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

CSP Overview Presentation

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Facilities at the NSTTF

NATIONAL SOLAR THERMAL TEST FACILITY

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What is CSP?

Solar concentration allows tailored design approaches for central and distributed power generation.

***Also known as Solar Thermal Electric Power**

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What can CSP do?

Concentrating Solar Power has demonstrated:

- Utility-Scale Solar Power
- High capacity factor and dispatchability
- 130 plant-years of commercial operation
  (9 plants, 354 MW)
- 80 MW/year production/installation capacity
- Dispatchable power for peaking and intermediate loads (with storage or hybridization)
- Distributed power for grid support and remote applications

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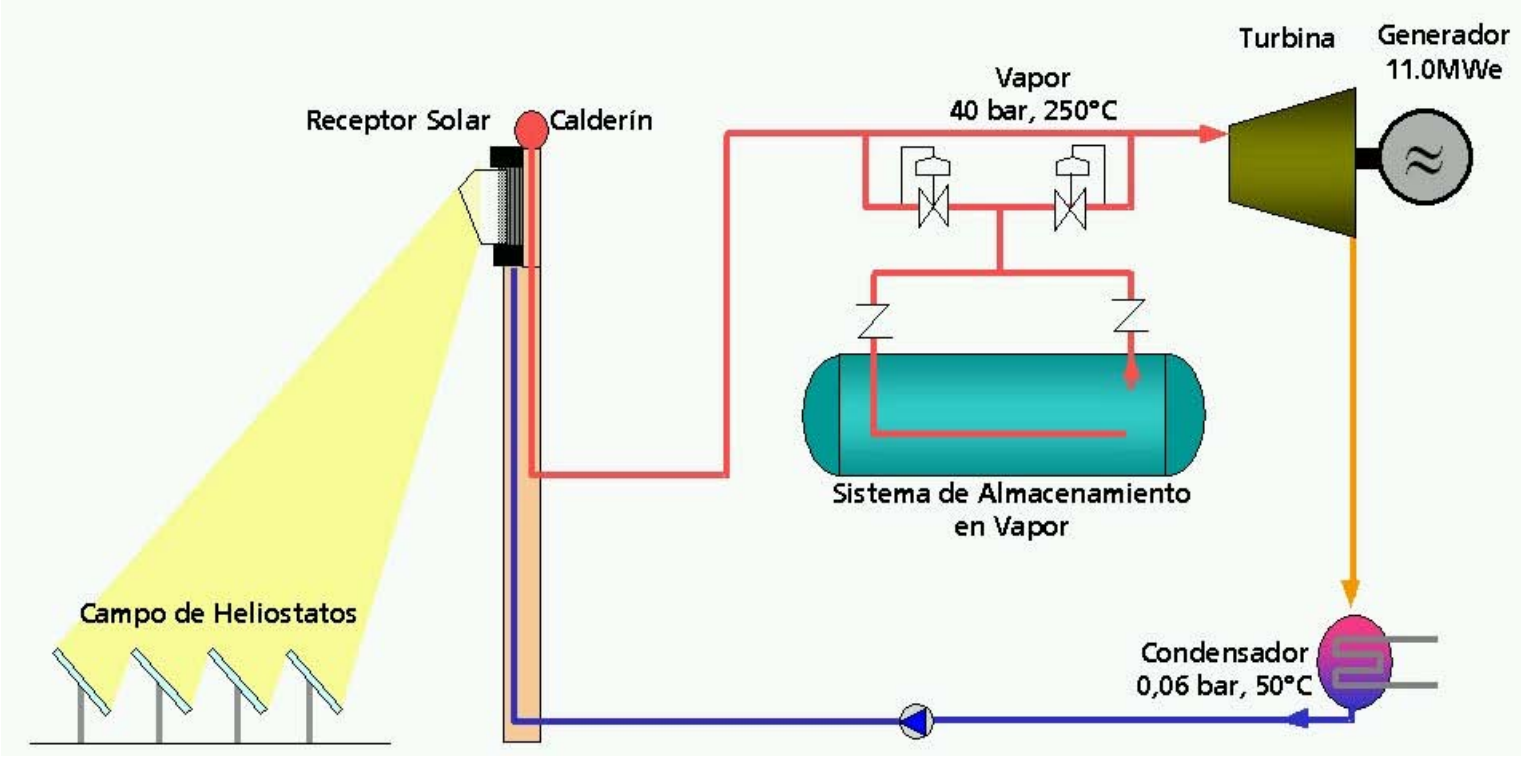
PS 10 Steam Cycle



