Concentrating Solar Power Systems

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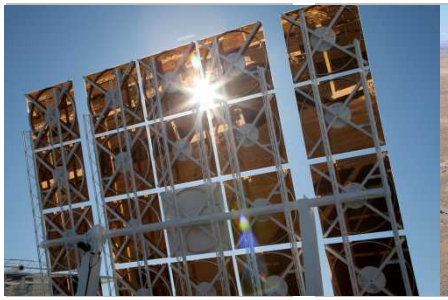

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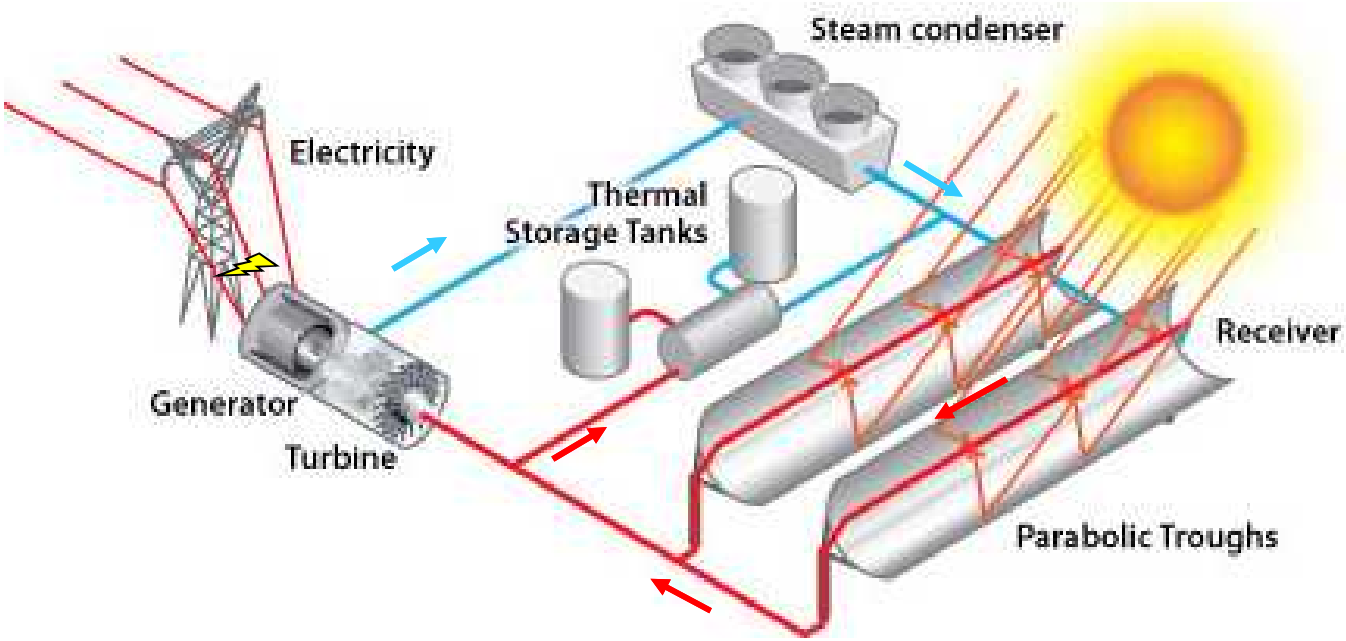
Outline – Concentrating Solar Power

- Introduction and Technology Description
- Commercial CSP Plants around the World
- Research Needs / Supplier Opportunities
- Summary

What is CSP?

- Concentrating solar power uses mirrors to concentrate the sun's energy onto a receiver to generate steam, which turns a turbine and generator to produce electricity

