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Solar Power for a Sustainable World

Concentrating Solar Power (CSP)

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Presented at Carnegie Mellon
Electricity Industry Center
Pittsburgh, PA
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Outline

- The resource – where and how large
- The technology – CSP
- Why CSP and why now?
- CSP industry, capabilities and projects
- Cost parameters and outlook
- Land and water requirements
- Financing
- Conclusions

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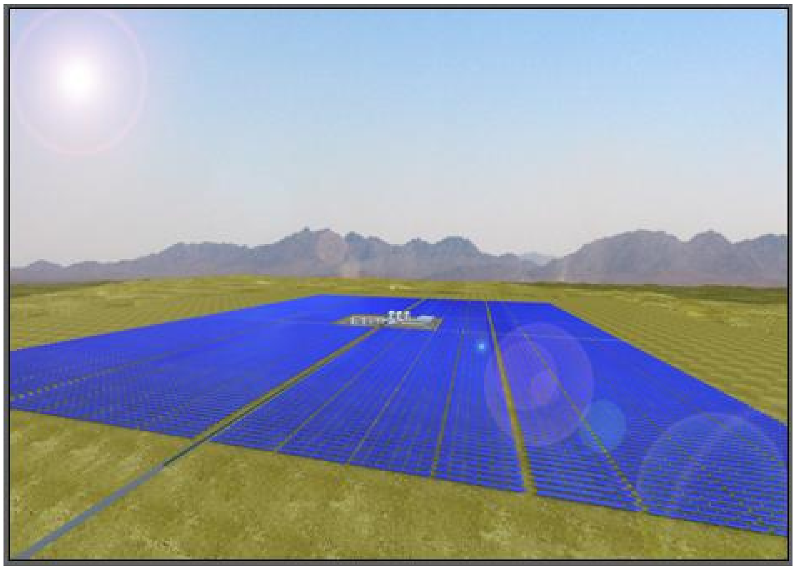
The Image of a CSP Plant



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50 MW Troughs – Solnovas 1, 3 and 4

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The Resource

- Solar energy comes in two flavors – diffuse and direct (beam)
- PV can use both components
- CSP can use only the direct because diffuse can not be effectively focused or concentrated
- So where is the direct solar energy found?

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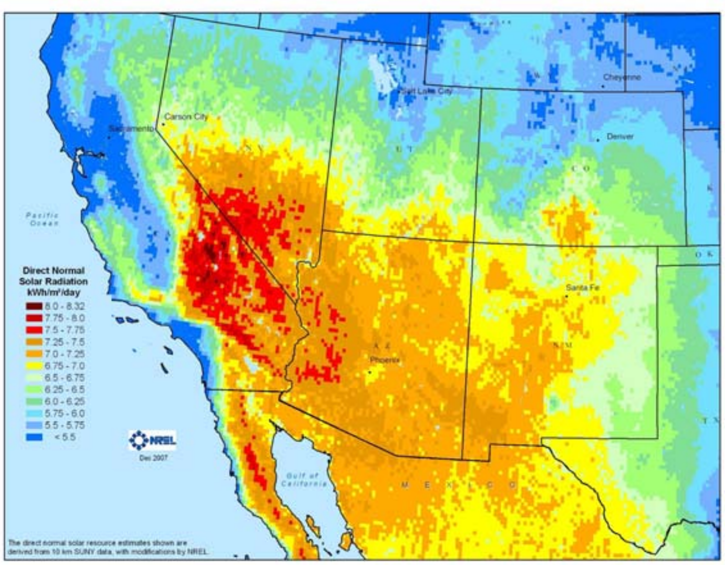
Southwest Solar Resources Unfiltered Data



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Filters to Identify Prime Locations for CSP Development

All Solar Resources

↓

Locations Suitable for Development

1. Start with direct normal solar resource estimates derived from 10 km satellite data.
2. Eliminate locations with less than 6.75 kWh/m^2/day as these will have a higher cost of electricity.
3. Exclude environmentally sensitive lands, major urban areas, and water features.
4. Remove land areas with greater than 1% (and 3%) average land slope.
5. Eliminate areas with a minimum contiguous area of less than 1 square kilometers.

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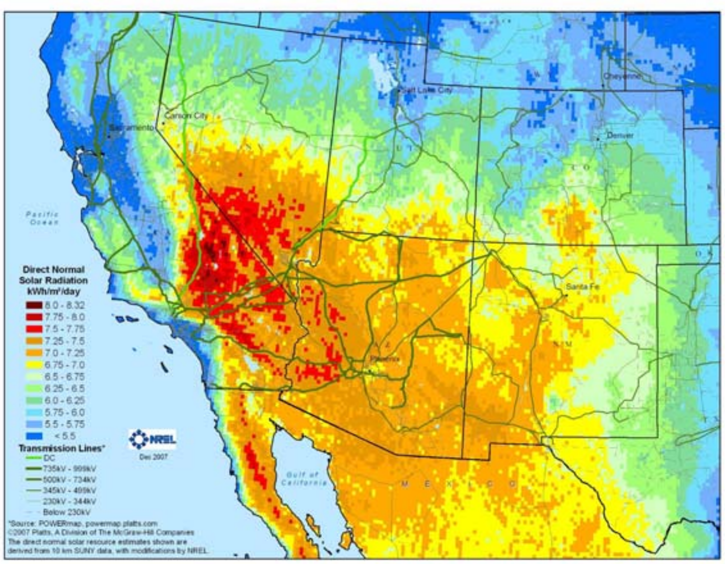
Southwest Solar Resources Transmission Overlay



