FRESNEL COLLECTORS FOR SOLAR THERMAL COOLING APPLICATIONS
25 % of all daily news are about natural disasters, saving energy and the necessity of reducing our carbon footprint

HOWEVER:
WHAT WE ARE DOING IN REALITY?
DEFINITELY NOT ENOUGH!!!
Industrial Solar Fresnel collectors are designed to generate heat at 130 - 400 °C.
### History

#### From PSE to MIROXX

<table>
<thead>
<tr>
<th>Development since 1999</th>
<th>Pilot-Experience since 2005</th>
<th>Commercialization since 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Development Photos" /></td>
<td><img src="image2.jpg" alt="Pilot Experience Photos" /></td>
<td><img src="image3.jpg" alt="Commercialization Photos" /></td>
</tr>
</tbody>
</table>

**Set up of international subsidiaries, JVs and cooperations for**

- Sales
- Installation
- Assembly
- Procurement

---

**PSE AG**

- Spin off from Fraunhofer ISE, Freiburg, founded 1999, staff 68
- CEO Dr. Andreas Häberle, member of ESTTP (European Solar Thermal Technology Panel), DSTTP (German Solar Thermal Technology Platform) and expert for European Commission on CSP related research
- Business units: Solar test stands, solar consulting, solar conferences
- Board: Prof. V. Wittwer, Prof. E. Weber, Prof. J. Luther
TECHNOLOGY

BASIC PRINCIPLE

Height 4.5 m

Width 7.5 m

Length of one module 4.06 m

11 rows of primary mirrors

1 2 3 4 5 6 7 8 9 10 11
• Low wind load
• Good weight-spread
• High ground usage factor
• No north-south alignment necessary compared to non-concentrating collectors

→ Best suited for rooftop installation
ADVANTAGES I
FRESNEL VS. PARABOLIC SMALL SIZE

Ground usage factor = \( \frac{A}{B} \)

- Fresnel: \( \frac{A}{B} \approx 0.66 \)
- Parabolic Trough: \( \frac{A}{B} \approx 0.33 \)
## ADVANTAGES I
FRESNEL VS. PARABOLIC SMALL SIZE

<table>
<thead>
<tr>
<th>THERMAL</th>
<th>FRESNEL</th>
<th>PTC</th>
<th>FRESNEL VS. PTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEAK POWER</td>
<td>GROUND AREA</td>
<td>GROUND AREA</td>
<td>GROUND USAGE FACTOR RATIO</td>
</tr>
<tr>
<td>88 kW(_{th})</td>
<td>264 m(^2)</td>
<td>458 m(^2)</td>
<td>1,73</td>
</tr>
<tr>
<td>176 kW(_{th})</td>
<td>528 m(^2)</td>
<td>869 m(^2)</td>
<td>1,65</td>
</tr>
<tr>
<td>500 kW(_{th})</td>
<td>1,500 m(^2)</td>
<td>2,462 m(^2)</td>
<td>1,64</td>
</tr>
<tr>
<td>1.0 MW(_{th})</td>
<td>3,000 m(^2)</td>
<td>4,923 m(^2)</td>
<td>1,64</td>
</tr>
<tr>
<td>10.0 MW(_{th})</td>
<td>30,000 m(^2)</td>
<td>48,574 m(^2)</td>
<td>1,62</td>
</tr>
</tbody>
</table>
• Primary mirrors made of flat glass vs. aluminum (durability, reflectivity)
• Precise temperature and power control
• Less absorber tube per m² allows high quality 70 mm vacuum absorber tube (industrial standard)
• Remote control and monitoring via LAN and internet

➤ Meets industry requirements
Date: 2008/07/16

Precise temperature control
• Stationary receiver, no twisting of flexible connections
• Concentrated sunlight hits absorber tube always from below

➔ Best suited for direct steam generation
• Easy cleaning (flat glass/ good access)
• Low water demand for cleaning
• Reliable components

→ Low O&M
SUMMARY ADVANTAGES

- Low wind load
- Good weight-spread
- High ground usage factor
- No north-south alignment necessary

- Primary mirrors made of flat glass vs. aluminum (durability, reflectivity)
- Precise temperature and power control
- Less absorber tube per m² allows high quality 70 mm vacuum absorber tube (industrial standard)
- Remote control and monitoring via LAN and internet

- Stationary receiver, no flexible connections
- Concentrated sunlight hits absorber tube always from below

- Easy cleaning (flat glass / good access)
- Low water demand for cleaning
- Reliable components (mirror/tube/drives)

