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Success and Challenges in Developing Large Scale PV in the US

Jim Torpey

November 1, 2011

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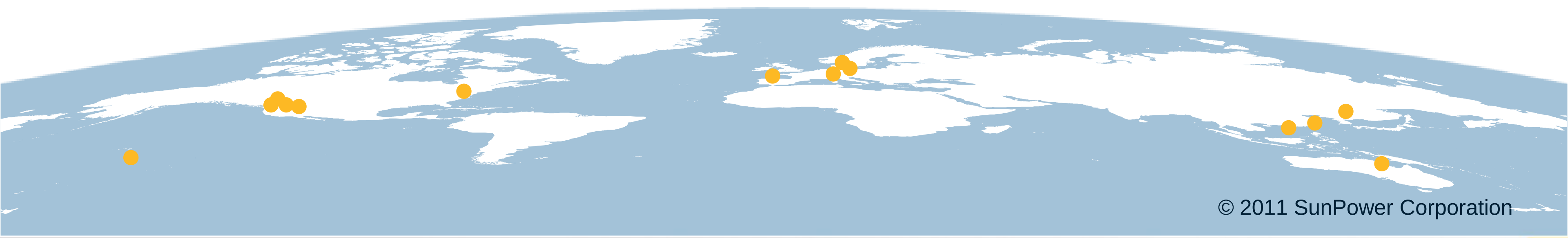
SunPower

- Founded 1985. Worldwide footprint.
- Has delivered cumulatively over 1.5 GW of PV
- Designed and installed over 650 turnkey systems totaling more than 450 MW
- Current production capacity of 600 MW will ramp to 1GW/yr by 2011
- Largest utility-scale projects in the US
- World record cell efficiency (23%)
- 5,500 employees. All we do is solar.
- Over 85 patents and publicly traded
- Over a quarter century of experience

Technology Leader. Proven Performance.



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SCALE OF U.S.A. SOLAR POWER PLANT DEVELOPMENT

Utility Scale Projects in the United States

- There are currently 582 MW (AC) capacity of utility scale solar projects operating in the US.
- Over 8520 MW (AC) of additional capacity are in development.
- Additional tens of thousands of capacity are in the pre-contract phase. In California alone, over 30 GW are in the transmission queue.
- This year alone, over 4 GW went into construction
- In total, over 9100 MW (AC) of capacity are either in development or operating in the US.

Source: GTM PV Tracker Report, October 2011

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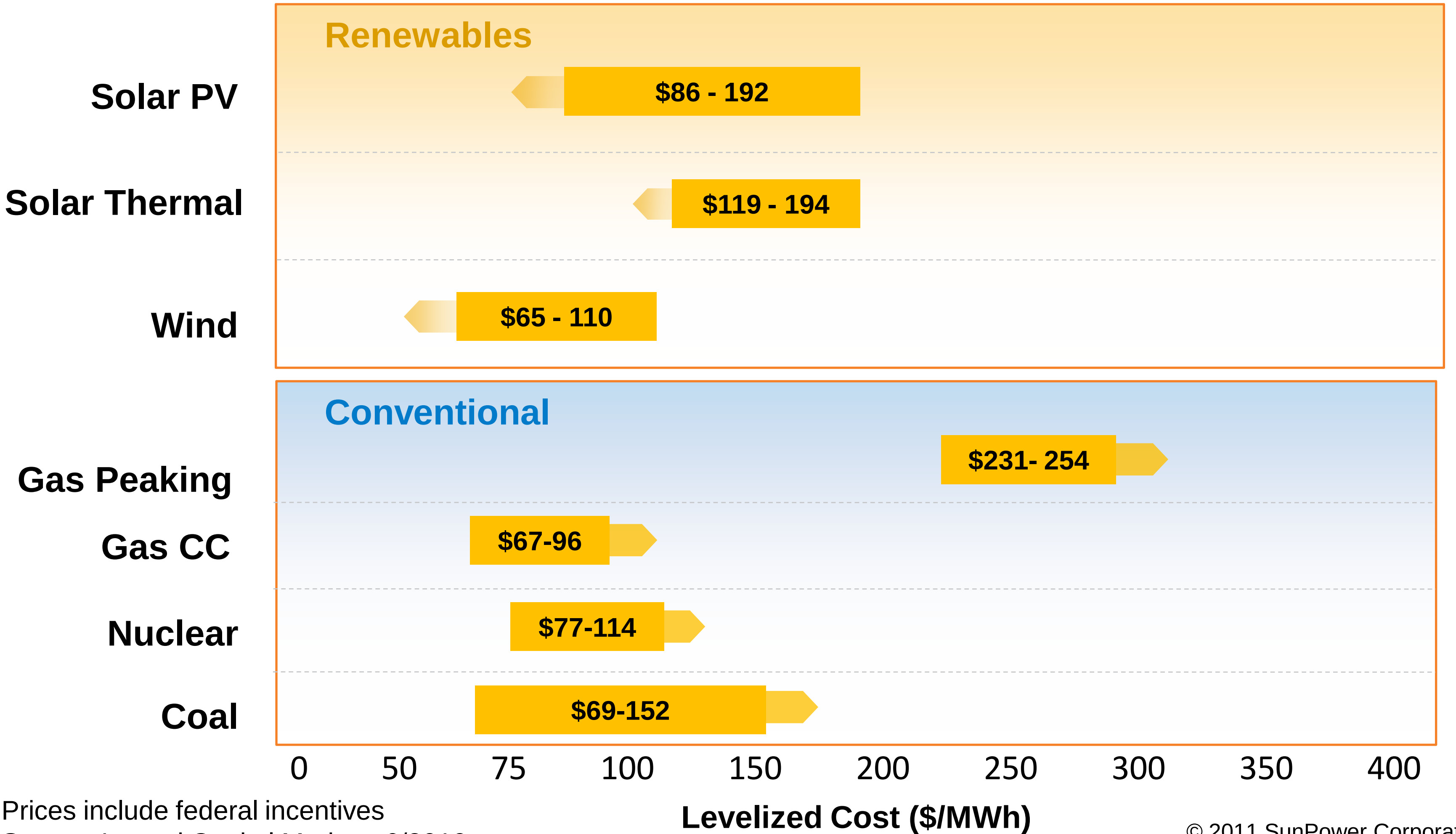
PRICE OF LARGE SCALE SOLAR POWER

