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Compact Thermal Energy Storage
Solar Thermal Technologies
Solar thermal for concentrated solar power and industrial applications

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Content

1. Concentrated Solar Power
2. Solar Thermal for Industrial Processes
CSP

Concentrated Solar Power
- Electricity generation
- Concentrated sunlight (only direct radiation)
- High temperatures
- With thermal storage: dispatchability
Production and consumption of CSP electricity by 2050

Repartition of the direct normal irradiance (DNI) in kWh/m²/yr, and of the production and consumption of CSP electricity (in TWh) by world region in 2050 as foreseen in this roadmap. Arrows represent transfers of CSP electricity from sunniest regions or countries to large electricity demand centres.

Sources: Breyer & Knies, 2009 based on DNI data from DLR-ISIS and IEA Analysis.
ST Power Plants

Andasol 1 plant (Spain)

ST power plants: typically 50 – 250 M W
Heat transfer by molten salts or direct steam or air (tower)
ST Power Plants

Solar 1 and 2 tower fields (USA)
ST Power Plants

PS10 and PS20 central receiver power plants (Spain)
How Does It Work?

MOLTEN SALT SYSTEM
- Collector Field
- HELIOSTATS
- Receiver
- Receiver Tower
- MOLTEN SALT LOOP
- 288°C
- 565°C
- Cold Salt
- Hot Salt
- Steam Gen./Evaporator
- Feedwater Preheaters
- Superheater
- Reheater
- Condensate Tank
- Condenser
- Power Block
- Steam Turbine Generator
- Generator
- HP Turbine
- IP/LP Turbine
- Reheated Steam
- Receiver
- Tower
- Condensate
- Tank
- Condenser
- IP/LP Turbine
- HP Turbine
- Generator
- Steam Turbine Generator
- Steam Generation System
- MOLTEN SALT LOOP
- THERMAL STORAGE SYSTEM

Source: Bill Gould, SolarReserve
Forecast for CSP in Spain

Connection schedule for the next STE Plants in Spain

MW
10,000
7,000
1000 -
4000 -
3000 -
2000 -
7000 -
6000 -
5000 -
8000 -
9000 -
10,000
850
1350
1850
2340
MW
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
?
F I
2010
F II
2011
F III
2012
F IV
2013
2014
2015
2016
2017
2018
2019
2020
10,000
7,000
ST for Process Heat

- Low to medium temperature range
- Large number of suited collector technologies
- Challenge is the process integration
Data for 2003, 32 Countries: EU25 + Bulgaria, Romania, Turkey, Croatia, Iceland, Norway and Switzerland.

Temperature levels of processes

- parabolic trough collector
- CPC collector
- vacuum tube collector
- flat plate collector

**Food industry**
- cooking
- cleaning and washing
- evaporation and distillation
- pasteurisation

**Textile industry**
- washing
- dyeing
- drying
- bleaching

**Surface treatment**
- cleaning
- finishing
- surface treatment

**Chemical industry**
- distillation
- extraction
- cocking

**All sectors**
- preheating of processes
- heating of industry halls

Process temperature:
- 100°C
- 200°C
- 300°C
What is a process heat collector?

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Collector or Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>below 100°C</td>
<td>“low” temperature</td>
</tr>
<tr>
<td>100 °C .. 250 °C</td>
<td>“mid” temperature</td>
</tr>
<tr>
<td>above 250 °C</td>
<td>“high” temperature</td>
</tr>
<tr>
<td>“low” temperature collector or application</td>
<td>“mid” temperature collector or application</td>
</tr>
</tbody>
</table>

“reasonable” collector output for “mid” and “high” temperature for industrial application

output exceeds 300 W/m² gross collector area (1000 W/m² hemispherical irradiance, 15 % diffuse fraction and 20 °C ambient temperature at an operating temperature of > 100 °C (mid temp) and > 250 °C (“high” temp)
Overview of collectors

- **250-450 °C**: «Large» Parabolic Troughs and Fresnel Collectors
- **120-250 °C**: «Small» Parabolic Trough and Fresnel Collectors, High Vacuum Flat Plate Collectors, (Advanced) Evacuated Tube Collectors
- **80-120 °C**: Evacuated Tube Collectors, Advanced Flat Plate Collectors, CPC Collectors
- **< 80 °C**: Standard Flat Plate Collectors
- **< 40 °C**: Uncovered Collectors

Concentration Factor

© SPF
Flat plate collectors

80-120 °C

www.schueco.com

www.solid.at
Combination flat plate collectors and heat loss reduction

Results (for 500 W/m² and ΔT = 60 K)

- Δη appr. 70% compared with good flat plate collector
- Δη appr. 30% compared with double glazed advanced flat plate collector
Vacuum tubes collectors

80-120 °C  120-250 °C

www.ritter-gruppe.com

www.kollektorfabrik.de
Vacuum Flat plate collectors

80-120 °C

120-250 °C

www.srbenergy.com

www.tvpsolar.com

www.aee-intec.at   AEE - Institute for Sustainable Technologies
Parabolic trough collectors

120-250 °C

www.smirro.de

www.nep-solar.com
Parabolic trough collectors

120-250 °C

www.solitem.com

www.aee-intec.at  AEE - Institute for Sustainable Technologies
Fresnel collectors

120-250 °C

www.industrial-solar.de

www.chromasun.com
Selection of collector type

- Standard-Flachkollektor
- Hochleistungs-Flachkollektor
- CPC - Vakuumröhrenkollektor
- Parabolrinnenkollektor

**Working temperature**

- mittlere Arbeitstemperatur $T_{m, \text{Abs}} = \frac{(T_{\text{tabs}, \text{ein}} + T_{\text{tabs}, \text{aus}})}{2}$ in °C

**Collector efficiency**

**Process heat**
- low temperature $<100°C$
- medium temperature $100°C - 400°C$

**Hot water and space heating**

www.aee-intec.at  AEE - Institute for Sustainability
Range of energy costs (USD/MWhth)
Integration on supply level – hot water

- Feed-in solar energy in heating circuit
- High set temperature
- Simple system integration
- Small number of system layouts
Integration on process level

• Solar energy is directly used for the process
• Different system layouts possible
• Often complex system integration
Case studies – Göss (1)

brewery
FP7 project „SolarBrew“
AEE INTEC, Sunmark, GEA
integration in mashing (50 – 75 °C)

System
In operation since 2013
1,375 m² flat plate collectors
Case studies – Göss (2)
Brewery Göss – SolarBrew

Solar heat integration
- 20 – 27 brews/week
  - min. 400 hl/brew
  - ca. 75 – 90 min/brew
- Retrofitting „dimple plates“
By 2050, the IEA ETP 2012 2DS scenario estimates the potential for solar heat in industrial applications to contribute up to 7 200 PJ per year (7.2 EJ/yr), on the basis of an installed capacity of over 3200 GW$_{th}$, in industrial low-temperature applications up to 120°C.

In comparison: Total installed capacity worldwide in 2011 was 245 GWth.
Conclusions

CSP
- Maturing technology
- Cost level is very important
- High initial investments
- Dependent on political decisions

ST for industrial processes
- Collector technology mature
- Challenge is the process integration
- Huge market potential
- Dependent on industry decisions