Concentrating Solar Power:
The ‘Other’ Solar…
A Systems Perspective

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Concentrating Solar Power - Trough
Concentrating Solar Power - Tower

Salt Storage

Heliostats
Advanced Towers

- Secondary concentrator
- Quartz window
- Concentrated solar radiation
- Insulation
- Inlet
- Exit
- Absorber
- Vessel
Other CSP/STE Systems

Dish/Engine

CLFR

CPV
CSP Applications

- Electricity and heat applications are near-term
  - $16 Trillion energy infrastructure projected worldwide through 2030, 70% for electricity*
  - Massive expansion possible: concrete, glass, steel
- Solar fuel applications are longer-term
  “A challenge for the chemical sciences is to provide a disruptive solar technology to meet 10-20 TW of carbon-free power”
  -Nathan Lewis, Caltech

* IEA 2003 World Energy Investment Outlook Summary
Daily Modeled Vs. Actual Gross Solar MWh
SEGS VI 1999 Data

Ref: NREL Trough Performance Model
How low can it go?

SEGS I-IX, 354 MWe of Trough Power Plants

Data Source: Luz International Limited, 1990
Solar-only Molten Salt Power Tower

- Hot Salt Storage Tank
- Cold Salt Storage Tank
- Conventional EPGS
- Steam Generator
- Solar Collector
Using storage to meet peak electric demand

- **Sunlight**
- **Energy in Storage**
- **Output Power**

The diagram illustrates the peak demand for electricity occurring during midday (noon), which is met by energy stored during the day and released during the peak hours.
Molten Salt Power Towers can provide high *solar-only* annual capacity factors (> 70%)

- “Around the clock” with 13 hrs of storage
- This design could provide steady power to an electrolyzer
### Thermal storage is inexpensive

<table>
<thead>
<tr>
<th>Storage System</th>
<th>Installed Cost of Energy Storage for a 220 MW$_e$ Plant ($/kWhr$_e$)</th>
<th>Lifetime of Storage System (years)</th>
<th>Annual Round-trip Storage Efficiency (%)</th>
<th>Maximum Operating Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molten-salt power tower</td>
<td>15</td>
<td>30</td>
<td>&gt;99</td>
<td>650</td>
</tr>
<tr>
<td>Battery Storage Grid Connected</td>
<td>500 to 800</td>
<td>5 to 10</td>
<td>76</td>
<td>Not Applicable</td>
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</table>
Thermal storage also lowers cost
Spain leads the way
Eventually, PV prices offered to CSP ...
5-10 plants promoted or in progress trough & tower
Dish and Engine Technology

- **25kW systems**
  - Over 25,000 Hours Of On-Sun Operating Time
  - Over 125,000 Hours Of Chemical Fuel Operation
  - 24.9 kW Peak Power
  - 29.4% Peak Efficiency
  - 95%+ Availability
- **10kW systems**
  - Potential to address off-grid and distributed applications
  - Not a current emphasis
• Near term opportunities
• Large grid-tied energy production facilities
  – Central plant reduces O&M costs
  – High volume production early on allows faster cost reduction
  – Aggressively pursue opportunities brought by RPS’s in Southwest US
• Longer term opportunities off-grid and distributed with fully mature products
Planned Installations

• Six 25-kW dishes at Sandia Labs by Christmas 2004
• Ten dishes to be installed for APS in 2005
• Forty dishes scheduled for “showcase” plant in early 2006.
• Production of 1000 units/month starting as early as 2007
Sargent & Lundy
Due-Diligence Review of
Parabolic Trough
and
Power Tower Technologies
May 2003
S&L Work Scope

- Examination of trough and tower baseline technology assumptions (next plant)
  - Relied heavily on SunLab and industry data
- Analysis of industry projections out to 2020
  - Evaluated scale-up, technology improvements, experience learning
  - Detailed review of cost and performance
  - Assessment of R&D risk
- Assessment of the level of cost reductions likely to be achieved based on S&L experience.
- Perform a financial analysis to determine Levelized Cost of Energy (LEC)
S&L Summary Findings

- Power Tower Levelized Energy Cost

<table>
<thead>
<tr>
<th>Year</th>
<th>Solar Tres</th>
<th>Solar 50</th>
<th>Solar 100</th>
<th>Solar 200</th>
<th>Solar 220</th>
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<tbody>
<tr>
<td></td>
<td>Based on Sunlab Estimate</td>
<td>Based on Sargent &amp; Lundy Estimate</td>
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<td>2004</td>
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<td>2006</td>
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<td>2012</td>
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<td>2018</td>
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– … it is S&L’s opinion that CSP technology is a proven technology for energy production
– There is a potential market for CSP technology
– Currently CSP electricity is more expensive than conventional fossil-fueled technology.
  • Early deployments will require incentives
  • Significant cost reductions will be required to reach market acceptance
– Significant cost reductions are achievable assuming reasonable deployment of CSP technologies occurs
  • 2 to 10 GW by year 2020
Concluding Remarks

• This is a Solar-H2 Workshop … how about CSP hydrogen??

• Near term – H2 via Electrolysis
  – Large central plants using trough, tower, and dish plants
  – Locate first plants in SW deserts near large population centers to minimize transportation cost and losses
    • Ample good locations near Los Angeles, Phoenix, and Las Vegas

• Longer term – H2 via Thermochemical cycle
  – Higher solar-to-H2 efficiency
  – Lower levelized H2-generation cost
H$_2$SO$_4$(g) $\rightarrow$ SO$_2$(g) + H$_2$O(g) + $\frac{1}{2}$ O$_2$(g)  
(850 °C)

SO$_2$(aq) + 2H$_2$O(l) $\rightarrow$ H$_2$SO$_4$(aq) + H$_2$(g)  
(80 °C electrolysis)
Solar Thermo-Chemical H2 Plant

- Annual solar-to-H2 efficiency for thermochemical plant ~20%
- Annual solar-to-H2 efficiency for electrolyzer plant ~12%

- Using H2A
  - Levelized H2 cost < $3/kg for power-tower thermochemical
  - Levelized H2 cost > $4/kg for power-tower electrolysis