How to Value a Solar Project: Levelized Cost of Electricity (LCOE)

1. Evaluates the life-cycle energy cost and life-cycle energy production
2. Accounts for the time value of money of all cash flows
3. Captures capital costs, ongoing system-related costs, fuel costs, and electricity production and converts them into a common metric: $/kWh

Solar PV Power Plants Are Cost Competitive

LCOE by Resource $/MWh: 2010 - 2013

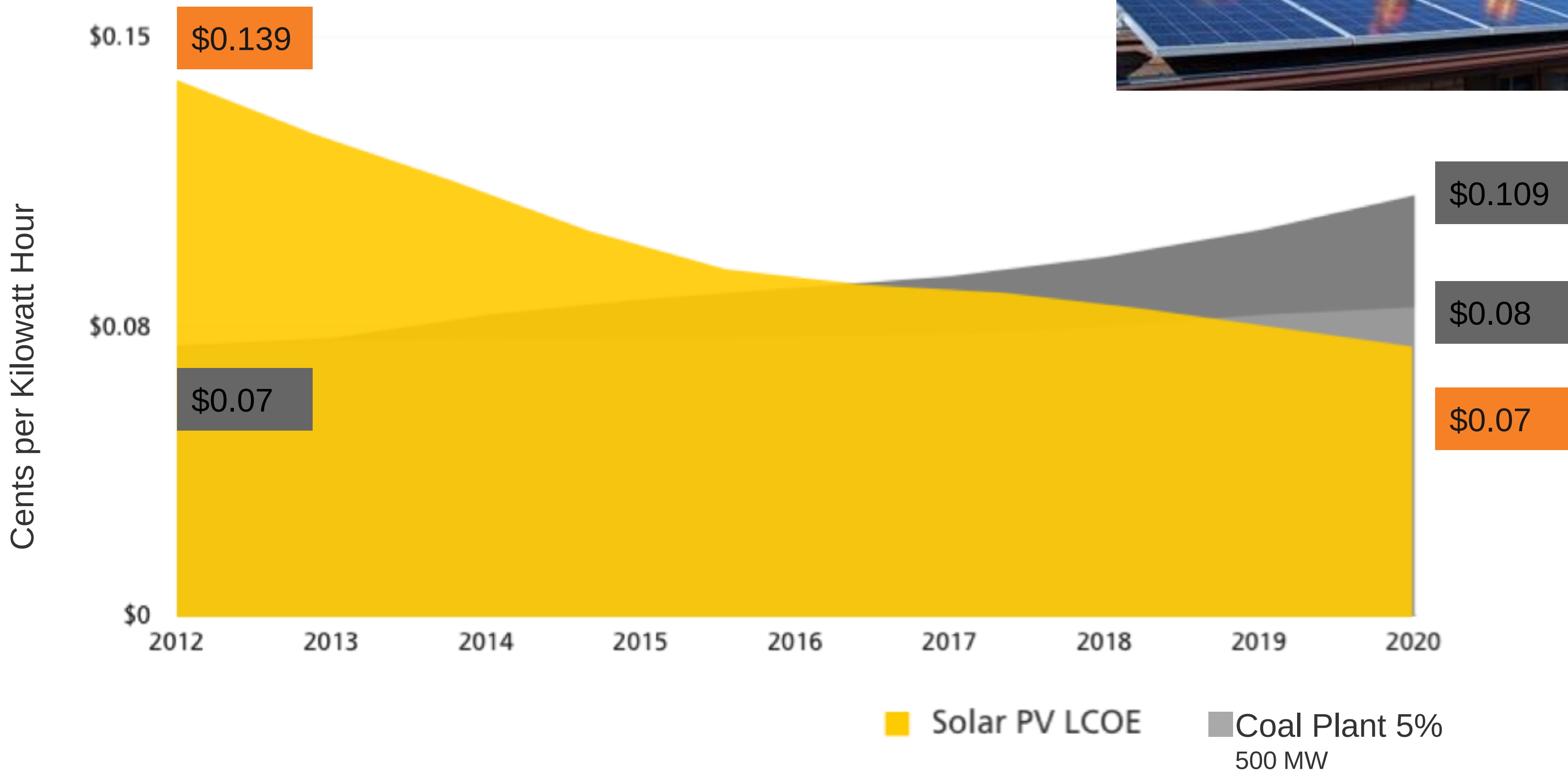


Prices include federal incentives
Source: Lazard Capital Markets 6/2010

PV Power Plant LCOE Drivers

- Capital cost dominated by PV, BOS, and land
  - PV costs driven down per experience curve and technology
  - BOS costs reduced by larger plant sizes, experience curve, modular deployment and higher panel efficiencies
  - Land development costs lowered by panel efficiency and scale
- Capacity factor increased with tracking systems
  - Tracking also delivers more energy during peak demand periods
- Cost of capital function of the perceived risk by investors
  - Proven technologies and performance lower cost of capital

