

Current Status of Solar Thermal Power in California

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SDSU Energy Discussion Group
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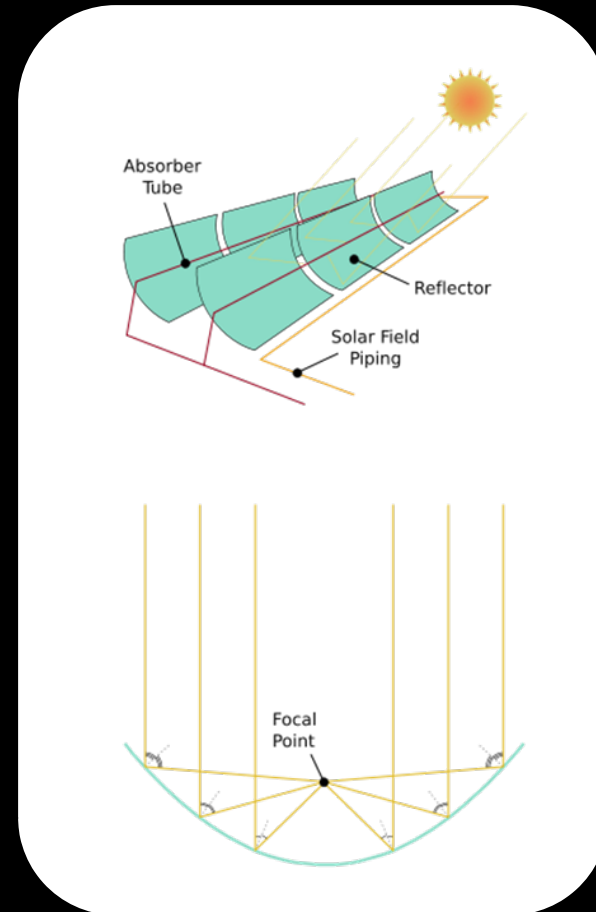
Overview

- Technology Overview
- Previous & Existing Solar Thermal Installations
- State Policy and Regulations
- Environmental & Technical Challenges
- Upcoming & Planned Projects
- Research and Future Projects



Parabolic Trough

- Most common
- Single Axis Tracking
- Distributed Receiver
- Relatively Lower concentrations, lower temperatures (350°C)



www.wikipedia.org

Linear Fresnel

- Single Axis Tracking
- Distributed Receiver
- Similar to Trough
 - Withstand higher winds
 - Flat mirrors



