ABENGOA SOLAR

Solar Power for a Sustainable World

Status and Role of Concentrating Solar Power in Rural America

USDA Outlook Conference

February 19, 2010

Arlington, VA

Outline

- The solar resource – what, where and how large
- The technology – Concentrating Solar Power (CSP)
- Why CSP and why now?
- CSP performance
- Land and water requirements
- CSP projects
- Cost parameters and outlook
- Economic benefits for rural America
- Conclusions

CSP – the other solar technology

- Solar energy can be converted into space and water heating and cooling – I will not address this application today
- Solar energy can be converted into electricity via photovoltaics located on roof-tops – I will not address this application today
- I will address the central station generation of electricity from solar energy using concentrating solar power technologies

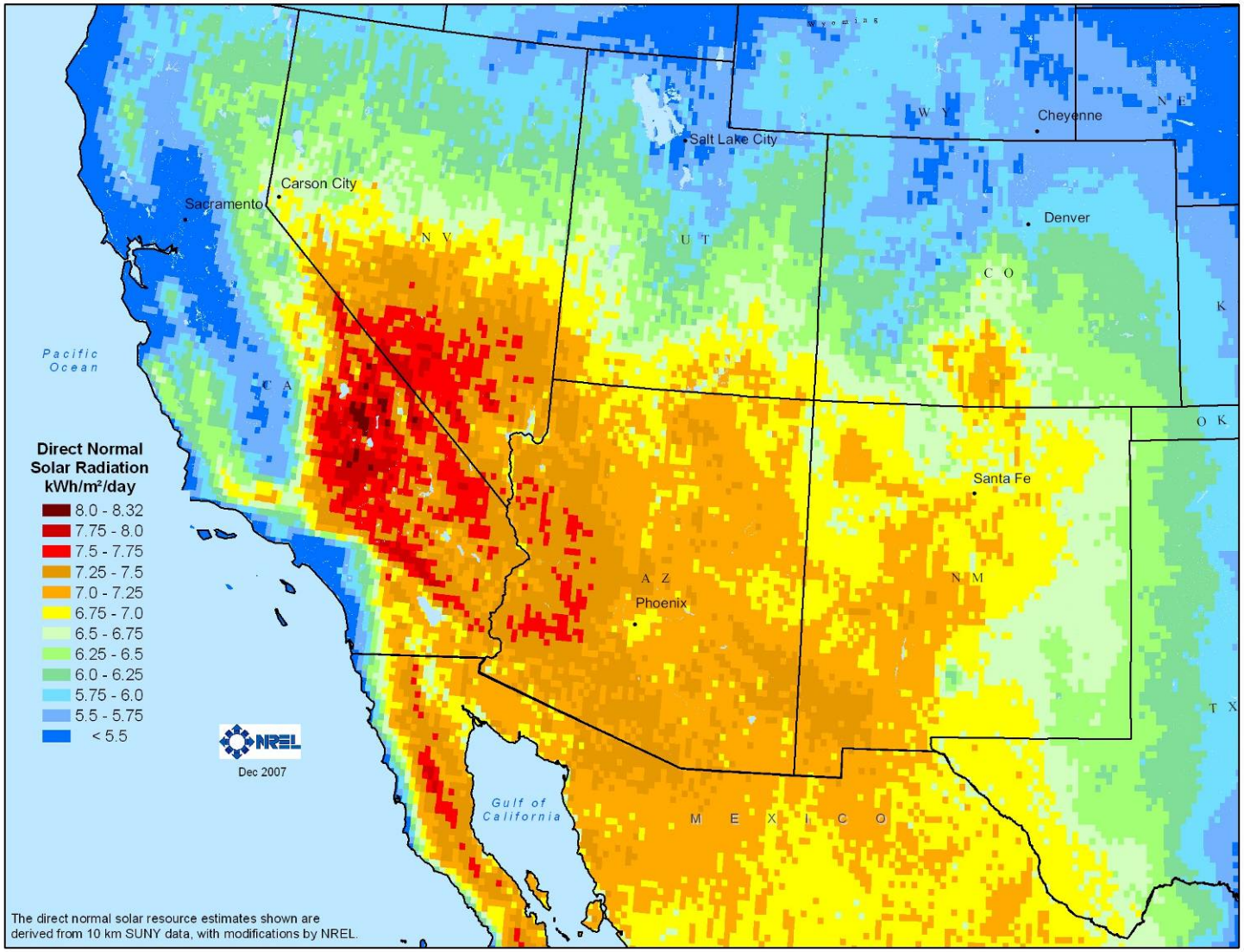
Image of CSP Plants

The Solar Resource

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?

Southwest Solar Resources Unfiltered Data



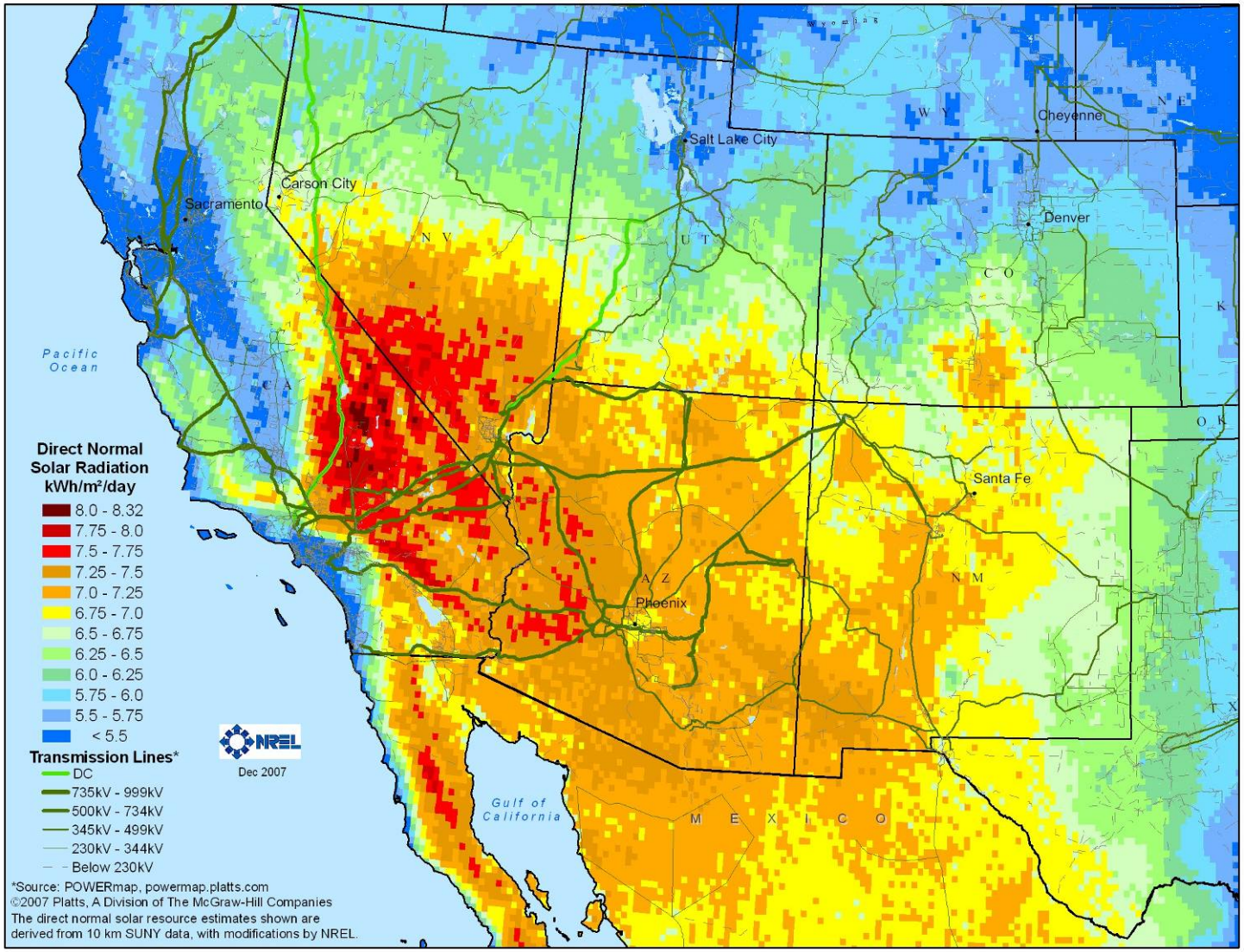
Filters to Identify Prime Locations for CSP Development

All Solar Resources

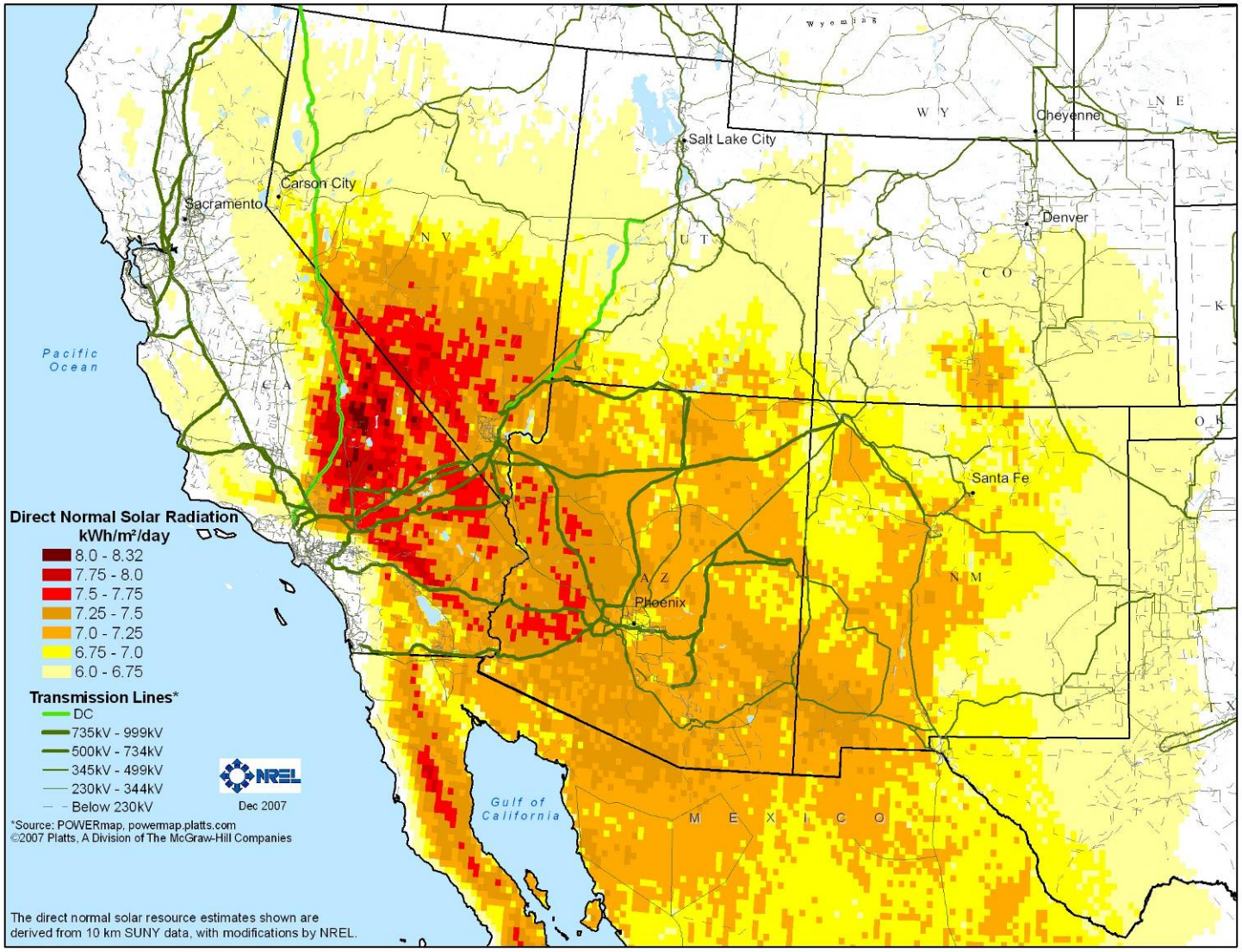
Locations Suitable for Development

1. Start with direct normal solar resource estimates derived from 10 km satellite data.
2. Eliminate locations with less than some minimum level 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.