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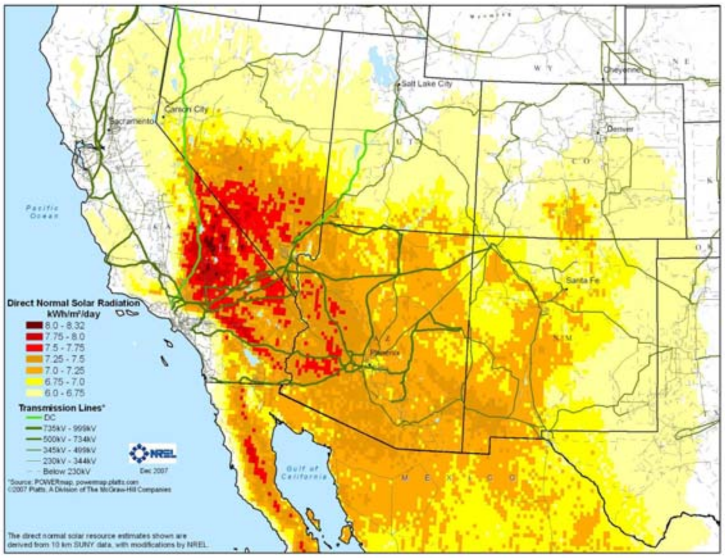
Southwest Solar Resources > 6.0 kWh/m²/day



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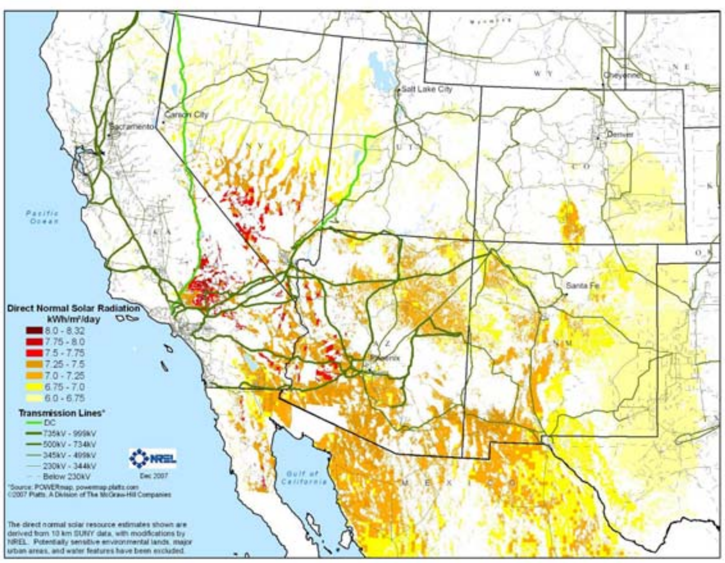
Southwest Solar Resources with Environmental and Land Use Exclusions



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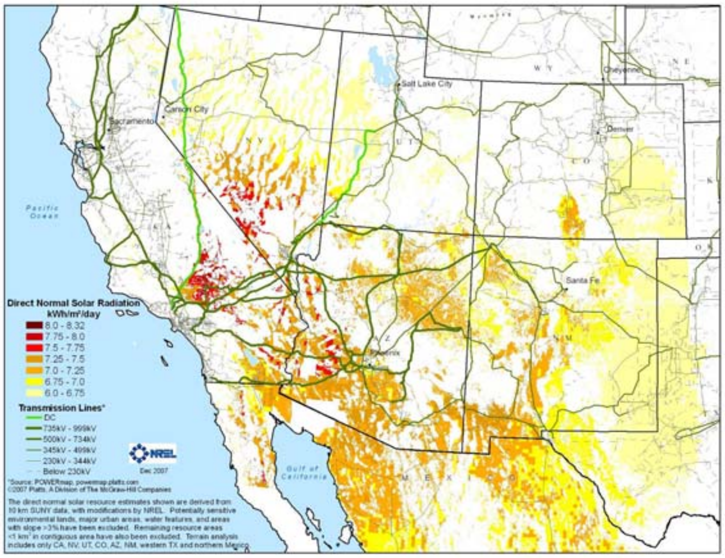
Southwest Solar Resources
Previous Plus Slope < 3%



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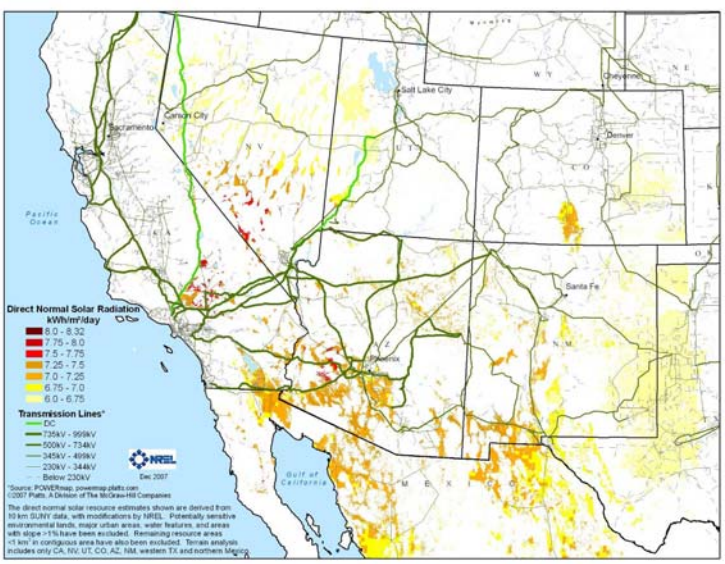
Southwest Solar Resources
Previous Plus Slope < 1%