www.wikipedia.org

Central Tower Receiver

- Two Axis Tracking
- Central Receiver
- High concentrations,
high temperatures



www.wikipedia.org

Parabolic Dish

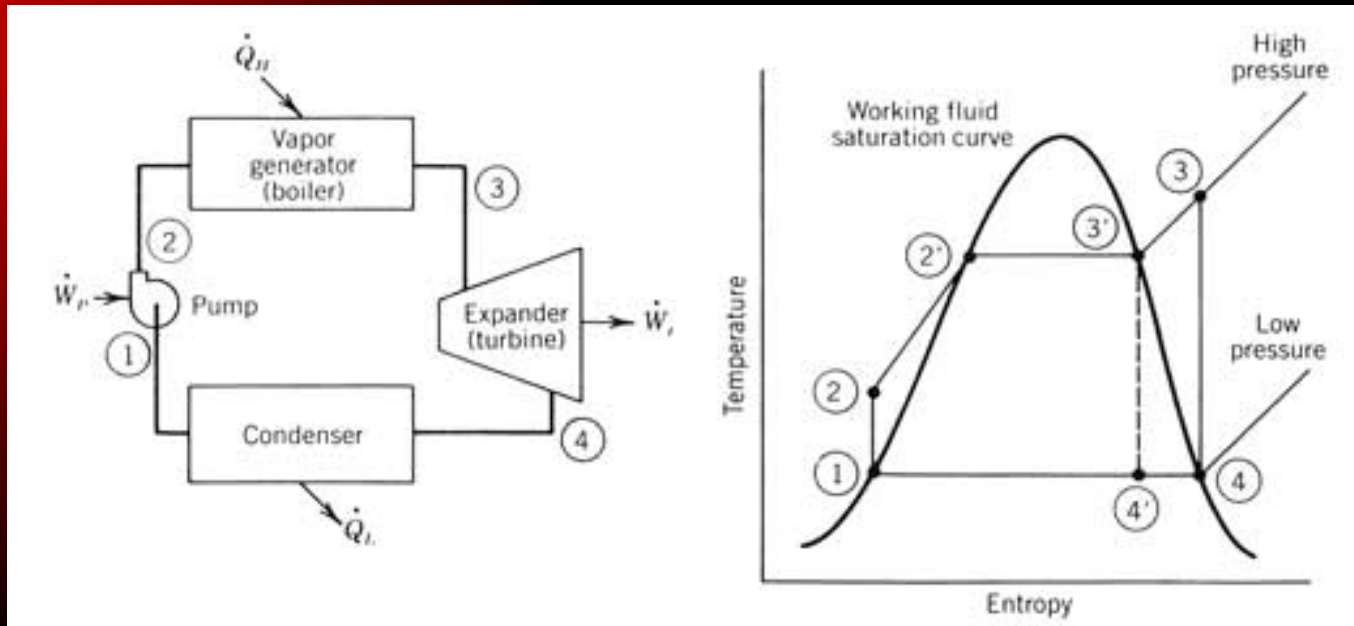
- Two Axis Tracking
- Multiple Single-Point Receivers
- Modular, Scalable



