Solar heating activities at the Technical University of Denmark

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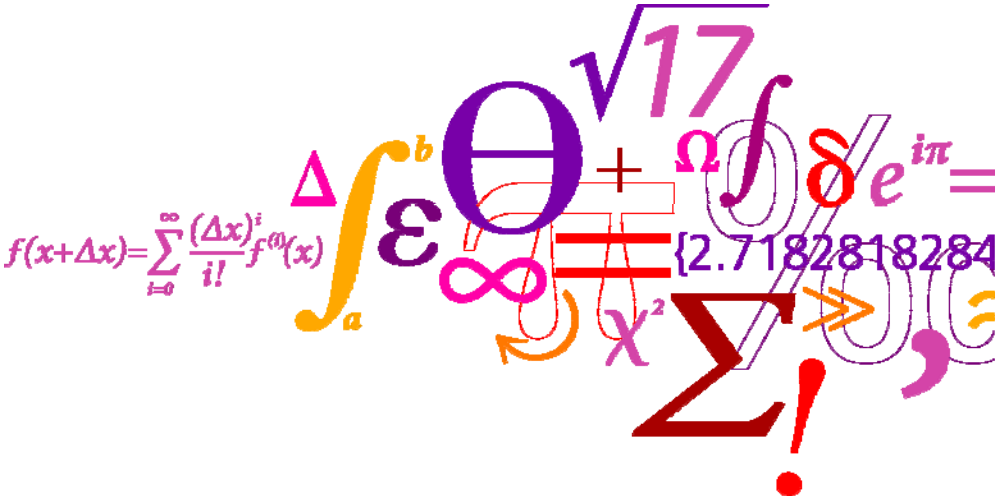
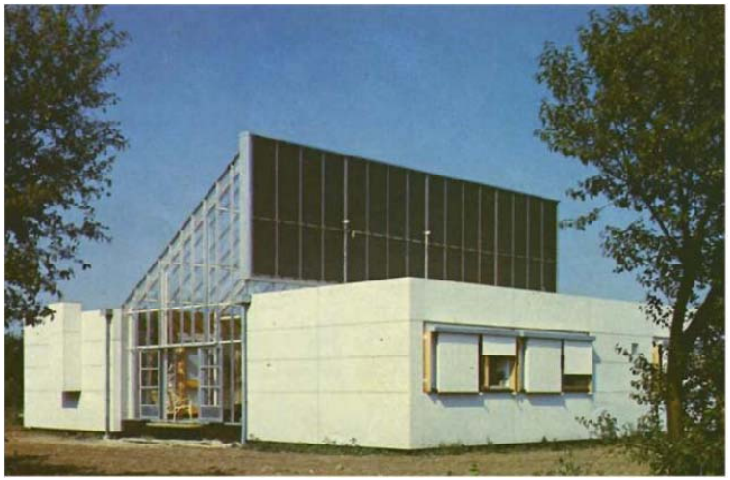


DTU Civil Engineering
Department of Civil Engineering

Solar heating research at Technical University of Denmark



1974: Start

1975: Zero Energy House

1974-1995: Thermal Insulation Laboratory

1996-2000: Department of Buildings and Energy

2001-2010: Department of Civil Engineering

Solar energy group

Scientific staff, July 2010

- Simon Furbo, associate professor, Ph.D.
- Jianhua Fan, associate professor, Ph.D.
- Elsa Andersen, senior researcher, Ph.D.
- Bengt Perers, senior researcher, Ph.D.
- Ziqian Chen, researcher, Ph.D.
- Janne Dragsted, Ph.D. student

Reseach areas

- Solar domestic hot water, SDHW systems
- Solar combi systems
- Solar heating plants
- Air collectors for dehumidification

Solar heating systems in Denmark

- Simple pay back time: 7-15 years
- Energy pay back time: 1-3 years
- **Huge** potential for technological improvements
- Need for education, research, development and demonstration

Solar heating research

Aim:

- To carry out research on a high international level
- To make the research results useable for the solar heating branch

Solar heating research

AIM:

Improvement of performance/cost-ratio

HOW:

Increased knowledge of thermal conditions and flow behaviour.
The knowledge is used for development and optimization

RESEARCH:

Parallel theoretical and experimental activities

- numerical models, CFD calculations
- flow visualization, PIV measurements
- full scale experiments

Research financed by

- Technical University of Denmark
- Danish Energy Authority
- The Danish Council for Strategic Research
- Ministry of Science, Technology and Innovation
- EU
- Greenland’s government
- Private foundations
- VILLUM FOUNDATION
- Private companies

Cooperation with:

Universities/research institutes abroad

Producers and consultants in the solar heating branch

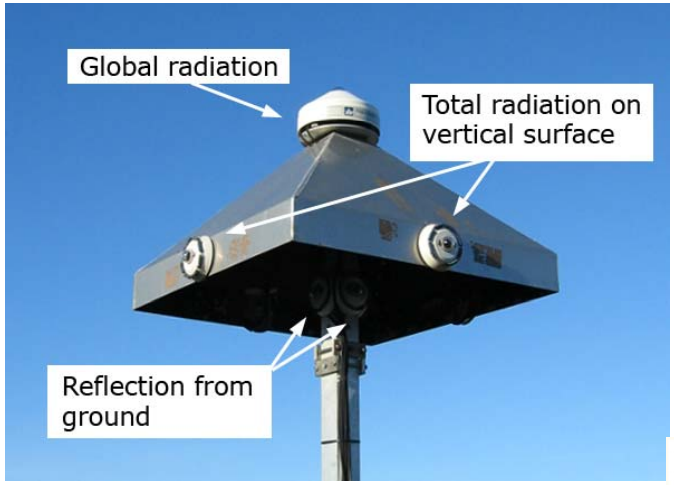
Other groups at the Technical University of Denmark

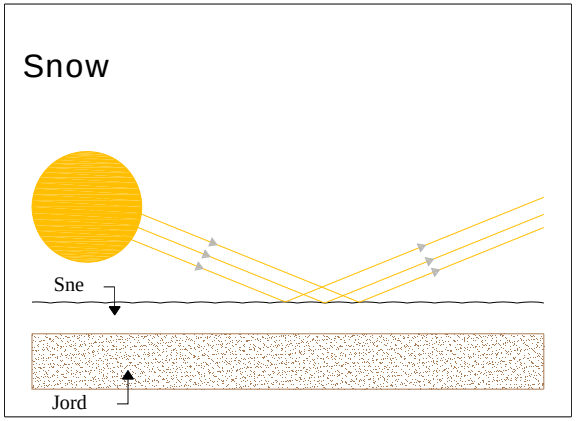
Danish research institutes, for instance TI

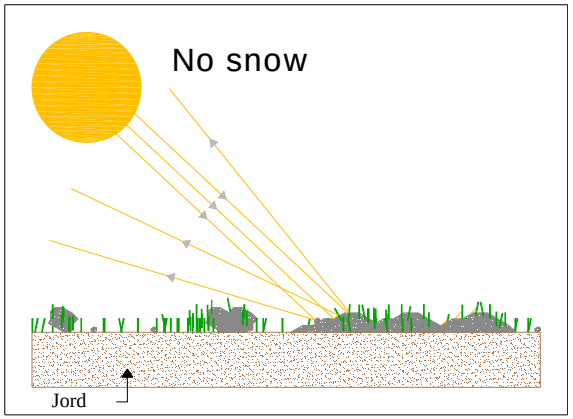
Ongoing research projects

- **Ph.D. study: Solar heating in Greenland, Janne Dragsted**
- **Solar heating systems based on evacuated tubular solar collectors for Knud Rasmussen Højskolen, Sisimiut**
- **Energy savings for solar heating systems, phase 2**
- **Solar / electric heating systems in the future energy system**
- **Research cooperation with SMV's on solar / electric heating systems in the future energy system**
- **IEA Task 42 Compact thermal energy storage: Material development and system integration**
- **Videncenter for energibesparelser i bygninger: Solar heating systems for large buildings**
- **Tracking solar collector**
- **Strategic research cooperation with China on solar combi systems**
- **IEA Task 44 on solar heating / heat pump systems**
- **Solar collector with cover plate with different profiles**
- **Supervision of Swedish Ph.D. student**
- **Air solar collectors**

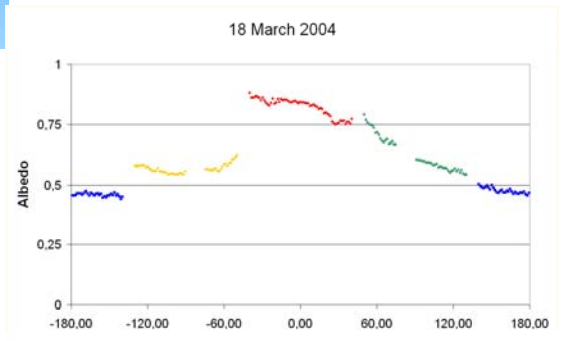
Ph.D. study: Solar heating in Greenland
Student: Janne Dragsted
Project period: 2007-2010



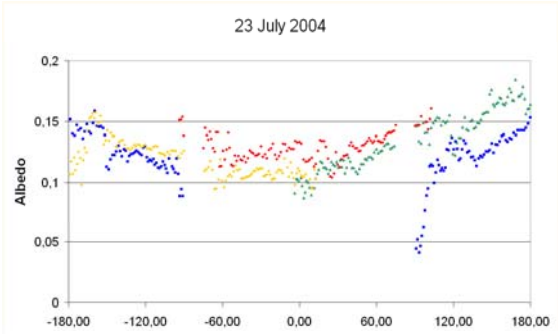




Solar radiation and albedo



Solar azimuth-surface azimuth,°



Solar azimuth-surface azimuth,°

Evacuated tubular solar collectors and solar heating systems

Ongoing research project:
Energy savings for solar heating systems

Financed by: Danish Energy Authority

Participants: Department of Civil Engineering,
Velux Danmark A/S
SONNENKRAFT Scandinavia A/S
Batec Solvarme A/S

Project period: January 2008 – December 2010

Aim: To determine energy savings for solar heating systems in one family houses

Activity:

- Analyses of energy consumption before and after installation of solar heating systems in one family houses

Solar heating systems investigated in the project

- 11 systems from SONNENKRAFT Scandinavia A/S
- 13 systems from Velux A/S
- 5 systems from Batec A/S
- 1 combined SONNENKRAFT Scandinavia/Velux system
- 10 SDHW systems and 20 solar combi systems
- Collector area: 2.2 m² - 12.5 m². Average collector area: 5.4 m²
- Store volume: 200 l - 800 l. Average store volume: 351 l
- Flat plate collectors and evacuated tubular solar collectors

Swedish investigations: Yearly energy savings: 650 - 900 kWh/m² solar collector

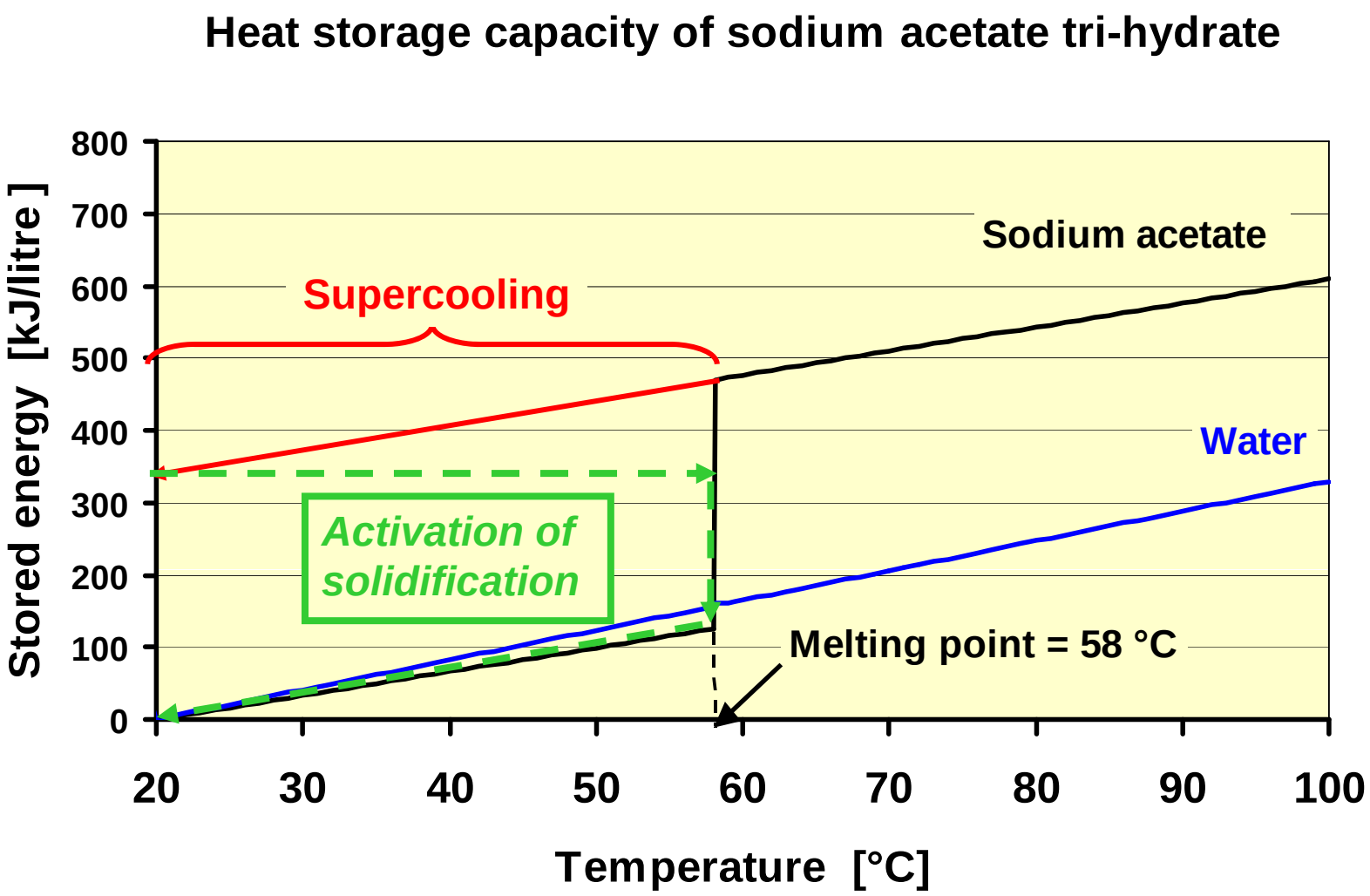
IEA Task 42 Compact thermal energy storage: Material development and system integration

Aim of work

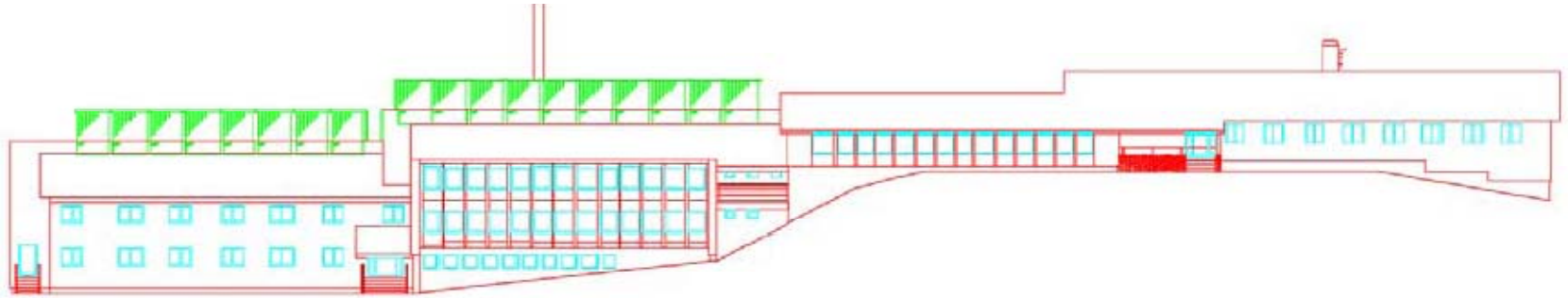
- To develop a compact seasonal heat storage based on a salt hydrate with a stable supercooling

- The heat storage can be used as a part of a solar heating system which can fully cover the yearly heat demand of new buildings in Denmark

Phase Change Material with supercooling

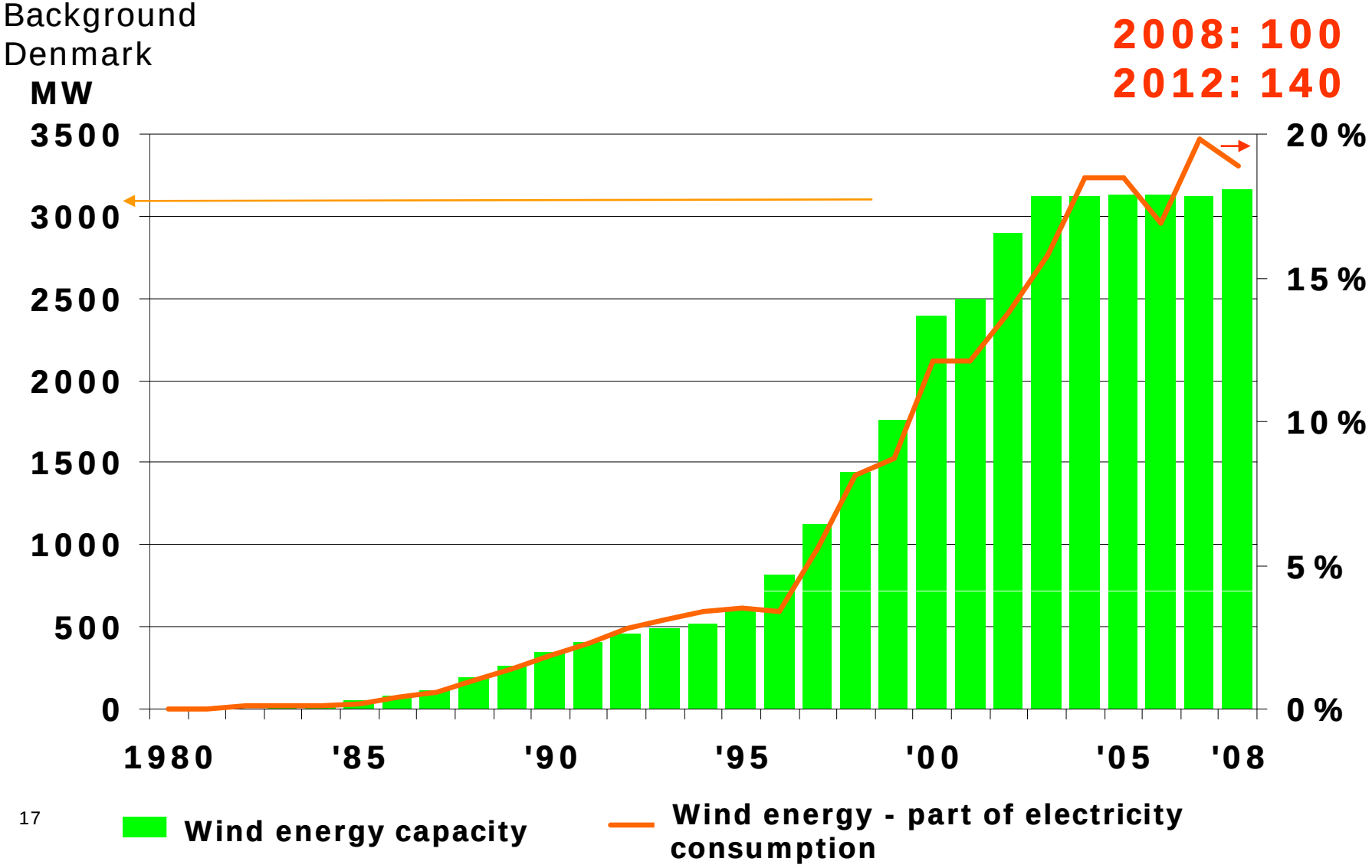


Solar heating system based on evacuated tubular solar collectors for Knud Rasmussen Highschool in Sisimiut, Greenland Installed 2008



Solar / electric heating systems for the future energy system
Project financed by Danish Agency for Science Technology and Innovation
Project period: October 2008 - March 2012

Background
Denmark



The heat unit

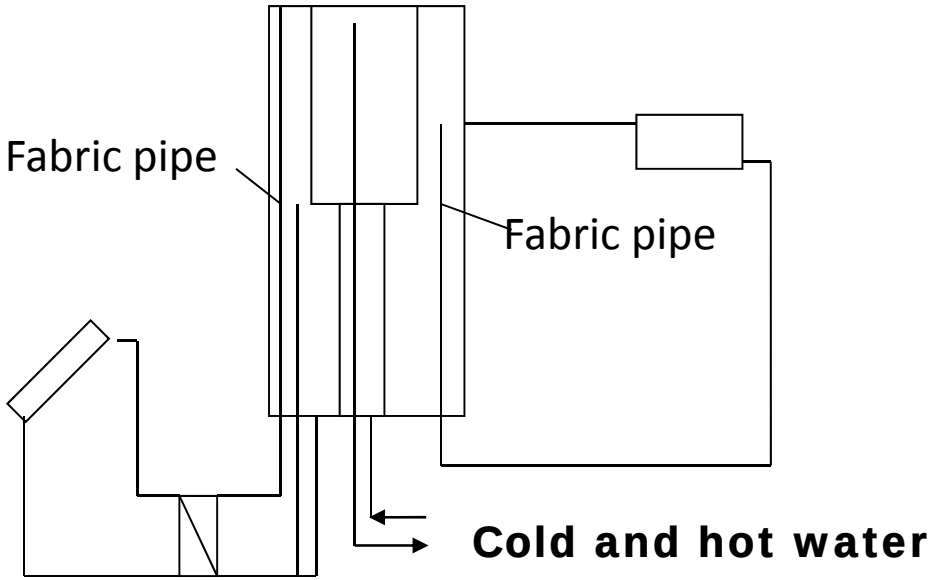
- Heat is produced by the solar heating system and by the electric heat elements or a heat pump
- The electric heat elements/heat pump should if possible only be in operation in periods where the contribution from solar heating can not cover the demand and where the electricity price is low
- The unit is equipped with a smart heat storage (variable auxiliary volume) and a smart control system which operates the unit based on prognoses for:
  - heat demand
  - solar heat production
  - electricity price
- It is expected that the unit is more cost-effective than traditional solar heating systems and an attractive alternative to individual oil- and natural gas boilers, both from an economic and environmental point of view

Activities

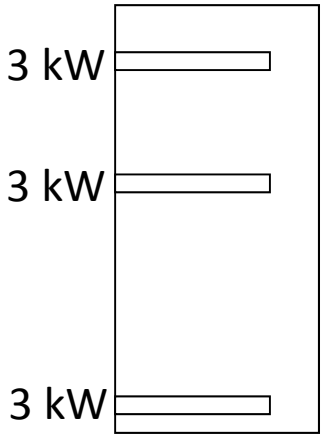
The project includes five main activities

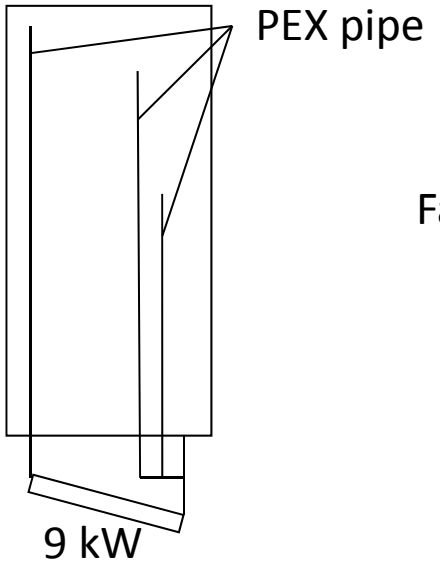
- Design of heat unit based on solar heating system, heat storage and electric heating elements / heat pump DTU Byg, Ajva ApS, Ohmatex ApS
- Development of detailed weather forecast model to predict solar radiation, temperatures and other important weather parameters DMI
- On line forecasting of heat demand, solar heat production and electricity prices DTU Informatics, ENFOR A/S
- Development of control system that can communicate with DMI and operate the solar-electric heat unit in the best possible way AllSun A/S
- Analysis of how the developed heat unit, if used in large numbers, will fit into the overall energy system COWI

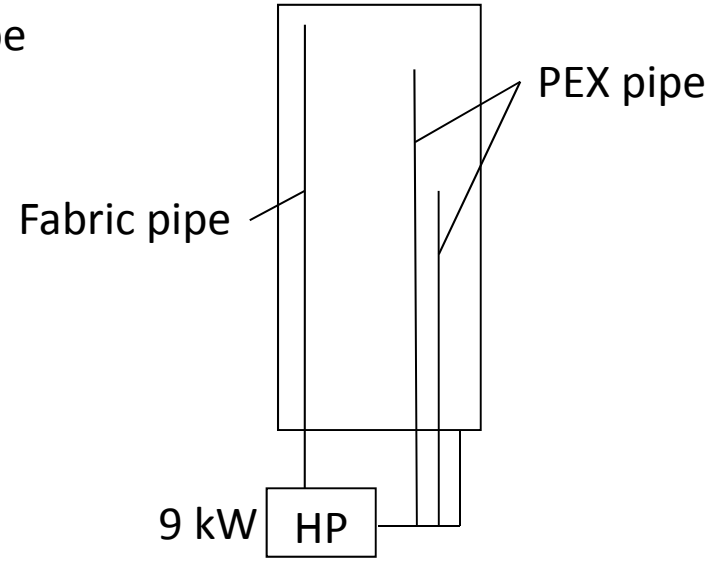
Solar collector loop & discharge loops



Auxiliary heating principles







Strategic research cooperation with China on solar combi systems

- Development and demonstration of solar combi systems for Denmark and China
- Laboratory tests
- Demonstration in practice

IEA Task 44 on solar heating / heat pump systems

- Test of solar/heat pump system in laboratory test facility
- Development and validation of simulation model

Solar collector with cover plate with different profiles

Cooperation with Nordic Energy Group A/S

- Development of new roof integrated solar collector with polymer cover plate

Ph.D. studies finished 2007

- Elsa Andersen: Solar combi systems
- Alexander Thür: Compact Solar Combisystem. High Efficiency by Minimizing Temperatures

Ph.D. study finished 2010

- Eshagh Yazdashenas: Advanced solar combi systems

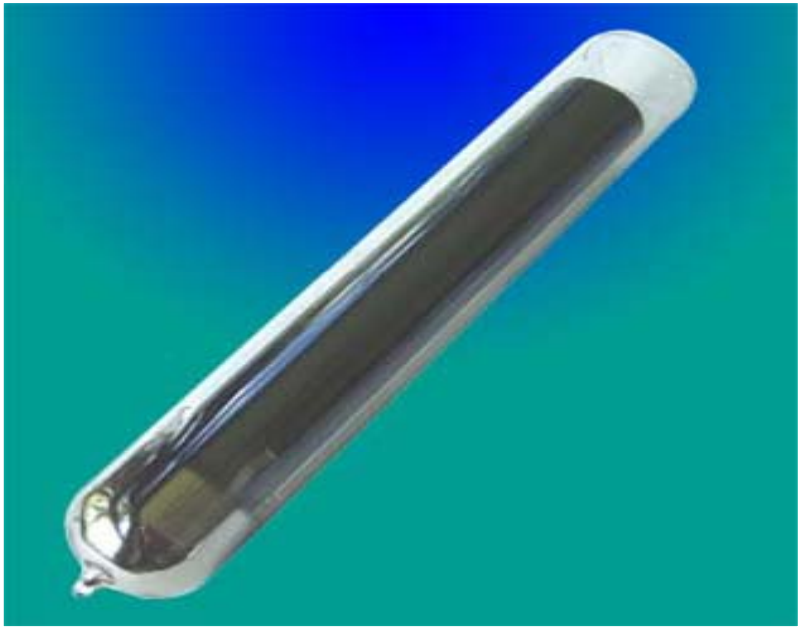
Test facilities

- Indoor heat storage test facility
- Indoor solar simulator
- Indoor clima simulator
- Clima station
- Test facility for solar collectors
- Test facility for side-by-side test of evacuated tubular solar collectors
- Test facility for SDHW systems
- Test facility for solar combi systems
- PIV equipment
- Goniospectrometer

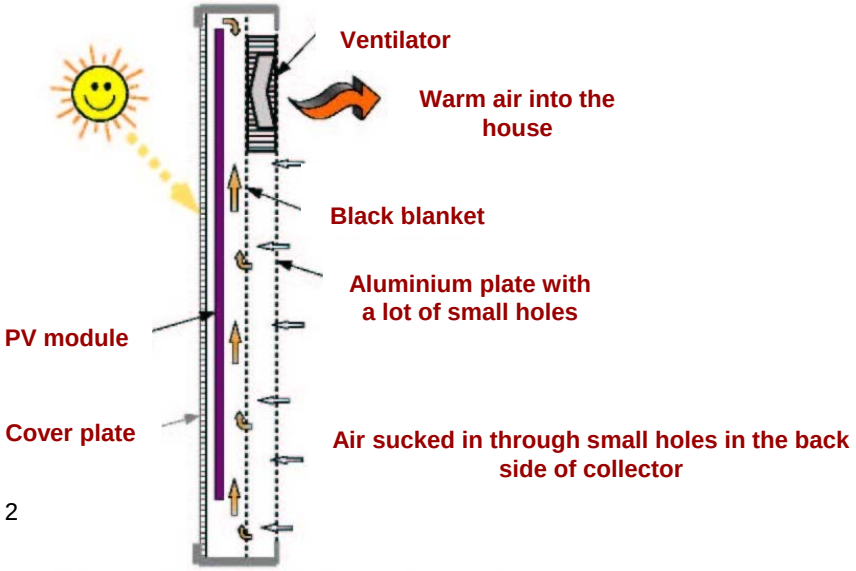
Solar collectors for solar heating plants

Antireflection treated glass

Evacuated tubular solar collectors



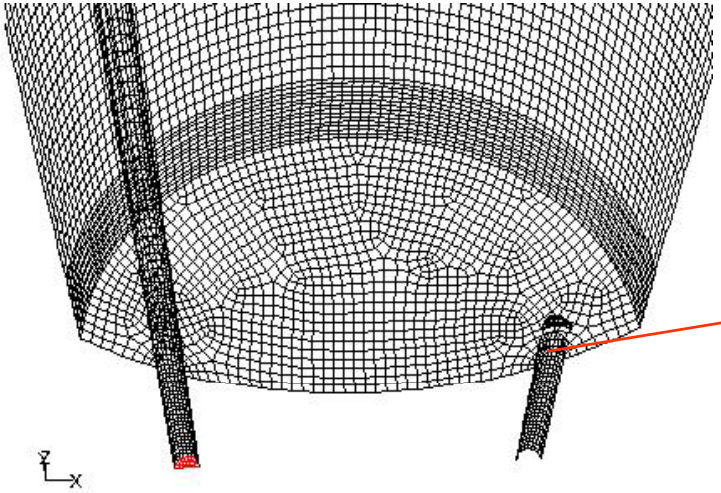
Air collector for dehumidification



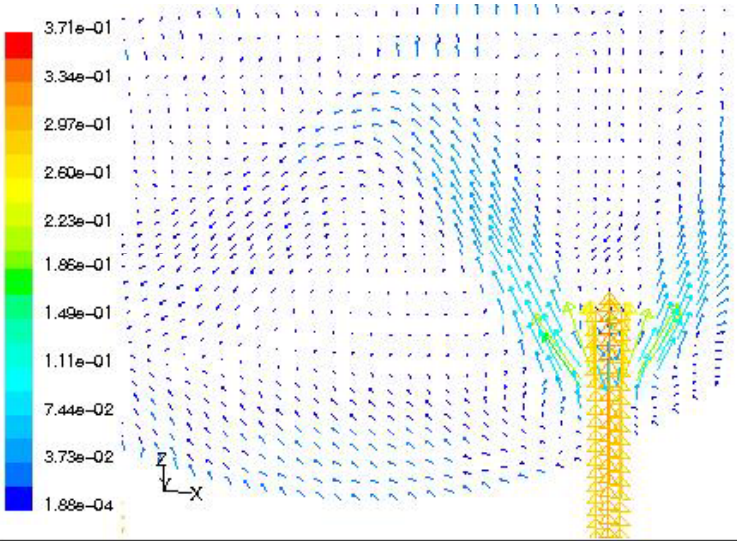
SDHW systems

Solar combi systems

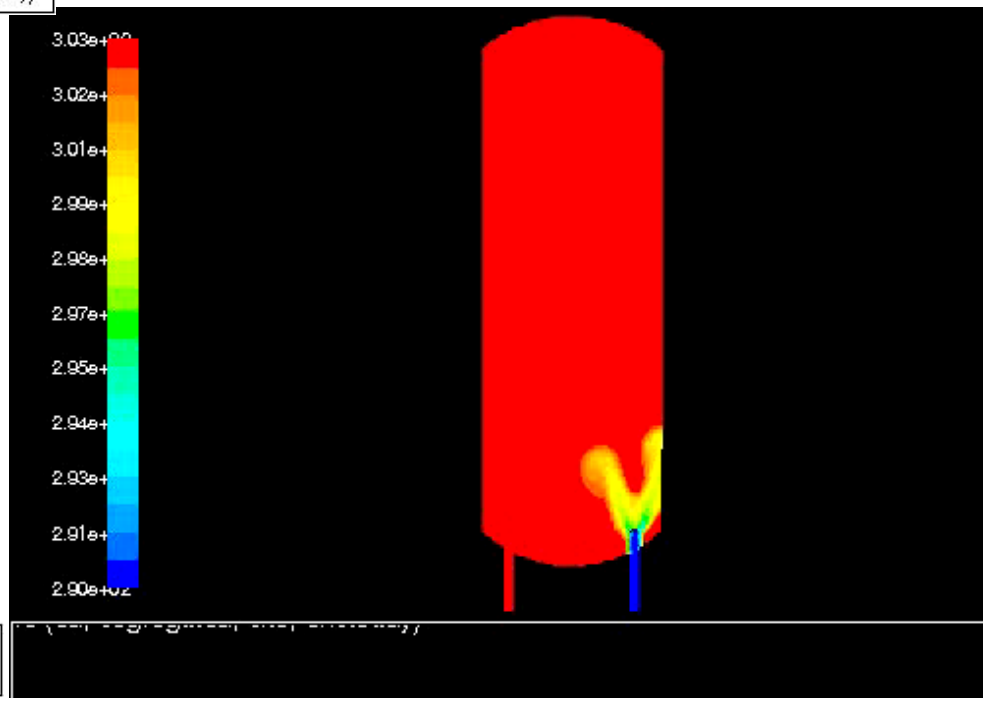
Cold water inlet in hot water tanks
CFD calculations



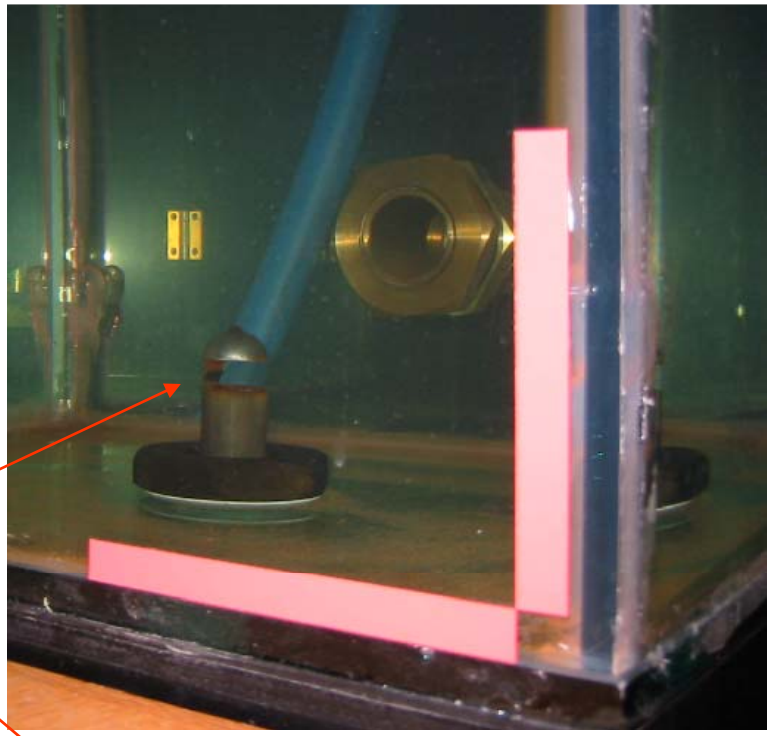
Grid (Time=1.0000e-01)
Jan 17, 2003
FLUENT 6.0 (3d, segregated, ske, unsteady)

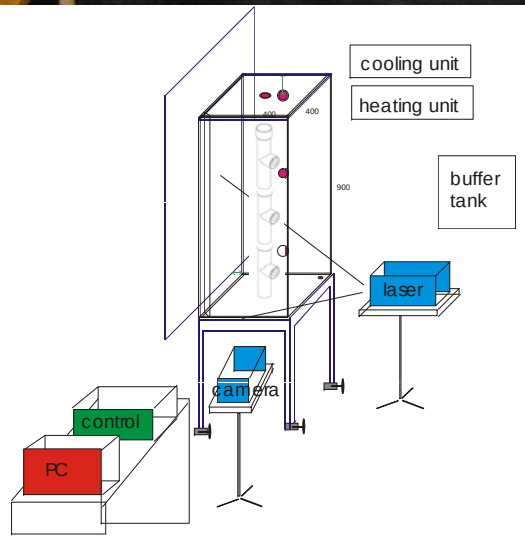


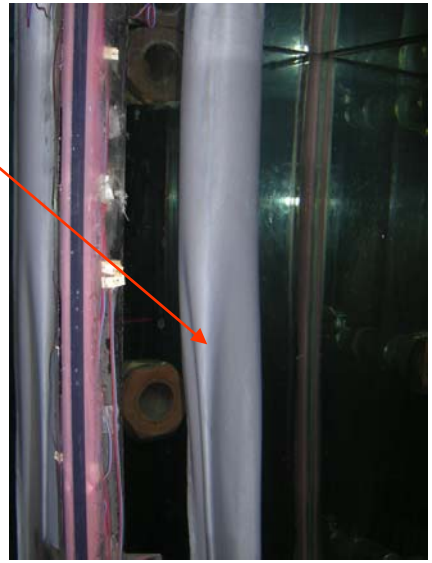
Velocity Vectors Colored By Velocity Magnitude (m/s) (Time=4.2000e+02)
Feb 20, 2003
FLUENT 6.0 (3d, segregated, ske, unsteady)



Particle Image Velocimetry equipment







Reports from:

- Thermal Insulation Laboratory
- Department of Buildings and Energy
- Department of Civil Engineering
  www.byg.dtu.dk