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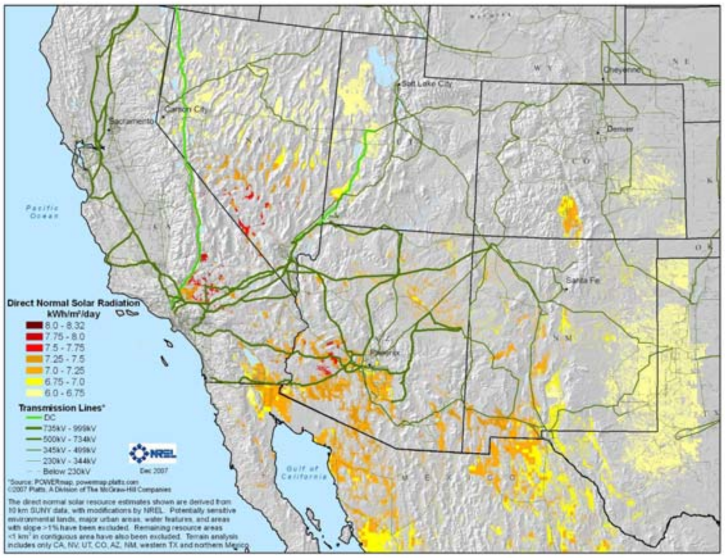
Southwest Solar Resources
Previous Plus Slope < 1% and Topography



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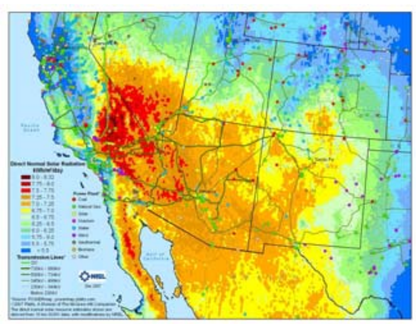
Energy Benefits
Southwest Solar Energy Potential

State	Land Area (mi^2)	Solar Capacity (MW)	Solar Generation Capacity GWh
AZ	13,613	1,742,461	4,121,268
CA	6,278	803,647	1,900,786
CO	6,232	797,758	1,886,858
NV	11,090	1,419,480	3,357,355
NM	20,356	2,605,585	6,162,729
TX	6,374	815,880	1,929,719
UT	23,288	2,980,823	7,050,242
Total	87,232	11,165,633	26,408,956



The table and map represent land that has no primary use today, exclude land with slope > 1%, and do not count sensitive lands. Also does not consider the emerging concept of solar zones

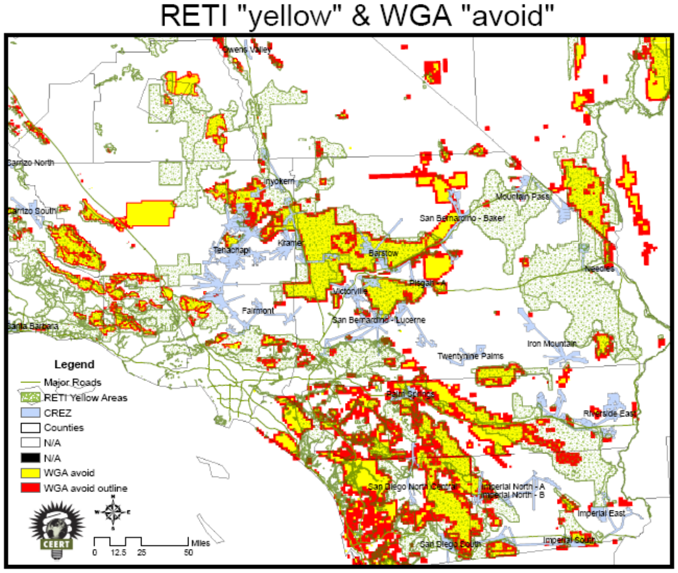
Solar Energy Resource ≥ 6.0
Capacity assumes 5 acres/MW
Generation assumes 27% annual capacity factor

ABENGOA SOLAR — Solar Zones

- Solar zones are being identified by several organizations:
  - WGA
  - BLM
  - RETI
  - States
- As these zones gain broad stakeholder support, the “CSP sweet spot” maps will need to be revised and the potential re-estimated, both downward but still likely to be very significant

ABENGOA SOLAR — Where to locate the Zones?

RETI "yellow" & WGA "avoid"



How Do We Develop This Resource?

- Concentrating Solar Technologies can be used to “mine” this resource.
- Some of these technologies use curved mirrors to focus the sun’s rays and to make steam, others directly produce electricity.
- This steam is used to produce electricity via conventional power equipment.
- In multi-Megawatt plants, CSP provides the lowest cost solar electricity.
- Can provide bulk and/or distributed generation.

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Concentrating Solar Power

Parabolic Trough

Power Tower

Linear Fresnel

Dish Engine

Concentrating PV

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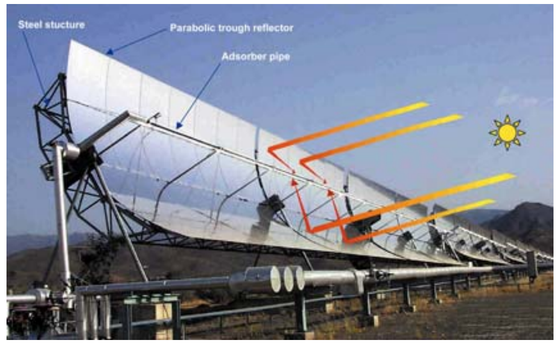
Trough Technology

- Trough collectors (single axis tracking)
- Heat-collection elements
- Heat-transfer Oil (Therminol VP1)
- Oil-to-water steam generator
- Oil-to-salt thermal storage
- Conventional steam-Rankine cycle power block



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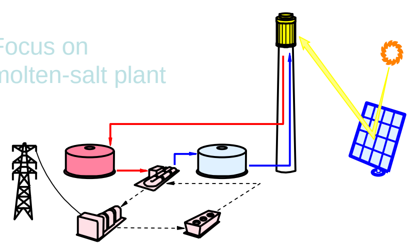
Power Tower Technology

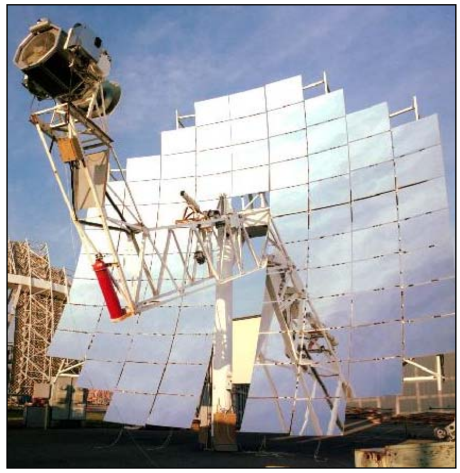
- Heliostats (two-axis tracking)
- Air or molten-salt receiver
- Air or molten-salt working fluid
- Thermal storage
- Conventional steam-Rankine cycle power block, or combustion turbine
- Several developers in the US and in Spain

