U.S. Department of Energy
Energy Efficiency and Renewable Energy

DOE Tribal Energy Program California Workshop Concentrating Solar Technologies & Applications

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Sandia National Laboratories

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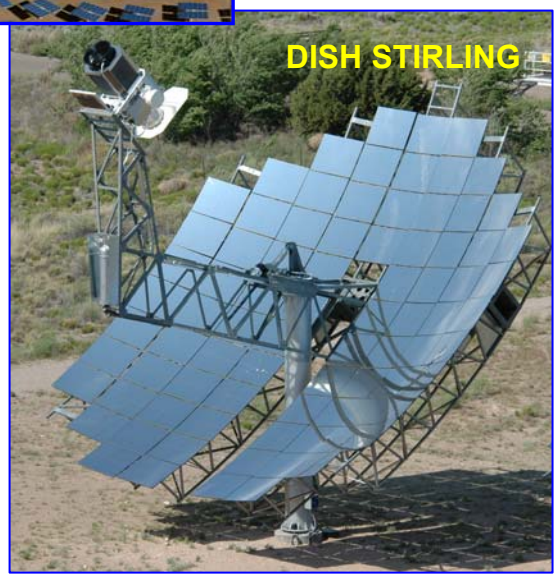
Concentrating Solar Power

Concentrating Solar Power (CSP) is also referred to as Solar Thermal Electric Power.



Concentrating Solar Power (CSP) systems …

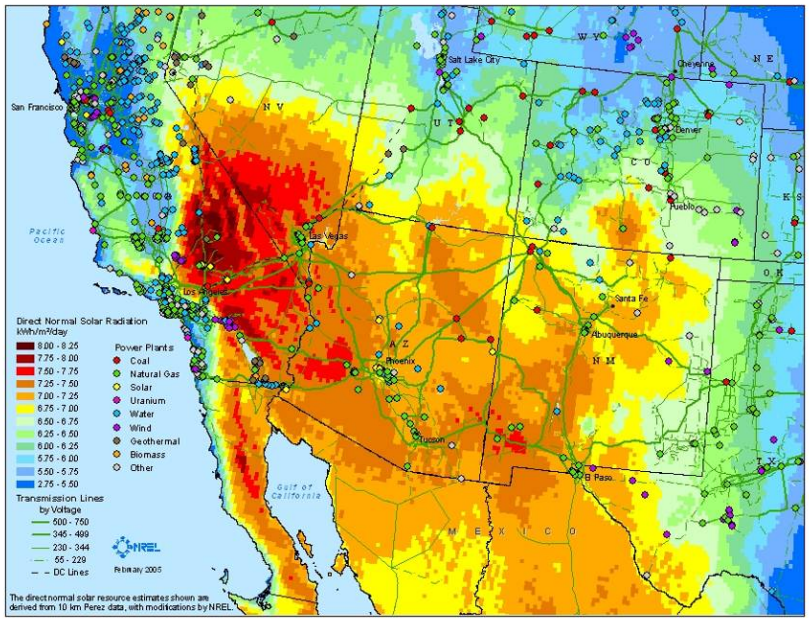
- convert the sun's energy to heat and use that heat to power and engine/generator.
- are utility-scale solar power (> 100 MW).
- comprise three generic technologies: parabolic trough, power tower, and dish Stirling.
- have more than 140 plant-years of commercial operation (9 plants, 354 MW) in California desert.
- can provide dispatchable power for peaking and intermediate loads (with storage or hybridization).
- mostly utilize commodity items for manufacture (glass, steel, aluminum, piping, controls, etc.).

Solar Resource in the US Southwest

Screening Approach

Filters applied:

- Direct-normal solar resource.
- Sites > 6.75 kwh/m^2/day.
- Exclude environmentally sensitive lands, major urban areas, etc.
- Remove land with slope > 1%.
- Only contiguous areas > 10 km^2

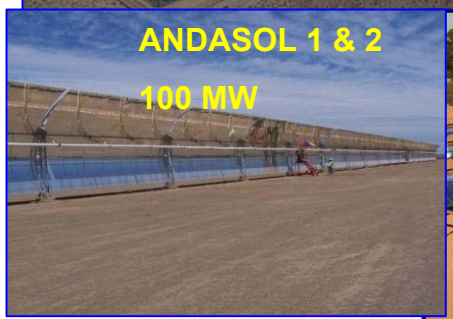


Data and maps from the Renewable Resources Data Center at the National Renewable Energy Laboratory

