Concentrating Solar Power

Overview for CSP PEER Reviewers

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CSP Overview Topics

- Goals, priorities, strategy, and issues
- CSP Technology Options
- Benefits and Barriers
- Addressing Barriers
- DOE's CSP Activity
  - Projects
  - Plans
  - Budget

Energy Policy

- **DOE[1]**
  - "A primary goal of the National Energy Policy is to add supply from diverse sources. ….And it means making greater use of non-hydro renewable sources now available."
  - A second goal is to improve the quality of the environment by reducing greenhouse gas emissions and environmental impacts to land, water, and air from energy production and use.
- **EERE[2]**
  - Mission: Bring clean, reliable, and affordable energy production and delivery technologies to the marketplace
  - Vision: a prosperous future where energy is clean, abundant, reliable, and affordable
  - Strategic Goal: increase the viability and deployment of renewable energy technologies
    - Improve performance and reduce cost of RE technologies
    - Facilitate market adoption of RE technologies by partnering with private companies

[1] National Energy Policy, Report of the National Energy Policy Development Group, May 2001
[2] Strategic Plan, Office of Energy Efficiency and Renewable Energy, October 2002

CSP Goals and Priorities

- **Vision:**
  - Inexpensive power generated from CSP technologies is transmitted throughout the country to provide a significant percentage of the country's electrical power, reducing the country's emission of CO^2 while creating millions of jobs.

- **Goals**:
  - Competitive in intermediate power market by 2015
  - Low cost thermal storage supporting the intermediate power market goal.

- **Priorities**:
  - Lower cost through R&D
  - Develop low cost storage options
  - Lower cost by helping reduce barriers to deployment of projects

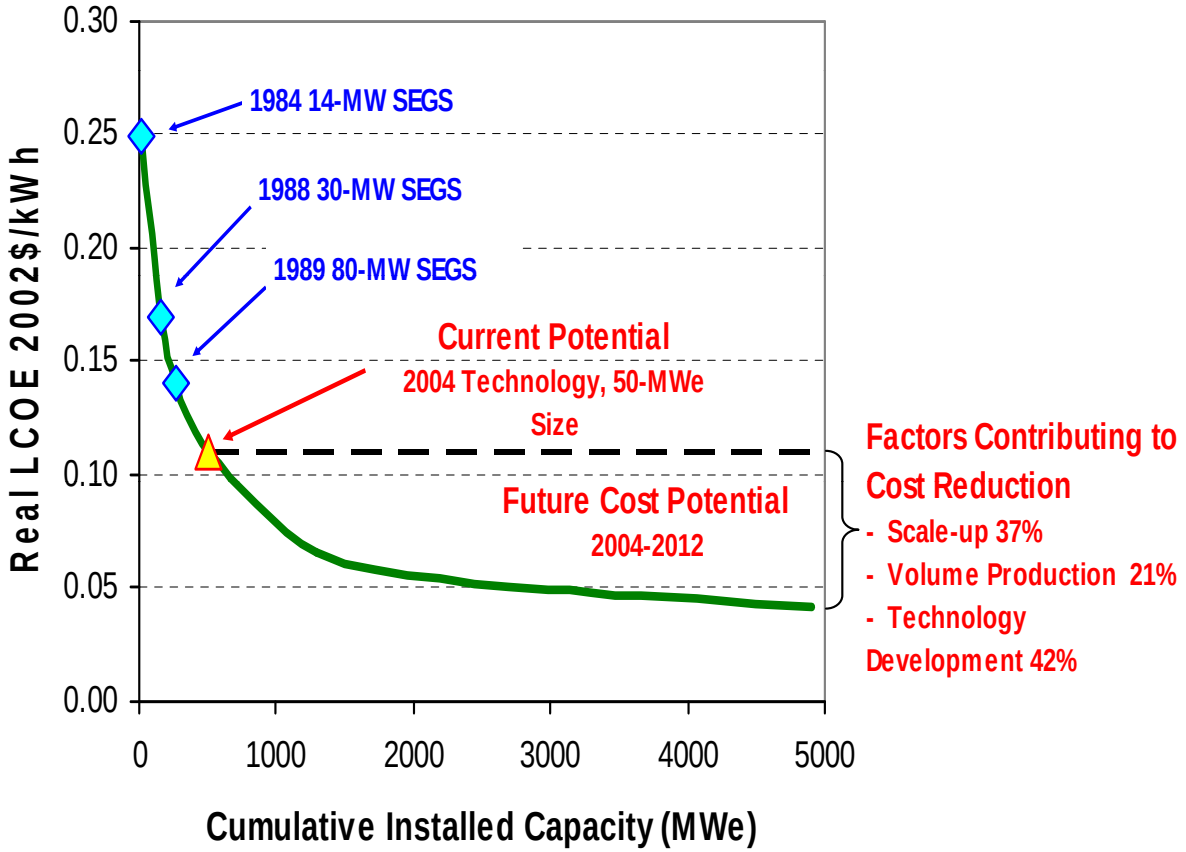
CSP Priorities, Strategies, and Issues

Priority 1 – lower cost of technology through R&D

- Urgency – CSP market (utilities) requires a reduction in cost of CSP power
- Strategy
  - Solicitations released through Golden resulting in cost shared R&D contracts with industry (concept development through demonstration)
  - Lab support to industry; increase staff and upgrade facilities at SNL and NREL
  - Analysis; keep track of goals (moving targets) and cost of technology (also moving with commodity prices), downselect best technology options
- Issues
  - Funding is insufficient to adequately address all CSP options
  - Lab staff must be rebuilt
  - Facilities must be upgraded, new capabilities added if necessary

CSP Cost Reduction

- Sargent & Lundy's due-diligence study* evaluated the potential cost reductions of CSP.
- Cost reductions for CSP technology will result from R&D and deployment.



