

# Solar Valuation in Utility Planning Studies

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**Environmental Energy Technologies Division**



# Research questions

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1. How does the economic value of additional variable generation change with increasing penetration levels?
2. How do utilities account for the economic value of solar in their planning studies and in making procurement decisions?

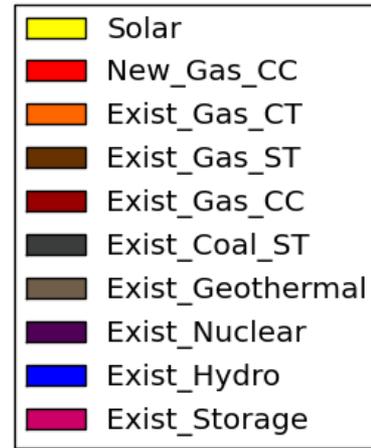
# Analysis framework and approach

- **Developed a long-run investment model that chooses what generation to build and how to dispatch that generation for each different assumed penetration of variable generation**
  - Uses a full year of hourly load and variable generation data
  - Accounts for wind and solar uncertainty through generation commitment based on imperfect day-ahead forecasts
  - Accounts for increased ancillary service requirements through AS targets that change with penetration of wind and solar
  - Includes standard conventional generation constraints such as part-load inefficiency, minimum generation limits, ramp-rate limits, and start-up costs
- **Analysis uses hourly day-ahead and real-time energy and ancillary service prices from this model to calculate the long-run value of an additional increment of variable generation**

# Primary caveats

- **Postulates certain penetrations of renewable energy**
  - Does not seek to “optimize” overall cost / design of electric system
- **Narrow definition of economic value:**
  - Avoided capital investment cost and variable fuel and O&M costs from other power plants in CA
  - Does not consider cost of renewable energy or transmission needs
- **Focus on California without evaluation of transmission:**
  - Renewable electricity only used to meet CA demand
  - Incumbent generation only includes generation in CA NERC region
- **Marginal economic value instead of average value:**
  - Only indicates value of next increment of VG
- **Simplified commitment and dispatch decisions:**
  - Vintages rather than individual unit commitment

# Investment and dispatch decisions with increasing PV penetration



PV Penetration	Incremental Reduction in Non-PV Capacity (GW)	Incremental Increase in Nameplate PV (GW)	Effective Marginal Capacity Credit (%)
0% -> 5%	2.8	5.8	48%
15% -> 20%	0.4	5.9	7%

# Decomposition of marginal economic value into additive components

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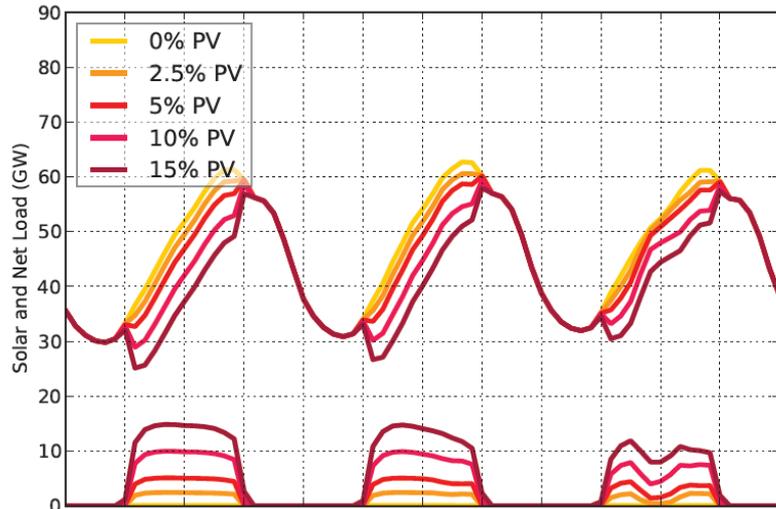
- **Capacity value (\$/MWh):**
  - Portion of short-run profit earned during hours with scarcity prices (defined to be greater than \$500/MWh)
- **Energy value (\$/MWh):**
  - Portion of short-run profit earned in hours without scarcity prices if DA forecast exactly matches RT generation
- **DA Forecast Error Cost (\$/MWh):**
  - The net earnings from RT deviations from the DA schedule
- **Ancillary Services Cost (\$/MWh):**
  - The net earnings from selling AS and/or paying for increased AS in the case of variable generation

# Marginal value of PV is high at low penetration due to high capacity value

Component (\$/MWh)	0% PV	2.5% PV	5% PV	10% PV	15% PV	20% PV	30% PV
+ Capacity Value (Capacity Value in \$/kW-yr)	+37 (120)	+34 (110)	+27 (82)	+13 (39)	+8 (24)	+4 (11)	+1 (4)
+ Energy Value	+54	+53	+52	+49	+45	+41	+27
+ DA Forecast Error	-0.4	-5	-4	-6	-5	-4	-3
+ Ancillary Services	-0.9	-0.8	-0.7	-0.4	-0.2	-0.1	-0.0
= Marginal Economic Value	90	81	73	55	47	41	25

Single-axis PV and CSP without TES have similar relative magnitude of different components and similar changes in value of components with increasing penetration.

