Challenges to increase penetration of CSP point focus technologies in the electricity market

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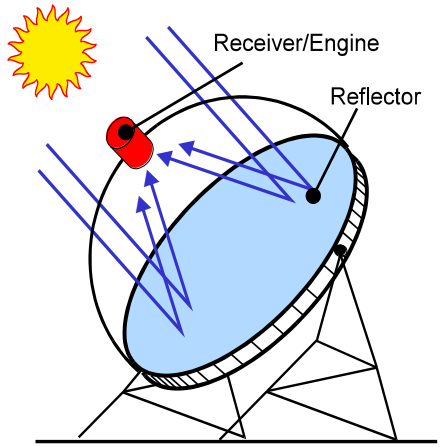
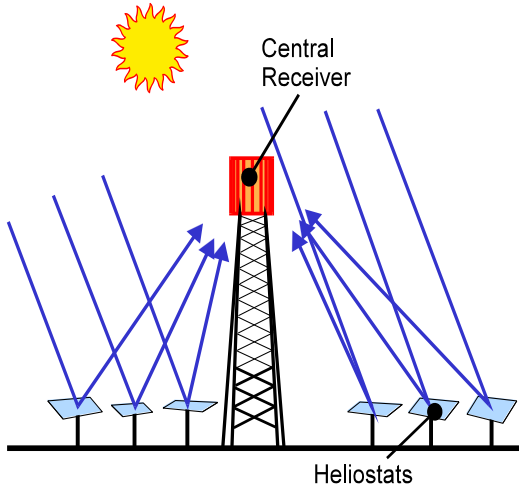