New Coal Can't Deliver Power for 6-8 Years, When Solar Will Be Competitive

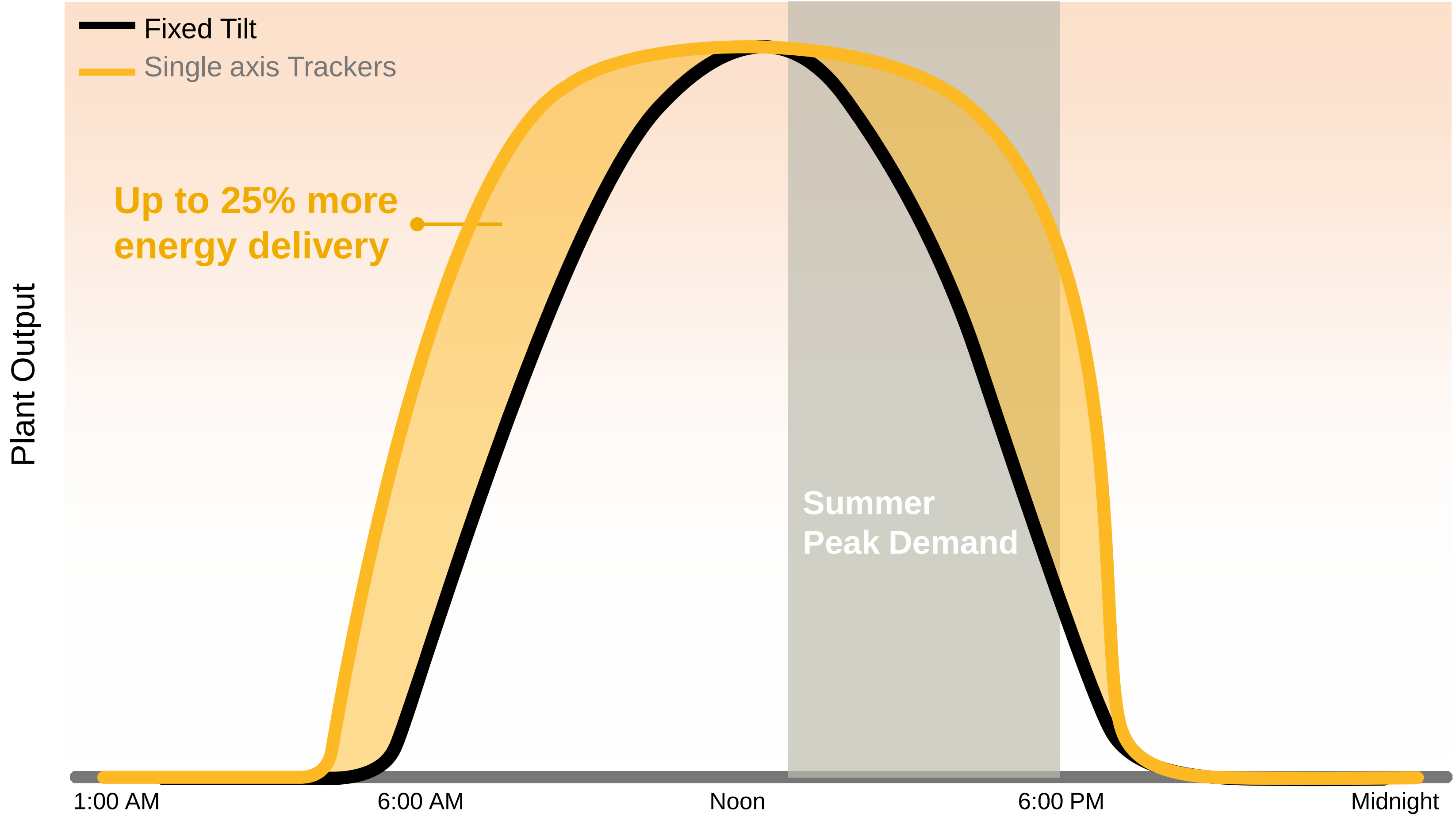


Source: 2011 coal price is the mid-point of the LCOE range given by Lazard, version 5.0. 2020 coal price is illustrative, calculated assuming 5% annual escalation. 