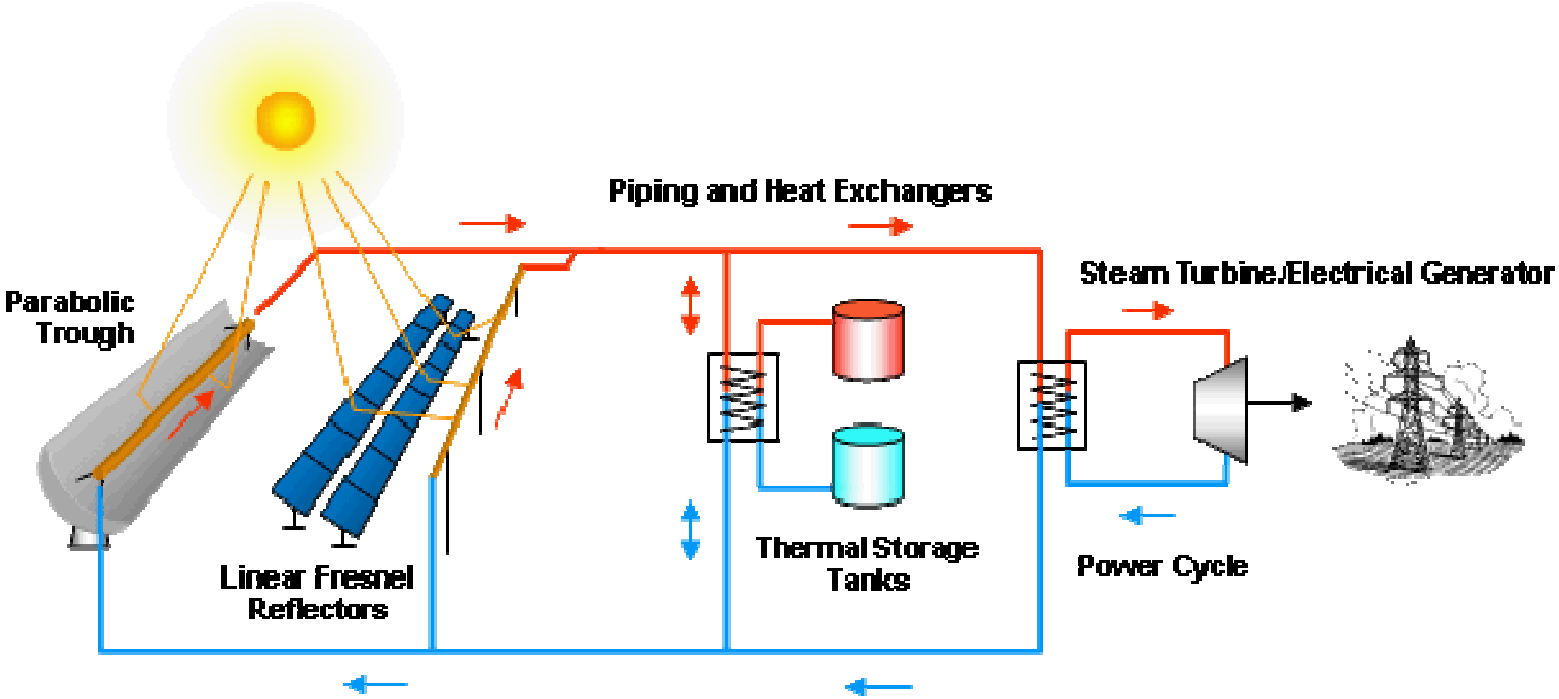


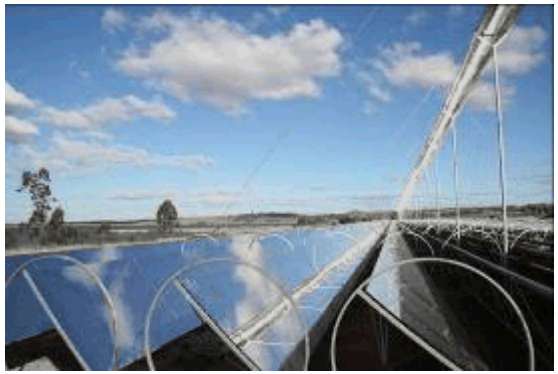
From the U.S. DOE Solar Energy Technologies Program Web Site:
http://www.eere.energy.gov/basics/renewable_energy/linear_concentrator.html

CSP Technologies

- Line Focus
  - Parabolic Troughs
  - Linear Fresnel
- Central Receivers “Power Towers”
- Dish Engines

