Financing Concentrating Solar Power – Subsidy or Investment?

Tobias Fichter
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Principle of a Concentrating Solar Power Plant

Qualities of CSP Plants:
- Operating as peak, medium or base load power plant
- Firm capacity
- Power on demand
- Spinning reserve
- Combined generation of process heat for industry, cooling, desalination, etc.
Main Barrier for Market Introduction in MENA

- LCOE of CSP at DNI 2400 kWh/m²/a
- Average LCOE
The Real Cost of Electricity (Model Case)
A Strategy for CSP Finance

Break even with different load segments

- LCOE of CSP at DNI 2400 kWh/m²/a
- Peak Load LCOE
- Medium Load LCOE
- Base Load LCOE
- Average LCOE without CSP
A Strategy for CSP Finance

Goal:
1. Trigger considerable investments in CSP in MENA in the near future
2. Market introduction of CSP with as low economic burden as possible

Approach:
1. Providing security by long-term international insured power purchase agreements (iPPA)
   - Easiest way to bring down electricity costs due to reduced interest rates (capital costs ~ 80% of electricity costs)
2. Profit from technical qualities of CSP plants
   - Step-by-step integration of CSP starting at the most expensive load segment (peak load)
Recommendations for Policy and CSP Finance

1. Calculate real full cost per kWh of each load segment and its possible future development

2. Calculate the required tariffs for CSP investments and its future development

3. Compare the cost of new conventional peak, medium and base load power plants with required CSP tariffs and identify cost break-even points

4. Identify quantitative requirements for additional capacity and its primary function within the peak, medium or base load segment
Recommendations for Policy and CSP Finance

5. Call for tender according to capacity planning and offering appropriate long-term PPA together with inflation and currency adjustment

6. Request bids for guaranteed quality for longevity of CSP plants and reasonable national share of manufacturing

7. Try to achieve governmental and in addition international guarantees for the PPA (iPPA) to reduce investment risk

8. Provide transparent information on the calculation of the tariffs and publish the long-term perspective of tariff reduction

➤ Carefully calculated iPPA can open business cases for CSP in MENA without additional economical burden
Thank You!
Contact Information

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Literature

Parameters for a model case electricity supply structure:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Load Capacity</td>
<td>MW</td>
<td>4000</td>
</tr>
<tr>
<td>Base Load Annual Electricity</td>
<td>GWh/a</td>
<td>30000</td>
</tr>
<tr>
<td>Base Load Fuel Cost (Coal + NG + HFO)</td>
<td>$/MWh</td>
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<tr>
<td>Medium Load Capacity</td>
<td>MW</td>
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<tr>
<td>Medium Load Annual Electricity</td>
<td>GWh/a</td>
<td>10000</td>
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<tr>
<td>Medium Load Fuel Cost (Coal + Fuel #2)</td>
<td>$/MWh</td>
<td>35.0</td>
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<tr>
<td>Peak Load Capacity</td>
<td>MW</td>
<td>1000</td>
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<tr>
<td>Peak Load Annual Electricity</td>
<td>GWh/a</td>
<td>2000</td>
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<tr>
<td>Peak Load Fuel Cost (Diesel + Fuel #2)</td>
<td>$/MWh</td>
<td>60.0</td>
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<tr>
<td>Cost Escalation of Fossil Fuels</td>
<td>%/a</td>
<td>1.5%</td>
</tr>
<tr>
<td>Specific Power Block Investment (B+M)</td>
<td>$/kW</td>
<td>1200</td>
</tr>
<tr>
<td>Specific Power Block Investment (Peak)</td>
<td>$/kW</td>
<td>400</td>
</tr>
<tr>
<td>Project Rate of Return</td>
<td>% of Inv./a</td>
<td>10.0%</td>
</tr>
<tr>
<td>O&amp;M Rate</td>
<td>% of Inv./a</td>
<td>2.5%</td>
</tr>
<tr>
<td>Fuel Efficiency Base &amp; Medium Load</td>
<td>%</td>
<td>35.0%</td>
</tr>
<tr>
<td>Fuel Efficiency Peak Load</td>
<td>%</td>
<td>30.0%</td>
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</table>
Model parameters for the required revenues of CSP:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Reference LCOE of CSP in 2010</td>
<td>$/kWh</td>
<td>0.280</td>
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<tr>
<td>Reference Direct Normal Irradiance</td>
<td>kWh/m²/y</td>
<td>2400</td>
</tr>
<tr>
<td>CSP Progress Ratio</td>
<td>%</td>
<td>88.0%</td>
</tr>
<tr>
<td>Project Rate of Return</td>
<td>%</td>
<td>10.0%</td>
</tr>
<tr>
<td>O&amp;M Rate</td>
<td>%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Exchange Rate</td>
<td>$/€</td>
<td>1.19</td>
</tr>
</tbody>
</table>

- CSP feed-in tariff in Spain is used as reference value (27 €/MWh)
- Feed-in tariff has proven to trigger considerable investment in CSP
- Average DNI in Southern Spain: 2090 kWh/m²/y
Main Barriers/Challenges of CSP Finance
Main Barriers/Challenges for Market Introduction of CSP in MENA

1. **Very high electricity costs** of CSP compared to present average market prices

2. Long-term investment (20-40 years) not only for the power plants but also for their „fuels“ → **High initial investment**

3. **Unknown future savings** due to volatile and unpredictable conventional fuel prices

