ELCC Study for 2030-2031 Mid-Term Reliability Procurement

August 2026

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Acknowledgement: The authors acknowledge the valuable contributions of many individuals to this report and to the underlying analysis, including peer review and input offered by CPUC staff. In particular, the authors would like to acknowledge the analytical, technical, and conceptual contributions of Nathan Barcic, Amin Younes, Brendan Burns, and Emily Turkel.

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Acronym Definitions

Acronym	Definition
CAISO	California Independent System Operator
CPUC	California Public Utilities Commission
D.	Decision
E3	Energy and Environmental Economics
ELCC	Effective Load Carrying Capability
EO	Energy-only
ERM	Energy Resource Modeling
EUE	Expected unserved energy
FR	Filing Requirements
GHG	Greenhouse gas
GW	Gigawatt
HE	Hour ending
IEPR	Integrated Energy Policy Report
IRP	Integrated resource planning
Li-ion	Lithium-ion
LOLE	Loss of load expectation
LOLP	Loss of load probability
LSE	Load-serving entity
MTR	Mid-Term Reliability
MTR-NQC	Mid-Term Reliability net qualifying capacity
MW	Megawatt
MWh	Megawatt-hour
NQC	Net qualifying capacity
PCAP	Perfect capacity
Pmax	Maximum power output
PSP	Preferred System Plan
RA	Resource Adequacy (CPUC program)
RPS	Renewables Portfolio Standard
SB	Senate Bill
SERVM	Strategic Energy and Risk Valuation Model
SOC	State of charge
TPP	Transmission Planning Process

Executive Summary

Purpose

In Decision (D.) 26-02-057, the California Public Utilities Commission (CPUC) issued an Integrated Resource Planning (IRP) procurement order to meet Mid-Term Reliability (MTR) needs for 2030-2032. The CPUC ordered load-serving entities (LSEs) to procure 2,000 megawatts (MW) of effective load carrying capability (ELCC) by June 1, 2030, an additional 2,000 MW ELCC by June 1, 2031, and an additional 2,000 MW ELCC by June 1, 2032, resulting in a cumulative procurement of 6,000 MW ELCC.[1] This report presents technology-specific and storage-duration-specific MTR effective load carrying capability (ELCC) values to be used for compliance with the 4,000 MW ELCC of 2030-2031 IRP procurement ordered by D.26-02-057. Indicative MTR ELCC values for 2032 will be released separately. The study also presents comparisons to previous MTR ELCC studies used for prior IRP procurement orders. MTR ELCC values differ by procurement tranche. Energy and Environmental Economics (E3) and PowerGEM (formerly Astrapé Consulting) produced this study as technical consultants to the CPUC using PowerGEM's Strategic Energy and Risk Valuation Model (SERVM), a stochastic loss of load probability (LOLP) model.

Background

Many renewable energy resource types, such as wind and solar resources, are non-dispatchable and variable in output and are dependent upon external conditions such as weather. Energy-limited resources such as 4-hour lithium-ion (Li-ion) battery storage have constraints on their maximum charge and discharge rates and may also be constrained by available charging energy. Even conventional dispatchable resources such as natural gas combustion turbines can experience forced outages or temperature-related performance degradation. Therefore, a measure of their equivalent capacity is needed so that these resources can be properly accounted for in reliability assessments and procurement. An industry standard for this purpose is ELCC, which measures the equivalent capacity of resources relative to a perfect capacity (PCAP) resource that is always available, is perfectly flexible, and can operate indefinitely.

This study primarily focused on accrediting resources for compliance with the procurement requirements of 2,000 MW ELCC by 2030 and an additional 2,000 MW ELCC by 2031 established in D.26-02-057. While D.26-02-057 ordered LSEs to source at least one-quarter of their total procurement requirements from clean firm resources and/or long-duration storage resources (i.e.,

[1] D.26-02-057 defined these procurement obligations in terms of MW of Net Qualifying Capacity (NQC) but also ordered that the accreditation of resources would be based on ELCC. In the CPUC's Resource Adequacy (RA) program, NQC refers to the deliverability-adjusted qualifying capacity amount that is used for RA compliance. To avoid confusion with the RA definition of NQC, this report uses "MW MTR-NQC" to describe the accredited MW obligations to which CPUC-jurisdictional load-serving entities (LSEs) are subject from the MTR orders. This report uses "MW ELCC" to describe the overall procurement obligations established in D.26-02-057 and the modeling constructs for this study.

1,500 MW ELCC from clean firm resources and/or long-duration storage resources across all LSEs), this study assumed that those resources would not come online until 2032.[2]

Methodology

ELCC measures the equivalent perfect capacity that a resource can provide to meet the CPUC's target reliability standard of one-day-in-ten-year loss of load expectation (i.e., 0.1 LOLE), given an expectation of a total resource portfolio installed at that time. ELCCs provide a standardized, technology-agnostic metric for measuring the contributions of different resource types to reliability in a given resource portfolio. The MTR ELCCs calculated in this study represent the CAISO reliability benefit of a multi-gigawatt tranche of additional resources that LSEs will use to meet the 2030-2031 IRP procurement requirements, analogous to determining the "marginal ELCC" benefit of adding a reasonably small amount of additional MW, which might be done for other similar use cases. For each resource type, the MTR ELCC is the ratio between the equivalent amount of perfect capacity and the incremental nameplate capacity added to the CAISO system, expressed as a percentage.

This study began with the baseline resource portfolio that was used as an input to modeling for CPUC's 2025-2026 and 2026-2027 Transmission Planning Process (TPP) portfolios, plus the minimum resource build needed to achieve full compliance with previous MTR procurement orders;[3] the resulting resource portfolio is referred to as the "MTR-compliant baseline portfolio." The 2030 MTR-compliant baseline portfolio was used as the starting portfolio prior to the 2030-2031 IRP procurement ordered by D.26-02-057. Recognizing that 1) solar and 4-hour storage resources significantly interact with each other and 2) solar and storage are likely to form the bulk of resource additions that LSEs will use for compliance with D.26-02-057 for the 2030 and 2031 procurement tranches, E3 and PowerGEM modeled multiple scenarios for future solar build rates and calculated the potential MTR ELCCs of solar and 4-hour storage for each scenario. In each scenario, E3 and PowerGEM modeled a single tranche of incremental capacity from solar and 4-hour storage, representing a cumulative addition of 4,000 MW ELCC to meet the 2030-2031 IRP procurement requirements. The solar and 4-hour storage MTR ELCCs from the Mid Solar scenario were ultimately selected as the final values.

To calculate the 2030-2031 MTR ELCCs for 8-hour storage, 12-hour storage, 100-hour storage with 1x Pmax charge, and 100-hour storage with 2x Pmax charge, respectively, the study assessed the marginal reliability benefit of a very small amount of additional capacity from each respective resource type on a resource portfolio that included the 4,000 MW ELCC provided by solar and 4-hour storage additions in the Mid Solar scenario.[4] E3 and PowerGEM used heuristic approaches to

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[2] Clean firm resources and long-duration storage resources as defined in D.21-06-035 Ordering Paragraph 2 and as modified by D.25-06-005.

[3] Mid-Term Need Determination Analysis, California Public Utilities Commission, 2025, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/2025_09_need-determination-analysis.pdf.

[4] Pmax is the maximum power output of a resource. 1x Pmax charge means that the maximum power rating (in MW) for charging is equal to the maximum power rating for discharging. 2x Pmax charge means that the maximum power rating for charging is twice as high as the maximum power rating for discharging.

estimate the MTR ELCCs for energy-only solar co-located with fully-deliverable storage and energy-only wind co-located with fully-deliverable storage, based on the alignment of the solar or wind generation profile, respectively, with the storage charging profile. Regarding resource types not explicitly modeled in this study, the MTR ELCC values of wind resources were taken from the marginal ELCC study used for 2026 Filing Requirements (FR) for LSE plans, and LSEs are instructed to use September NQC counting rules for geothermal, hydro, demand response, and other eligible resources.[5]

Results

The MTR ELCCs for 2030-2031 IRP procurement requirements are presented in Table 1. The 2030 marginal ELCCs from the 2026 Filing Requirements (FR) marginal ELCC study and the MTR ELCC values from the last two tranches (2027 and 2028) in the January 2023 Incremental ELCC Study for Mid-Term Reliability Procurement (2023 MTR ELCC study)[6] are shown for comparison. The MTR ELCCs for storage resources presented in Table 1 are applicable to multiple storage technologies, including Li-ion batteries, generic long-duration energy storage, and pumped storage hydro, provided that such storage resources have comparable round-trip efficiencies and durations (see Table 4). As noted in the CPUC Energy Division Staff Memo accompanying this report, results for storage technologies with durations that were not explicitly modeled in this study should be linearly interpolated based on the round-trip efficiency and duration of the procured technology.

[5] Reliability Filing Requirements for Load Serving Entities' 2024-26 Integrated Resource Plans: Results of Marginal ELCC Studies, California Public Utilities Commission, 2026, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/2024-2026-irp-cycle-events-and-materials/reliability-filing-requirements_lses-2024-26_irp-plans_20260210.pdf.

[6] Incremental ELCC Study for Mid-Term Reliability Procurement (January 2023 Update), Astrapé Consulting and Energy and Environmental Economics, 2023, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/20230210_irp_e3_astrape_updated_incremental_elcc_study.pdf.

Table 1. MTR ELCCs for 2030-2031 IRP Procurement Requirements

<table>
<tr><th>Resource Type</th><th colspan="2">2023 MTR ELCC Study for 2027 & 2028 Compliance (Tranches 5 & 6)</th><th>2026 Marginal ELCC Study (LSE Filing Requirements)</th><th>MTR ELCCs From This Study (Tranches 7 & 8)</th></tr>
<tr><td></td><td>2027</td><td>2028</td><td>2030</td><td>2030/2031</td></tr>
<tr><td>Solar</td><td>7.5%</td><td>8.8%</td><td>10%</td><td>10%</td></tr>
<tr><td>4-Hour Storage</td><td>74.0%</td><td>76.5%</td><td>22%</td><td>38%</td></tr>
<tr><td>8-Hour Storage</td><td>87.1%</td><td>90.1%</td><td>39%</td><td>55%</td></tr>
<tr><td>12-Hour Storage</td><td>89.7%</td><td>92.7%</td><td>47%</td><td>59%</td></tr>
<tr><td>100-Hour Storage with 1x Pmax Charge</td><td>N/A</td><td>N/A</td><td>74%</td><td>85%</td></tr>
<tr><td>100-Hour Storage with 2x Pmax Charge</td><td>N/A</td><td>N/A</td><td>N/A</td><td>90%</td></tr>
<tr><td>In-State Wind (NorCal)</td><td rowspan="2">14.0%</td><td rowspan="2">14.7%</td><td>35%</td><td>35%*</td></tr>
<tr><td>In-State Wind (SoCal)</td><td>15%</td><td>15%*</td></tr>
<tr><td>Out-of-State Wind (WY)</td><td>31.7%</td><td>30.9%</td><td>37%</td><td>37%*</td></tr>
<tr><td>Out-of-State Wind (ID/WA/OR)</td><td>N/A</td><td>N/A</td><td>25%</td><td>25%*</td></tr>
<tr><td>Out-of-State Wind (AZ/NM)</td><td>33.7%</td><td>31.9%</td><td>36%</td><td>36%*</td></tr>
<tr><td>Offshore Wind (NorCal)</td><td rowspan="2">44.0%</td><td rowspan="2">44.7%</td><td>57%</td><td>57%*</td></tr>
<tr><td>Offshore Wind (SoCal)</td><td>30%</td><td>30%*</td></tr>
<tr><td>Energy-Only, Co-located Solar</td><td>N/A</td><td>N/A</td><td>N/A</td><td>7.8%**</td></tr>
<tr><td>Energy-Only, Co-located In-State Wind (NorCal)</td><td>N/A</td><td>N/A</td><td>N/A</td><td>6.5%**</td></tr>
<tr><td>Energy-Only, Co-located In-State Wind (SoCal)</td><td>N/A</td><td>N/A</td><td>N/A</td><td>2.6%**</td></tr>
<tr><td>Geothermal</td><td>N/A</td><td>N/A</td><td>87%</td><td>Sept. NQC counting rules at contracting</td></tr>
<tr><td>Small Hydro</td><td>N/A</td><td>N/A</td><td>30%</td><td>Sept. NQC counting rules at contracting</td></tr>
<tr><td>Large Hydro</td><td>N/A</td><td>N/A</td><td>50%</td><td>Sept. NQC counting rules at contracting</td></tr>
<tr><td>Demand Response</td><td>N/A</td><td>N/A</td><td>42%</td><td>Sept. NQC counting rules at contracting</td></tr>
<tr><td>Other</td><td>N/A</td><td>N/A</td><td>N/A</td><td>Sept. NQC counting rules at contracting</td></tr>
</table>

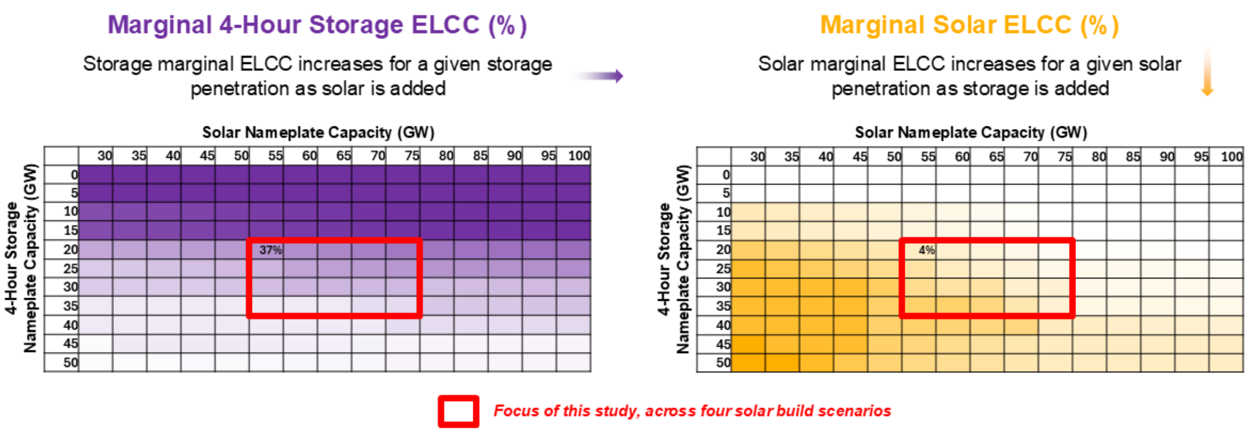
**Technology was not modeled in this study. MTR ELCC is set equal to the 2030 marginal ELCC from the 2026 FR marginal ELCC study.*

***Energy-only co-located resource ELCCs displayed in the table are solely for the purposes of compliance with the D.26-02-057 IRP procurement order and are not an indication of Resource Adequacy value.*

Table Notes: The 2023 MTR ELCC study used blended Northern California/Southern California values for Wind CA and Wind Offshore. In addition, ELCC values for Wind NM and 12-Hour Pumped Storage Hydro from 2023 MTR ELCC study are shown for Out-of-State Wind (AZ/NM) and 12-Hour Storage, respectively. ELCC values for technologies not modeled in previous studies are replaced with N/A (not applicable).