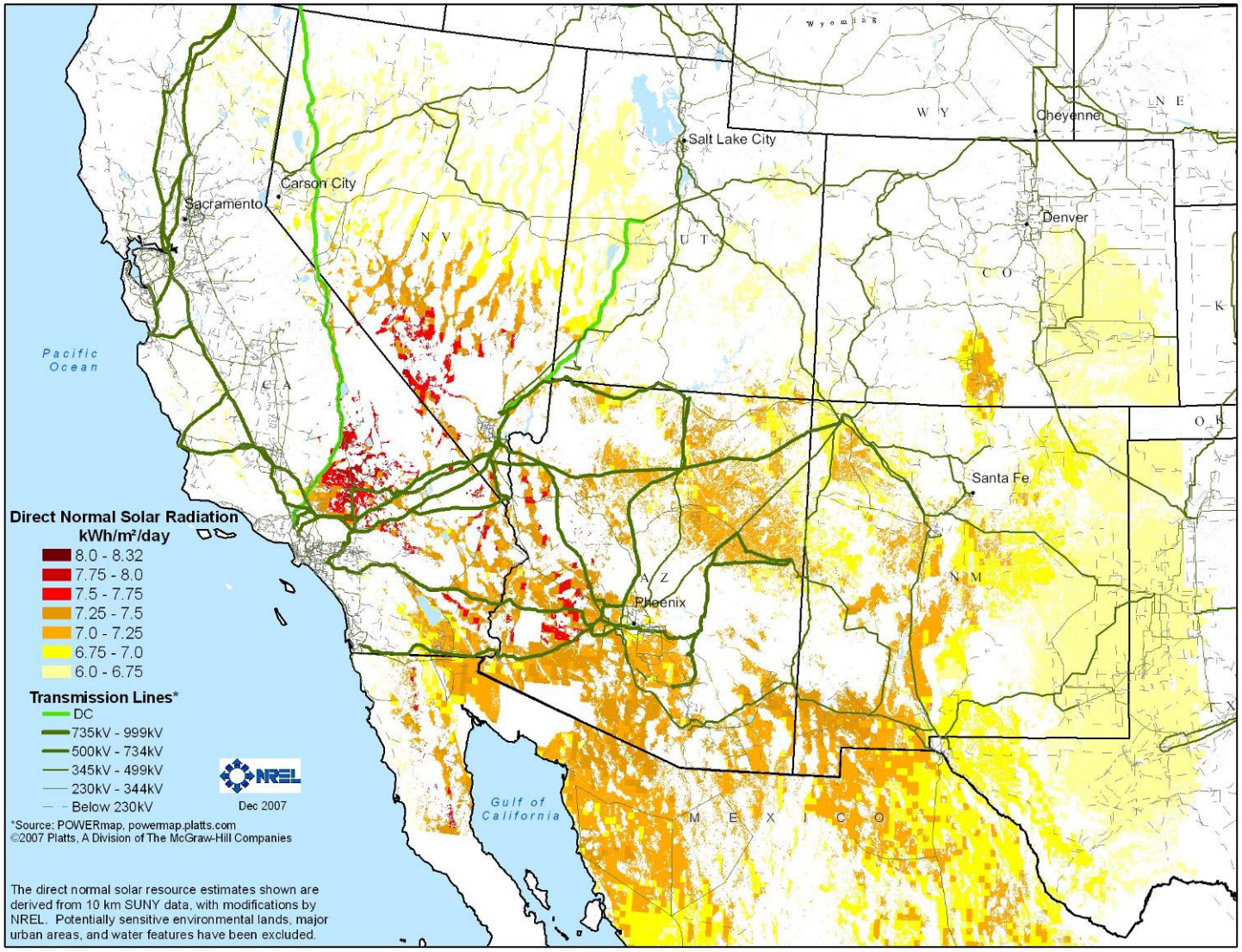
Southwest Solar Resources Transmission Overlay



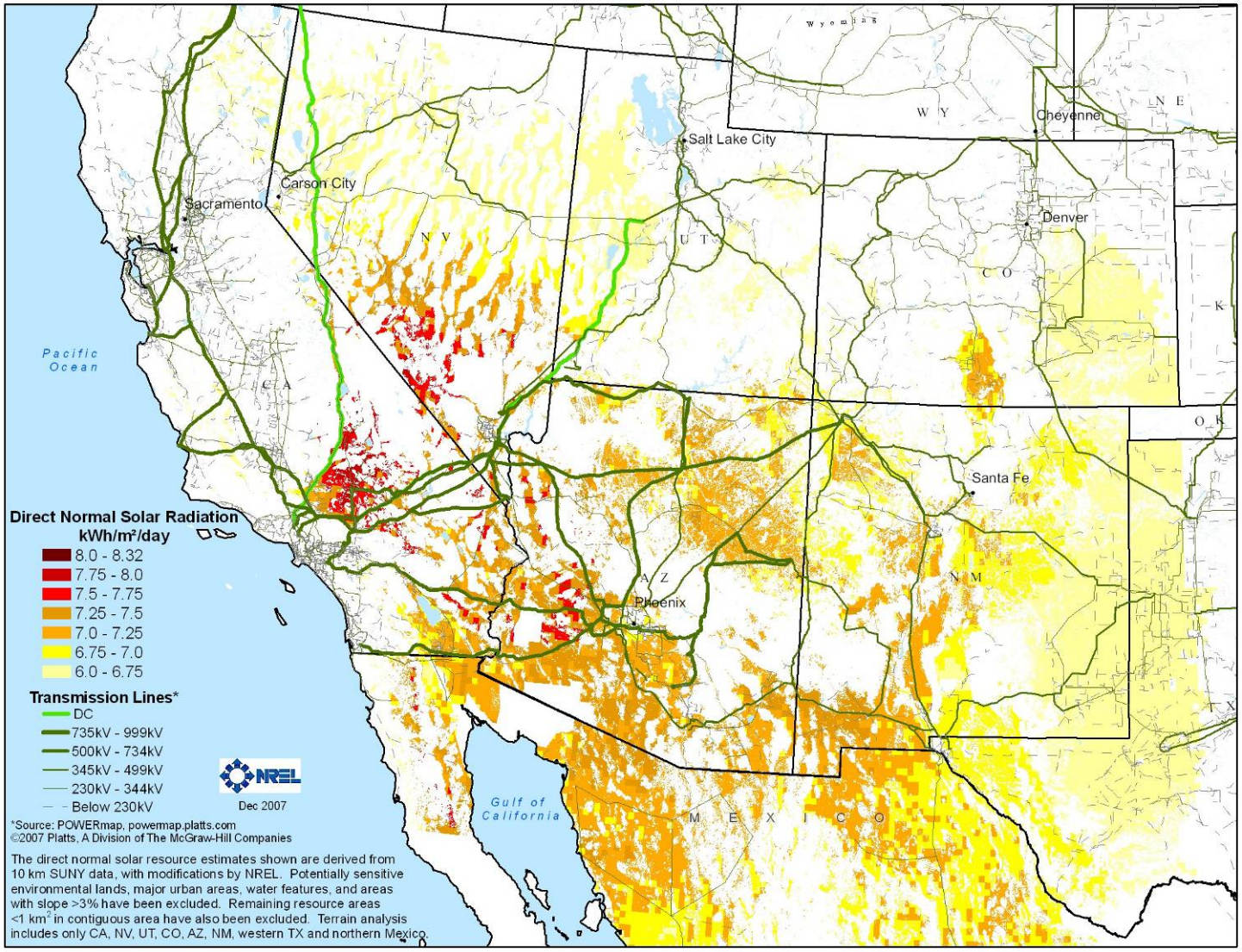
Southwest Solar Resources > 6.0 kWh/m²/day