Rooftop installation
Industry
Steam
Low O&M
• Heat transfer fluid
  – Pressurized water
  – Steam
  – Thermal oil

• Receiver SCHOTT PTR® 70
  – Maximum pressure
    up to **120 bar** (different versions 40, 60, 120 bar)
  – Maximum temperature
    up to **380 °C** with thermal oil
    up to **330 °C** with saturated steam or pressurized water
  – Thermal loss per m² of primary reflector
    \( u_1 = 0.00043 \, \text{W/(m}^2\text{K}^2) \) (according to DLR)
MARKET
MOTIVATION FOR SOLAR COOLING

- Peak load of electricity is already determined by air-conditioning demand in some areas.
- At the same time, high solar gains may be utilised.

Source: Fraunhofer ISE
MOTIVATION FOR SOLAR COOLING

- Savings in primary energy consumption
- Reduction in peak electricity power demand
- Reduction in CO\textsubscript{2} emissions
- Refrigerants without global warming potential; favorable: water
- All-season use of the solar thermal system: heating, cooling, domestic hot water
SOLAR COOLING TECHNOLOGY

Source: Henning, Fraunhofer ISE
## ABSORPTION CHILLERS

<table>
<thead>
<tr>
<th></th>
<th>Double effect H₂O/LiBr</th>
<th>Triple effect H₂O/LiBr</th>
<th>Single effect NH₃/H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature lift (max)</td>
<td>25 K</td>
<td>25 K</td>
<td>55 K</td>
</tr>
<tr>
<td>Temperature of Cold</td>
<td>5-20° C</td>
<td>5-20° C</td>
<td>-20° -20° C</td>
</tr>
<tr>
<td>Driving temperature</td>
<td>140-180° C</td>
<td>230-270° C</td>
<td>160-180° C</td>
</tr>
<tr>
<td>Max. COP</td>
<td>1,1-1,4</td>
<td>1,6-2,1</td>
<td>0,6-0,7</td>
</tr>
</tbody>
</table>
SOLAR COOLING WITH NH₃-H₂O CHILLER
SOLAR COOLING WITH NH₃-H₂O CHILLER
Collector
• 16 modules, 352m² aperture area
• Pressurized water circuit at 16 bar
• Operating temperature 180 °C

Absorption chiller
• 2E water-LiBr
• Cooling capacity 174 kW
• Built in 2007
• Aperture area 352 m²
• Pressurized water circuit at 16 bar
• Outlet temperature 180°C
• Double effect absorption chiller with 50 TR / 174 kW cooling capacity
Collector
- 64 modules, 1408m² aperture area
- Pressurized water circuit at 16 bar
- Operating temperature 180 °C

Absorption chiller
- 2E water-LiBr
- Cooling capacity 650 kW
COMFORT-PERFORMANCE

No cooling – decreased performance
Low energy costs
Low operation costs

Full Air-Conditioning
Constant temperature
Draught, Noise, SBS
High energy costs
High operation costs

Thermo-Active-Building-Systems
Temperature ramps
Reasonable energy costs
Low operation costs
Labour productivity as a function of operative (room) temperature

... which directly influences their labour efficiency

source: Hettinger, Th., Kaminsky, G., Schmale, H.: Ergonomy at the work place
We all spend 90% of the day time indoors: at work, commuting and at home

BUT:
WHAT IS COMFORT FOR US?
Reem Emirates Aluminum HQ, Abu Dhabi, UAE

• Radiant floor cooling 5,000m²
• Central Air Handling Unit
COMBINATION WITH RADIANT COOLING
COMBINATION WITH RADIANT COOLING

GARDENS BY THE BAY SINGAPORE
Figure 27: Thermal power in Cool Dry Conservatory for unshaded floor cooling area, maximum floor cooling power (fluid side) not fixed and slab cooling fluid (water) supply temperature 10°C
COMBINATION WITH RADIANT COOLING

Solar radiation (IWEC Weather data Singapore)

Shading:
- External operable textile shading system
  - TS = 0.20

Glazing:
- U-value = 1.6 W/m²K
- SHGC = 0.37
- TV = 0.65

“Conditioned Zone”
- approx. 2-4 m height above floor

Floor cooling system

Air conditioning / cooling by return air system

Internal heat gains:
- 10 W/m² (static gains)
- Visitors: 5 m²/person
Material properties:
- PE-RT plastic tube
- 5 layer technology / 5 layer technology
- High acid resistance and temperature stability
- Co-extruded EVOH layer according to DIN 4724
- Pressure-resistant
- Corrosion-resistant
- Ethylene octene co-polymer / medium density
- High durability and fatigue strength
- Unique molecular structure with linear ethylene main chain and the octene side chains
- Particularly flexible and easy to install (oxygen impermeable according to DIN 4726)
- Extreme acid resistance and resistance to chemicals
- Very low flow resistance in the inner tube
- Extremely good thermal conductivity
Why radiant cooling with solar cooling