Compared to the 2023 MTR incremental ELCCs and to the 2026 FR marginal ELCC forecast, the primary driver of different ELCC values in this study is different underlying resource portfolios (e.g., more or less solar, storage, and wind); load shape changes associated with the Integrated Energy Policy Report forecast evolution are a secondary driver. Relative to the 2023 MTR ELCC study, storage ELCCs have declined due to higher storage penetration levels and greater energy constraints on the system, while solar ELCCs have increased due to the diversity benefits that storage provides. It is also worth noting that the MTR ELCCs for solar and 4-hour storage are for a multi-gigawatt tranche of additional capacity, whereas the 2026 FR marginal ELCCs represent the reliability benefit of a very small amount of capacity added to a very different portfolio with higher solar and storage penetration. The CAISO system is entering a dynamic portion of the multi-dimensional ELCC surface where resource marginal ELCCs, especially energy storage and solar, are sensitive to portfolio changes. Figure 1, a heatmap of the marginal 4-hour storage ELCCs and the marginal solar ELCCs for various penetrations of solar and 4-hour storage, drawn from a slice of the solar and storage ELCC surface from the 2024-2026 IRP inputs and assumptions, provides one illustration of the strong effect of the resource portfolio on ELCCs. The ELCC Comparison to Past Studies section of this report explains why and how ELCC values shift from study to study in more detail. The fact that ELCC values evolve as system portfolios change and as new weather and operational data become available is a key benefit of the methodology that supports continuous improvement in the CPUC's reliability framework for Integrated Resource Planning.

Figure 1. Slice of RESOLVE Solar-Storage ELCC Surface and Studied Subsection



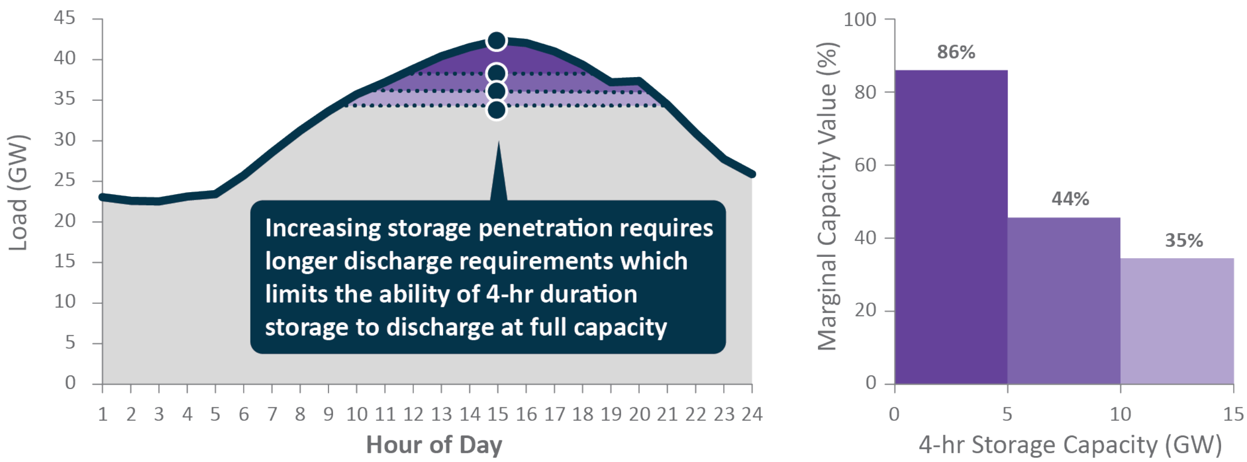
Background and Methodology

IRP Reliability Modeling and Uses of ELCCs

Reliability modeling is a foundational element of the CPUC's Integrated Resource Planning (IRP) program, ensuring that both the planning and procurement track generate portfolios that meet the CPUC's minimum reliability standard of no more than one-day-in-ten-year loss of load expectation (0.1 days/year LOLE), amidst evolving loads and resource portfolios. Effective Load Carrying Capability (ELCC) values are a critical component of IRP modeling and procurement compliance with multiple types of studies with different use cases.

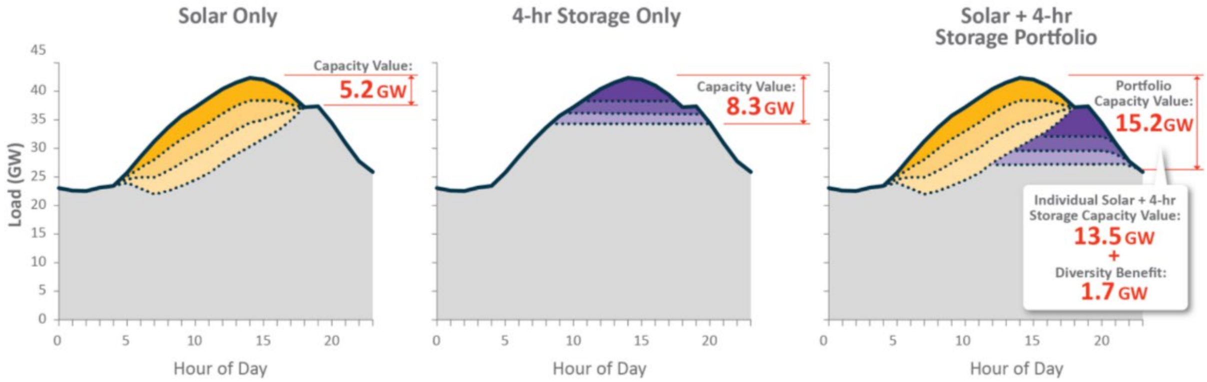
The reliability contributions of renewable and energy-limited resources decline with greater penetrations of such resources in the system's portfolio. For example, adding more 4-hour storage resources to the system flattens the net peak load and extends the time period over which storage must discharge, reducing its ability to discharge at full capacity. Figure 2 illustrates the diminishing marginal effectiveness of storage at higher penetrations. The result is that over time, as more storage is added to the system, the marginal ELCC decreases. These dynamics are often referred to as "saturation effects."

Figure 2. Diminishing Marginal Reliability Contributions of Storage



In addition to ELCC dynamics within a resource type (e.g., storage), there are ELCC dynamics between resource types, which are referred to as "diversity benefits." This concept is illustrated in Figure 3 below, which shows that solar and energy storage added together provide more than the sum of their parts. Energy storage shifts the peak back to the higher solar production hours, during which solar can both charge energy storage and narrow the residual net peak period that storage must serve as solar production wanes.

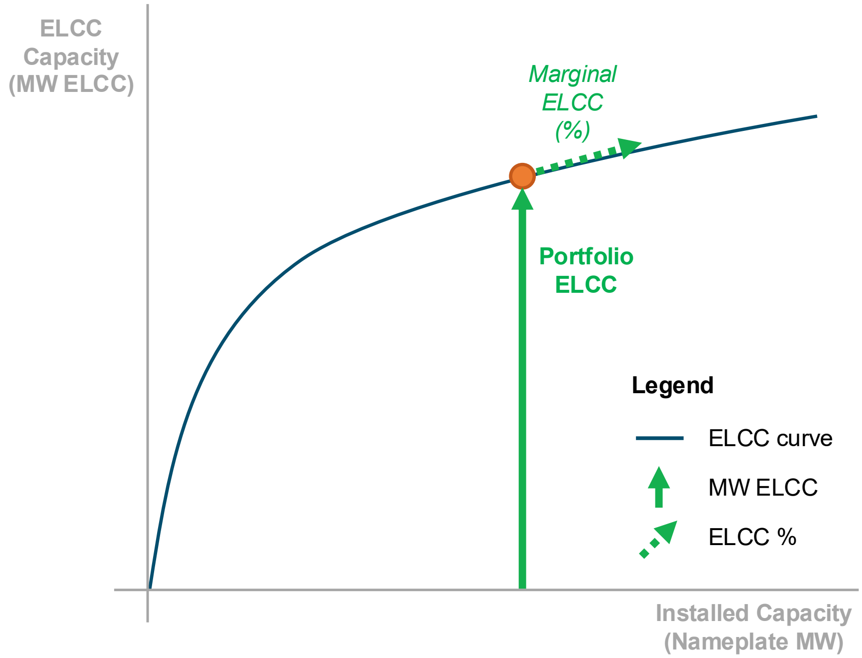
Figure 3. Schematic of Diversity Benefits between Solar and 4-Hour Storage[7]



Accurately capturing saturation effects and diversity benefits is a key feature of all types of ELCC calculations. Figure 4 illustrates two types of ELCC calculations common in IRP reliability modeling and how they relate to the existing resource portfolio: portfolio ELCC and marginal ELCC. Portfolio ELCC measures the combined reliability contributions of a portfolio of resources in terms of equivalent perfect capacity, capturing the interactive effects, diversity benefits, and saturation effects among multiple resource types. Portfolio ELCC is typically expressed in terms of MW of equivalent perfect capacity, denoted in this study as ELCC capacity or MW ELCC. Marginal ELCC measures the reliability benefit of adding a reasonably small amount of MW of a specific resource to an existing portfolio compared to the reliability benefit of adding perfect capacity. When this additional MW represents the last MW of capacity added to a portfolio, this is also called the "last-in" marginal ELCC. Marginal ELCC is typically calculated as the ratio between the reliability benefit of adding a small amount of a resource to the system and the nameplate capacity added, expressed as a percentage. For example, if the reliability benefit of adding 1 MW nameplate of a specific resource type is equivalent to the reliability benefit of adding 0.1 MW of perfect capacity, then the marginal ELCC of the resource type would be 10%.

[7] "Capacity and Reliability Planning in the Era of Decarbonization: Practical Application of Effective Load Carrying Capability in Resource Adequacy," Energy and Environmental Economics, 2020, https://www.ethree.com/wp-content/uploads/2020/08/E3-Practical-Application-of-ELCC.pdf.

Figure 4. Illustration of Portfolio ELCC and Marginal ELCC



In the procurement context, larger amounts of additional capacity can be added to the system. If the marginal ELCC changes significantly between the first MW of new capacity added (first-in marginal ELCC) and the last MW of new capacity added (last-in marginal ELCC), then it may be appropriate to calculate an ELCC value for this entire "tranche" of additional capacity that will generally fall between the first-in and last-in marginal ELCCs. This calculation approach accounts for the range of marginal reliability benefits across the volume of new resource procurement. In previous ELCC studies such as the January 2023 Incremental ELCC Study for Mid-Term Reliability Procurement (2023 MTR ELCC study),[8] this type of ELCC metric was referred to as "incremental ELCC." The term "MTR ELCC" is used in this study since this is the ELCC metric that was calculated for compliance with the 2030-2031 IRP procurement order. Figure 5 illustrates the relationships between first-in marginal ELCC, last-in marginal ELCC, the ELCC capacity of the tranche, and the MTR ELCC. This is a simplified example showing a tranche that has only one type of resource. In this study, two different types of resources were included in the tranche of additional ELCC capacity, and the diversity benefits associated with this combination of resources were allocated between the two resource types using the delta method. The specific methodology used to calculate the MTR ELCCs in this study is described in greater detail under ELCC Calculation Methodology.

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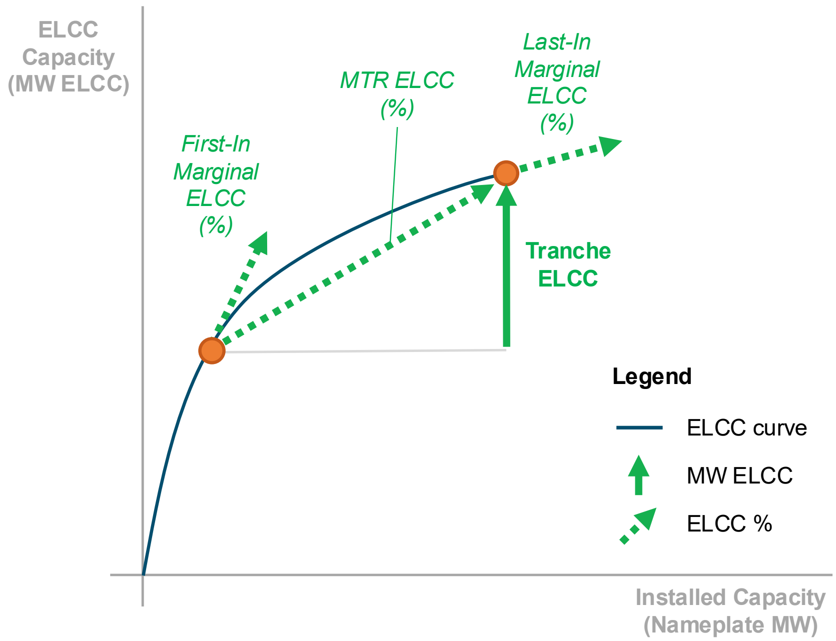
[8] Incremental ELCC Study for Mid-Term Reliability Procurement (January 2023 Update), Astrapé Consulting and Energy and Environmental Economics, 2023, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/20230210_irp_e3_astrape_updated_incremental_elcc_study.pdf.