Line Focus Systems

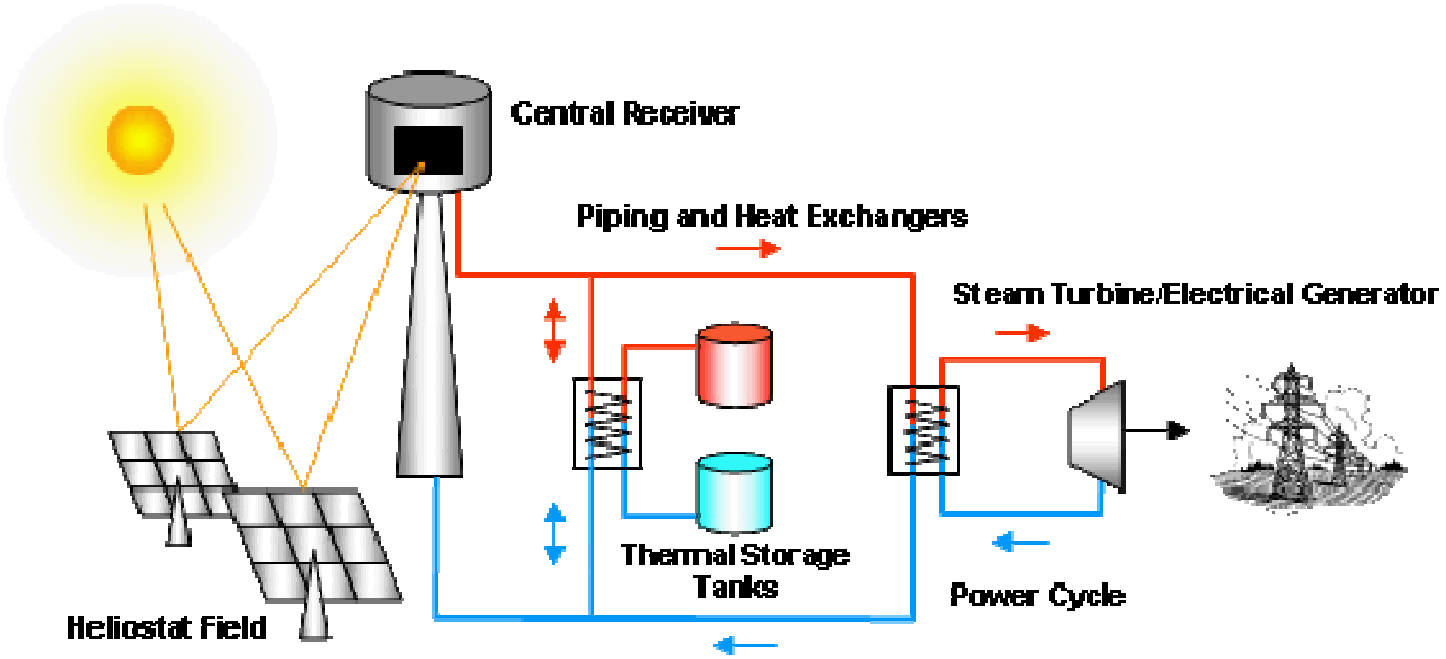




Parabolic trough (left) and linear Fresnel (right) collector systems (photos from http://en.wikipedia.org/wiki/Solar_thermal_energy)

Central Receivers

“Power Towers”



Central Receivers

“Power Towers”

