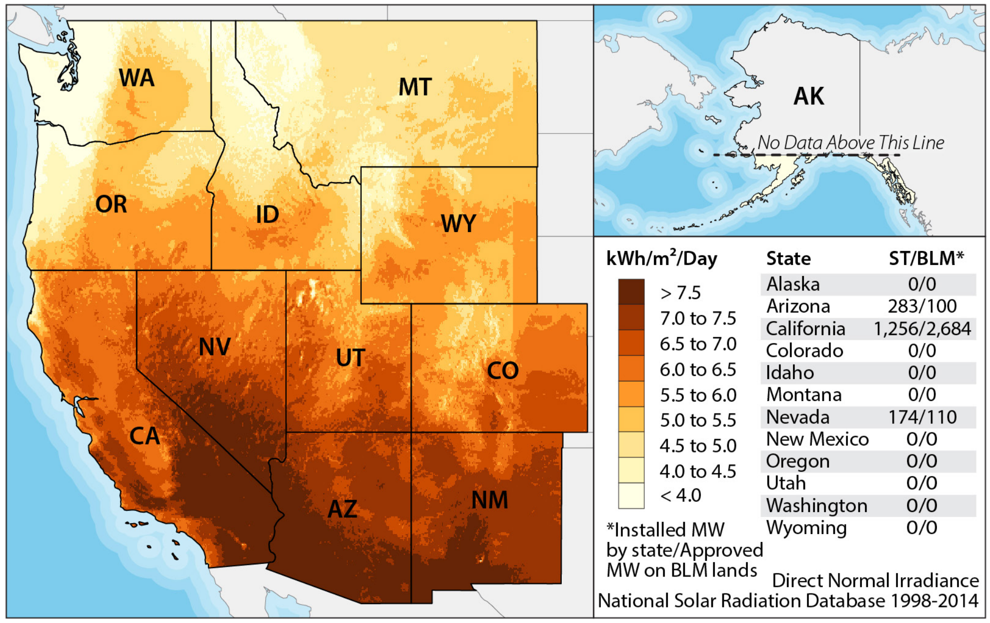
Concentrating Solar Power



Market Outlook

Concentrating solar power (CSP) technologies can vary greatly in design, making it difficult to generalize across technologies. Typically, CSP technologies are constructed at utility scale (50MW or greater), with higher plant capacity factors than solar PV due to their ability to store excess heat energy gathered during the day and then produce electricity on demand. However, levelized CSP energy costs have not fallen as quickly as solar PV costs. CSP projects tend to require more water for operations, as well as proximity to large substations, which can impact plant siting decisions.

Key U.S. Technology Statistics

- Total CSP Capacity: **1.8 GW**[2]
- 2015 capacity factor range: **20-50%** (100 MW ≈ 175-438 GWh/yr)[3]
- Recent Capacity Additions:
  - 2012: **0 MW**
  - 2013: **250 MW**
  - 2014: **877 MW**
  - 2015: **110 MW**
- PPA price range: [3]
  - ($135-185/MWh)
- ITC Extended
  - Present – 2019: **30%**
  - 2020: **26%**
  - 2021: **22%**
  - 2022 onward: **10%**
- Installed Cost Range: [3]
  - **\$5-9/W_{AC}** (Range is due to storage capacity and solar field size)
- BLM Projects:
  - Approved: **2,894 MW**
  - In Operation: **980 MW**

Technology Basics

Concentrating solar power systems focus and intensify sunlight, absorb the energy to heat a fluid, and use that heat energy to drive a turbine connected to a generator. There are four primary configurations of CSP systems. *Parabolic trough* systems use mirrors that reflect and focus sunlight onto a linear receiver tube. *Power tower* systems use numerous tracking mirrors, called heliostats, which reflect the sun's rays to a receiver located on top of a centrally located tower. The receiver in each of these configurations contains a fluid that is heated by the sunlight and then used to create superheated steam, which spins a turbine and drives a generator to produce electricity. The other two technologies, *linear fresnel* and *dish-engine* systems, are far less common and not discussed further. CSP technology inherently lends itself to energy storage because the materials used to deliver energy to the energy conversion device (turbine or engine) may be held in a tank (typically molten salt) and then used to produce electricity on demand, or extended into nighttime.