Focus on molten-salt plant



ABENGOA SOLAR — Dish Stirling Technology

- Dish (two-axis tracking)
- 10 and 25 kW Stirling engines
- Thermal receivers
- Distributed generation or bulk power
- 8 Different system configurations built and tested over the last 20 years
- Significant utility interest



ABENGOA SOLAR — Concentrating PV Technology

- 25- 35 kW CPV systems
- Two axis tracking structure
- 350 m^2 concentrator
- 3M acrylic lens concentrator at 250X or parabolic dish with PV at focal point
- Silicon solar cells
- Many companies are developing new designs and sound business plans

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Why CSP and Why Now?

- Necessity – the utilities' other options (coal, nuclear or NG) have significant long term risks with cost implications
- Uniqueness of thermal energy **storage**
- Favorable but still unreliable policies, such as the RPS and the ARRA incentives (both of which are essential) in the US and Feed-in tariffs elsewhere
- Public opinion favors solar

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Awareness of CSP

- Utilities – Growing fast where good DNI and policies exist
- Policy makers – Generally lagging as evidenced by inadequate or unreliable policies at all levels of government
- Investors – Growing fast as evidenced by news articles and conferences but lagging wind and PV investments, held back by policy uncertainty and today's financial market situation

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Attributes of CSP in the Eyes of Utilities

- Utilities are familiar with **steam** generation
- Suitability for utility **scale** installations of 100MW or more
- **Stable**, known and decreasing costs and zero carbon emissions provide hedge against NG price volatility and carbon caps
- Other generation options have significant **risks**
- Ability to provide firm **dispatchable** output which is of great value to utilities

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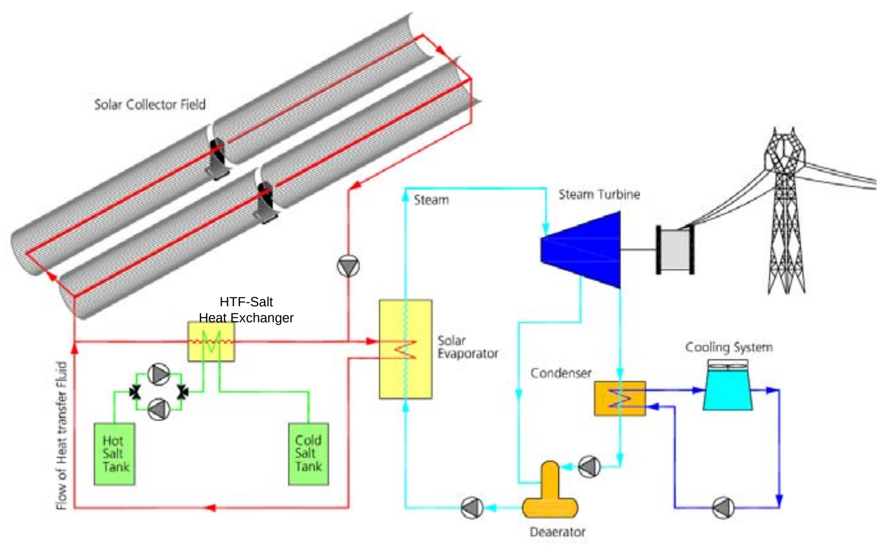
Flow Diagram



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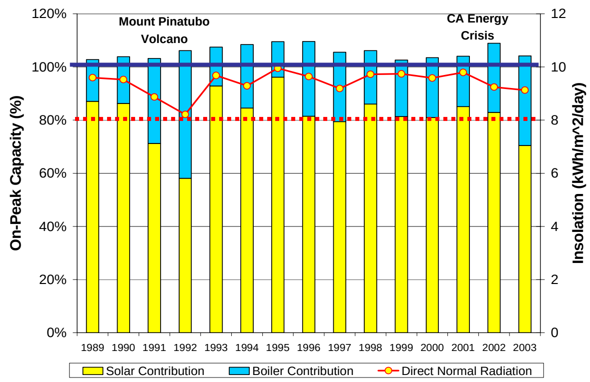
CSP has worked in California



- Averaged 80% on-peak capacity factor from solar
- Over 100% with fossil backup
- Could approach 100% from solar with the addition of thermal energy storage.

SCE Summer On-Peak
Weekdays: Jun - Sep
12 noon - 6 pm

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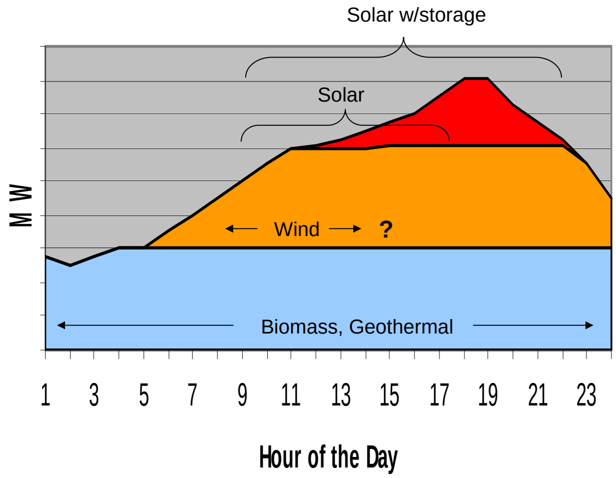
Summer Generation Profile
Renewable Resource Fit
(from Barbara Lockwood, APS)