Once-through steam boiler similar to Solar 1

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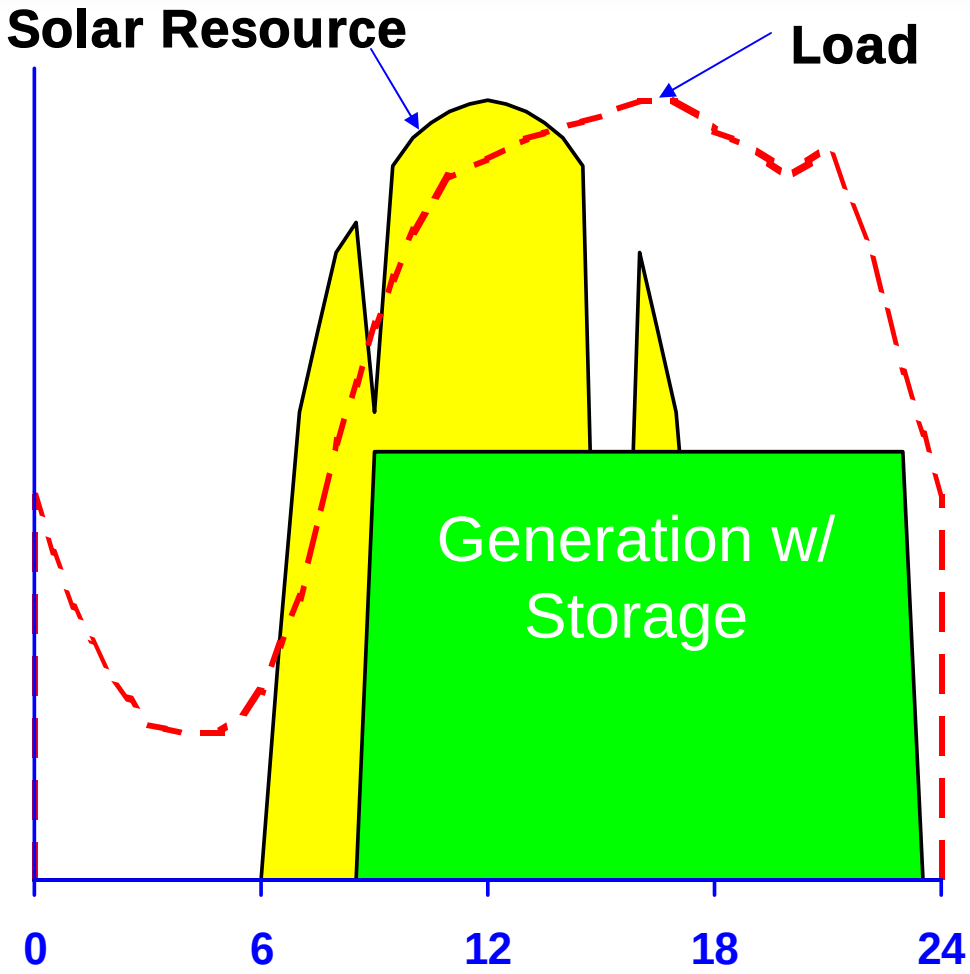
PS 10 Power Tower

PS 10 Plant Operational Fall 2006. Construction started on first PS 20 Plant.