Figure 5. Types of ELCC Metrics Used in This Study



Portfolio ELCC, marginal ELCC, and MTR ELCC studies serve different purposes in the context of integrated resource planning and procurement. Table 2 provides an overview of CPUC's ELCC studies and their use cases, all of which are performed using the Strategic Energy and Risk Valuation Model (SERVM).

First, multiple ELCC studies are conducted to develop the inputs for long-term capacity expansion modeling in RESOLVE, such as the modeling of the Preferred System Plan (PSP) and Transmission Planning Process (TPP) portfolios. These studies are detailed in the 2024-2026 Integrated Resource Planning Inputs and Assumptions Report. [9] A stack of ELCCs captures baseline resource contributions. A set of ELCC curves, a multi-dimensional solar-storage ELCC surface, and resource-specific multipliers capture the incremental value of additions of wind, solar, storage, and demand response. Since the ELCC curves and surfaces must sample from a very large potential solution space of future resource additions, their granularity is relatively coarse and the marginal ELCCs reported in the RESOLVE Results Viewer are not precise enough to support near-term procurement decisions.

Second, once a single RESOLVE system portfolio is selected from the long-term planning scenarios, marginal ELCC studies are used for load-serving entity (LSE) IRP Filing Requirements to capture the marginal reliability value of different resource types as that resource portfolio and the loads evolve

[9] 2024-2026 Integrated Resource Planning Inputs and Assumptions, California Public Utilities Commission, 2026, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/2024-2026-irp-cycle-events-and-materials/2025_inputs_and_assumptions_report_20260210.pdf.

over time. Marginal ELCCs provide an economically efficient signal for selecting new resources to meet reliability needs because they reflect the reliability benefit of the next unit of capacity under current (or future expected) system conditions. Their use in the Filing Requirements guides LSEs to select economically optimal resource mixes amidst evolving marginal resource contributions of the system.

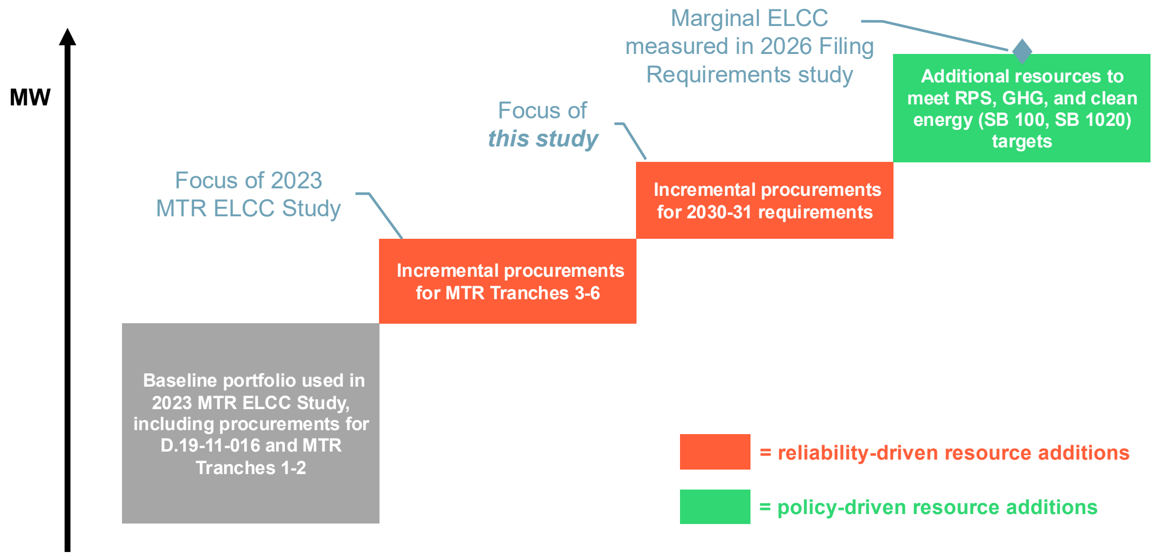
Third, MTR ELCC studies, like the calculation approach for solar and storage in this study, are similar to marginal ELCC studies but capture the value of larger levels of resource additions. These are used for CPUC procurement orders for multiple gigawatts of new resource capacity, like the levels studied herein.

Table 2. Types of ELCC Studies Used in CPUC IRP

Study	Description	Use Case(s) in CPUC IRP	Frequency
RESOLVE Long-Term Planning Inputs	Derive relatively coarse ELCC curves and surfaces for a broad range of possible future portfolios	ELCC inputs to long-term capacity expansion modeling to generate portfolios for the PSP, TPP, and Filing Requirements	Updated at the start of each new IRP cycle (with mid-cycle refinements as needed)
Marginal ELCCs for Filing Requirements	Calculate resource marginal ELCCs for a specific planning portfolio	Resource accreditation and need determination in LSE plan Filing Requirements	Updated prior to LSE plan development
MTR ELCCs for Procurement Orders	Calculate MTR ELCCs for a larger amount of resource additions as dictated by CPUC procurement orders	Compliance with CPUC procurement orders (e.g., MTR, D.26-02-057)	As-needed basis when CPUC orders new reliability procurement

In D.26-02-057, the CPUC ordered the procurement of 2,000 MW ELCC by June 1, 2030, an additional 2,000 MW ELCC by June 1, 2031, and an additional 2,000 MW ELCC by June 1, 2032. This study sets ELCC values to be used for compliance with the 2030 and 2031 procurement requirements, with a total combined capacity of 4,000 MW ELCC; a future study will determine the ELCC values for the 2032 procurement requirement. Figure 6 below illustrates how this study relates to other recent ELCC studies. Notably, the portfolio used in this study does not include the additional resources identified in recent RESOLVE modeling needed to meet Renewables Portfolio Standard (RPS), greenhouse gas (GHG) targets, and statewide clean energy goals (e.g., Senate Bill 100 and Senate Bill 1020), which were included in the portfolio used in the marginal ELCC study for 2026 Filing Requirements. As a result, the ELCC values produced in this study reflect less extreme saturation effects for resources such as solar and storage.

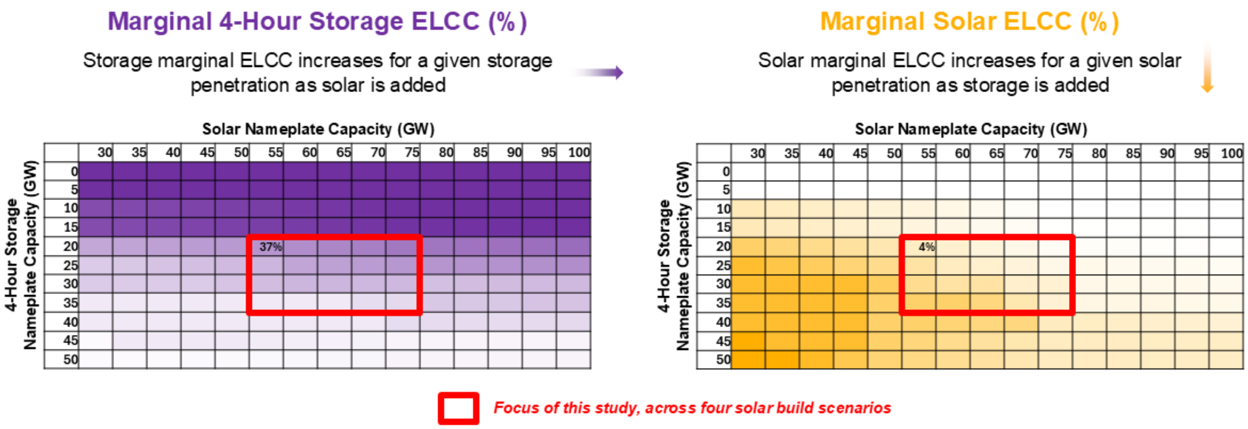
Figure 6. Schematic of Relationships Between Recent ELCC Studies



Contextualizing Solar and Storage ELCC Dynamics

A slice of the solar and storage ELCC surface from the 2024-2026 IRP inputs and assumptions is shown in Figure 7. This figure provides a heatmap indicating the marginal 4-hour storage ELCCs and the marginal solar ELCCs for various penetrations of solar and 4-hour storage while holding the 8-hour storage capacity constant, allowing a three-dimensional solar-storage surface to be represented in this two-dimensional format. The 4-hour storage ELCC and solar ELCC heatmaps are nearly a perfect inverse of one another, clearly displaying the interactive effects between the two resources and the fact that the reliability benefit of one resource is dependent on having sufficient capacity of the other. This large surface was generated from SERVM for use in RESOLVE capacity expansion, whereby the optimization is granted wide freedom to test the reliability and economics of traversing in multiple directions across the surface. The red boxes in Figure 7 represent the portion of the surface that this study examines in greater detail. The upper left-hand corner of each box roughly corresponds to the installed capacities of solar and storage in the MTR-compliant baseline portfolio in 2030. Notably this is a key region of the surface where solar and storage interactive effects become pronounced and storage ELCCs decline dramatically without additional concurrent solar additions.

Figure 7. Slice of RESOLVE Solar-Storage ELCC Surface and Studied Subsection



Study Design

This study calculated MTR ELCC values for six resource types using SERVM: solar, 4-hour storage, 8-hour storage, 12-hour storage, 100-hour storage with 1x Pmax charge, and 100-hour storage with 2x Pmax charge.[10] In addition, MTR ELCC values for new energy-only solar and in-state wind (with separate calculations for Northern California and Southern California) resources that are co-located with fully-deliverable storage were estimated using a heuristic approach. The design of this study is similar to that of previous MTR ELCC studies, including the 2023 MTR ELCC study. One notable difference is the consideration of multiple solar and storage build scenarios. Recognizing that (1) solar and storage resources significantly interact with each other, (2) solar and storage are likely to form the bulk of resource additions in 2030 and 2031, and (3) the level of solar build is uncertain, E3 and PowerGEM determined that it was appropriate to model multiple scenarios for future solar build rates and calculate the MTR ELCCs of solar, 4-hour storage, and 8-hour storage for each scenario. Instead of calculating two sets of MTR ELCCs for 2030 and 2031, E3 and PowerGEM calculated the MTR ELCCs for 2030-2031 with one tranche of new capacity for each resource type, representing a cumulative addition of 4,000 MW ELCC. CPUC staff then selected a particular scenario to use for modeling the 2030/2031 ELCCs of the other resource types. The same scenario was also used for modeling the forthcoming indicative 2032 ELCCs.

This study followed these steps, explained in more detail later in this report:

1. Add at least 4,000 MW of perfect capacity to the MTR-compliant baseline portfolio for 2030 and retire thermal units until the system is recalibrated to 0.1 LOLE

[10] Pmax is the maximum power output of a resource. 1x Pmax charge means that the maximum power rating (in MW) for charging is equal to the maximum power rating for discharging. 2x Pmax charge means that the maximum power rating for charging is twice as high as the maximum power rating for discharging.

2. Calculate "first-in" marginal ELCCs[11] for solar, 4-hour storage, and 8-hour storage and estimate "first-in" marginal ELCCs for 12-hour storage, 100-hour storage with 1x Pmax charge, and 100-hour storage with 2x Pmax charge
3. Design four solar build scenarios to represent near-term solar build rates through 2031: Low Solar, Mid-Low Solar, Mid Solar, and High Solar
4. For each solar build scenario, remove 4,000 MW of perfect capacity, add solar capacity based on pre-defined build rate, and determine amount of 4-hour storage required to fill the remaining need, i.e., restore system to 0.1 LOLE
5. Calculate "last-in" marginal ELCCs[12] for solar, 4-hour storage, and 8-hour storage for each solar build scenario
6. Calculate MTR ELCCs for solar, 4-hour storage, and 8-hour storage under each solar build scenario
7. Select one solar build scenario to use for modeling "last-in" marginal ELCCs for other resource types
8. Calculate "last-in" marginal ELCCs for 12-hour storage, 100-hour storage with 1x Pmax charge, and 100-hour storage with 2x Pmax charge
9. Calculate MTR ELCCs for 12-hour storage, 100-hour storage with 1x Pmax charge, and 100-hour storage with 2x Pmax charge
10. Identify critical hours using the energy equity method
11. Estimate marginal ELCCs for energy-only solar and wind co-located with storage based on alignment of solar, wind, and storage charging profiles on critical days
12. Set MTR ELCCs for non-modeled resources equal to the 2030 marginal ELCCs from the marginal ELCC study for 2026 Filing Requirements

ELCC Calculation Methodology

Probabilistic reliability modeling is used for ELCC calculations because it produces robust estimates of reliability contributions across decades of system conditions and captures interactive effects between new resource additions and the existing system fleet. This study used PowerGEM's stochastic LOLP reliability model SERVM. SERVM's modeling approach ensures that the reliability impact of resource additions is evaluated across a broad range of weather patterns via historical weather years, economic growth scenarios, and outage conditions.

When assessing ELCC, either the addition of perfect load (i.e., flat load) or the removal of perfect capacity (i.e., a dispatchable generator with no forced or planned outages) can be used. This study used the perfect capacity method. In addition to being always available, a perfect capacity (PCAP) resource has no energy limitations: it does not need to recharge, carries no round-trip efficiency losses, and its availability in any hour is independent of how it was operated in prior hours. Because

[11] First-in marginal ELCC is the marginal ELCC of the first MW of a particular resource type added in this study to the recalibrated MTR-compliant baseline portfolio.