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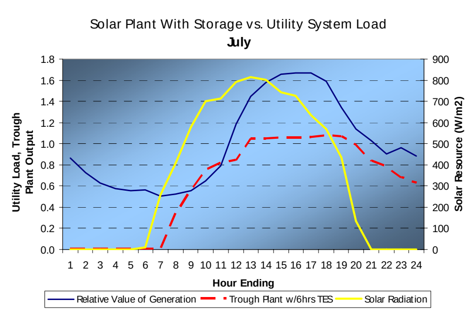
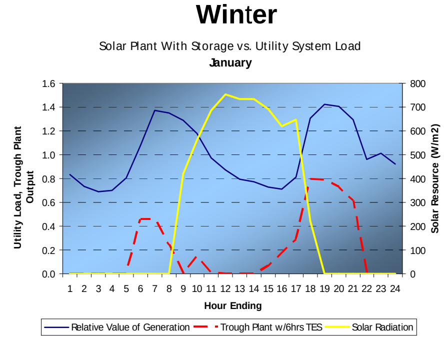
Dispatching Solar Power

Generation from solar plant with storage can be shifted to match the utility system load profile

Summer



Winter



Key: - Solar
- Demand
- Generation

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TES Test Facility

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Land Usage

- CSP plants typically need about 5 acres per MW or 1 sq miles per 100MW or about 10 sq miles per GW
- With TES this increases to about 6-8 acres per MW, depending on the hours of TES
- This estimate generally applies to all USP technologies

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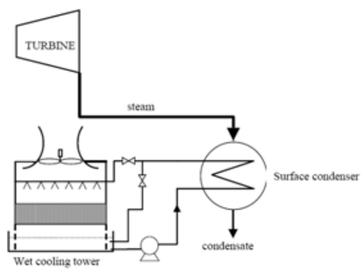
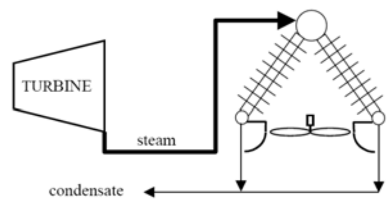
Wet Vs. Dry Cooling Technology



Wet Cooling



Dry Cooling

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Wet Vs. Dry Cooling Technology

Wet Cooling

- Uses 3.5 m^3 water per MWh
  - **~90%** for cooling
  - The rest for the steam cycle and washing

Dry Cooling

- Reduces plant water consumption by ~90%
- Increases plant capital cost ~5%
- Reduces annual net output >5%
  - Significant reduction during hot periods
- Increases cost of electricity ~10%

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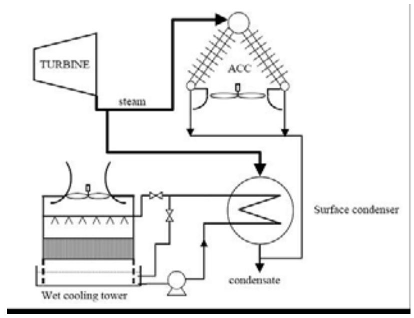
Hybrid Cooling Technology

- A "hybrid" mix of wet and dry cooling
- A number of approaches are possible
- Commercially available option
  - Includes both dry and wet cooling towers
  - Relative size of wet and dry cooling towers determines water use



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Attributes of CSP in the Eyes of Policy Makers

- Very large domestic resource potential
- Carbon free electricity
- Potential for cost reduction
- Economic benefits will result from its development
- Increased public awareness and support of the benefits of clean energy

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Attributes of CSP in the Eyes of Investors

- Scalable
- With a good Power Purchase Agreement, the return on investment can be adequate to encourage main-stream equity and favorable debt financing terms.
- Once debt is paid, operates with no fuel – has potential of becoming a “clean cash cow”.

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CSP industry active in the US

- Trough – Abengoa Solar, Acciona, FPL Energy, Solar Millennium, Solel, SkyFuel
- Tower – Abengoa Solar, Bright Source Energy, eSolar, Solar Reserve/UTC
- Dish – SES, Infinia
- Fresnel – Ausra, SkyFuel

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CSP Business Estimated Activity in the US (Oct 2008)

Name or Location	Utility	State	In Operation	Contracts & Awards[1]	Technology	Begin Operation	Company
SEGS	SCE	California	354 MW		Parabolic trough	1985 - 1991	FPL Energy
Saguaro	APS	Arizona	1 MW		Parabolic trough	2006	Aciona
Nevada Solar One	NVEnergy	Nevada	64 MW		Parabolic trough	2007	Aciona
Kimberlina Power Plant	PG&E	California	5 MW		Linear Fresnel	2008	Ausra
Sierra Sun Tower	SCE	California	5 MW		Power tower	2009	eSolar
Keahole Solar Power	HELCO	Hawaii	1 MW		Parabolic trough	2009	Sopogy
Maricopa Solar	SRP	Arizona		1+ MW	Dish/engine	2010	SES / Tessera Sp;ar
Carrizo Energy Solar Farm	PG&E	California		177 MW	Linear Fresnel	2010	Ausra
West Texas	CPS Energy	Texas		27 MW	Dish/engine	2010	SES / Tessera Solar
SES Solar Two – Ph 1	SDG&E	California		300 MW	Dish/engine	2010 - 2012	SES / Tessera Solar
Solana	APS	Arizona		280 MW	Parabolic trough	2011	Abengoa Solar
Mojave Solar Park	PG&E	California		553 MW	Parabolic trough	2011	Solel
Beacon	LADWP	California		250 MW	Parabolic trough	2011	NextEra Energy
Sunland Park, NM	EPE	New Mexico		92 MW	Power tower	2011	NRG / eSolar
California	SCE	California		140 MW	Power tower	2011	NRG / eSolar
Coalinga	PG&E	California		107 MW	Parabolic trough	2011	Martifer Renewables
Martin Solar Energy Ctr.	FPL	Florida		75 MW	Trough add-on to IGCC	2011	NextEra Energy
SES Solar One – Ph 1	SCE	California		500 MW	Dish/engine	2011 - 2012	SES / Tessera Solar
SES Solar Two – Ph 2/3	SDG&E	California		600 MW [2]	Dish/engine	2011 - 2013	SES / Tessera Solar
Lancaster, CA	PG&E	California		92 MW	Power tower	2012	NRG / eSolar
Ivanpah, CA	PG&E	California		300 MW	Power Tower	2012 - 2013	BrightSource Energy
Harper Lake	PG&E	California		250 MW	Parabolic trough	2013	Abengoa Solar
Harper Lake Solar Plant	PG&E	California		250 MW	Parabolic trough	2013	NextEra Energy
Ivanpah, CA	SCE	California		100 MW	Power tower	2013	BrightSource Energy
Blythe, CA	SCE	California		242 MW	Parabolic trough	2013	Solar Millennium
Kingman, AZ	(TBD)	Arizona		200 MW	Parabolic trough	2013	Albiasa Solar
SES Solar One – Ph 2	SCE	California		350 MW [2]	Dish/engine	2013 - 2014	SES / Tessera Solar
Nevada	NVEnergy	Nevada		250 MW	Parabolic trough	2013 - 2014	Solar Millennium
Ridgequest, CA	SCE	California		242 MW	Parabolic trough	2014	Solar Millennium
(Multiple plants)	SCE	California		1200 MW [2]	Power tower	Unspecified	BrightSource Energy
(Multiple plants)	PG&E	California		1000 MW [2]	Power tower	Unspecified	BrightSource Energy
California	SDG&E	California		100 MW	Parabolic trough	Unspecified	Bethel Energy
California	SCE	California		242 MW [2]	Parabolic trough	Unspecified	Solar Millennium
		Column Totals	430 MW	7,920 MW			
		U.S. Total	8,350 MW				

