AN EVALUATION OF SOLAR VALUATION METHODS USED IN UTILITY PLANNING AND PROCUREMENT PROCESSES

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ABSTRACT

As renewable technologies mature, recognizing and evaluating their economic value will become increasingly important for justifying their expanded use. This paper reviews a recent sample of U.S. load-serving entity (LSE) planning studies and procurement processes to identify how current practices reflect the drivers of solar's economic value. In particular, we analyze the LSEs' treatment of the capacity value, energy value, and integration costs of solar energy; the LSEs' treatment of other factors including the risk reduction value of solar, impacts to the transmission and distribution system, and options that might mitigate solar variability and uncertainty; the methods LSEs use to design candidate portfolios of resources for evaluation within the studies; and the approaches LSEs use to evaluate the economic attractiveness of bids during procurement.

We found that many LSEs have a framework to capture and evaluate solar's value, but approaches varied widely: only a few studies appeared to complement the framework with detailed analysis of key factors such as capacity credits, integration costs, and tradeoffs between distributed and utility-scale photovoltaics. Full evaluation of the costs and benefits of solar requires that a variety of solar options are included in a diverse set of candidate portfolios. We found that studies account for the capacity value of solar, though capacity credit estimates with increasing penetration can be improved. Furthermore, while 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. Transmission and distribution benefits, or costs, related to solar are rarely included in studies. Similarly, few LSE planning studies can reflect the full range of potential benefits from adding thermal storage and/or natural gas augmentation to concentrating solar power plants.

1. INTRODUCTION

Recent declines in the cost of photovoltaic (PV) energy, increasing experience with the deployment of concentrating solar power (CSP), the availability of tax-based incentives for solar, and state renewables portfolio standards (RPS) (some with solar-specific requirements) have led to increased interest in solar power among U.S. load-serving entities (LSEs). This interest is reflected within LSE planning and procurement processes and in a growing body of literature on the economic value of solar energy within utility portfolios [1-8]. This report identifies how current LSE planning and procurement practices reflect the drivers of solar's economic value identified in the broader literature. This comparison can help LSEs, regulators, and policy makers identify ways to improve LSE planning and procurement.

The paper summarizes a detailed review of 16 planning studies and nine documents describing procurement processes created during 2008–2012 by LSEs interested in solar power among other options (Table 1) [9]. We first summarize the typical approach used by LSEs in planning studies and procurement processes. We then analyze the LSEs' treatment of the capacity value, energy value, and integration costs of solar energy; the LSEs' treatment of other factors including the risk reduction value of solar, impacts to the transmission and distribution system, and options that might mitigate solar variability and uncertainty; the methods LSEs use to design candidate portfolios of resources for evaluation within the studies; and the approaches LSEs use to evaluate the economic attractiveness of bids during procurement. We offer several recommendations that could help LSEs improve planning studies and procurement processes.

The intended audience for this paper is LSE planners and their regulators that often oversee or approve planning studies and resource procurement, stakeholders that are involved with or provide input to public planning studies, and renewable energy project developers or equipment manufacturers.

This paper builds on previous analysis of the treatment of renewable energy [10] and carbon regulatory risk [11] in utility resource plans in the western United States, and a survey of the treatment of solar in utility procurement processes [12]. Research into incorporating renewables, other non-conventional technologies, and uncertainty into utility planning has a long history and remains active. Hirst and Goldman, for example, review best practices for integrated resource planning and distinguish it from traditional utility planning [13].

TABLE 1: PLANNING STUDIES AND PROCUREMENT PRACTICES REVIEWED

Load-serving entity	Planning study (yr)	Procurement practices (yr)
APS	2012	2011
CA IOU Process	2010	2011
Duke Energy Carolinas	2011	-
El Paso Electric	2012	2011
Idaho Power	2011	-
IID	2010	-
LADWP	2011	2012
NPCC	2010	-
NV Energy	2012	2010
PacifiCorp	2011	2010
PGE	2009	2012
PSCo	2011	2011
PNM	2011	2011
Salt River Project	2010	-
Tri-State G&T	2010	-
TEP	2012	-

2. SUMMARY OF STEPS USED BY LSES IN PLANNING STUDIES AND PROCUREMENT PROCESSES

Many of the LSEs followed a similar set of steps (Fig. 1) that began with an assessment of demand forecasts, generation options, fuel price forecasts, and regulatory requirements over a planning horizon. Based on this assessment, LSEs created candidate resource portfolios that satisfy these needs and regulatory requirements. These candidate portfolios were typically created using one of three methods:

- Manual creation based on engineering judgment or stakeholder requests
- Creation using capacity-expansion models based on deterministic future assumptions
- Creation using an intermediate approach in which resource options are ranked according to metrics defined by each LSE

The present value of the revenue requirement (PVRR) of candidate portfolios was then evaluated in detail. The PVRR of each portfolio was based primarily on the capital cost of each portfolio and the variable cost of dispatching each portfolio to maintain a balance between supply and demand over the planning period. The variable cost was commonly evaluated by simulating the dispatch of the portfolio using a production cost model. Many LSEs used scenario analysis or Monte-Carlo analysis (or some combination of both) to evaluate the exposure of each portfolio to changes in uncertain factors such as fossil-fuel prices, demand, or carbon dioxide prices. LSEs then chose a preferred portfolio based on the relative performance of the candidate portfolios. The preferred portfolio was often determined by balancing a desire for both low costs and low risks. During procurement, LSEs often solicited bids for resources that matched the characteristics of resources identified in the preferred portfolio.

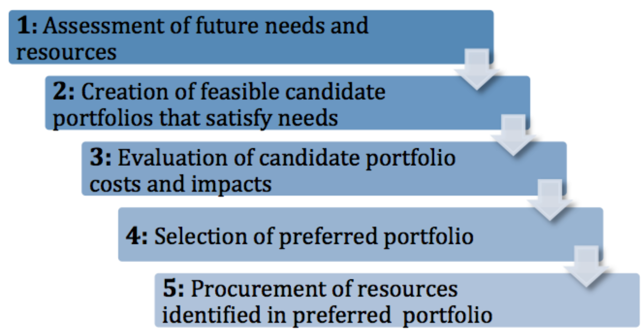


Fig. 1: General steps followed by LSEs in planning and procurement

3. SOLAR TECHNOLOGIES CONSIDERED IN PLANNING AND PROCUREMENT

Among our sample, many LSEs considered PV and CSP with or without thermal storage or natural gas augmentation (Table 2). The PV technologies considered by LSEs were not always described in detail. When they were described, LSEs typically considered fixed PV or single-axis tracking PV; some also distinguished between distributed and utility-scale PV. One LSE considered a PV plant coupled with a lead-acid battery. The CSP technology was usually based on a parabolic trough or a solar power tower configuration. One LSE considered a solar chimney, and another LSE considered a solar thermal gas hybrid (a natural gas power plant with solar concentrators that preheat water used in the plant's steam cycle).

TABLE 2: SOLAR TECHNOLOGIES INCLUDED IN ASSESSMENT OF POTENTIAL FUTURE RESOURCES

Technology Category	Variation	Integrated thermal storage	Natural gas firing in boiler
PV	Fixed	N/A	N/A
	Single-axis tracking	N/A	N/A
	With lead acid battery	N/A	N/A
CSP	Trough	None	No
	Trough	None	Yes
	Trough	3 hours	No
	Trough	6-8 hours	No
	Power tower	7 hours	No
	Solar chimney	None	No
Solar thermal gas hybrid plants		N/A	N/A

4. RECOGNITION OF SOLAR CAPACITY VALUE IN PLANNING STUDIES

In regions where solar generation is well correlated with periods of high demand, one of the main contributors to solar's economic value is the capacity value. The capacity value of solar reflects the avoided costs from reducing the need to build other capacity resources, often combustion turbines (CTs), to meet peak demand reliably. LSEs usually added sufficient capacity to meet the peak load plus a planning reserve margin in each candidate portfolio (Fig. 2). Portfolios that included solar need not include as much capacity from other resources, so solar offset some of the capital cost that would otherwise be included in the portfolio's PVRR. Thus, solar's capacity value was based in part on the capital cost of the avoided capacity resources and the timing of the need for new capacity.