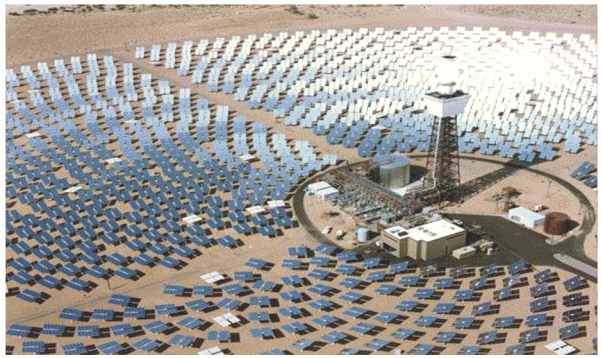
Point focus technologies



Parabolic Dishes



Solar Towers



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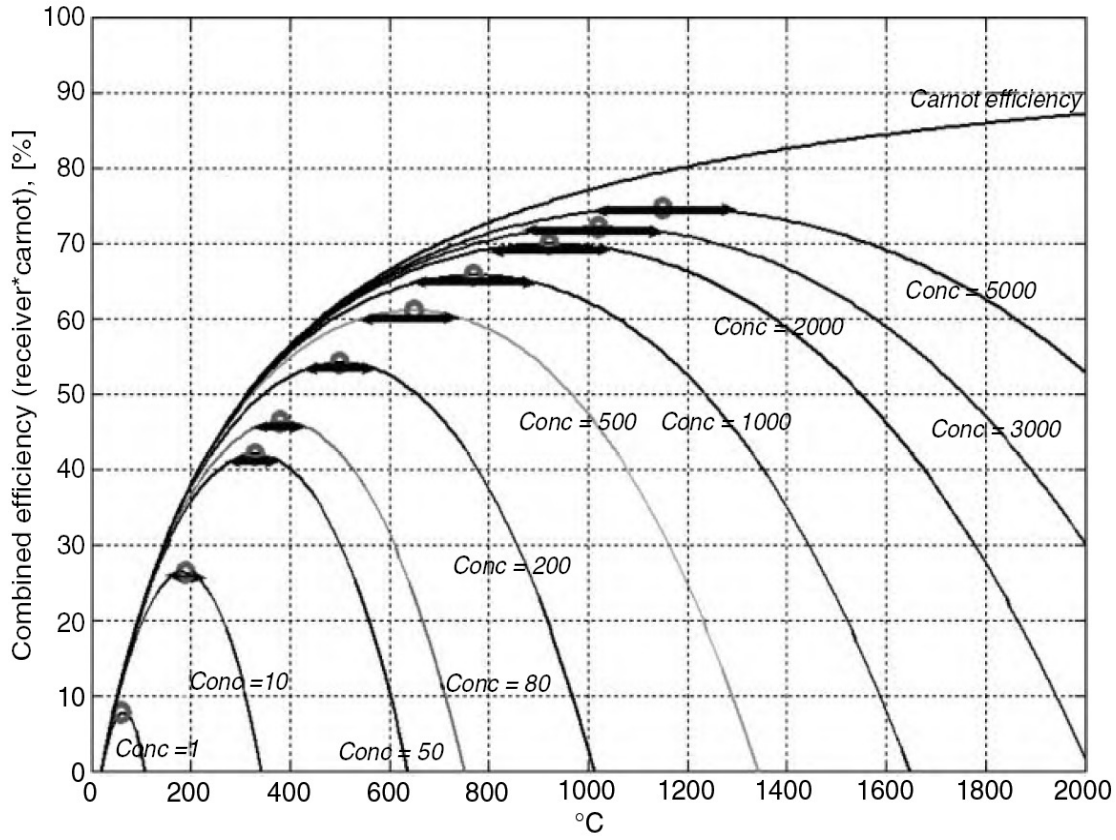
Point focus technologies