1 Agreement signed or award announced

2 Contractual expansion option

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Major Steps to Bring a CSP Plant On-Line

- Site control, PPA negotiation, regulatory approval, interconnection agreement and financial close (some in parallel) – 12-24 months
- Permitting and engineering (in parallel) – 18 – 24 months
- Construction – 18 – 24 months
- Total time – 4-6 years

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View of PS10 and PS20

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PS-10

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ABENGOA SOLAR — PS10 Operating

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ABENGOA SOLAR — PS10 Heliostats

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PS20 Operating

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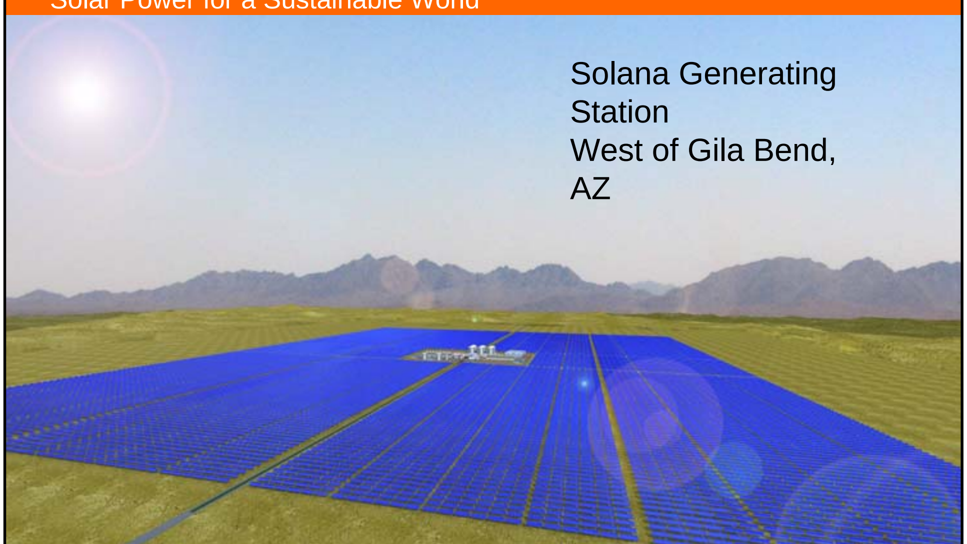
Solana Overview



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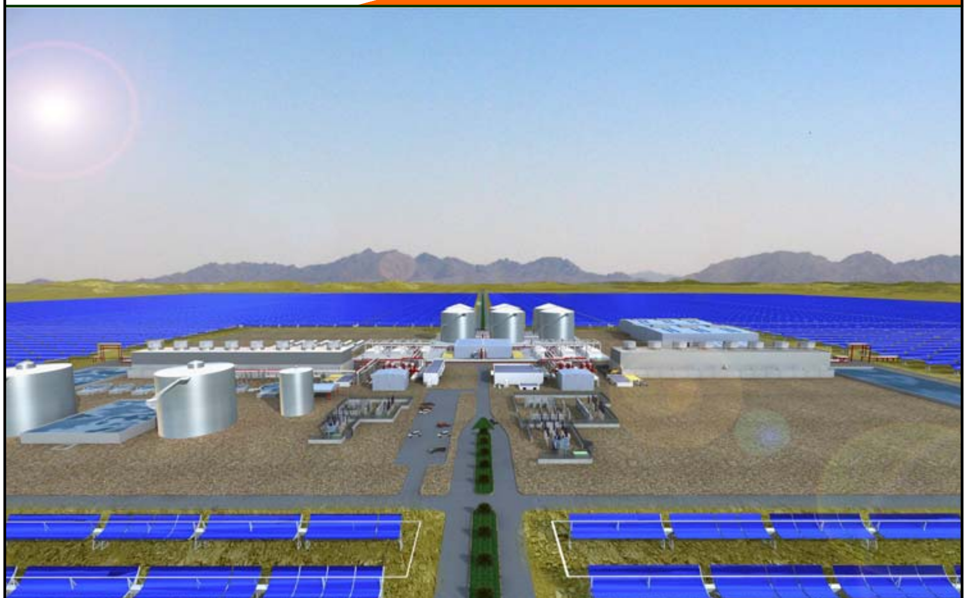

