STATE OF CALIFORNIA **GAVIN NEWSOM,** *Governor*

PUBLIC UTILITIES COMMISSION
505 Van Ness Avenue
San Francisco CA 94102-3298

Southern California Edison Company
ELC (Corp ID 338)
Status of Advice Letter 4243E
As of August 6, 2020

Subject: Southern California Edison Company, San Diego Gas & Electric Company, and Pacific Gas and Electric Company's ELCC Study Submission

Division Assigned: Energy

Date Filed: 07-01-2020

Date to Calendar: 07-06-2020

Authorizing Documents: D1909043

Disposition: **Accepted**

Effective Date: **07-31-2020**

Resolution Required: No

Resolution Number: None

Commission Meeting Date: None

CPUC Contact Information:
edtariffunit@cpuc.ca.gov

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STATE OF CALIFORNIA **GAVIN NEWSOM,** *Governor*

PUBLIC UTILITIES COMMISSION
505 Van Ness Avenue
San Francisco CA 94102-3298

To: Energy Company Filing Advice Letter

From: Energy Division PAL Coordinator

Subject: Your Advice Letter Filing

The Energy Division of the California Public Utilities Commission has processed your recent Advice Letter (AL) filing and is returning an AL status certificate for your records.

The AL status certificate indicates:

Advice Letter Number
Name of Filer
CPUC Corporate ID number of Filer
Subject of Filing
Date Filed
Disposition of Filing (Accepted, Rejected, Withdrawn, etc.)
Effective Date of Filing
Other Miscellaneous Information (e.g., Resolution, if applicable, etc.)

The Energy Division has made no changes to your copy of the Advice Letter Filing; please review your Advice Letter Filing with the information contained in the AL status certificate, and update your Advice Letter and tariff records accordingly.

All inquiries to the California Public Utilities Commission on the status of your Advice Letter Filing will be answered by Energy Division staff based on the information contained in the Energy Division's PAL database from which the AL status certificate is generated. If you have any questions on this matter please contact the:

Energy Division's Tariff Unit by e-mail to
edtariffunit@cpuc.ca.gov

SOUTHERN CALIFORNIA
EDISON®
An EDISON INTERNATIONAL® Company

Gary A. Stern, Ph. D.
Managing Director, State Regulatory Operations

July 01, 2020

ADVICE 4243-E
(Southern California Edison Company - U 338-E)

ADVICE 3560-E
(San Diego Gas & Electric Company - U902 M)

ADVICE 5868-E
(Pacific Gas and Electric Company – U39 M)

PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA
ENERGY DIVISION

SUBJECT: Southern California Edison Company, San Diego Gas & Electric Company, and Pacific Gas and Electric Company's ELCC Study Submission

PURPOSE

Pursuant to Ordering Paragraph (OP) 2 of Decision (D.) 19-09-043, Southern California Edison Company (SCE), on behalf of itself, Pacific Gas and Electric Company (PG&E), and San Diego Gas & Electric Company (SDG&E) (collectively Joint Utilities), submit their Effective Load Carrying Capability (ELCC) study results.

BACKGROUND

As ordered in D.19-09-043, the three investor owned utilities (IOUs) performed a joint study to assess the ELCC values used in Renewables Portfolio Standard (RPS) bid evaluations. The Decision required using a specific dataset, software, and methodology including the following:

- The IOU study shall use the Strategic Energy Risk Valuation Model (SERVM).
- Behind the Meter (BTM) Photovoltaics (PV) must be treated as a supply-side resource.
- An annual loss of load expectation (LOLE) study must be conducted using a 0.1 LOLE metric.
- Annual, marginal ELCC values must be determined.
- The resource portfolio must be from the 2017-18 Integrated Resource Plan's preferred system plan.
- The following years 2022, 2026, and 2030 must be studied.
- For the first report, the storage duration for hybrid systems, tracking PV paired with storage and wind paired with storage, should be 4 hours. Report #2, due at the end of the year, will contain hybrid storage durations of 1 and 2 hours.
- The study shall analyze the following resource classes (wind, solar PV, and storage) and six resource class subtypes (fixed axis PV, tracking PV, tracking PV paired with storage, distributed PV, wind, and wind paired with storage).
- The study shall be performed across seven regions, four in the California Independent System Operator (CAISO) area and three outside of CAISO.

To fulfill the joint study and its associated requirements, the Joint Utilities hired Astrapé Consulting to perform the analysis.

ELCC Study Results

For solar, the marginal ELCC values continue to fall with increased penetration of solar PV. Due to the high penetration of solar PV in 2030, the marginal ELCC values for solar PV, regardless of technology, is nearly zero. For wind, the marginal ELCC value remains similar across the three study years. This is not surprising as the wind capacity does not increase significantly in the future. For the solar paired with storage hybrid resource, the ELCC remains high (>93%)[1] across the three study years due to the following reasons: (i) the energy from solar can consistently charge a 4-hour storage device having the same installed capacity prior to hours when energy is most critical for grid reliability; and (ii) the storage penetration remains modest across the three study years. These two facts contribute to the high marginal ELCC value for solar paired with

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[1] For purposes of the ELCC Study, ELCC is calculated as a percentage of interconnection capability, where interconnection capability is assumed equal to (i) the installed capacity of non-hybrid resources, or (ii) in the case of hybrid resources, the installed capacity of the renewable resource or storage device, which are equally-sized for all hybrids analyzed.

storage. In contrast, the wind paired with storage ELCC values show more modest gains when compared with the wind ELCC values. The main driver of this relatively small increase is the inability of the wind to consistently charge a 4-hour storage device having the same installed capacity during times of need. The results for the Report #1 are summarized in the tables below (please note: blacked out boxes in the tables indicate that no data was available for those values).

Table ES1. Recommended ELCC Values for 2022[2]

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE	4.3%	5.4%	6.9%	99.6%	21.8%	54.0%
SCE/SDGE	3.6%	4.6%	5.4%	99.9%	18.0%	47.0%
AZ APS		4.6%	5.4%	99.0%	38.8%	78.3%
NM EPE		4.6%	5.4%	99.0%	38.8%	78.3%
BPA					32.7%	57.2%
CAISO	**4.0%**	**5.0%**	**6.2%**	**99.8%**	**19.9%**	**50.5%**
Average	**4.0%**	**4.8%**	**5.8%**	**99.4%**	**30.0%**	**62.0%**

Table ES2. Recommended ELCC Values for 2026

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE	1.3%	2.1%	3.4%	98.8%	17.9%	43.5%
SCE/SDGE	0.6%	1.2%	1.9%	96.4%	17.8%	35.3%
AZ APS		~0.0%	1.9%	96.0%	30.8%	79.2%
NM EPE		~0.0%	1.9%	96.0%	30.8%	79.2%
BPA					32.8%	52.8%
CAISO	**1.0%**	**1.7%**	**2.7%**	**97.6%**	**17.9%**	**39.4%**
Average	**1.0%**	**0.8%**	**2.3%**	**96.8%**	**26.0%**	**58.0%**

---

[2] Values for all three study years reflect post-processing to reduce statistical noise. This included averaging Northern and Southern California raw results since the underlying renewable profiles were more similar than suggested by the variability in raw simulation results. It also included capping solar ELCC by using longitude to prevent projects further east from having higher capacity values than those further west. Additionally, as ELCC approaches zero, it becomes increasingly difficult to converge on values that are distinguishable from statistical noise. Hence, the "approximation" of zero.

Table ES3. Recommended ELCC Values for 2030

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE	0.4%	1.3%	3.4%	93.4%	20.5%	39.2%
SCE/SDGE	~0.0%	~0.0%	~0.0%	93.0%	17.4%	31.7%
AZ APS	[redacted]	~0.0%	~0.0%	90.5%	30.2%	63.4%
NM EPE	[redacted]	~0.0%	~0.0%	90.5%	30.2%	63.4%
BPA	[redacted]	[redacted]	[redacted]	[redacted]	28.2%	51.6%
CAISO	**0.2%**	**0.7%**	**1.7%**	**93.2%**	**19.0%**	**35.5%**
Average	**0.2%**	**0.3%**	**0.9%**	**91.9%**	**25.3%**	**49.9%**

Joint Utilities Recommendations

While the ELCC study was performed across the seven regions, the Joint Utilities recommend, that for any CAISO located resource, the CAISO ELCC values for the respective technologies be used for any RPS evaluation purposes. The geographic differences remain difficult to capture without significant time and effort.