* Sargent and Lundy (2003). Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Impacts. http://www.nrel.gov/docs/fy04osti/34440.pdf

CSP Priorities, Strategies, and Issues

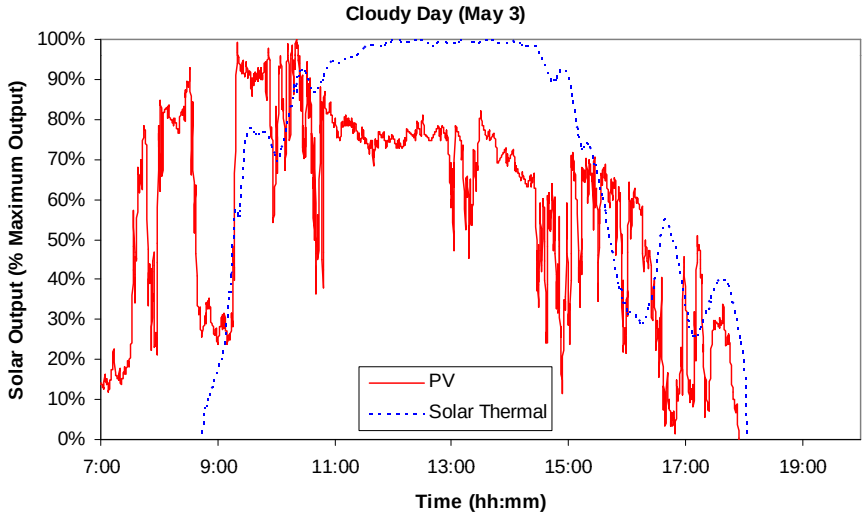
Priority 2 – develop low-cost storage options

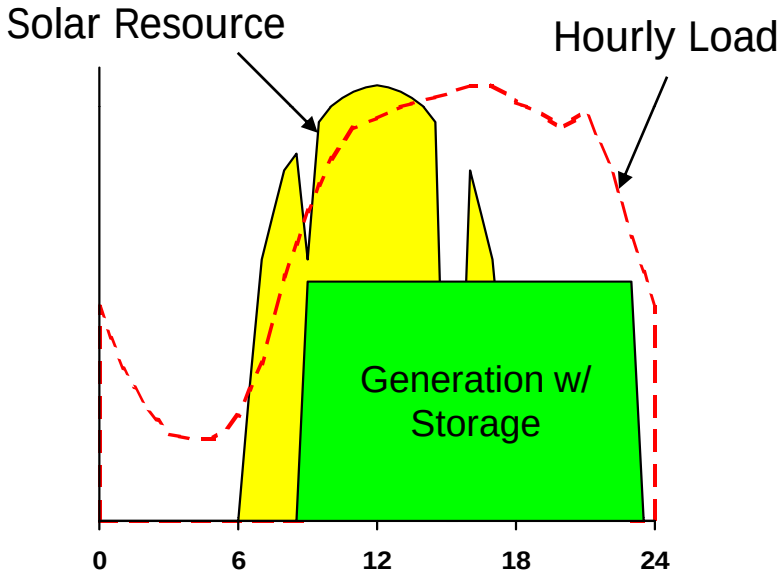
- Urgency – storage mitigates solar intermittency, provides stability to grid, and enables dispatchability
- Strategy
  - Build long term plan with industry and lab input
  - Solicitations released through Golden resulting in cost shared R&D contracts with industry (concept development through demonstration)
  - Develop facilities needed to test storage concepts
- Issue
  - Time: new activity requires new lab staff and new facilities – all must come up learning curve fast

Storage: Meeting Peak Power Demand

Storage provides

- decoupling of energy collection and generation, helping grid stability
- higher value because power production can match utility needs
- additional energy with slightly lower cost





CSP Priorities, Strategies, and Issues

Priority 3 – lower cost by helping reduce barriers to the deployment of projects

- Urgency – cost reduction requires plants being built, operating plants need to demonstrate the viability of the technology
- Strategy
  - Complete the programmatic environmental impact statement with BLM to make access to land easier
  - Work with the Western Governors' Association and Western States to get support for land designated suitable for solar projects and their access to transmission
  - Provide technical assistance to utilities and utility consortiums (e.g. the Joint Development Group)
  - Provide resource assessment analysis to industry
- Issue
  - DOE can influence, but does not have direct control over deployment of projects

