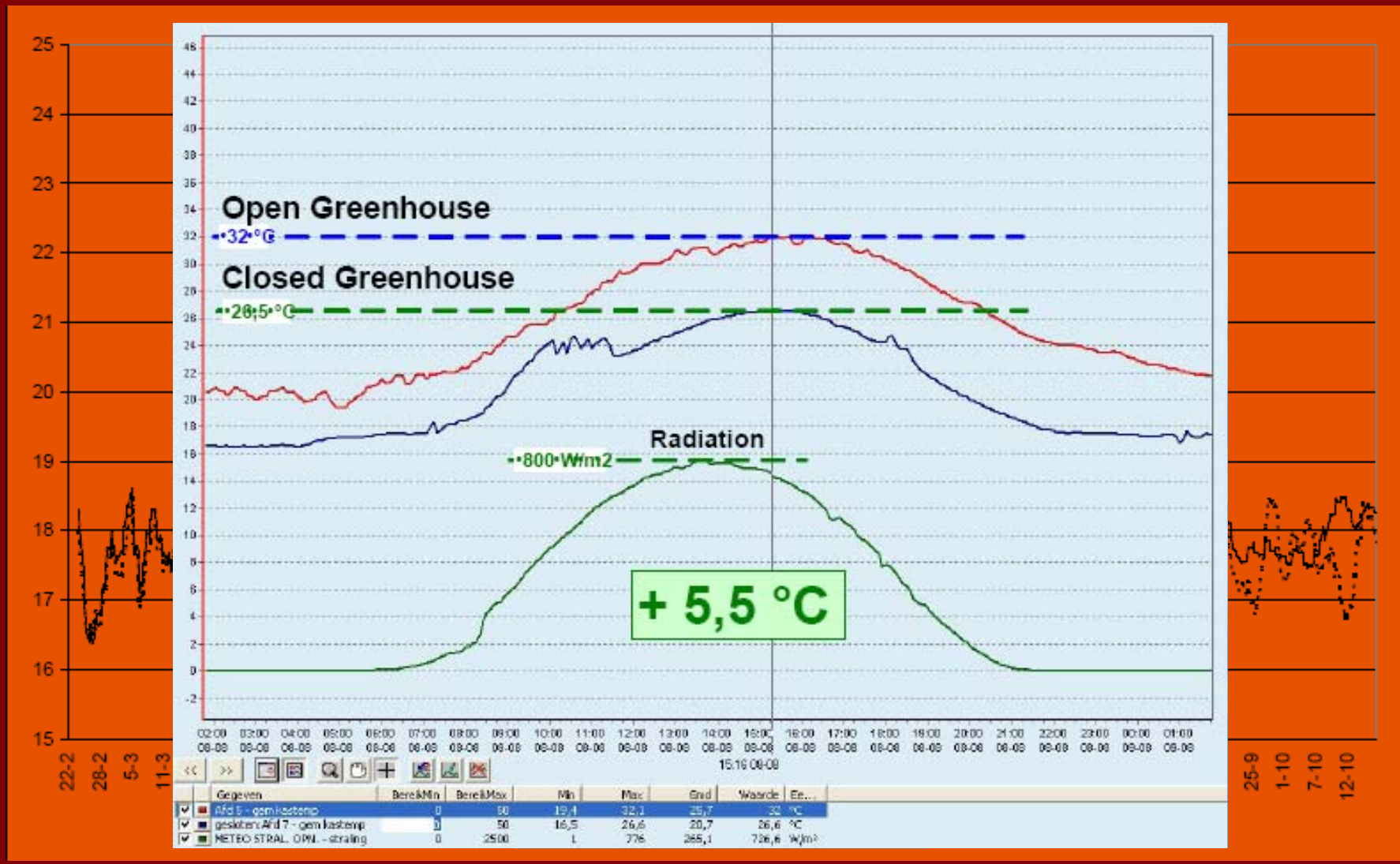
Jop Kipp, Wageningen, *Applied Plant Research, Greenhouse Horticulture*, June 2005
Joep van den Bosch, Priva Computers Incoroporated, *Technology Overview; Closed Greenhouses*