As noted in Report #1, Astrapé Consulting discovered that the wind profiles for the three regions outside of CAISO could be improved to more accurately capture those areas' characteristics. The Joint Utilities recommend that additional effort be undertaken to establish wind profiles for regions outside of the CAISO area that are of comparative data quality to those within the CAISO footprint. Once these improvements are made, annual and marginal ELCC values should be updated.

REQUEST FOR COMMISSION APPROVAL

SCE proposes an Energy Division disposition within 30 days of the submittal of this Advice Letter.

APPENDICES

This advice letter contains appendices as listed below.

Appendix A:	ELCC Study

TIER DESIGNATION

Pursuant to D.19-09-043, OP 2, this advice letter is submitted with a Tier 2 designation.

EFFECTIVE DATE

This advice letter will become effective on July 31, 2020, the 30th calendar day after the date submitted.

PROTEST

Anyone wishing to protest this advice letter may do so by letter via U.S. Mail, facsimile, or electronically, any of which must be received no later than 20 days after the date of this advice letter. Protests should be submitted to:

CPUC, Energy Division
Attention: Tariff Unit
505 Van Ness Avenue
San Francisco, California 94102
E-mail: EDTariffUnit@cpuc.ca.gov

Copies should also be mailed to the attention of the Director, Energy Division, Room 4004 (same address above).

In addition, protests and all other correspondence regarding this advice letter should also be sent by letter and transmitted via facsimile or electronically to the attention of:

For SCE:

Gary A. Stern, Ph.D.
Managing Director – State Regulatory Operations
Southern California Edison Company
8631 Rush Street
Rosemead, CA 91770
Telephone (626) 302-9645
Facsimile: (626) 302-6396
Email: AdviceTariffManager@sce.com

Laura Genao
Managing Director, State Regulatory Affairs
c/o Karyn Gansecki
Southern California Edison Company
601 Van Ness Avenue, Suite 2030
San Francisco, California 94102
Telephone: (415) 929-5544
E-mail: Karyn.Gansecki@sce.com

For SDG&E:

Attn: Greg Anderson
Regulatory Tariff Manager
8330 Century Park Ct., CP31F
San Diego, CA 92123-1548
E-mail: GAnderson@sdge.com

For PG&E:

Erik Jacobson
Director – Regulatory Relations
c/o Megan Lawson
Pacific Gas and Electronic Company
77 Beale Street, Mail Code B13U
P.O. Box 770000

San Francisco, CA 94177
Email: PGETarrifs@pge.com

There are no restrictions on who may submit a protest, but the protest shall set forth specifically the grounds upon which it is based and must be received by the deadline shown above.

NOTICE

In accordance with General Rule 4 of General Order (GO) 96-B, SCE is serving copies of this advice letter to the interested parties shown on the attached GO 96-B and R.18-07-003 service lists. Address change requests to the GO 96-B service list should be directed by electronic mail to AdviceTariffManager@sce.com or at (626) 302-4039. For changes to all other service lists, please contact the Commission's Process Office at (415) 703-2021 or by electronic mail at Process_Office@cpuc.ca.gov.

Further, in accordance with Public Utilities Code Section 491, notice to the public is hereby given by submitting and keeping the advice letter at SCE's corporate headquarters. To view other SCE advice letters submitted with the Commission, log on to SCE's web site at https://www.sce.com/wps/portal/home/regulatory/advice-letters.

For questions, please contact Eric Sezgen at (626) 302-1054 or by electronic mail at Eric.Sezgen@sce.com.

Southern California Edison Company

/s/ Gary A. Stern, Ph.D.
Gary A. Stern, Ph.D.

GAS:es:jm
Enclosure

California Public Utilities Commission

ADVICE LETTER SUMMARY

ENERGY UTILITY

MUST BE COMPLETED BY UTILITY (Attach additional pages as needed)

Company name/CPUC Utility No.: Southern California Edison Company (U 338-E)

Utility type:
☑ ELC ☐ GAS ☐ WATER
☐ PLC ☐ HEAT

Contact Person: Darrah Morgan
Phone #: (626) 302-2086
E-mail: AdviceTariffManager@sce.com
E-mail Disposition Notice to: AdviceTariffManager@sce.com

EXPLANATION OF UTILITY TYPE
ELC = Electric
PLC = Pipeline
GAS = Gas
HEAT = Heat
WATER = Water

(Date Submitted / Received Stamp by CPUC)

Advice Letter (AL) #: 4243-E

Tier Designation: 2

Subject of AL: Southern California Edison Company, San Diego Gas & Electric Company, and Pacific Gas and Electric Company's ELCC Study Submission

Keywords (choose from CPUC listing): Compliance

AL Type: ☐ Monthly ☐ Quarterly ☐ Annual ☑ One-Time ☐ Other:

If AL submitted in compliance with a Commission order, indicate relevant Decision/Resolution #:
Decision 19-09-043

Does AL replace a withdrawn or rejected AL? If so, identify the prior AL:

Summarize differences between the AL and the prior withdrawn or rejected AL:

Confidential treatment requested? ☐ Yes ☑ No

If yes, specification of confidential information:
Confidential information will be made available to appropriate parties who execute a nondisclosure agreement. Name and contact information to request nondisclosure agreement/access to confidential information:

Resolution required? ☐ Yes ☑ No

Requested effective date: 7/31/20

No. of tariff sheets: -0-

Estimated system annual revenue effect (%):

Estimated system average rate effect (%):

When rates are affected by AL, include attachment in AL showing average rate effects on customer classes (residential, small commercial, large C/I, agricultural, lighting).

Tariff schedules affected: None

Service affected and changes proposed[1]:

Pending advice letters that revise the same tariff sheets: None

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[1] Discuss in AL if more space is needed.

Clear Form

Protests and all other correspondence regarding this AL are due no later than 20 days after the date of this submittal, unless otherwise authorized by the Commission, and shall be sent to:

CPUC, Energy Division
Attention: Tariff Unit
505 Van Ness Avenue
San Francisco, CA 94102
Email: EDTariffUnit@cpuc.ca.gov

Name: Gary A. Stern, Ph.D.
Title: Managing Director, State Regulatory Operations
Utility Name: Southern California Edison Company
Address: 8631 Rush Street
City: Rosemead
State: California Zip: 91770
Telephone (xxx) xxx-xxxx: (626) 302-9645
Facsimile (xxx) xxx-xxxx: (626) 302-6396
Email: advicetariffmanager@sce.com

Name: Laura Genao c/o Karyn Gansecki
Title: Managing Director, State Regulatory Affairs
Utility Name: Southern California Edison Company
Address: 601 Van Ness Avenue, Suite 2030
City: San Francisco
State: California Zip: 94102
Telephone (xxx) xxx-xxxx: (415) 929-5515
Facsimile (xxx) xxx-xxxx: (415) 929-5544
Email: karyn.gansecki@sce.com

Clear Form

ENERGY Advice Letter Keywords

- Affiliate
- Agreements
- Agriculture
- Avoided Cost
- Balancing Account
- Baseline
- Bilingual
- Billings
- Bioenergy
- Brokerage Fees
- CARE
- CPUC Reimbursement Fee
- Capacity
- Cogeneration
- Compliance
- Conditions of Service
- Connection
- Conservation
- Consolidate Tariffs
- Contracts
- Core
- Credit
- Curtailable Service
- Customer Charge
- Customer Owned Generation
- Decrease Rates
- Demand Charge
- Demand Side Fund
- Demand Side Management
- Demand Side Response
- Deposits
- Depreciation
- Direct Access
- Disconnect Service
- ECAC / Energy Cost Adjustment
- EOR / Enhanced Oil Recovery
- Energy Charge
- Energy Efficiency
- Establish Service
- Expand Service Area
- Forms
- Franchise Fee / User Tax
- G.O. 131-D
- GRC / General Rate Case
- Hazardous Waste
- Increase Rates
- Interruptible Service
- Interutility Transportation
- LIEE / Low-Income Energy Efficiency
- LIRA / Low-Income Ratepayer Assistance
- Late Payment Charge
- Line Extensions
- Memorandum Account
- Metered Energy Efficiency
- Metering
- Mobile Home Parks
- Name Change
- Non-Core
- Non-firm Service Contracts
- Nuclear
- Oil Pipelines
- PBR / Performance Based Ratemaking
- Portfolio
- Power Lines
- Preliminary Statement
- Procurement
- Qualifying Facility
- Rebates
- Refunds
- Reliability
- Re-MAT/Bio-MAT
- Revenue Allocation
- Rule 21
- Rules
- Section 851
- Self Generation
- Service Area Map
- Service Outage
- Solar
- Standby Service
- Storage
- Street Lights
- Surcharges
- Tariffs
- Taxes
- Text Changes
- Transformer
- Transition Cost
- Transmission Lines
- Transportation Electrification
- Transportation Rates
- Undergrounding
- Voltage Discount
- Wind Power
- Withdrawal of Service

Clear Form

Appendix A

2020 Joint IOU ELCC Study

Report 1

06/26/2020

PREPARED FOR

California Investor Owned Utilities
Southern California Edison Company
Pacific Gas & Electric Company
San Diego Gas & Electric Company

PREPARED BY

Kevin Carden
Alex Krasny Dombrowsky
Chase Winkler
Astrapé Consulting

TABLE OF CONTENTS

EXECUTIVE SUMMARY

As directed in the "Decision Adopting Modeling Requirements to Calculate Effective Load Carrying Capability Values for Renewables Portfolio Standard Procurement"[1] ("Decision") on October 3rd, 2019 in California Public Utilities Commission's ("CPUC's") RPS Proceeding R. 18-07-003, the Commission ordered the California Investor Owned Utilities ("IOUs"), which comprise of Pacific Gas & Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company, to perform an Effective Load Carrying Capability ("ELCC") study.