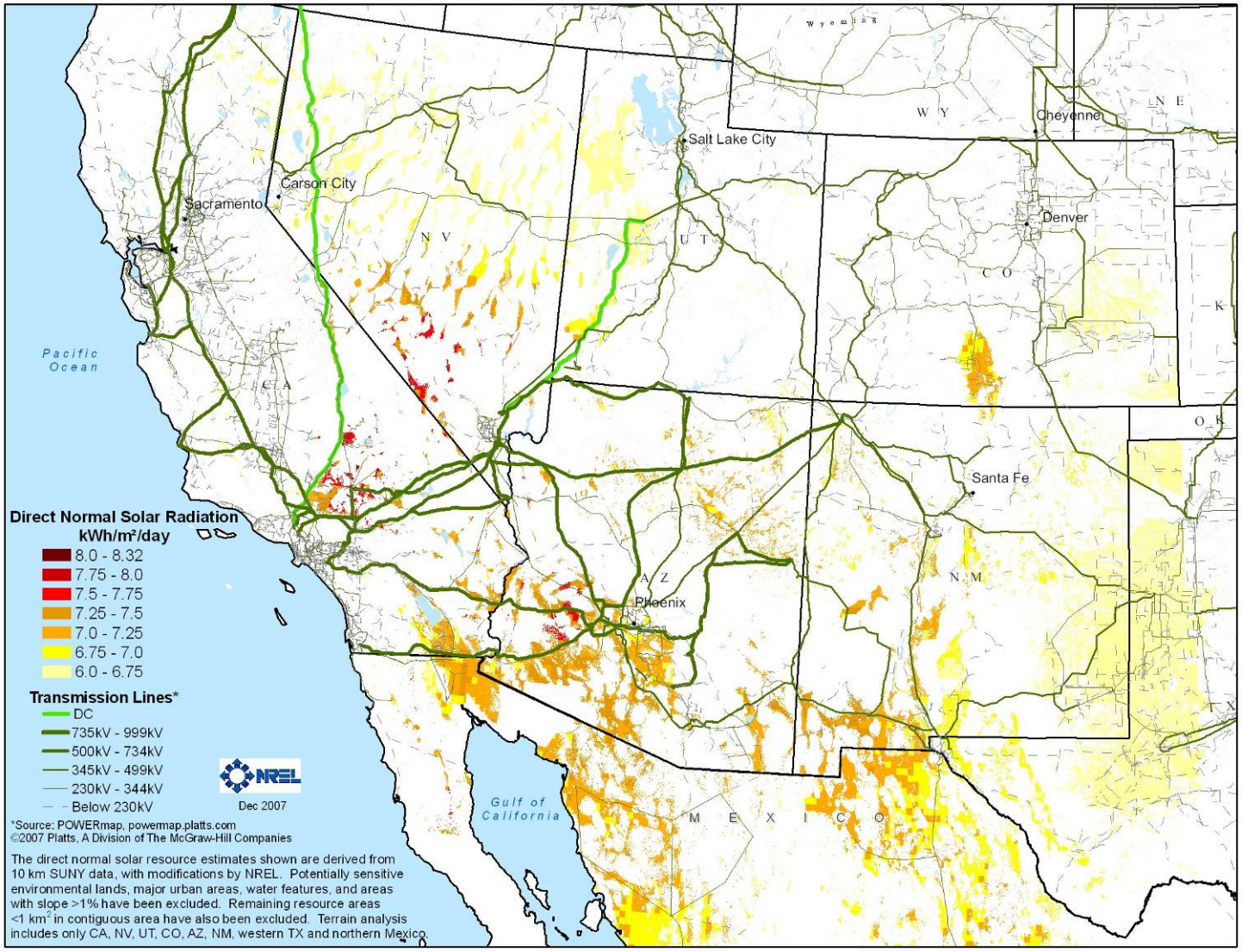
Southwest Solar Resources with Environmental and Land Use Exclusions



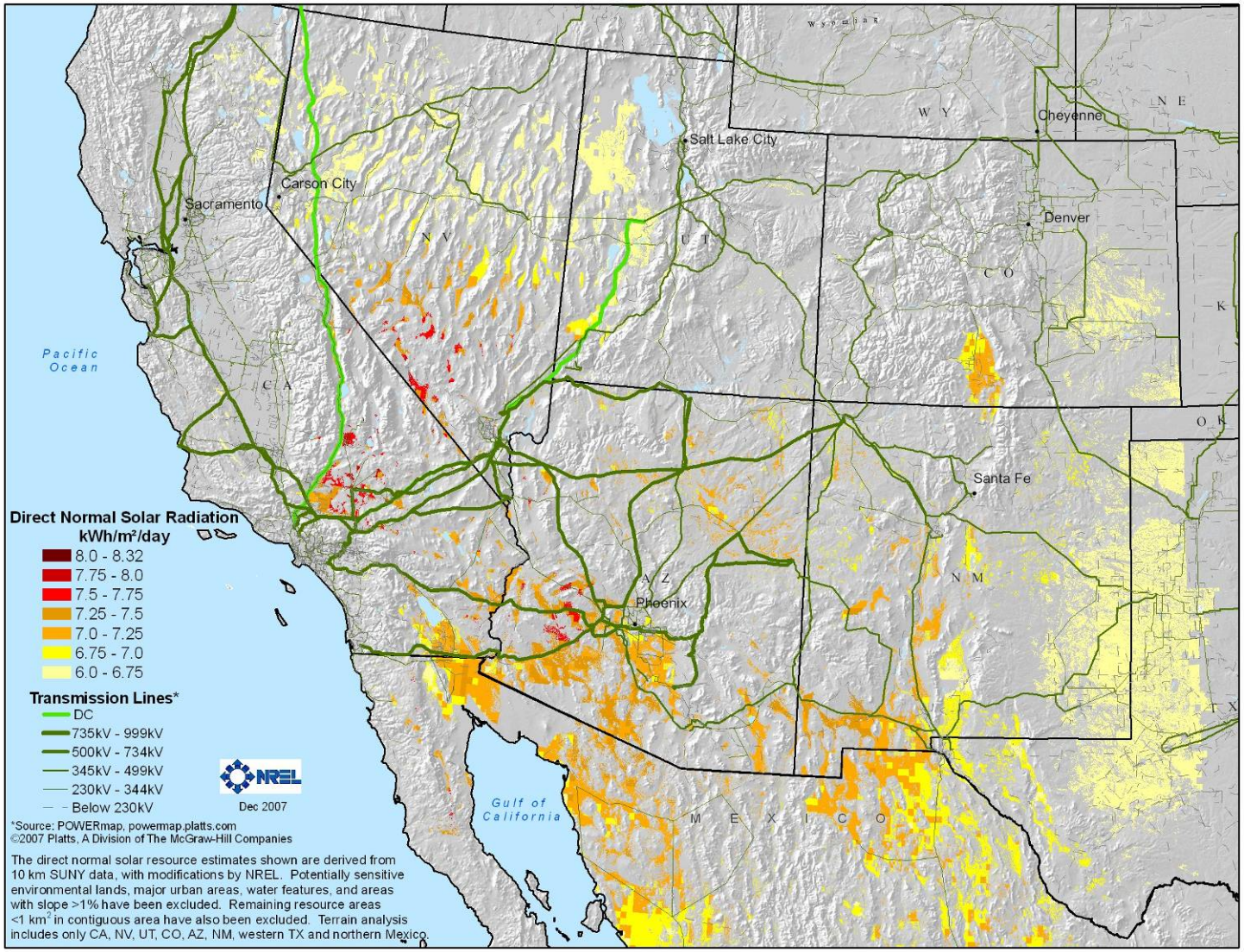
Southwest Solar Resources Previous Plus Slope < 3%



Southwest Solar Resources Previous Plus Slope < 1%

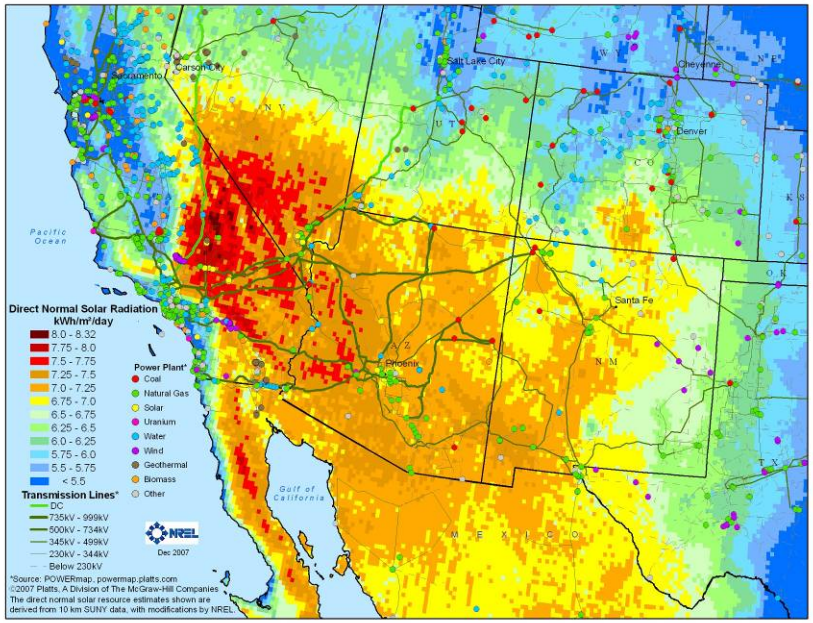


Southwest Solar Resources
Previous Plus Slope < 1% and Topography



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



While only a small fraction of this area can be used for CSP plants, there is ample land for siting them and the potential is very large

Solar Zones

- Using filtered maps such as these, solar zones are being identified to encourage CSP development where environmental impacts are minimized and infrastructure requirements are more easily met.
- 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
- The zones lie in rural SW America

The CSP Technologies

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.
- Can provide bulk and/or distributed generation.