The Value of Storage: Dispatchable Power



Storage/hybridization provide

- **decoupling of energy collection and generation**
- **lower costs because storage is cheaper than incremental turbine costs**
- **higher value because power production can match utility needs**

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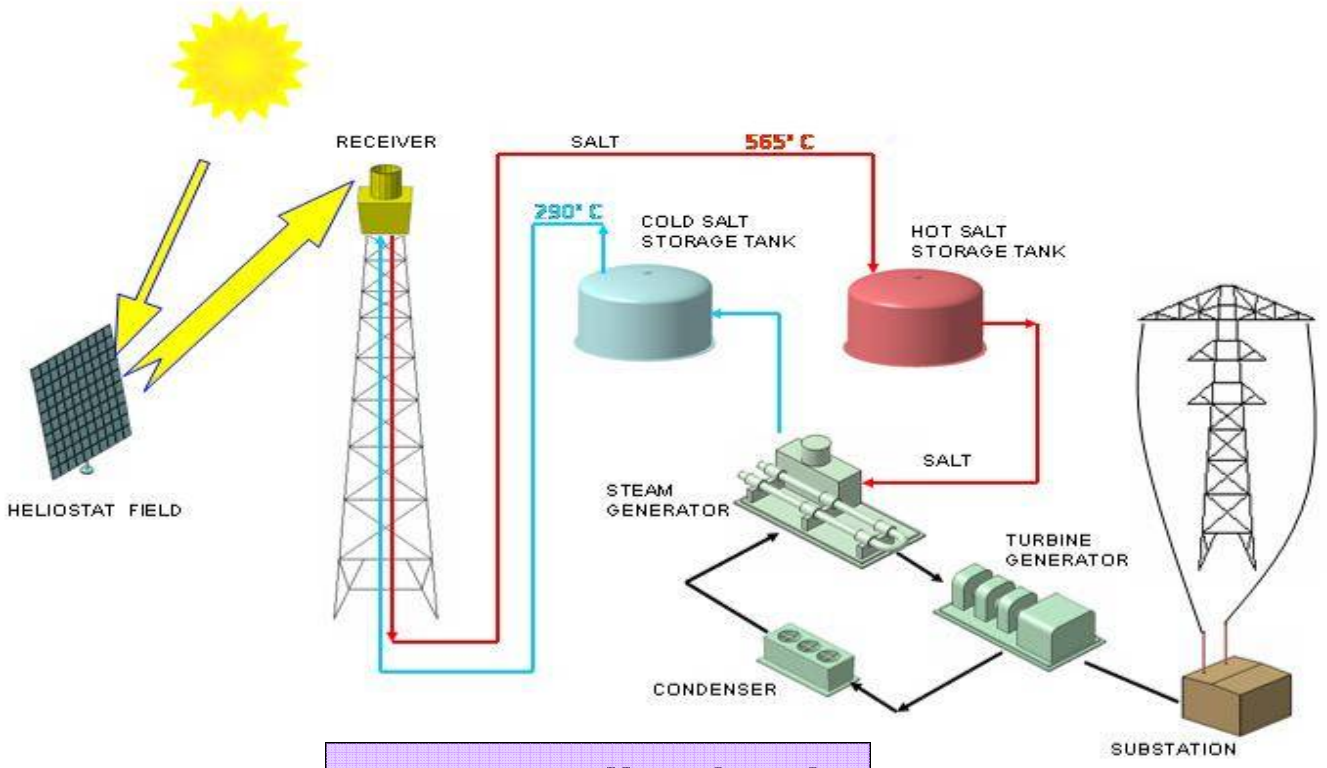
Molten-Salt Power Tower

Power Tower or "Central Receiver"



Energy collection is uncoupled from power production

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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**