Parabolic Troughs

Line-focus technologies state-of-the-art (SOA) is the parabolic trough

- Total annual average solar-to-electric efficiency at 12 - 14%.
- No thermal Storage
- Capacity ~ 29%
- Could be hybrid with NG



Key Element: Receiver Tube

Emerging Technologies:

- Thermal Storage
- Higher Temperature
- New low-cost designs

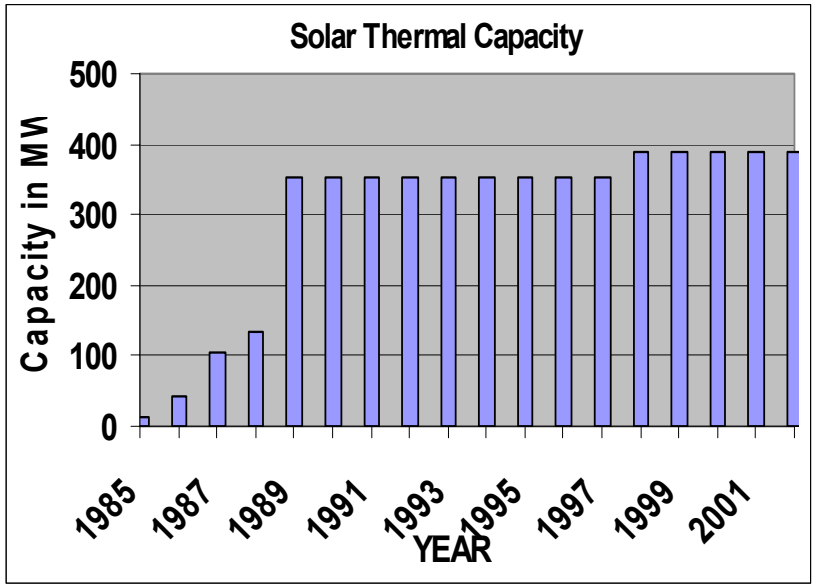
SEGS Plants

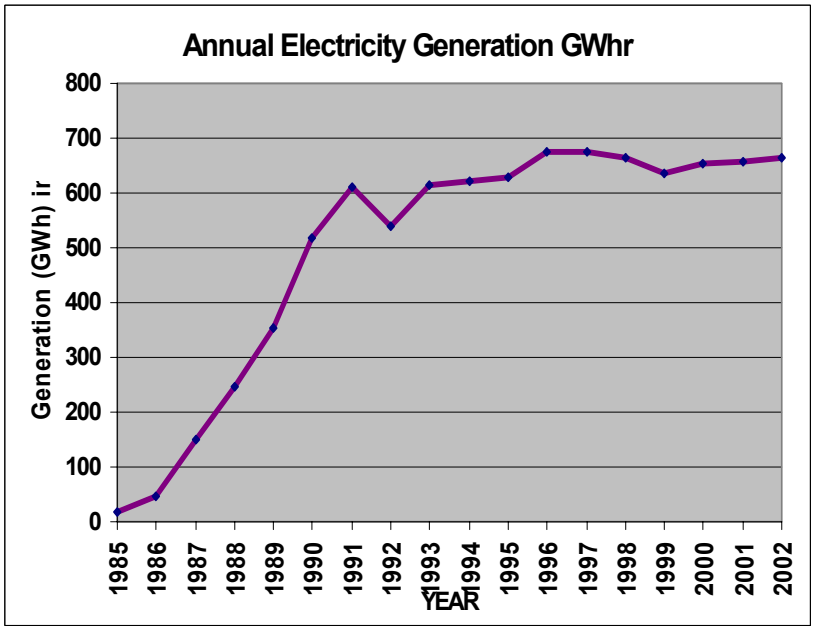
- Owned by FPL
- Solar Electric Generating Stations (SEGS): 354 MW
- Total annual average solar-to-electric efficiency at 12%.
- Plants use conventional equipment and are "hybridized" for dispatchability (25%)

