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

CSP Technologies at Sandia

Nathan Siegel
Solar Technologies Dept.

Sandia National Laboratories
Albuquerque, New Mexico, USA

Sandia National Laboratories

What is CSP?

Concentrating Solar Power:

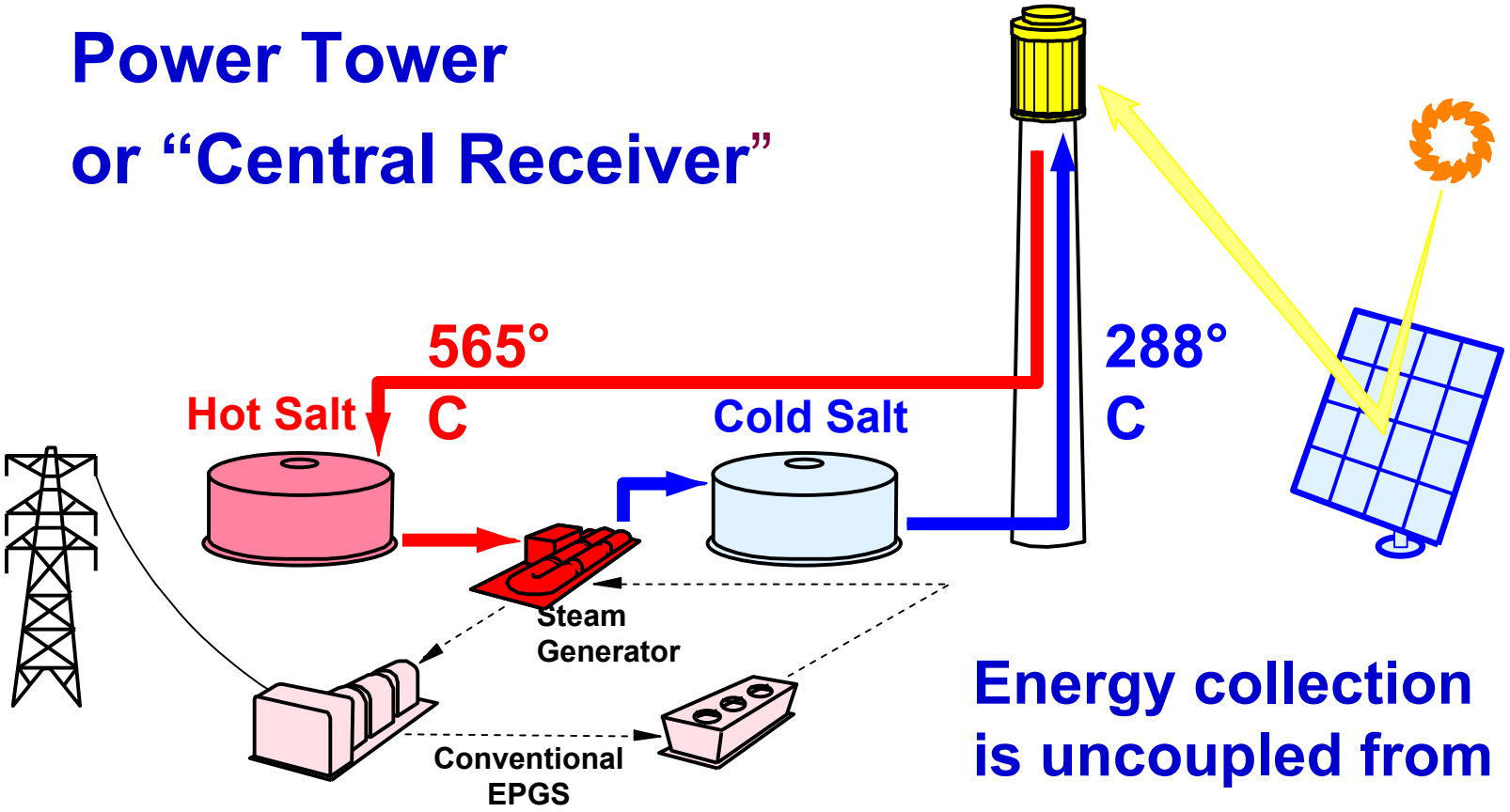
Solar concentration allows tailored design approaches for central and distributed power generation and solar fuels production.