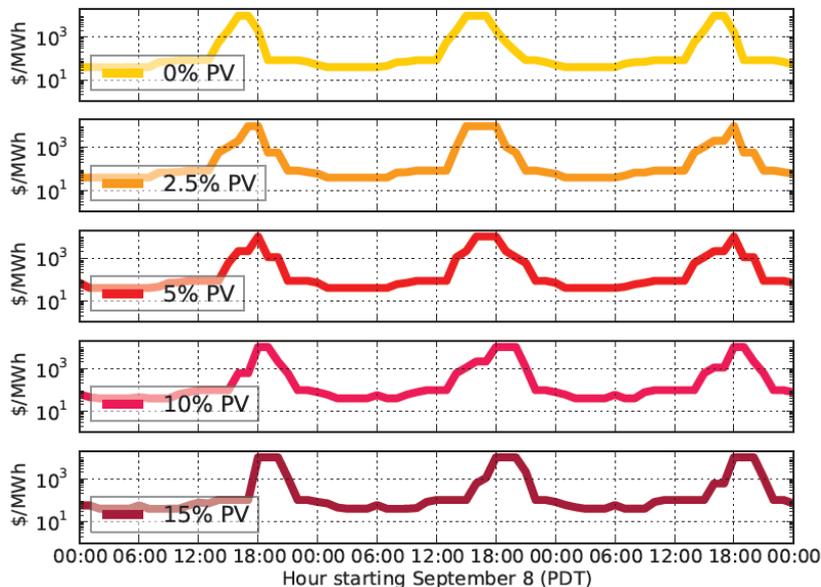
# Times with high net load and high prices shift to early evening with increasing PV



Highest load hours occur in late afternoon.

With high PV penetration, highest net-load hours occur in the early evening.

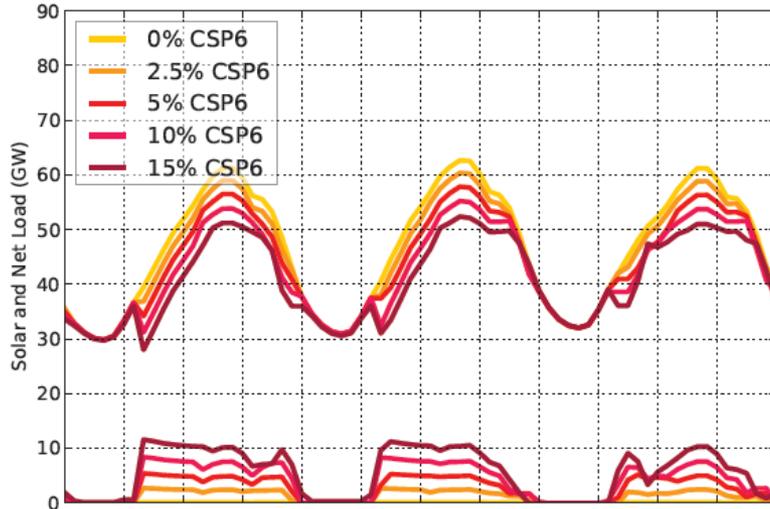
PV does not generate in early evening hours



High price periods shift from times with **high load** to times with **high net-load**

Contribution of high price hours to marginal economic value of PV declines with high PV penetration

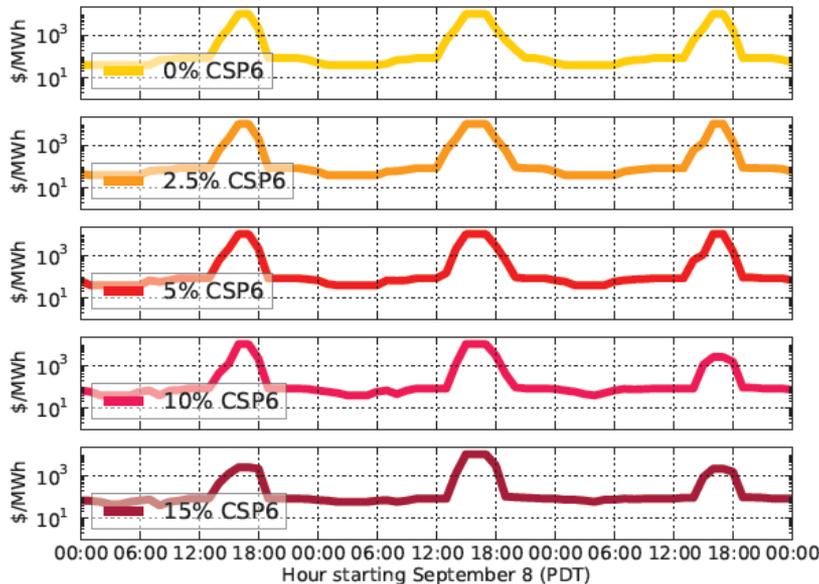
# Times with high net load remain similar with modest penetration of CSP6



Highest load hours occur in late afternoon.

With CSP<sub>6</sub>, highest net-load hours remain in the late afternoon.