Total reflective area > 2.3 Million m2

30 MW increment based on regulated power block size

SEGS Deployment and Production

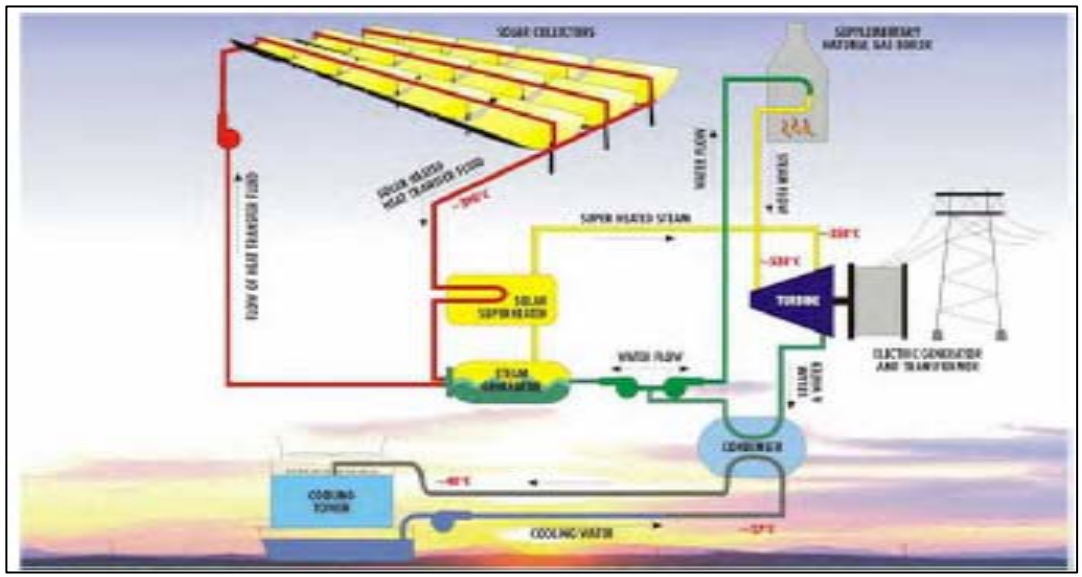




Solar Electric Generation Stations (SEGS) Deployment and power production 1985 – 2002.

- 64 MW Capacity
- 357,200m² Solar Field
- 30 Minutes Thermal Storage
- Minimal Fossil fuel
- Long term PPA signed with Nevada Power
- EPC Notice to Proceed – January 2006
- Commissioned June 2007

Nevada Solar One Technical Characteristics

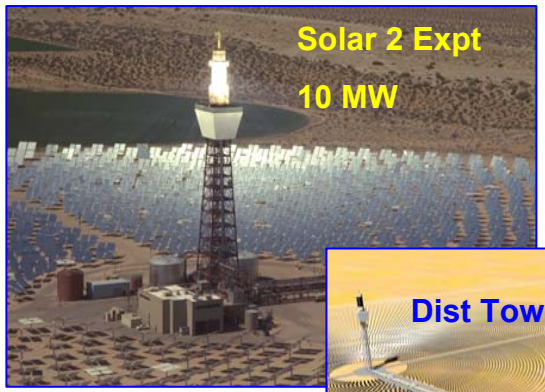


SOLAR FIELD	
64 MW solar field – 30 Minutes Storage –No fossil fuel added	
Solar Collector Assemblies:	760
Aperture Area (m²/Sq.ft):	5.0 / 59
Length (m/ft):	100/328
Concentration Ratio:	71
Optical Efficiency:	0.77
# of Mirror Segments:	182400
# of receiver tubes	18240
Field Aperture (m²):	357,200
Site area (Km²/acres):	1.42/360
Field Inlet Temp.(°C/°F):	350/662
Field Outlet Temp. (°C/F°):	395/743

Annual electricity production estimated to be 140 - 150GWh

Turbine Generator Gross Output	75 MWe
Net Output to Utility	70 MWe
Solar Steam Conditions	
Inlet Pressure	102 bars/1480 psi
Reheat Pressure	17.5 bars/254 psi
Inlet Temperature	371 Deg.C / 700 Deg.F

Power Towers



Point-focus technology

SOA is water/steam system

- Total annual average solar-to-electric efficiency ~ 12%.
- Minimal thermal Storage
- Capacity ~ 30%