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Solana Overview

Site Location:

The Solana site is located west of Gila Bend, AZ, approximately ~70 miles southwest of Phoenix

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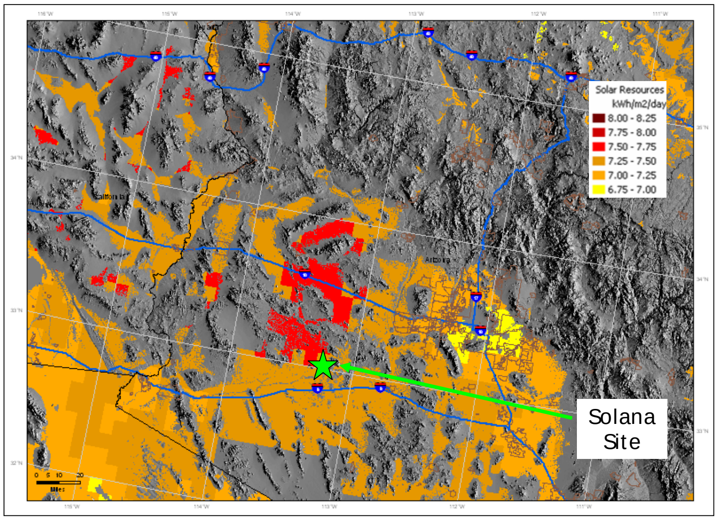
Overview: Solana Site Selection

- High solar resource
- Minimal slope
- Proximity to electric grid
- Proximity to transportation corridors
- Water availability
- Previously disturbed land



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Solana Overview

Project Facts

- 280 MW gross output with conventional steam turbines
- “Solar Field” will cover 775 hectares (3 square miles) and contain ~ 2,900 trough collectors
- Collectors are ~ 6m wide, 125m long, and over 6m in height
- Plant water consumption approximately eight times less than current agricultural use
- Thermal storage tanks allow electricity to be produced on cloudy days or several hours after sunset

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Solana Overview

Constructing Solana will require over 80,000 tons of steel – enough to build a second Golden Gate Bridge.

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Solana's Distinctions

- Well capitalized project sponsor
  -Parent company with > $12B in collective project finance
  -Strong relationships with banks
- Strong management team
- Experienced in-house EPC provides:
  -Minimized risk of schedule delays, cost overruns
  -Wrap-around guarantee
- Low technology risk
  -Trough is proven
  -TES is well tested with 1/4 scale test loop and major heat exchanger

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Broad Support for Solana

"You can create jobs, you can put Arizona at the forefront of new technology that can be sold around the world and you can help the environment at the same time".

-Governor Janet Napolitano

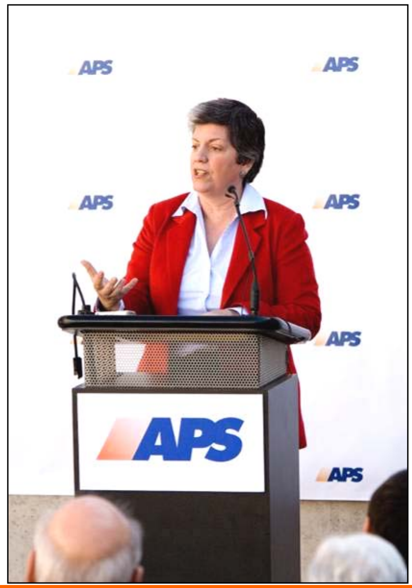

WHERE TO FIND great steak

Weekend festivals to highlight Japan, Scotland, India ALL IN CALENDAR

THE ARIZONA REPUBLIC

azcentral.com

Plant to brighten state's solar future



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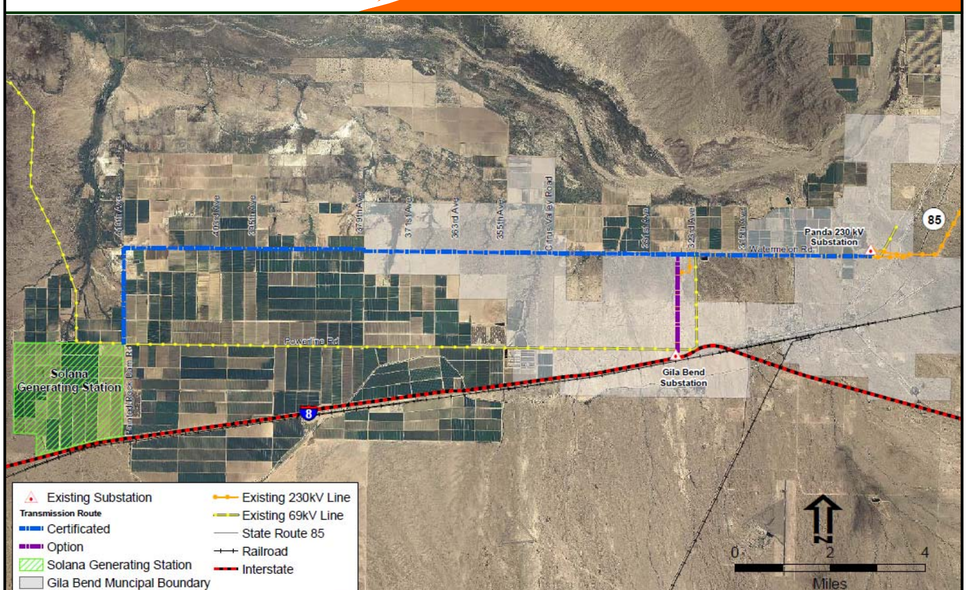
Interconnection



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Interconnection

- Feasibility Study — complete
- System Impact Study — complete
- Facilities Study — in progress