Water storage/buffer in hot and cold water



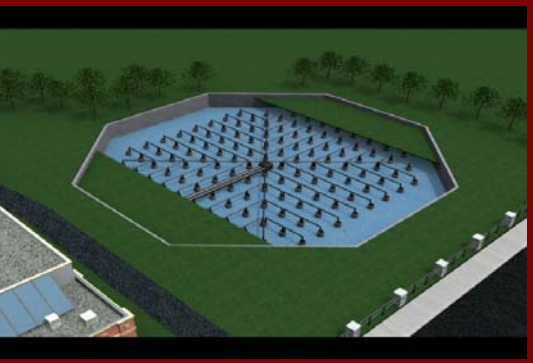
Solar energy management

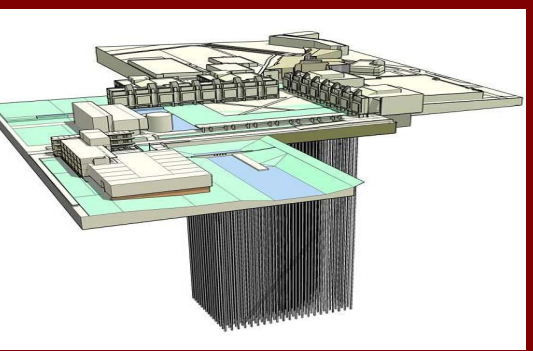
Solar energy management – results from Jop Kipp and Joep van den Bosch



Jop Kipp, Wageningen, *Applied Plant Research, Greenhouse Horticulture*, June 2005
Joep van den Bosch, Priva Computers Incoroporated, *Technology Overview; Closed Greenhouses*

Environment Canada Environnement Canada





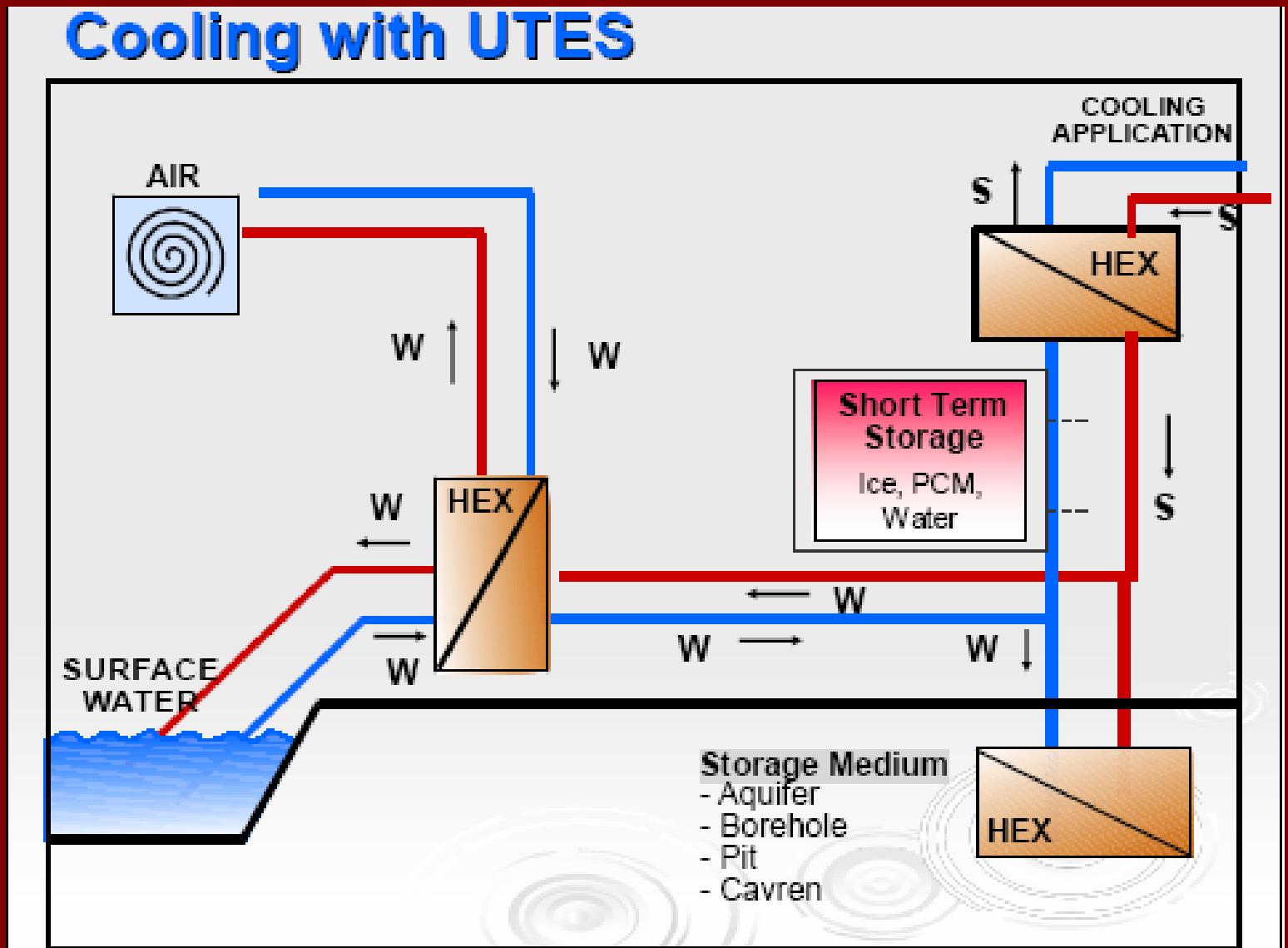
Energy storage application in a closed greenhouse offers:

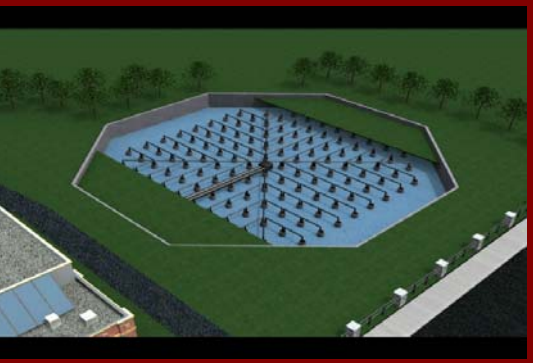
- Use of renewable energy 'sources'
- Overall efficiency of greenhouse operation
- Improved economic viability

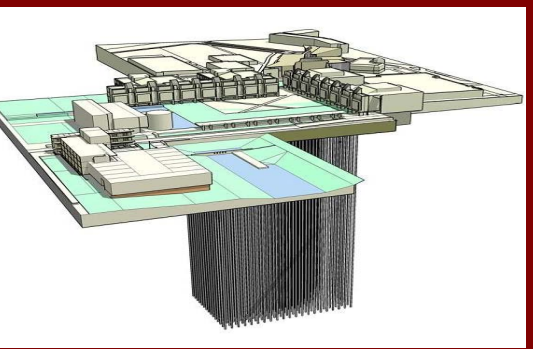
By what means?

- Addressing combined heating and cooling
- Providing dehumidification
- Decreasing overall energy use

Combined heating & cooling





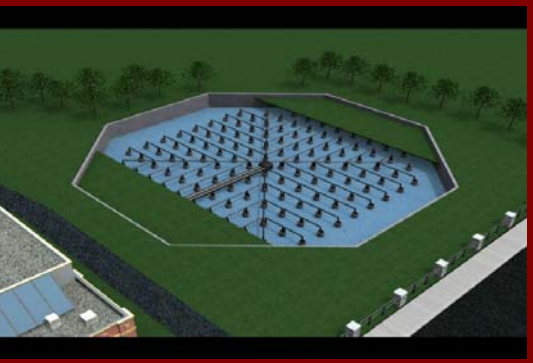


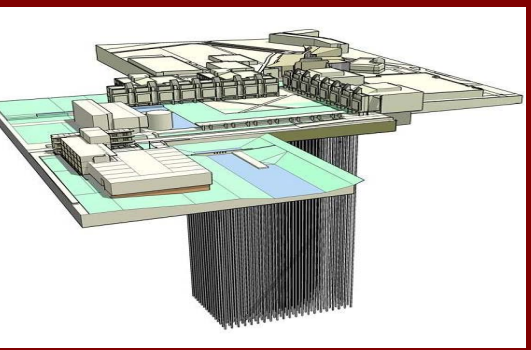
Benefits of TES to closed greenhouse:

- **30-34% higher overall energy efficiency**

- 60-80% saving on electricity consumption for cold production with ATES system
- 80-90% reduction of electrical peak for cold production with ATES system
- 20-30% saving on primary energy consumption for heat production with ATES system

Jop Kipp, Wageningen, *Applied Plant Research, Greenhouse Horticulture*, June 2005
Aart Snijders, IF Technology, *Underground Thermal Energy Storage: A Source of RenewableEnergy? Applications and future Developments,* 2005
Joep van den Bosch, Priva Computers Incoroporated, *Technology Overview; Closed Greenhouses*