2011 & 2016 PV Prices from [illegible] Research Projects Agency - Energy, $1/Watt Photovoltaic Systems, May 2011, 2020 PV price illustrative, assuming [illegible] (further validated by prices bid by solar developers into the [illegible]

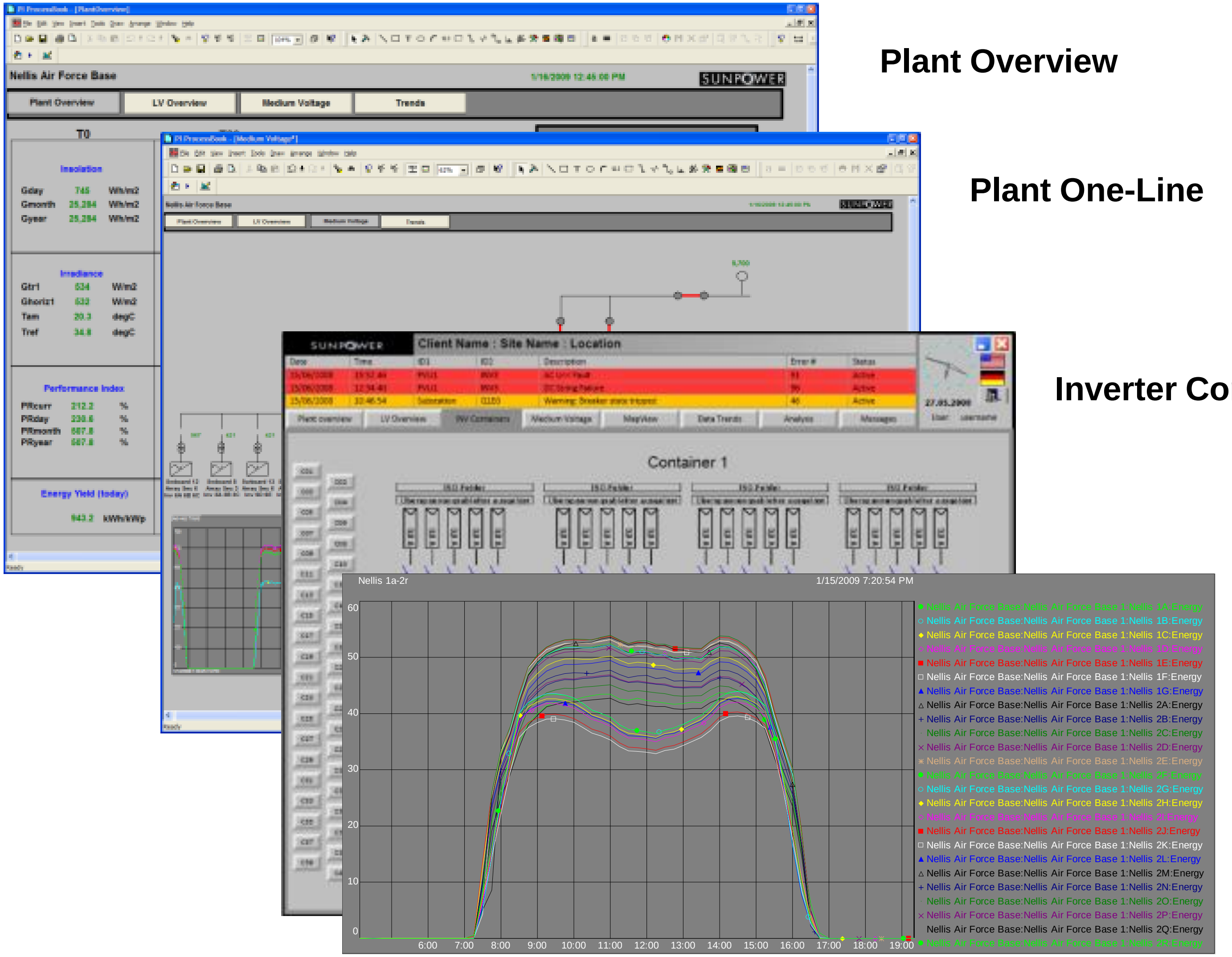
SOLAR POWER PLANT TECHNOLOGY DEVELOPMENT