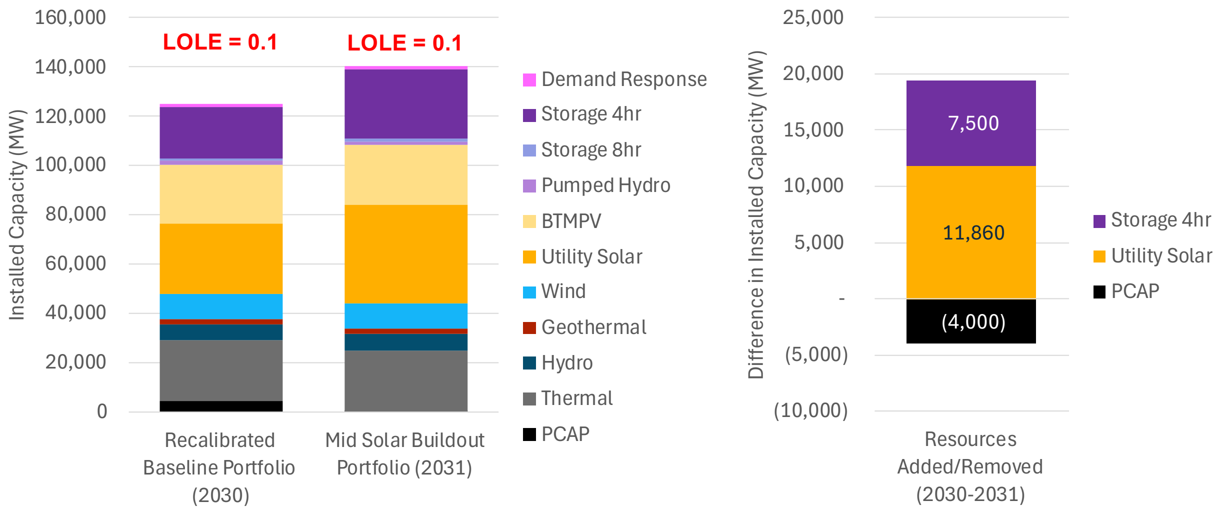
[12] Last-in marginal ELCC is the marginal ELCC of the last MW of a particular resource type added in this study. If the resource does not have any installed capacity in the portfolio, then a very small amount of capacity is added to the portfolio to test its potential reliability benefit, and the last-in marginal ELCC is the marginal ELCC of that addition.

it is modeled as a generation resource, its output can serve load directly or charge storage resources when doing so avoids subsequent loss of load. Perfect capacity therefore both covers shortfall hours and helps replenish energy-limited resources between them. A PCAP resource could be modeled as a “first in the stack” firm resource (i.e., a resource dispatched before other dispatchable resources), or as a “last in the stack” firm resource (i.e., a peaking resource dispatched after other dispatchable resources when required to avoid loss of load). With the “last in the stack” method, the PCAP resource is only operated in a manner to avoid loss of load risk versus operating in a way that changes the operations of the rest of the existing fleet. Thus, the “last in the stack” method results in less distortion of the ELCC values of other resources and is used in this study. For a more detailed discussion of the strengths and weaknesses of perfect load vs. perfect capacity methods, see the January 2023 Incremental ELCC Study for Mid-Term Reliability Procurement.[13]

The first step in SERVM modeling for this study was to add at least 4,000 MW of PCAP to the MTR-compliant baseline portfolio for 2030 and to retire thermal units until the system was recalibrated to 0.1 days/year LOLE. The PCAP was added so that it could later be removed during the MTR ELCC calculations. Next, the first-in marginal ELCCs for solar, 4-hour storage, and 8-hour storage were calculated based on their marginal ELCCs in the recalibrated MTR-compliant baseline portfolio, before adding additional resources to satisfy the procurement order. Then, 4,000 MW of the previously added PCAP was removed, and an incremental amount or “tranche” of solar and storage resources was added until the system returned to the 0.1 days/year LOLE target. The ELCC capacity of the tranche was therefore equal to 4,000 MW ELCC, the cumulative procurement requirement for 2030-2031, and the “last-in” marginal ELCCs for all resource types modeled in this study were calculated after the tranche buildout. Figure 8 shows how the portfolio evolved between the first-in marginal ELCC calculations (using the recalibrated MTR-compliant baseline portfolio) and the last-in marginal ELCC calculations (using the buildout portfolio from the Mid Solar scenario). In practice, each portfolio configuration was simulated across a range of perfect capacity levels, and the perfect capacity corresponding to 0.1 days/year LOLE was determined from a log-linear fit of LOLE as a function of perfect capacity.

[13] Incremental ELCC Study for Mid-Term Reliability Procurement (January 2023 Update), Astrapé Consulting and Energy and Environmental Economics, 2023, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/20230210_irp_e3_astrape_updated_incremental_elcc_study.pdf.

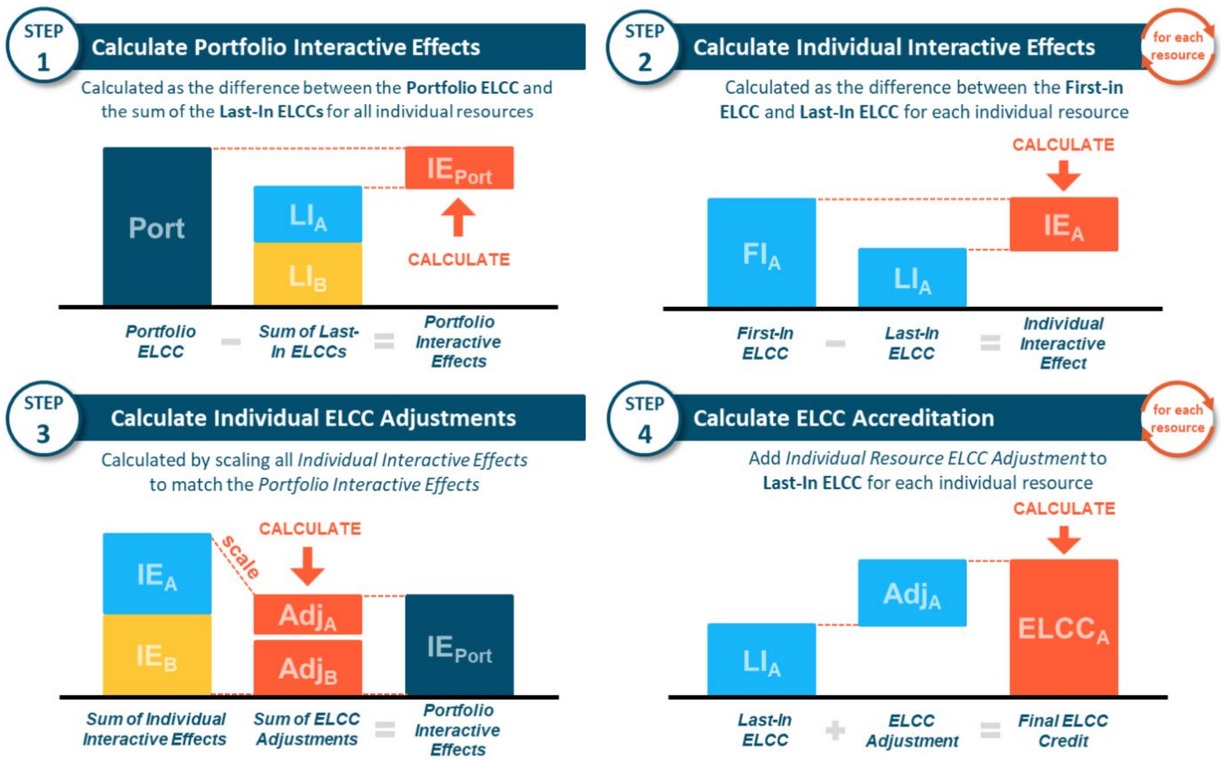
Figure 8. Comparison of Recalibrated Baseline and Mid Solar Buildout Portfolios



When solar and storage are added together, they provide diversity benefits that make a tranche of solar and storage resources contribute more to reliability than the sum of their individual ELCCs. In this study, E3's delta method (depicted in Figure 9) was used to calculate the MTR ELCCs for solar, 4-hour storage, 8-hour storage, 12-hour storage, 100-hour storage with 1x Pmax charge, and 100-hour storage with 2x Pmax charge.[14] Although only solar and 4-hour storage were included in the tranche to meet the 4,000 MW ELCC need, the delta method can still be used to interpolate between the first-in and last-in marginal ELCCs for other resource types and adjust for diversity benefits by assuming that marginal amounts (e.g., 1 MW each) of the other resources are added to the portfolio. The delta method credits each resource in a manner that reflects the nature of their synergistic, antagonistic, or neutral interactions with the rest of the portfolio by adjusting each resource's last-in marginal ELCC based on the difference from its first-in marginal ELCC as well as allocating diversity benefits derived from the difference between the portfolio ELCC and the last-in marginal ELCCs. Applying the delta method to the MTR ELCC calculations in this study essentially meant treating the "tranche" of added resources as a mini portfolio. Specifically, the ELCC capacity of the tranche was used in place of the portfolio ELCC shown in Figure 9, and the first-in and last-in marginal ELCCs represented the marginal ELCCs of the first 1 MW and last 1 MW of each resource type in the tranche. All ELCC metrics shown in Figure 9 are in units of MW ELCC. The MTR ELCC values were calculated by dividing the final ELCC credits (in MW ELCC) represented in Step 4 of Figure 9 by the amount of new installed capacity of each resource type in the tranche.

[14] For additional background information on E3's delta method, refer to: "Capacity and Reliability Planning in the Era of Decarbonization: Practical Application of Effective Load Carrying Capability in Resource Adequacy," Energy and Environmental Economics, 2020, https://www.ethree.com/wp-content/uploads/2020/08/E3-Practical-Application-of-ELCC.pdf.

Figure 9. Delta Method ELCC Calculation Methodology



Inputs and Assumptions

Starting Portfolio and Calibration

The starting portfolio used in SERVM for this study was the MTR-compliant baseline portfolio in 2030, which represents the baseline portfolio used in CPUC's 2025-2026 and 2026-2027 TPP portfolios modeling plus the minimum resource build needed to comply with MTR procurement orders in D.21-06-035 and D.23-02-040, as modified by D.24-02-047.[15] Table 3 shows the installed capacity by resource type for the MTR-compliant baseline portfolio in 2030. Consistent with the 2028-2032 need determination study presented in Administrative Law Judge's ruling issued in R.25-06-019 on September 30, 2025,[16] this study used the CAISO load forecast from the planning scenario in the 2024 Integrated Energy Policy Report (IEPR).

Before the ELCC calculations, perfect capacity was added to the MTR-compliant baseline portfolio so that it could later be removed during the ELCC calculation process. In addition, the portfolio was recalibrated to the 0.1 days/year LOLE reliability standard, which required retiring some thermal units. In the recalibration process, 3,750 MW of the oldest thermal units were retired, and perfect capacity was added in 250 MW units. The system was simulated at several perfect capacity levels, and 4,250 MW was selected as the level closest to 0.1 days/year LOLE. During the MTR ELCC calculations later in the study process, 4,000 MW of this perfect capacity was removed, leaving 250 MW in place.

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[15] Mid-Term Need Determination Analysis, California Public Utilities Commission, 2025, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/2025_09_need-determination-analysis.pdf.

[16] Administrative Law Judge's Ruling Seeking Comments on Electricity Portfolios for 2026-2027 Transmission Planning Process and Need for Additional Reliability Procurement, California Public Utilities Commission, 2025, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M582/K082/582082526.PDF

Table 3. Composition of MTR-Compliant Baseline Portfolio in 2030[17]

Unit Category	Nameplate Capacity (MW)
Natural Gas	26,398
Cogen	2,365
Nuclear	635
Geothermal	2,240
Biomass/Biogas	837
Hydro	9,144
In-State Wind	6,605
Out-of-State Wind	3,621
Utility Solar	28,356
Behind-the-Meter Solar	24,593
4-Hour Storage	20,662
8-Hour Storage	1,043
Pumped Hydro Storage	1,643
Demand Response	3,438

SERVM Modeling Assumptions

This analysis used the CPUC Energy Resource Modeling (ERM) team's latest SERVM database as of December 2025, with its existing load and resources data across 23 weather years (2000-2022), but the database was converted to SERVM version 2026.2 at the beginning of this analysis. SERVM version 2026.2 is a newer SERVM version than version 10, which was used for the marginal ELCC study for 2026 Filing Requirements and is currently used by the CPUC ERM team. As SERVM software is improved, newer versions with improved performance become available over time. Key changes to SERVM between version 10 and version 2026.2 include multi-day discharging in the energy equity method used to create critical hours heatmaps. Notably, this study used the same planned maintenance logic and storage dispatch charging and discharging prioritization used in the marginal ELCC study for 2026 Filing Requirements, although updates were made to enable storage-to-storage charging, which are described in the next paragraph.

Solar and storage modeling assumptions were similar to previous ELCC studies. For new solar resources, a single CAISO-wide profile was used for each of the 23 historical weather years (2000-2022), constructed as the average shape across all CAISO solar weather stations and scaled to the nameplate capacity of new solar in the tranche under study. The new storage resources were modeled as dispatchable, energy-limited units within SERVM's 8,760-hour chronological economic dispatch, alongside all other dispatchable resources. The round-trip efficiency and duration assumptions for each new storage resource are shown in Table 4 and are consistent with the 2024-

[17] Capacities are shown in nameplate MW per RESOLVE portfolio reporting, consistent with slide 22 of Slides on Need Determination Analysis (2025). Note that SERVM portfolio reporting is often reported in monthly NQC (for a summer month), rather than nameplate capacity, for various technologies, including cogeneration, geothermal, biomass/biogas, hydro, and demand response.

2026 Integrated Resource Planning Inputs and Assumptions Report.[18] Each new storage resource was modeled as a 250 MW unit. The maximum charge rate was set equal to the 250 MW maximum discharge rate except for the 100-hour storage with 2x Pmax charge resource, which had a doubled (500 MW) maximum charge rate. Storage-to-storage charging for the 100-hour storage resources, which allowed the 100-hour resource to charge the shorter-duration storage fleet during surplus hours, was enabled when it provided a system reliability benefit. E3 and PowerGEM found that this was true for 100-hour storage with 2x Pmax charge but not true for 100-hour storage with 1x Pmax charge. No changes were made to the representation of existing solar and storage resources in ERM's SERVM database.