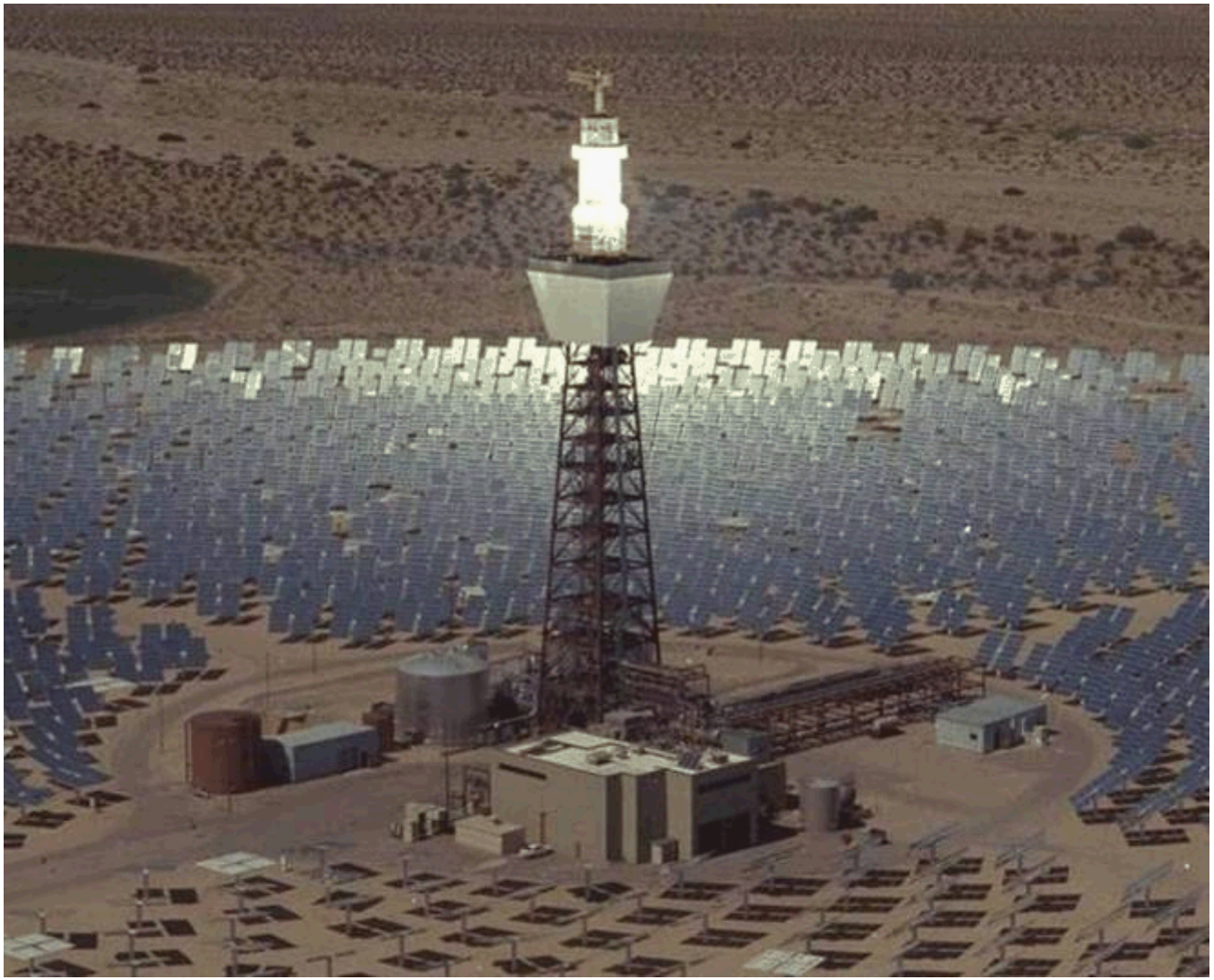


Photo of Solar Two power tower plant in operation in Daggett, CA (photo from Sandia National Laboratories, photo 2897)