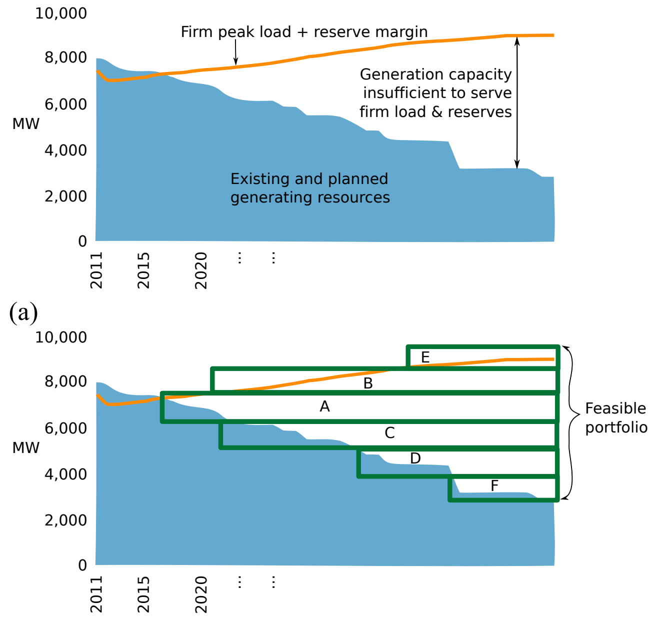


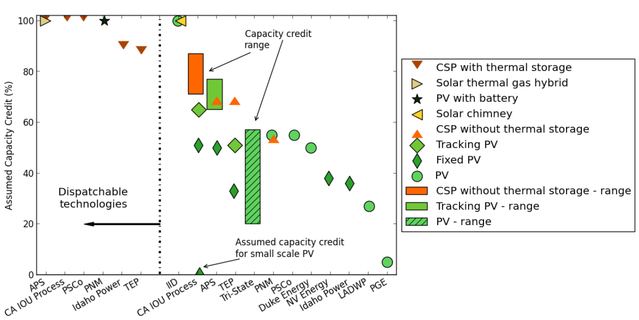
Fig. 2: Example of LSE assessment of (a) expected future peak loads and existing resources and (b) the creation of a feasible candidate portfolio that meets those needs (adapted from PSCo)

The capacity value of solar was affected by the study methodology. In at least one case, the LSE assumed that the generating resources used for capacity were very "lumpy" (i.e., only available in blocks of 290 MW or greater). As a result, adding a small amount of solar to a portfolio could not change the timing or amount of other capacity resources required; thus, the same amount of CT capacity was needed with or without the inclusion of solar, even though the LSE recognized that some of the solar nameplate capacity could contribute to meeting peak loads. Including capacity resources that are available in smaller size increments—e.g., 50-MW CTs, which were modeled by other LSEs—or modeling the value of selling excess capacity to neighboring LSEs better recognizes solar's capacity value.

5. ESTIMATES OF SOLAR CAPACITY CREDIT IN PLANNING STUDIES AND BROADER LITERATURE

The primary driver of solar's capacity value is the capacity credit: the percentage of the solar nameplate capacity that can be counted toward meeting the peak load and planning reserve margin. The capacity credit assigned to solar technologies by the LSE determines how much capacity from an alternative resource can be avoided by including solar in a portfolio. For example, a capacity credit of 50% for PV indicates that a 100-MW PV plant can contribute roughly the same toward meeting peak load and the planning reserve margin as a 50-MW CT. Analysis in the literature shows that the capacity credit of solar largely depends on the correlation of solar production with LSE demand, meaning the capacity credit varies by solar technology (e.g., PV vs. CSP with thermal storage), configuration (e.g., single-axis tracking PV vs. fixed PV), and LSE (e.g., summer afternoon peaking vs. winter night peaking) [14-22]. As expected, the capacity credit assigned by LSEs to solar in planning studies varied by technology, configuration, and LSE (Fig. 3). However, few studies appeared to use detailed loss of load probability (LOLP) studies to determine the capacity credit of solar. Instead, most LSEs relied on analysis of the solar production during peak-load periods or assumptions based on rules of thumb. The reliance on assumptions or simple approximation methods to assign a capacity credit to solar may also contribute to much of the variation in capacity credit across studies.

Only one LSE, Arizona Public Service (APS), appeared to account for changes in the capacity credit of solar with increasing penetration. Analysis in the broader literature finds that solar capacity credit decreases with increasing solar penetration, particularly for PV and CSP without thermal storage or natural gas augmentation (Fig. 4). One of the main factors in the literature that distinguishes the economic value of CSP with thermal storage from the economic value of PV and CSP without thermal storage or natural gas augmentation is the ability of CSP with thermal storage to maintain a high capacity credit with increasing penetration. If LSE planning studies do not reflect this difference in capacity credit with increasing penetration, then the difference in economic value among different solar technologies will not be reflected in their planning studies.



Note: Imperial Irrigation District (IID) appears to assume a 100% capacity credit for PV and a solar chimney. Capacity credit for APS represent capacity credit applied at low penetration level; capacity credit is reduced with higher PV penetration. Range of capacity credits for APS and CA IOU process are based on different plant locations.