Table 4. Storage Round-trip Efficiencies and Durations

Resource Type	Round-trip Efficiency	Duration (hours)
4-Hour Storage	85%	4
8-Hour Storage	85%	8
12-Hour Storage	65%	12
100-Hour Storage with 1x Pmax Charge	45%	100
100-Hour Storage with 2x Pmax Charge	45%	100

Other changes to the SERVM database for this study were limited. The portfolio calibration changes (thermal retirements and the addition of perfect capacity) are described in the Starting Portfolio and Calibration section. Transmission constraints between zones within the CAISO system were removed to allow for unconstrained transfers. No changes were made to forced outage rate assumptions; the incremental 250 MW battery units have the same outage characteristics as existing CAISO battery units. Unless otherwise described in this report, the remaining inputs and assumptions were consistent with the 2024-2026 Integrated Resource Planning Inputs and Assumptions Report.[19]

Solar Build Scenarios

Solar and 4-hour storage resources are likely to form the bulk of resource additions in 2030 and 2031 based on the CAISO interconnection queue and recent procurement trends. In addition, these resource types have significant interactive effects and each resource type's ELCC is highly dependent on the relative penetration level of the other. Therefore, multiple scenarios for future

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[18] 2024-2026 Integrated Resource Planning Inputs and Assumptions, California Public Utilities Commission, 2026, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/2024-2026-irp-cycle-events-and-materials/2025_inputs_and_assumptions_report_20260210.pdf.

[19] 2024-2026 Integrated Resource Planning Inputs and Assumptions, California Public Utilities Commission, 2026, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/2024-2026-irp-cycle-events-and-materials/2025_inputs_and_assumptions_report_20260210.pdf.

solar build rates were modeled and calculations performed for the MTR ELCCs of solar, 4-hour storage, and 8-hour storage in each scenario.

The four scenarios—Low Solar, Mid-Low Solar, Mid Solar, and High Solar—were designed based on different build rate projections for solar. In the Low Solar scenario, E3 and PowerGEM projected that the build rate through 2031 would be equal to the 2020-2024 average build rate for solar. Based on the CAISO's Master Control Area Generating Capability List downloaded from the CAISO Open Access Same-Time Information System in March 2026, the 2020-2024 average solar build rate was 1,487 MW nameplate per year.[20] The 2020-2024 average build rate was used as the lower bound of solar builds because the solar build rates have accelerated in recent years; the 2023-2024 average build rate was 2,117 MW per year. The Mid-Low Solar scenario projects a build rate of 2,125 MW per year from 2027 to 2031, roughly equal to the 2023-2024 average build rate. The Mid Solar scenario projects continued growth in the solar deployment rate, at 2,965 MW per year. The High Solar scenario projects a more aggressive build rate of 4,461 MW per year. The final solar builds added to the recalibrated MTR-compliant baseline portfolio in SERVM for all scenarios are shown in Table 5, which reflects the solar additions based on the projected build rate for each scenario through 2031.

For each scenario, the solar nameplate capacity shown in Table 5 was added to the system and 4,000 MW of PCAP was removed. Then, 4-hour storage was added until the system was restored to 0.1 days/year LOLE. At first, E3 and PowerGEM planned to allow 8-hour storage additions if 8-hour storage was more cost-effective than 4-hour storage. E3 and PowerGEM considered using the Expansion Planning feature in SERVM or a manual heuristic-based approach to determine the most cost-effective buildout. For the manual approach, PowerGEM compared the marginal ELCC ratio of 8-hour to 4-hour storage to the capital cost ratio provided by E3 based on E3's RECOST model and added 8-hour storage if the marginal ELCC ratio was higher than the cost ratio. However, after calculating the MTR ELCCs using the delta method, the ratio of 8-hour storage ELCC to 4-hour storage ELCC was generally lower than the cost ratio and therefore was not cost-effective for the tranche as a whole. Thus, only 4-hour storage was ultimately added to fill the rest of the tranche after the solar build. The solar and storage nameplate capacities added in each solar build scenario are provided in Table 5.

Table 5. Added Solar and Storage Capacity to Fill the 4 GW ELCC Tranche by Scenario

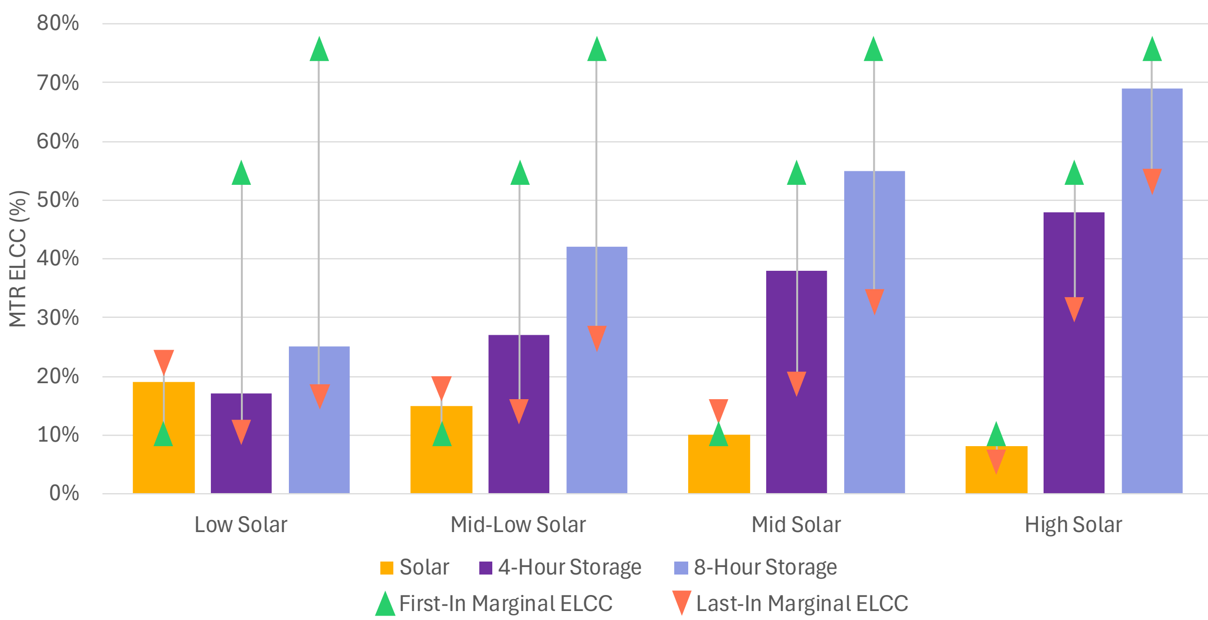
Solar Build Scenario	Added Solar Capacity (MW Nameplate)	Added 4-Hour Storage Capacity (MW Nameplate)	Added Total Capacity (MW Nameplate)
Low Solar	5,913	17,000	22,913
Mid-Low Solar	8,500	10,000	18,500
Mid Solar	11,860	7,500	19,360
High Solar	17,807	5,250	23,057

MTR ELCCs for each solar build scenario were calculated with the delta method, using the first-in and last-in marginal ELCCs as inputs. Figure 10 shows the solar, 4-hour storage, and 8-hour storage

[20] CAISO Open Access Same-Time Information System data is available at https://oasis.caiso.com/mrioasis/logon.do.

MTR ELCCs calculated for each solar build scenario. The first-in and last-in marginal ELCCs are also superimposed in the green and red triangles, with a line between them showing the spread. Although no 8-hour storage capacity was added in the study tranche, the delta method can still be used to interpolate between the first-in and last-in marginal ELCCs and adjust for diversity benefits by adding a marginal amount (i.e., 1 MW) of 8-hour storage capacity to the portfolio. As seen in Figure 10, the MTR ELCCs are between the first-in and last-in marginal ELCCs. While the last-in marginal ELCC for storage tends to be lower than its first-in marginal ELCC, this is not always true for solar. Diversity benefits between solar and storage can cause the last-in marginal ELCC of solar to be higher than its first-in marginal ELCC. Some of those diversity benefits get reallocated to storage after the MTR ELCCs are calculated with the delta method.

Figure 10. Solar, 4-Hour Storage, and 8-Hour Storage MTR ELCCs by Scenario



Of the four scenarios, the Mid Solar scenario was selected for modeling the 2030/2031 ELCC values of the resource types analyzed in this study. As displayed in Table 6, under the Mid Solar scenario, the addition of over 19,000 MW of new resources attributable to the order yielded the assumed resource portfolio for 2031.

Table 6. Composition of 2031 Resource Portfolio in Model[21]

Unit Category	2030 Baseline Portfolio, Nameplate Capacity (MW)	Modeled 2030-31 Additions From Order, Nameplate Capacity (MW)	Modeled 2031 Resource Portfolio, Nameplate Capacity (MW)
Natural Gas	26,398		26,398
Cogen	2,365		2,365
Nuclear	635		635
Geothermal	2,240		2,240
Biomass/Biogas	837		837
Hydro	9,144		9,144
In-State Wind	6,605		6,605
Out-of-State Wind	3,621		3,621
Utility Solar	28,356	11,860	40,216
Behind-the-Meter Solar	24,593		24,593
4-Hour Storage	20,662	7,500	28,162
8-Hour Storage	1,043		1,043
Pumped Hydro Storage	1,643		1,643
Demand Response	3,438		3,438
Nameplate Total	*131,580*	*19,360*	*150,940*

The Mid Solar scenario was also used for calculating the indicative ELCC values for 2032, which are outside the scope of this report. Table 7 shows the first-in marginal ELCCs, last-in marginal ELCCs, and MTR ELCCs for 12-hour storage, 100-hour storage with 1x Pmax charge, and 100-hour storage with 2x Pmax charge for the Mid Solar scenario. For these resources, the last-in marginal ELCCs were derived from SERVM modeling, but the first-in marginal ELCCs were estimated by multiplying the first-in marginal ELCC for 8-hour storage with multipliers derived from interpolations between 2028 and 2030 results in the marginal ELCC study for 2026 Filing Requirements.[22] The case of 100-hour storage with 2x Pmax charge was not studied in the marginal ELCC study for 2026 Filing Requirements, but it was assumed that the ratio between the first-in marginal ELCCs for 2x Pmax charge versus 1x Pmax charge would be similar to the ratio between the last-in marginal ELCCs for 2x Pmax charge versus 1x Pmax charge. Similar to 8-hour storage, MTR ELCCs were calculated with the delta method, using the first-in and last-in marginal ELCCs as inputs.

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[21] Capacities are shown in nameplate MW per RESOLVE portfolio reporting, consistent with slide 22 of Slides on Need Determination Analysis (2025). Note that SERVM portfolio reporting is often reported in monthly NQC (for a summer month), rather than nameplate capacity, for various technologies, including cogeneration, geothermal, biomass/biogas, hydro, and demand response.

[22] Reliability Filing Requirements for Load Serving Entities' 2024-26 Integrated Resource Plans: Results of Marginal ELCC Studies, California Public Utilities Commission, 2026, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/2024-2026-irp-cycle-events-and-materials/reliability-filing-requirements_lses-2024-26_irp-plans_20260210.pdf.

Table 7. ELCCs for 12- and 100-Hour Storage in the Mid Solar Scenario

Resource	First-In ELCC (%)	Last-In ELCC (%)	MTR ELCC (%)
12-Hour Storage	82%	33%	59%
100-Hour Storage with 1x Pmax Charge	92%	77%	85%
100-Hour Storage with 2x Pmax Charge	97%	82%	90%

Results

The MTR ELCCs for 2030-2031 IRP procurement requirements are presented in Table 8. Some of the MTR ELCCs were calculated in this study, while others were taken from the marginal ELCC study for the 2026 FR. The 2030 marginal ELCCs from the 2026 FR marginal ELCC study and the incremental ELCCs from the last two tranches in the 2023 MTR ELCC study are shown for reference. The MTR ELCCs for storage resources presented in Table 8 are applicable to multiple storage technologies, including Li-ion batteries, generic long-duration energy storage, and pumped storage hydro, provided that such storage resources have comparable round-trip efficiencies and durations. As discussed in the staff memo accompanying this report, results for storage technologies with durations that were not explicitly modeled in this study should be linearly interpolated based on the round-trip efficiency and duration of the procured technology.

Table 8. MTR ELCCs for 2030-2031 IRP Procurement Requirements

Resource Type	2023 MTR ELCC Study for 2027 (Tranche 5) & 2028 (Tranche 6) Compliance		2026 Marginal ELCC Study (LSE Filing Requirements)	MTR ELCCs From This Study (Tranche 7 & Tranche 8)
	2027	2028	2030	2030/2031
Solar	7.5%	8.8%	10%	10%
4-Hour Storage	74.0%	76.5%	22%	38%
8-Hour Storage	87.1%	90.1%	39%	55%
12-Hour Storage	89.7%	92.7%	47%	59%
100-Hour Storage with 1x Pmax Charge	N/A	N/A	74%	85%
100-Hour Storage with 2x Pmax Charge	N/A	N/A	N/A	90%
In-State Wind (NorCal)	14.0%	14.7%	35%	35%*
In-State Wind (SoCal)			15%	15%*
Out-of-State Wind (WY)	31.7%	30.9%	37%	37%*
Out-of-State Wind (ID/WA/OR)	N/A	N/A	25%	25%*
Out-of-State Wind (AZ/NM)	33.7%	31.9%	36%	36%*
Offshore Wind (NorCal)	44.0%	44.7%	57%	57%*
Offshore Wind (SoCal)			30%	30%*
Energy-Only, Co-located Solar	N/A	N/A	N/A	7.8%**
Energy-Only, Co-located In-State Wind (NorCal)	N/A	N/A	N/A	6.5%**
Energy-Only, Co-located In-State Wind (SoCal)	N/A	N/A	N/A	2.6%**
Geothermal	N/A	N/A	87%	Sept. NQC counting rules at contracting
Small Hydro	N/A	N/A	30%	Sept. NQC counting rules at contracting
Large Hydro	N/A	N/A	50%	Sept. NQC counting rules at contracting
Demand Response	N/A	N/A	42%	Sept. NQC counting rules at contracting
Other	N/A	N/A	N/A	Sept. NQC counting rules at contracting

**Technology was not modeled in this study. MTR ELCC is set equal to the 2030 marginal ELCC from the 2026 FR marginal ELCC study.*

***Energy-only co-located resource ELCCs displayed in the table are solely for the purposes of compliance with the D.26-02-057 IRP procurement order and are not an indication of Resource Adequacy value.*

Table Notes: The 2023 MTR ELCC study used blended Northern California/Southern California values for Wind CA and Wind Offshore. In addition, ELCC values for Wind NM and 12-Hour Pumped Storage Hydro from 2023 MTR ELCC study are shown for Out-of-State Wind (AZ/NM) and 12-Hour Storage, respectively. ELCC values for technologies not modeled in previous studies are replaced with N/A (not applicable).