Dish/Engine Systems

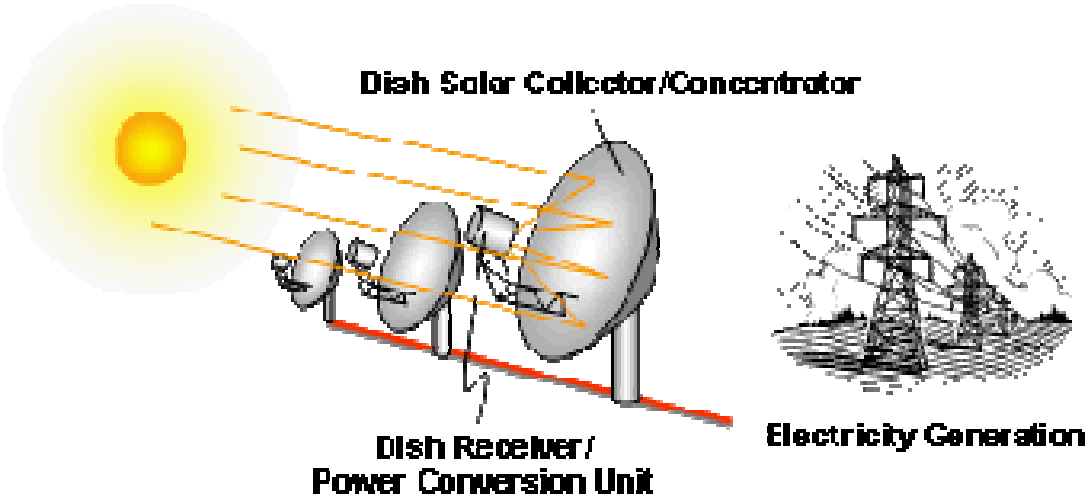


Illustration and photo of dish/engine system
(photo from http://en.wikipedia.org/wiki/Solar_thermal_energy)

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CSP Plants in the U.S.

http://en.wikipedia.org/wiki/SEGS

- Solar Electric Generating System (SEGS) Plant
  - 9 parabolic trough plants in Mojave Desert, CA (started in 1980's)
  - 354 MW installed capacity
- Nevada Solar One
  - Near Las Vegas, NV
  - 64 MW installed capacity
  - Commissioned ~2009

eSolar Power Tower

5 MW in Lancaster, CA (started in 2009)
24,000 heliostats, two modules

Power Towers Under Construction

392 MWe direct-steam power tower plants (3) under construction by BrightSource in Ivanpah, CA. Construction from 2010 – 2013.

110 MWe molten-salt power tower under construction by SolarReserve near Tonopah, NV. Construction from 2011 – 2014.

Stirling Energy Systems Dish/Engine Plant

Sandia National Laboratories

1.5 MW, 60 dishes near Phoenix, AZ (started in 2010; filed for bankruptcy in 2011)

CSP in Spain

Nearly 500 MW of CSP power plants are in operation or have been constructed

- Many more CSP plants are planned

Gemasolar

(near Seville, Spain)

- 1st commercial power tower (19 MW) in the world with 24/7 dispatchable energy production (15 hours of thermal storage using molten salt). Commissioned in May 2011.

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DOE SunShot Goal

- **Reduce LCOE of solar-generated electricity to $0.06/kWh by 2020 with no tax credits**
  - Reduce cost of installed solar energy systems by 75%
  - Enable solar-generated power to account for 15–18% of America's electricity generation by 2030