SEGS Plants

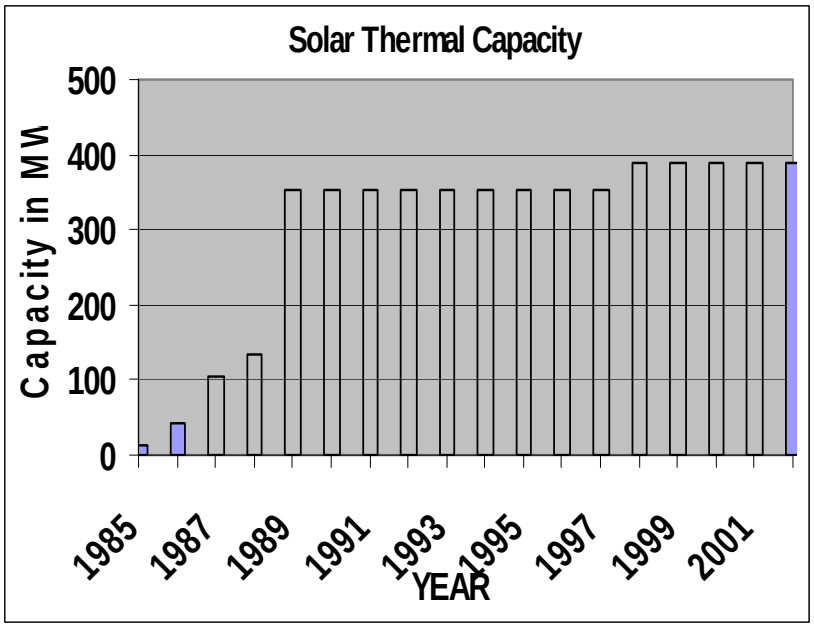
- Solar Electric Generating Stations (SEGS): 354 MW
- Total annual average solar-to-electric efficiency at 12%.
- Plants use conventional equipment and are "hybridized" for dispatchability (25%)