Fig. 3: Capacity credits applied by LSEs in planning studies

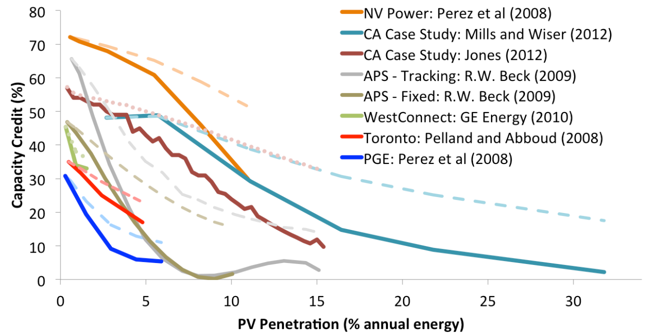


Fig. 4: PV capacity credit estimates with increasing penetration levels (dashed line is average capacity credit, solid line is incremental capacity credit)

Given the importance of solar's capacity credit for determining economic value and ensuring reliability, LSEs should consider conducting detailed estimates of solar capacity credit. LSEs considering portfolios with large amounts of solar may also need to account for expected changes in the solar capacity credit with increasing penetration.

6. EVALUATION OF THE ENERGY VALUE OF SOLAR USING PRODUCTION COST MODELS

In addition to capacity value, another primary driver of solar's economic value is the energy value. The energy value reflects the reduction in the PVRR from avoiding variable fuel and operational costs from conventional power plants in portfolios with solar. When LSEs evaluate candidate portfolios, they often use production cost models that account for the temporal variation in solar generation, demand, and other resource profiles. Many of the production cost models used by LSEs in planning studies have hourly temporal resolution (either over a one-week period each month or over the full year), and some production cost models account for the various operational constraints of conventional generation. These models appear to account for any benefit from solar generation being correlated with times when plants with high variable costs would otherwise be needed.

The LSEs in our sample that included CSP with thermal storage in candidate portfolios did not describe the approach they used to account for the dispatchability of CSP with thermal storage in the production cost models. In previous analyses, CSP with thermal storage was assumed to operate with a fixed generation profile in which the thermal storage generates as much power as possible in specific, static periods. While this simplified approach may capture some of the benefits of thermal storage, the full benefits to a particular LSE can be better captured by modeling the dispatchability of CSP directly in the production cost model. Compared to thermal storage, natural gas augmentation is relatively easier to model in a production cost model. One LSE described its approach to incorporating natural gas augmentation into its model.

The production cost models used by most LSEs also can account for changes in the energy value as the penetration of solar increases. One key factor in this regard is how LSEs consider the broader wholesale market and the assumptions they make about solar penetration in neighboring markets. If the LSE assumes other regions do not add solar, then selling power to the broader market during times of high insolation and low load may mitigate reductions in the energy value as the penetration of solar increases in the candidate portfolio. Such opportunities may not be available to the same degree, however, if many LSEs in a region simultaneously add solar. LSEs can improve their planning studies by better describing the assumptions and approaches used to account for broader wholesale markets when using production cost models to evaluate candidate portfolios.

7. ADJUSTING THE ENERGY VALUE TO ACCOUNT FOR INTEGRATION COSTS

Many LSEs adjust production cost model assumptions or results to account for solar integration costs. Adjustments make sense when there are factors that cannot be represented in the production cost model owing to data or computational limitations. In that case, the adjustments could be tailored to account for the shortcomings of a specific LSE's modeling approach or production cost model. Two studies accounted for solar integration costs by increasing the operating reserve requirement in the hourly production cost model to account for sub-hourly variability and uncertainty that otherwise would be ignored. The increase in operating reserves was based on a separate detailed analysis of sub-hourly variability and uncertainty of solar, wind, and load. Alternatively, other LSEs directly added an estimated integration cost to the production cost model results depending on the amount of solar included in the candidate portfolio (Table 3). The integration costs for solar added to the production cost model results ranged from \$2.5/MWh to \$10/MWh. Of the LSEs that used this approach, only one conducted a detailed study of solar integration costs (based on day-ahead forecast errors). The remaining LSEs relied on assumptions, results from studies in other regions, or integration cost estimates for wind. Based on the scarcity of detailed analysis of solar integration costs and the wide range of integration cost estimates used in the planning studies, more LSEs should consider carefully analyzing solar integration costs for their system (estimating what is not already captured by their modeling approach) to better justify their assumptions.