CSP Technologies

- CSP w/ Storage
  - Parabolic trough
  - Power tower
  - Linear Fresnel

- CSP w/o Storage
  - Dish/Engine

64 MWe Solargenix Solar Plant

Boulder City, NV

10 MW and 20 MW Abengoa Towers
Seville, Spain

5 MW Ausra Linear Fresnel Facility

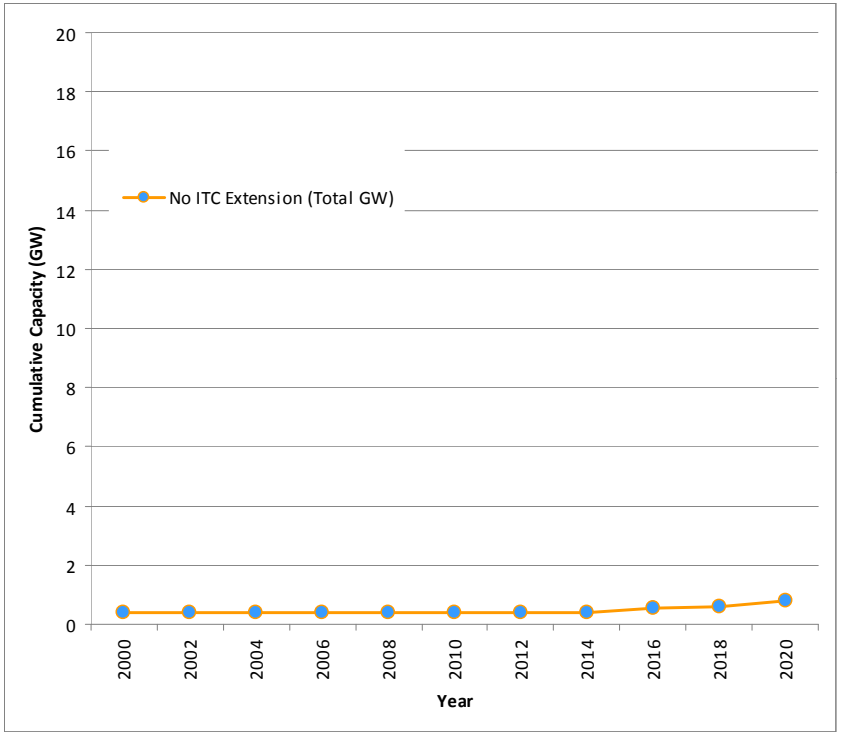
Bakersfield, CA

6-Dish/Stirling Prototypes – Sandia Lab, Albuquerque

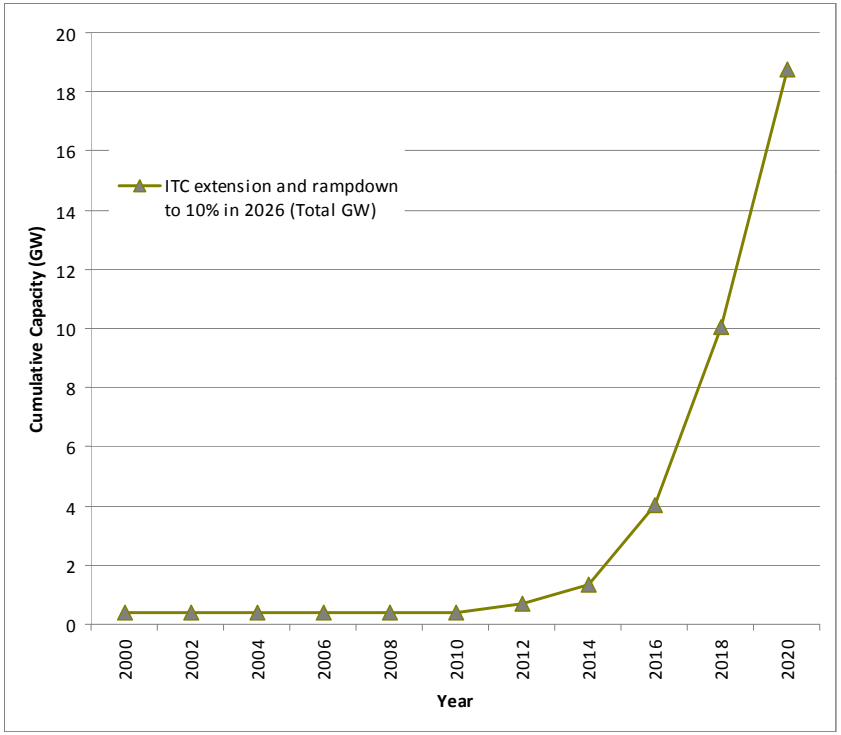
Energy Benefits of CSP

ReEDS* Model Projection of CSP Market Penetration

No ITC Extension



8yr 30% ITC Extension (or 30% refund)



*NREL Regional Energy Deployment System Model

Economic Benefits of CSP Plants

Assuming utility scale deployment of solar power generation projects between 2000 (2GW) and 4000 MW (4GW) of capacity, the following economic benefits can be realized*:

Deployment Level	2GW	4GW
Increase in Gross State Output	$12.9 billion	$24.6 billion
Creation of construction jobs	77,300 job-years	145,000 job-years
Creation of permanent operations jobs	1,500	3,000

Each dollar spent on a CSP plant adds $1.40 to the state economy while similar investment in natural gas plants yields $0.90 to $1.00 to gross state product.

*** "Economic, Energy, and Environmental Benefits of Concentrating Solar Power in California", L. Stoddard, J. Abiecunas, R. O'Connell, *Black & Veatch Overland Park, Kansas, Report* NREL/SR-550-39291, April 2006**

Environmental Benefits of CSP Plants

Emissions Reduction by CSP Plants			
	CSP Plant Capacity		
Pollutant (tons/year)	100 MW	2,100 MW (2GW)	4,000 MW (4GW)
NO_x	7.4	156	297
CO	4.5	95	181
VOC	2.6	54	103
CO_2	191,000 (mt)	4,000,000 (mt)	7,600,000 (mt)

*** "Economic, Energy, and Environmental Benefits of Concentrating Solar Power in California", L. Stoddard, J. Abiecunas, R. O'Connell, *Black & Veatch Overland Park, Kansas, Report* NREL/SR-550-39291, April 2006**

CSP Market Barriers

COST - Current cost is too high for large-scale power without incentives

TAX CREDITS - Tax credits and other government incentives need to be consistent for a period of 8 years or more

TRANSMISSION - CSP plants need access to transmission, which is a problem throughout the West

Land - Environmental impact (e.g. desert tortoise)

Water - Water is scarce in best CSP locations

CSP R&D Weaknesses

Lab staff

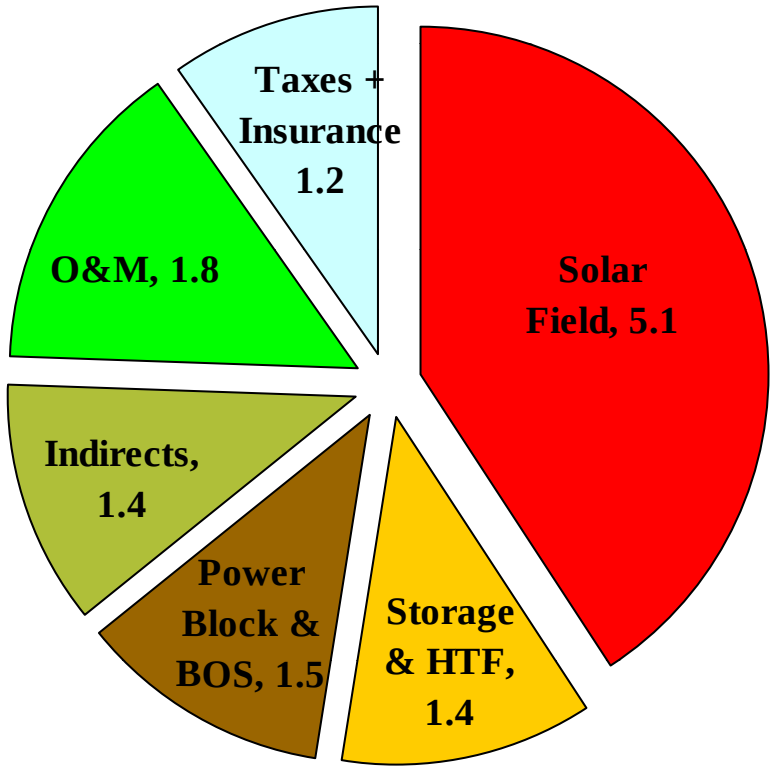
- NREL and Sandia staff, severely reduced in early 2000's, needs to be strengthened

Lab facilities

- Existing lab facilities need to be repaired and upgraded
- New facilities needed to test new industry concepts

Addressing Cost Barrier

Baseline 100 MWe trough system
with 6 hours thermal storage
40% capacity factor
12.4 ¢/kWh



R&D is targeting technical obstacles in CSP systems to improve performance and reduce costs

Line Focus

- Optimize receiver and concentrator designs for higher temps, increase component suppliers, evaluate new heat transfer fluids, and create advanced evaluation capabilities.