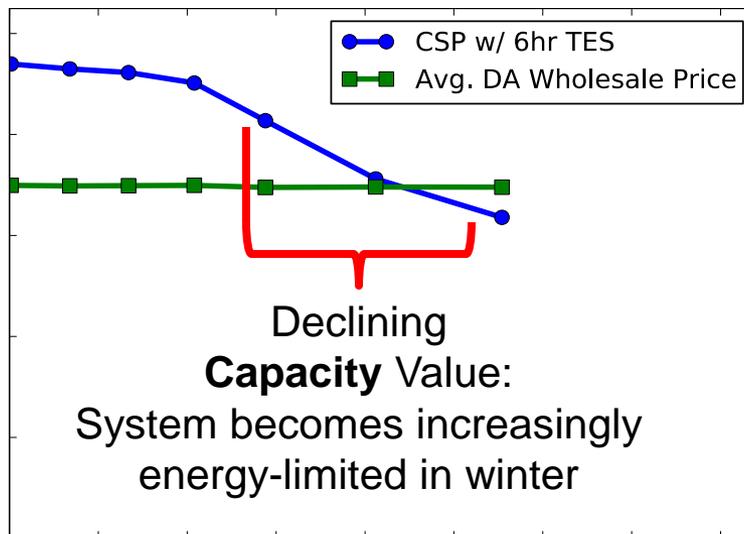
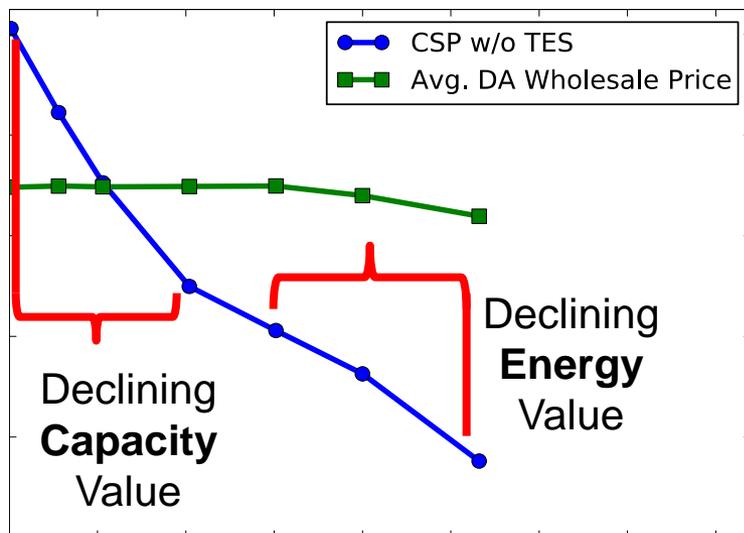
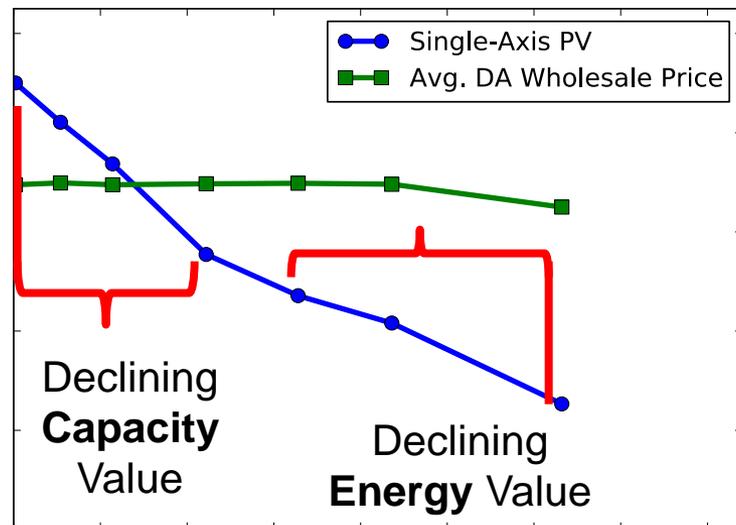
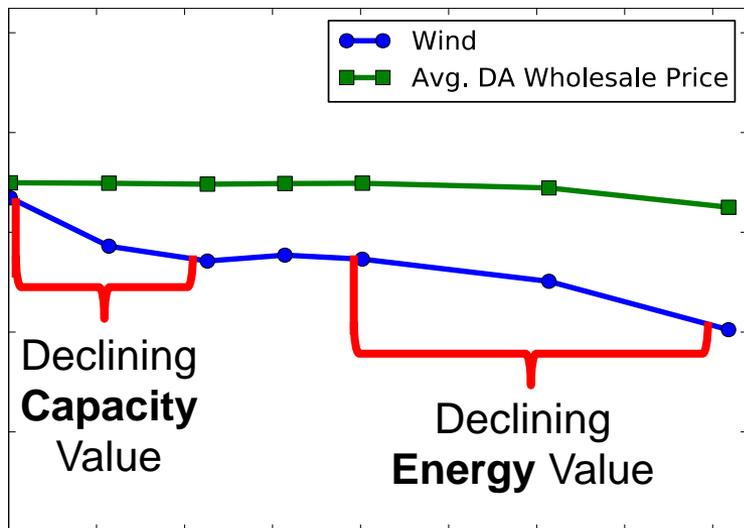
CSP<sub>6</sub> extracts energy from thermal storage starting in the early evening.