Solar ELCC

As the penetration of solar increases, the net load peak shifts towards evening hours when solar output is generally a small fraction of its nameplate capacity due to low solar angles. With continued solar growth, the net peak can shift to nighttime hours when solar output is zero. Even in this extreme case when the net peak after solar and wind output is after sunset, solar achieves positive ELCC by allowing energy-limited resources such as storage, hydro, or demand response programs to charge or conserve energy before the net peak. The positive ELCC which solar derives from its interactions with other resources on the system is a result of diversity benefits and contributes significantly to the increasing ELCC values for solar from 2027 to 2031 in Table 7.

Storage ELCC

Storage ELCC values are predominantly determined by storage resources' ability to serve load during extreme conditions without exhausting their store of energy. Storage ELCCs are a function of both storage resources' maximum discharge duration and their ability to charge from and retain energy provided by both firm generators and renewables prior to critical hours (which depends on both charging energy availability and storage round-trip efficiency). Diversity benefits with solar therefore also contribute significantly to the storage ELCC values reported in Table 7; after the diversity benefit allocation, storage MTR ELCCs increase relative to their last-in marginal ELCCs.

As a result of higher storage penetrations, as well as changing IEPR load forecasts, storage ELCC values are lower in 2030/2031 relative to previous MTR ELCC studies. Storage resources with longer maximum discharge duration have consistently higher ELCC than 4-hour storage.

Figure 11 shows a heatmap of criticality (the percent of critical hours in each month-hour across all SERVM cases) for the 2031 buildout portfolio from the Mid Solar scenario, after new solar and 4-hour storage capacity is added to meet the 4,000 MW ELCC target. All critical hours heatmaps shown in this report were produced using SERVM's energy equity method, which is a post-processing step that redispatches storage in order to minimize the maximum expected unserved energy (EUE) across all hours. The heatmap shows that loss-of-load risk is the highest in September and there are 10 consecutive hours (HE15-HE24) with criticality of at least 5%. Storage ELCCs will naturally decline when the critical period exceeds the duration over which the resource can sustain its maximum discharge rate. The ELCC of 12-hour storage, despite its longer duration, is only slightly higher than the ELCC of 8-hour storage due to its lower assumed round-trip efficiency.

Figure 11. Critical Hours Heatmap for 2031 Mid Solar Buildout Portfolio

	Jan-Jul	Aug	Sep	Oct	Nov	Dec
HE1	-	-	0.0%	-	-	0.1%
HE2	-	-	-	-	-	0.1%
HE3	-	-	-	-	-	0.1%
HE4	-	-	-	-	-	0.1%
HE5	-	-	-	-	-	0.1%
HE6	-	-	-	-	-	0.1%
HE7	-	-	-	-	-	0.2%
HE8	-	-	-	-	-	0.2%
HE9	-	-	-	-	-	0.0%
HE10	-	-	-	-	-	0.0%
HE11	-	-	-	-	-	0.0%
HE12	-	-	-	-	-	0.0%
HE13	-	-	-	-	-	0.0%
HE14	-	0.0%	0.1%	-	-	0.0%
HE15	-	0.0%	5.0%	-	-	0.1%
HE16	-	0.1%	9.8%	-	-	0.1%
HE17	-	0.1%	10.2%	-	-	0.2%
HE18	-	0.1%	10.2%	-	-	0.2%
HE19	-	0.1%	10.2%	-	-	0.2%
HE20	-	0.1%	10.2%	-	-	0.2%
HE21	-	0.1%	10.2%	-	-	0.2%
HE22	-	0.1%	10.2%	-	-	0.2%
HE23	-	0.1%	10.2%	-	-	0.2%
HE24	-	0.1%	10.1%	-	-	0.2%

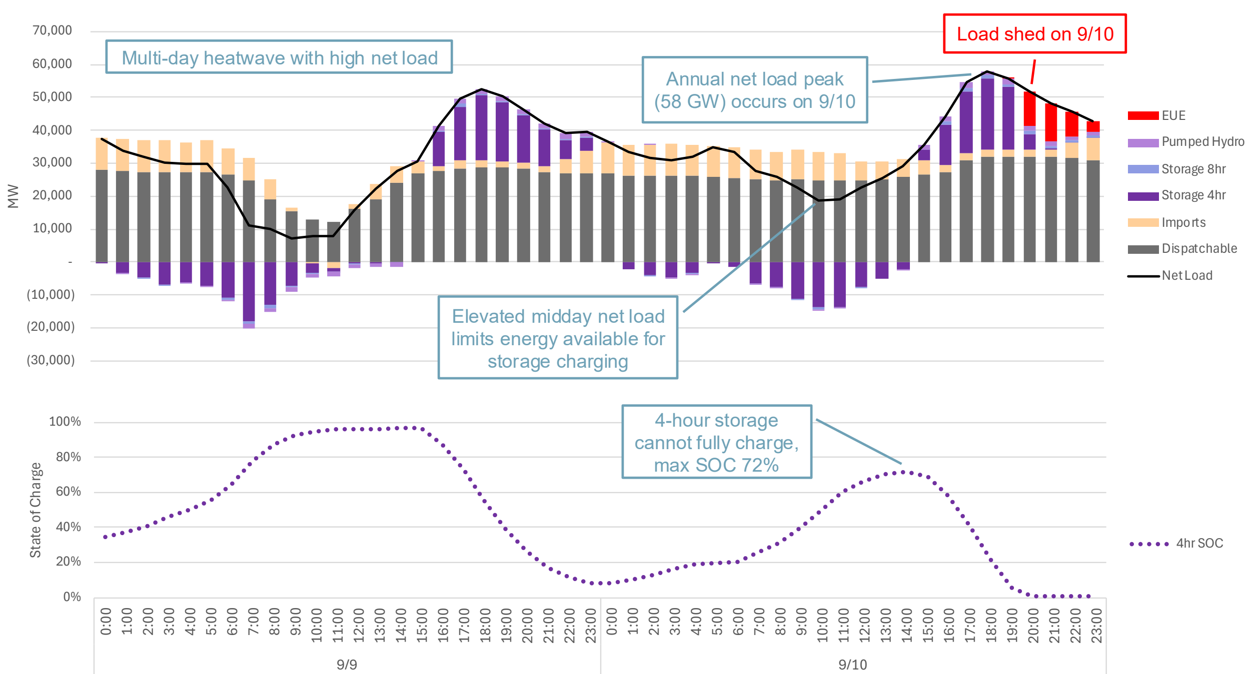
A few cases in this study had loss-of-load in December. While previous ELCC studies have predicted that winter loss of load risk may increase in future years, this was usually not expected until the 2040s. The section Changes to Critical Hours goes into further detail about what changes in this study may have contributed to this effect. However, the overall impact on storage ELCCs is minimal because the total percentage of critical hours in December is less than 3%.

Planned maintenance contributed to the December critical hours. SERVM places planned maintenance in the periods with the lowest expected net load, which concentrates it in winter. About 4.4 gigawatts (GW) of thermal capacity is on scheduled maintenance during an average December hour in this study's SERVM runs, and 5.1 GW is scheduled across the December 24-25 event window. The schedule is set before the simulation and held fixed, so it does not respond to conditions that develop within a random outage draw. This planned maintenance contributes directly to the size of the December events, although the maintenance schedule itself is not a distinguishing factor between the cases: the base case run on the starting portfolio carries the same December schedule and records no unserved energy in any of its ten outage draws.

These studies were run on the SERVM version 2026.2 release, with planned maintenance scheduled against daily net load shapes and thermal capacity adjusted for expected forced outage rates. On that basis, winter days show wide capacity reserves and attract most of the year's maintenance. The same release offers a newer scheduling basis that was not applied in these studies: daily net load after expected storage dispatch, along with the ability to restrict maintenance to specific months or seasons by unit. With a large storage fleet, storage dispatch flattens the daily load shape, and the apparent off-peak headroom is committed to recharging. As a result, the post-storage basis rates winter windows as tighter than the net load basis does. Scheduling against post-storage net load could shift maintenance away from the winter stretches in which the storage fleet is depleted and possibly mitigate the December critical hours.

To further illustrate why storage ELCC values are saturating in this study, E3 and PowerGEM analyzed dispatch patterns for cases with high EUE. Figure 12 shows a dispatch chart for a two-day period in September 2030 that ends with a loss-of-load event driven by charging energy constraints, using weather year 2015. A multi-day heatwave leads to high net load across the system. On September 9, there is excess energy from dispatchable resources (mostly thermal) and imports that can charge storage in the middle of the day. However, on September 10, net load is elevated throughout the day and hits an annual peak of 58 GW in the evening hours. As a result, there is insufficient excess energy to charge the 4-hour storage fleet, which reaches only 72% state of charge (SOC), and these energy constraints lead to a loss-of-load event when the storage SOC is exhausted. In an energy-constrained system, the ELCC of 4-hour storage is expected to decline relative to storage resources with longer durations and firm generators.

Figure 12. Dispatch Chart for a Charging Energy Constrained Event in 2030 (WY 2015)



The incremental value of longer-duration storage—meaning storage with 8+ hours duration—is not only driven by differences in energy duration. Longer-duration storage is modeled with forced outage risk during both charging and discharging periods. An 8-hour battery storage resource must charge for over 8 hours a day, due to round-trip losses, to sustain its maximum discharge rate for 8 hours. As a result, longer-duration storage carries more outage risk than a firm generator with the same equivalent forced outage rate that only operates for 8 hours a day. In addition, longer-duration storage can become charging constrained when energy is not available for the full period required to fully charge. These charging constraints had a significant effect on this model. A more detailed discussion of the effect of charging constraints in this analysis relative to previous studies is in the ELCC Comparison to Past Studies section.

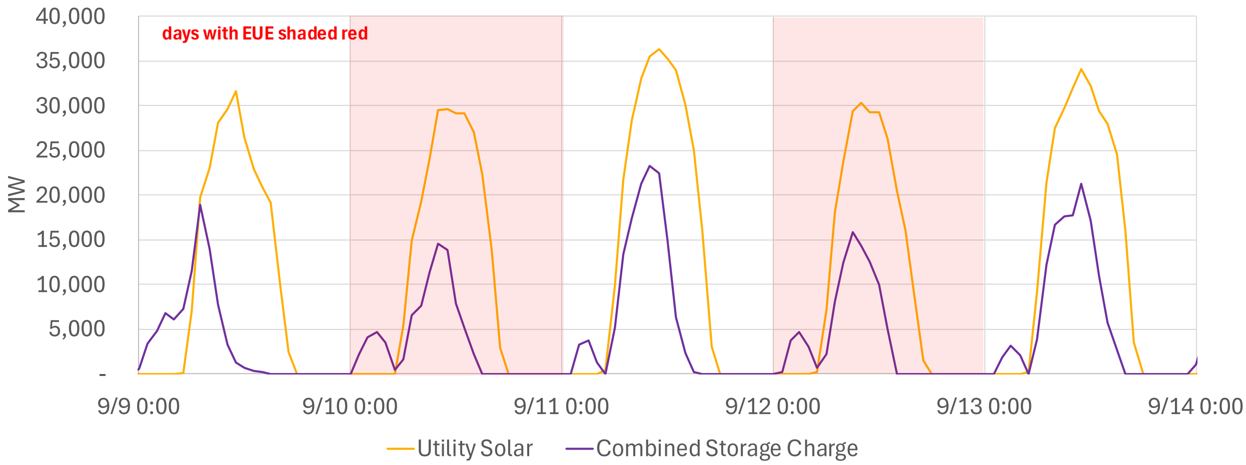
Energy-Only, Co-Located Solar and Wind ELCC

D.26-02-057 established that new energy-only (EO) resources that are co-located with fully deliverable storage would be eligible to count towards the procurement requirements. EO resources were not modeled in SERVM for this analysis, but a heuristic approach was developed to estimate the marginal ELCC values of three types of EO co-located resources based on SERVM modeling results: EO co-located solar, EO co-located Northern California wind, and EO co-located Southern California wind.

E3 and PowerGEM expected that eligible energy-only resources would primarily contribute to reliability by charging their co-located storage resources, which harmonizes with the direction of the Decision not to count capacity for standalone EO resources. As part of the heuristic approach, E3 and PowerGEM analyzed the dispatch reports for five cases with different weather years (WY) and particularly high expected unserved energy (EUE), and compared the generation profiles of solar, Northern California wind, and Southern California wind with the storage charge and discharge profile on an hourly basis. E3 and PowerGEM examined the results from multiple cases to capture a greater range of weather conditions. The storage charge and discharge profiles used in this analysis were the aggregations of 4-hour and 8-hour storage profiles. Storage charge energy was attributed to solar, Northern California wind, and/or Southern California wind based on the overlap between the storage charge profile and the generation profile. A "charging energy capacity factor" was calculated for each day by dividing the total attributed storage charge energy by the product of the nameplate capacity and 24 hours. Each day with EUE was defined as a critical day, and the ELCC in each case was estimated as the average charging energy capacity factor across critical days.