In accordance with the Decision, Astrapé Consulting, acting as contractor, shall provide to the IOUs two reports that summarize the ELCC values for the resource classes and class subtypes located in the seven locations, detail the inputs assumptions (e.g., load, installed capacity), explain the methodology used to calculate the ELCC values, and compare the impact of the different locations on the same technology types. This document addresses the requirements of Report #1, providing the annual, marginal ELCC values for the resource classes and class subtype locations including hybrid resources using 4-hour duration storage. As directed in the Decision, the 2017-2018 Preferred System Plan (PSP) was used as the basis for the analysis.

The major findings of this phase of the study are:

- The marginal ELCC value of solar is expected to continue to decline as the penetration of solar increases.
- Some interactions between solar and storage are expected in the ELCC valuation of each resource, but the penetrations of storage analyzed were not large enough to surface this effect.
- Assuming solar and 4-hour storage hybrid resources have equal capacities, the hybrid facility is expected to provide an ELCC value near the maximum output of the storage facility since solar energy is consistently able to fully charge the connected batteries prior to the daily net load peak. This finding is expected to change as the penetration of storage increases.
- Wind and 4-hour storage hybrid resources provide lower ELCC values because of the variable ability of the wind to fully charge the batteries prior to the daily net load peak.
- Some issues were identified with the wind profiles from the 2017-2018 Preferred System Plan. Namely, external wind profiles exhibit unrealistically positive correlation with California load suggesting the quantified ELCCs for those resources are too high. External area wind profile development needs further review to ensure comparability with in-state profiles and fidelity of actual reliability contributions for each class and location of wind resource.

Tables ES1 – ES3 provide the recommended ELCC values by technology and region for the study years 2022, 2026, and 2030.

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[1] http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M316/K882/316882092.PDF

Table ES1. Recommended ELCC Values for 2022[2]

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE	4.3%	5.4%	6.9%	99.6%	21.8%	54.0%
SCE/SDGE	3.6%	4.6%	5.4%	99.9%	18.0%	47.0%
AZ APS		4.6%	5.4%	99.0%	38.8%	78.3%
NM EPE		4.6%	5.4%	99.0%	38.8%	78.3%
BPA					32.7%	57.2%
CAISO	**4.0%**	**5.0%**	**6.2%**	**99.8%**	**19.9%**	**50.5%**
Average	**4.0%**	**4.8%**	**5.8%**	**99.4%**	**30.0%**	**62.0%**

Table ES2. Recommended ELCC Values for 2026

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE	1.3%	2.1%	3.4%	98.8%	17.9%	43.5%
SCE/SDGE	0.6%	1.2%	1.9%	96.4%	17.8%	35.3%
AZ APS		~0.0%	1.9%	96.0%	30.8%	79.2%
NM EPE		~0.0%	1.9%	96.0%	30.8%	79.2%
BPA					32.8%	52.8%
CAISO	**1.0%**	**1.7%**	**2.7%**	**97.6%**	**17.9%**	**39.4%**
Average	**1.0%**	**0.8%**	**2.3%**	**96.8%**	**26.0%**	**58.0%**

Table ES3. Recommended ELCC Values for 2030

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE	0.4%	1.3%	3.4%	93.4%	20.5%	39.2%
SCE/SDGE	~0.0%	~0.0%	~0.0%	93.0%	17.4%	31.7%
AZ APS		~0.0%	~0.0%	90.5%	30.2%	63.4%
NM EPE		~0.0%	~0.0%	90.5%	30.2%	63.4%
BPA					28.2%	51.6%
CAISO	**0.2%**	**0.7%**	**1.7%**	**93.2%**	**19.0%**	**35.5%**
Average	**0.2%**	**0.3%**	**0.9%**	**91.9%**	**25.3%**	**49.9%**

Report 2 is expected to provide annual, marginal ELCC values for hybrid resources using 1 and 2 hour duration storage, detail the inputs assumptions (e.g., load, installed capacity), explain the methodology used to calculate the ELCC values, and compare the impact of the different locations on the same technology types. Report 2 is expected to be delivered in late 2020.

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[2] Values for all three study years reflect post-processing to reduce statistical noise. This included averaging Northern and Southern California raw results since the underlying renewable profiles were more similar than suggested by the variability in raw simulation results. It also included capping solar ELCC by using longitude to prevent projects further east from having higher capacity values than those further west.

INPUT ASSUMPTIONS

STUDY REQUIREMENTS

Astrapé Consulting was contracted by the California Investor Owned Utilities to examine the annual marginal ELCC values for the resource classes and locations, found in Table 1 for 3 study years (2022, 2026, and 2030).

Table 1. Resource Class and Location Combinations Calculated

	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE Bay	X	X	X	X	X	X
PGE Valley	X	X	X	X	X	X
SCE	X	X	X	X	X	X
SDGE	X	X	X	X	X	X
AZ APS		X	X	X	X	X
NM EPE		X	X	X	X	X
BPA					X	X

Astrapé performed simulations to determine the ELCC values using the Strategic Energy and Risk Valuation Model (SERVM). The base database was constructed using the 2017-2018 Preferred System Plan (PSP) as directed in the "Decision Adopting Modeling Requirements to Calculate Effective Load Carrying Capability Values for Renewables Portfolio Standard Procurement' ("Decision") on October 3rd, 2019 in California Public Utilities Commission's ("CPUC's") RPS Proceeding R. 18-07-003.[3] A base case of the system is first established by calibrating the CAISO region to a reliability of 0.1 Loss of Load Expectation (LOLE) for each of the three study years (2022, 2026, and 2030) by either adding load uniformly across each hour of the year or adding energy storage capacity. Using the base case from each respective study year, multiple technology and locational ELCC values were studied. Table 2 contains the resource mix at 0.1 LOLE used as the base case simulations for each study year.

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[3] http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M316/K882/316882092.PDF

Table 2. Study Year Resource Mix at 0.1 LOLE

Unit Category	Total Capacity by Year (MW)		
	2022	**2026**	**2030**
Battery Storage	1,115	1,514	3,431
Thermal	23,310	22,717	20,726
Nuclear	2,300	0	0
DR/EE	3,906	6,450	8,813
EV	-1,268	-2,198	-3,086
Hydro	6,032	6,032	6,032
PSH	1,832	1,832	1,832
Other Renewable*	2,449	2,519	4,235
Wind	8,566	8,994	9,121
BTM PV	12,301	16,727	20,759
Solar Thermal	1,248	1,248	1,248
Solar_Fixed	7,933	8,187	8,233
Solar_Tracking_SingleAxis	15,222	16,569	16,776
ELCC Adjustment**	-2,737	800	270
Total	**82,209**	**91,392**	**98,391**

** Other Renewable includes biogas, biomass, and geothermal units*

***Negative indicates added load, positive indicates 4hour storage added*

ELCC METHODOLOGY

After calibrating the system, the study technology resource was added to the system. The load peak was then artificially increased uniformly across all hours until the reliability returned to 0.1 LOLE. The following equation was used to calculate the ELCC value:

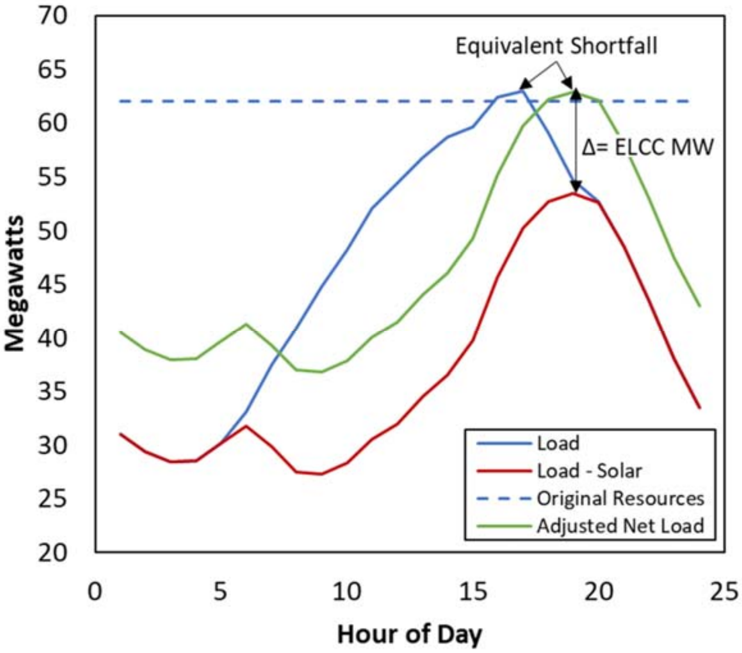
$$ELCC = \frac{Load\ Peak\ Increase\ (MW)}{Study\ Technology\ Resource\ Added\ (MW)} * 100\%$$

The process is as follows, using illustrative values and a solar resource:

1. Add a 30 MW solar resource to system calibrated to 0.1 LOLE
    a. The LOLE decreases to 0.08, indicating an improvement in reliability
2. Add 10 MW of load every hour
    a. The LOLE increases to 0.1, indicating a return to original reliability
3. The ELCC is calculated as the ratio of step 2 and step 1
    a. 10 MW / 30 MW = 33.3% ELCC

Figure 1 contains a graphic example of the process described above.

Figure 1. ELCC Calculation Methodology Illustration



REGIONS

CAISO is separated into 4 distinct regions in SERVM: PGE Bay, PGE Valley, SCE, and SDGE. The following external regions were included in the study: AZPS, BCHA, BPAT, CFE, IID, IPCO, LADWP, NEVP, NLZ, NWMT, PACE, PACW, Portland General, PSCO, SMUD, SPPC, SRP, TEPC, TIDC, WACM, and WALC. The neighboring resources were assumed to be fully deliverable to CAISO subject to an 11,665 MW aggregated Maximum Import Capability limit (MIC).

Since neighboring Balancing Authorities were not explicitly modeled, North and South neighbor assistance was modeled as a proxy. Table 3 defines which neighboring entities were classified as North and which neighbors were classified as South.

Table 3. Region Definitions for Proxy Neighbor Assistance

Region	Entity
North	BANC
	BPA
	PACW
	TIDC
South	AZPS
	CFE
	IID
	LADWP
	NEVP
	SRP

A time series of imports into CAISO was developed for North and South neighboring entities separately and was based on historic interchange as a function of CAISO net load by season. This relationship was applied to all 35 weather years studied (1980-2014) so that each weather year included a unique profile of assistance from neighboring areas reflective of each year's renewable output and weather conditions. Supporting information for CAISO was retrieved from the EIA website based on 2019 actual data.[4] Total imports were capped at 11,665 MW to reflect aggregate transmission MIC constraints. The average hourly imports as a function of demand net of renewables is provided in Figure 2, where demand net of renewables is calculated as load net of wind, utility scale solar PV, EE, and behind the meter PV ("BTM PV"). As shown in the figure, imports increase as a function of net demand, with the majority of imports from entities connected to the South region, however the incremental imports for each MW of net demand becomes attenuated at higher net demand periods.

Figure 2. Average Hourly Imports by Zone

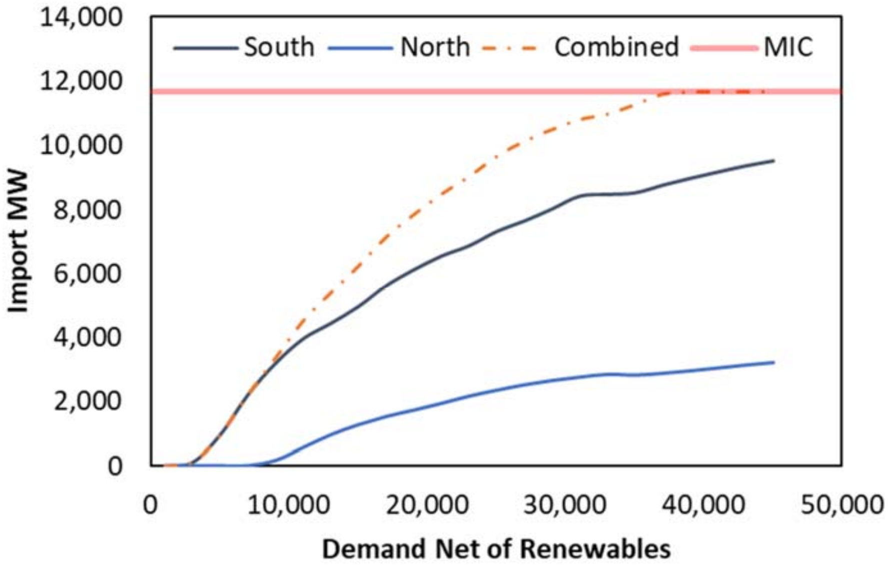


Figure 3 provides an illustrative example of a week of imports for both the North and South zones.

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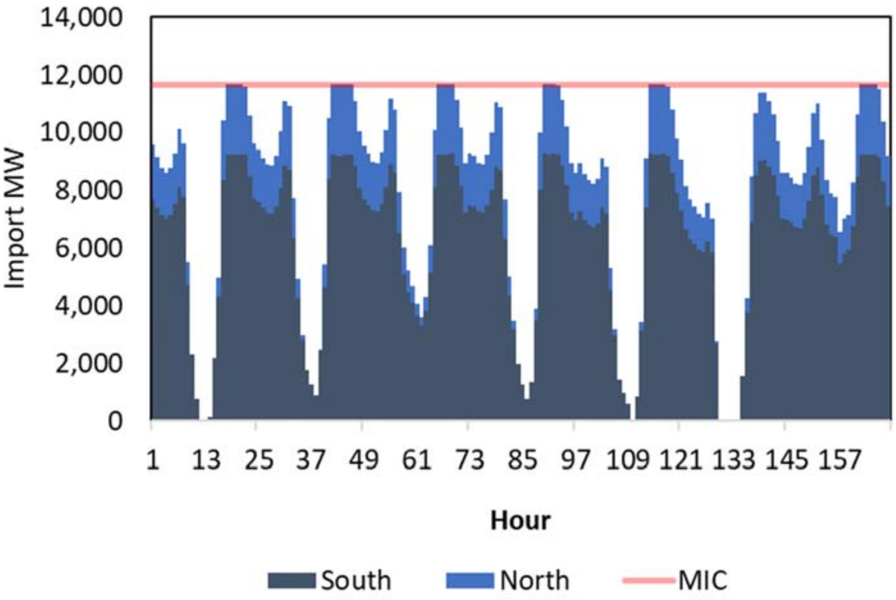
[4] https://www.eia.gov/beta/electricity/gridmonitor/dashboard/electric_overview/balancing_authority/CISO

Figure 3. Imports – 1 Week Illustrative Example



LOAD SHAPES

Hourly load was modeled for each of the 4 CAISO regions within SERVM. To capture the effects of weather uncertainty, load shapes in the 2017 – 2018 PSP were developed by Astrapé for thirty-five historical weather years (1980 – 2014) to reflect the impact of weather on load. A neural network program was used to develop relationships between weather observations and load based on provided historical weather and load data. Other inputs into the neural network program consisted of an hour of week factor, temperature, and average temperatures from the past 8, 24, and 48 hours. Different weather and load relationships were built for each month. These relationships were then applied to the 1980 – 2014 weather profiles to develop 39 synthetic load profiles for the future study years (2022, 2026, and 2030). The synthetic load profiles represent expected load given customer electric use patterns today if historic weather conditions were to occur. The forecast peak load and energy by study year for each CAISO region is displayed in Table 4.