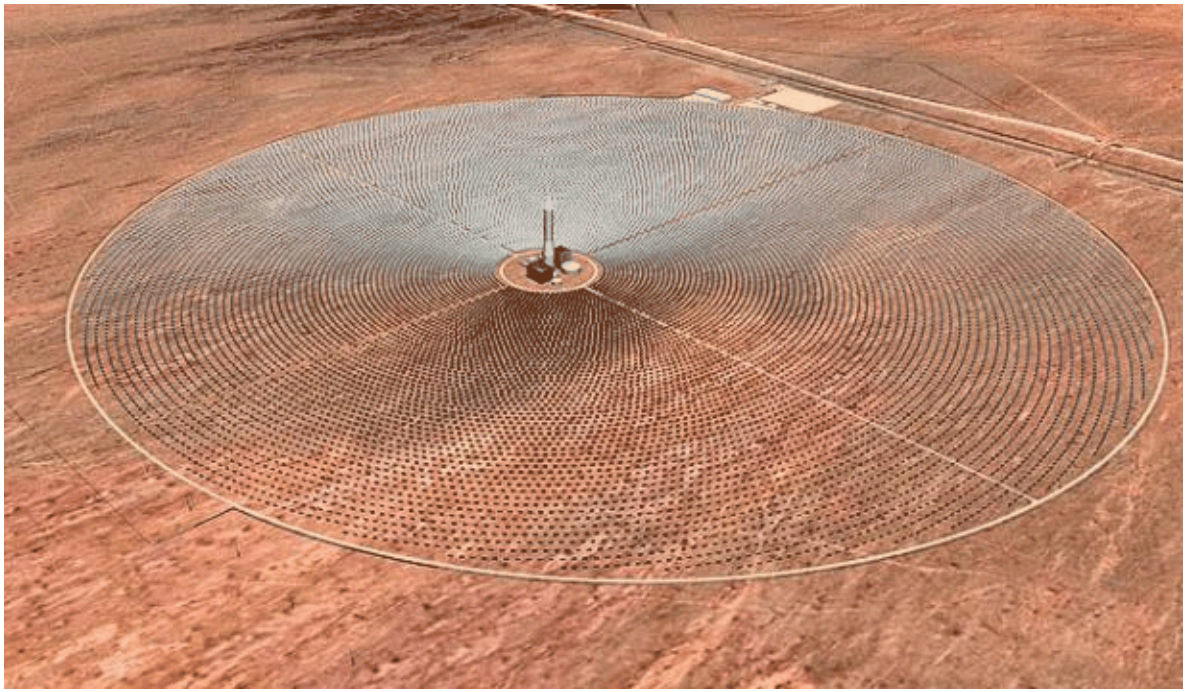
Research Needs

- Collectors (Mirrors) and Optical Performance
- High-Temperature Receivers
- Advanced Power Cycles
- Thermal Energy Storage

Need Lots of Mirrors

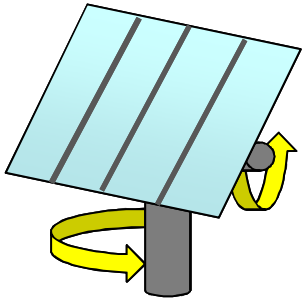
(Up to ~40% of total capital cost of CSP plant)

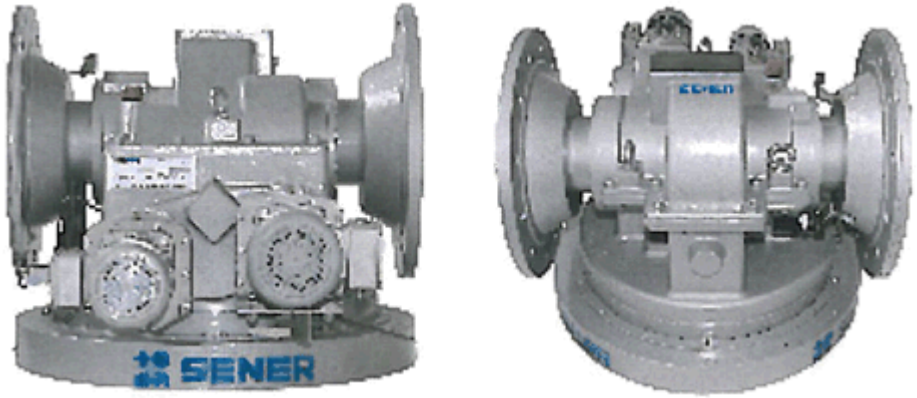
80 MW Solar Electric Generating Station IX (~500,000 square meters of glass mirrors)



SolarReserve's 110 MW Power Tower, Tonopah, NV (~1 million square meters of glass mirrors)

Need Low-Cost Motors and Drives to Position the Mirrors





SENER Two-Axis Drive

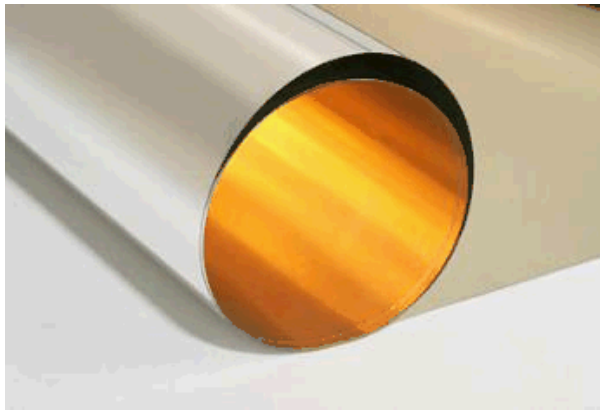
Siemens Two-Axis Drive

Alternative Reflective Materials

- Reflective polymer films (e.g., Mylar) vs. silvered glass mirrors
  - Durability, costs, performance?

