CSP Technologies, Markets, Challenges

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Agenda

• Why renewable energies?
• Why Concentrated Solar thermal Power (CSP) plants?
• Solar resources
• Value of CSP electricity
• Technologies
  • Trough
  • Tower
  • Fresnel
• CSP vs PV
• Real data of CSP dispatchable solar generation
• Markets
• Trends
Why renewable energies?
- Scenarios on global warming -

Source: M. Meinshausen et al. (2009)
Why solar thermal power plants?
Why solar thermal power plants?
Why solar thermal power plants?

- can be integrated into conventional thermal power plants
- provide firm capacity (thermal storage, fossil backup)
- serve different markets (bulk power, remote power, heat, water)
- have an energy payback time of only 6-12 months
World Sun Belt
World Sun Belt

DNI – Direct Normal Irradiance [W/m²]
Renewable energy resources in Europe and MENA

in brackets: (max. yield in GWh$_{el}$/km$^2$/y)

- Biomass (1)
- Geothermal (1)
- Wind (50)
- Hydropower (50)
- Solar (250)
Renewable energy resources in Europe and MENA

- renewable resources greatly exceed the present and future electricity demands
- solar radiation is by far the most abundant source of energy

Economic renewable electricity potentials vs. demand in Europe and MENA
Renewable energy resources in Europe and MENA

- Renewable resources greatly exceed the present and future electricity demands.
- Solar radiation is by far the most abundant source of energy.
- 1 km² of desert land may generate 50 MW of electricity.
- 1 km² of desert land may produce 200 - 300 GWh\text{el} / year.
- 1 km² of desert land avoids 200,000 tons CO₂ / year.
- Solar thermal power plants are the most effective technology to harvest this vast resource.

The electrical energy produced by a solar power plant with the size of Lake Nasser equals the total Middle East oil production.
The Value of CSP Electricity

- Flexible Design: From peak load to base load at similar costs
- Thermal Storage = high efficient shift of supply
The Value of CSP Electricity

- Relative electricity costs [%]
- Storage capacity [full-load hours]

* assuming specific investment costs for the storage of 10 Euro/kWh

no storage, electricity costs = 100%
Types of Concentrating Solar Thermal Technologies

- Dish-Stirling
- Solar Power Tower
- Parabolic Trough
- Linear Fresnel
Parabolic Trough Collector

- **Advantages:**
  - Large scale proven technology
  - Bankable

- **Disadvantages:**
  - Up to now max. temperature of HTF limits the efficiency
  - Nearly flat side topography needed
Linear Fresnel Collector

- Advantages:
  - Simple construction
  - High land use
  - Possible integration into buildings

- Disadvantages:
  - Low efficiency
  - State of the art without storage

Quelle: MSM
Solar Power Tower

- **Advantages:**
  - High efficiency potential
  - High cost reduction potential
  - Usable in hilly area

- **Disadvantages:**
  - Less commercial experience
  - Radiation attenuation by dust in the atmosphere
Dish-Stirling

- Advantages:
  - Very high efficiency
  - Small units
  - Decentralized application

- Disadvantages:
  - Expensive
  - No storage
Theoretical efficiency potential

\[ \eta_{\text{max}} = \eta_{\text{th,Carnot}} \cdot \eta_{\text{absorber}} \]

- Flat plate Collector
- Parabolic Trough
- Solar Tower
- Solar Dish

\( (T_{\text{absorber}} = T_{\text{process}}) \text{ [K]} \)
CSP vs PV
Simulation of supply and demand with increasing PV share
CSP vs PV
Simulation of supply and demand with increasing PV share

Source: NREL/TP-6A20-52978, Nov. 2011
CSP vs PV
Simulation of supply and demand with increasing PV share

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CSP vs PV
Simulation of supply and demand with increasing PV share

Source: NREL/TP-6A20-52978, Nov. 2011
Real data of CSP dispatchable generation (Andasol III data)

<table>
<thead>
<tr>
<th>Andasol 3: Facts &amp; Figures</th>
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<tbody>
<tr>
<td>&gt; Owner: Marquesado Solar S.L.</td>
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<td>&gt; Location: Aldeire/La Calahorra (Granada, Spain)</td>
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<td>&gt; Technology: Parabolic trough incl. 7.5h molten salt storage</td>
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<td>&gt; Capacity: 50 MW_{el}</td>
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<td>&gt; Size of the collector area: (~500,000 \text{ m}^2)</td>
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<td>&gt; Forecasted electricity production: (~200 \text{ GWh/a})</td>
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<td>&gt; Annual CO(_2) savings: 150,000 tonnes</td>
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<tr>
<td>&gt; Commissioning in autumn 2011</td>
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<tr>
<td>&gt; Investors:</td>
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<td>&gt; EPC contractor: UTE</td>
</tr>
</tbody>
</table>

Source: RWE Innogy, F. Dinter
Continuous generation 24 h/d

Source: RWE Innogy, F. Dinter
Dispatchable generation

Source: RWE Innogy, F. Dinter
Dispatchable generation

14.10.2012

CECOGE: Tech minimum request 14.10.2012

Source: RWE Innogy, F. Dinter
Market: Medium term generation to 2018

<table>
<thead>
<tr>
<th>Country</th>
<th>TWh</th>
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<tbody>
<tr>
<td>Spain</td>
<td>2206</td>
</tr>
<tr>
<td>United States</td>
<td>1973</td>
</tr>
<tr>
<td>South Africa</td>
<td>700</td>
</tr>
<tr>
<td>Morocco</td>
<td>480</td>
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<tr>
<td>China</td>
<td>318</td>
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<td>India</td>
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<td>Chile</td>
<td>340</td>
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<tr>
<td>Israel</td>
<td>231</td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>101</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>100</td>
</tr>
<tr>
<td>Others</td>
<td>310</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7138</strong></td>
</tr>
</tbody>
</table>

Source: IEA, MTRMR 2013

Source: Bloomberg New Energy Finance
Trends / Challenges

Reasons for the Trend
1. Higher potential in cost reduction
2. More balanced yearly yield
Market

1 GW by 2015
3 GW by 2020
no progress

2,7 GW by 2017
only 3 projects built
no progress

100-200 MW per year, target 1.2 GW (3.3 GW)
on track, 400 MW confirmed already
no progress

KSA: 25 GW by 2032
900 MW by end of 2016
Kuwait: Projects in tender process
serious but slow approach

Source: DCSP
Ivanpah (392 Mwel, 347000 Heliostats, DSG)
Crescent dunes (110 MW, 17500 Heliostats, Molten Salt)
Challenges: Collectors

- Lightweight construction
- New designs
- Entire collector performance measurement
- and STANDARDS
Challenges: Heat Transfer Fluids for Higher Temperature

- Liquid salt
- Liquid metal
- Particles

Solar Radiation

Particle-curtain

qualitative radiation loss
Challenges: Advanced Solar Power Cycles (Solarized Design)

• Top-cycles with pressurized air, liquid salt, liquid metal or particles

• Molten salt in parabolic troughs
Conclusion

• The increasing global warming makes CO2 free systems necessary
• CSP is one of the possible CO2 free systems for electricity production
• CSP systems can be equipped with a high efficient storage system, enabling them to deliver dispatchable electric power
• CSP enables a higher feeding of PV and wind power to the grid
• The demand of cost reduction of CSP systems lead to
  • Higher temperatures of the heat transfer fluid
  • Higher steam parameters
  • New heat transfer fluids like molten salt, liquid metal and particle...
Thank you for your attention