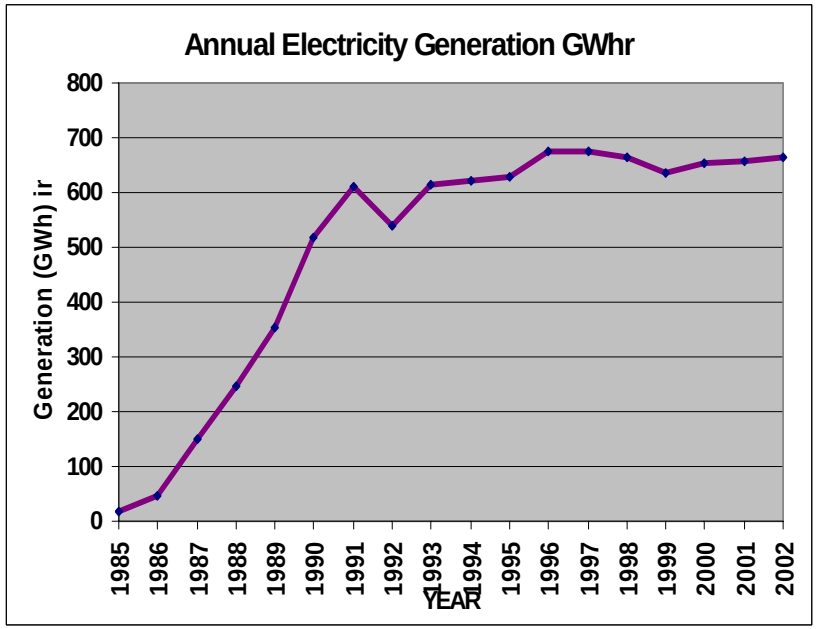
Total reflective area > 2.3 Mill. m^2

More than 117,000 HCEs

30 MW increment based on regulated power block size

SEGS Deployment and Production





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

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Nevada Solar One

- 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
- Start Up in June 2007

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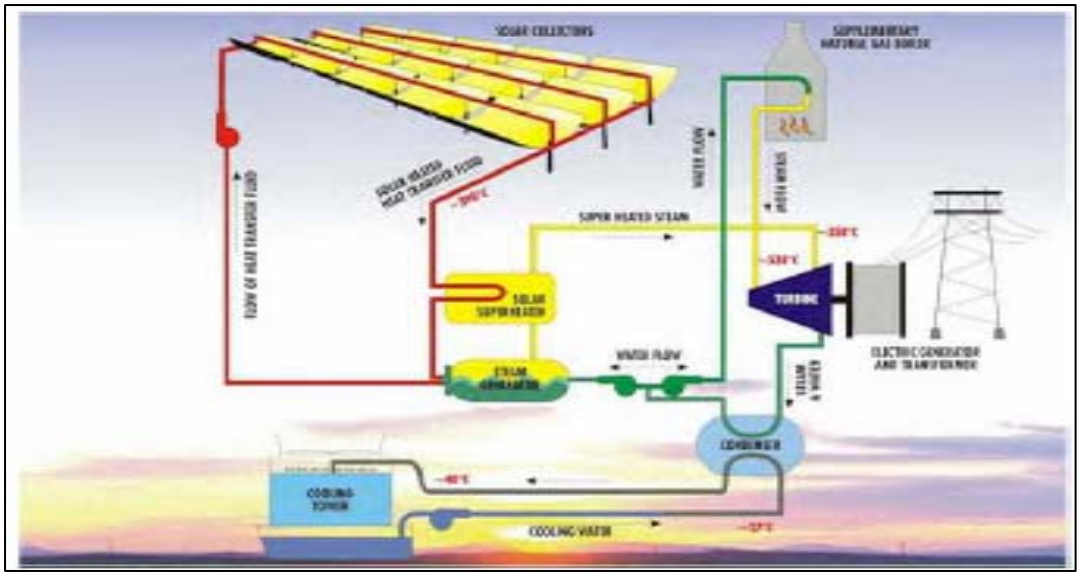
Nevada Solar One Technical Characteristics



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

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1-MW Organic Rankine Cycle Plant at APS

APS Saguaro Solar Plant

CSP 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.

Working Relationship with SES

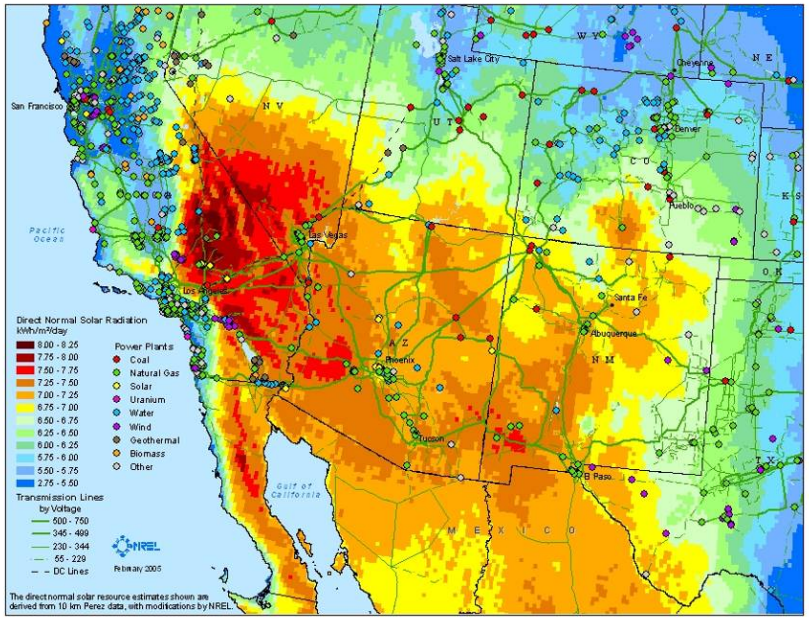
New model of cooperation for the DOE Program: SES provides staff and funding, DOE funds SNL to support and provide testing. CRADA being completed.

DNI Solar Resource in the Southwest

Screening Approach

Filters applied:

- Direct-normal solar resource.
- Sites > 6.75 kwh/m²/day.
- Exclude environmentally sensitive lands, major urban areas, etc.
- Remove land with slope > 1%.
- Only contiguous areas > 10 km²



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

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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)

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Project Costs

- **Sometimes represented as $/kW installed**
- **Sometimes represented as the Levelized Cost of Energy (LEC) from a plant (includes financing, O&M, profit, over the lifetime of the plant etc.)**
- **These are large power projects requiring 4 – 5 years to develop and deploy.**
  - ***Financing terms***
  - ***Plant ownership***
  - ***Incentives***
  - ***Proximity to/capacity of substation***
  - ***Ownership/cost of land***
  - ***Transmission Capacity***