Concentrating Solar Power

Parabolic Trough

Power Tower

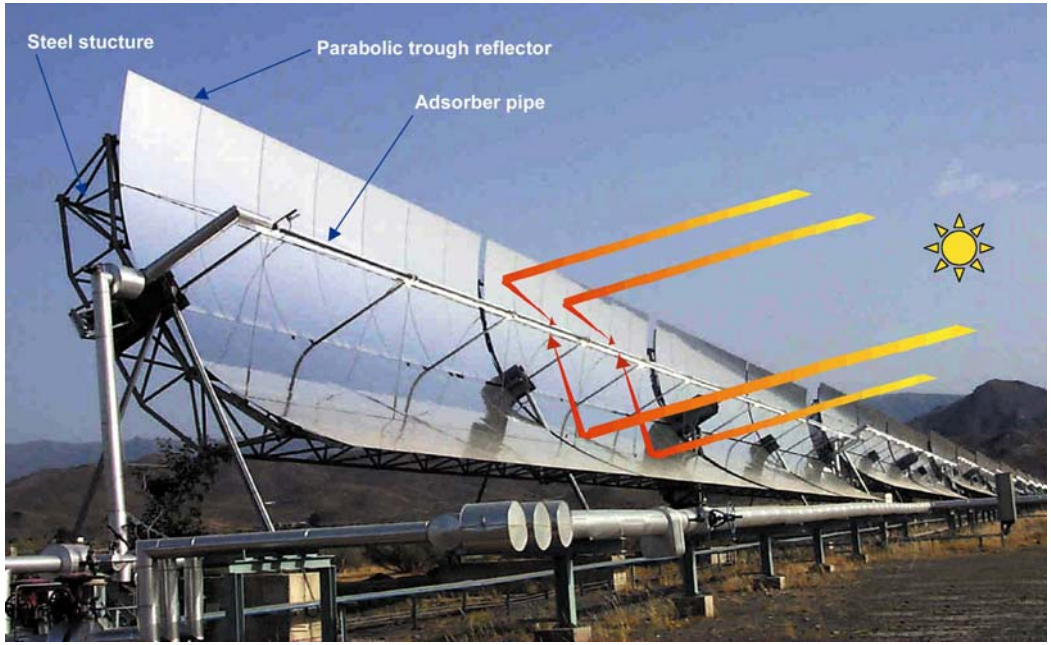
Linear Fresnel

Dish Engine

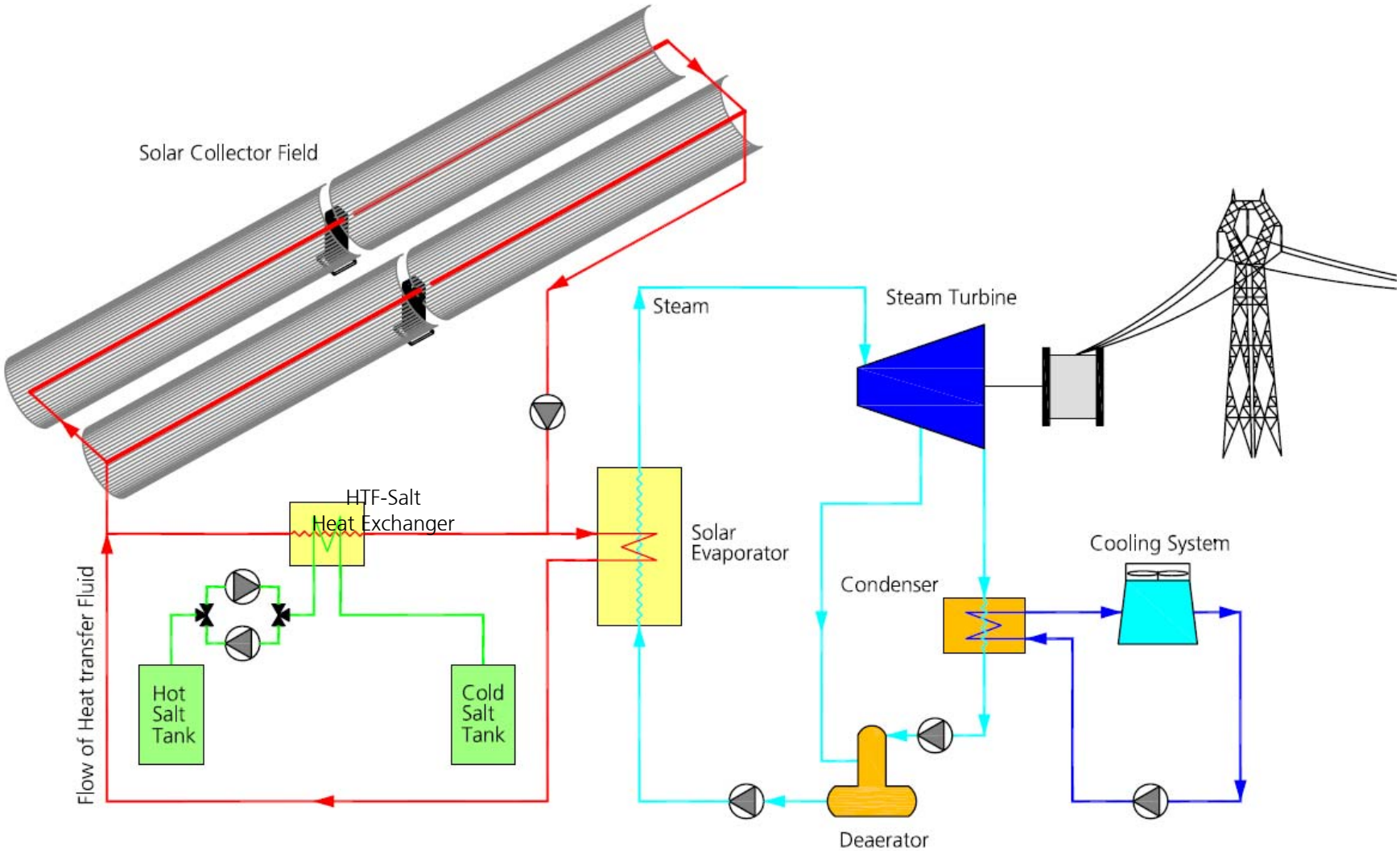
Concentrating PV

Trough Technology

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

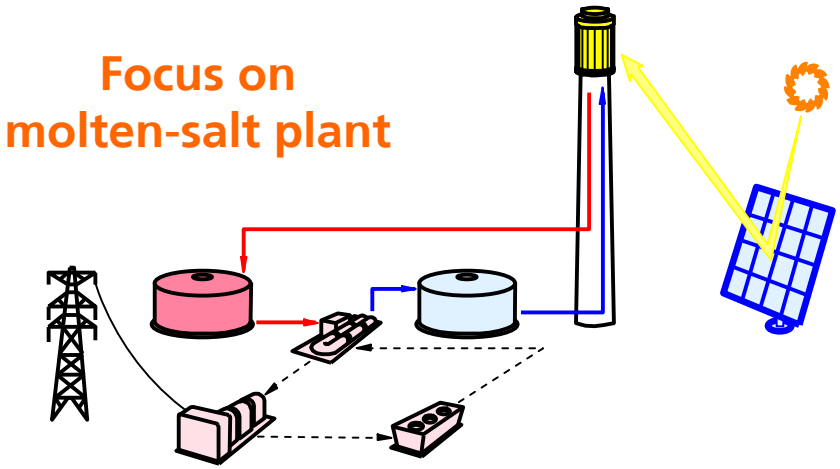


Flow Diagram

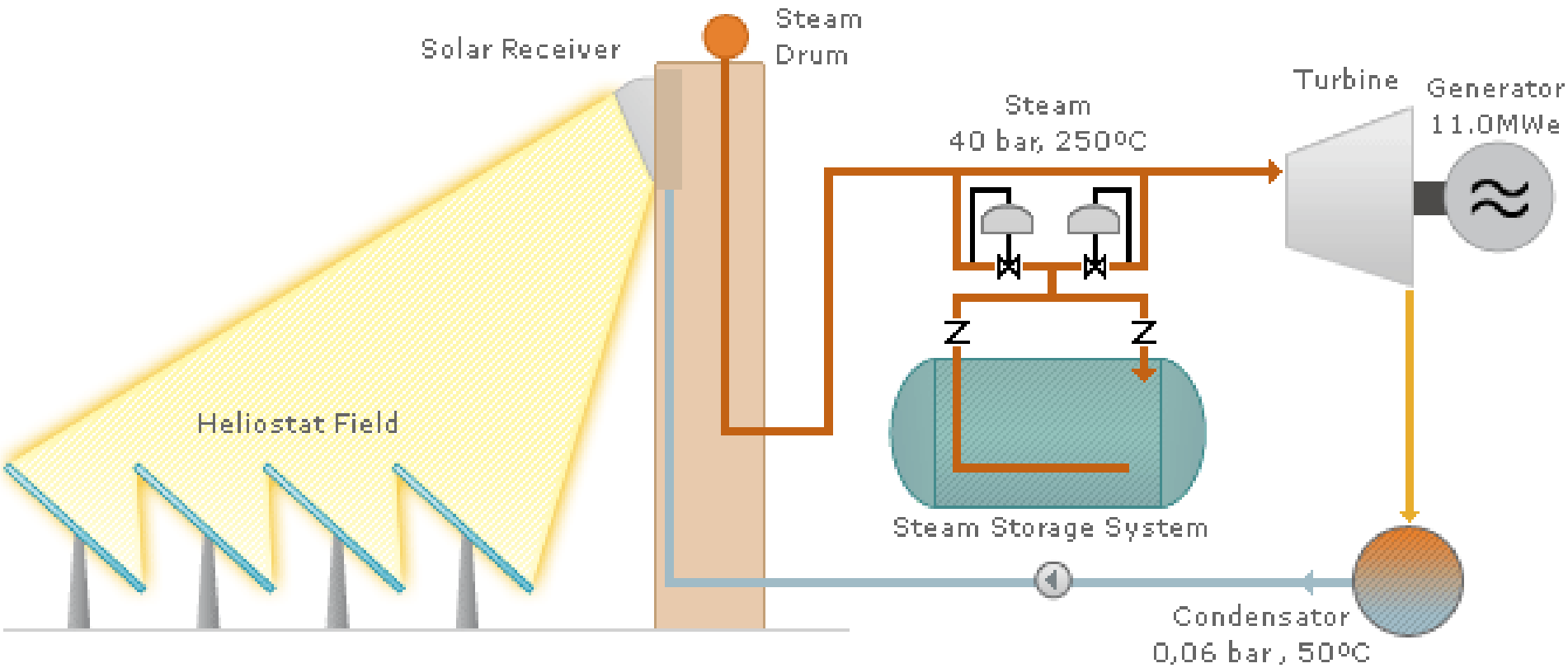


Power Tower Technology

- Heliostats (two-axis tracking)
- Steam, air or molten-salt receiver
- Steam, air or molten-salt working fluid
- Thermal storage
- Conventional steam- Rankine cycle power block, or combustion turbine

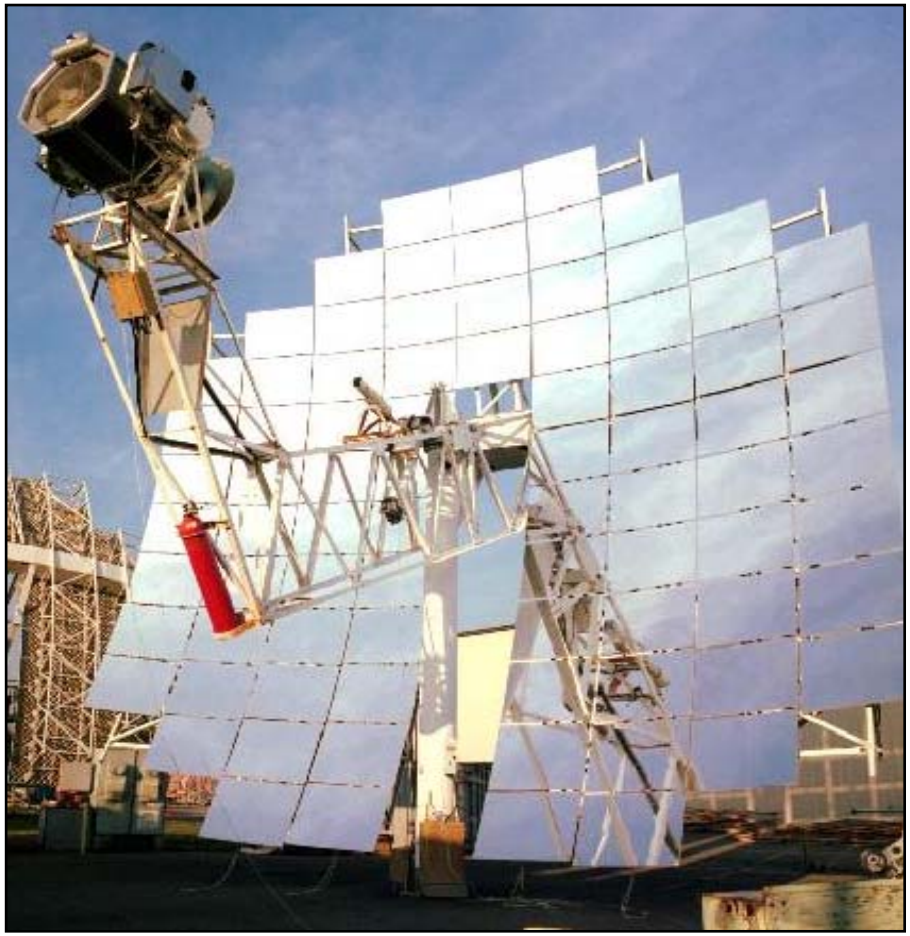


Power Tower Diagram



Dish Stirling Technology

- Dish (two-axis tracking)
- High efficiency
- 10 and 25 kW Stirling engines
- Does not need water cooling
- Distributed generation or bulk power



Why CSP and Why Now?