High price periods remain in the late afternoon even with increasing CSP<sub>6</sub> penetration

Contribution of high price hours to marginal economic value of CSP<sub>6</sub> remains relatively high even at 15% penetration

# Marginal value of variable generation varies with technology and penetration



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Do utilities capture these same drivers of the value of solar?

# REVIEW OF UTILITY PLANNING STUDIES

# Approach

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- **Review 16 planning studies and nine documents describing procurement processes**
- **All created during 2008–2012 by LSEs interested in solar power**
- **Identify how current practices reflect the drivers of solar's economic value with a focus on:**
  - Treatment of the capacity value, energy value, and integration costs of solar energy
  - Treatment of other factors including the risk reduction value of solar and impacts to T&D
  - Methods used to design candidate portfolios of resources for evaluation within the studies
  - Approaches used to evaluate the economic attractiveness of bids during procurement

# Studies included in sample

<b>Load-serving entity or study author</b>	<b>Planning study (year)</b>	<b>Procurement practices (year)</b>
Arizona Public Service	2012	2011
California IOU Process	2010	2011
Duke Energy Carolinas	2011	-
El Paso Electric	2012	2011
Idaho Power	2011	-
Imperial Irrigation District	2010	-
Los Angeles Department of Water and Power	2011	2012
Northwest Power and Conservation Council	2010	-
NV Energy	2012	2010
PacifiCorp	2011	2010
Portland General Electric	2009	2012
Public Service of Colorado	2011	2011
Public Service of New Mexico	2011	2011
Salt River Project	2010	-
Tri-State Generation and Transmission	2010	-
Tucson Electric Power	2012	-

Sample primarily includes LSEs in the western United States that are considering solar power, among other options

# General planning process adopted by many LSEs followed similar pattern

Steps 2 and 3 are the most important for capturing the economic value of solar, and are largely the focus of this review

**1:** Assessment of future needs and resources

**2:** Creation of feasible candidate portfolios that satisfy needs

**3:** Evaluation of candidate portfolio costs and impacts

**4:** Selection of preferred portfolio

**5:** Procurement of resources identified in preferred portfolio

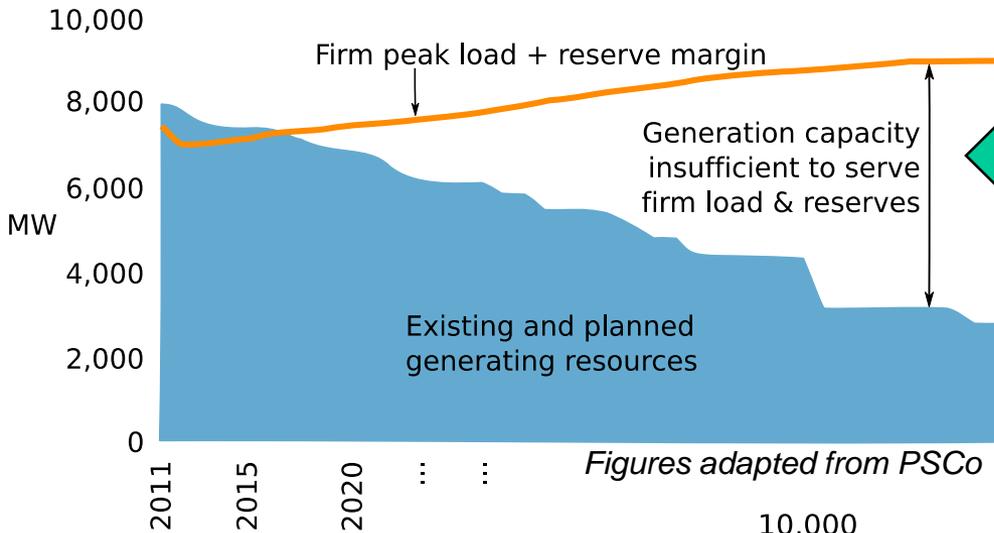
*Not all LSEs exactly followed these steps: depending on the plan, some steps were not included, multiple steps were bundled into one step, or the order of steps did not follow this same pattern*

# Solar technologies included in assessment of potential future resources

Solar technology category	Variation	Integrated thermal storage	Natural gas firing in boiler
Photovoltaic	Fixed	N/A	N/A
	Single-axis tracking	N/A	N/A
	With lead acid battery	N/A	N/A
Concentrating solar power	Parabolic trough	None	No
	Parabolic trough	None	Yes
	Parabolic trough	3 hours	No
	Parabolic trough	6-8 hours	No
	Solar power tower	7 hours	No
	Solar chimney (or solar updraft tower)	None	No
Solar thermal gas hybrid plants (or integrated solar combined cycle, ISCC)		N/A	N/A