CSP Reference Plant

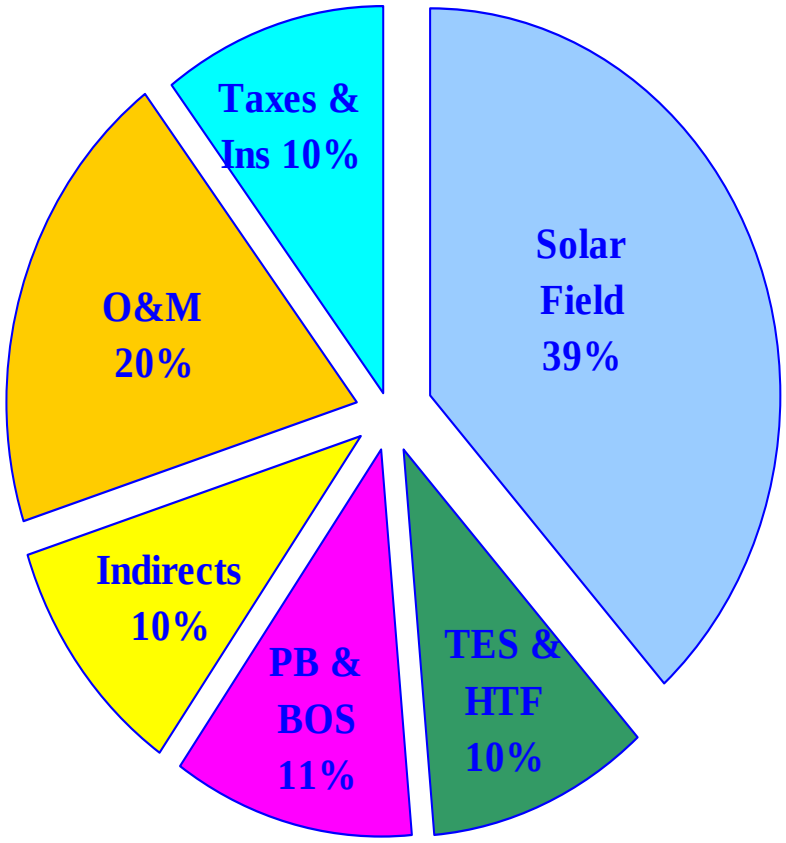
Parabolic Trough Technology Proxy for CSP

- Current solar technology
- Rankine cycle plants
- 6-hours of thermal energy storage

Finance Assumptions

- Based on IPP financing

Breakdown of LEC for 100 MWe Reference System



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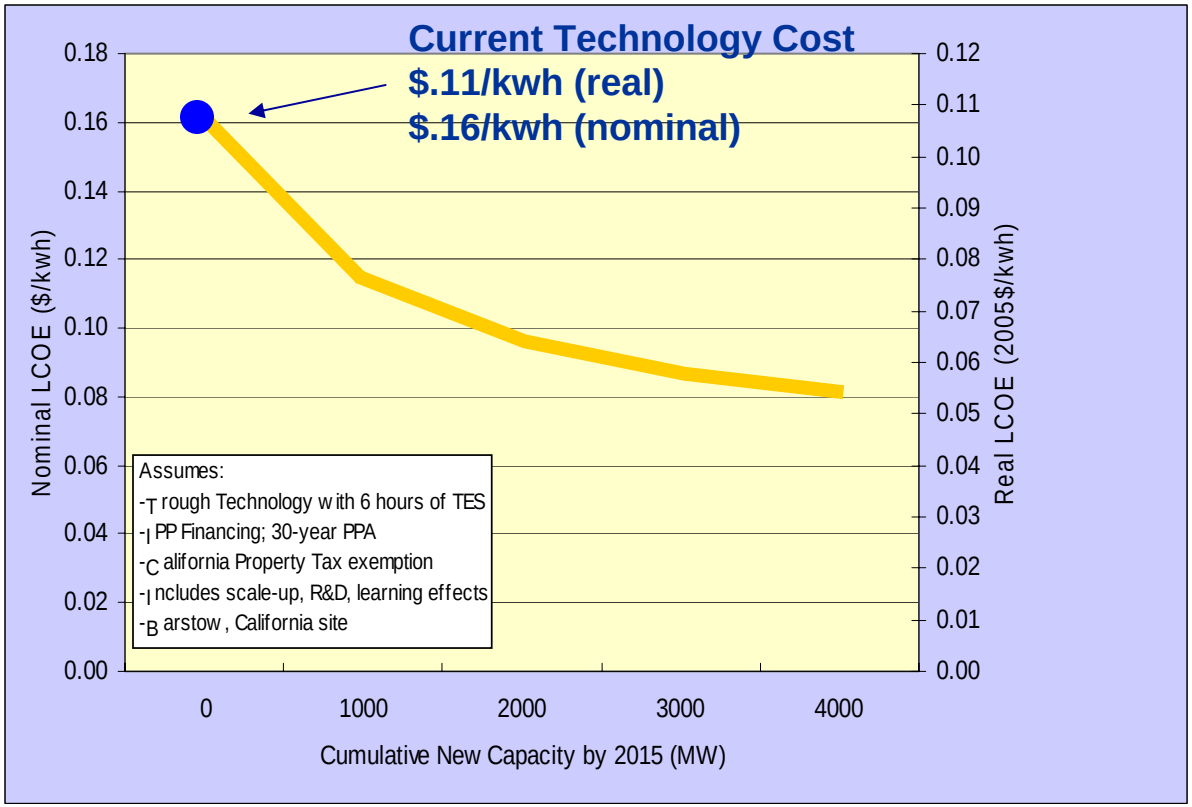
Cost of CSP