SkyTrough® with ReflecTech® Mirror Film (SEGS II)

Heliostat with 3M SMF1100

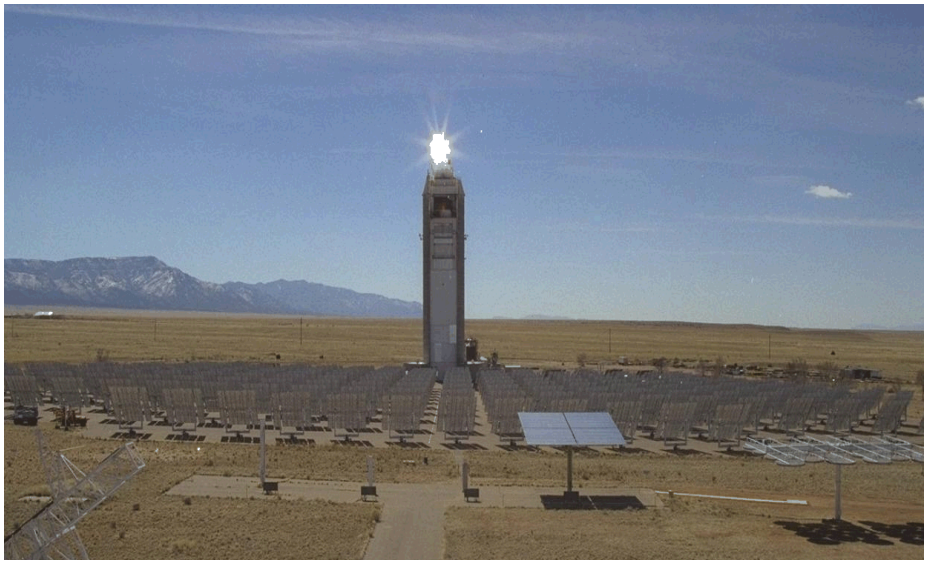


3M™ Solar Mirror Film 1100

Anti-Soiling Coatings

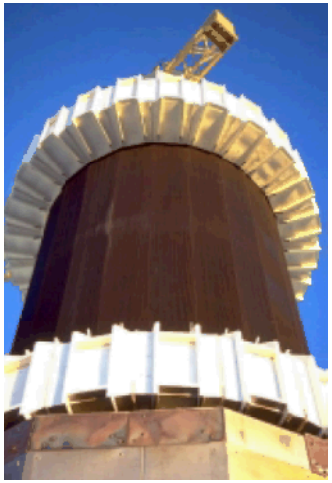
- Need anti-soiling coatings for mirrors to reduce need for washing and maintain high reflectivity

High-Temperature Receivers



National Solar Thermal Test Facility, Sandia National Laboratories, Albuquerque, NM

Cavity tubular receiver



External tubular receiver

- Need high strength materials that can withstand high temperatures and many thermal cycles
  - E.g., Haynes 230
- Corrosion resistance to high-temperature molten salts

Advanced Power Cycles

- Turbomachinery
- Heat exchangers

Thermal Energy Storage

- Sensible (single-phase) storage
  - Low temperature melting-point molten salts
    - Reduce heating needs at night to prevent freezing
  - Stability of heat transfer fluids at higher temperatures
  - Solid storage (particles, graphite, concrete, ceramics)
- Phase-change materials
  - Use latent heat to store energy
- Thermochemical storage
  - Converting solar energy into chemical bonds (e.g., sulfur thermochemical cycle)

Molten-salt storage tanks at Andasol parabolic trough plant in Spain

Summary

- Concentrating Solar Power (CSP) provides utility-scale electricity
  - Uses mirrors to concentrate solar flux onto receiver
  - Hot working fluid converts heat to mechanical energy via heat engine (e.g., steam turbine, Stirling engine), which spins a generator for electricity
  - Extra heat can be used for thermal storage to generate electricity during night or cloudy periods

Summary

- Some Research Needs for CSP (Supplier Opportunities)
  - Collectors (Mirrors) and Optical Performance
  - High-Temperature Receivers
  - Advanced Power Cycles
  - Thermal Energy Storage

Thank you for your attention!

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