TABLE 3: ASSUMED INTEGRATION COSTS USED TO ADJUST PRODUCTION COSTS FOR PORTFOLIOS WITH SOLAR

Planning Studies	Integration Cost Added to Production Costs (\$/MWh)		
	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
PGE	\$6.35	N/A	N/A
NPCC	\$8.85–\$10.9	N/A	\$0

8. ADDITIONAL FACTORS INCLUDED OR EXCLUDED FROM PLANNING STUDIES

Aside from the capacity and energy values, other attributes of solar are often also included in planning studies. The potential risk-reduction benefit of solar, for example, can be accounted for in studies that evaluate the performance of candidate portfolios with and without solar under different assumptions about the future. Transmission and distribution benefits, or costs, related to solar are not often accounted for in LSE studies. In one clear exception, avoided distribution costs were directly accounted for by one LSE in portfolios with distributed PV. In a few other cases, candidate portfolios with solar required less transmission than candidate portfolios with other generation options. The difference in avoided costs between utility-scale solar and distributed PV are not well known, but as more studies provide insight into these differences, LSEs should consider incorporating that information into their planning studies.

A number of LSE planning studies included options that may increase the economic value of solar. Some LSEs included thermal storage or natural gas augmentation with CSP plants, one study considered PV coupled with a lead-acid battery, and another added grid-scale batteries to candidate portfolios with wind and solar (in both cases the additional capital cost of the batteries was too high to reduce the overall PVRR relative to the cases without batteries). Other studies considered a wide range of grid-level storage options without explicitly tying these storage resources to the candidate portfolios with wind or solar. None of the studies appeared to directly consider the role of demand response in increasing the value of solar or directly identify synergies in the capacity credit or integration costs for combinations of wind and solar. Any such synergy in energy value, on the other hand, may have been indirectly accounted for in production cost modeling of candidate portfolios with combinations of wind and solar.

9. DESIGNING CANDIDATE PORTFOLIOS TO USE IN PLANNING STUDIES

While the overall framework used by many of the LSEs for evaluating candidate portfolios appears to capture many (but not all) solar benefits, one important area for improvement is creating candidate portfolios in the first place. The 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 complexity, a number of LSEs relied on capacity-expansion models to design candidate portfolios, most of which were based on deterministic assumptions about future costs and needs (Table 4). The LSEs that did not use capacity-expansion models either manually created candidate portfolios based on engineering judgment or stakeholder input or created candidate portfolios by ranking resource options using simplified criteria.

TABLE 4: CAPACITY-EXPANSION MODELS USED BY LSE'S CONSIDERING SOLAR

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

A logical way to rank resources is to estimate the change in the PVRR of a portfolio from including a particular resource in the portfolio and displacing other resources. This change in PVRR 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 to ensure the portfolio can meet reliability and regulatory constraints. Since the goal of many planning studies is to minimize the expected PVRR, 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.

In contrast, a number of LSEs used the levelized cost of energy of resource options along with various adjustments (often based on capacity and integration cost adjustments) to rank resource options. The adjustments, particularly the capacity adjustments, were often not clearly justified and did not always link back to the broader objective of minimizing the expected PVRR. Based on these findings, we recommend that, where possible, LSEs use capacity-expansion models to build candidate portfolios. Improvements in capacity expansion models to account for factors like risk, uncertainty, dispatchability of CSP plants with thermal storage, and operational constraints for conventional generation may be appropriate for some LSEs. If using a capacity-expansion model to build candidate portfolios is not possible, then an approach like the net cost ranking should be considered instead.

10. ECONOMIC EVALUATION OF BIDS IN PROCUREMENT PROCESSES

Finally, we found that 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.

Although this review focused on the valuation of solar in planning and procurement, many of the LSEs are considering other renewable technologies, particularly wind. The lessons learned from this analysis and many of the recommendations apply to the evaluation of other renewable energy options beyond solar.

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ACRONYMS AND ABBREVIATIONS

APS	Arizona Public Service
CA IOU	California Investor-Owned Utility
CSP	Concentrating solar power
CT	Combustion turbine
IID	Imperial Irrigation District
IRP	Integrated resource plan
LADWP	Los Angeles Department of Water and Power
LOLP	Loss of load probability
LSE	Load-serving entity

NPCC	Northwest Power and Conservation Council
PGE	Portland General Electric
PNM	Public Service of New Mexico
PSCo	Public Service of Colorado
PV	Photovoltaics
PVRR	Present value of the revenue requirement
RPS	Renewables portfolio standard
T&D	Transmission and distribution
TEP	Tucson Electric Power

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