- Why point focus technologies?
  - Concentrating solar radiation allows for more efficient sun to heat conversion at high T
  - Point focus technologies achieve higher concentration than line focus technologies
  - **Point focus technologies have the potential to achieve high sun to power efficiencies**
- What is the toll?
  - Higher complexity, essentially.
  - Higher cost?



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Parabolic dishes

- Modularity
- High efficiency
- Complex integration with TES
- High cost (compare with PV!)
- Commercial development of parabolic dishes is negligible
- Very scarce R&D activities

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Central Receiver Systems (*solar towers*)

- Scalability (from 10^1 to 10^5's kW)
- Potentially high efficiency
- Options with easy integration with TES
- High cost (compared with PV!) – TES is mandatory nowadays
- Non-smooth commercial deployment
- Not fully mature (many technology options open, none having achieved sufficient commercial deployment or having demonstrated the required reliability)

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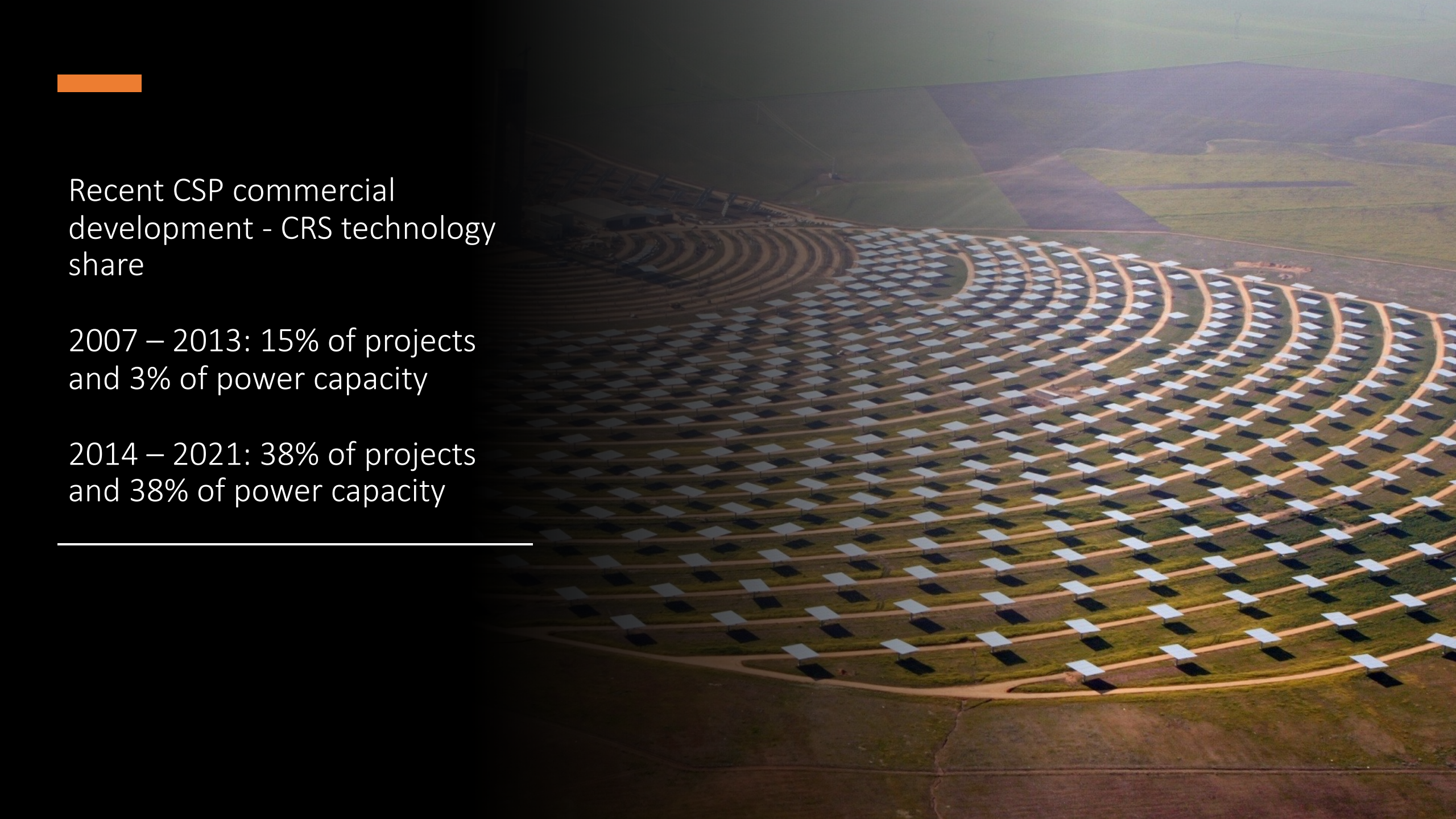
Recent CSP commercial development - CRS technology share