Tracking the Sun Enhances Peak Production

Produces more energy during peak summer demand



Site Monitoring and SCADA Displays



Plant Overview

Plant One-Line

Inverter Control

Inverter Trends

Solar Plant Controller

- Standard SCADA system configured around the Oasis power block
- System with prepared standard reports and screens

Ride Through Capability	Does not trip during faults and other system disturbances
Ramp Rate Control	Limits rate of change of power from variations in sunshine
Frequency Droop	Reacts to changes in grid frequency
Startup and Shutdown Control	Controls the insertion and removal of large power blocks
Solar Reactive Power	Provides reactive power when needed

POWER PLANT PRODUCT EVOLUTION

2007 SINGLE AXIS TRACKERS

2012 CONCENTRATING PV (7X)

2010 PRE ASSEMBLED POWER BLOCKS (OASIS)

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DEVELOPING LARGE SCALE SOLAR POWER PLANTS

California Valley Solar Ranch: 315 MW DC

CALIFORNIA VALLEY
SOLAR RANCH

Project Site Plan

LEGEND

- Preserved Open Space
- Solar Arrays
- O + M Building
- PG&E Switchyard
- Substation

SPWR's California Valley Solar Ranch

- The California Valley Solar Ranch (CVSR) will be a 250 MW (AC) solar power plant in San Luis Obispo county, California.
- The plant began construction in early September, 2011 and received a federal loan guarantee of $1.2 billion on September 30, 2011. NRG Energy acquired the plant on the same day.
- The process, however, began long before the final loan guarantee was accepted…

CVSR: Timeline

Step in Development	Date
Began biological surveys on project	May 2008
Filed CUP application and CEQA process commenced	January 2009
Draft EIR prepared by County and Aspen Environmental Comments	August 24-November 1, 2010
County Workshop on DEIR held	September 22, 2010
Planning Commission Workshop	December 9, 2010
Final Environmental Impact Report published	January 2011
Six hearings resulted in unanimous approval By SLO County Planning Commission	February 2011

CVSR: Timeline

Step in Development	Date
Decision appealed to SLO County Board of Supervisors by four parties	
Appeal unanimously denied, CUP granted, and EIR certified by SLO County Board of Supervisors	April 2011
Litigation filed in State Superior Court against county	May 2011
US DOE final loan guarantee approval	September 30, 2011
NRG Energy acquisition of CVSR	September 30, 2011