www.stirlingenergy.com



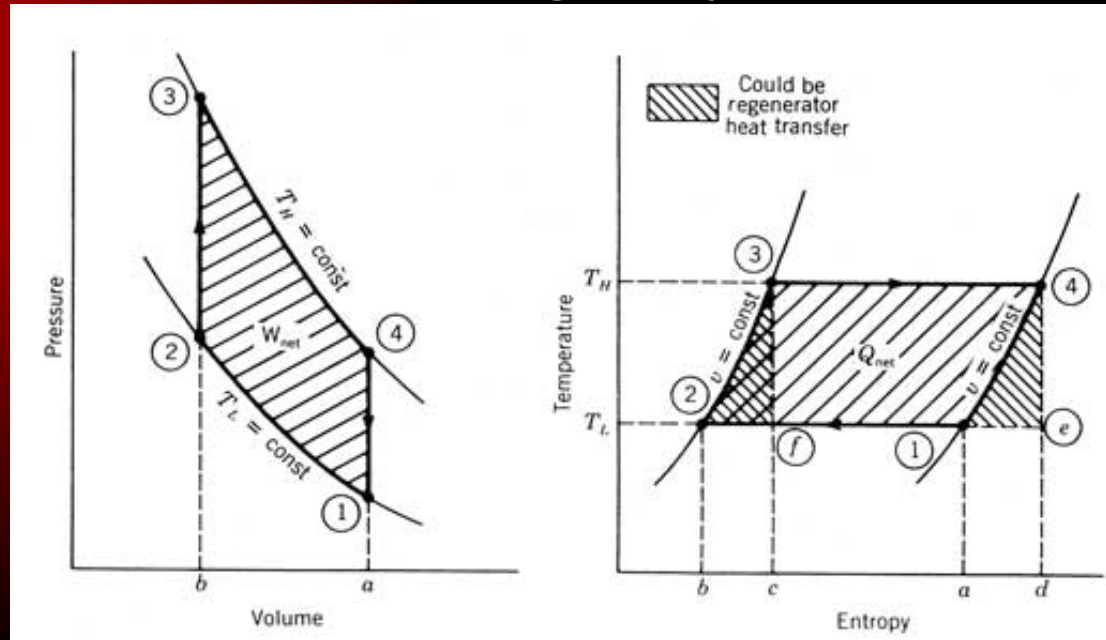
Rankine Cycle



www.powerfromthesun.net

- Phase-Change Cycle
 - Requires condenser
- Closed Loop

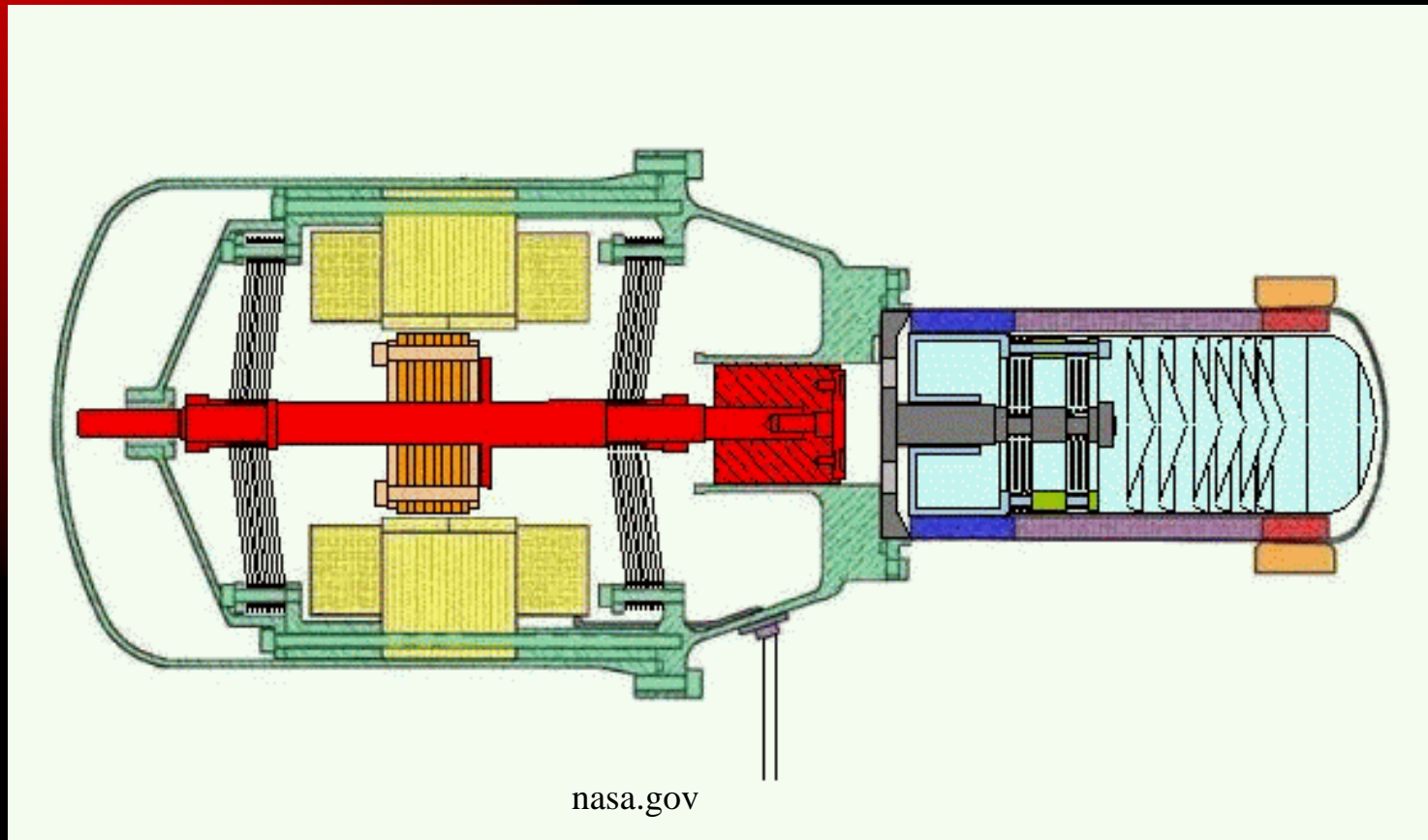
Stirling Cycle



www.powerfromthesun.net

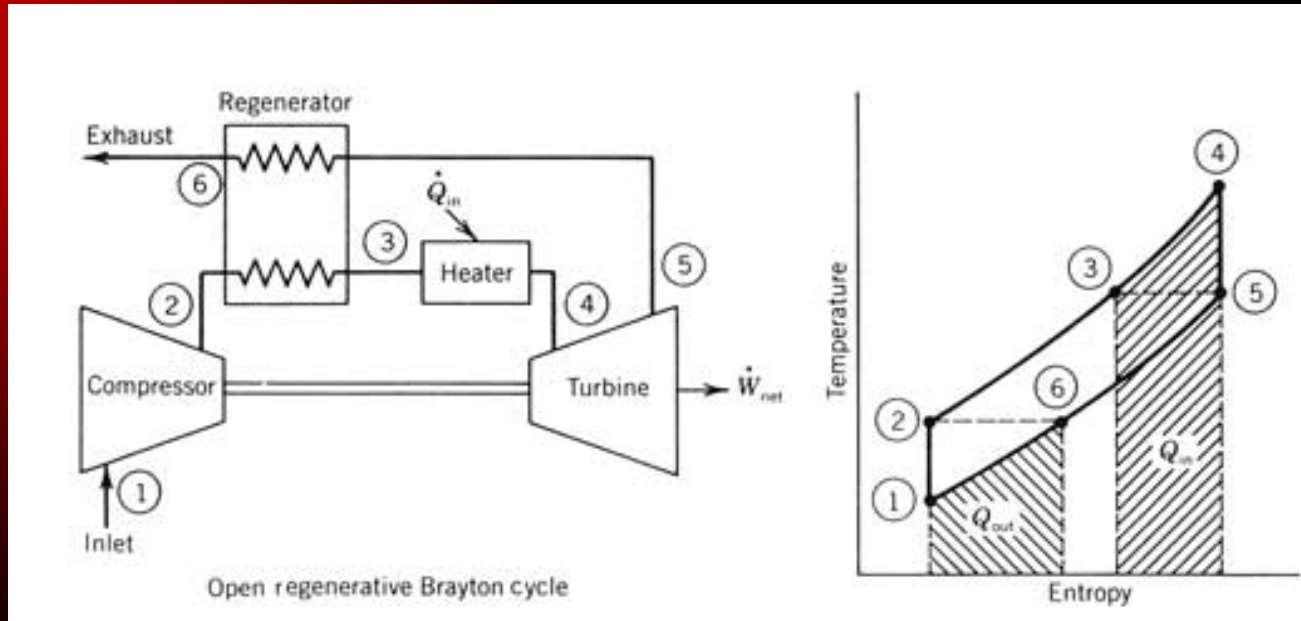
- Closed Loop
- Gas Phase
- Highest theoretical thermodynamic efficiency

Stirling Cycle Visualization



Animation of Free Piston Stirling Engine

Brayton Cycle



www.powerfromthesun.net

- Open or Closed Loop
- Gas Phase
- Highest temperatures

Previous & Existing Solar Thermal in California

- Solar One 10 MW (1982-1986)
- Solar Two 10 MW (1996-1999)
- SEGS - Luz 354 MW (built 1984-1991)
- Sierra Sun Tower - eSolar 5MW (2009)
- Kimberlina Linear Fresnel - Areva Solar 5MW (2008)