2007 – 2013: 15% of projects and 3% of power capacity

2014 – 2021: 38% of projects and 38% of power capacity



Direct Steam Generation

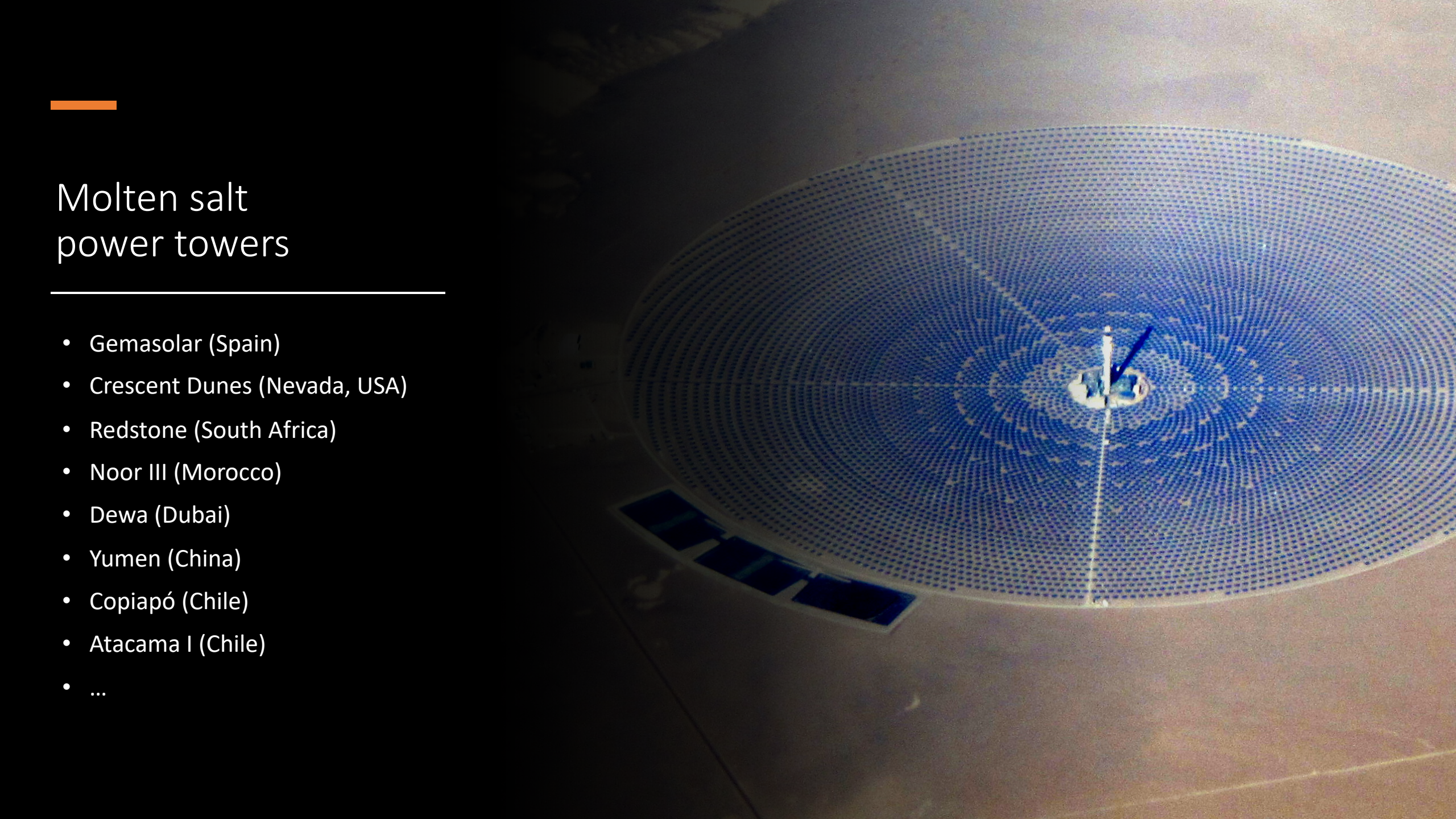
- saturated steam – PS10, PS20
- superheated steam – Khi Solar One
- PCM TES development required

The Molten Salt option

- Solar Two: “molten salt power towers”, including a large *direct* two-tank thermal energy storage system.

Molten salt power towers

- Gemasolar (Spain)
- Crescent Dunes (Nevada, USA)
- Redstone (South Africa)
- Noor III (Morocco)
- Dewa (Dubai)
- Yumen (China)
- Copiapó (Chile)
- Atacama I (Chile)
- …