Point Focus

- Improve engine reliability and system manufacturability, and develop next-generation dish system designs. Test new tower receiver panel and explore low cost heliostat options.

Storage

- Develop advanced heat transfer fluids for more efficient operation at high temperatures, and test innovative designs for low-cost storage using sensible and latent heat options .

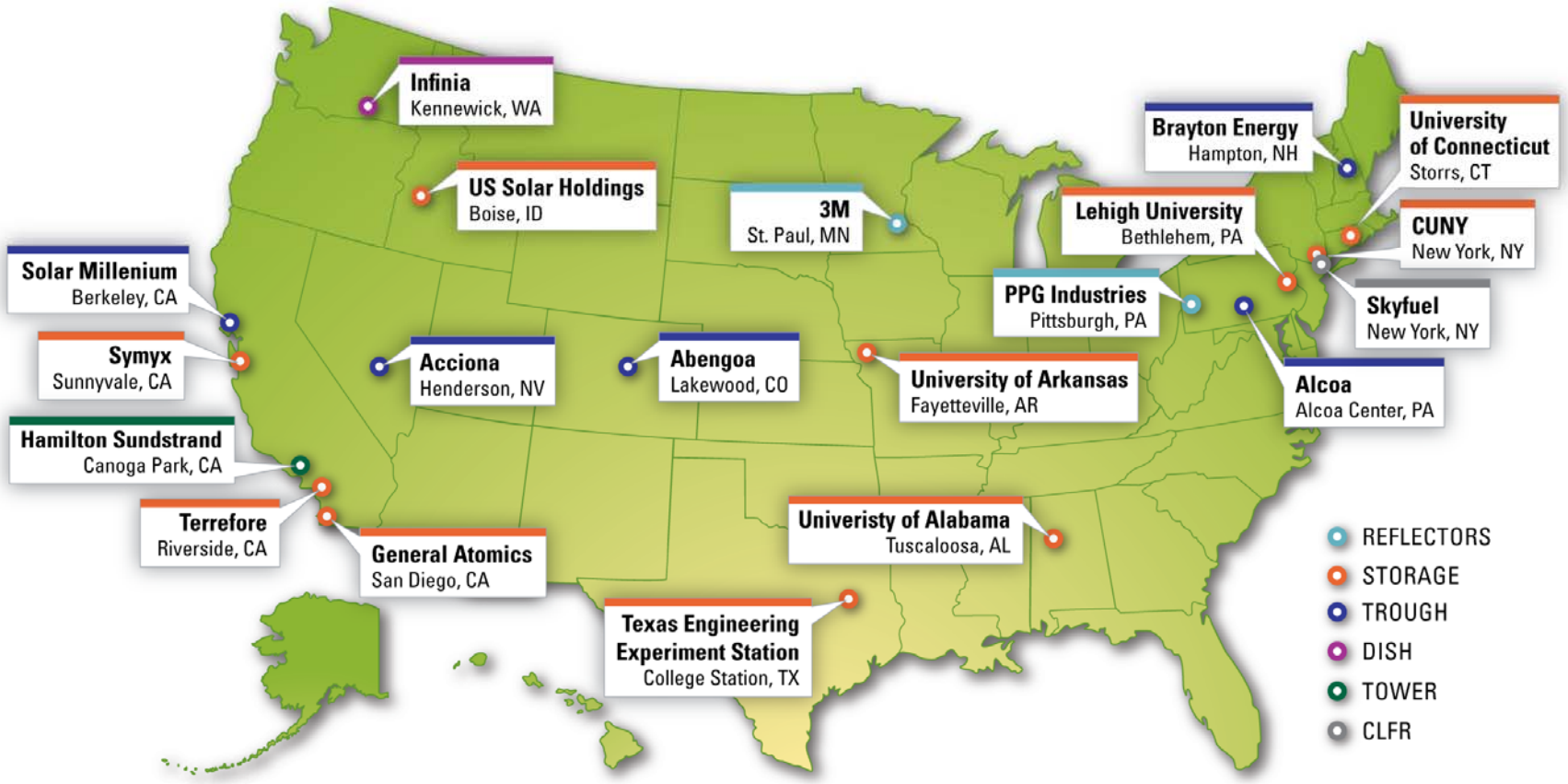
CSP R&D Contracts

- **CSP FOA* (Nov 2007):** 12 awards
  - Storage (2)
  - Troughs (5)
  - Dishes (2)
  - Linear Fresnel (2)
  - Tower (1)

- **Storage/HTF FOA (Sep 2008):** 15 awards
  - Storage (14)
    - Molten salt
    - Thermocline
    - Phase change materials
    - Thermochemical
  - Heat transfer fluids (1)

FOA – Funding Opportunity Announcement

CSP Contracts FY 2009



DOE is also targeting barriers to CSP deployment

Land Access

- Co-leading with the Bureau of Land Management a programmatic environmental impact statement to make suitable federal land available for solar project development.

Transmission Access

- Working with DOE's Office of Electricity, Western Governors' Association, and States to identify best location for transmission corridors.

