Effective Load Carrying Capacity and Qualifying Capacity Calculation Methodology for Wind and Solar Resources

Staff Proposal
Resource Adequacy Proceeding R.11-10-023
California Public Utilities Commission – Energy Division
January 16, 2014

Introduction

In compliance with Senate Bill (SB) 2 (1X), this Energy Division Staff Proposal (Proposal) recommends a calculation methodology for the California Public Utilities Commission's determination of the Effective Load Carrying Capability (ELCC) and Qualifying Capacity (QC) of wind and solar resources. A resource's Qualifying Capacity (QC) is the number of Megawatts eligible to be counted towards meeting a load serving entity's (LSE's) System and Local Resource Adequacy (RA) requirements, subject to deliverability constraints.[1]

ELCC is a percentage that expresses how well a resource is able to meet reliability conditions and reduce expected reliability problems or outage events (considering availability and use limitations). It is calculated via probabilistic reliability modeling, and yields a single percentage value for a given facility or grouping of facilities. ELCC can be thought of as a derating factor that is applied to a facility's maximum output (P_{max}) in order to determine its QC. Because this derating factor is calculated considering both system reliability needs and facility performance, it will reflect not just the output capabilities of a facility but also the usefulness of this output in meeting overall electricity system reliability needs.

In accordance with the RA proceeding Scoping Memo (R.11-10-023), Energy Division (ED) staff issues this Proposal and seeks formal comments. Party comments will inform the development of a Proposed Decision, and will become part of the rulemaking's record. Formal comments on this Proposal should be emailed to the service list for the RA proceeding, R.11-10-023, on or before February 18, 2013. These comments are to be filed and served.

It is noted that only the ELCC and QC methodology for supply-side wind and solar resources is within the scope of this Proposal. "Solar resources" here includes both photovoltaic and solar thermal resources; however, behind the meter resources are not considered. Flexibility and effective flexible capacity (EFC) are also not within the scope of this document. The modeling upon which the ELCC and QC methodology depends is described in a separate, companion staff proposal: Probabilistic Reliability Modeling Inputs and Assumptions (Assumptions Proposal).[2] The QC and EFC methodologies for energy storage and

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[1] The revised QC that incorporates deliverability constraints is called the Net Qualifying Capacity (NQC).

[2] The most recent version of that proposal can be found at http://www.cpuc.ca.gov/PUC/energy/Procurement/RA/ra_history.htm.

demand response resources are also addressed in a separate proposal: Qualifying Capacity and Effective Flexible Capacity Calculation Methodologies for Energy Storage and Supply-Side Demand Response Resources. It is not recommended that the QC and EFC methodologies for fossil-fuel resources be modified at this time; any potential modifications are not within the scope of this Proposal.

While ELCC calculations have been conducted for conventional resource types since the 1960s and are now also relatively well-understood for renewable resources, there can be some differences in implementation. The extensive literature developing and documenting the ELCC concept for renewable resources includes recent publications from the North American Electric Reliability Corporation (NERC),[3] National Renewable Energy Laboratory (NREL),[4] the IEEE Power and Energy Society,[5] and the California Energy Commission (CEC) Public Interest Energy Research (PIER) Program.[6] Parties seeking more detailed background on ELCC calculations and their usage in other jurisdictions are encouraged to review these publications. This Proposal recommends one particular approach, and the primary purpose of this Proposal is to solicit stakeholder feedback regarding the validity of this approach. However, stakeholders with alternative proposals are invited to share these in their comments and to contact staff regarding participation in forthcoming RA workshops.

Regardless of how the ELCC is calculated, it is ultimately a derating factor applied to the nameplate capacity (P_{max}) of a resource in order to determine its QC. Mathematically, this translates into the following formula: QC = ELCC (%) * P_{max} (MW).

The following sections outline the calculation methodology recommended by ED staff. The document ends with a review of ELCC values for wind and solar resources calculated in other studies and jurisdictions. Staff will also publish preliminary Energy Division modeling results in the coming month as part of its effort to conduct transparent modeling and ELCC/QC calculations.

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[3] *Methods to Model and Calculate Capacity Contributions of Variable Generation for Resource Adequacy Planning*, NERC, 2011. http://www.nerc.com/docs/pc/ivgtf/IVGTF1-2.pdf.