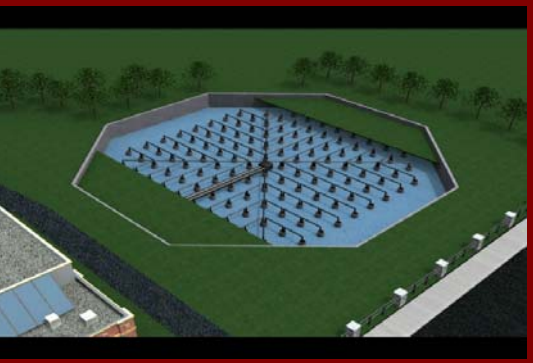


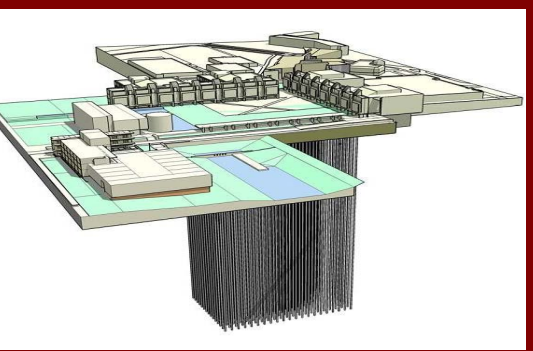


Benefits of TES to closed greenhouse:

- **Higher CO_2 levels**

- By storing unwanted heat as a means of cooling, ventilation can be reduced, which results in higher CO_2 levels and higher production.





Benefits of TES to closed greenhouse:

- **Reduced risk of liquid fuel spills**
  - spill risk poses large insurance costs

- **Cost-effectiveness**
  - Reduced equipment size
  - Lower operating costs

- **Replicable in all climates**
- **Technology currently available**

Jop Kipp, Wageningen, *Applied Plant Research, Greenhouse Horticulture*, June 2005
Aart Snijders, IF Technology, *Underground Thermal Energy Storage: A Source of RenewableEnergy? Applications and future Developments,* 2005
Joep van den Bosch, Priva Computers Incoroporated, *Technology Overview; Closed Greenhouses*





Previous activities:

Belgium

Canada

China

Denmark

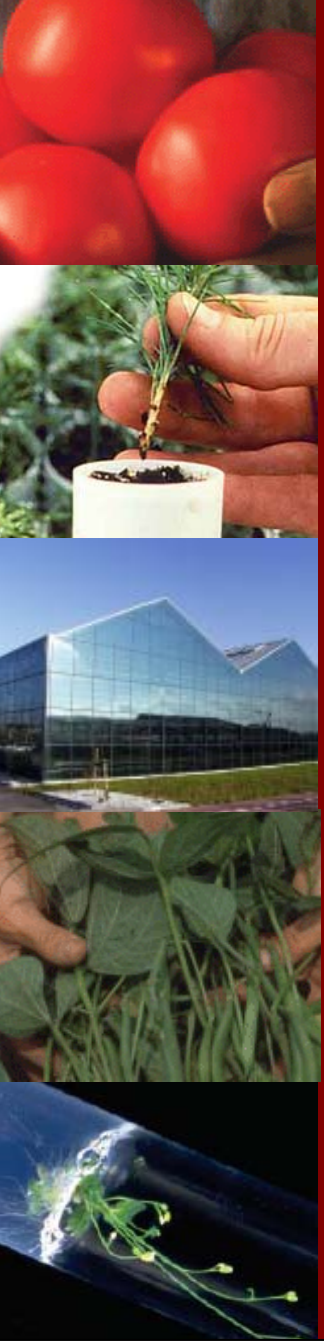
Netherlands

Norway

Switzerland

Sweden ?

Turkey



Canada: An Example of the Scope

- Approximately 214 million square feet under glass in 2005 (20 million square metres)
- Ontario has 52.5% of Canada's greenhouses; British Columbia 25%; Quebec 12%
- Increase in total operating expenses – $1.96 billion in 2005
- Average fuel cost increase of 8% per greenhouse from 2004.
- The average fuel cost = $69,906 per greenhouse or $ 257,326,000 in total 2004.

Statistics Canada (2005). Greenhouse, Sod and Nursery Industries Report
Dave Harrison, (May 2006). *Greenhouse Canada*, magazine.