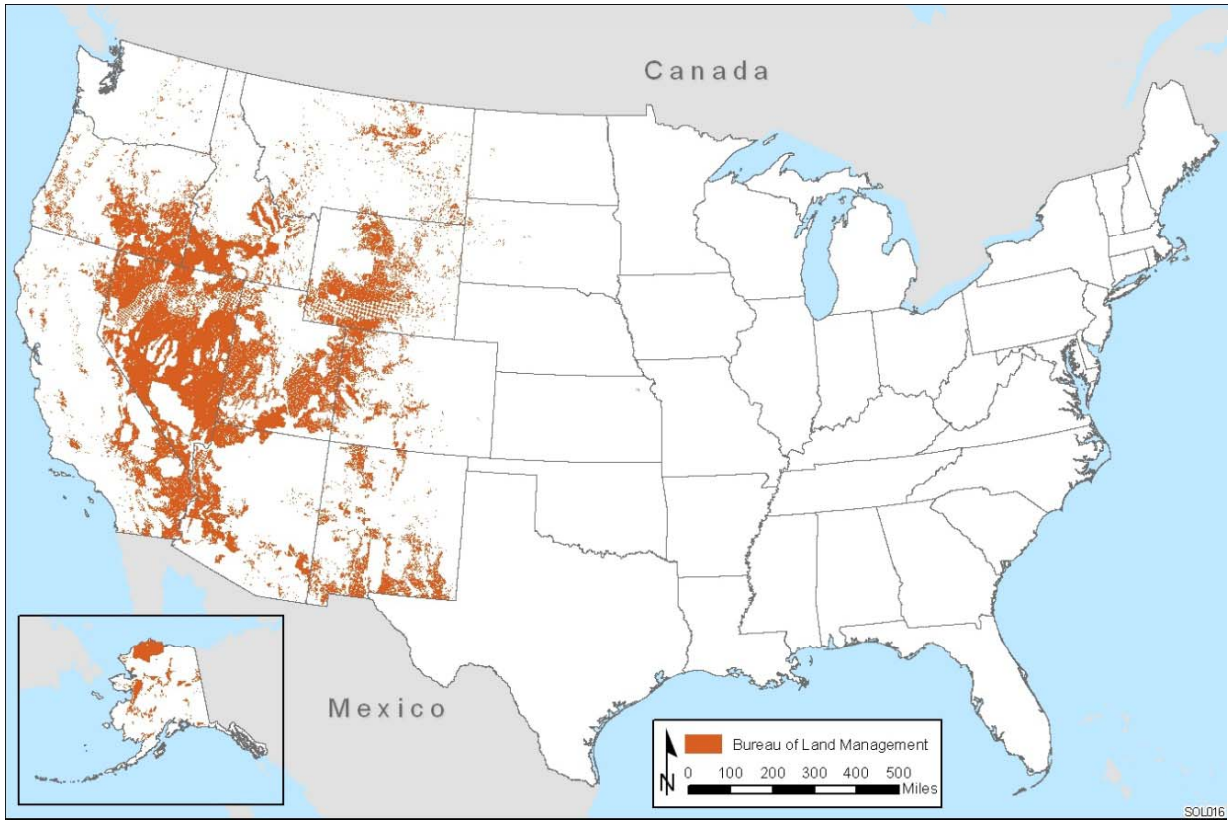
Resource Assessment

- Improving satellite data, obtaining ground data from additional sites, forecasting .

DOE & BLM: identifying land for CSP deployment

Approach: a programmatic environmental impact statement (PEIS)

- BLM manages 119 million acres in the 6 Southwestern states where the solar resource is most intense (CA, NV, NM, AZ, CO, and UT)



What results are expected from the PEIS?

- Identification of land that is appropriate for solar deployment from technical and environmental perspectives
- Establishment of “best practices” policy to streamline evaluation and processing of solar projects
- Tiering of future site-specific assessments to the PEIS.
- Identification of additional transmission corridors crossing BLM-managed land
- PEIS to be completed May 2010
- **BOTTOM LINE**: more solar projects coming on line faster resulting in lower costs

Solar Applications for BLM-Managed Land

- No currently installed solar capacity on public land
- Over 50 different companies have filed applications
- More than 70,000 MWs total capacity under application
- 40% trough; 20% PV; 20% tower; 20% other

Solar Energy Applications (January 1, 2009)

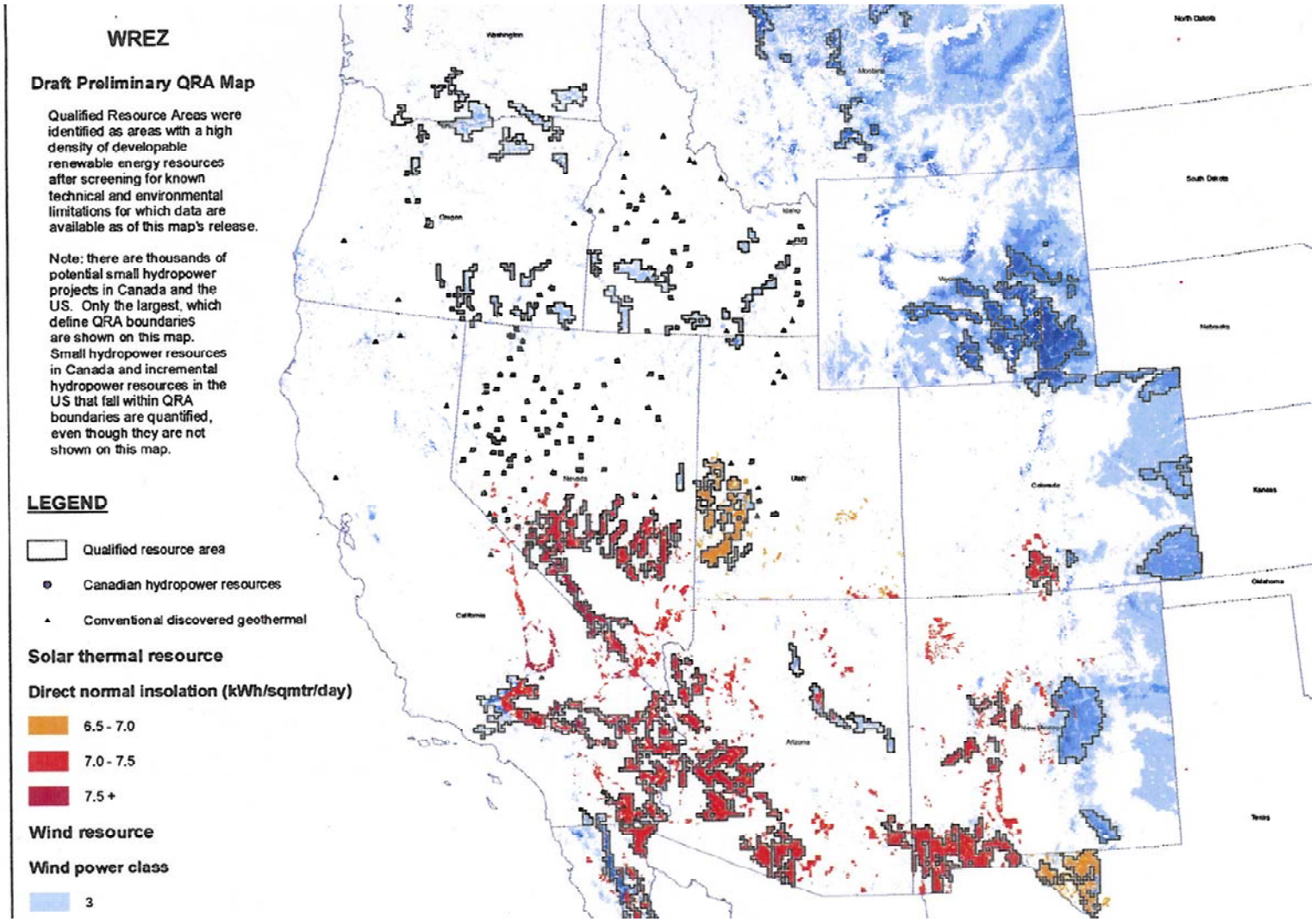
State	Applications	Acres
AZ	35	718,477
CA	107	899,681
CO	1	2,100
NM	7	54,136
NV	71	561,138
UT	2	2,240
Total	**223**	**2,237,772**