[4] *Summary of Time Period-Based and Other Approximation Methods for Determining the Capacity Value of Wind and Solar in the United States*, NREL, 2012. http://www.nrel.gov/docs/fy12osti/54338.pdf.

[5] *Capacity Value of Wind Power*, NERC, 2011. http://www.nerc.com/docs/pc/ivgtf/ieee-capacity-value-task-force-confidential%20(2).pdf

[6] *California Renewables Portfolio Standard Renewable Generation Integration Cost Analysis*, the California Wind Energy Collaborative, NREL, Oak Ridge National Laboratory (ORNL) and Dynamic Design Engineering, 2006. http://www.energy.ca.gov/2006publications/CEC-500-2006-064/CEC-500-2006-064.PDF

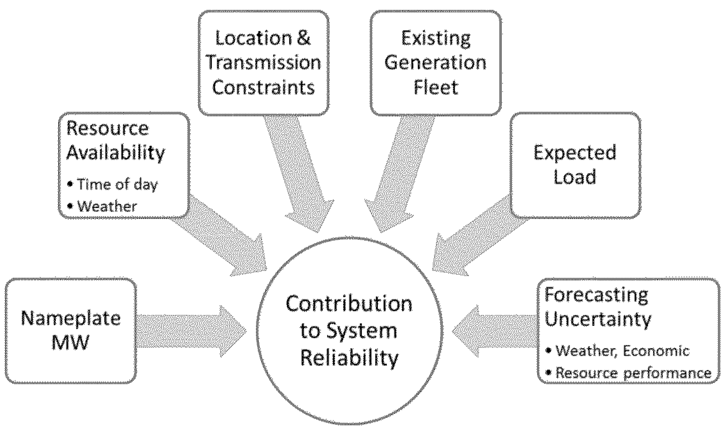
Effective Load Carrying Capability (ELCC) Framework

<u>ELCC reflects the contribution of a resource type towards meeting reliability needs</u>

As previously mentioned, effective load carrying capability (ELCC) is an output of probabilistic modeling, which assesses likely system needs and the potential for wind and solar resources to contribute to these needs. The ELCC expresses how well the facility is able to meet reliability conditions and reduce expected reliability problems or outage events caused by capacity shortfalls as compared to a perfect generator (considering availability and use limitations).

ELCC can be viewed as matching the usefulness of a resource's operating characteristics to reliability conditions; for example, if modeling indicates that reliability needs are greatest in the afternoon, then a resource that only operates in the morning would be derated more than an otherwise-identical resource that only operates during the afternoon, because its contribution to reliability needs would be smaller. Similarly, a resource with a high outage or underperformance rate at times of system stress would also be derated more than an otherwise-identical, more reliable resource. For wind and solar resources, monthly ELCC values are calculated to reflect seasonal variation in both generation profiles and system needs. In order to conduct this assessment, modeling must encompass the complete electrical system, from load forecasts to transmission constraints to generation forecasts, as shown in Figure 1.

Figure 1. Factors considered in determining ELCC.



<u>A single ELCC will be calculated for groups of similar facilities</u>

Proposed approach and groupings

The probabilistic reliability modeling is conducted using a program called SERVM, as described in the companion staff proposal, Probabilistic Reliability Modeling Inputs and Assumptions (Assumptions Proposal).[7] This software allows every facility in the Western Electricity Coordinating Council (WECC) to be modeled individually. As documented in the Assumptions Proposal, with the exception of

[7] The most recent version of that proposal can be found at http://www.cpuc.ca.gov/PUC/energy/Procurement/RA/ra_history.htm.

hydropower, all facilities are modeled individually in SERVM. However, ELCC will be calculated for combined groups of wind and solar facilities that belong to a single technology category and region, for each month of the year. The proposed technology categories and regions are described in further detail in the Assumptions Proposal, as is the process for developing their generation profiles. The technology categories and regions are briefly listed in the tables below. Based on these designations, there will be one monthly ELCC value calculated for each combination of the five technologies and eighteen regions, yielding 12*5*18 = 1,080 distinct ELCC values for a given compliance year.

Table 1. Wind and Solar Technology Categories

Wind	Solar
Above 70 Meters	Solar Thermal
Below 70 Meters	Photovoltaic: Fixed Tilt[8]
	Photovoltaic: Tracking

Table 2. Modeling Regions

California Regions	Regions external to California
IID (Imperial Irrigation District) Service Territory	Arizona
LADWP Balancing Authority Area (BAA)	Canada
PG&E Bay Area *(Greater Bay Area LCR Area)*	Colorado
PG&E Valley *(Other PG&E Local Capacity Areas)*	Mexico
SCE TAC Area	Montana
SDG&E Service Territory	Nevada
Balancing Authority of Northern California (aka SMUD)	New Mexico
TID (Turlock Irrigation District) BAA	Pacific Northwest
	Utah
	Wyoming

Aggregated ELCC calculation is advisable for both technical and practical reasons

There are a number of reasons to calculate aggregated ELCC values. While it might seem preferable to have unique ELCC calculations for each facility to reflect facility-specific reliability parameters, there are technical and market-related reasons to nevertheless aggregate ELCC calculations by technology and region. For example, if ELCC is calculated on a facility-specific basis, the reliability contribution of one single facility must be accurately detected. If the facility is small or if the region already has significant excess capacity, the reliability contribution will be technically very difficult to accurately assess.

Additionally, facility-specific calculations are very sensitive to the generation profile assumed for that facility. Because of weather data availability limitations, it would be prohibitively difficult to develop a

[8] Excludes rooftop photovoltaic systems, which do not receive a QC or ELCC.

production profile that is as accurate as would be required to yield improved results over aggregated profiles; any inaccuracies could yield significant deviations in QC. Moreover, the process of coming to consensus on what production profiles are appropriate for an individual facility would be much more difficult than conducting the same process for aggregated production profiles.

The modeling and administrative burden of conducting facility-specific, monthly ELCC calculations would also be significant. With most facility parameters modeled on a facility-specific basis (the notable exception being generation profiles, the calculation of which is described in detail in the Assumptions Proposal) and 1,080 distinct ELCC values already envisioned for each compliance year, staff believes that grouping the ELCC calculations across five technologies and eighteen regions represents a reasonable compromise between specificity and feasibility.

It is also important that QC values be relatively predictable, so that developers and LSEs can efficiently respond to the market signal they provide. Grouping by technology category and region will enable market participants to more easily assess what types of wind and solar projects will be most cost-effective, while still providing a reasonably accurate indication of those resources' contributions to reliability.

Perhaps most importantly, however, facilities are grouped into categories due to the fact that resources of a similar type contribute to reliability with diminishing returns, considered on an incremental basis; in other words, one can imagine that the first solar facility that provides reliability benefit during the middle of the day produces the highest marginal benefit, while subsequent solar facilities with the same performance pattern produce a diminishing level of marginal benefit, as the need for capacity that time has already been met. Wind facilities are less susceptible to the dynamic of diminishing returns due to the higher variability of wind patterns across geographical distance, but the issue remains – subsequent installations of similar technologies create diminishing returns.

However, in actual operations, there is no "first" facility providing reliability benefits in a given moment – all of the facilities that are generating output are doing so simultaneously. Modeling a given resource type in aggregate addresses the issue of marginal reliability contributions by in essence averaging the aggregate reliability contribution across all facilities. This approach is also preferable to modeling individual facilities while assuming that all other facilities of that type are already present, because that approach would be equivalent to designating each and every facility modeled as the "last" facility to come online – and thus the one with the lowest reliability contribution. Such an approach would dramatically underestimate the total reliability contribution of the overall resource type.

Facilities will be compared to a "perfect generator"

There are three primary approaches to calculating ELCC:

1. Modeling reliability with and without a given resource type, and determining how much load can be increased such that it cancels out the reliability improvement of including the resource.

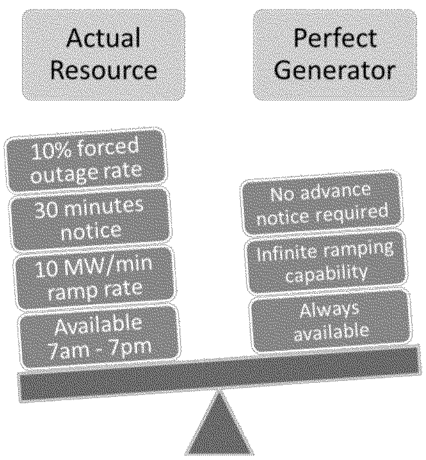
2. Comparing the reliability impact of including the resource type to the reliability impact of including a conventional resource with assumed operating and outage characteristics.

3. Comparing the reliability impact of including the resource type to the reliability impact of including an idealized, "perfect generator".

As previously mentioned, the approach recommended by staff is to compare the reliability contribution of an actual resource type to that of a perfect generator. This is done to create a derating relative to the maximum possible reliability contribution from a given MW of nameplate capacity, and to avoid dependence on load and conventional generator assumptions. This approach is consistent with that adopted in a recent NREL/GE Energy study, and a more detailed discussion of the reasoning behind this choice can be found in that publication.[9]

A perfect generator is modeled as a facility with ideal operating characteristics: no transmission constraints, immediate start-up and shut-down, infinite ramping capability, no use limitations, and no outages. This generator has positive output only (no charging or dispatchable load). The comparison concept is illustrated in Figure 2. The perfect operating characteristics are primarily modeled via the standard unit inputs described in the Assumptions Proposal. However, the transmission constraints are modeled by placing the perfect generator in its own modeling region, and by setting this region to have no load and full deliverability to all other regions.

Figure 2. ELCC calculations compare actual resource characteristics to an ideal generator



While it is only recommended that solar and wind resources receive QC in this manner for RA compliance year 2015, fossil resources are also subject to a derating from the CAISO, reducing their qualifying capacity to their "dependable" capacity. Fossil resources are also subject to the Standard Capacity Product (SCP), which penalizes facilities that are not available for a sufficiently high percentage

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[9] *Western Wind and Solar Integration Study*, prepared for NREL by GE Energy, 2010. Note that the recommended approach is referred to as "capacity value" in that document, while the term ELCC is used exclusively to refer to the load-increasing approach. See Section 9, "Capacity Value Analysis" and specifically Section 9.5, "Comparison to Other Measures". http://www.nrel.gov/docs/fy10osti/47434.pdf.

of Availability Assessment Hours;[10] as a result, many fossil facilities will voluntarily reduce their QC to account for factors such as reduced efficiency at high ambient temperatures. Moreover, all resources are subject to CAISO deliverability calculations, which result in a net qualifying capacity (NQC). The NQC is the value ultimately adopted by the CPUC as the capacity eligible to meet RA requirements.

ELCC calculations will consider all 8760 hours of the year

Because the modeling is probabilistic, many sample years are modeled in order to derive the expected contribution of a given resource type. ELCC calculations consider reliability contributions during all of these modeled hours. However, it could be possible to only consider contributions during the Availability Assessment Hours currently utilized for assessing fossil fuel facilities. Alternatively, both methodologies could be utilized and the higher of the two ELCCs applied to a given technology type and region. Staff looks forward to parties' comment as to which approach should be pursued.

Co-located storage will not be addressed at this time

In the Draft CPUC Energy Storage Use Case Analysis,[11] On-Site Variable Energy Resource (VER) Storage is defined as:

> Energy storage that is located on-site of an intermittent resource such as wind and solar. These storage deployments are used to enhance the capacity, energy, or ancillary services revenues of that generator. Some technologies, such as batteries, may choose to operate a part of the battery independently of the on-site generation source. That participation would be counted in either the bulk storage system or ancillary services storage.

This storage will be modeled as a part of the WECC system in the reliability calculations, but will not be considered to be operating in conjunction with the co-located wind or solar facility at this time. If the storage independently meets RA eligibility criteria, then it may receive its own QC according to the rules currently being developed for energy storage systems. If the storage does not independently meet RA eligibility criteria, then it will not receive a QC value. In neither case will the storage facility influence the QC of the on-site wind or solar facility. Treatment of co-located storage will be revisited for RA compliance year 2016.

ELCC is calculated based on a monthly Loss of Load Expectation (LOLE) metric

Loss of load expectation is the amount of time during which system capacity is unable to meet system load. For example, in a monthly LOLE calculation, if CAISO system load exceeds available generation for

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[10] For more information, see CAISO Tariff Section 40.9.3, Availability Assessment Hours for Standard Capacity Product: http://www.caiso.com/Documents/ConformedTariff_Dec17_2013.pdf, page 929. For the availability assessment hours starting in compliance year 2010, see Section 7.6: http://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Reliability%20Requirements.

[11] http://www.cpuc.ca.gov/NR/rdonlyres/3E556FDB-400D-4B24-84BC-CD91E8F77CDA/0/TransmissionConnectedStorageUseCase.pdf

ten hours out of a total of 744 hours in the month, then the system LOLE for that month is equal to 10 hours ÷ 744 hours, or 0.013.

This metric enables system reliability to be compared across multiple scenarios and portfolio types. If two model runs yield the same LOLE, then they are considered to have the same level of reliability, even if the generation portfolio and causes of load shedding are very different. For example, if the model is run once with 10 MW of wind in a given region (in addition to all other plants that make up the overall generation fleet), and again with that wind replaced by 4 MW of natural gas combined cycle plants, and both runs result in the same LOLE, then the two portfolios are considered to be equally reliable. It is possible that the wind scenario is more likely to have load shedding during mid-day, while the natural gas scenario is more likely to have load shedding in the early morning, but on the whole, the system reliability is equivalent. Similar comparisons form the basis of the 1,080 ELCC calculations, as described in the following section.

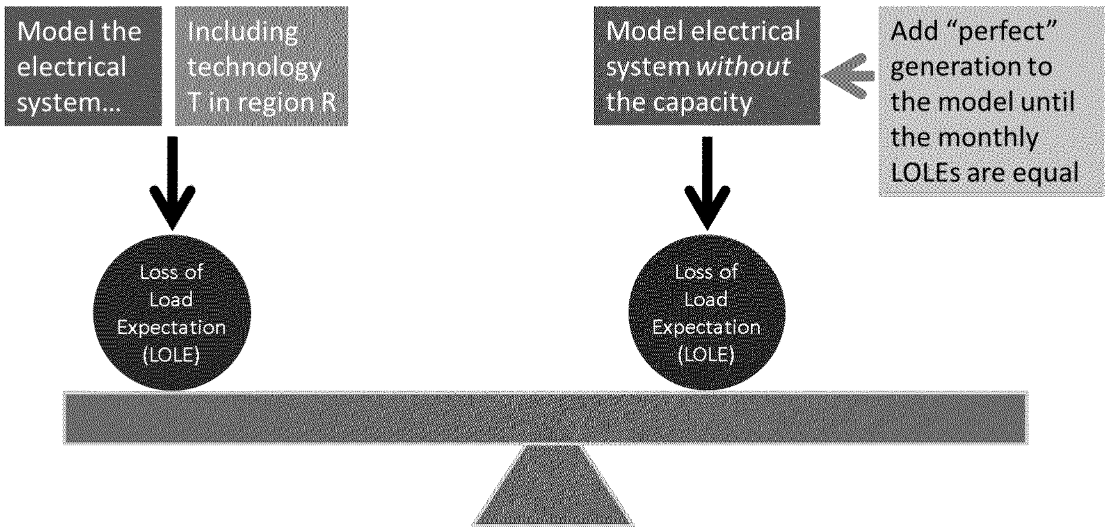
ELCC Methodology

The ELCC calculation requires modeling with a reliability calculator. As discussed above, this modeling will incorporate the specific operating characteristics of each facility where possible (performance, advance notice required, use limitations, P_{max} and P_{min}, etc.); however, the ELCC will be calculated as an aggregate number for a given technology category, region, and month.

Conceptually, the ELCC for a given technology category, region, and month is a comparison of the amount of generation capacity of that category and in that region to the amount of perfect generation required to yield the same monthly LOLE, if the capacity in question is excluded from modeling. Note that in order to create a derating factor (percentage below 100%), this relationship is inverted. This comparison is illustrated in Figure 3.

For example, imagine there is 100 MW of fixed tilt photovoltaic solar capacity in a given region, and modeling results show that the system LOLE for May is 0.001. If this solar capacity is removed from modeling, system reliability would decrease and the May LOLE would increase, perhaps to 0.002. If 25 MW of perfect generation is required to bring the May LOLE back down to 0.001, then the ELCC would be 25 MW / 100 MW = 25%. In other words, in the month of May, fixed tilt photovoltaic solar capacity in the region in question improves system reliability 25% as much as the same nameplate capacity of perfect generation.

Figure 3. ELCC is based on a comparison of the actual and "perfect" capacities yielding identical LOLEs



ELCC Calculation

Each combination of technology category, region, and month requires a unique ELCC calculation. Let T be the technology category in question, R be the region in question, and M be the month in question for the calculation methodology detailed below.

1. Use a reliability calculator to model the WECC electrical system with all resources included, as described in the Assumptions Proposal, and determine the loss of load expectation (LOLE) for month M.

2. Model the system again, excluding all capacity of technology T in region R.

   a. This will very likely increase the LOLE for month M, because there is less capacity available to meet system needs. If it does not, then the capacity of technology T in region R does not provide any reliability benefit in month M, at current levels. In other words, there is so little of technology T installed in region R that its output is insufficient to prevent load-shedding at times of system stress. In that case, the base case in step one needs to be modified to simulate a level of penetration that is sufficient to create a measurable reliability benefit. This can be accomplished by returning to step one and modeling additional capacity of T in R. While this modified base case does not represent the actual system, it nevertheless enables accurate calculation of the reliability impact of each incremental MW of technology T in region R.

3. Add a small amount of perfect generation[12] capacity to the model, and recalculate the LOLE for month M (continuing to exclude all capacity of T in R).

4. Repeat step three, stopping when the LOLE for month M is equal to that found in step one.

5. Define the ELCC of technology T in region R and month M to be equal to the total amount of perfect capacity added upon completion of step four, divided by the total capacity of technology T in region R (the sum of P_{max} across all such facilities), as illustrated in Figure 4, below. Referring back to Figure 3 above, this concept can be thought of as taking the MW capacity represented by the "perfect generation" box on the right, and dividing it by the MW capacity represented by the orange "technology T in region R" box on the left hand side. Because perfect generation by definition has a greater contribution to reliability, less of it will be needed to yield the desired LOLE. As a result, the numerator will be less than the denominator, and the ELCC will be below 100%.

Figure 4. ELCC is a ratio of the MW needed to provide identical LOLEs

$$\text{ELCC} = \frac{\text{Perfect MW Added}}{\text{Capacity of T in R (MW)}}$$

Qualifying Capacity (QC) Calculation

As previously discussed, the ELCC percentage is a derating factor applied to the nameplate capacity (P_{max}) of a resource in order to determine its QC. While a monthly ELCC is calculated across all facilities of a given technology and region in aggregate, it is applied to each individual facility to yield a facility-specific QC, according to the following formula: QC = ELCC (%) * P_{max} (MW).

In the future, it is possible that the QC or ELCC calculations could be modified to incorporate facility-specific differences. However, that level of granularity is not under consideration for the 2015 RA compliance year.

Review of ELCC Study Results from Other Agencies and Jurisdictions

While there are slight differences in ELCC methodologies across various studies, and while regional differences significantly impact ELCC results (for example, regions that are windy during the day and early evening are likely to have higher ELCCs for wind than regions where it is primarily windy at night), it is nevertheless helpful to review existing literature and results. Several representative ELCC results are reproduced below. As staff conducts its modeling, results will be compared with these values to ensure reasonableness and understand the causes of any deviations from commonly accepted ELCC ranges.

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[12] Generation with ideal operating characteristics: immediate start-up, infinite ramping capability, no use limitations, and no outages. Perfect generation has a P_{min} of zero. It also has no transmission constraints.

California-specific ELCC Results

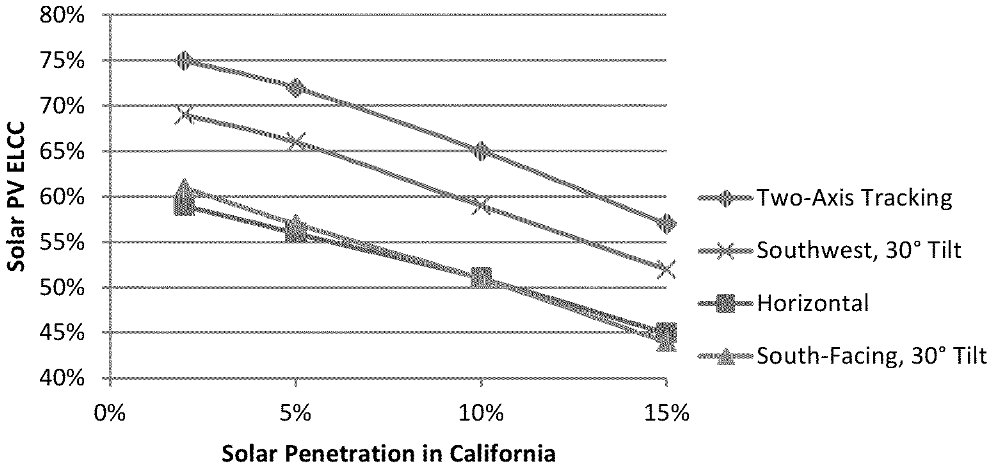
Both NREL and the CEC have conducted ELCC studies calculating wind and solar values that are specific to California. Generally speaking, solar PV ELCCs range from about 60-75% at low penetrations (or higher with natural gas backup), and decrease as penetration increases. This is because very high penetration scenarios likely no longer face significant capacity shortfalls during times when solar PV is generating. As penetration approaches 15%, the NREL findings shown in Figure 4, below, suggest that the ELCC of fixed-tilt solar PV is likely to drop to roughly 44-52%, depending on orientation.

Table 3. Capacity credits calculated for the CEC PIER Program[13]

Resource Type	2002 ELCC		2003 ELCC		2004 ELCC	
	Relative to peak output	Relative to nameplate	Relative to peak output	Relative to nameplate	Relative to peak output	Relative to nameplate
Solar PV <u>with auxiliary gas generators</u>	82%	88%	68%	83%	75%	79%
Wind: Northern California	33%	24%	37%	25%	44%	30%
Wind: San Gorgonio	42%	39%	28%	24%	27%	25%
Wind: Tehachapi	29%	26%	34%	29%	29%	25%

[13] This analysis compares resources to conventional natural gas when calculating ELCC. Each year is a separate run based on historical hourly generation data, and not a Monte Carlo simulation of manyweather years. The report can be found at http://www.energy.ca.gov/2006publications/CEC-500-2006-064/CEC-500-2006-064.PDF.

Figure 4. Solar photovoltaic (PV) ELCC values decrease with PV penetration in California: 2006 NREL study[14]



Concentrating solar power (CSP) must be treated separately from solar PV, however, because it uses a different technology. Its ELCC is also highly dependent on the sizing of the solar field relative to the generation equipment (powerblock), a factor called the *solar multiple* (SM), with higher SMs yielding higher ELCCs. CSP may also include significant onsite thermal energy storage, increasing dispatchability and therefore improving a facility's ELCC. NREL recently conducted a detailed study on methodologies and considerations for calculating the ELCC of CSP facilities (*Capacity Value of Concentrating Solar Power Plants*), and some of the results are reproduced below.[15]

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[14] *Update: Effective Load-Carrying Capability of Photovoltaics in the United States*, NREL, 2006. http://www.nrel.gov/docs/fy06osti/40068.pdf.

[15] *Capacity Value of Concentrating Solar Power Plants*, NREL, 2011. http://www.nrel.gov/docs/fy11osti/51253.pdf. This study assumed parabolic trough technology (likely a lower bound when considering more flexible power tower systems), and assumes CSP operators are able to forecast weather and price perfectly when optimizing plant dispatch (creating slightly inflated values). It calculates capacity values via an ELCC calculation that compares CSP facilities to a natural-gas-fired combustion turbine with an expected forced outage rate of 7%.Data are from 1998-2005.

Figure 5. Average ELCCs of CSP plants without storage, 1998-2005: 2011 NREL CSP study