What are CSP technologies?

- Power Towers
- Trough Electric Systems
- Dish Stirling Systems

Molten-Salt Power Tower

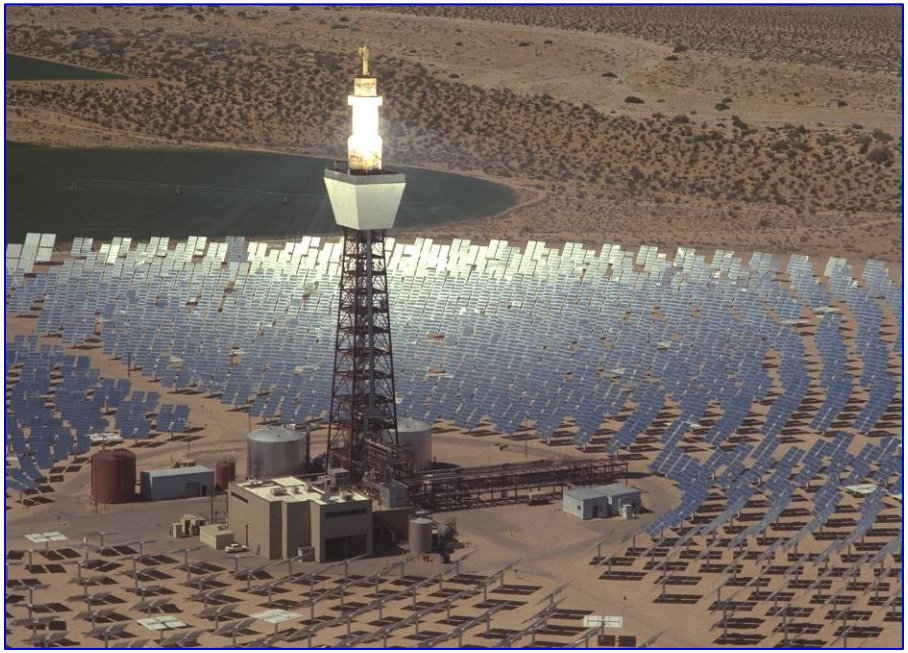
Power Tower or "Central Receiver"



Energy collection is uncoupled from power production

Power Tower: Solar Two

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



- 10 MW_e, 82,750 m^2 mirror area (1926 heliostats)
- Receiver design validated
- Receiver η = 88%
- η of Storage > 98% - heat in to heat out.
- Dispatchability demonstrated for > 6 days
- 40MW (equivalent) Solar Tres plant prop. in Spain

Sandia National Laboratories

Solar Trough: SEGS Plants

- SEGS: 354 MW since 1985
- 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

Dish Stirling System

Technology Features:

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

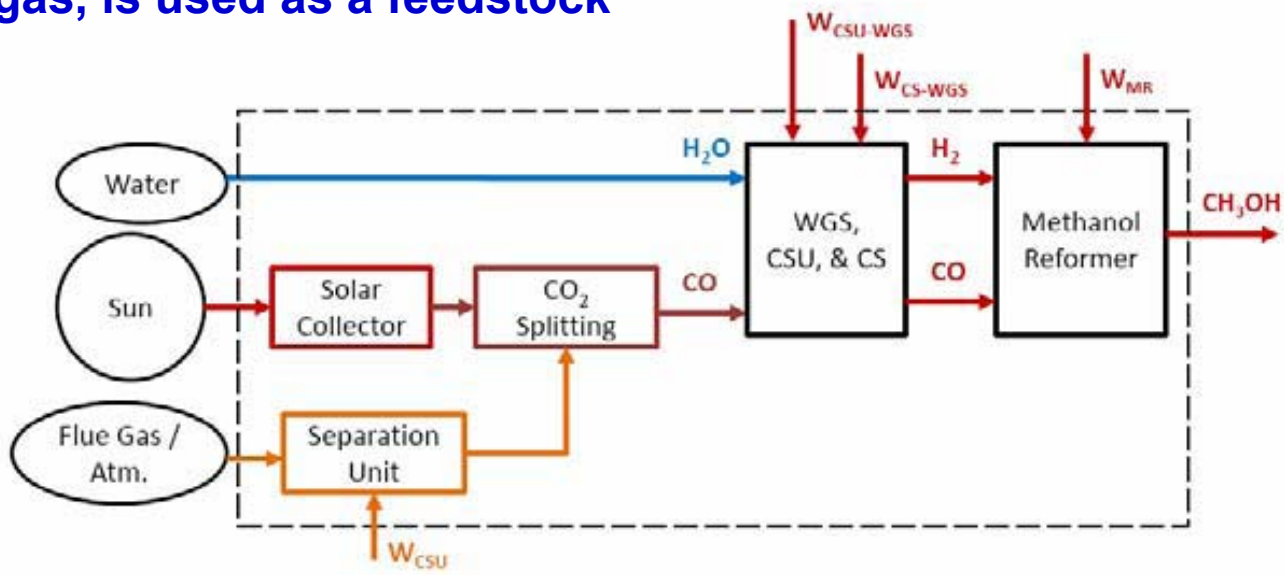
Current R&D focus is on Reliability improvement and cost reduction.

Solar Fuels

Sunlight + CO_2 + H_2O = Fuel + O_2

- A range of fuels including gasoline and JP-8 can be produced
- An overall sunlight to fuel conversion efficiency > 10% is possible
- Solar fuels reduce dependence on foreign energy sources
- CO_2, a greenhouse gas, is used as a feedstock

A Sunshine to Petrol (S2P) System



Hydrogen Production Using Concentrated Solar Energy

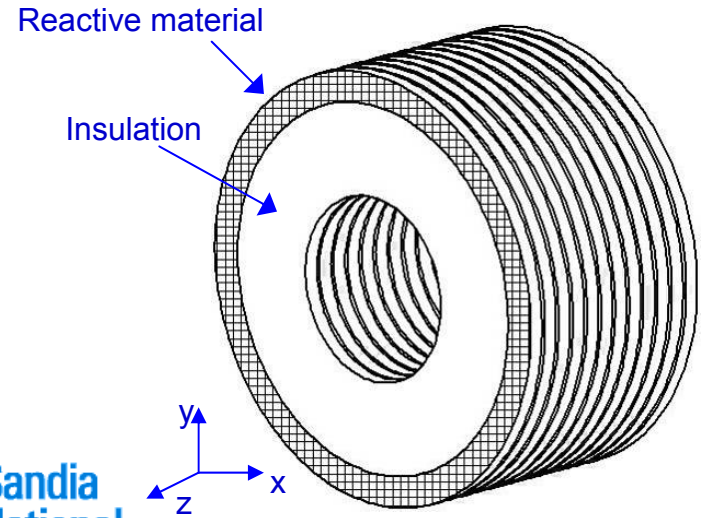
Sandia-Invented device uses a two step solar-thermochemical process based on iron-oxide to split water:

1) Fe_3O_4 + Heat→ 3FeO + 1/2O_2

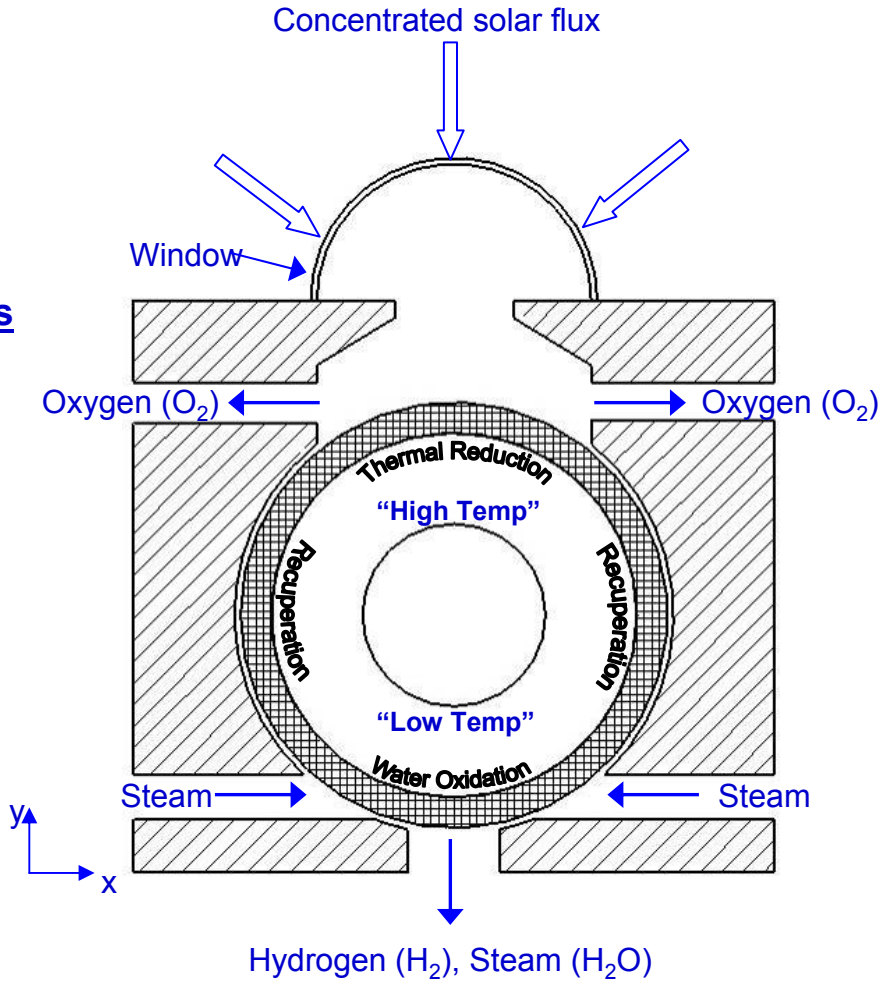
2) 3FeO + H_2O → Fe_3O_4 + H_2

Net: H_2O → H_2 + 1/2O_2

Set of Counter-Rotating Rings

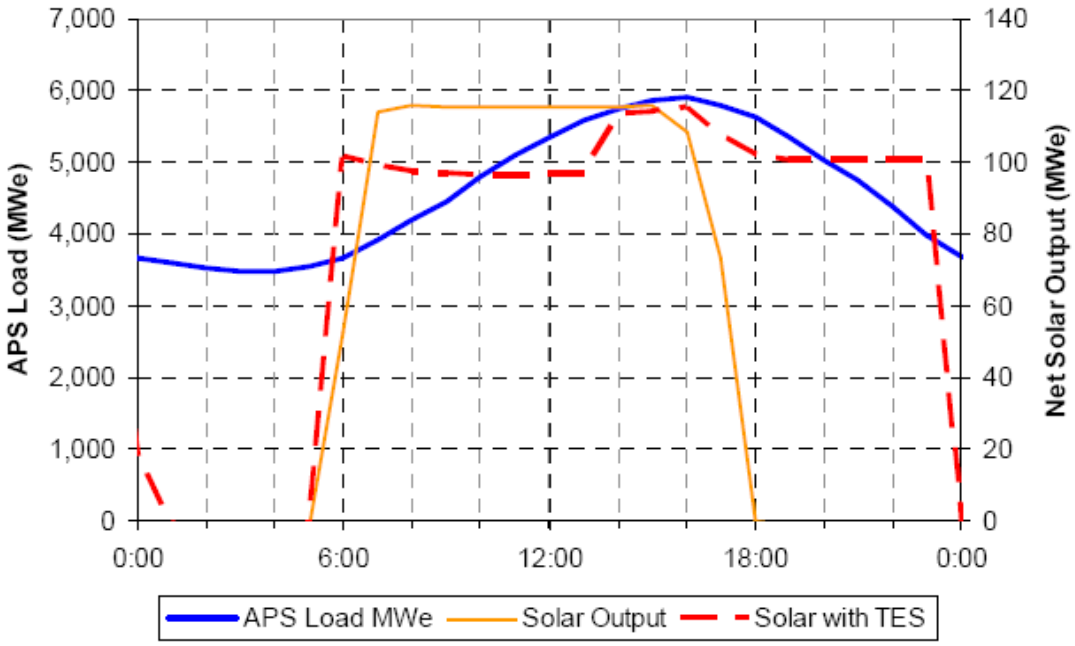


Cross-Section Illustration



Sandia National Laboratories

The CSP Advantage: Cost-Effective Energy Storage



ASME ES2007-36171