Existing Capacity

Renewables Production

24-Hour Renewables Production

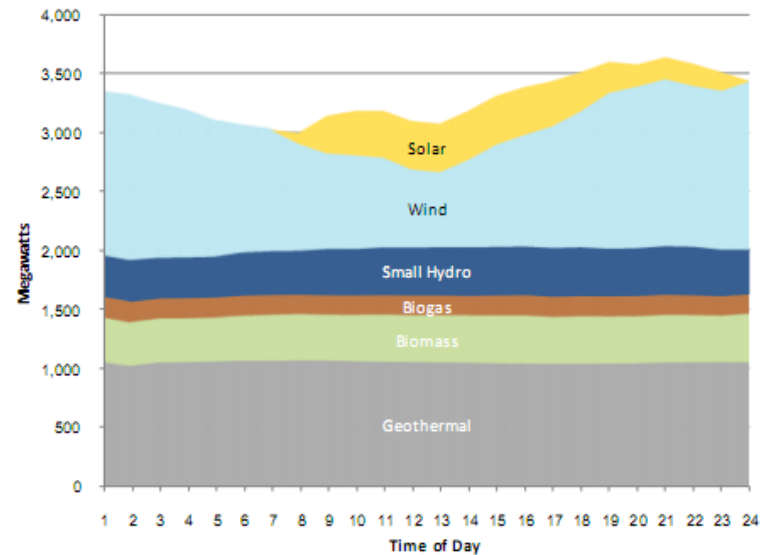
Renewable Resources	Peak Production (MW)	Daily Production (MWh)
Solar	411	4,860
Wind	1,447	25,774
Small Hydro	429	9,679
Biogas	173	4,051
Biomass	413	9,350
Geothermal	1,075	24,313
Other Renewables *	72	1,640
Total Renewables		79,667

Total 24-Hour System Demand (MWh): 654,999

This table gives numeric values related to the production from the various types of renewable resources for the reporting day. The total renewable production in megawatt-hours is compared to the total energy demand for the ISO system for the day.

* Other Renewables is comprised of multiple technology within one aggregated Resource ID

Hourly Breakdown of Renewable Resources



This graph shows the production of various types of renewable generation across the day.

www.caliso.com

- 411 MW Peak Solar Production (PV?)
- Total Electricity use peak ~15-19h

California Regulations

- SB 1078 – Renewable Electricity Portfolio (2002)
 - 20% from renewable sources by 2010
 - 33% by 2020 (updated 2008)
 - Investor Owned Utilities Only
 - SCE :17% PG&E: 14.4% SDG&E: 6%
 - LA DWP: 20% SMUD: 23% (targets for 2010)
- AB 32 – Emissions Reductions (2006)
 - Reduce greenhouse gas emissions to 1990 levels by 2020
- Proposition 23
 - Repeals AB 32 (until 4 quarters of 5.5% unemployment)



Environmental Challenges

- Environmental Impact
 - Land use approval
 - State – California Energy Commission
 - Federal – Bureau of Land Management
 - Wildlife (Desert tortoise)
- Water use
 - Dry vs. Wet Thermodynamic cycle condenser
 - Working Fluid
 - Mirror washing



Technical Challenges

- Thermal Storage
 - Shifts production to peak load times
 - Improves stability
- Plant Efficiency
- Proximity to Existing Transmission