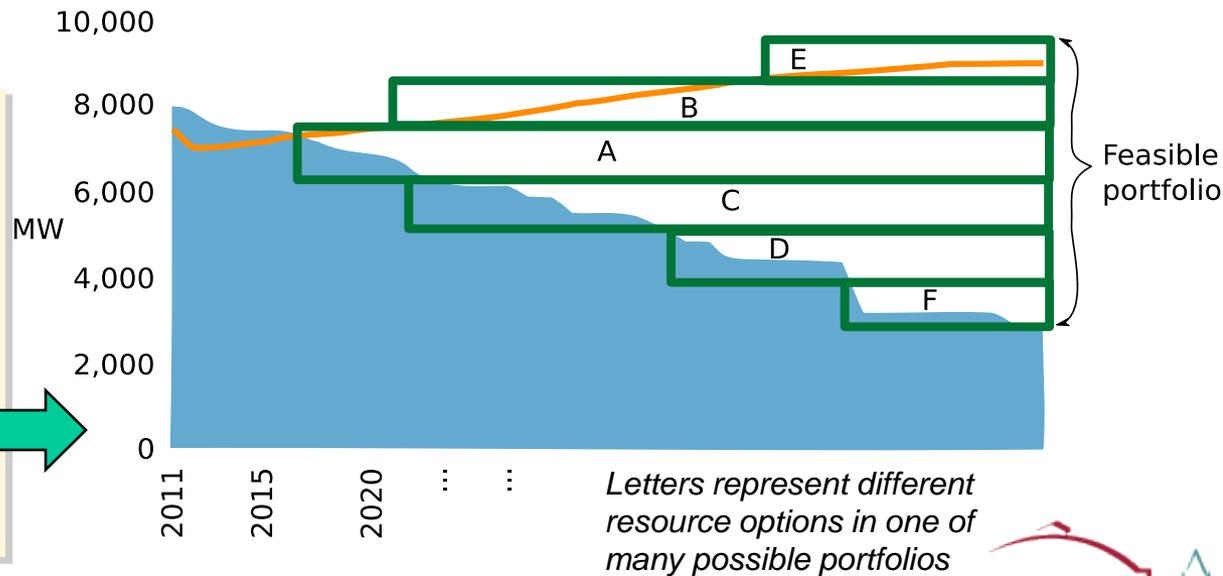
Flat-panel PV (fixed and tracking), parabolic-trough and power-tower CSP with or without thermal storage or natural gas augmentation are mature enough for commercially application. Other technologies, like solar chimney, are still in pilot or early-demonstration stage.