Total litigation and permitting cost was at least $45 million

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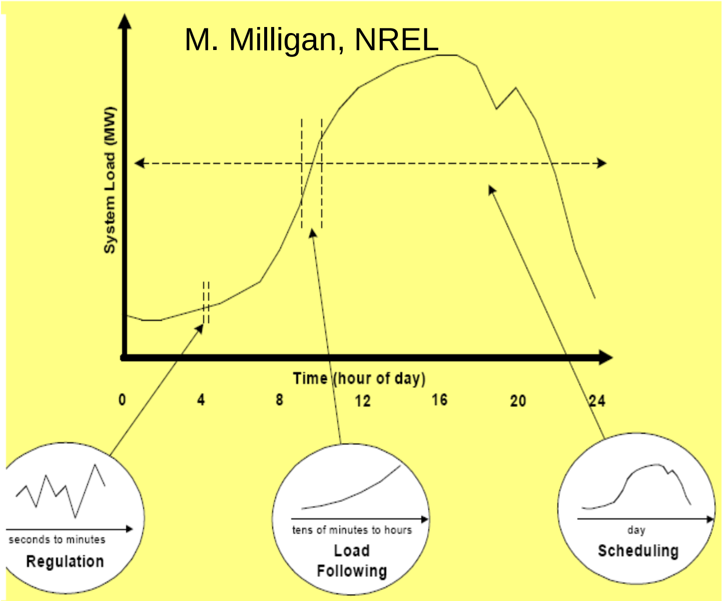
SOLAR POWER PLANT GRID INTEGRATION

Dealing with Solar Variability



Timeframe	System Impacts	Local Impacts
Short term Seconds to Minutes	Regulation	Voltage Fluctuation
Mid term 10's of Minutes to Hours	Load Following	Voltage Profile
Longer term Hours to Days	Scheduling	

Mitigation Of Local Voltage Impacts

- Geographical diversity has a substantial impact in mitigating variability over small distances, even within a distribution feeder.

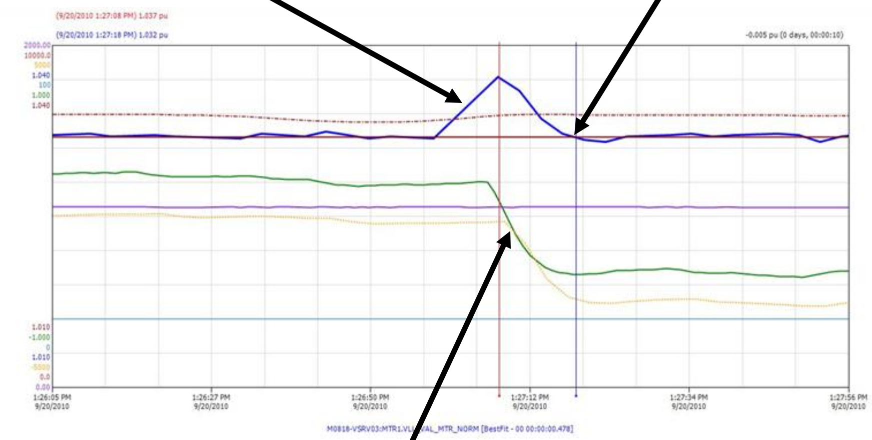
- Though uncommon, voltage fluctuations can result when a single, high penetration system is interconnected to a circuit with high impedance (such as a long rural feeder).

- Reactive power control can substantially reduce the impacts of output variability on voltage.

- Active voltage regulation (AVR) is particularly effective, if mitigation is needed.

(1) Spike in voltage at POI detected

(3) Voltage returns to setpoint



(2) SunPower smart controller commands reactive power change to reduce voltage

SunPower has pioneered the implementation of AVR in large-scale PV plants.

System Level Impacts Of Short Duration Variability

- System level impact is cost required to provide incremental frequency regulation due to added sub-10 minute variability from PV.

- PV integration cost per recent LBNL (Mills & Wiser) stud - comparable to wind, because

  - Geographical diversity substantially damps short duration fluctuations

  - Reserves can be scheduled based on deterministic "clear sky" envelope

- Regulation costs for wind (up to ~ 30% penetration) across multiple studies are generally very modest at <$1 / MWh.