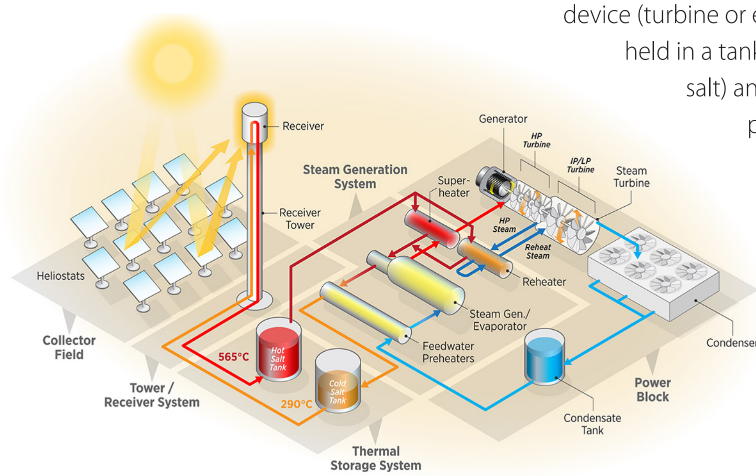
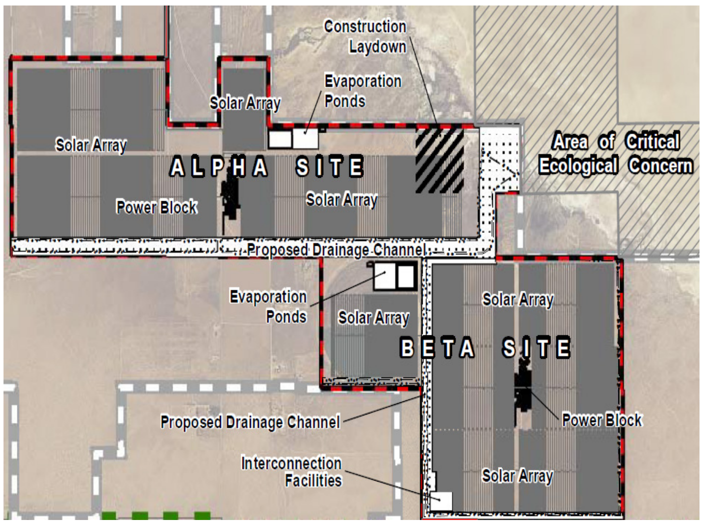


Diagram of a Power Tower System (NREL). Illustration by Alfred Hicks, NREL

Typical Project Requirements & Specifications

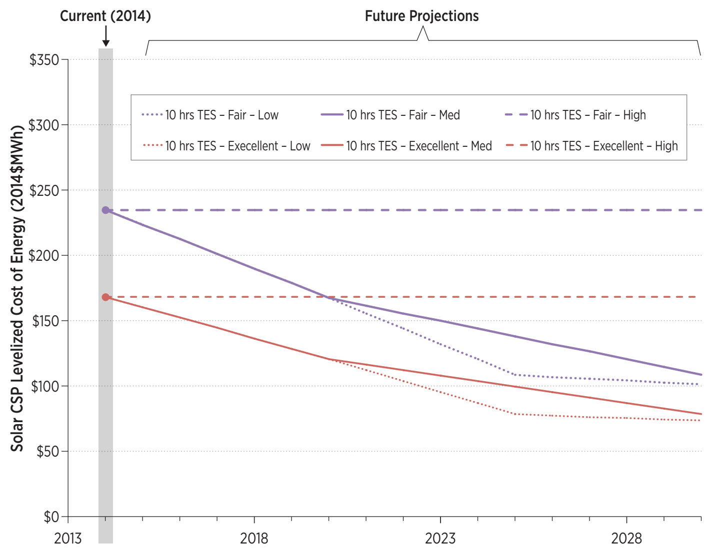
Site Requirements	Power Tower	Parabolic Trough
Land Slope[5]	<5%	<3%
Water Use (For Dry cooling)[4]	26 gal/MWh	78 gal/MWh
Total Land Use[6]	9.5-14.5 acres /MW_{AC}	6.3-18.6 acres/MW_{AC}
Plant Capacity Factor (long-term expectations)[1*]	42-59%	28-38%
Interconnection Proximity	<1-10 miles (typical for all technologies)	
Contiguous Land needed?	Yes	
O&M Cost (Fixed-F and Variable-V)[1]	F: $66/kW/yr V: $4/MWh	
Typical Operating Temp[5]	565°C	390°C

Energy Storage		
Technology	Molten Salt	Parabolic Trough
MW installed in U.S.[7,9] (capacity/storage energy)	110 MW / 1,100 MWh_t	250 MW / 1,500 MWh_t
Incremental storage installed cost[10]	$24/$kWh_t$ / $58/$kWh_e$	$65/$kWh_t$ / $183/$kWh_e$
Storage round-trip efficiency[7,9]	99%	90%
Value of energy storage for grid services[11]	Energy Arbitrage: $0-100/kW-yr Regulation Reserves: $20-200/kW-yr Resource Adequacy: $60-160/kW-yr	



Abengoa Mojave Solar Project. See reference 8.

Technology LCOE Cost Curve



Depicts the impact on LCOE at various resource qualities (Fair- Excellent) and cost reduction trajectories (Low-High)[1]

Resources

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*Plant capacity factor is determined by the configuration of the plant (amount of storage and size of the solar field). It can range from 20-70%.

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