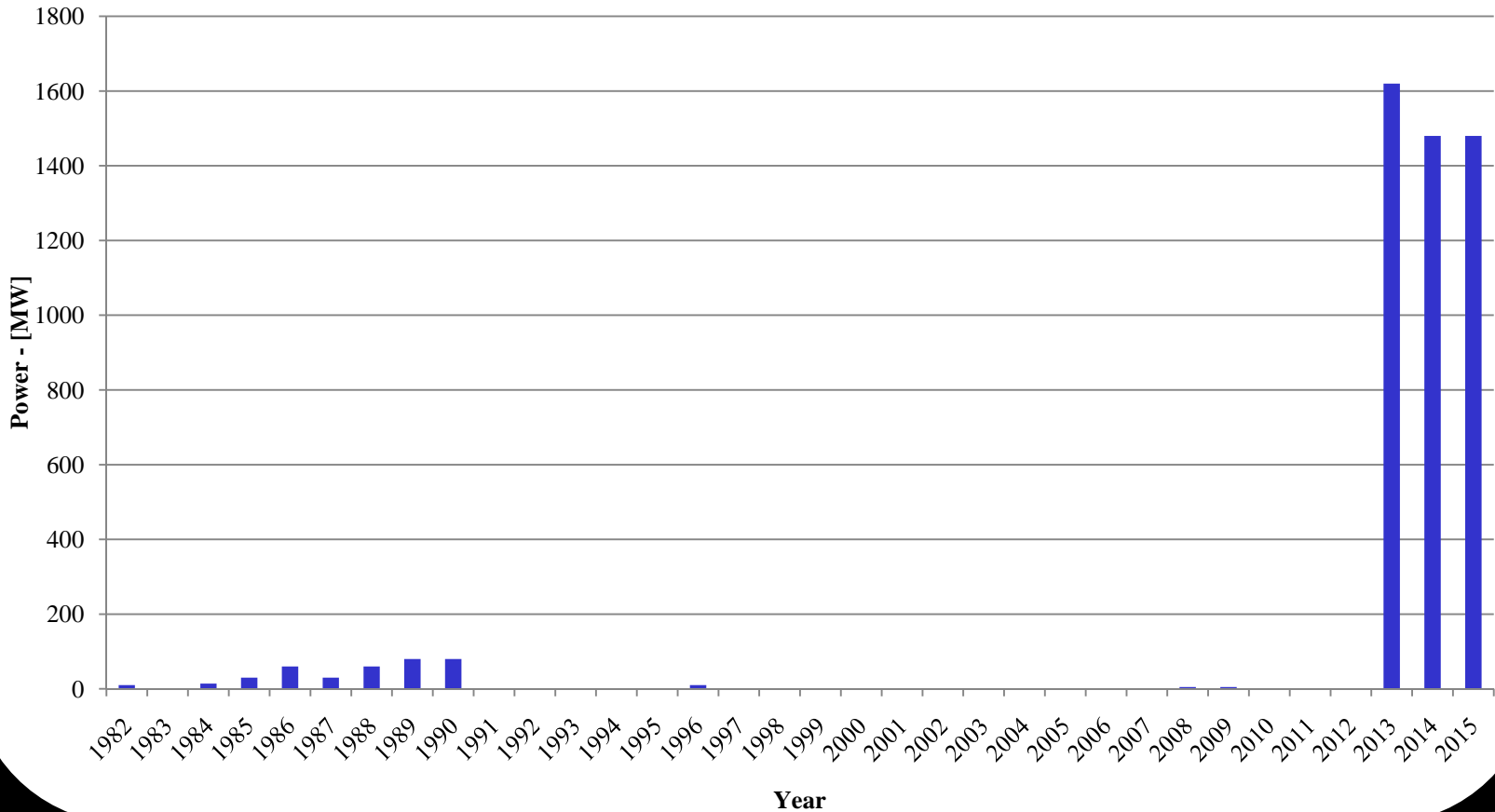
Planned Projects

- ~400 MW Existing Capacity
- 2829 MW Approved by CA energy commission
- 1750 MW Waiting Approval
- ~4.5 Million Tons of CO₂/yr saved
- Trough, Tower, & Dish Concentrators
- Rankine and Stirling Cycles



New Construction

Additional Annual Capacity of New Solar Thermal Plants



Solar Millennium

- 1000 MW Approved
- 500 & 250 MW Waiting
- Largest solar plant in the world
- Trough
- Dry-cooling
- 2010 – Construction
- 2013 – On-line
- 1.5 million tons of CO₂/yr saved