U.S. Projects Under Development

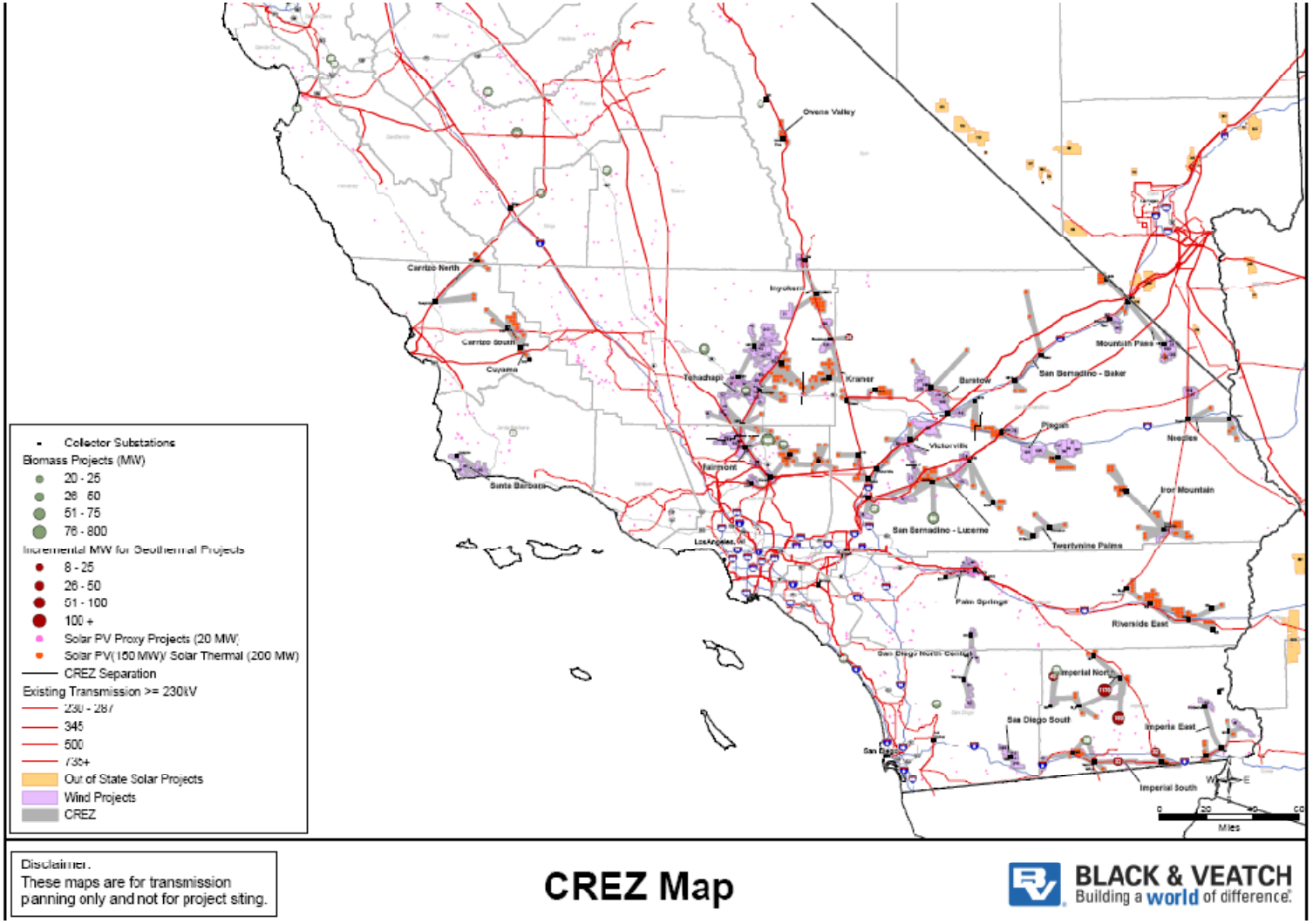
Name	Utility	State	Installed[1]	Under Contract[2]	Technology	Operational Date	Company
SEGS	SCE	California	354 MW		Parabolic trough	1985 - 1991	FPL Energy
Saguaro	APS	Arizona	1 MW		Parabolic trough	2006	Aciona
Nevada Solar One	Nev. Power	Nevada	64 MW		Parabolic trough	2007	Aciona
Kimberlina Solar Thermal Power Plant	PG&E	California	5 MW		Linear Fresnel	2008	Ausra
SES Solar One – Ph 1	SCE	California		500 MW	Dish/engine	2009 - 2012	SES
SES Solar Two – Ph 1	SDG&E	California		300 MW	Dish/engine	2009 - 2010	SES
Carrizo Energy Solar Farm	PG&E	California		177 MW	Linear Fresnel	2010	Ausra
	SDG&E	California		100 MW	Parabolic trough	TBD	Bethel Energy
Mojave Solar Park	PG&E	California		553 MW	Parabolic trough	2011	Solel
Solana	APS	Arizona		280 MW	Parabolic trough	2011	Abengoa Solar
Ivanpah Solar	PG&E	California		500 MW	Power tower	2011 - 2013	Bright Source
Beacon	LADWP	California		250 MW	Parabolic trough	2011	FPL Energy
	EPE	New Mexico		66 MW	Power tower	2011	eSolar
	SCE	California		245 MW	Power tower	2011	eSolar
Coalinga	PG&E	California		107 MW	Parabolic trough	2011	Martifer Renewables
Martin Next Generation Solar Energy Center	FPL	Florida		75 MW	Parabolic trough add-on to IGCC	2011	FPL Energy
SES Solar One – Ph 2	SCE	California		350 MW[3]	Dish/engine	2013 - 2014	SES
SES Solar Two – Ph 2/3	SDG&E	California		600 MW[3]	Dish/engine	2011 - 2013	SES
	PG&E	California		400 MW[3]	Power tower	TBD	Bright Source
		Total	**424 MW**	**4503 MW**			

