SPF activities in the field of Solar Cooling

IEA SHC Task Definition Meeting
Paris, March 2013

Dr. Elimar Frank, Dr. Paul Gantenbein
Research Director SPF - Institut für Solartechnik
Hochschule für Technik Rapperswil (HSR)
- SPF Institute for Solar Technology
- University of Applied Sciences Rapperswil
- Approx. 40 scientists and engineers
- 30% in Department Testing
- 70% in Department Research
Sorption Storage Project

- Design and construction of sorption heat and mass exchanger, design
- Use of vacuum technology (vessel, data and fluid feed through)

Flow Double Jacket (DJ)
Flow A/D HX Unit
Flow C/E HX Unit (series with DJ)

Mass spectroscopy up to 200amu
Sorbtent concentration in a particle (Particle model)
1) Sorbent fixed bed (D, L, dp)

2) Water / sorbate tank (p, T)

Sensor 1 to 10

Fixed bed

Vapour flow direction

Fixed sorption bed - zeolite.

Vapour pressure p [mbar]

position z in the fixed bed [cm]

Parameter: time t (s)

Vapour pressure loss \( \Delta p(t, z) \) → Power loss.

Velocity and concentration profile.
(Fixed bed model)
Absorption Cooling – System Characterization

LiBr-H₂O machine at SPF-HSR

Solar collector field ($T_{\text{solar}}$)

Cooling tower ($T_{\text{AC}}$)

Cold seiling ($T_{\text{E}}$)

Absorption Cooling Machine
PHÖNIX SonnenKlima GmbH
Heat rejection: Reduction of auxiliary energy and water use

Open Cooling Tower versus Hybrid Cooler
Thermal characterisation of sorption heat and mass exchangers: 
Test rig for components of 1 kW cooling power. 
Sorption kinetics $m(t)$ in the gram range (sorption material)

Coated heat and mass exchanger.

$T_{solar} = 85^\circ C$  $T_{AC} = 30^\circ C$  $T_E = 20^\circ C$
Simulation of solar thermal cooling system

Simulation of systems, solar thermal energy plant combined with hot water and cold water storage as well as free cooling and cold storage
Simulation of Solar thermal cooling system

- Validation with measurement data from an adsorption system (with additional free cooling) and an adsorption system
- Optimization of control conditions / strategies.
**CO₂ Emissions of different systems and locations**

**Locations. Lugano, Athens & Dubai**

**Buildings: SFH, Office Building, Factory Building**

<table>
<thead>
<tr>
<th>Location</th>
<th>System</th>
<th>AKM</th>
<th>KKM + PV</th>
<th>nur KKM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lugano</strong></td>
<td>EFH</td>
<td>3.5</td>
<td>5.4</td>
<td>19.8</td>
</tr>
<tr>
<td></td>
<td>Bürobau</td>
<td>46.9</td>
<td>100.6</td>
<td>369.6</td>
</tr>
<tr>
<td></td>
<td>Fabrikbau</td>
<td>147.5</td>
<td>316.6</td>
<td>1'163.4</td>
</tr>
<tr>
<td><strong>Athen</strong></td>
<td>EFH</td>
<td>11.8</td>
<td>18.2</td>
<td>67.0</td>
</tr>
<tr>
<td></td>
<td>Bürobau</td>
<td>81.1</td>
<td>174.1</td>
<td>639.7</td>
</tr>
<tr>
<td></td>
<td>Fabrikbau</td>
<td>175.3</td>
<td>376.2</td>
<td>1'382.3</td>
</tr>
<tr>
<td><strong>Dubai</strong></td>
<td>EFH</td>
<td>18.3</td>
<td>28.2</td>
<td>103.5</td>
</tr>
<tr>
<td></td>
<td>Bürobau</td>
<td>106.4</td>
<td>228.4</td>
<td>839.1</td>
</tr>
<tr>
<td></td>
<td>Fabrikbau</td>
<td>458.7</td>
<td>984.5</td>
<td>3'617.2</td>
</tr>
</tbody>
</table>

Tabelle 4: CO₂ Emission der Systeme an den jeweiligen Standorten in t/Laufzeit
### Assessment Criteria

<table>
<thead>
<tr>
<th>A</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Investment</td>
</tr>
<tr>
<td>C</td>
<td>Operation costs</td>
</tr>
<tr>
<td>D</td>
<td>Heating costs</td>
</tr>
<tr>
<td>E</td>
<td>Total costs for 20 years</td>
</tr>
<tr>
<td>F</td>
<td>CO₂ emission</td>
</tr>
</tbody>
</table>

#### Tabelle 5: Beurteilung der Systeme an den verschiedenen Standorten. Für Dubai ist keine Heizbedarf vorhanden, daher ist in der Spalte D kein Eintrag.

<table>
<thead>
<tr>
<th>Gebäude</th>
<th>Solarthermie / AKM</th>
<th>PV Anlage / KKM</th>
<th>Strom-Mix / KKM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lugano</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EFH</td>
<td>1 0 1 1 0 2 5</td>
<td>2 1 2 1 1 8</td>
<td>2 2 0 1 2 0 7</td>
</tr>
<tr>
<td>Bürogemeinde</td>
<td>2 0 1 2 0 2 7</td>
<td>2 1 2 0 1 7</td>
<td>2 2 0 1 2 0 7</td>
</tr>
<tr>
<td>Produktsions-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Industriebau</td>
<td>2 1 1 2 2 10</td>
<td>2 0 2 0 1 5</td>
<td>2 2 0 1 1 0 6</td>
</tr>
<tr>
<td>Athen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EFH</td>
<td>1 0 1 2 2 6</td>
<td>2 1 2 0 2 1 8</td>
<td>2 2 0 1 2 0 7</td>
</tr>
<tr>
<td>Bürogemeinde</td>
<td>2 1 1 2 2 10</td>
<td>2 1 2 0 2 1 8</td>
<td>2 2 0 1 0 0 5</td>
</tr>
<tr>
<td>Produktsions-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Industriebau</td>
<td>2 1 1 2 2 10</td>
<td>2 0 2 0 1 1 6</td>
<td>2 2 0 1 0 0 5</td>
</tr>
<tr>
<td>Dubai</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EFH</td>
<td>1 0 1 0 2 4</td>
<td>2 1 1 1 1 6</td>
<td>2 2 1 2 0 7</td>
</tr>
<tr>
<td>Bürogemeinde</td>
<td>2 1 1 0 2 8</td>
<td>2 1 2 - 2 1 8</td>
<td>2 2 0 0 0 4</td>
</tr>
<tr>
<td>Produktsions-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Industriebau</td>
<td>2 1 2 - 2 9</td>
<td>2 0 2 0 1 5</td>
<td>2 2 0 1 0 5</td>
</tr>
</tbody>
</table>
Whole System Test (Concise Cycle Test)

- simulated / emulated
- installed and measured

Building diagram:
- solar collectors
- space heating
- controller
- heat pump
- TES
- mains water
- ambient air

Equipment:
- DHW
- solar collector
- controller
- heat pump
- TES
- mains water
- ambient air

Text:
- controller
- heat pump
- TES
- building
- solar collectors
- space heating
- simulated / emulated
- installed and measured
Good components do not yet make a good system

- heat pump
- storage
- collectors

Single test vs system test

- collectors
- control
- solar group
- heat pump
- hydraulics
- storage

Model and simulation
Good components do not yet make a good system

- heat pump
- storage
- PV panels

Single test vs. system test:
- PV panels
- control
- power electronics
- hydraulics
- heat pump
- storage

Model and simulation
Good components do not yet make a good system

- absorption cooler
- storage
- collectors

Single test

System test
- control
- solar group
- hydraulics
- absorpt. cooler
- storage

Model and simulation
Subtask A: Process Heat Collectors
Lead country: Switzerland (Elimar Frank – SPF)

Objectives:

- Improving solar process heat collectors and collector loop components
- Providing a basis for the comparison of collectors with respect to technical and economical conditions
- Recommendations for further improvement of standardized testing procedures
HoTT: SPF Test Rig for Collector Measurements up to 200 °C
SPF activities related to Subtasks

Subtask A
- Components, Systems & Quality
- CCT System Tests

Subtask B
- Control, Simulation & Design

Subtask C
- Testing and demonstration projects

Subtask D
- Dissemination & market deployment

- Some options...
- CCT System Tests?
SPF activities (summary and outlook)

Magneto-Caloric Effect

PV/T ?

- Vapour compression cycle
- Heat transformation process
- Thermomechanical process

Open cycles:
- Liquid sorbent
  - Counterflow absorber
- Solid sorbent
  - Dehumidifier rotor
  - Fixed bed process

Closed cycles:
- Liquid sorbent
  - Water / lithium bromide
  - Ammonia / water

Solid sorbent
  - Adsorption (e.g., water / silica gel)
  - Dry absorption (e.g., ammonia / salt)

Source: Henning et al. (extended)
Thank you!

elimar.frank@spf.ch
www.spf.ch