Storage provides

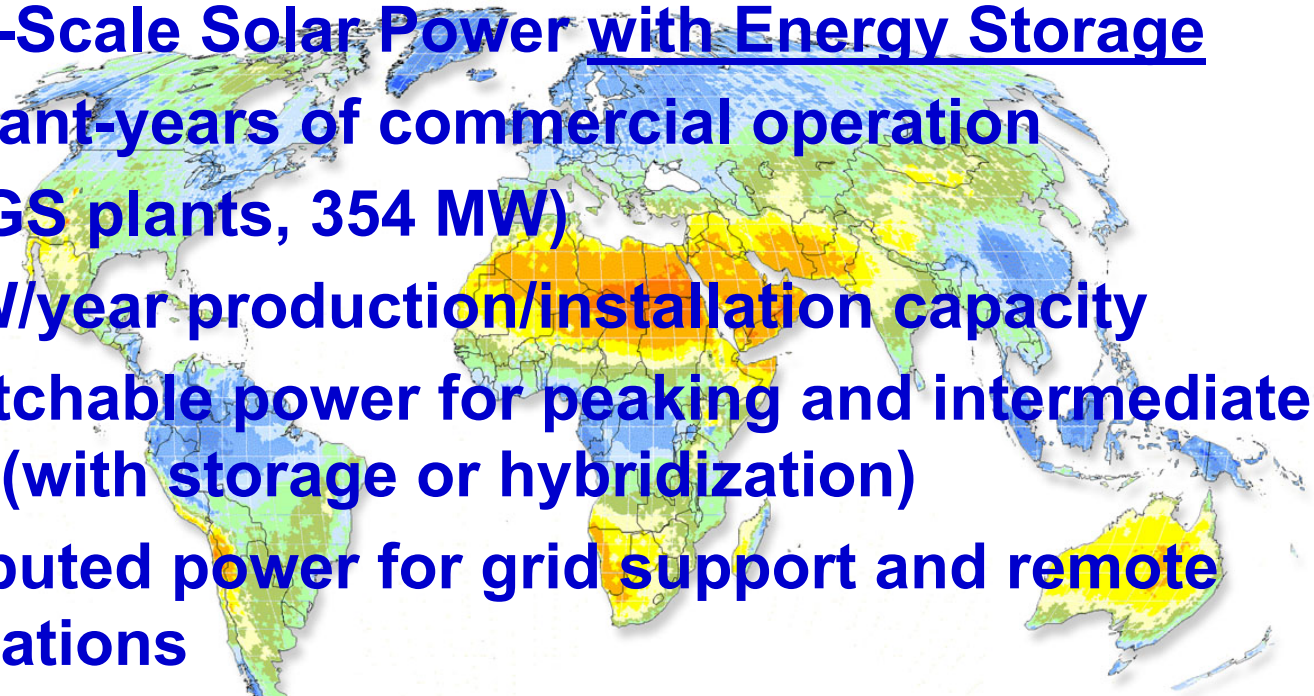
- decoupling of energy collection and generation
- lower costs because storage is cheaper than incremental turbine costs
- higher value because power production can match utility needs
- Better match for chemical fuel production systems

Sandia National Laboratories

What can CSP do?

