IEA CSP Workshop:

Frank Lenzen, 03.03.2014
## Different CSP Technologies

<table>
<thead>
<tr>
<th>Parabolic trough collector</th>
<th>Linear Fresnel collector</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Parabolic trough collector" /></td>
<td><img src="image2" alt="Linear Fresnel collector" /></td>
</tr>
<tr>
<td>Solar tower</td>
<td>Dish Sterling</td>
</tr>
<tr>
<td><img src="image3" alt="Solar tower" /></td>
<td><img src="image4" alt="Dish Sterling" /></td>
</tr>
</tbody>
</table>
Until end of 2013, a cumulated capacity of more than 3.6 GW has been installed

**Cumulated CSP installations and technology share (MW)**

- Approx. 90% of the installed capacity is Parabolic Trough
- 5% is Fresnel
- 5% Tower…

<table>
<thead>
<tr>
<th></th>
<th>in operation</th>
<th>under construction / in commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresnel</td>
<td>175</td>
<td>470</td>
</tr>
<tr>
<td>Tower</td>
<td>189</td>
<td>66</td>
</tr>
<tr>
<td>Parabolic Trough</td>
<td>3.632</td>
<td>1.624</td>
</tr>
</tbody>
</table>
Overview of possible collector systems, heat transfer media and storage media for CSP power plants

<table>
<thead>
<tr>
<th>Collector system</th>
<th>Heat transfer fluid</th>
<th>Storage medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parabolic trough collector</td>
<td>Oil</td>
<td>Sensible molten: Solar salt</td>
</tr>
<tr>
<td>Fresnel collector</td>
<td>Molten salt</td>
<td>Sensible solid: Concrete, sand</td>
</tr>
<tr>
<td>Solar tower</td>
<td>Water (for DSG)</td>
<td>Phase Change Material (PCM): Salt</td>
</tr>
<tr>
<td></td>
<td>Air</td>
<td>Water / Steam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compressed Air</td>
</tr>
</tbody>
</table>
Overview of potential future CSP combinations consisting of collector, heat transfer fluid and storage medium

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<th>Collector system</th>
<th>Heat Transfer Fluid</th>
<th>Storage medium</th>
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<tr>
<td>Parabolic trough collector</td>
<td>Thermal oil</td>
<td>Sensible: Molten solar salt</td>
</tr>
<tr>
<td></td>
<td>Melted solar salt</td>
<td>• Sensible solid combined with Phase Change Material-PCM: Concrete &amp; salt</td>
</tr>
<tr>
<td></td>
<td>Water (for Direct Steam Generation - DSG)</td>
<td>• Water / Steam</td>
</tr>
<tr>
<td>Linear Fresnel collector</td>
<td>Oil</td>
<td>Sensible: Molten solar salt</td>
</tr>
<tr>
<td></td>
<td>Melted solar salt</td>
<td>• Sensible solid combined with PCM: Concrete &amp; salt</td>
</tr>
<tr>
<td></td>
<td>Water (for DSG)</td>
<td>• Water / Steam</td>
</tr>
<tr>
<td>Power tower</td>
<td>Melted salt</td>
<td>Sensible: Molten solar salt</td>
</tr>
<tr>
<td></td>
<td>Water (for DSG)</td>
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<td>Air</td>
<td>• Water / Steam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sensible solid; Sand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Compressed Air</td>
</tr>
</tbody>
</table>
CSP Technology will move to Molten Salt or DSG as HTF in future if storage up to 3 hours and more is required → Molten Salt

<table>
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<tr>
<th>Advantage / Disadvantage</th>
<th>Salts</th>
<th>Water (DSG)</th>
</tr>
</thead>
</table>
| **Advantages**           | • High evaporation point and hence high HTF temperatures possible  
                           • Same material used for heat storage and as heat transfer fluid, thus saving of heat exchanger  
                           • Lower specific costs compared to oil | • Reliable HTF, non toxic  
                           • Direct admission of the steam turbine with steam provided by the solar field, hence saving of heat exchanger  
                           • Very low specific costs compared to oil |
| **Disadvantages**        | • Advanced freeze protection system required  
                           • No long term experience regarding corrosion risk | • Sophisticated handling of the DSG-process in the solar field  
                           • Elaborate design of a heat storage for DSG required |
Higher Temperatures will lead to higher Efficiencies in the Power Block