Feb 11 – Southern California Edison and BrightSource announced contracts for 1,300 MW

Western Governors' Association Renewable Energy Zones

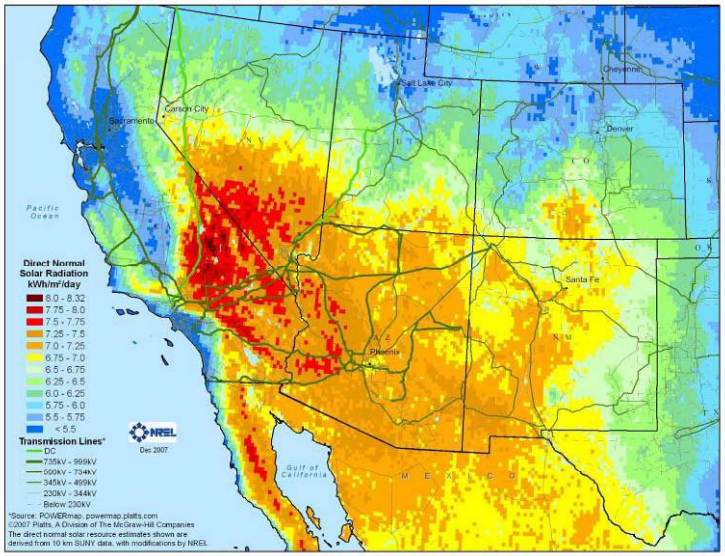


California Renewable Energy Zones

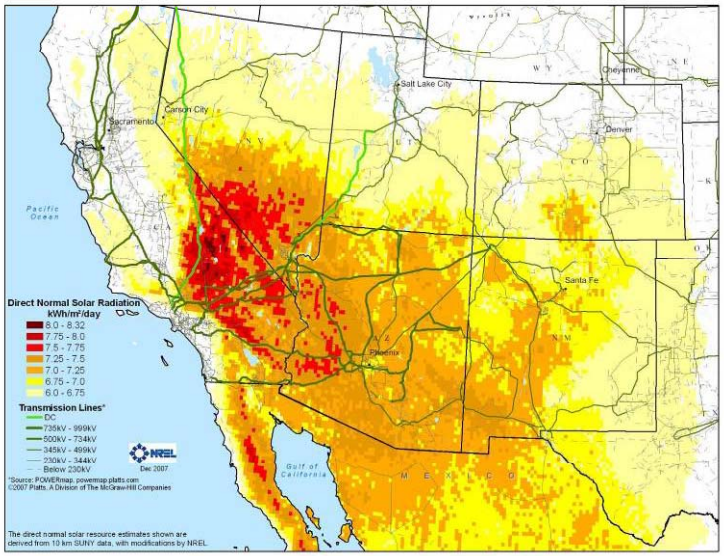


California Renewable Energy Transmission Initiative

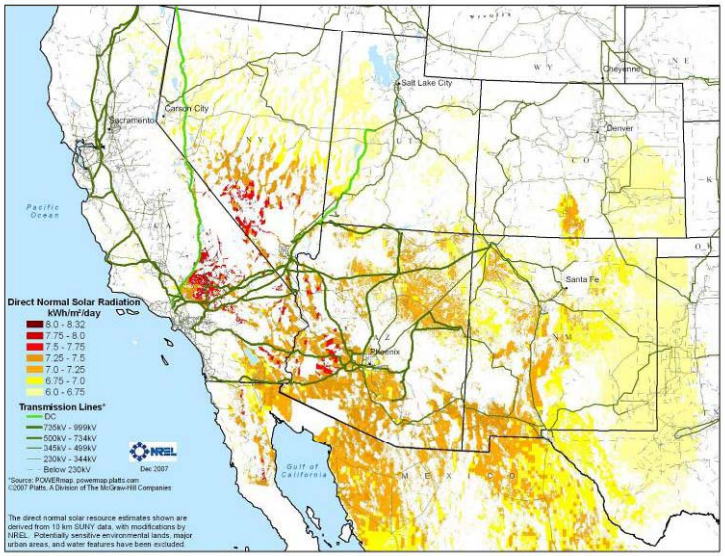
Solar Resource Screening Analysis



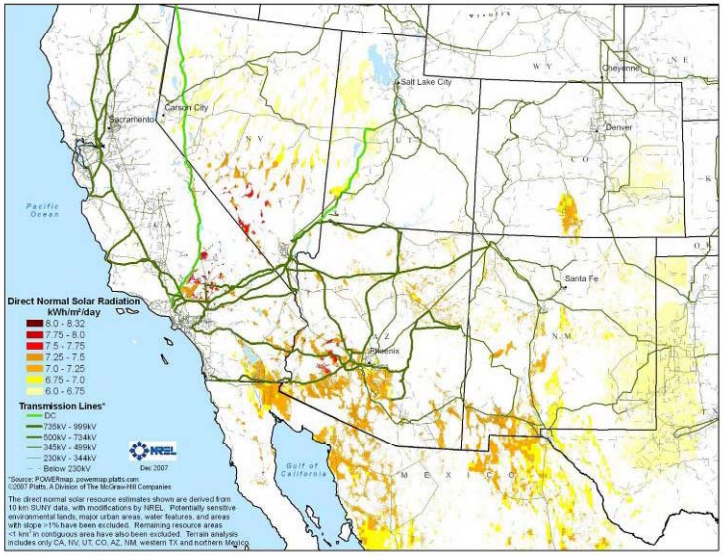
Unfiltered Resource



Solar > 6.0 kwh/m^2-day



Land Exclusions



Slope Exclusions

Resulting CSP Resource Potential

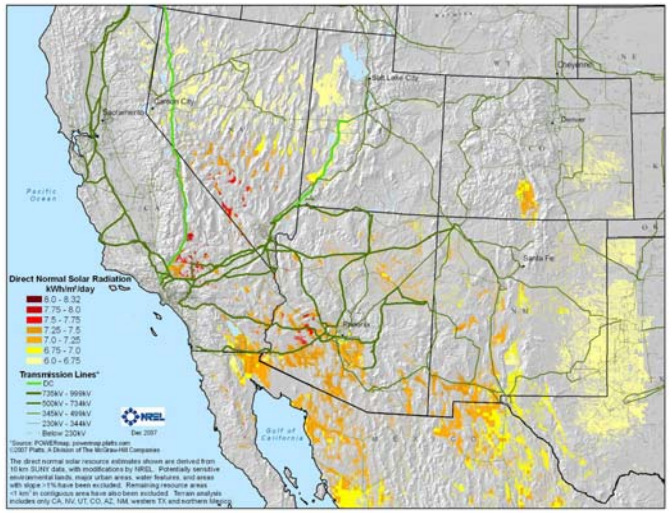
Comparison:

- SW solar potential of 6,877 GW and 16,265,611 GWh annual generation versus
- U.S. current capacity of 1,000 GW and of 4,000,000 GWh

Significant Population Growth Centers

- 15 of the 20 fastest-growing metro areas in the country are in close proximity to solar resource
- By 2030, an estimated 41 million additional people will move to the Western United States (from 90 million in 2000 to 131 million people)

Direct-Normal Solar Resource for the Southwest U.S.



Potential Solar Generation Capacity by State

State	Land Area (mi²)	Capacity (GW)	Generation (GWh)
AZ	19,279	2,468	5,836,517
CA	6,853	877	2,074,763
CO	2,124	272	643,105
NV	5,589	715	1,692,154
NM	15,156	1,940	4,588,417
TX	1,162	149	351,774
UT	3,564	456	1,078,879
Total	53,727	6,877	16,265,611

The table and map represent land that has no primary use today, exclude land with slope > 1%, and do not count sensitive lands.

Solar Energy Resource ≥ 6.75 kWh/m2/day
Capacity assumes 5 acres/MW
Generation assumes 27% annual capacity factor

CSP Funding Distribution: FY 2009

R&D Activities

Not reviewed → 27 contracts - $12 M (stage-gate reviews)

Reviewed → $13M Including $1M facilities

Sandia National Laboratories

NREL

Deployment

PEIS reviewed → $2M

Argonne – PEIS

WGA – renewable zones

Not reviewed

Other: $3M (SBIR, recision,…)

CSP FY09 Budget – Under Continuing Resolution

		NREL			Sandia			Other			Solar		
	POC	In $	Out $	T	In $	Out $	T	In $	Out $	T	In $	Out $	Total $
Concentrating Solar Power	**Wilkins**	**6006**	**705**		**6045**	**0**		**954**	**16290**		**13005**	**16995**	**30000**