• We can use chilled water temperature above 12 °C
• PERFECT FOR ABSORPTION CHILLERS as the capacity increase with higher chilled water leaving temperature (30 -50 % more capacity)
• Higher comfort, less O&M cost

• SUSTAINABILITY. LETS TAKE THIS RESPONSIBILITY.
## Table 2B - 2: Primary inputs and outputs of tests varying chilled-water supply temperature

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Chilled-water flow</th>
<th>Cooling-water flow</th>
<th>Chilled-water return temp.</th>
<th>Cooling-water supply temp.</th>
<th>Steam supply temp.</th>
<th>Condensate return temp.</th>
<th>Steam flow</th>
<th>Chilled-water supply temp.</th>
<th>Cooling load</th>
<th>COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.03</td>
<td>1.43</td>
<td>10.93</td>
<td>30.49</td>
<td>165.30</td>
<td>99.14</td>
<td>17.53</td>
<td>5.14</td>
<td>13.66</td>
<td>0.88</td>
</tr>
<tr>
<td>2</td>
<td>2.07</td>
<td>1.44</td>
<td>11.11</td>
<td>30.40</td>
<td>165.32</td>
<td>98.99</td>
<td>18.35</td>
<td>5.37</td>
<td>13.86</td>
<td>0.91</td>
</tr>
<tr>
<td>3</td>
<td>2.06</td>
<td>1.43</td>
<td>12.22</td>
<td>30.57</td>
<td>165.25</td>
<td>99.16</td>
<td>20.10</td>
<td>6.01</td>
<td>14.87</td>
<td>0.94</td>
</tr>
<tr>
<td>4</td>
<td>2.08</td>
<td>1.43</td>
<td>12.22</td>
<td>30.43</td>
<td>165.30</td>
<td>98.92</td>
<td>18.65</td>
<td>6.16</td>
<td>14.66</td>
<td>0.95</td>
</tr>
<tr>
<td>5</td>
<td>2.04</td>
<td>1.43</td>
<td>13.52</td>
<td>30.46</td>
<td>165.20</td>
<td>99.13</td>
<td>19.78</td>
<td>6.91</td>
<td>15.65</td>
<td>1.01</td>
</tr>
<tr>
<td>6</td>
<td>2.08</td>
<td>1.43</td>
<td>14.44</td>
<td>30.59</td>
<td>165.14</td>
<td>99.11</td>
<td>20.88</td>
<td>7.70</td>
<td>16.33</td>
<td>0.99</td>
</tr>
<tr>
<td>7</td>
<td>2.07</td>
<td>1.43</td>
<td>15.56</td>
<td>30.68</td>
<td>165.13</td>
<td>99.12</td>
<td>22.90</td>
<td>8.35</td>
<td>17.35</td>
<td>1.02</td>
</tr>
<tr>
<td>8</td>
<td>2.07</td>
<td>1.43</td>
<td>16.67</td>
<td>30.66</td>
<td>165.05</td>
<td>99.14</td>
<td>23.28</td>
<td>9.20</td>
<td>17.95</td>
<td>1.07</td>
</tr>
<tr>
<td>9</td>
<td>2.10</td>
<td>1.43</td>
<td>17.77</td>
<td>30.61</td>
<td>164.94</td>
<td>99.15</td>
<td>24.03</td>
<td>9.90</td>
<td>19.21</td>
<td>1.09</td>
</tr>
<tr>
<td>10</td>
<td>2.10</td>
<td>1.43</td>
<td>18.88</td>
<td>30.53</td>
<td>164.74</td>
<td>99.15</td>
<td>25.47</td>
<td>10.69</td>
<td>19.98</td>
<td>1.11</td>
</tr>
<tr>
<td>11</td>
<td>2.13</td>
<td>1.43</td>
<td>22.02</td>
<td>30.50</td>
<td>164.66</td>
<td>99.14</td>
<td>25.85</td>
<td>13.53</td>
<td>21.03</td>
<td>1.14</td>
</tr>
</tbody>
</table>
Thank you for your attention.

Dipl.-Ing. Volker Rühle, Director Centrogulf LLC.