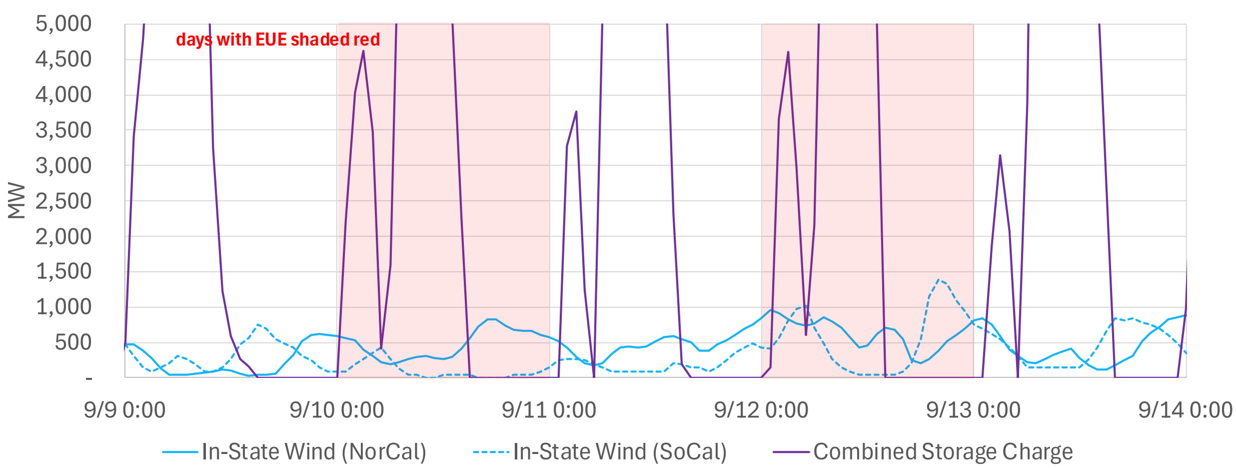
Since the benefits of storage charging are already a large component of the reliability value of fully deliverable solar, E3 and PowerGEM expected that the ELCC value for the energy-only, co-located solar would be similar to the ELCC of fully deliverable solar. Figure 13 shows how the solar and storage profiles compare on the two days with EUE in the case with the highest EUE (Case 390, using WY 2015). As expected, the degree of overlap between solar and storage charging profiles is large, although there are some early morning hours with storage charging on critical days. The solar generation in excess of storage charging did not count towards the ELCC value for the energy-only, co-located solar in this analysis. While it is likely that a co-located storage resource would alter its charging behavior to better utilize the solar generation, optimizing storage dispatch to simulate the expected behavior of a co-located resource was outside the scope of this study.

Figure 13. Solar and Storage Charge Profiles in a High EUE Case (WY 2015)



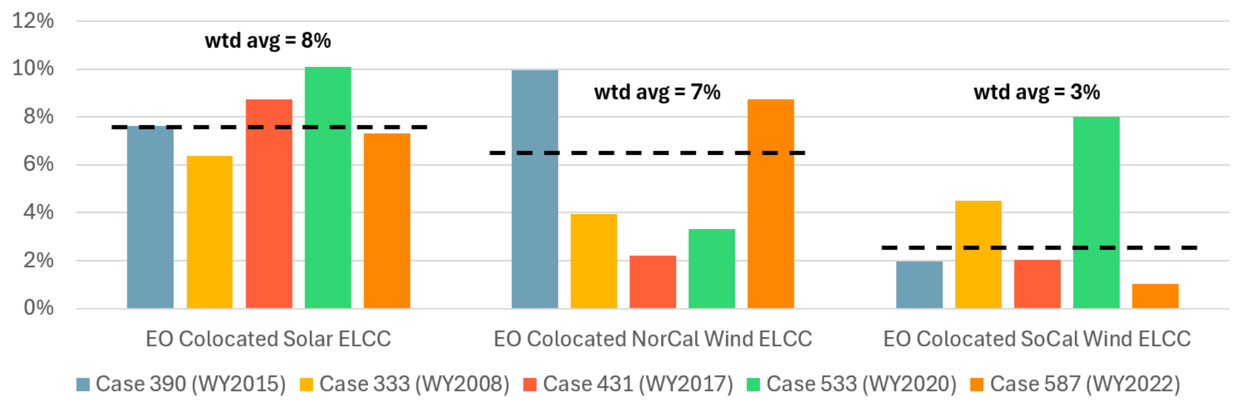
While much of the reliability value of full-capacity solar comes from its ability to charge storage, full-capacity wind resources have generation profiles that overlap more with critical periods and their ELCC values are not as dependent on interactive effects with storage. While the generation of the energy-only, co-located wind during critical periods did not count towards its ELCC value if it overlapped with storage discharging hours, there was still some wind generation that overlapped with storage charging on critical days, as shown in Figure 14, which shows the wind and storage profiles from the same case as Figure 13 (Case 390, using WY 2015). The storage charge profiles are identical in Figure 13 and Figure 14, but the shorter y-axis in Figure 14 allows the wind profiles to be shown at a higher resolution.

Figure 14. Wind and Storage Charge Profiles in a High EUE Case (WY 2015)



Finally, E3 and PowerGEM computed the weighted average ELCC across all cases, weighting by the total EUE in each case, to produce the final ELCC values for compliance purposes. From highest to lowest, the total EUE in each case was: 77,306 megawatt-hours (MWh) in Case 390 (WY 2015), 50,973 MWh in Case 431 (WY 2017), 41,902 MWh in Case 587 (WY 2022), 36,465 MWh in Case 333 (WY 2008), and 14,924 MWh in Case 533 (WY 2020). Figure 15 shows the estimated ELCC values for the energy-only (EO), co-located resources from the five cases analyzed as well as the weighted average ELCC, shown in the black dashed line. While these ELCC values are nonzero, they are lower than the MTR ELCCs of their fully-deliverable counterparts shown in Table 7. In particular, the ELCC values for energy-only, co-located wind is significantly lower than the fully-deliverable wind ELCCs.

Figure 15. Energy-Only, Co-located Solar and Wind ELCC Values by Case



Approach for Other Resources Not Modeled

For resources that were not modeled in this study but are eligible to count towards the 2030-2031 IRP procurement requirements, the marginal ELCC values were taken from the marginal ELCC study for 2026 Filing Requirements.[23] The 2030 marginal ELCCs from the 2026 Filing Requirements marginal ELCC study are expected to be reasonable approximations of the reliability value of wind, geothermal, and other eligible technologies for the 2030-2031 IRP procurement order due to either limited differences in resource nameplate capacity between the two portfolios or relatively insensitive ELCC values in this portion of the ELCC surface. For example, in the 2026 Filing Requirements marginal ELCC study, the in-state wind ELCC values did not change significantly between 2030 and 2035 even though the installed capacity increased by 5,000 MW. The asterisks on the 2030-2031 MTR ELCCs in Table 7 indicate the ELCC values that were set equal to the 2030 marginal ELCCs from the 2026 Filing Requirements study.

[23] Reliability Filing Requirements for Load Serving Entities' 2024-26 Integrated Resource Plans: Results of Marginal ELCC Studies, California Public Utilities Commission, 2026, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/2024-2026-irp-cycle-events-and-materials/reliability-filing-requirements_lses-2024-26_irp-plans_20260210.pdf.

ELCC Comparison to Past Studies

Why Resource ELCC Values Change

The CPUC frequently conducts ELCC studies for various use cases associated with reliability planning. To aid stakeholders' understanding about why changes occur between study vintages, this section describes drivers of change generally and then examines this study's results as compared to prior studies' results.

Table 9 shows the reasons why ELCCs change between studies and their general magnitude, informed by the authors' past experiences and the sensitivities analyzed in the 2023 MTR ELCC study. The dynamic nature of ELCC values is an expected part of the ELCC methodology and does not represent a failure in method or process. Reflecting the evolving marginal value of resources as the forecasted portfolio, load, or other key assumptions change allows for ELCC values to adapt as new weather, operational data, and LSE procurement data become available. When comparing across studies, it is also important to note that recent IRP ELCC studies typically report marginal or incremental ELCC values that tend to be more sensitive to change, while the underlying total reliability contribution (portfolio ELCC) of all resources is more stable. As described above, the CAISO system is entering a dynamic portion of the multi-dimensional ELCC surface where resource marginal ELCCs, especially energy storage and solar, are sensitive to portfolio changes.

Table 9. Why ELCC Values Change Between Studies

Study	Description	Use Case(s) in CPUC IRP	Magnitude
Portfolio Changes	Can change ELCCs due to saturation effects and interactive effects between resources, as well as changes in seasons when EUE occurs; the resource portfolio is the primary input into ELCC calculations	Changing marginal ELCCs used for LSE IRPs based on the changing CAISO resource portfolio	High
Resource shape changes	Impact solar and wind ELCCs most directly, as temporal performance profiles of variable energy resources weighs significantly in the ELCC calculation	Updated wind shapes	Medium-High
Load shape changes	Impact the load shape to which resources are dispatched when ELCCs are calculated	Re-calibration of SERVM load shapes when updating IEPR vintage	Medium
New weather years added	Impact the periods of extreme weather that drive reliability events, and therefore ELCCs	Addition to the 2023 MTR ELCC study of the August 2020 extreme weather event	Medium
Changes to other input parameters	May impact resource ELCCs due to interactive effects between resources	Hydro modeling, neighbor modeling, forced outage rates	Low-Medium
Methodological changes	May change slightly between different studies	Type of LOLE tuning method used (perfect capacity vs. firm load)	Low

Changes to Critical Hours

Portfolio differences between the 2026 FR marginal ELCC study and this study led to differences in critical hours, which explains many of the differences in ELCC values for various resources. Figure 16 compares the installed capacity[24] of the calibrated 2030 portfolio from the 2026 FR study to the 2031 buildout portfolio for the Mid Solar scenario from this study after new solar and storage resources were added to meet the 4,000 MW ELCC target. Although the model years are only one year apart, the 2026 Filing Requirements study used a RESOLVE portfolio that was optimized to meet near-term GHG targets in addition to reliability requirements and thus includes a much more

[24] Installed capacity as reported by SERVM. Note that SERVM portfolio reporting is often reported in monthly NQC (for a summer month), rather than nameplate capacity, for various technologies, including cogeneration, geothermal, biomass/biogas, hydro, and demand response.

aggressive buildout of solar and wind. Relative to the 2030 portfolio from the 2026 FR study, the 2031 Mid Solar buildout portfolio in this study has more 4-hour storage and more natural gas but less 8-hour storage, solar, wind, and geothermal. The decrease in solar, wind, and geothermal capacity suggests that the system may be more energy-constrained in this study. Furthermore, the portfolio in this study has more 4-hour storage and less 8-hour storage, which means that the portfolio will be more susceptible to loss-of-load events driven by energy constraints.

Figure 16. Comparison of Portfolios Between Filing Requirements Study and This Study

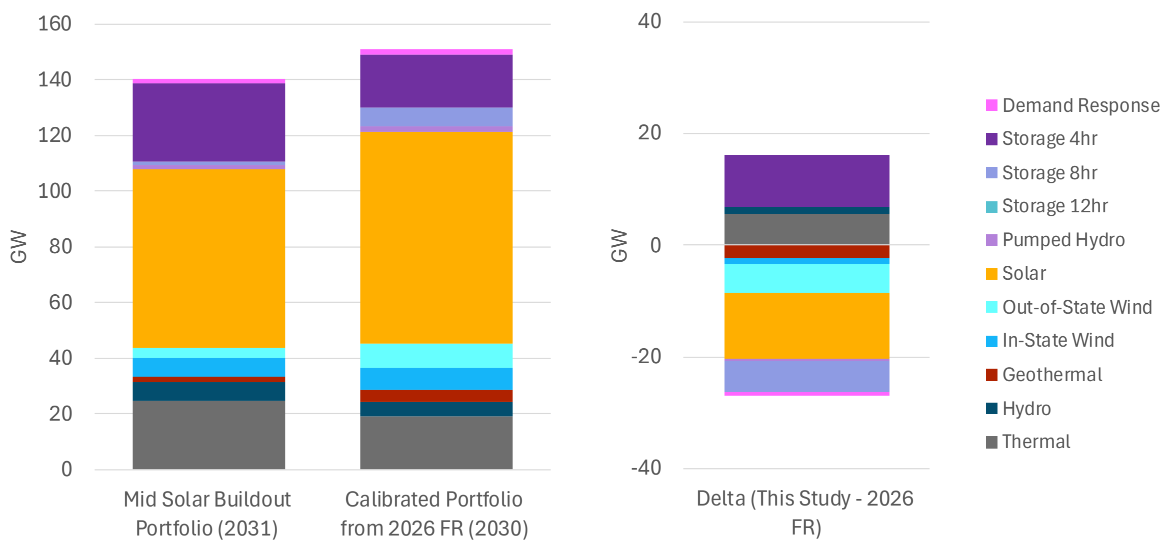


Figure 17 below shows the critical hours heatmaps side-by-side for model year 2030 from the 2026 FR marginal ELCC study on the left and this study on the right. These heatmaps represent the normalized distribution of critical hour frequency as a percentage in each month-hour. The heatmap for this study reflects the critical hours after the buildout of the solar and storage tranche to meet the 4,000 MW ELCC target. In the 2026 FR study, the critical hours were the most concentrated in September hour ending (HE) 19 in 2030, although September HE16-24 were all fairly critical, accounting for 75% of critical hours. However, in this study, there are 10 consecutive hours (HE15-24) in September with criticality of at least 5%, accounting for 96% of critical hours. Furthermore, HE17-24 have nearly the same percentage of critical hours, which is a sign of an energy-constrained system. This is unsurprising given the portfolio differences shown in Figure 16.