www.solarmillennium.de

Brightsource

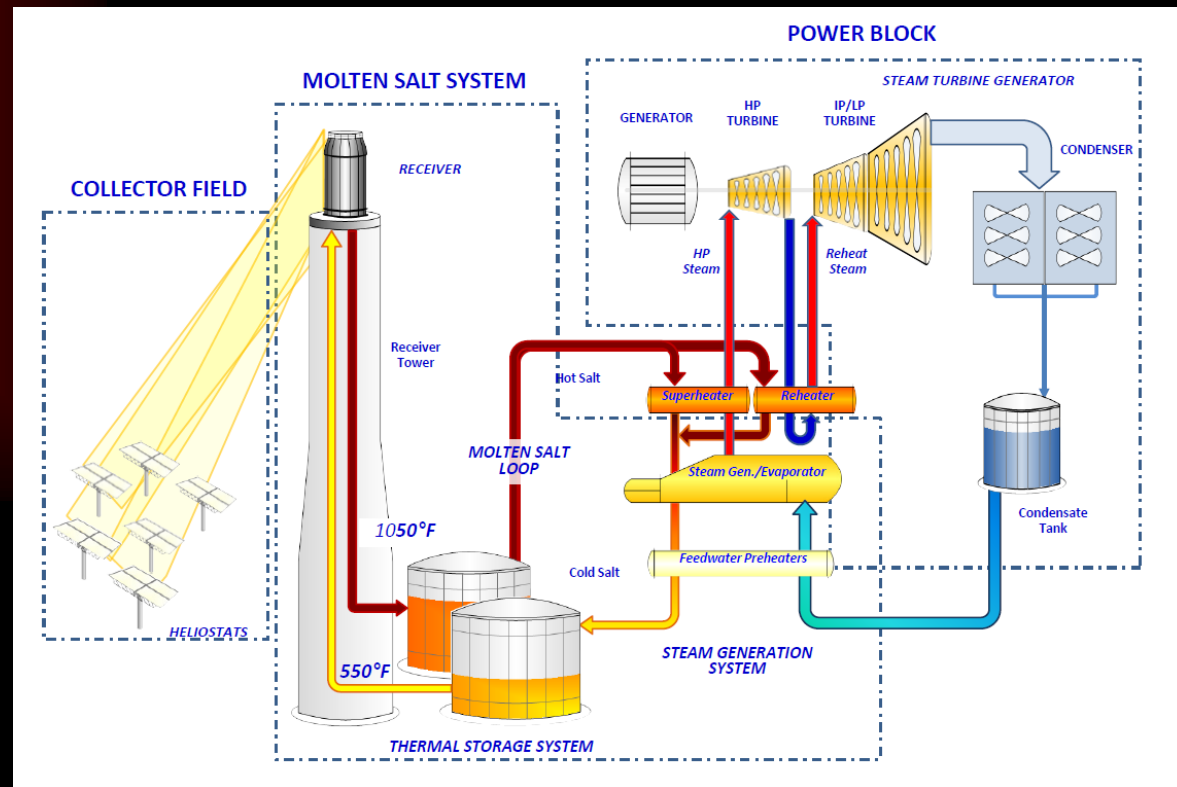
- 370 MW Approved
- Central Receiver
- 550° C, 160 bar steam
- 2600 MW of power purchase agreements with PG&E and SCE, 14 plants
- Dry-cooling
- Construction begins now
- 2013 – On-line
- 400 kilotons of CO₂/yr saved



www.brightsourceenergy.com

Solar Reserve

- 150 MW Waiting
- Central Receiver
- Integrated Thermal Storage
- 550° C Molten Salt
- Dry cooling
- Private land



www.solar-reserve.com

Stirling Energy Systems

- 709 MW Approved, 850 MW Waiting
- Parabolic Dish
- 25 kW each
- Hydrogen working fluid
- No Storage
- Minimal water use
- 2010 – Construction
- 2011 – On-line