Year	Study	Wind Capacity Penetration	Regulation
2003	Xcel-UWIG	3.5%	0
2003	We Energies	29%	1.02
2004	Xcel-MNDOC	15%	0.23
2005	PacifiCorp-2004	11%	0
2006	Calif. (multi-year)*	4%	0.45
2006	Xcel-PSCo	15%	0.20
2006	MN-MISO**	31%	-
2007	Puget Sound Energy	12%	-
2007	Arizona Pub. Service	15%	0.37
2007	Avista Utilities	30%	1.43
2007	Idaho Power	20%	-
2007	PacifiCorp-2007	18%	-
2008	Xcel-PSCo***	20%	-
2009	Bonneville (BPA)+	36%	0.22
2010	EWITS++	48%	-
2010	Nebraska+++	63%	-

Diurnal Variability Must Also Be Considered

- Daily solar cycle adds load following and unit commitment integration costs; bigger ramps.

- LBNL, NREL (EWIS / WWIS) and others find modest total integration cost up to ~30% energy penetration: typically less than $5 / MWh (for wind and solar).

- Forecast error dominates cost, PV forecasting is new, often assumed to be very inaccurate in integration studies (5-20% error)

- However 4-5% RMSE is achieved in practice for regional-level PV forecasts in Germany, comparable to best in class wind forecasting.

- Example: Spain at ~16% VER energy: 14% wind, 2% PV (3.4 GW), with limited interties but world-class operations. Peak of 54% of system demand served by wind.

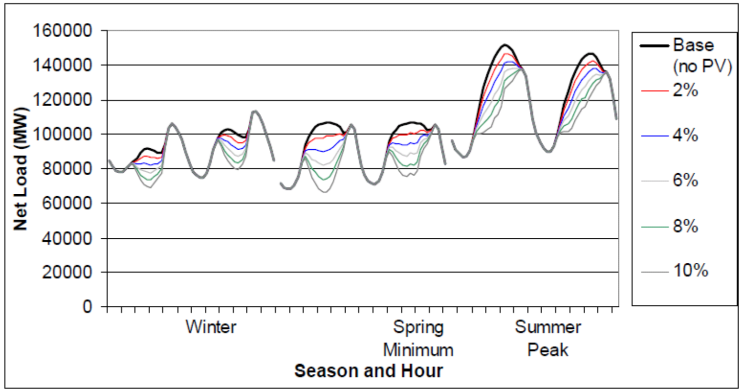


Figure 9. Load Shapes in WECC with Various PV Penetration Scenarios

Denholm *et al* 2008 (% system energy)

	MW	GWh
Biogas	279	2,078
Biomass	478	3,346
Geothermal	1,497	11,471
Hydro - Small	40	177
Solar PV	3,235	6,913
Solar Thermal	7,298	17,956
Wind	10,972	32,709
Total	**23,799**	**74,650**

CPUC 33% RPS Reference Case: ~25% energy from VERs ; 11% solar

Conclusions

- Geographical diversity substantially mitigates short duration variability.

- Local impacts of PV variability on the distribution system do not appear to be a significant issue in general, and can be managed with advanced controls if needed.

- Penetration of VERs up to ~20-30% of energy has been shown to be manageable, with current technology and generation mix, in multiple recent in-depth studies.

- Accurate forecasts; flexibility (flexible generation, energy storage, demand response); operation strategies; transmission; and changes to markets & policies will all reduce integration costs now and may be necessary to achieve VER penetrations beyond ~ 30% without excessive curtailment.

- The combination of storage and PV to provide added value to the customer appears promising. Technical and economic validation is in progress.

THANK YOU

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APPENDIX

Solar Market Context

- $1 trillion global electric power market
- Global power demand to roughly double by 2025
- Solar power market share today < 0.1%
- Policy driven by rate increases, security and environment
- Solar power within reach of mass-market cost-effectiveness

Australia can be managing to an incentive-free solar market.