Trough R&D	**Rueckert**	**1935**	**105**		**580**	**0**		**150**	**3686**		**2665**	**3791**	**6456**
Trough Solar Field	Kutscher/Moss	1249	30		580	0		0	0		1829	30	1859
Power Cycle & BOP	Kutscher/Moss	34	75		0	0		0	0		34	75	109
Industry Support	Kutscher/Elam	652	0		0	0		150	3836		802	3836	4638
Dish/Stirling R&D	**Rueckert**	**0**	**0**		**1500**	**0**		**0**	**1155**		**1500**	**1155**	**2655**
Dish Solar Field	Andr/Wendo	0	0		1400	0		0	0		1400	0	1400
CSP FOA - Dish	Andr/Wendo	0	0		100	0		0	1155		100	1155	1255
Thermal Storage R&D	**Rueckert**	**839**	**0**		**1250**	**0**		**0**	**4198**		**2089**	**4198**	**6287**
Storage Systems & components	Glatz/Seigel	435	0		700	0		0	0		1135	0	1135
Advanced HTF Development	Siegel/Blake	354	0		500	0		0	0		854	0	854
CSP FOA #1 - Storage	Elam/Kutscher	50	0		50	0		0	3079		100	3079	3179
CSP FOA #2 - Storage/HTF	Elam/Glatz	0	0		0	0		0	1119		0	1119	1119
Advanced CSP Concepts	**Rueckert**	**710**	**0**		**900**	**0**		**0**	**2749**		**1610**	**2749**	**4359**
Advanced Materials & Concepts	Kenn/Kolb	460	0		0	0		0	0		460	0	460
Power Tower R&D	Kolb	0	0		850	0		0	500		850	500	1350
CSP FOA _ Advanced Concepts	Elam/Kenn	250	0		50	0		0	2249		300	2249	2549
CSP Market Transmformation	**Rueckert**	**1885**	**600**		**250**	**0**		**0**	**1360**		**2135**	**1960**	**4095**
Southwest Stakeholder Outreach	Mancini	0	0		250	0		0	160		250	160	410
CSP Resource Assessment	Mehos	725	225		0	0		0	0		725	225	950
Market Analysis & Grid Integration	Mehos	730	300		0	0		0	0		730	300	1030
Solar Advisor Support	Mehos	305	75		0	0		0	0		305	75	380
Programmatic Support for PEIS	Mehos/Smith	125	0		0	0		0	1200		125	1200	1325
Operation and Planning	**Rueckert**	**637**	**0**		**1565**	**0**		**804**	**3142**		**3006**	**3142**	**6148**
Program Management	Meh/Man	305	0		720	0		454	0		1479	0	1479
CSP Capital Equipment & Facilities	Meh/Man	202	0		800	0		0	0		1002	0	1002
CSP Communication	Nahan/Sena	130	0		45	0		0	142		175	142	317
CSP Communications EN		0	0		0	0		0	0		0	0	0
CSP International	Mancini	0	0		0	0		350	0		350	0	350
PBA Activities	Humphries	0	0		0	0		0	1750		0	1750	1750
SBIR	Bulawka	0	0		0	0		0	750		0	750	750
Recission	Booher	0	0		0	0		0	500		0	500	500

DOE Funding for Concentrating Solar Power