- LGIA expected: by December 2009

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Permitting

State siting permit (Arizona corporation commission)	approximately 12 months
Air permit non-title V (Maricopa County air quality department)	approximately 7-13 months
Aquifer protection permit (Arizona department of environmental quality)	approximately 10-16 months
Cultural resources clearance (Arizona state historic preservation office)	approximately 60-90 days
Arizona pollutant discharge elimination system (Arizona department of environmental quality)	may be required depending on storm water runoff

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ABENGOA SOLAR — Key Project Activities & Schedule

Comprehensive plan amendment	approximately 6-9 months
Special use permit (Maricopa County planning and zoning)	approximately 8-10 months
Encroachment permit (Arizona department of transportation)	approximately 60-90 days
Temporary construction permit (Maricopa County planning and zoning)	approximately 30 days
Temporary power permit (Maricopa County planning and zoning)	approximately 30 days
Building permits (Maricopa County planning and zoning)	approximately 60-90 days
Permit to drill (Arizona department of water resources)	approximately 30 days

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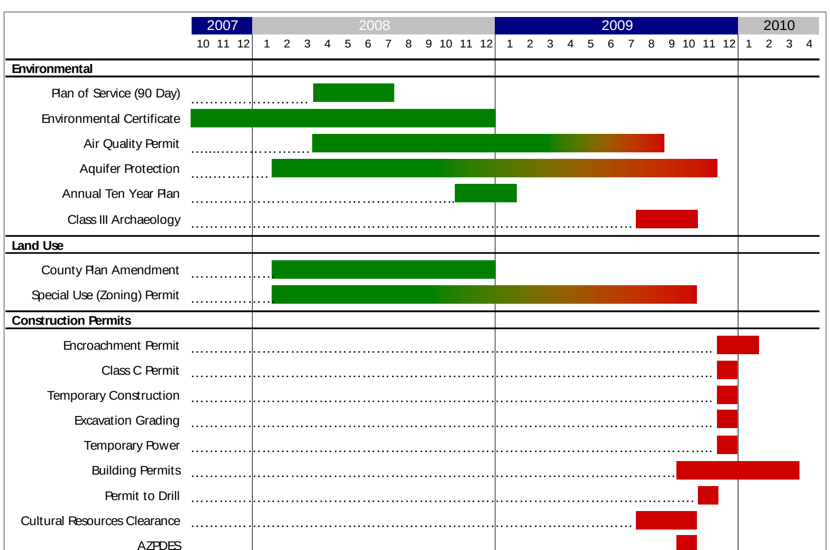
ABENGOA SOLAR — Permitting Status July 2009



Key: Complete Not Complete

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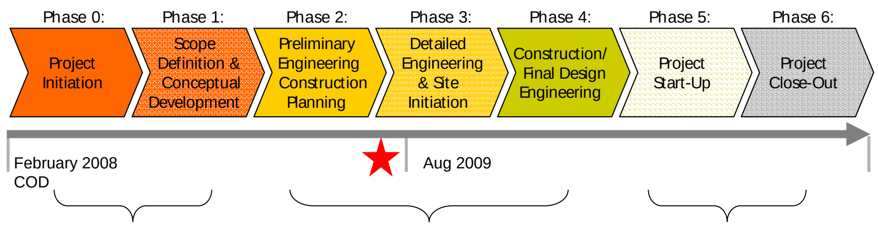
ABENGOA SOLAR — Overall Progress Status August 2009



- Contract award
- Program set-up
- Team selection
- Technical Studies
- Permitting start
- Reporting frameworks

- Conceptual, preliminary, and detailed engineering
- Financing
- Permitting
- Interconnection
- Site preparation
- Procurement
- Construction

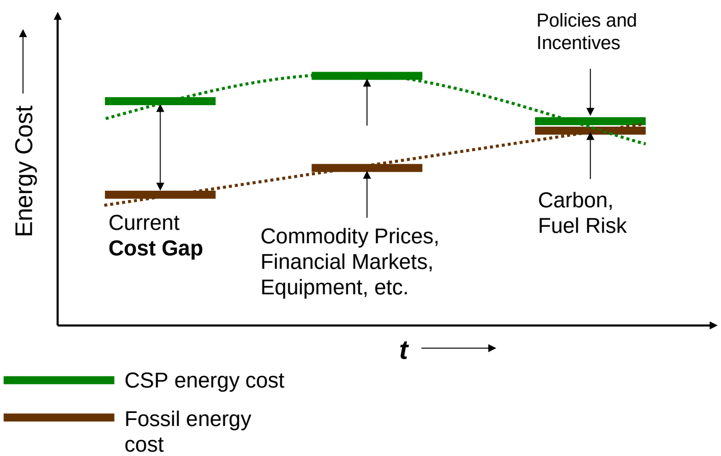
- Commissioning, testing and start-up
- Systems coordination
- Project completion reports
- Commercial operation
- Ongoing compliance

ABENGOA SOLAR — Energy Benefits

- Diversification of generation sources
  - Reduce reliance on fossil fuels
- Reliability
  - Abundant, renewable resource
  - Proven technology
- Guaranteed, fixed cost
- Thermal storage extends electrical generation through peak load when power is most needed

ABENGOA SOLAR — Cost Gap will Close

RPS, incentives and policies can close the cost gap between fossil and CSP-derived energy (from Kate Maracas, Abengoa Solar)



ABENGOA SOLAR — My Message

As Chairman of the USP Division of SEIA, I offer these thoughts to preface this presentation:

- CSP is an attractive high-value resource because of its fixed cost, hedging, dispatchable and local economic benefits
- CSP projects generally face the same financing, siting and transmission challenges as do other resources but, because of their desert location, siting becomes a special challenge
- CSP also faces policy challenges including making the APPA incentives work, the anticipated national RPS, transmission legislation, carbon policy, to name a few
- CSP has proven performance and reliability
- The cost of CSP will continue to decline as a result of R&D, larger plants and learning curve effects
- Proposed HV back-bone transmission, increased CF via thermal energy storage and the use of the solar zones, will allow CSP to power the load centers on the two coasts

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