# Creation of feasible candidate portfolios implicitly provides solar's capacity value

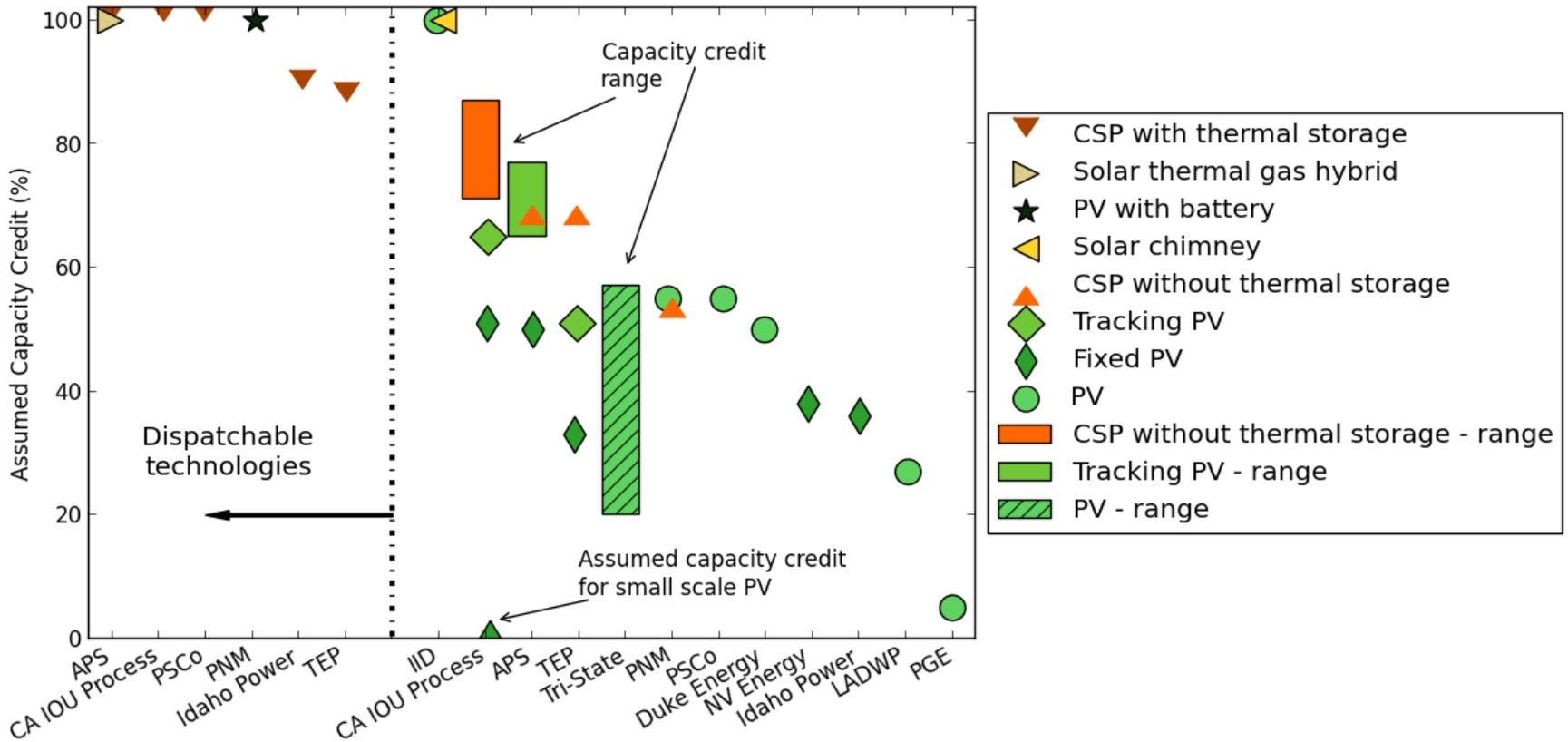


In almost all planning studies, the amount of resources added to each portfolio (including solar) was sufficient to meet forecasted peak load and planning reserve margin over the planning horizon

As a result, adding solar to a candidate portfolio reduced the need for some other capacity resource (often CTs or CCGTs) to meet the peak load and planning reserve margin



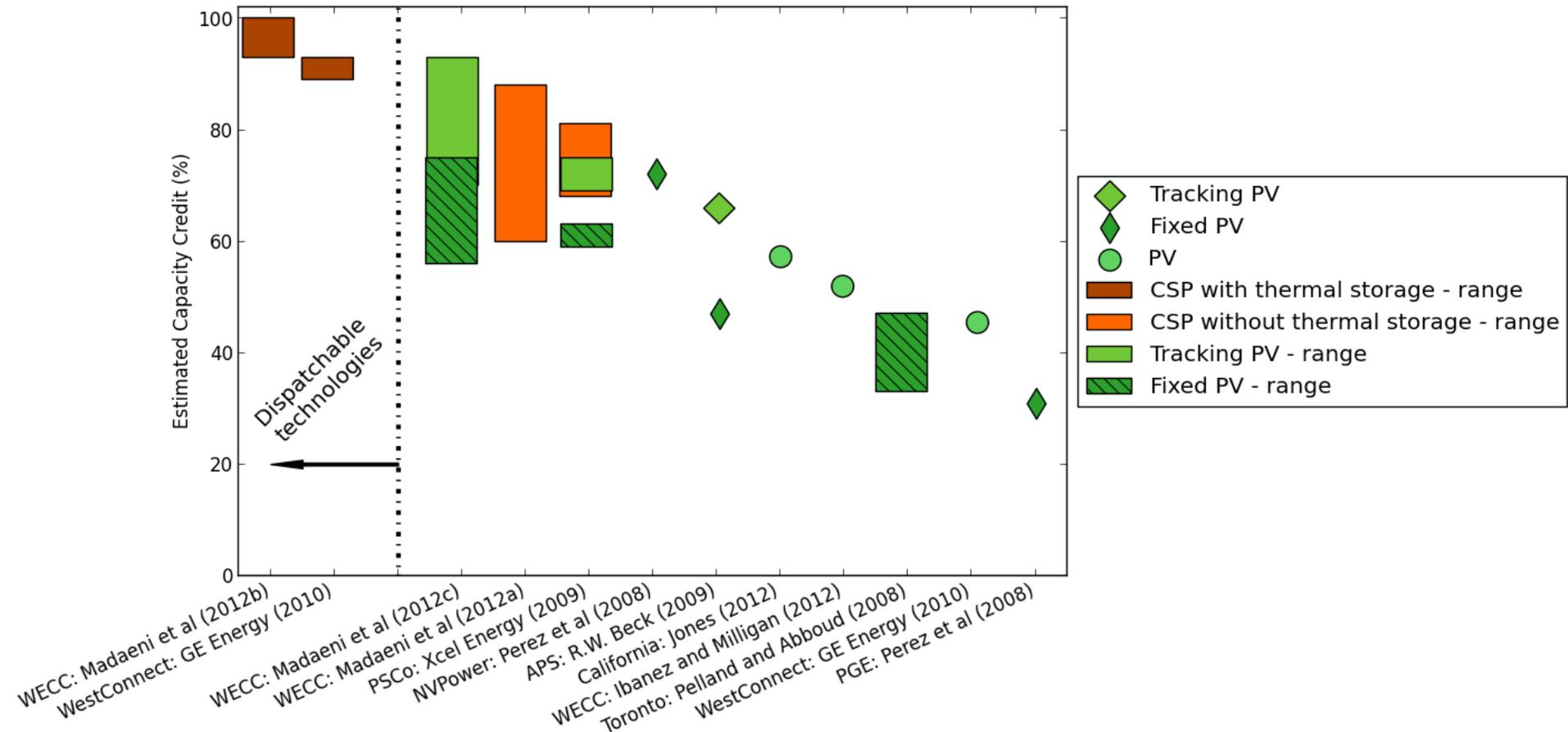
# Solar capacity value (in economic terms) depends on assumed capacity credit



Capacity credit used by utilities in planning studies covers a wide range depending on technology, utility, and tools used by utilities to estimate capacity credit.