Cost Reductions to Bridge the Gap

- Plant Size
- Deployment
- Financing
- R&D

Cost Goals
$.05-.07/kwh (real)
$.08-.10/kwh (nominal)

Source: WGA Solar Task Force Summary Report

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Markets in the West

- The DOE Energy Information Agency predicts for the Western U. S. the addition of 86 GW of capacity over the next 20 years
- Most of this is expected to be met with the addition of coal and natural gas fired generation
- Western states have demonstrated interest in developing renewable resources
- In many ways, states are more proactive than the federal government in providing incentives for solar energy development

Government Incentives for CSP

Federal Incentive:

- Investment Tax Credit of 30% through end of 2008 (working on an 8 – 10 year extension)
- Loan guarantee program

State Incentives:

- Renewable Portfolio Standards
- Solar "set asides"
- State production tax credits
- Property and sales tax relief
- Possible state loan guarantee programs

Projects in SW U. S.

- 1 MW trough/ORC in Arizona (APS, Acciona) operating
- 64 MW trough electric project in Nevada (Nevada Power, Acciona) commissioned June 2007
- 500 to 850 MW Dish Stirling plant (SCE, SES, Aug 2005)
- 300 to 900 MW Dish Stirling plant (SDG&E, SES, Sep 2005)
- 50 MW ISCCS plant (Victorville, Feb 07)
- 553 MW Trough plant (SCE, Solel, July 2007)
- 400 MW 3 solar towers (BrightSource, Aug 07)
- 177 MW Linear Fresnel Reflector (AUSRA, PG&E, Nov 2007) AFC
- 250 MW Solar Thermal (Beacon Solar, March 08)
- 280 MW Parabolic Trough with storage (Abengoa, APS, Feb. 2008)
- 250 MW Trough (Harper Lake Solar)
- 250 MW Arizona PS Consortium RFP issued Dec 2007
- Other RFPs issued but not announced

Projects Around the World

Algeria: 150 MW hybrid gas/trough (30 MW from solar) at Hassi R'mel (Abener, NEAL, 2006)

Morocco: ISCCS for a 250 MW plant (30 to 50 MW from solar) (Abener, under contract)

Egypt: 140 MW hybrid trough plant at Kuraymat (Iberdrola, Orascom, Dec 2007).