Why CSP and Why Now?

- **Necessity** – the utilities' other options (coal, nuclear or natural gas) have significant long term risks with cost implications
- **Uniqueness** of thermal energy storage
- Favorable but still unreliable **policies,** such as mandated targets plus incentives in the US or feed-in tariffs in other countries
- **Public opinion** favors solar

Awareness of CSP

- **Utilities** – Growing fast where good DNI and policies exist
- **Policy makers** – Generally lagging as evidenced by inadequate or unreliable policies in many countries
- **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

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

Additional Utility Attributes

- **Large, multi-national corporations are now involved in every part of chain**
  - Project and Technology Developers
  - Utilities and Independent Power Producers
  - Engineering and Construction Companies
- **Quality counterparties reduce project risk**
  - Large balance sheets
  - Power and construction expertise
  - Strategic technology deployment

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

Attributes of CSP in the Eyes of Investors

- **Scalable**
- With a good Power Purchase Agreement of Feed-in Tariff, 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 **very profitable** asset

Performance Aspects

Hybrid option

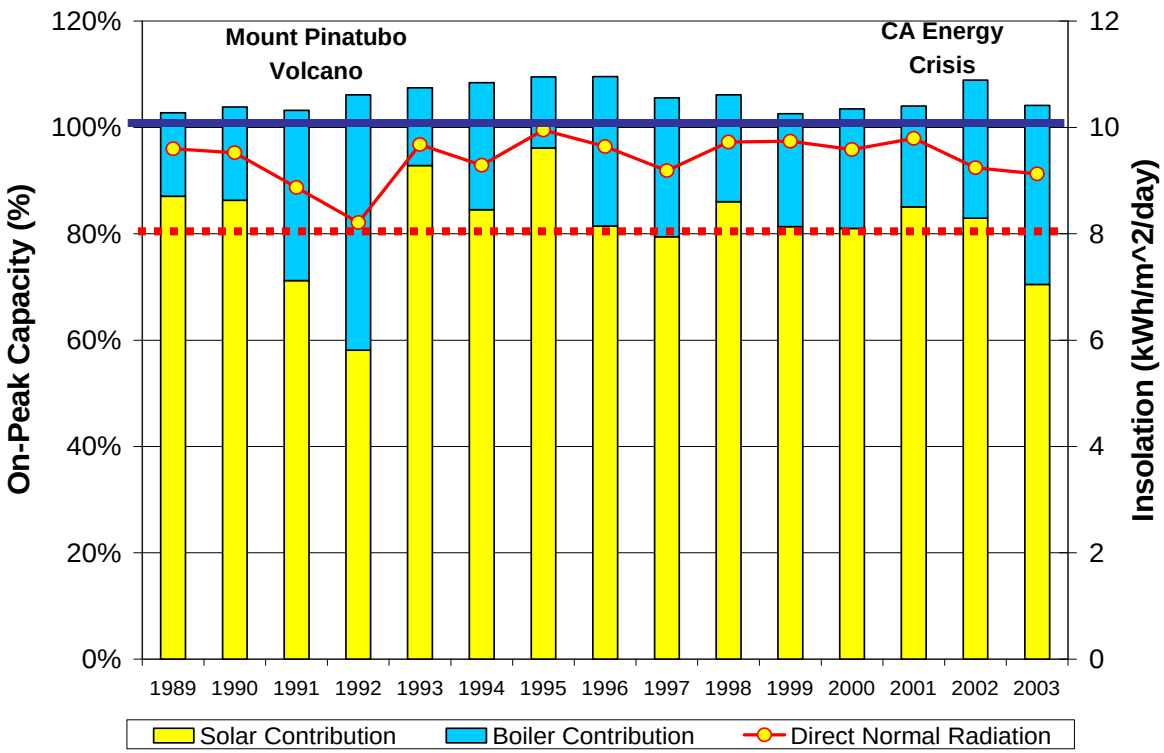
Peak Capacity Factor

Thermal Energy Storage

Land Requirements

Water or Air Cooling

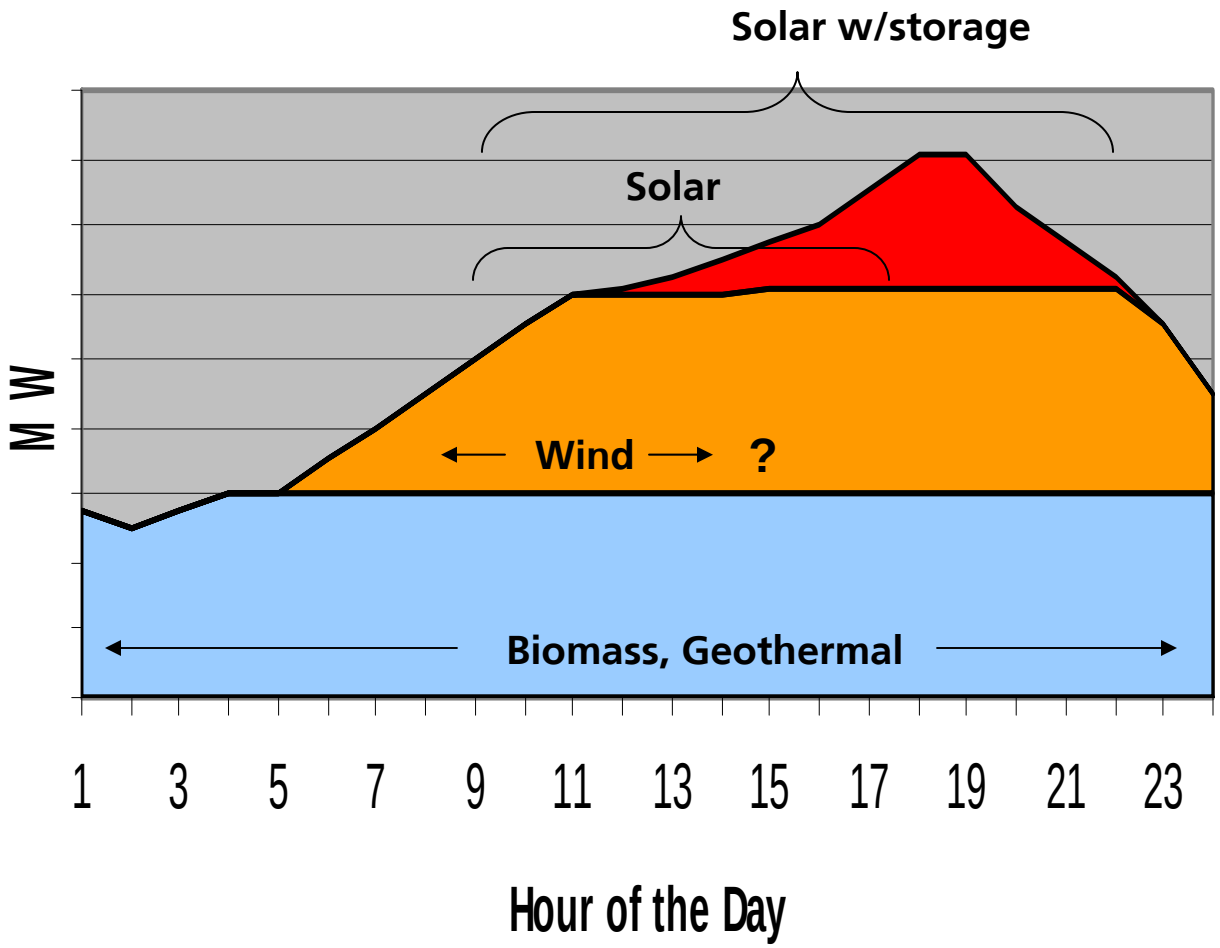
CSP is working in California



- 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.

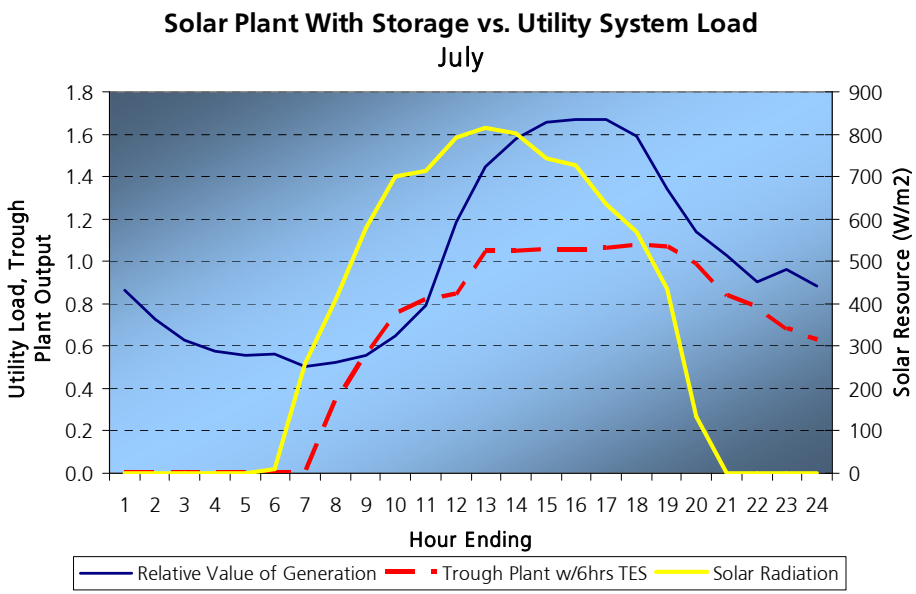
SCE Summer On-Peak
Weekdays: Jun - Sep
12 noon - 6 pm