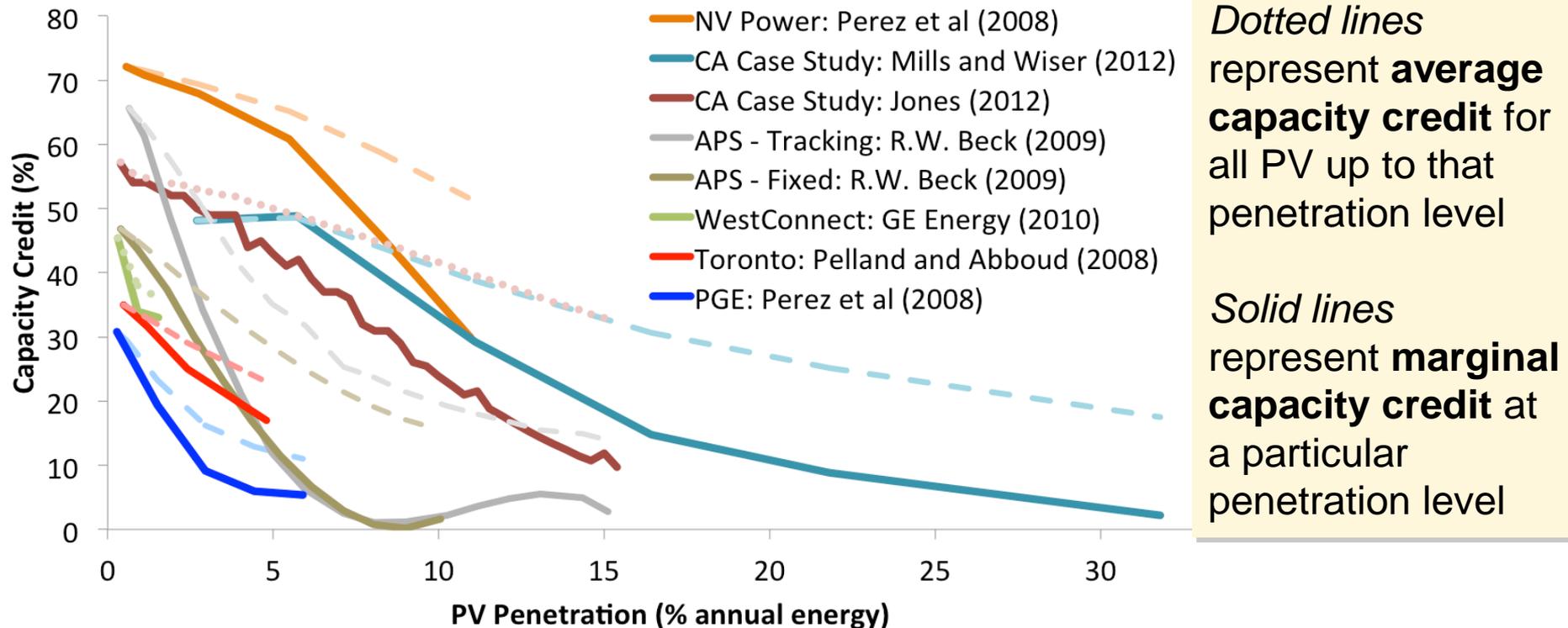
Capacity credits were rarely estimated using detailed LOLP studies (only PSCo and APS). More often they were based on solar production during peak load periods or rules of thumb.

# Estimates of capacity credit at low solar penetration from LOLP-based studies



The range of capacity credits used by LSEs in planning studies largely falls within the range reported in the broader literature for low-penetration PV and CSP

# Broader literature indicates capacity credit of PV declines with penetration



While a number of LSEs are aware that the capacity credit can decrease with increasing penetration, only APS appeared to account for this in its planning study.

Planning studies should consider improving estimates of solar capacity credit.

# Evaluation of the energy value of solar using production cost models

- Variable costs associated with dispatching power plants were simulated with some form of production cost model
- Most studies should be able to reflect correlations between solar generation and times when the fuel costs of conventional power plants are high
  - Most studies should also be able to reflect any change in energy value of solar with increasing penetration due to displacing production from resources with lower and lower variable cost
  - Not all production cost models included unit-by-unit operational constraints for conventional generation
- Planning studies provide little detail on how thermal energy storage dispatchability is captured in production cost models

Partial list of production cost models used:

- AURORAxmp (EPIS)
- PLEXOS (Energy Exemplar)
- PROMOD IV (Ventyx)
- PROSYM (Ventyx)
- PROVIEW (Ventyx)

# Adjustments to the energy value to account for integration costs

Some LSEs (NV Energy and CA IOU Process) increased ancillary service requirements in production cost models to account for short-term variability and uncertainty of solar. Integration costs due to ancillary services were then embedded in evaluation of portfolio with solar.