Source DII CSP 2020
LCOE reduction of 30 % expected for Molten Salt compared to oil as HTF

1. Efficiency improvement of the Power Block performance
   • 380 °C / 100 bar       39 %
   • 550 °C / 150 bar       45 % → 16 % rel. performance improvement

2. Reduced parasitic loads

3. Increased process temperature leads to reduced salt quantities and improved Cost for thermal heat storage
   Andasol – Typ       100 %
   Molten Salt design  36 %

Cost efficiency for heat storage significantly better
No need for heat exchanger between oil and salt
Equipment for the permanent quality stabilisation of HTF/oil is expensive and can be avoided
Corrosion of Molten Salt and increased process temperatures require selected materials
Anti freezing protection necessary
Design Aspects for the Study

- Solar only power plants
- Large scale power plants beyond 100 MW_{el} output for utility applications
- **CSP systems capable of installation of large storage capacities, > 3h**
- Heat transfer fluid interaction with the solar field, power cycle and storage system shall not cause any major technical or commercial problems
- Optimization of the power plant design regarding lowest levelized cost of electricity
LCOEs of Investigated CSP Technologies

- Significant cost reduction by 2020 for CSP possible
- Average values of 13€ct/kWh can be reached
- Differentiation of CSP technologies not possible at this stage; highly depending on site criteria required storage capacity and other boundary conditions

Source DII CSP 2020
Between 2020-2030 all renewable technology will be competitive to all fossil technologies

LCOE, medium fuel prices [€/MWh]

Source: Dii
Since the market entry in 2005, SCHOTT Solar CSP has achieved a leading market position.

CSP capacity installed or under construction

- 0.35 GW in 2005
- ~1 GW in 2012
- ~3 GW

More than 3 Gigawatts capacity equipped with SCHOTT PTR®70 receivers

More than 1 Million receivers supplied to over 50 CSP projects worldwide
SCHOTT pursues a continuous improvement of its PTR® receiver

**SCHOTT PTR®70 Receiver Development**

- **SCHOTT PTR® 1st Gen**
  - **2006**
  - + 2.9% plant efficiency

- **SCHOTT PTR® 2nd Gen**
  - **2008**
  - + 1.0% plant efficiency

- **SCHOTT PTR® 3rd Gen**
  - **2011**
  - + noble gas capsule = life-time insurance

- **SCHOTT PTR® 3rd Gen Premium**
  - **2012**
  - high temperature (550°C)

- **SCHOTT PTR® 4th Gen**
  - **2013**
  - + 2.9% plant efficiency
The 4th generation receiver of SCHOTT Solar paves the way to competitiveness of CSP technology

- Operation temperatures up to 550°C
- Usable with Molten Salts as heat transfer fluids
- Optimized robustness for easy handling

SCHOTT PTR®
1st Gen

SCHOTT PTR®
2nd Gen

SCHOTT PTR®
3rd Gen

SCHOTT PTR®
4th Gen

© SCHOTT Solar CSP GmbH
Based on a new receiver platform, SCHOTT issues three receiver products

**SCHOTT PTR® 4th generation receiver platform**

- SCHOTT PTR®70 Advance
  - New steel grade for 550°C
  - Novel absorber coating

- SCHOTT PTR®70 Premium
  - Integrated Noble Gas Capsule as lifetime extender

- SCHOTT PTR®70
  - New bellow design, suitable for high-temperature operation
  - Glass-to-metal seal with matching coefficients of thermal expansions
  - Protection cap for improved product robustness and easy handling
Conclusion

- Investigated parabolic trough, linear Fresnel and solar tower systems are feasible CSP concepts to lower LCOEs by 2020. 13Cent/KWh seems to be a possible target (2020)

- Storage is a crucial feature for all CSP power plants in terms of lowering the LCOEs and enabling power dispatchability, especially when considering high grid penetration of renewable energy sources such as PV and Wind

- Technology leap compared to existing systems is necessary to reach defined targets

- Molten salt is considered by all players in the CSP branch to be one of the preferred HTFs for all investigated systems which will enable the necessary technology leap by 2020

- System optimization shows a trend toward high storage capacities for all technologies by 2020 leading to high full load hours

→ First test installations will show the prove of concept short term