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

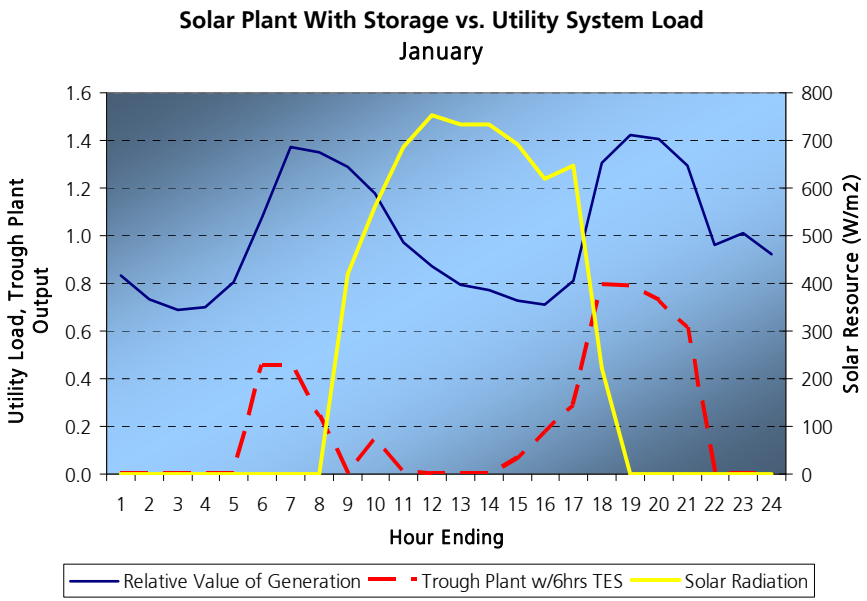


Generation from solar plant with storage can be shifted to match the utility system load profile

Summer



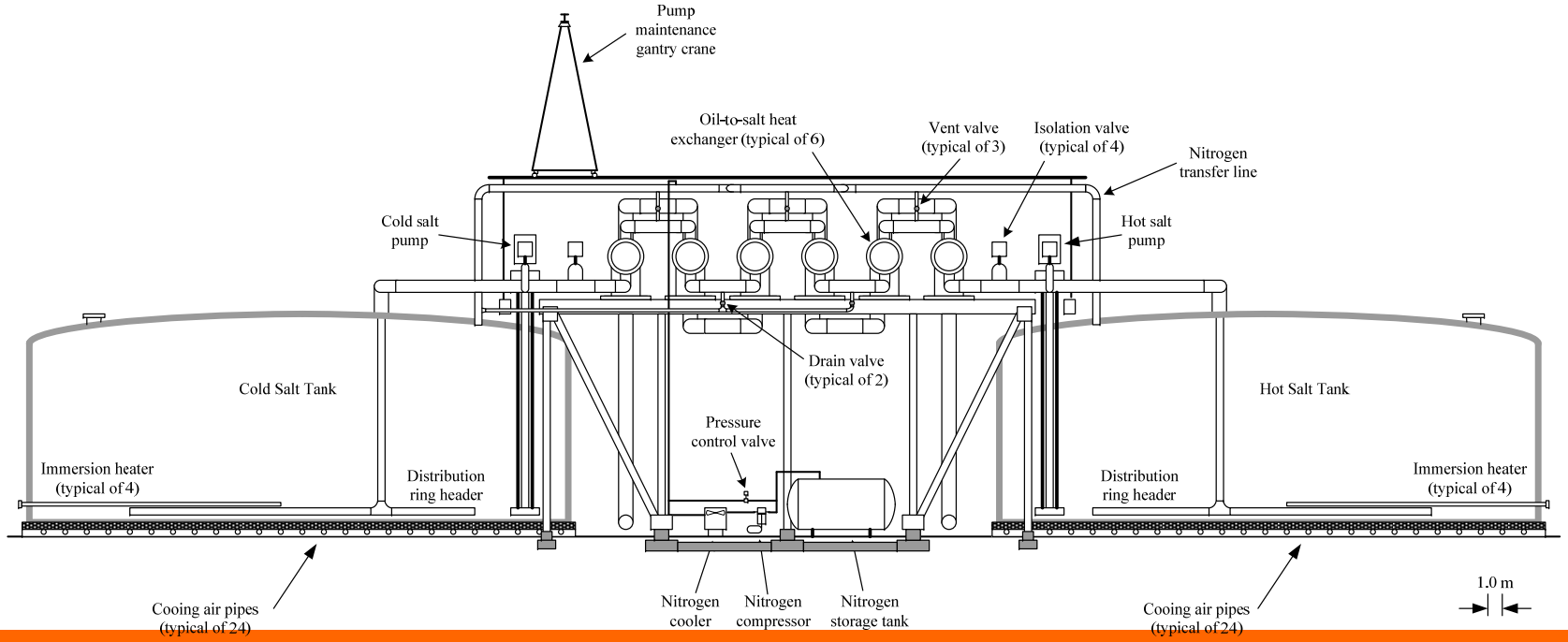
Winter



Key: - Solar
- Demand
- Generation

Thermal Energy Storage

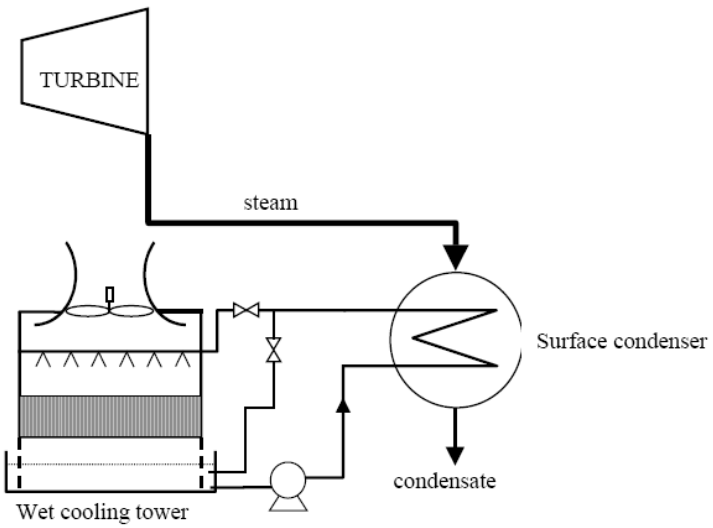
- Based on Solar Two molten-salt power tower experience
- Indirect 2-tank molten-salt design for parabolic trough plants
- Uses oil to salt heat exchangers to transfer energy to and from storage



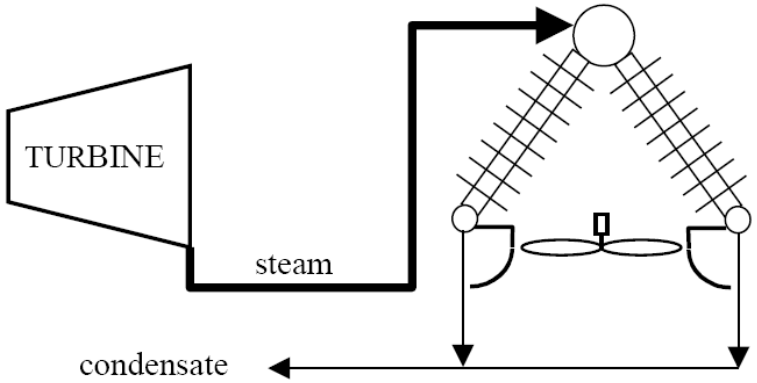
Land Usage

- CSP plants in good solar areas typically need about 5 acres per MW or about 1 sq mile 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 CSP technologies

Wet Vs. Dry Cooling Technology



Wet Cooling



Dry Cooling

Wet Vs. Dry Cooling Technology

Wet Cooling

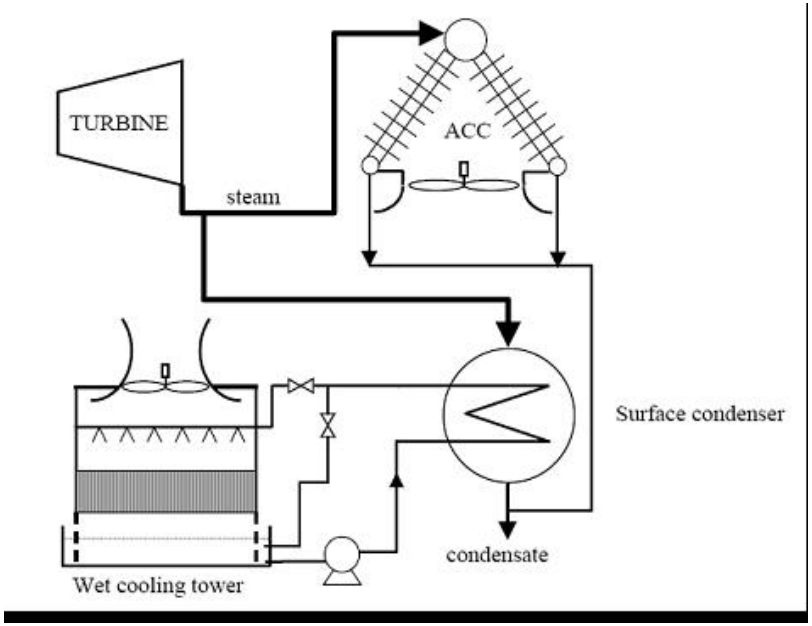
- Uses 3.5 m^3 water per MWh, same as fossil plants
  - ~90% for cooling
  - The rest for the steam cycle and washing

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%

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



CSP Projects

CSP Projects

- US has 430 MW in operation and 8,280 MW under signed contracts with utilities

CSP Business Estimated Activity in the US (January 2010)

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
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 1 & 3	PG&E	California		310 MW	Power Tower	2012 - 2013	BrightSource Energy
Solana	APS	Arizona		280 MW	Parabolic trough	2013	Abengoa Solar
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
Tonopah, NV	NVEnergy	Nevada		100 MW	Power tower	2013	SolarReserve
Rice, CA	PG&E	California		150 MW	Power tower	2013	SolarReserve
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
California	SDG&E	California		100 MW	Parabolic trough	Unspecified	Bethel Energy
California	SCE	California		100 MW [2]	Power tower	Unspecified	NRG / eSolar
(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	SCE	California		242 MW [2]	Parabolic trough	Unspecified	Solar Millennium
		Column Totals	430 MW	8,280 MW			
		U.S. Total	8,710 MW				