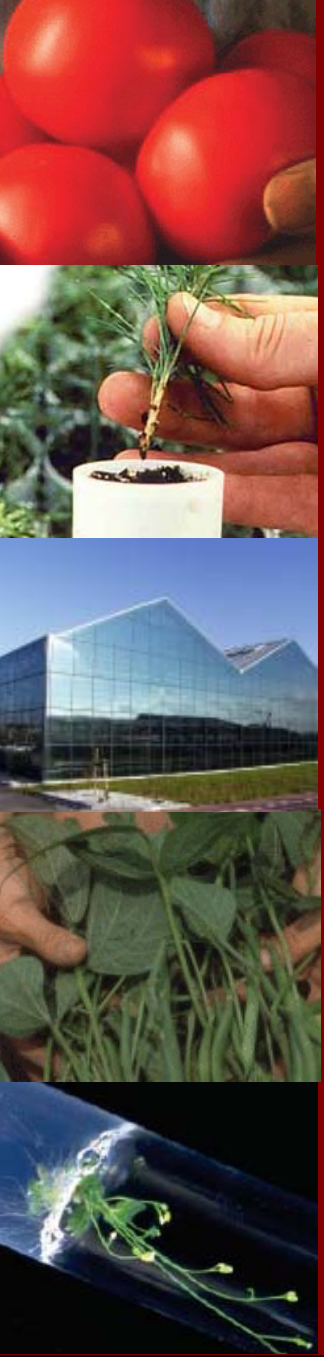




Canada: A Snapshot of the Situation

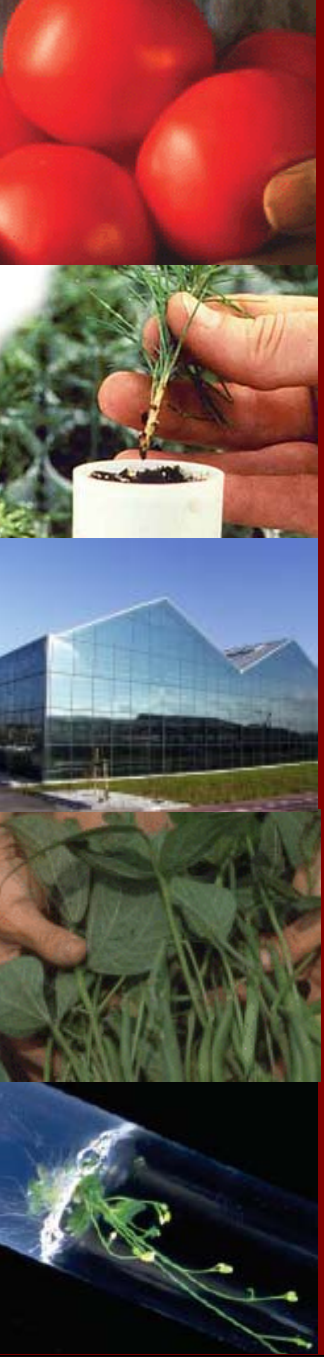
- Quebec: Proposed study about ground source heat within greenhouse system
- Ontario: DeCloet Greenhouse Manufacturing Ltd. doing energy research trials on energy balance modeling and Removal Foam Insulation
- Manitoba: Comparative study of three passive solar designs. This study has identified the need for improved dehumidification and *storage*
- Nova Scotia: Positive and similar results from a small research project at the N.S. Agricultural College.
- Nationally: The *Green Energy for Greenhouses Conference* (2005) identified the need to study aquifer characteristics around major production areas for closed greenhouses.
  - *Flowers Canada Ontario* proclaimed desire to "reinforce links with the scientific community . . . research will lead to … more efficiency and lower production costs."
  - Canada recently obtained funds to outline there approach to closed greenhouse research.

V. Ismet Ugursal, Department of Mechanical Engineering, Dalhousie University
Jim Rollesfson, PhD, Industrial Research Assistance Program National Research Council Canada



Suggested Scope of Annex

The details of implementing a closed greenhouse system which incorporates TES are critically important from a technical and economic standpoint. A new Annex dedicated to energy storage options in closed greenhouses will follow a project oriented approach to . .



Suggested Objectives of Annex

- Technology development (aquifer and borehole storage in combination with alternative sustainable and renewable energy sources).
- Demonstration of projects – Suggested by Subtask 4 of Annex 14 – field testing and validation
- Development of design guidelines/standards ?
- Market study/ID of barriers to exploitation/transfer of technology?
- Inclusion of Masters and PhD students...
- Utility involvement





Next Steps: