Solar Thermal Cooling with Adsorption Chillers
Experiences and Consequences for Future Projects

Task 53 - Workshop 20th April 2017 - CNR_ITAE  Messina
Eng. Gabriele Penello
From SorTech to Fahrenheit

- **2002**: Founding of SorTech AG in Freiburg as a spinoff of Fraunhofer Institute for Solar Energy (ISE). Released prototype chiller ACS 05 for field testing.
- **2008**: Launched first commercial chillers ACS 08/ACS 15 in the German market.
- **2009**: First international deliveries.
- **2011**: Developed first zeolite heat pump.
- **2013**: Launched advanced silica gel based eCoo line of products.
- **2015**: Launched eZea, the first zeolite based chiller.
- **2016**: Expanded into high-power applications with introduction of eCoo industry.
- **2017**: Company relaunched as FAHRENHEIT to mark a dedicated expansion into international markets and the commercial readiness of groundbreaking zeolite technology.
About Projects that have already used our machine

Patent office Munich - Germany

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet temperature</td>
<td>75 °C</td>
</tr>
<tr>
<td>Cooling capacity</td>
<td>150 kW</td>
</tr>
<tr>
<td>Cooling temperature</td>
<td>14 °C</td>
</tr>
<tr>
<td>Commissioning</td>
<td>2011</td>
</tr>
<tr>
<td>Running time per year</td>
<td>1500 h</td>
</tr>
</tbody>
</table>

- From small and compact system of 8kW to 150-250kW cooling
- Mainly in central Europe

Fraunhofer-Institut - Solar Energy system (ISE), Freiburg

- Solar panel 20 m² and CHP as backup
- Cooling & heat pumps – ACS 08
- Recooling and cold source: Geothermie
Planning a solar cooling system with PolySun

A real case: Richard Fehrenbach Gewerbeschule - Freiburg - „Projekt SolCoolSys“

Advantages:

- Planning with different working temperature – good match between request of cooling and availability of heat.
- Different way of recooling for the best efficiency of the system.
- Standard and easy modelling, with optimization and simulation.
- Outlook and feedback about Pay Back time

Adsorption Machine with Silicagel or Zeolite
SorTech/Fahrenheit
Planning a solar cooling system with PolySun

Balance between simulation with PolySun and real data of 24th June 2014 *

<table>
<thead>
<tr>
<th></th>
<th>( Q_{HT} )</th>
<th>( Q_{M} )</th>
<th>( Q_{LT} )</th>
<th>Different</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation</td>
<td>9.68 kW</td>
<td>-10.23 kW</td>
<td>4.68 kW</td>
<td>4.13 kW</td>
</tr>
<tr>
<td>Reality</td>
<td>10.49 kW</td>
<td>-15.09 kW</td>
<td>4.73 kW</td>
<td>0.13 kW</td>
</tr>
</tbody>
</table>

*Details from „implementierung der Adsorptionskältemachine „eCoo“ in die Softwareumgebung Polysun“: M- Dölz

Difficulties with Solar cooling system:

- Suitable for base load but hard to follow the peak load demand.
- Cooling demand and heat source (red line) should match well or… backup systems.
Planning solar cooling system with PolySun

Backup of heat source as CHP, gas boiler, fuel cell… and Backup of cooling system, or a HYBRID CHILLER

**Hybrid Chiller** instead of two backup systems → 1Adcm + 1 electric Chiller integrated
Hybrid Chiller – HC a solution for industry and office with:

- Waste heat
- Solar cooling
- CHP
- Air compressor system

What we have already done:

- Combination of Adsorption an electrical chiller in one casing.
- Compact and efficient.
- Flexible to use with base load and peak load.
- Modular, 3 different powers and 2 different Refrigerants.

With Cold water temperature 16/19 °C
European Seasonal Energy Efficiency Ration ESEER: (electrical) 19,6
(max thermic) 0,65

<table>
<thead>
<tr>
<th>Kreisläufe</th>
<th>Cold water</th>
<th>Hot water</th>
<th>Re-cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature range</td>
<td>8-21 °C</td>
<td>50-95 °C</td>
<td>22-40 °C</td>
</tr>
</tbody>
</table>
Operation regimes

1. Monovalent compression
2. Bivalent compression and adsorption
3. Monovalent adsorption
4. Free cooling

Through direct integration system, switching between the areas is done internally.

Shares in the cooling demand coverage

<table>
<thead>
<tr>
<th></th>
<th>kWh</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adsorption chiller</td>
<td>60.974</td>
<td>67%</td>
</tr>
<tr>
<td>Free cooling</td>
<td>16.246</td>
<td>18%</td>
</tr>
<tr>
<td>Compression chiller</td>
<td>14.151</td>
<td>15%</td>
</tr>
<tr>
<td>In total</td>
<td>91.371</td>
<td>100%</td>
</tr>
</tbody>
</table>
What are we doing now?

„Lego-Model“ of Hybrid Chiller. Customized with different cooling capacities, peak load and base load; and different refrigerators: R134a - R404 - R290 (propan) – R600 (Butan) - R744 (CO\textsubscript{2}) – Rxxx - ...

Complete integrated solar cooling machine also with recooler (new European Projekt ZEOSOL + other partner and CNR/ITAE)
Economic feasibility

In the last years the Solar cooling technology was a not very successful:

- complicate and expensive system
- No „peak load“ but „base load“ of cooling
- Not a real culture and business strategy about this topic.
- No Company with „Turn Key project“

New Chances thanks to:

- decrease of the cost of Solar Panel and collector
- higher kW/m² for Adsorber → More compact and cheaper machine
- Subsidies: as Conto Termico 2.0 in Italy for solar cooling technology
Example - Private House - Madrid

- Drive circuit: Solar thermal
- Cooling circuit: Space Cooling
- Recooling circuit: Wet cooling tower

- High running time per year as typically in warm regions in the South of Europe
- Subsidies as Conto Termico 2.0 for Solar Cooling
- High c€/kWh as in the industrialized Countries
- Higher kW/m² thanks to new technical solutions

A solution with Hybrid Chiller in Solar Cooling may reach an attractive Pay Back time of 3 years.
Current Standard

Current specific cooling power

8.0 kW/m² (SorTech eCoo 2.0) to

12.0 kW/m² (SorTech eCoo Industry)
With zeolite as adsorbent, the power per area can be increased significantly.

Adsorber modules are becoming smaller at identical power...

... allowing for increasingly more cooling power in a smaller footprint.

Specific power [kW/m²]

<table>
<thead>
<tr>
<th>Year</th>
<th>Device</th>
<th>Specific Power [kW/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>ACS (2008)</td>
<td>6</td>
</tr>
<tr>
<td>2016</td>
<td>eCoo (2013)</td>
<td>8</td>
</tr>
<tr>
<td>2017</td>
<td>eCoo XL¹</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Zeo (2017+)</td>
<td>~70</td>
</tr>
</tbody>
</table>

¹ Special variant for data centers: taller, and hydraulics placed above modules.
We are always looking for new business partnership. Contact us!

Thank you!