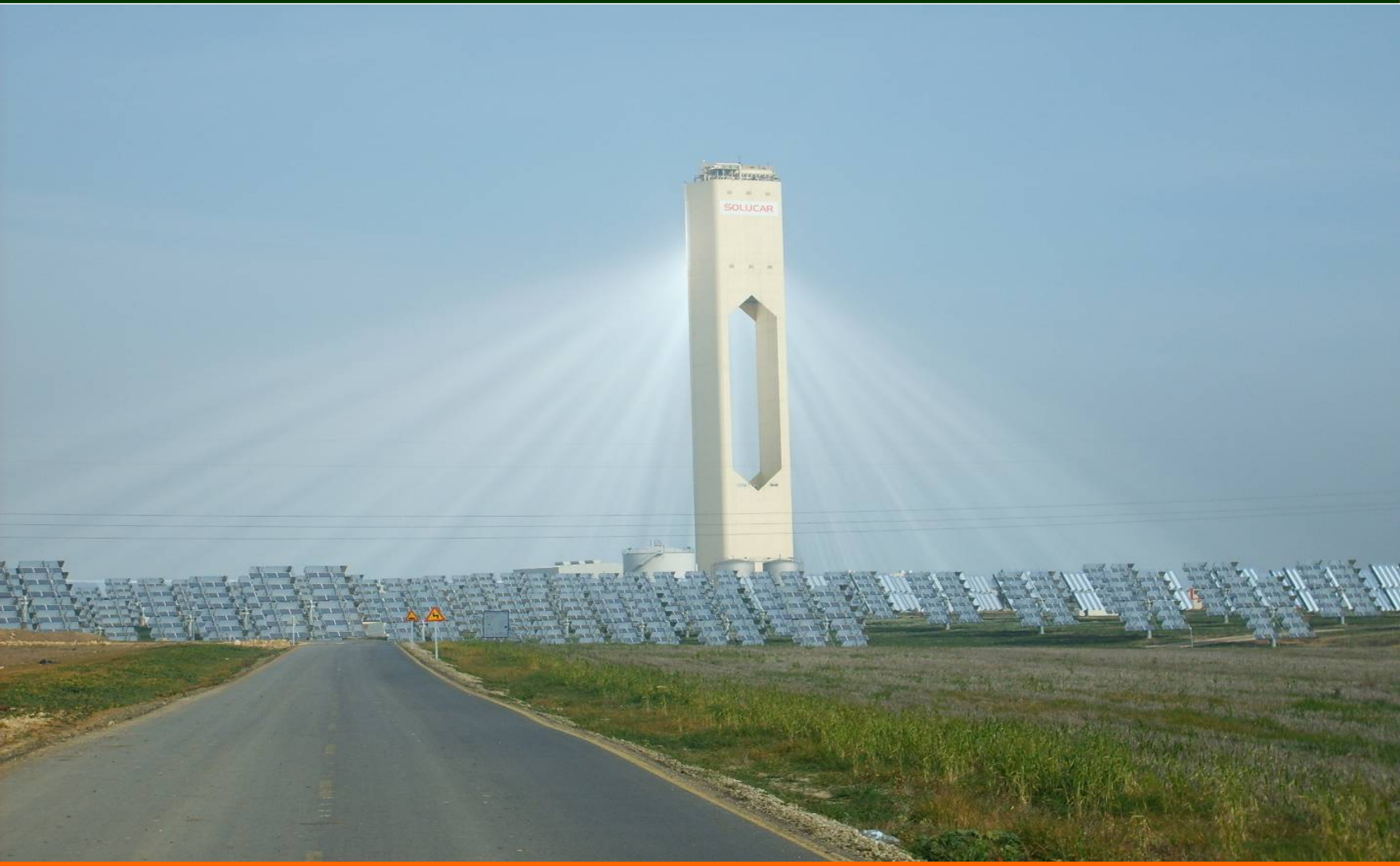
1 Agreement signed or award announced

2 Contractual expansion option

Solnova 1 and 3 as of December 2009

View of PS10 and PS20

PS10



PS10 Operating

PS10 Heliostats

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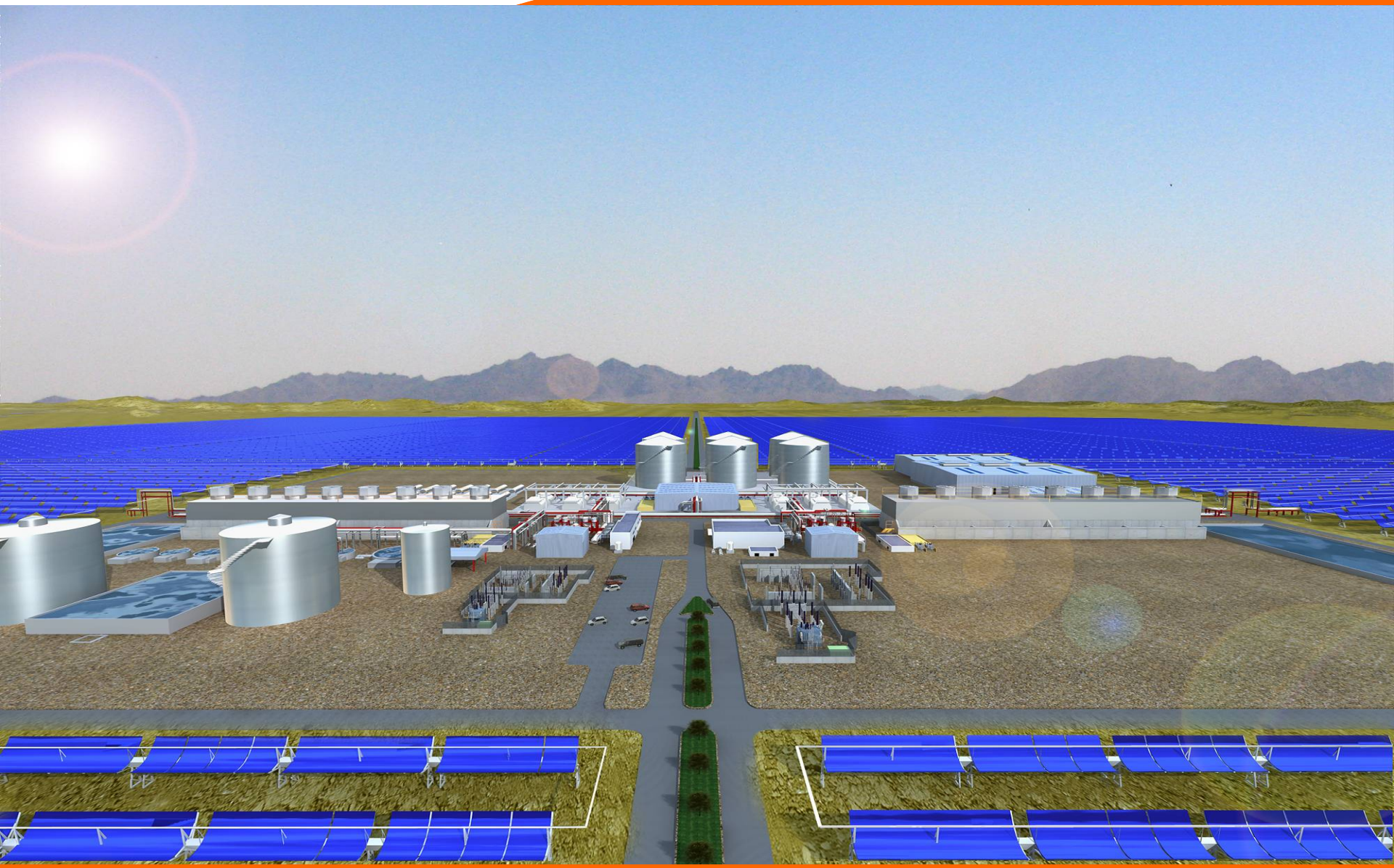
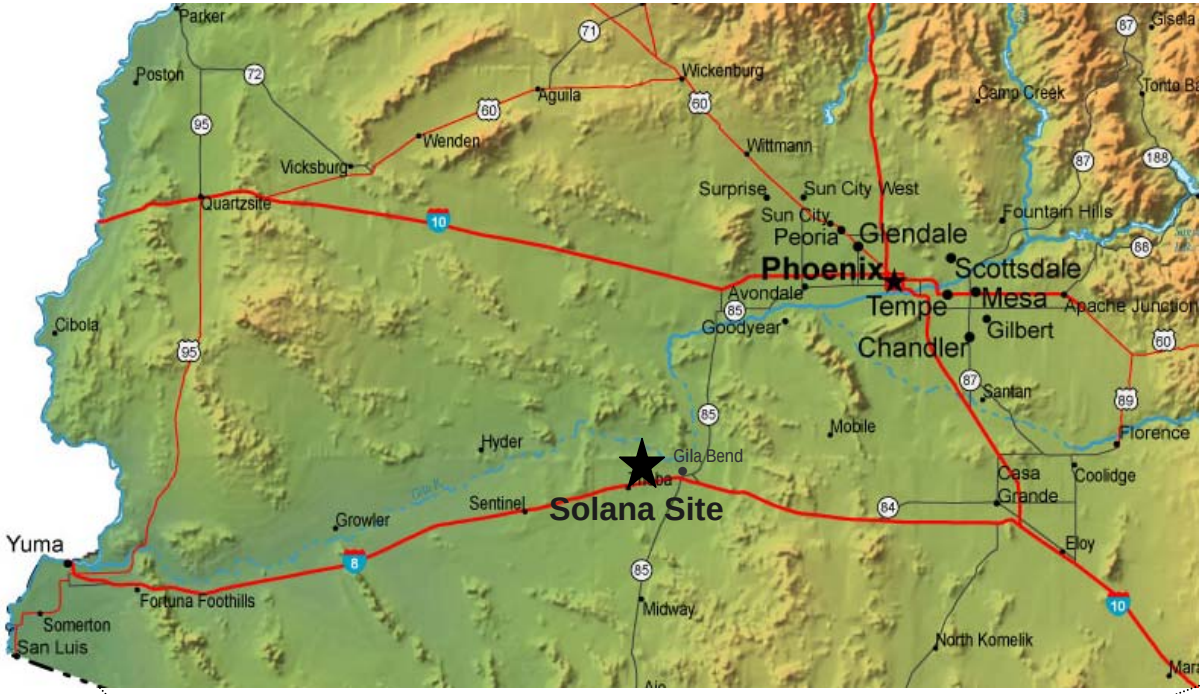
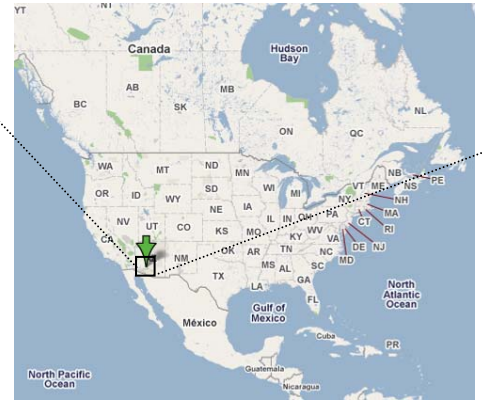


Site Location:

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

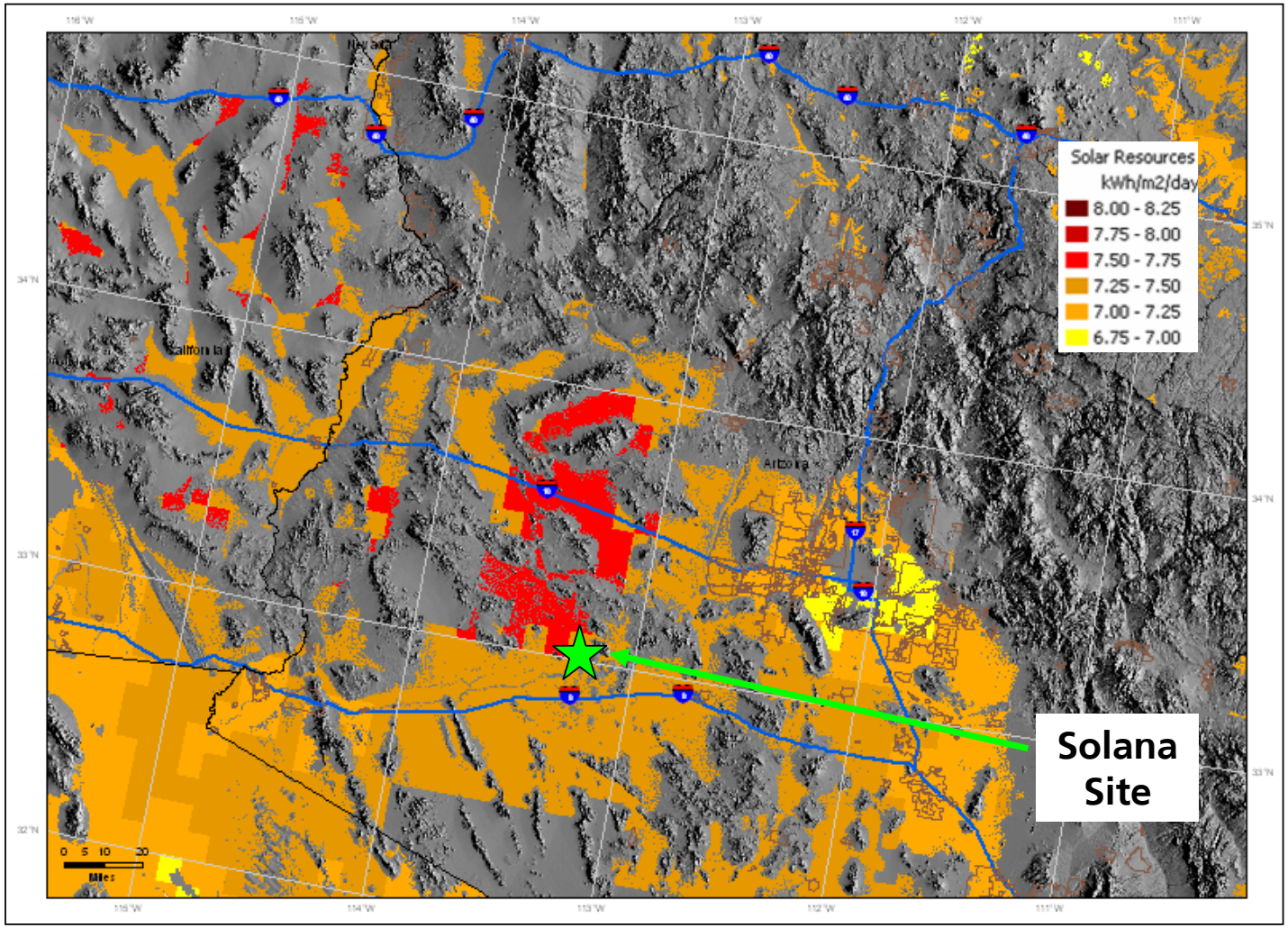




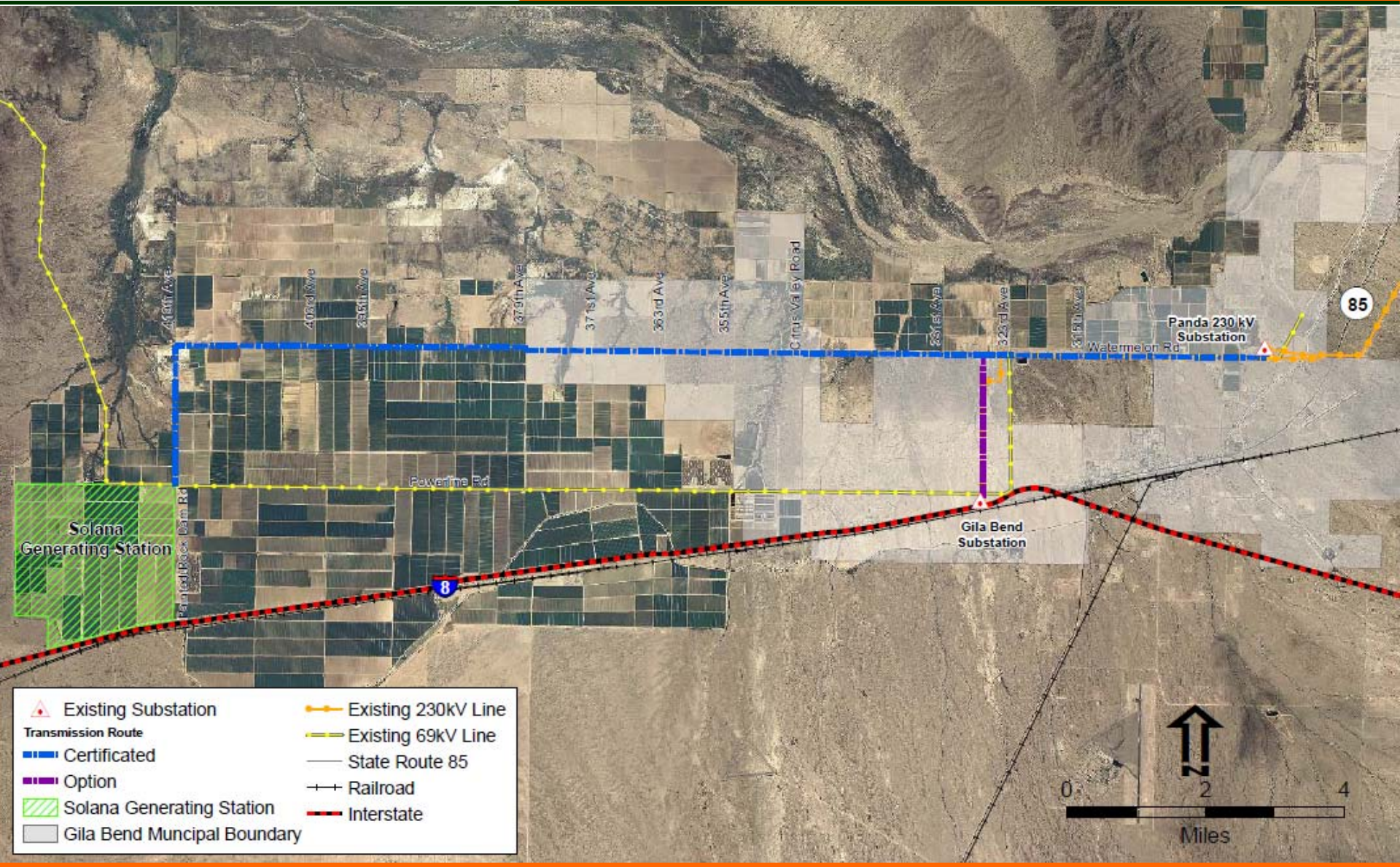
Map extent

Overview: Solana Site Selection

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



Previously disturbed Land



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

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

Cost and Benefits

The Cost of CSP

- There are many costs and they are must be carefully defined – nominal, real, constant dollars, first year, levelized and average
- The capital cost and the energy costs are most important to the market
- Both costs depend on many variables, all of which must be known (the EPC contractor and the investors must know what it is)
- Component and commodity costs change and that risk must be managed
- The market will find the energy cost and the value of CSP

A Narrowing Cost Gap (From Barbara Lockwood, APS)

CSP

✓Large Scale Projects
✓Global Uptake
✓Strong Developers
✓Incentives

➢Carbon Policy
➢Fuel Risk

✓Equipment and Labor Costs
✓Increasing Fuel Prices
✓Environmental

Traditional Resources

Economic Benefits

Using Solana (280 MW) as an example

- Jobs
  - 1,500-2,000 jobs during construction
  - 85-100 permanent jobs during operation
- Investment
  - Nearly $1 billion in direct investment
- Tax revenues
  - Between $300 and $400 million over 30 years
- Mirror factory
  - Additional 180 permanent jobs

Energy Benefits

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

Abengoa and Abengoa Solar

Abengoa is a technology and project development company applying innovative solutions for sustainable development in infrastructure, environment and energy sectors.

Mature	Founded 1941
Profitable	Sales in 2008 of $4.5 billion US
Focused	Innovative solutions for long term sustainability
Global	Present in more than 70 countries, 64% of business outside Spain
Large	Over 23,000 employees
Public	Quoted on the Madrid stock exchange (ABG)

Abengoa Business Units

Abengoa Solar	Abengoa Bioenergy	Befesa	Telvent	Abeinsa
Solar Energy	**Bioenergy**	**Environmental Services**	**Information Technologies**	**Industrial, Engineering and Construction**
• 42 MW in Operation • 400 MW under Construction • Hundreds of MW under Development in Spain • Solana and Mojave Solar Project (250 MW each)	• Largest Producer in Europe • Fifth Largest Producer in U.S. • One of the Largest Producers in Brazil	• International Leader in industrial waste treatment as well as in water management • Listed on Madrid Stock Exchange (Abengoa retains minority stake)	• International leader in IT for the energy, traffic, transport and environmental sectors • Will be an equipment provider for Solana and Mojave Solar Project • NASDAQ listed (Abengoa retains majority stake)	• EPC Contractor for other group companies • Abener is U.S. Subsidiary and EPC Contractor for Solana and Mojave Solar Project and U.S. Projects

Experienced Development Team

Abengoa Solar

- Develops …
- Builds …
- Operates …

Troughs and Towers

Parabolic Trough / Solar Tower Plants and Installations

Some Examples …

Solucar Platform: Solnova, Solar Tower Plants

(Spain)

Solnova

1, 3 & 4 (Construction)

2 & 5 (Development)

250 MW (Spain)

Helioenergy

1 y 2 (Construction)

100 MW (Spain)

PS10 & PS20

31 MW (Spain)

Solana & Mojave Solar Project

560 MW (U.S.)

ISCCs

150/480 MW (Algeria/ Morocco)

Steam and water heating installations

2.4 MW (U.S.)

Outlook for CSP

- The SW of the US has a large CSP **resource**
- CSP is an attractive **high-value** resource because of its fixed cost, hedging, dispatchable and local economic benefits
- CSP has **proven** performance and reliability and utility-scale
- The **cost** of CSP will continue to decline as a result of R&D, larger plants, global market growth and the associated learning curve effects
- CSP projects generally face the same financing, siting and transmission **challenges** as do other resources
- CSP projects require project finance and need access to long-term low-interest **debt**.
- In addition appropriate **permitting** and **transmission** access is required
- With suitable policies, CSP plants will be built in the rural parts of the SW creating **jobs** and stimulating the **local economies**.
- **Factories** to provide the needed components will be built across America adding to the jobs and economic development.

Contact Information

Fred Morse
Senior Advisor, US Operations
Abengoa Solar
and
Chairman, USP Division, SEIA

236 Massachusetts Avenue, NW, Suite 605
Washington, DC 20002
Tel: +1-202-543-6601
fred.morse@solar.abengoa.com