SunPower Tracking Technology: Power Plants

Greater Sandhill, Mosca, Colorado
19 MW SunPower T20 Tracker

Muehlhausen, Bavaria, Germany,
6 MW SunPower T0 Tracker

Trujillo, Extremadura, Spain-Elecnor
23 MW SunPower T0 Tracker

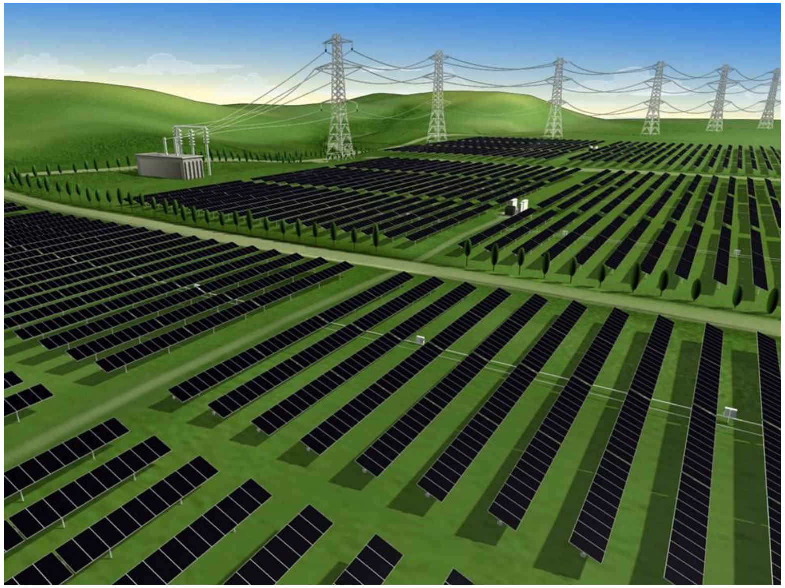
Montalto Di Castro, Lazio, Italy
24 MW SunPower T0 Tracker

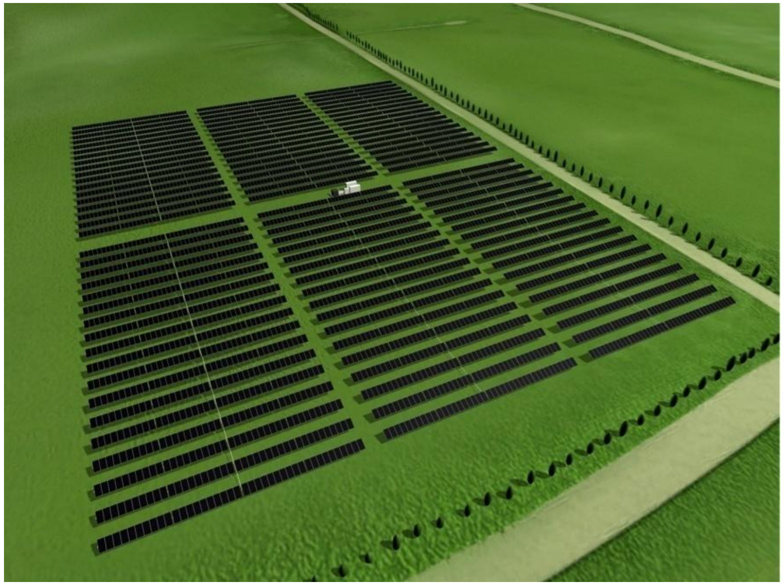
Exelon City Solar, Chicago, Illinois
10 MW SunPower T0 Tracker

DeSoto, Arcadia, Florida
25 MW SunPower T0 Tracker

SunPower Oasis Power Block

Quick Overview





1 **T0 Tracker with 425-Watt Panel**: 18.6% module efficiency coupled with optimized energy capture

2 **Smart Inverter**: features voltage ride-through, curtailment control and dynamic power factor adjustment

3 **Standard DC Electrical**: pre-manufactured electrical system minimizes cost and maximizes reliability

4 **TMAC**: advanced tracker controls maximize energy production and enable efficient operation and maintenance

Local Impacts Of Short Duration Variability

Concerns about flicker and voltage regulation are often expressed, **but have not been reported as issues** in numerous high penetration circuits being studied:

Location	Description	Penetration	Notes
Ota City, Japan (2003)	550 Sites / 2 MW residential, one circuit	Not Reported	Residential energy storage evaluated and removed; no issues reported post-removal.
Freiburg, Germany (2006)	70 Sites / 440 kW multi-unit residential	110% on capacity (400 kVA XFR)	Minimal, correctable issues reported (phase imbalance)
Kona, HI (2009)	700 kWac commercial	35% on capacity (2 MVA feeder), backfeed up to 30% in low load	No issues reported
Lanai, HI (2009)	600 kWac commercial (1.2 MW system, brought online incrementally)	~12% on capacity, ~25% in low load, weak island system	No issues reported.
Anatolia, CA (2009)	115 Sites / 238 kW residential	4% on capacity, 11-13% low load	No issues reported, PV variability less than AC cycling variability.
Las Vegas, NV (2008)	> 10 MW commercial, 35 kV interconnection	~ 50% on capacity, ~100% low load	No issues reported
Atlantic City, NJ (2009)	1.9 MW commercial, 23 kV interconnection	~24% on capacity, ~63% low load	No issues reported

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