4. **Known long-term cost** but **unknown long-term revenues** if electricity is sold at spot markets

→ Lack of security for private and public investors
→ Technical qualities of CSP plants are not taken into consideration
Challenges of CSP Finance:

Challenge 1: High initial investment

Investment ($/kW):
- SM 1: 4700
- SM 2: 8000
- SM 3: 11300
- SM 4: 14600

Capacity Factor:
- SM 1: 25%
- SM 2: 45%
- SM 3: 65%
- SM 4: 85%
Challenges of CSP Finance:

Challenge 2: Known immediate costs but unknown future savings

Data: www.oilnergy.com
Challenge of CSP Finance:

Challenge 3: Fix costs but non-fix revenues
Challenge of CSP Finance:

Challenge 4: Initial cost levels above market price

Source: Ragwitz 2009
Calculation of Annual Solar Share in the Initial Phase
1st Step: The Load Curve is divided into Peak, Medium and Base Load
In higher time resolution it looks like this for a summer week.
Demand and Supply in Summer Peak Load Week

- **Residual**
- **CSP Hybrid**
- **CSP Solar**

Power [MW]

Hour of Year [h]

Demand and Supply in Summer Peak Load Week
Demand and Supply in Winter Peak Load Week

- **Power [MW]**
  - Residual
  - CSP Hybrid
  - CSP Solar

- **Hour of Year [h]**
  - 8580
  - 8630
  - 8680
  - 8730

- **Demand and Supply in Winter Peak Load Week**
Demand and Supply in Spring Week

Power [MW]

Hour of Year [h]

- Residual
- CSP Hybrid
- CSP Solar

Demand and Supply in Spring Week
Calculation of Annual Solar Share Summary

<table>
<thead>
<tr>
<th>Load Segment</th>
<th>Peak Load</th>
<th>Medium Load</th>
<th>Base Load</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed Capacity (MW)</td>
<td>1285</td>
<td>2455</td>
<td>4000</td>
<td>7740</td>
</tr>
<tr>
<td>Electricity Production (GWh/a)</td>
<td>1925</td>
<td>10004</td>
<td>30095</td>
<td>42024</td>
</tr>
<tr>
<td>CSP Capacity (MW)</td>
<td>600</td>
<td>1700</td>
<td>3200</td>
<td>5500</td>
</tr>
<tr>
<td>CSP Solar Multiple</td>
<td>1</td>
<td>2</td>
<td>3.5</td>
<td>--</td>
</tr>
<tr>
<td>CSP Storage (h)</td>
<td>6</td>
<td>8</td>
<td>18</td>
<td>--</td>
</tr>
<tr>
<td>CSP Solar Share (GWh/a)</td>
<td>1159</td>
<td>6574</td>
<td>21313</td>
<td>29046</td>
</tr>
<tr>
<td>CSP Fuel Share (GWh/a)</td>
<td>537</td>
<td>3124</td>
<td>6560</td>
<td>10221</td>
</tr>
<tr>
<td>Residual Capacity (MW)</td>
<td>685</td>
<td>755</td>
<td>800</td>
<td>2240</td>
</tr>
<tr>
<td>Residual Electricity (GWh/a)</td>
<td>230</td>
<td>306</td>
<td>2222</td>
<td>2758</td>
</tr>
<tr>
<td>Solar Share</td>
<td>60%</td>
<td>66%</td>
<td>71%</td>
<td>69%</td>
</tr>
</tbody>
</table>
The graph shows the load (MW) over the hour of the day, divided into Peak Load, Medium Load, and Base Load. The peak load occurs around 17 hours, with medium load covering most of the day, and base load being constant throughout.
2nd Step: The peak segment is separated and then, the lower part is covered by CSP (solar or hybrid), while the upper part (residual capacity) is covered by conventional peaking plants.
In higher time resolution it looks like this for a summer week
3rd Step: Medium Load is separated and the lower part covered by CSP
In higher time resolution it looks like this for a summer week.
4th Step: Base Load is separated and the lower part covered by CSP
In higher time resolution it looks like this for a summer week
Case 1: 100% Substitution in peak and medium load segment by CSP

- Peak CSP Capacity
- Medium CSP Capacity
- Base CSP Capacity
- Peak Fuel Capacity
- Medium Fuel Capacity
- Base Fuel Capacity
Case 1: 100% Substitution in peak and medium load segment by CSP

- **a**: Average LCOE without CSP
- **b**: Average LCOE with CSP
- **c**: Average LCOE with Peak CSP
Case 2: Partial Substitution of Fuel by CSP

- **Average LCOE without CSP**
- **Average LCOE with CSP**
- **Average LCOE with Peak CSP**
Decreasing Cost of Concentrating Solar Power

The graph illustrates the decreasing cost of concentrating solar power over the years 2010 to 2050. The x-axis represents the year, while the y-axis shows the required CSP tariff ($2010/kWh) and the global installed capacity (MW). The graph includes lines for different Direct Normal Irradiation (DNI) levels: 2000 kWh/m²/y, 2400 kWh/m²/y, and 2800 kWh/m²/y. The green line indicates the CSP capacity.
Future Work by DLR within the topic:

- Including other renewable energies into the presented approach

- Using General Algebraic Modelling Software for calculation of optimal capacity adding plans for renewable energies in MENA

- Developing country specific case-studies

- For more information please visit: http://www.dlr.de/tt/csp-finance