Table 4. Peak Load and Energy by Weather Year and Region

	Peak Load (MW)			Energy (GWh)		
	2022	2026	2030	2022	2026	2030
PGE Bay	9,289	9,699	10,029	47,700	49,694	51,237
PGE Valley	13,093	13,728	14,234	65,837	68,863	71,232
SCE	25,994	27,424	28,511	115,740	121,608	125,890
SDGE	5,009	5,297	5,490	22,688	23,815	24,522
CAISO	53,385	56,148	58,264	251,965	263,980	272,881

RENEWABLE PROFILES

The wind and solar shapes are from the 2017-2018 Preferred System Plan originally developed by Astrapé. The wind profiles were produced using historical metered output from wind facilities in California from 2010 to 2014. The raw data was normalized to 100% by dividing the hourly output by the maximum annual capacity for each of the five years. A correlation was created between the wind output and load for SCE and PGE Valley. Profiles for 1980 to 2009 were created by selecting the day that most closely matched the total load out of all the days +/- 5 days of the source day. For example, the wind profile for January 10, 1981 was selected by looking at the load from January 5 to 15 from all source years (2010 to 2014) and selecting the date that most closely matched the load of January 10, 1981. Each unique wind profile in all California regions used the same historical day (e.g. all January 1, 1980 used December 27, 2011 for all profiles) to preserve the historical diversity between wind projects in California. Hours 24 and 1 were interpolated from hour 23 and 2 to avoid a drastic hourly change in output. Wind profiles from the Pacific Northwest and AZ/PNM were created with generic data from public sources to match expected capacity factors.

Solar shapes in the 2017-2018 PSP were developed by downloading data from the NREL National Solar Radiation Database (NSRDB) Data Viewer.[5] Data was downloaded for 170 different cities for the years that were available at the time: 1998 through 2014. Historical solar data from the NREL NSRDB Data Viewer included variables such as temperature, cloud cover, humidity, dew point, and global solar irradiance. The data obtained from the NSRDB Data Viewer was input into NREL's System Advisor Model (SAM) for each year and city to generate the hourly solar profiles based on the solar weather data for both fixed and tracking solar PV plants.[6] SAM inputs included the DC to AC ratio of the inverter module and tilt and azimuth angle of the PV array. Output data from SAM was then normalized to 100%. Solar profiles for 1980 to 1998 were selected by using the daily solar profiles from the day that most closely matched the total daily load out of the corresponding data for the days available. 1998 to 2014 profiles came directly from the normalized raw data. The profiles were aggregated for each region by averaging the cities that fell within each region.

Studies were performed for each study year for PGE Bay, PGE Valley, SCE, SDGE, AZ APS, NM EPE, and BPA. Each technology and location has a distinct set of renewable profiles in SERVM.[7] For the four CAISO regions, marginal ELCC values were calculated for each of the following technologies: BTM PV, fixed PV, tracking PV, tracking PV hybrid, wind, and wind hybrid. AZ APS and NM EPE marginal ELCC values were calculated for the following technologies: fixed PV, tracking PV, tracking PV hybrid, wind, and wind hybrid. Marginal ELCC values were calculated for the following technology types in BPA: wind and wind hybrid. For each case, 500 MW increments for each respective technology and location were added. The average annual capacity factor for the set of profiles used for each technology and region is provided in Table 5.

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[5] https://nsrdb.nrel.gov/

[6] https://sam.nrel.gov/

[7] NMEPE and AZAPS have a single set of wind profiles.

Table 5. Average Capacity Factor for Renewable Profiles Used

	BTM PV	Solar Fixed	Solar Tracking Single Axis	Wind
PGE Bay	20.5%	21.4%	26.0%	25.2%
PGE Valley	20.7%	25.9%	31.2%	27.5%
SCE	22.5%	26.5%	31.5%	28.1%
SDGE	21.0%	26.8%	33.3%	24.8%
AZAPS	N/A	27.6%	32.1%	30.2%
NMEPE	N/A	27.1%	31.1%	30.2%
BPA	N/A	N/A	N/A	30.9%
Average	**21.2%**	**25.9%**	**30.8%**	**28.2%**

TECHNOLOGY ASSUMPTIONS

SOLAR TECHNOLOGIES

For each region, the PV units total 500 MW and used the corresponding technology weather stations for each region with varying inverter loading ratios. The breakdowns were setup to match the breakdowns of weather station and inverter loading ratios that were used in the 2017-2018 PSP[8]. As a result, a set of two profiles was used for the SCE and SDGE solar technology simulations and one profile was used for each PGE Region. The weather shape, Inverter Loading Ratio (ILR), and capacity breakdowns for each region and technology are defined in Table 6.

Table 6. Solar Technology Assumptions

Region	Technology	Weather Shape	Capacity (MW)	ILR	Capacity Factor (%)
PGE Bay	BTM PV	PGE Bay Fixed	500	1.00	20.5
PGE Valley	BTM PV	PGE Valley Fixed	500	1.00	20.7
SCE	BTM PV	NEVP Fixed	103.2	1.00	22.5
	BTM PV	SCE Fixed	396.8	1.00	
SDGE	BTM PV	IID Fixed	161.0	1.00	21.0
	BTM PV	SDGE Fixed	339.0	1.00	
AZAPS	Solar Fixed	AZ APS Fixed	500	1.18	27.6
NMEPE	Solar Fixed	NM EPE Fixed	500	1.18	27.1
PGE Bay	Solar Fixed	PGE Bay Fixed	500	1.04	21.4
PGE Valley	Solar Fixed	PGE Valley Fixed	500	1.26	25.9
SCE	Solar Fixed	NEVP Fixed	103.2	1.18	26.5
	Solar Fixed	SCE Fixed	396.8	1.18	
SDGE	Solar Fixed	IID Fixed	161.0	1.30	26.8
	Solar Fixed	SDGE Fixed	339.0	1.30	
AZAPS	Solar Tracking Single Axis	AZ APS Tracking	500	1.11	32.1
NMEPE	Solar Tracking Single Axis	NM EPE Tracking	500	1.11	31.1
PGE Bay	Solar Tracking Single Axis	PGE Bay Tracking	500	1.00	26.0
PGE Valley	Solar Tracking Single Axis	PGE Valley Tracking	500	1.18	31.2
SCE	Solar Tracking Single Axis	NEVP Tracking	103.2	1.11	31.5
	Solar Tracking Single Axis	SCE Tracking	396.8	1.11	
SDGE	Solar Tracking Single Axis	IID Tracking	161.0	1.29	33.3
	Solar Tracking Single Axis	SDGE Tracking	339.0	1.29	

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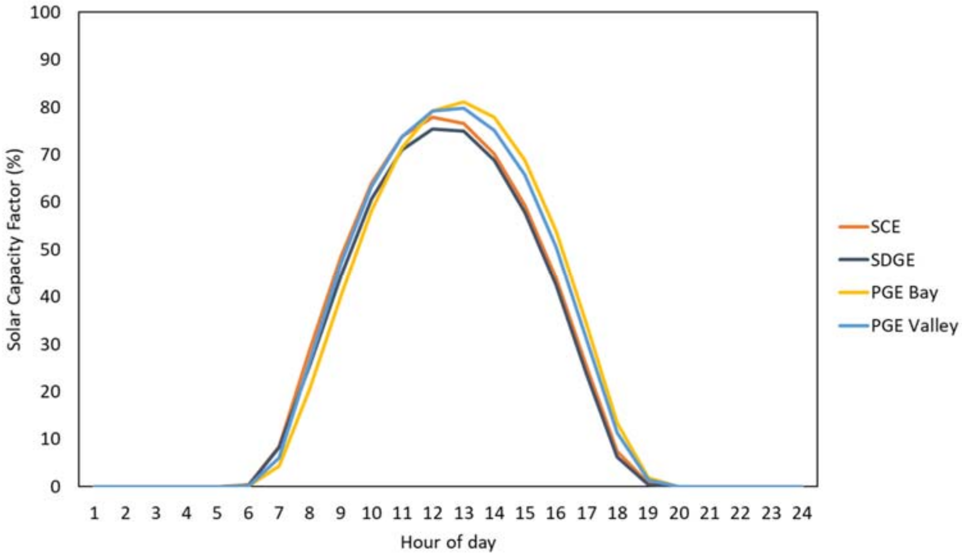
[8] https://www.cpuc.ca.gov/General.aspx?id=6442451195

BTM PV solar output during high net demand days is shown in Figure 4. Northern California shapes (PGE Bay, PGE Valley) show greater amounts of generation at critical reliability hours (18-20) than Southern California shapes (SCE, SDGE) due to longitudinal effects.[9] PGE Bay and Valley solar shapes are approximately three degrees longitude farther west than SCE and SDGE, resulting in a greater amount of insolation during twilight hours. Solar shapes further east in the NMEPE/AZAPS zones had higher capacity factors, likely due to input development and calibration approaches for those shapes, which apparently offset some of the longitudinal effects. Our expectation is that longitudinal differences should have a more consistent impact on ELCC results. In future studies the consistency between profile development and other input assumption development across multiple regions should be carefully monitored.