Others added estimated integration costs to production cost results (below). Few studies were used to estimate these integration costs for solar.

Planning Studies	Integration Cost Added to Production Costs (\$/MWh)			Notes
	PV	CSP without thermal storage	CSP with thermal storage	
PSCo	\$5.15	N/A	\$0	
APS	\$2.5	\$0	\$0	
TEP	\$4	\$2	\$0	
Tri-State	\$5–\$10	N/A	\$5–\$10	Most scenarios used low end of costs; scenarios with more renewables used higher costs
PGE	\$6.35	N/A	N/A	
NPCC	\$8.85–\$10.9	N/A	\$0	Integration costs assumed to escalate up to 2024

# Additional factors included or excluded from planning studies

- **The risk-reduction benefits of solar can be included in LSE planning assessments by accounting for uncertainty in future parameters when evaluating candidate portfolios**
  - Many of the planning studies accounted for the exposure of an LSE to changes in assumptions about the future when evaluating candidate portfolios, including portfolios with solar
- **Most LSEs did not distinguish between distributed PV and utility-scale PV or their respective benefits and costs**
  - A few LSEs, however, adjusted portfolio costs to account for the presumed benefits of distributed PV
  - In one case, the benefit of distributed PV varied by location but was most often around \$5/MWh (with a range of \$4.3 to \$26.2/MWh)
- **Some studies included options that might mitigate output variability and uncertainty of solar, examples include:**
  - Thermal storage and natural gas augmentation on CSP plants, batteries coupled to a PV system, and bulk power storage as a resource option

# Designing candidate portfolios to use in planning studies

- Many used detailed methods to *evaluate* and *select* the preferred portfolio from the various candidates, but they did not always use as sophisticated methods to first *create* candidate portfolios
- Complex interactions between various resource options and existing generation make it difficult to identify which resource options will be most economically attractive
- To manage this a number of LSEs used commercially available capacity-expansion models to guide creation of candidate portfolios
- Alternatively, LSEs:
  - Manually created candidate portfolios based on engineering judgment or stakeholder input
  - Applied a ranking, often based on economic criteria, to the options

LSE/planning entity	Capacity-expansion model
Duke Energy	System Optimizer, Ventyx
El Paso	Strategist, Ventyx
NPCC	Regional Portfolio Model
PacifiCorp	System Optimizer, Ventyx
PNM	Strategist, Ventyx
PSCo	Strategist, Ventyx
TEP	Capacity Expansion, Ventyx
Tri-State	System Optimizer, Ventyx

# Ranking resource options based on “net cost”

- When a capacity-expansion model is not available to create feasible portfolios, simple methods to identify which resources are most likely to minimize portfolio revenue requirements can be used to rank potential resources
- A logical way to rank resources is to estimate the change in the revenue requirement of a portfolio from including a particular resource in the portfolio and displacing other resources.
- This change in revenue requirement is called the “net cost” of a resource since it represents the difference between the cost of adding the resource and the avoided cost from displacing other resources that are no longer needed
- Since the goal of many planning studies is to minimize the expected revenue requirement, the resources with the lowest net cost should be added to the portfolio
- LSEs in California used a similar approach to identify renewable resource options that were included in their candidate portfolios

# Economic evaluation of bids in procurement processes

- LSE procurement often evaluated the economic attractiveness of bids based on the estimated net cost, but often it was unclear exactly how this net cost was evaluated
- The lack of clarity in many procurement documents makes it difficult for a bidder to estimate how various choices it makes in terms of solar technology or configuration will impact the net cost of its bid
- The bidder will know how these choices affect the cost side of the bid but often must guess or try to replicate the LSE's planning process to determine how different choices will affect the LSE's avoided costs
- LSEs likely could elicit more economically attractive bids by providing as much detail as possible on how the net cost of each bid will be evaluated and the differences in the LSE's avoided costs for different technologies and configurations

# Conclusions

- Full evaluation of the costs & benefits of solar requires that a variety of solar options are included in diverse set of candidate portfolios
- Design of candidate portfolios, particularly regarding the methods used to rank potential resource options, can be improved
- Studies account for the capacity value of solar, though capacity credit estimates with increasing penetration can be improved
- Most LSEs have the right approach and tools to evaluate the energy value of solar. Improvements remain possible, particularly in estimating solar integration costs used to adjust energy value
- T&D benefits, or costs, related to solar are rarely included in studies
- Few LSE planning studies can reflect the full range of potential benefits from adding thermal storage and/or natural gas augmentation to CSP plants
- The level of detail provided in RFPs is not always sufficient for bidders to identify most valuable technology or configurations

# For More Information

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## Download the full reports:

<http://emp.lbl.gov/sites/all/files/lbni-5933E.pdf>

<http://eetd.lbl.gov/ea/emp/reports/lbni-5445e.pdf>

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