Concentrating Solar Power has demonstrated:

- **Utility-Scale Solar Power with Energy Storage**
- **130 plant-years of commercial operation (9 SEGS 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**
- **Efficient solar fuel production**



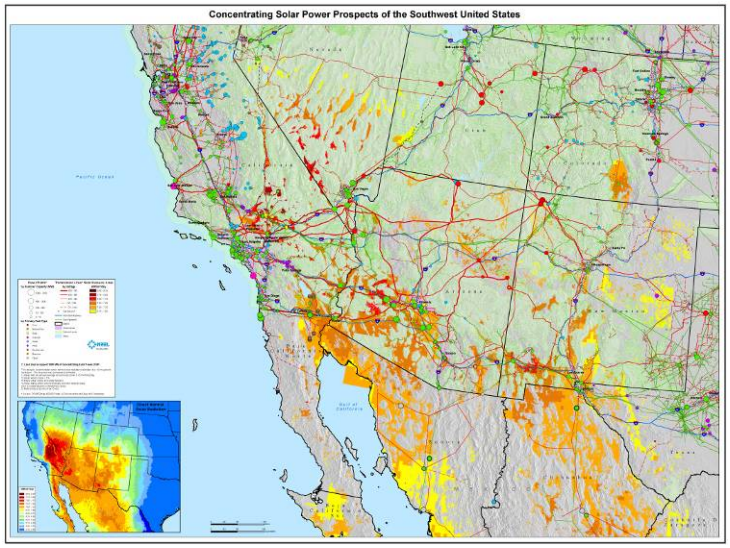
Projects in SW U. S.

- 354 MW SEGS in California operating since 1985.
- 1 MW trough/ORC in Arizona (APS, Solargenix) operating
- 64 MW trough electric project in Nevada (Nevada Power, Solargenix) operating
- ~ 500 MW of CSP (PG&E, Luz 2). Announced August 10, 2006.
- ~ 250 MW SW Utility Consortium. Planning.

CSP Deployment Potential in SW

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

Table refers to electrical capacity from solar energy



Bottom Line:

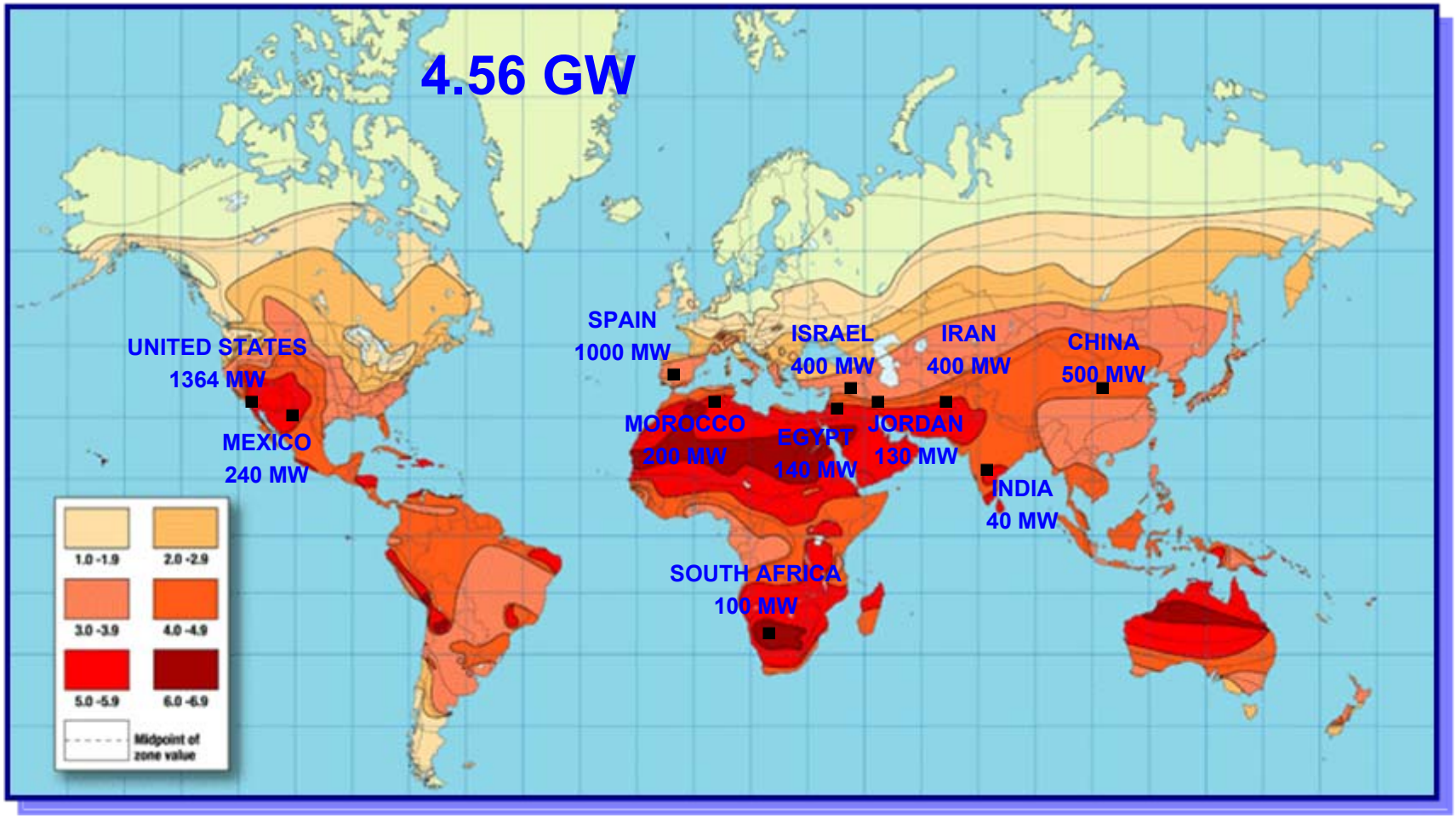
- **Almost 7 TW Available Resource (Total U. S. Capacity is 1.1 TW)**
- **WGA recommendations will likely be for about 0.004 TW of CSP by 2015**