Figure 4. Solar Shapes by Region and Longitudinal Effect



TRACKING PV HYBRID

The tracking PV hybrid units used the tracking PV weather stations and capacities defined in Table 6 above. Though weather station allocation may have differed between hybrids, the tracking PV units and battery units totaled 500 MW each, yielding 1,000 MW of nameplate capacity with 500 MW maximum combined output based on an assumed 500 MW interconnection capability.[10] The battery units were modeled with 4-hour storage capability, 85% round trip efficiency, used economic commitment and dispatch, and could only charge from the corresponding tracking PV unit. As DC coupled would be expected to result in relatively higher ELCC than AC coupled, the tracking PV and battery units were assumed AC coupled to serve as a conservative estimate of hybrid configuration ELCC. A sensitivity was performed to determine the optimal configuration to be used for this study. The results of the sensitivity are discussed in Appendix A.

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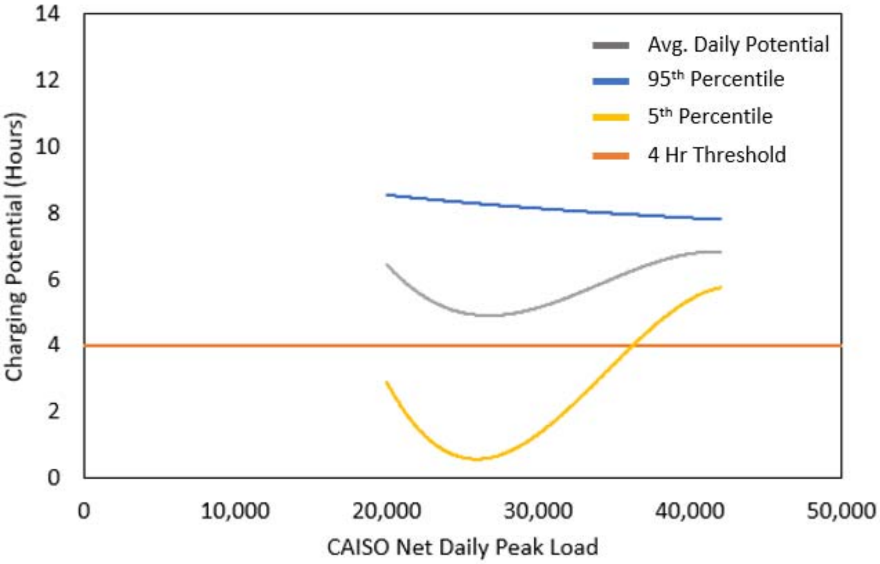
[9] These hours represent the peak net load hours, considering all solar, wind, EE, and EV and serves as a proxy for timing of expected reliability events.

[10] See Appendix for recommendation of maximum combined output.

The following figure was developed to determine if the solar profiles would provide adequate energy to consistently charge the linked energy storage resource. The charging potential of the PGE Bay solar shape describes the amount of energy produced prior to hour 18 by the solar plant, expressed in terms of hours of energy which could be stored within a 500 MW storage device. ELCC is highly correlated with ability to fully charge prior to the highest peak periods. Figure 5 shows during the highest net daily load peaks across the year 2022,[11] the coupled solar should be able to consistently charge a storage device to 4 hours with a 90% confidence interval, with an average charging potential of roughly 7 hours. The 90% confidence interval is figured as the difference in the 95th percentile and 5th percentile curves. Considering that the PGE Bay shape exhibits the lowest annual capacity factor of hybrid resources studied, other configurations should also have enough energy to achieve a 4-hour charge.

Figure 5. Charging Potential of PGE Bay Tracking PV Hybrid



WIND

The wind units being studied totaled 500 MW for each region and used the wind weather stations in SERVM for each region. Table 7 displays the wind shape and capacity breakdown for each region being tested. A set of three profiles was used for the SCE wind technology simulations, reflecting the possibility that incremental wind could be developed at any of the listed locations. The breakdown of wind capacity assigned to each weather station in the base case was used to calculate the capacities assigned to each of the three shapes for the SCE wind units.

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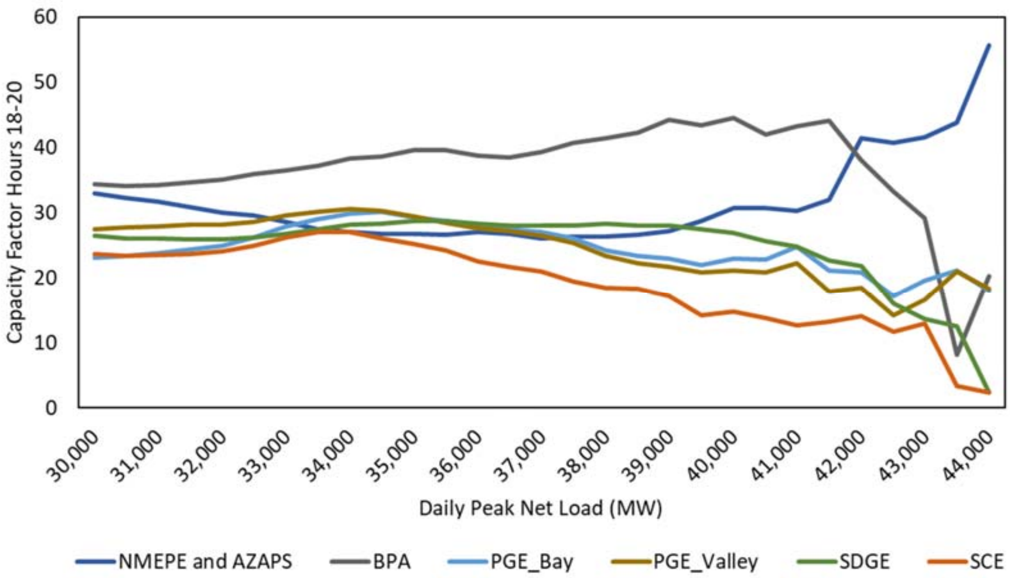
[11] Considering all solar, wind, EE, and EV.

Table 7. Wind Technology Assumptions

Region	Wind Shape	Capacity (MW)	Capacity Factor (%)	Capacity Factor on CAISO Net Peak (%)
PGE Bay	Wind_PGE Bay	500	25.2	23.0
PGE Valley	Wind_PGE Valley	500	27.5	21.6
SCE	Wind_San Gorgonio	412.6	28.1	17.2
	Wind_SCE	34.6		
	Wind_Tehachapi	52.8		
SDGE	Wind_SDGE	500	24.8	28.0
AZAPS	Wind_AZAPS/NMEPE	500	30.2	27.2
NMEPE	Wind_AZAPS/NMEPE	500	30.2	27.2
BPA	Wind_BPA	500	30.9	44.2

To understand the characteristics of each wind shape and serve as a validation of ELCC results, the capacity factor during the expected CAISO net peak demand was calculated.[12] Figure 6 illustrates each wind shape's generation during hours 18 to 20 for high demand periods across all weather years.

Figure 6. Average Wind Output Hours 18 to 20 on Peak Net Load Days



As illustrated in the figure above, California-derived wind shapes generally result in lower capacity factors during high net demand hours and show correlation between one another.[12] Out of state shapes such as NM EPE / AZ APS and BPA show a stronger positive or negative correlation, which is primarily due to decreased data quality relative to that which was available for California based profiles rather than an effect which is expected to materialize in actual operations.

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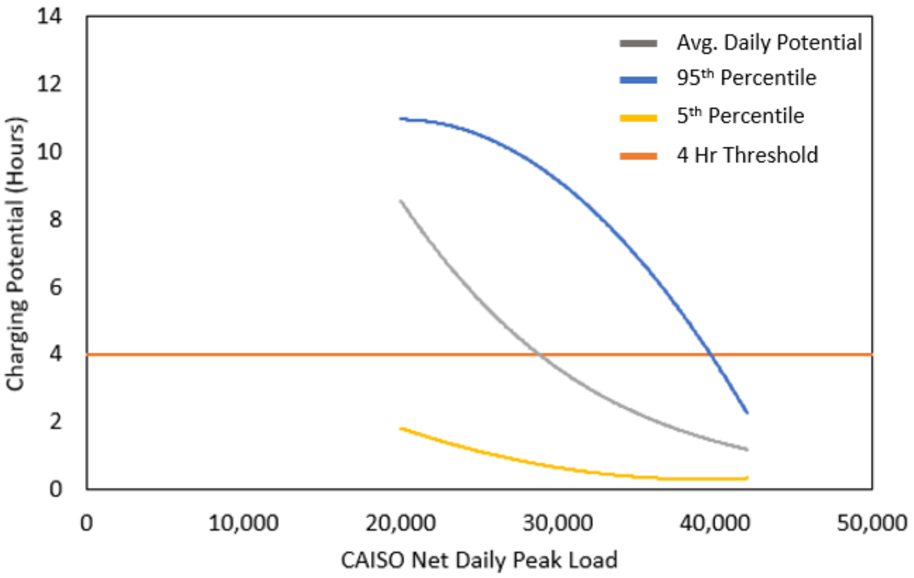
[12] Where net demand considers all solar, wind, EE, and EV.