Figure 17. Comparison of Critical Hours Between Filing Requirements Study and This Study

2026 FR Study (2030)

	Jan-Jul	Aug	Sep	Oct	Nov	Dec
HE1	-	0.1%	0.0%	-	-	-
HE2	-	-	-	-	-	-
HE3	-	-	-	-	-	-
HE4	-	-	-	-	-	-
HE5	-	-	-	-	-	-
HE6	-	-	-	-	-	-
HE7	-	-	-	-	-	-
HE8	-	-	-	-	-	-
HE9	-	-	-	-	-	-
HE10	-	-	-	-	-	-
HE11	-	-	-	-	-	-
HE12	-	-	-	-	-	-
HE13	-	-	-	-	-	-
HE14	-	0.1%	-	-	-	-
HE15	-	1.4%	0.9%	-	-	-
HE16	-	2.4%	6.2%	-	-	-
HE17	-	2.4%	8.0%	-	-	-
HE18	-	2.4%	8.0%	-	-	-
HE19	-	2.4%	13.4%	-	-	-
HE20	-	2.4%	8.0%	-	-	-
HE21	-	2.4%	8.0%	-	-	-
HE22	-	2.4%	8.0%	-	-	-
HE23	-	2.4%	8.0%	-	-	-
HE24	-	2.4%	8.0%	-	-	-

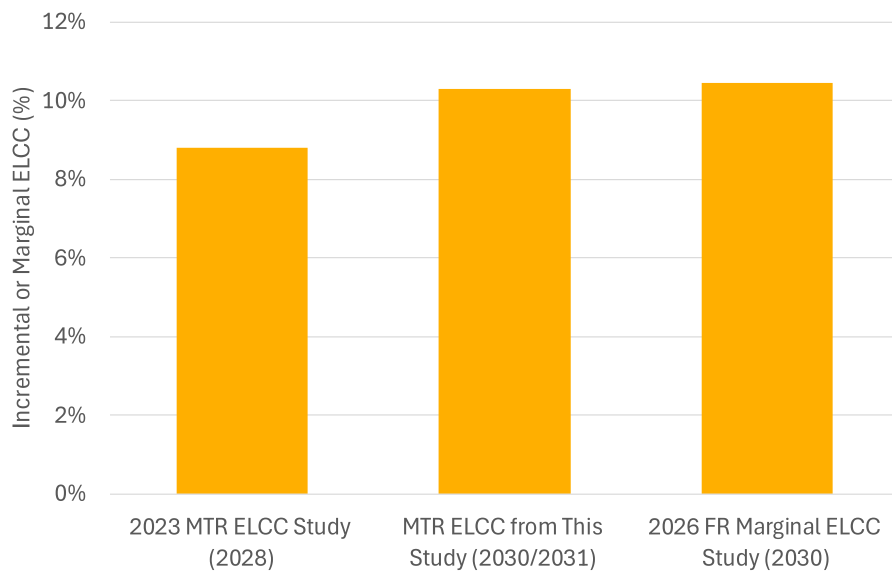
This Study (2031 Post-Buildout)

	Jan-Jul	Aug	Sep	Oct	Nov	Dec
HE1	-	-	0.0%	-	-	0.1%
HE2	-	-	-	-	-	0.1%
HE3	-	-	-	-	-	0.1%
HE4	-	-	-	-	-	0.1%
HE5	-	-	-	-	-	0.1%
HE6	-	-	-	-	-	0.1%
HE7	-	-	-	-	-	0.2%
HE8	-	-	-	-	-	0.2%
HE9	-	-	-	-	-	0.0%
HE10	-	-	-	-	-	0.0%
HE11	-	-	-	-	-	0.0%
HE12	-	-	-	-	-	0.0%
HE13	-	-	-	-	-	0.0%
HE14	-	0.0%	0.1%	-	-	0.0%
HE15	-	0.0%	5.0%	-	-	0.1%
HE16	-	0.1%	9.8%	-	-	0.1%
HE17	-	0.1%	10.2%	-	-	0.2%
HE18	-	0.1%	10.2%	-	-	0.2%
HE19	-	0.1%	10.2%	-	-	0.2%
HE20	-	0.1%	10.2%	-	-	0.2%
HE21	-	0.1%	10.2%	-	-	0.2%
HE22	-	0.1%	10.2%	-	-	0.2%
HE23	-	0.1%	10.2%	-	-	0.2%
HE24	-	0.1%	10.1%	-	-	0.2%

Changes to Solar ELCC

The solar MTR ELCC published in this study is very similar to the solar ELCC value for 2028 published in the 2023 MTR ELCC study. Solar ELCC values in both studies generally remain between 5% and 10%, although this study found that the diversity benefits provided by solar in an energy-constrained system led to a higher ELCC relative to the 2023 MTR ELCC study. Load shape changes associated with a different version of the IEPR forecast are secondary drivers of ELCC differences compared to the 2023 MTR ELCC study. Furthermore, the solar MTR ELCC is nearly identical to the 2030 marginal ELCC for solar from the 2026 FR marginal ELCC study. These comparisons are shown in Figure 18 below.

Figure 18. Solar ELCC Comparison Between Recent ELCC Studies



Changes to Storage ELCC

This study is generally consistent with previous ELCC studies, which show that storage ELCCs decline as storage penetration increases. Figure 19 shows how the installed capacity[25] and resource mix in the CAISO system has evolved between the 2023 MTR ELCC study (for model year 2028), the Mid Solar buildout portfolio in this study (2031), and the 2026 Filing Requirements marginal ELCC study (2030). In Figure 19, the portfolio size increases from left to right. Compared to the 2023 MTR ELCC study, this study's portfolio was much larger and had a higher penetration of storage resources. Even though this study's portfolio was smaller than the 2026 FR study portfolio, this study's portfolio had higher penetration of storage, especially 4-hour storage, but less energy-generating resources such as solar, wind, and geothermal relative to the 2030 portfolio from the 2026 FR study.

[25] As mentioned previously, this is installed capacity from SERVM, which is often reported in monthly NQC (for a summer month), rather than nameplate capacity.

Figure 19. Portfolio Comparison Between Recent ELCC Studies

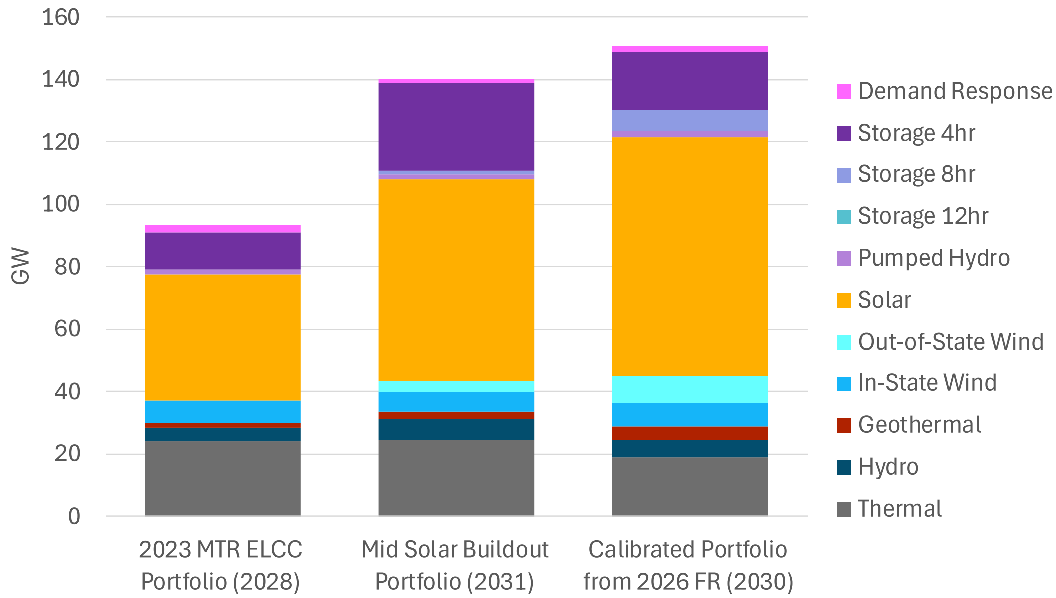
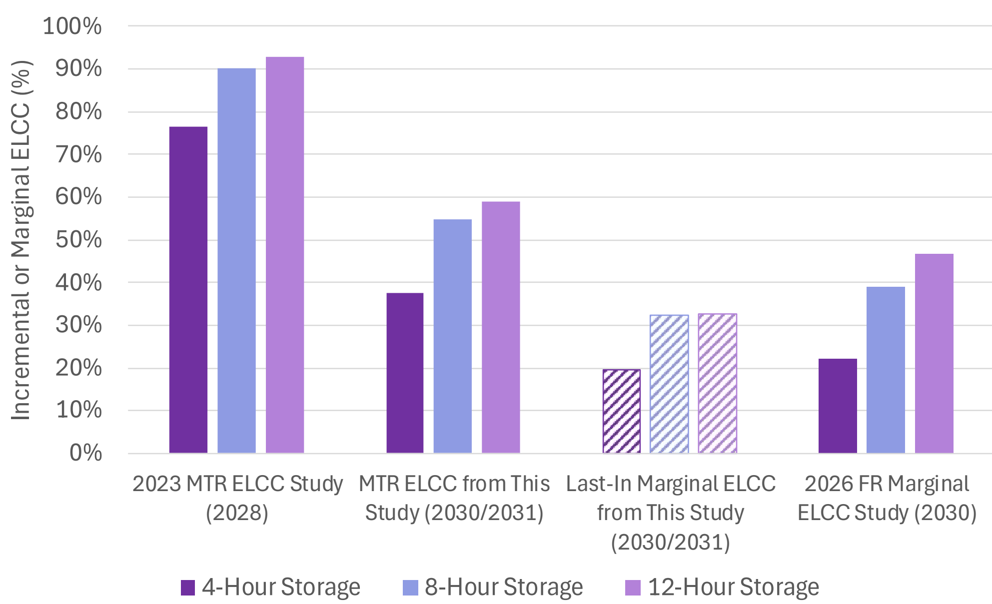


Figure 20 shows how the storage ELCCs compare between the 2023 MTR ELCC study (2028), this study (2030), and the 2026 FR marginal ELCC study (2030). While the last-in marginal ELCCs were not the final product of this study, they are shown as hashed bars in Figure 20 to facilitate comparison with the last-in marginal ELCCs produced in the 2026 FR study. Note that the 2023 MTR ELCC study did not model a generic 12-hour storage resource, so the ELCC shown is for 12-hour pumped hydro.

Figure 20. Storage ELCC Comparison Between Recent ELCC Studies



Compared to the 2023 MTR ELCC study, the storage MTR ELCCs from this study are lower. This is consistent with the fact that the storage penetrations in this study's portfolio are higher than they were in the 2023 MTR ELCC study. Changes to the load shape associated with a newer version of the IEPR forecast (e.g., increase in flatter loads from data centers) could also be driving some differences.

The storage MTR ELCCs in this study are higher than the 2030 marginal ELCCs for storage from the 2026 FR marginal ELCC study. The primary reason why the MTR ELCCs for storage from this study are higher than the marginal ELCCs in the 2026 FR study is because the MTR ELCC is interpolated between the first-in and last-in marginal ELCCs (with adjustment for diversity benefits), whereas the 2026 Filing Requirements study only calculated the last-in marginal ELCC for each resource type. The storage last-in marginal ELCCs from this study are slightly lower than the 2030 marginal ELCCs from the 2026 Filing Requirements study. This can be attributed to the higher penetration of storage resources, a lower amount of energy-generating resources, and greater spreading of critical hours described previously in this report. In addition, for 12-hour storage, the 2026 Filing Requirements marginal ELCC study assumed a higher round-trip efficiency (75%) than the round-trip efficiency used for 12-hour storage in this study (65%), which was based on the latest inputs and assumptions report.[26]

[26] 2024-2026 Integrated Resource Planning Inputs and Assumptions, California Public Utilities Commission, 2026, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan/2024-2026-irp-cycle-events-and-materials/2025_inputs_and_assumptions_report_20260210.pdf.

Table A-1: MTR ELCCs Across All IRP MTR Procurement Tranches

Resource Type	2021 MTR ELCC Study for 2023 & 2024 Compliance (Tranches 1 & 2)		2023 MTR ELCC Study for 2025 -2028 Compliance (Tranches 3, 4, 5, & 6)				2026 Marginal ELCC Study (LSE Filing Requirements)	MTR ELCCs From This (2026) Study (Tranches 7 & 8)
	2023	2024	2025	2026	2027	2028	2030	**2030/2031**
Solar	7.8%	6.6%	6.6%	7.0%	7.5%	8.8%	10%	10%
4-Hour Storage	96.3%	90.7%	75.1%	76.6%	74.0%	76.5%	22%	38%
8-Hour Storage	98.2%	94.3%	84.0%	84.0%	87.1%	90.1%	39%	55%
12-Hour Storage	N/A	N/A	86.6%	86.6%	89.7%	92.7%	47%	59%
100-Hour Storage with 1x Pmax Charge	N/A	N/A	N/A	N/A	N/A	N/A	74%	85%
100-Hour Storage with 2x Pmax Charge	N/A	N/A	N/A	N/A	N/A	N/A	N/A	90%
In-State Wind (NorCal)	13.9%	16.5%	12.0%	13.2%	14.0%	14.7%	35%	35%*
In-State Wind (SoCal)							15%	15%*
Out-of-State Wind (WY)	28.9%	28.1%	31.0%	33.0%	31.7%	30.9%	37%	37%*
Out-of-State Wind (ID/WA/OR)	N/A	N/A	N/A	N/A	N/A	N/A	25%	25%*
Out-of-State Wind (AZ/NM)	31.1%	31.0%	30.0%	35.0%	33.7%	31.9%	36%	36%*
Offshore Wind (NorCal)	N/A	N/A	48.0%	46.0%	44.0%	44.7%	57%	57%*
Offshore Wind (SoCal)							30%	30%*
Energy-Only, Co-located Solar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.8%**
Energy-Only, Co-located In-State Wind (NorCal)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.5%**
Energy-Only, Co-located In-State Wind (SoCal)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.6%**
Geothermal	N/A	N/A	N/A	N/A	N/A	N/A	87%	Sept. NQC counting rules at contracting
Small Hydro	N/A	N/A	N/A	N/A	N/A	N/A	30%	Sept. NQC counting rules at contracting
Large Hydro	N/A	N/A	N/A	N/A	N/A	N/A	50%	Sept. NQC counting rules at contracting
Demand Response	N/A	N/A	N/A	N/A	N/A	N/A	42%	Sept. NQC counting rules at contracting
Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Sept. NQC counting rules at contracting

* Technology was not modeled in this study. MTR ELCC is set equal to the 2030 marginal ELCC from the 2026 FR marginal ELCC study.
** Energy-only co-located resource ELCCs displayed in the table are solely for the purposes of compliance with the D.26-02-057 IRP procurement order and are not an indication of Resource Adequacy value.
Table Notes: The 2021 and 2023 MTR ELCC studies used blended Northern California/Southern California values for Wind CA and Wind Offshore. In addition, ELCC values for Wind NM and 12-Hour Pumped Storage Hydro from the 2021 and 2023 MTR ELCC studies are shown for Out-of-State Wind (AZ/NM) and 12-Hour Storage, respectively. ELCC values for technologies not modeled in previous studies are replaced with N/A (not applicable).