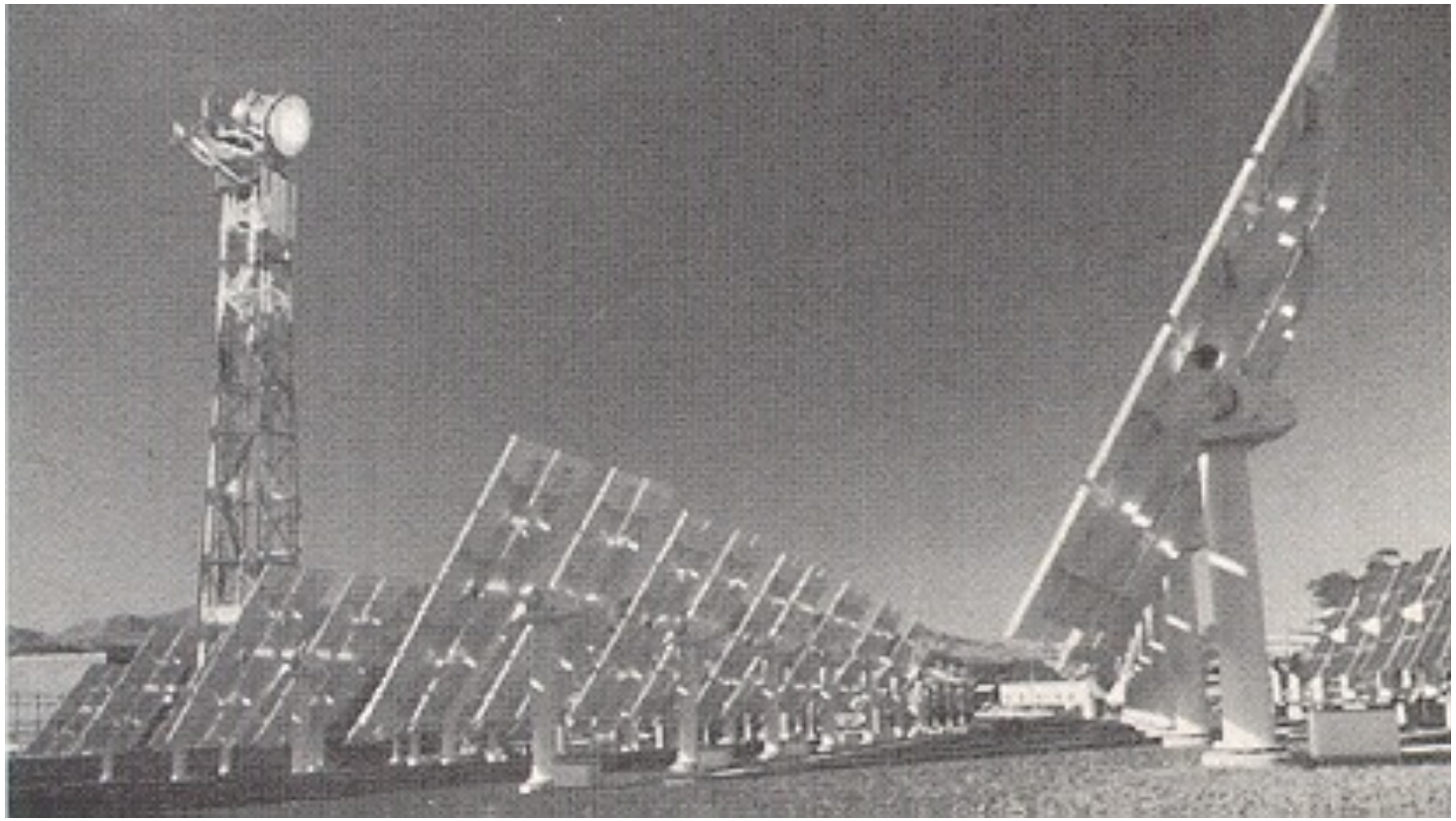
State of the art – commercial plants

- Large heliostats (aperture > 50 m^2)
- One-stage concentration
- Limited maximum flux (< 1 MW/m^2)
- Limited operation temperature
- Molten salt thermal energy storage
- Rankine cycle (wet or dry cooling)

- **The potential of CRS for high concentration – high temperature remains unexploited!**

Central Receiver Systems - main elements

- Heliostats
- Receivers
- Thermal Energy Storage
- Power block



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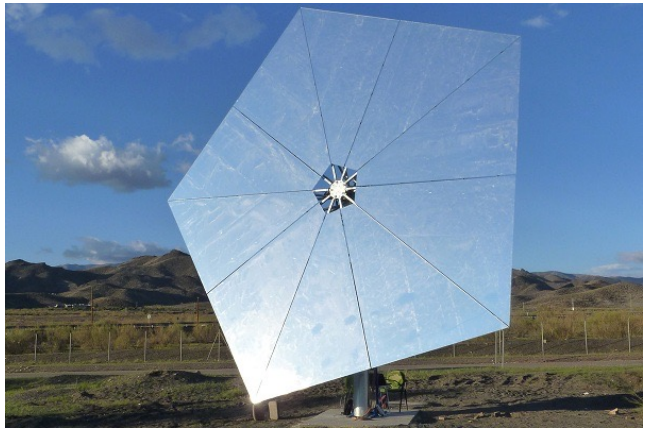
Central Receiver Systems - Heliostats