WIND HYBRID

The wind hybrid units used the weather stations and capacities defined in Table 6 above. Though weather station allocation may have differed between hybrids, the wind units and battery units totaled 500 MW each, yielding 1,000 MW of nameplate capacity with 500 MW maximum combined output based on the assumed interconnection capability.[13] The battery units were modeled with a 4-hour storage capability, 85% round trip efficiency, used economic commitment and dispatch, and could only charge from the corresponding wind unit.

Figure 7 was developed to determine if the wind profiles would provide adequate energy to consistently charge the coupled energy storage resource. The charging potential of the SCE wind shape describes the amount of energy produced prior to hour 18 by the wind plant,[14] expressed in terms of hours of energy which could be stored within a 500 MW storage device. The figure shows during the highest net daily peaks, the coupled wind would not be able to consistently charge a 500 MW storage device to 4 hours in a 90% confidence interval. The 90% confidence interval is figured as the difference in the 95th percentile and 5th percentile curves. The expected charging capability at the highest net demand periods is expected to be less than 2 hours, with some days as low as a fraction of 1 hour. Considering that the SCE shape exhibits the lowest annual capacity factor on net peak of hybrid resources studied, other wind shapes may have improved charging potentials.

Figure 7. Charging Potential of SCE Wind Hybrid



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[13] See Appendix for recommendation of maximum combined output

[14] These hours represent the peak net load hours, considering all solar, wind, EE, and EV and serves as a proxy for timing of expected reliability events.

SIMULATION RESULTS

Astrapé performed simulations to determine the annual, marginal ELCC values for the defined resource classes and class subtypes locations. Table 8 defines the results for the 2022 study year. The hybrid projects have total nameplate capacity of 1,000 MW (500 MW renewable and 500 MW battery), but the marginal ELCC is calculated as a percentage of the maximum simultaneous output from the facility,[15] which is 500 MW based on the assumed interconnection capacity.[16]

Table 8. 2022 Study Results[17]

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE	4.3%	5.4%	6.9%	99.6%	21.8%	54.0%
SCE/SDGE	3.6%	4.6%	5.4%	99.9%	18.0%	47.0%
AZ APS		4.6%	5.4%	99.0%	38.8%	78.3%
NM EPE		4.6%	5.4%	99.0%	38.8%	78.3%
BPA					32.7%	57.2%
CAISO	**4.0%**	**5.0%**	**6.2%**	**99.8%**	**19.9%**	**50.5%**
Average	**4.0%**	**4.8%**	**5.8%**	**99.4%**	**30.0%**	**62.0%**

The results for the 2026 study year are provided below in Table 9.

Table 9. 2026 Study Results

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE	1.3%	2.1%	3.4%	98.8%	17.9%	43.5%
SCE/SDGE	0.6%	1.2%	1.9%	96.4%	17.8%	35.3%
AZ APS		~0.0%	1.9%	96.0%	30.8%	79.2%
NM EPE		~0.0%	1.9%	96.0%	30.8%	79.2%
BPA					32.8%	52.8%
CAISO	**1.0%**	**1.7%**	**2.7%**	**97.6%**	**17.9%**	**39.4%**
Average	**1.0%**	**0.8%**	**2.3%**	**96.8%**	**26.0%**	**58.0%**

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[15] These hours represent the peak net load hours, considering all solar, wind, EE, and EV and serves as a proxy for timing of expected reliability events.

[16] Given the wide range of possible configurations for hybrid facilities, multiple methods of accounting for their ELCC may need to ultimately be employed, but for simplicity and comparability, using maximum simultaneous output as the denominator was most appropriate for this report. The implications of hybrid configuration on ELCC are further explored in Appendix A.

[17] Values for all three study years reflect post-processing to reduce statistical noise. This included averaging Northern and Southern California raw results since the underlying renewable profiles were more similar than suggested by the variability in raw simulation results. It also included capping solar ELCC by using longitude to prevent projects further east from having higher capacity values than those further west.

The results from the 2030 study year are shown in Table 10.

Table 10. 2030 Study Results

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE	0.4%	1.3%	3.4%	93.4%	20.5%	39.2%
SCE/SDGE	~0.0%	~0.0%	~0.0%	93.0%	17.4%	31.7%
AZ APS		~0.0%	~0.0%	90.5%	30.2%	63.4%
NM EPE		~0.0%	~0.0%	90.5%	30.2%	63.4%
BPA					28.2%	51.6%
CAISO	**0.2%**	**0.7%**	**1.7%**	**93.2%**	**19.0%**	**35.5%**
Average	**0.2%**	**0.3%**	**0.9%**	**91.9%**	**25.3%**	**49.9%**

SOLAR RESULTS DISCUSSION

The marginal ELCC value of solar is expected to continue to decline as the penetration of solar increases and declines more so for BTM PV and Fixed PV technologies than Tracking PV.

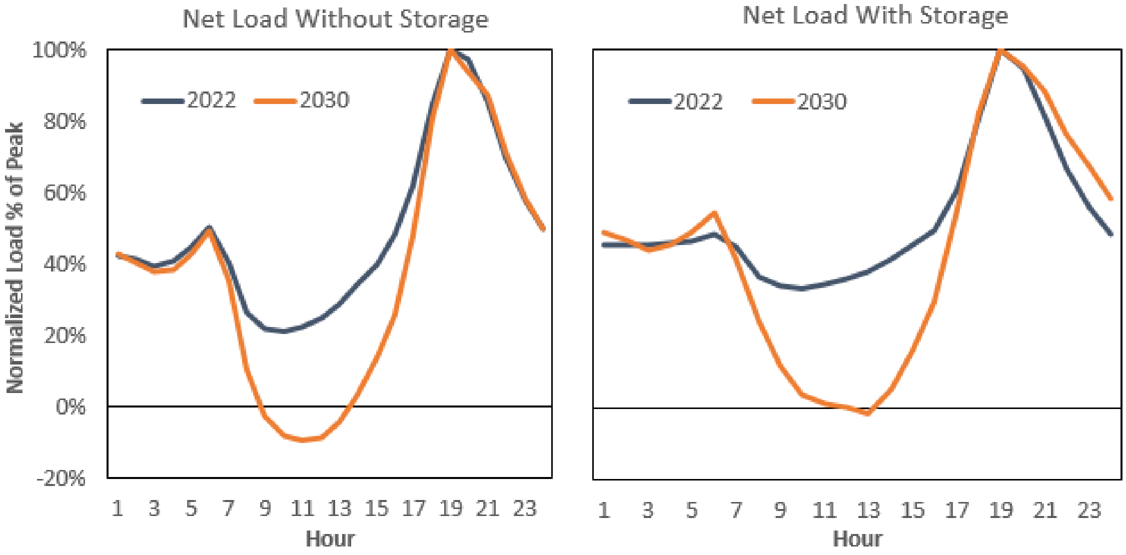
Additional solar tends to steepen the net load curve, narrowing the duration of the net peak. By narrowing the duration of peak load hours, this facilitates greater capacity value for storage resources within the footprint. The relatively low amount of storage penetration in the 2017 - 2018 PSP appears to be below the threshold for creating detectable renewable-storage interactions.

HYBRID RESULTS DISCUSSION

The decline seen in hybrid marginal ELCC can be attributed to increased storage penetration within the CAISO footprint. As shown in Figure 8, left, the 2022 and 2030 CAISO system has a similar net load shape in reliability critical hours after normalizing to net load. The figure on the right illustrates the normalized net load while considering existing standalone battery storage (i.e. storage charge and discharge is included in the net load, reducing peak periods) The increased penetration in 2030 relative to 2022 has the effect of broadening the demand in the evening, reducing the value (as measured by marginal ELCC) that energy-limited systems are able to provide.

Tracking PV and battery units were assumed AC coupled to serve as a conservative estimate of hybrid configuration. In a high penetration solar environment, the assumption of AC versus DC coupling is expected to not have as significant of an effect compared to a low solar penetration environment. Based on the inverter loading ratios used in this analysis, clipped energy is not expected to exceed 1.5% on an annual basis for the studied hybrid resources.