Australia: 2 – 5 MW ISCCS CLFR Liddell

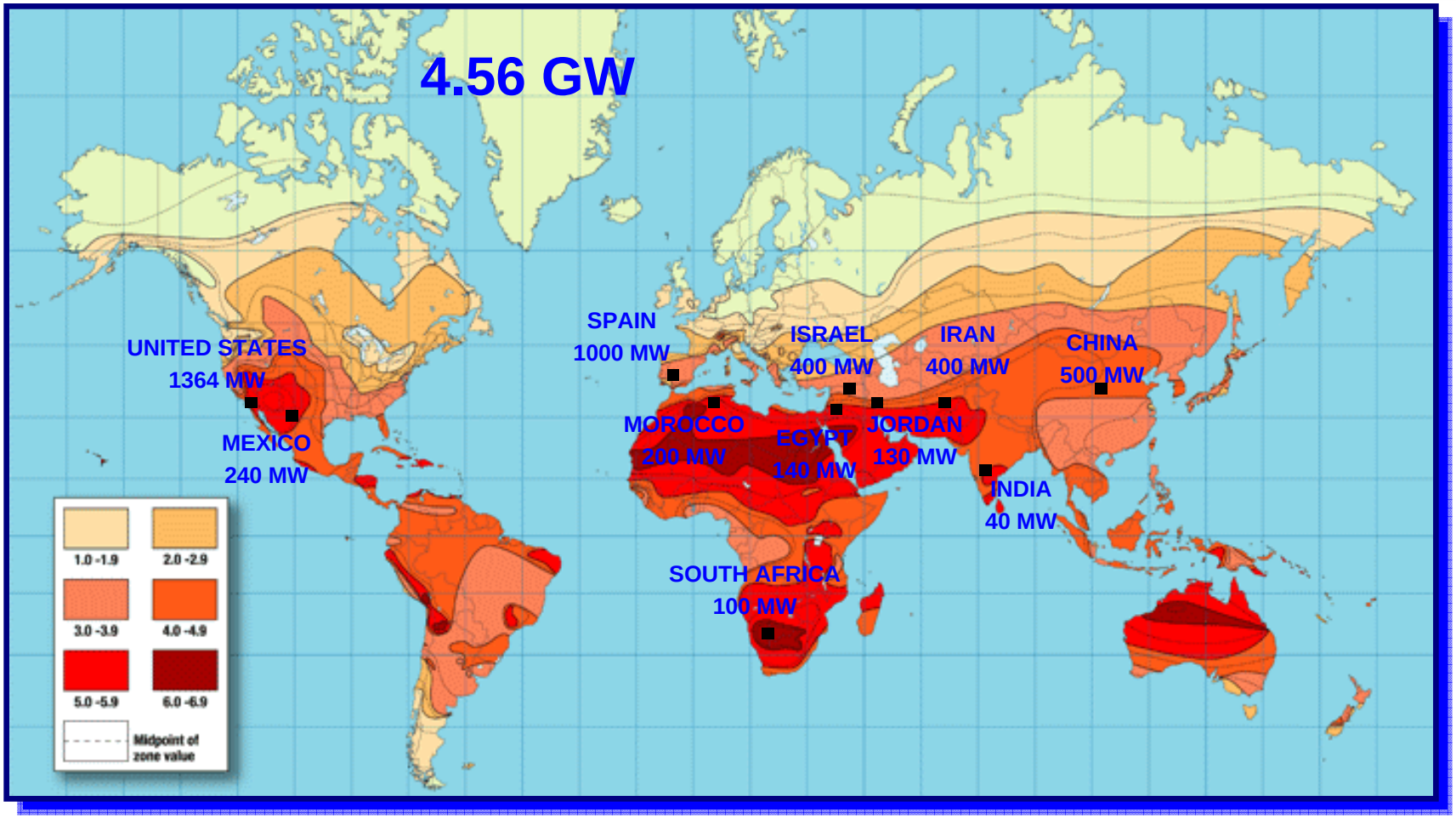
South Africa: ESKOM in Phase V of molten-salt power tower development; currently performing an EIA.

Israel: SOLEL signed a contract for a 150 MW trough plant.

Mexico: 30 MW trough project being restructured Agua Prieto, Sonora.

Spain: 10 MW PS 10, 20 MW PS 20 (Abengoa, 2006, 2008); Andasol 1 and 2 with 7.5 hours of storage (Cobra, Sener, Solar Millenium) under construction. Estimates of more than 3 GW under development.

CSP Worldwide Deployment Plans



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