- Glass metal heliostats, different sizes (large heliostats in most of commercial plants)
- Cost goals have been met, further cost reduction may be required
- Heliostat performance may impose a limit to heliostat field size (receiver thermal power)



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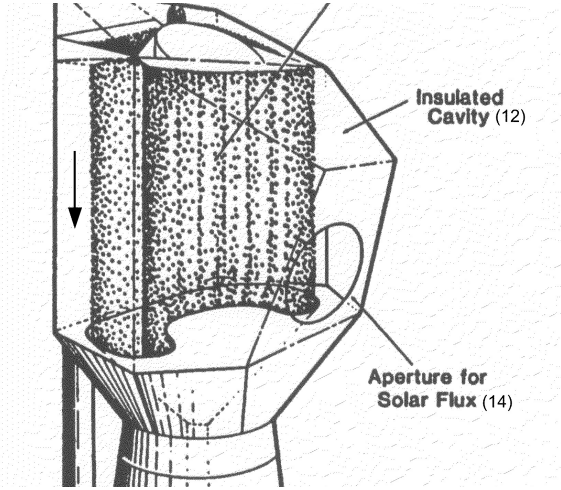
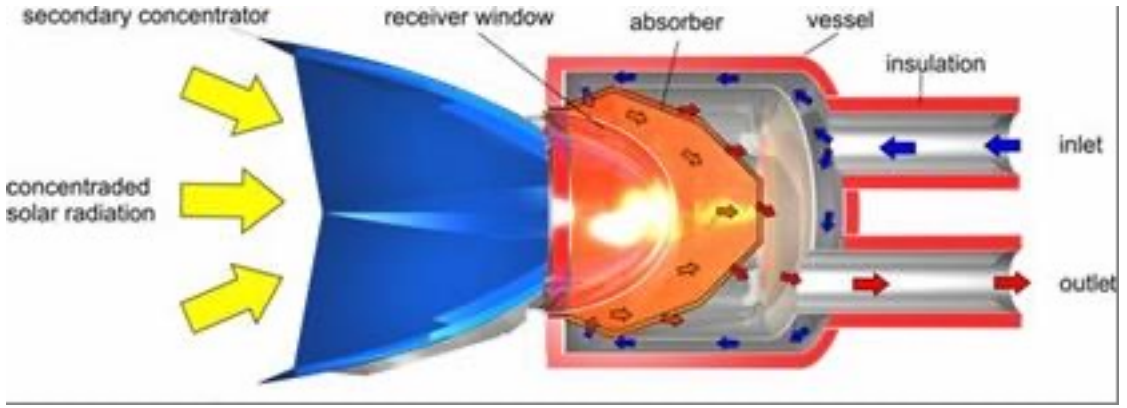
Central Receiver Systems - Receivers

High temperature receiver development 1980 – 1990's

- Tubular
  - Steam
  - Air receivers
  - Sodium
  - Molten salts
- Volumetric receivers (air)
  - atmospheric
  - pressurized
- Direct absorption
  - Falling particles
  - (Molten salt)





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Central Receiver Systems - TES

- Molten Salt, direct TES, two tanks
- Solid particles, direct
- Thermochemical
- Diverse materials, indirect (air)