www.stirlingenergy.com

Abengoa

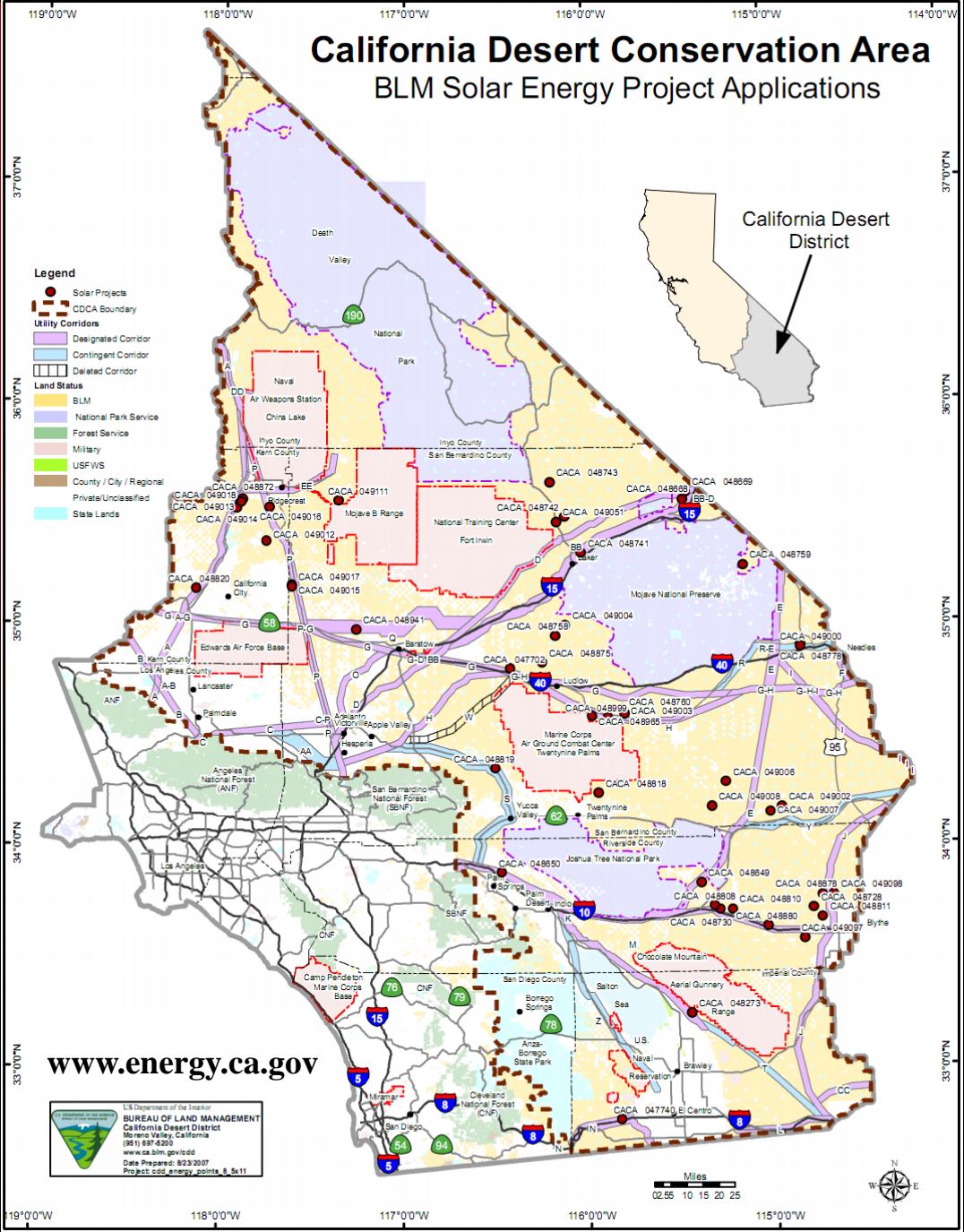
- 250 MW Approved
- 370° C Steam
- 2013 – On-line
- 431 kilotons of CO₂/yr saved



www.abengoasolar.com



California Desert Conservation Area BLM Solar Energy Project Applications



Timeline of Plant Construction – Brightsource

- 2006 – Brightsource Energy founded
- 9/2007 – Filed Application for Construction w/CA (first since 1989)
- 4/2008 – Power Purchase Agreement w/PG&E
- 10/2008 – Contract with Siemens for Turbine
- 2/2009 – PPA w/SCE
- 8/2009 – CA Public Utilities Commission approves PG&E contracts
- 12/2009 – Labor agreement for construction
- 2/2010 – Proposed reduced footprint for environmental impact
- 2/2010 – Federal loan guarantees secured
- 8/2010 – CA Energy Commission recommends approval
- 8/2010 – US BLM issues final environmental impact statement
- 9/2010 – CA Energy Commission licenses plant
- 10/2010 – US BLM approves project



Future Research and Projects Impact

- Brayton Cycle, Air-cooled receive
- Direct to steam in parabolic troughs
- Direct to salt in parabolic troughs
- Storage systems
- Costs
 - Currently \$5.00-6.50 /Watt installed
- Jobs
 - 500-1000 construction per plant
 - 50-100 operation per plant