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.**

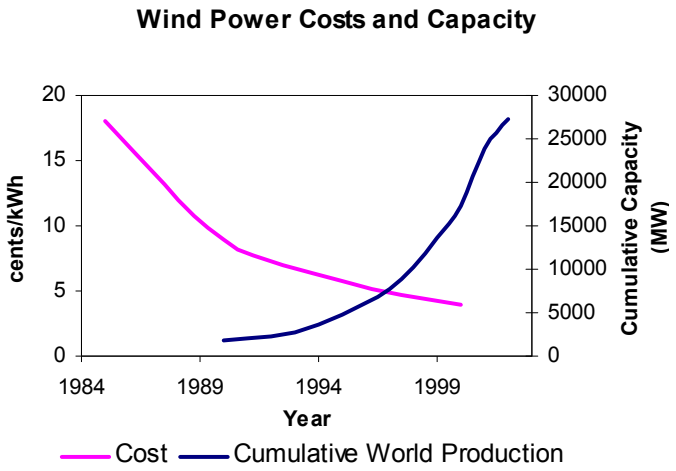
Sandia National Laboratories

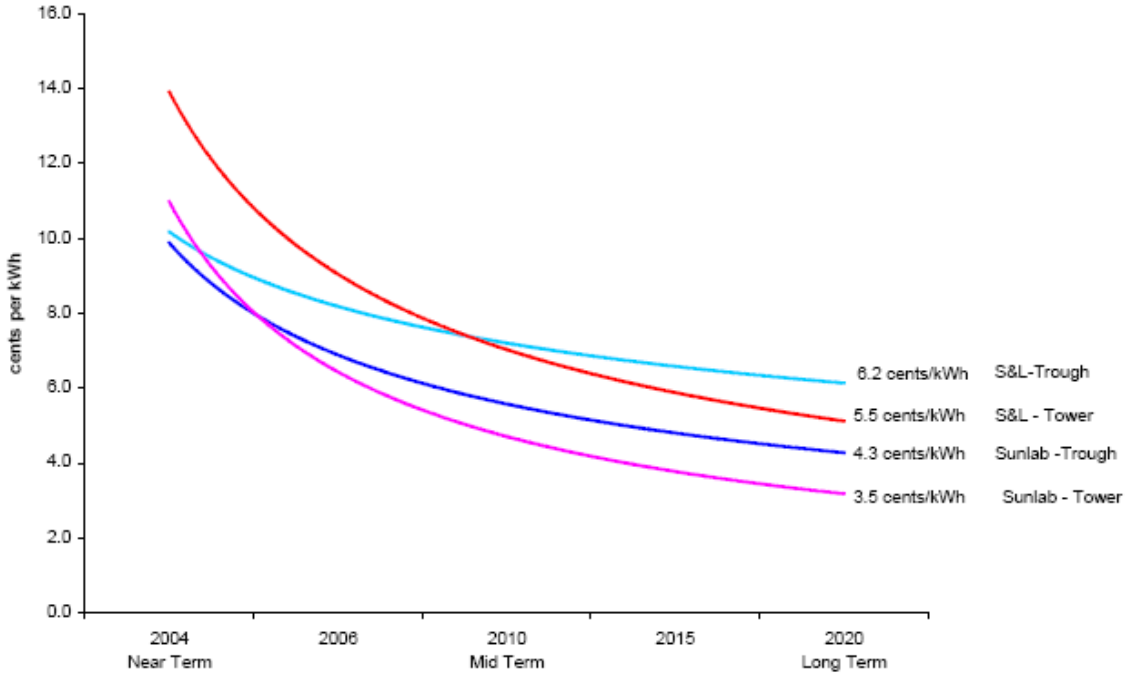
CSP Worldwide Deployment Plans



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

CSP Costs Will Decline with Deployment





- **Wind power required 30 GW of deployment to reach ~ 5 ¢/kWhr**
- **CSP is projected to require only 3 GW of deployment to reach this level.**

	S&L High-Cost Bound	Cumulative Deployment 2002–2020	SunLab Low-Cost Bound	Cumulative Deployment 2002–2020
Troughs	6.2 cents/kWh	2.8 GWe	4.3 cents/kWh	4.9 GWe
Towers	5.5 cents/kWh	2.6 GWe	3.5 cents/kWh	8.7 GWe

S&L Executive Summary

Sandia National Laboratories

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

Facilities at the NSTTF

NATIONAL SOLAR THERMAL TEST FACILITY

Sandia National Laboratories

NSTTF Testing

Testing for the DOE CSP Program

- Thermal Receivers for Towers, Dishs and Troughs
- Trough, Dish, and Heliostat Test and Evaluation
- Molten-Salt Receiver, Component and Thermal Storage Testing
- Test and Equipment Design
- Integrated Systems Test/Evaluation

Testing for DOE Hydrogen Program and DARPA

- Development of solar hydrogen production processes
- Design of testing of high temperature central receivers
- Conversion of carbon dioxide into fuel

Other Users: the NAVY, APL, NCAR, STACEE, NASA Marshall and Langley, Air Force, Northrup, Atlantis, and Sandia Departments.

- Thermal Radiation Effects Testing
- Materials and Systems Testing
- Astronomical radiation measurements

CSP Websites

TroughNet: http://www.nrel.gov/csp/troughnet/

SunLab: http://www.energylan.sandia.gov/sunlab/

FPL-SEGS: http://www.fplenergy.com/portfolio/contents/segs_viii.shtml

Solucar: http://www.solucar.es/sites/solar/en/index.jsp

SolarPaces: http://www.solarpaces.org/