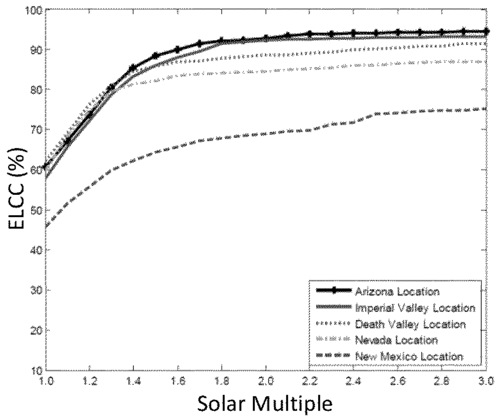
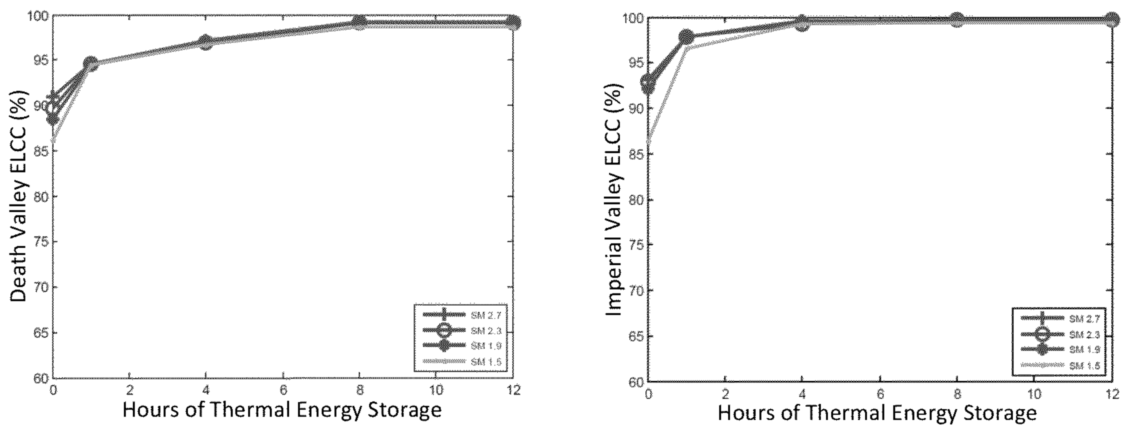


Figure 6. ELCC of CSP with thermal energy storage in Death Valley and Imperial Valley: 2011 NREL CSP study[16]



ELCC Results from Beyond California

For more extensive descriptions of capacity value studies and calculated ELCC values from across North America, parties are encouraged to read the 2012 NREL report, *Summary of Time Period-Based and Other Approximation Methods for Determining the Capacity Value of Wind and Solar in the United States*; that report serves as the source for Table 5, below.

Table 5. Wind and solar capacity values in North America[17]

Region/Utility/Study	ELCC Results	Notes
APS (Arizona)	South-facing, 45-47% Southeast-facing, 33%	Averages based on loss of load expectation (LOLE) simulations for

[16] *Capacity Value of Concentrating Solar Power Plants*, NREL, 2011. http://www.nrel.gov/docs/fy11osti/51253.pdf. These results are taken from NREL's "energy and capacity market" scenario, because that scenario incorporates more reliability-oriented dispatch optimization than the energy-only scenario. Data are from 1998-2005.

[17] Source: *Summary of Time Period-Based and Other Approximation Methods for Determining the Capacity Value of Wind and Solar in the United States*, NREL, 2012. http://www.nrel.gov/docs/fy12osti/54338.pdf.

	Southwest-facing, 56% Single-axis tracking, 70%	2003-2007.
BC Hydro	24% for on- and off-shore wind	Used wind output-duration tables based on synthesized chronological hourly wind data for different regions.
City of Toronto	23-37% for solar PV	Garver ELCC approximation; results depended on location, orientation, and penetration level.
ERCOT	8.7% for wind	Random data: no correlation between wind and load.
Eastern Wind Integration and Transmission Study: NREL/Enernex Corp	16.0-30.5% (with existing transmission system) and 24.1-32.8% (with a new transmission overlay) for wind	
Hydro-Québec	30% for wind	Utilized a Monte Carlo simulation that chronologically matched wind and load data for a 36-year period.
Midwest ISO	12.9% in 2011 and 14.7% in 2012 for wind	
New York: Solar Alliance and the New York Solar Energy Industry Association	For solar PV, by penetration: 2%: 51-90% 10%: 51-74% 20%: 31-44%	
PacifiCorp	8.53% for wind, but decreasing with increasing installed capacity	Utilized a sequential Monte Carlo method to capture variation across different weather years.
PSCO/Xcel (Colorado)	Fixed-tilt PV: 59-63% Single-axis tracking PV: 69-75% Solar thermal parabolic troughs without thermal energy storage: 68-81%	Based on 2004 and 2005 data at three site locations.
Western Wind and Solar Integration Study (AZ, CO, NV, NM, and WY): NREL/GE Energy	Wind: Between 10 and 15%, for 10-30% penetration Solar PV: 25-30% at 1-5% penetration Concentrating Solar Power (CSP) with 6 hours of thermal energy storage: 90-95% at 1-5% penetration.	Parties are encouraged to review this extensive study in more detail. See Section 9, available for download at http://www.nrel.gov/docs/fy10osti/47434.pdf.