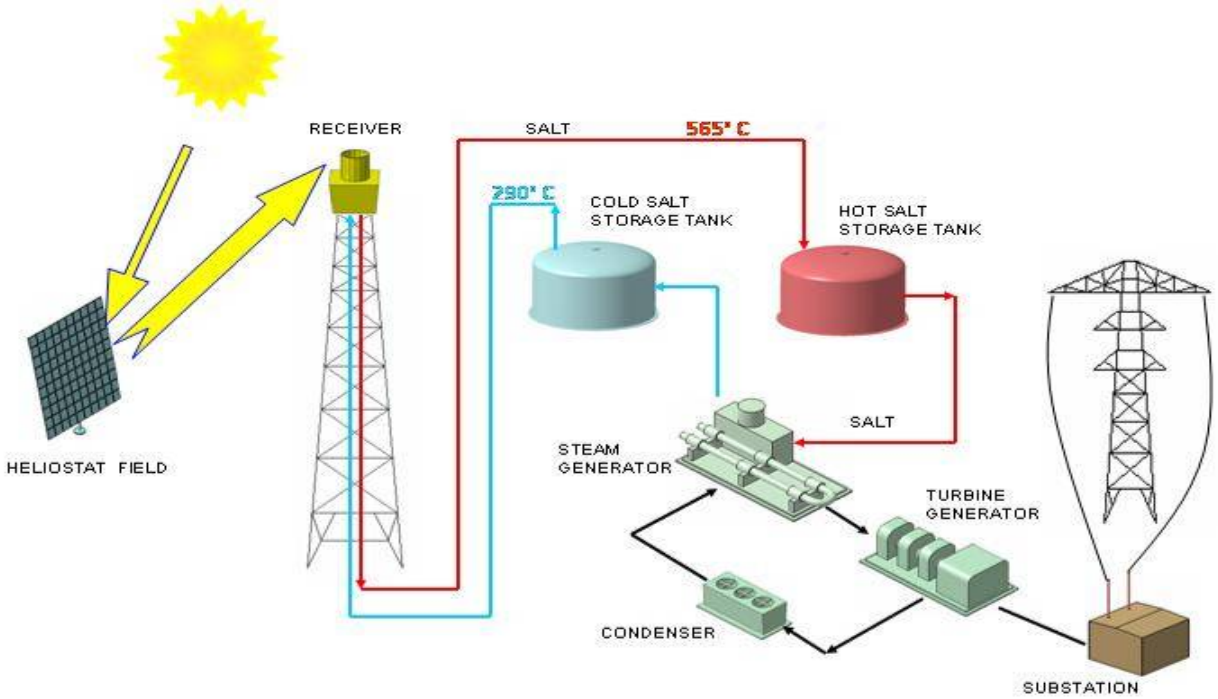
Key Element: Central Receiver

Emerging Technologies

- Higher Temperature molten Salt operating fluid
- Integrated MS Thermal storage
- Higher Efficiency ~ 18 – 20%

Molten-Salt Power Tower

Power Tower or "Central Receiver"



Energy collection is uncoupled from power production

Solar Two Results

Molten-Salt Power tower technology was successfully demonstrated at Solar Two and all of the test objectives were met.

- Receiver design validated
- Receiver η = 88%
- η of Storage > 98%
- Dispatchability demonstrated for > 6 days
- 40MW (equivalent) Solar Tres plant prop. in Spain

Dish Stirling Systems

Point-focus technology

SOA 25 kW Dish Stirling

- Total annual average solar-to-electric efficiency ~ 22%.
- Does not accommodate thermal Storage
- Capacity ~ 30%

Key Element: Stirling engine

Emerging Technologies

- Alternative engines in development
- Limited mass production of engines required to reduce cost

Dish Stirling Systems

Technology Features:

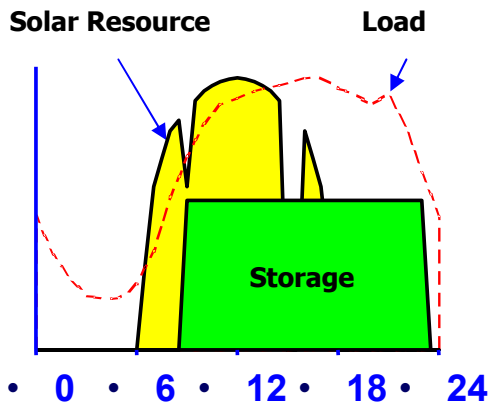
- High efficiency (Peak > 30% net solar-to-electric)
- Annual Efficiency ~ 22 – 25 %
- Modularity (10, 25kW)
- Autonomous operation
- High-Efficiency Stirling Engine

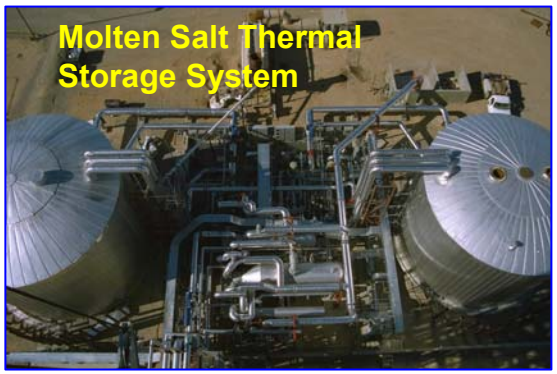
R&D focus is on Reliability improvement, engineering for mass production and cost reduction.