Figure 8. Impact of Storage Penetration on CAISO Load Shape



This effect is more pronounced for wind hybrids over solar hybrids, as wind hybrids are effectively shorter duration storage devices relative to the solar hybrids during peak net loads, as seen in Figure 7, and as such can provide relatively less reliability benefit to a broader net load shape.

CONCLUSION AND LESSONS LEARNED

CONCLUSION

This report sought to provide the marginal ELCC values for the resource classes and class subtypes located in the seven locations of interest, detail the inputs assumptions (e.g., load, installed capacity), explain the methodology used to calculate the ELCC values, and compare the impact of the different locations on the same technology types.

The marginal ELCC values were observed to decline for all studied resource types as storage and renewable penetration increases in the CAISO footprint. Wind hybrid ELCC values fall faster than solar hybrid ELCC values as these resource types are able to charge less during CAISO peak periods, rendering them shorter duration devices, and consequently more sensitive to the higher storage deployment in the 2026 and 2030 study years.

For the purpose of this study, given the composition of CAISO with no existing hybrid resources, the marginal ELCCs for hybrid resource types equal the average ELCC. Marginal versus average ELCC would be expected to diverge as the penetration of hybrid (i.e. storage backed renewable resources) increases.

LESSONS LEARNED

In reviewing the results and input assumptions, several potential improvements to future ELCC studies were identified:

1. Given the low expectation for storage penetration by 2030 in the 2017-2018 PSP, a number of expected reliability interactions between solar and storage were not detected in this study. Subsequent ELCC studies with higher storage penetrations will explore these interactions.
2. Alternative wind-storage hybrid configurations could have been explored. The results shown in the report assume a 1:1:1 ratio of storage:renewable:interconnection. Alternative wind configurations, such as a higher wind:storage ratio, may have resulted in higher wind ELCC values as the storage device could be more fully charged.
3. Data quality for out-of-state wind profiles needs to be similar to that of in-state wind profiles to ensure comparisons of the resulting ELCCs are valid.

APPENDIX

A.1 HYBRID CONFIGURATION SENSITIVITIES

A.1.1. PURPOSE

The ELCC of standalone storage, standalone solar, and 5 different configurations of a hybrid resource were assessed to understand the limitations imposed by charging constraints and a common interconnection. To determine limitations to the ELCC, the hybrid resource ELCCs were compared to the standalone sums of component resources.

A.1.2. MAJOR ASSUMPTIONS

Consistent with assumptions in the base case study, battery units were assumed to have a 4-hour storage capability with an 85% round trip efficiency. The five solar sites used in the study were assumed to be single axis tracking technology and have a 1.35 inverter loading ratio[18]. Solar assumptions differ from those used in the base case study, as discussed further below.

A.1.3. RESULTS

Table A.1 has the ELCC calculations for the standalone storage at different capacities, standalone solar, and six different configurations of hybrid resources.

Table A.1. Hybrid Configuration Sensitivity Results

Sensitivity #	Solar (MW)	Storage (MW)	Interconnection (MW)	ELCC (MW)	ELCC (%)
1	500	-	500	45	9%
2	-	250	250	239	96%
3	-	375	375	346	92%
4	-	500	500	462	92%
5	500	250	500	265	53%
6	500	250	750	285	38%
7	500	375	500	378	76%
8	500	375	875	392	45%
9	500	500	500	496	99%
10	500	500	1,000	506	51%

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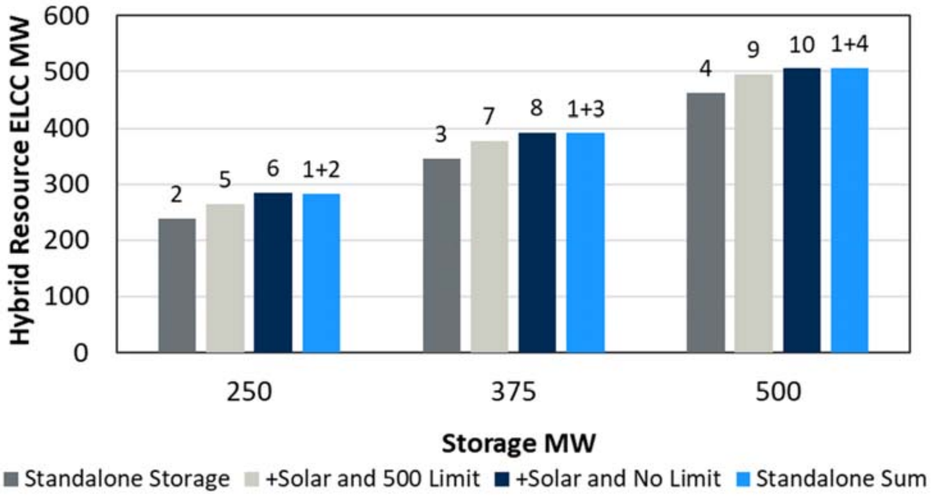
[18] The 1.35 inverter loading ratio is consistent with the inverter loading ratio used for single axis tracking technologies in the 2019-2020 IRP.

Figure A.1 shows the tabular results graphically.

Figure A.1. Hybrid Configuration Results



It should be noted the 9% ELCC produced in sensitivity #1 differs from the 2022 results as the sensitivities utilized a different set of assumptions. The assumptions for the 500 MW of solar utilized in the sensitivities is provided below in Table A.2. The linked solar in the sensitivity had a higher ILR than those used in the final runs for the official study, resulting in a greater capacity factor and correspondingly higher ELCC. Additionally, the 5 sites likely provided greater diversity in output stemming for geographic diversity.

Table A.2. Hybrid Configuration Assumptions

Solar	MW	ILR*	Location	Capacity Factor (%)
1	100	1.35	PGE Valley	34.5
2	100	1.35	PGE Bay	33.6
3	100	1.35	SCE	37.0
4	100	1.35	SDGE	33.9
5	100	1.35	LADWP	37.6

*** From 2019-2020 IRP**

A.1.1.4. FINDINGS

1. The study was performed with and without a solar charging restriction. The restriction does not seem to have a measurable effect on the capacity value up to a 1:1 ratio, and not significant up to a 2:1 storage:solar ratio.
    a. As discussed in the main body of the report, hybrid resource ELCC is sensitive to the penetration of storage. If an alternative portfolio such as the 2019 RSP portfolio was used, the hybrid ELCC results would be expected to change.
    b. The ability to support high storage:solar ratios with little measurable effect on ELCCs is due in part to the high capacity factors assumed within this sensitivity. Referring to Table A.2, the 5 solar projects show a capacity factor of roughly 35%, higher than those assumed in the body of this report. However, even with the lower capacity factors assumed in the body of the report, as shown in Table 7, the 2:1 storage:solar hybrid would likely have sufficient access to energy, considering the plant has the ability to charge 6 to 7 hours during the highest net demand periods.
2. The interconnection limit sized at the solar inverter prevents hybrid projects from fully capturing independent contributions when dispatched economically. This effect is lessened when storage is dispatched for only reliability purposes, and for configurations such as sensitivity 5 the ELCC may reach standalone storage + standalone solar ELCCs. Higher ratio storage:solar configurations do not see as much capacity value difference between economic and reliability dispatch methods since the storage dispatch is already limited by the interconnection. In other words, from an economic standpoint, the storage would have been scheduled to dispatch in peak load hours but was ultimately prevented by the interconnection size. Since the storage did not dispatch in these hours, it was available for later net load peak hours.
3. This analysis was performed assuming AC coupled hybrid configurations. In an environment where solar penetration is lower, the assumption on AC versus DC coupling may have a more significant effect. For example, if the solar provides significant capacity value, having to use the solar to charge the battery could reduce the aggregate capacity value; therefore, being able to use clipped solar energy to charge the battery would be advantageous.
4. Given the wide range of potential configurations for hybrid facilities a heuristic for calculating a specific project's ELCC may be needed. A general heuristic of calculating a solar hybrid facility's ELCC using the sum of the solar and battery standalone ELCC subject to a cap of the maximum combined output imposed by the interconnection capability, is a reasonable approximation at the solar and storage penetrations modeled in 2022 – 2030. This relationship was assessed for the 2022 year and is expected to hold for 2026 and 2030 as standalone storage ELCC falls slightly with penetration. Though this heuristic was found reasonable for the 2017-18 PSP, this may need to be revisited in subsequent ELCC studies given portfolio changes.

A.1.1.5. RECOMMENDATION

It was determined that utilizing a 1:1:1 solar:storage:interconnection ratio that captures the limitation imposed by a mutual interconnection is not especially dependent on assumptions regarding storage economic dispatch. A 1:1:1 ratio is therefore recommended for the purposes of hybrid resource marginal / average ELCC accreditation.