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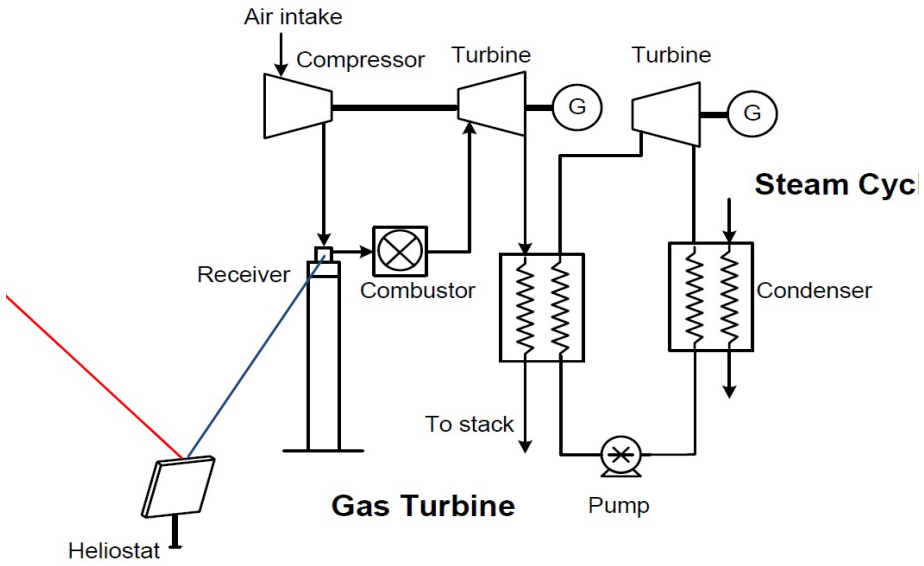
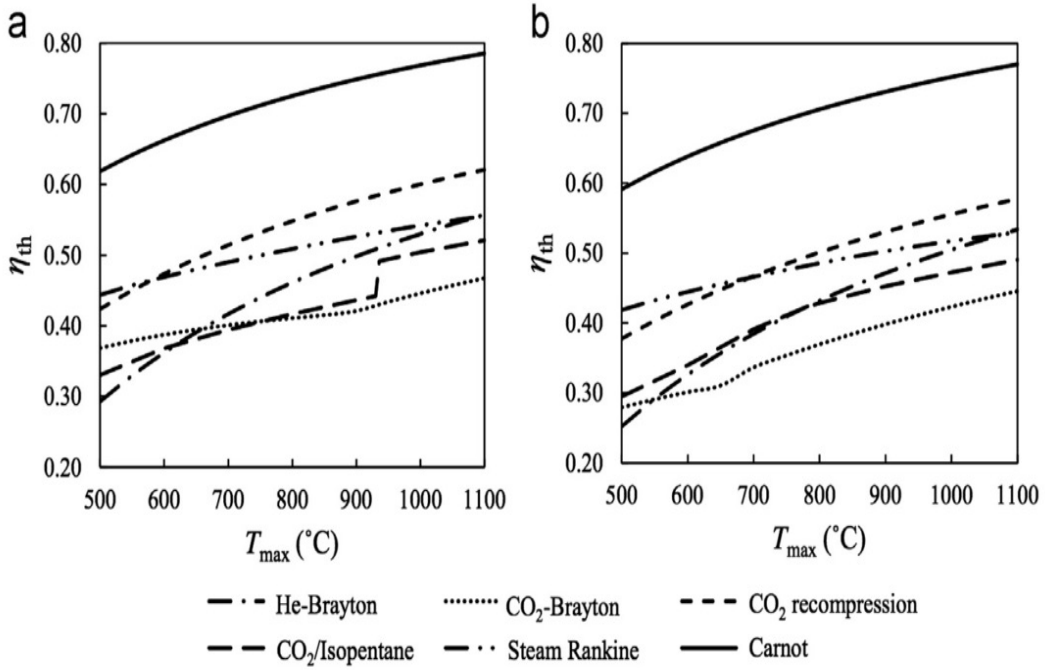
Power cycles

- The Rankine power cycle efficiency is today a limiting factor
- High-T, High-efficiency power cycles
  - Brayton and combined Brayton – Rankine cycles (800 – 1200 ºC)
  - Supercritical CO2 cycles (800 - 1000 ºC)
  - Supercritical steam (600 ºC)
- Thermal efficiency > 50%





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Some thoughts

- The most relevant challenges are common to all technologies, but some are CRS-specific
- Reliability and cost reduction are critical issues In the short term
- Cost reduction or efficiency increase? Both are required
- A holistic approach is required to develop the next generation of CRS, which must be based on:
  - Advances in optics, required to achieve high concentration e
  - Advances in materials – receivers, storage, HTMs
  - Advances in power cycles
  - Advances in manufacturing processes (3D-printing?…)
  - Application of advanced control concepts and tools

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