Projects in SW U. S.

- 1 MW trough/ORC in Arizona (APS, Acciona) operating
- 64 MW trough electric project in Nevada (Nevada Power, Solargenix) commissioned June 2007
- 500 (option to 850 MW) Dish Stirling plant in Southern California (SCE, SES, Aug 2005)
- 300 (option to 900 MW) of Dish Stirling plants in Southern CA (SDG&E, SES, Sep 2005)
- 553MW Trough plant (SCE, Solel, July 2007)
- 300 MW Linear Fresnel Reflector (AUSRA, FPL, Sep 2007)
- 177 MW Linear Fresnel Reflector (AUSRA, PG&E, Nov 2007)
- 250 MW Arizona PS Consortium RFP issued Dec 2007
- Other RFPs issued but not announced (SCE, PG&E, LADWP, SMUD, SDG&E, etc.)

The Value of Storage: Dispatchable Power





Thermal Storage

- uncouples solar energy collection and generation.
- produces higher value electricity because power production can better match utility time-of-day needs.
- is high efficiency (~98% roundtrip)

Molten salt power towers utilize the salt as the working fluid and storage.

Two trough systems are under construction in Spain to use the salt as storage.

Technology Status

- Solar-only parabolic trough is the most mature and commercially available of the three CSP technology.
- Dish Stirling technology is unique and may fill some near term solar applications but does not accommodate thermal storage.
- Some emerging technologies may provide lower costs.
- Thermal storage for trough systems is yet to be validated for performance and cost, but likely will be.
- Molten salt power tower (with storage, capacity factor 0.5 – 0.7) is attractive in mid term – 10 to 15 years.
- Long term – high performance power cycle (high T) with storage (capacity factor > 0.5) is the likely "winner".

CSP Deployment Potential

State	Land Area (mi^2)	Solar Capacity (MW)	Solar Generation Capacity GWh
AZ	19,279	2,467,663	5,836,517
CA	6,853	877,204	2,074,763
CO	2,124	271,903	643,105
NV	5,589	715,438	1,692,154
NM	15,156	1,939,970	4,588,417
TX	1,162	148,729	351,774
UT	3,564	456,147	1,078,879
Total	53,727	6,877,055	16,265,611

Bottom Line: Almost 7,000 GW Available Resource (Total U. S. Capacity is 950 GW)

Distributed Generation & PV

7. What potential does CSP have in terms of distributed generation?
   - Generally, CSP is utility-scale systems (> 100 MW)
   - Dish systems could potentially accommodate smaller, distributed applications but not currently being considered for this application
8. Will it (CSP) compete with PV technologies, and if so, what are the relative strengths of the two systems?
   - This is not likely for distributed generation.
   - If the cost of PV declines as many projections indicate, PV and CSP could become competitors for utility-scale power generation.
   - However, since PV does not currently have a cost-effective storage option and CSP has thermal storage potential, CSP may be in a better initial position.

DOE Laboratory Program

Sandia and the National Renewable Energy Laboratory work together with the DOE in the Concentrating Solar Power Program (OSET).

Note: Laboratory roles are not exclusively limited to the identified activities. There is crossover and sharing of activities in many areas.

Sandia's Role

- **Systems engineering laboratory**
- **Engineering analysis and design**
- **Large-scale component and systems tests**

NREL's Role

- **Optical materials development**
- **Resource assessment and evaluation**
- **Systems analysis and evaluation**

National Solar Thermal Test Facility (NSTTF)

- **Energy and infrastructure assurance**
- **Working in CSP since 1975**

Sandia is:
- Over 8,500 employees
- Over 1,500 PhDs; over 2,500 MS/MA
- Over 700 on-site contractors
- $2.7 billion FY07 operating budget

DOE Laboratory Program

Reduced budgets over the past 7 years has resulted in a near-term focus to support industry commercial projects. Budget is returning and a longer-term focus should be possible within the next few years.

- Cost reduction for parabolic trough collectors
- Reliability improvement of Dish Stirling systems
- Thermal storage development for trough collectors

Near-term important developments

- The application of thermal storage to trough collector systems extending operational capacity factor (number of hours of operation.)