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

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

Pacific Gas & Electric Company
ELC (Corp ID 39)
Status of Advice Letter 6041E
As of January 28, 2021

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

Division Assigned: Energy

Date Filed: 12-29-2020

Date to Calendar: 01-01-2021

Authorizing Documents: D1909043

Disposition:	**Accepted**
Effective Date:	**01-28-2021**

Resolution Required: No

Resolution Number: None

Commission Meeting Date: None

CPUC Contact Information:

edtariffunit@cpuc.ca.gov

AL Certificate Contact Information:

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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Disposition of Filing (Accepted, Rejected, Withdrawn, etc.)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

December 29, 2020

ADVICE 4382-E
(Southern California Edison Company - U 338-E)

ADVICE 3665-E
(San Diego Gas & Electric Company - U902 M)

ADVICE 6041-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 Second Effective Load Carrying Capability 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) evaluations. The Decision required use of a specific dataset, software, and methodology, including the following:

- The joint IOU study shall use the Strategic Energy Risk Valuation Model.
- Behind-the-meter 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.
- The study shall analyze the following resources: fixed axis PV, tracking PV, tracking PV paired with storage, distributed PV, wind, and wind paired with storage.
- For the first report, the storage duration for hybrid systems, tracking PV paired with storage and wind paired with storage, should be 4 hours. The second report focuses on hybrid storage durations[1] of one- and two-hours.
- The study shall be performed across 7 regions, 4 in CAISO, and 3 outside of CAISO.

To fulfill the joint study and its associated requirements, the IOUs hired Astrapé Consulting to perform the analysis. The first report, filed on July 1, 2020, provided the ELCC values for fixed axis PV, tracking PV, tracking PV paired with storage (4-hour duration), distributed PV, wind, and wind paired with storage (4-hour duration). The second report, attached to this advice letter, specifically focuses on shorter hybrid storage durations and includes a correction to the ELCC values for 4-hour hybrid storage resources.

ELCC Study Results

Hybrid resources with shorter storage durations are still able to provide high ELCC value. For solar hybrid configurations, the marginal ELCC values are 92% or greater.[2] Similarly, for wind hybrid configurations, the marginal ELCC values are 83% or greater. The high ELCC values for shorter duration hybrid resources are directly tied to the ability to provide ancillary services during loss of load events. However, if the resource cannot provide ancillary services during loss of load events, the ELCC value for shorter

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[1] Shorter duration is defined as 1-2 hours.

[2] 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.

duration hybrid resources could be significantly reduced. For example, in 2030, 1-hour duration energy-only, hybrid resources have an ELCC values of 55% and 62% for wind hybrid and solar hybrid, respectively. Astrapé performed a dispatch heuristic sensitivity for the three storage durations of wind and solar hybrid resources to highlight the impact on ELCC values from various operating modes. ELCC values for 2022, 2026, and 2030 (Table 1-3) and the ancillary service sensitivities (Table 4) are provided in the tables below.

Table 1. Recommended ELCC Values for 2022[3] (expressed as a percentage of assumed interconnection capability)

Region	1-Hour Tracking PV Hybrid	2-Hour Tracking PV Hybrid	4-Hour Tracking PV Hybrid	1-Hour Wind Hybrid	2-Hour Wind Hybrid	4-Hour Wind Hybrid
CA-N[4]	99%	100%	100%	88%	91%	96%
CA-S	99%	100%	100%	91%	93%	96%
AZ APS	95%	96%	97%	92%	95%	100%
NM EPE	95%	96%	96%	92%	95%	100%
BPA	N/A	N/A	N/A	86%	91%	92%
CAISO	**99%**	**100%**	**100%**	**90%**	**92%**	**96%**
Average	**97%**	**98%**	**98%**	**90%**	**93%**	**97%**

Table 2. Recommended ELCC Values for 2026 (expressed as a percentage of assumed interconnection capability)

Region	1-Hour Tracking PV Hybrid	2-Hour Tracking PV Hybrid	4-Hour Tracking PV Hybrid	1-Hour Wind Hybrid	2-Hour Wind Hybrid	4-Hour Wind Hybrid
CA-N	94%	95%	100%	86%	89%	94%
CA-S	95%	97%	100%	91%	93%	95%
AZ APS	94%	94%	97%	90%	95%	97%
NM EPE	93%	91%	95%	90%	95%	97%
BPA	N/A	N/A	N/A	84%	88%	90%
CAISO	**94%**	**96%**	**100%**	**89%**	**91%**	**94%**
Average	**94%**	**94%**	**98%**	**88%**	**92%**	**95%**

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[3] Values for all three study years reflect post-processing to reduce statistical noise.

[4] Results shown have aggregated PGE Bay and Valley results together into the “CA-N”, or California North region, and SCE and SDGE results together into the “CA-S” or California South region.

Table 3. Recommended ELCC Values for 2030 (expressed as a percentage of assumed interconnection capability)

Region	1-Hour Tracking PV Hybrid	2-Hour Tracking PV Hybrid	4-Hour Tracking PV Hybrid	1-Hour Wind Hybrid	2-Hour Wind Hybrid	4-Hour Wind Hybrid
CA-N	93%	95%	96%	86%	89%	93%
CA-S	93%	95%	97%	90%	91%	93%
AZ APS	93%	93%	93%	90%	92%	94%
NM EPE	92%	91%	92%	90%	92%	94%
BPA	N/A	N/A	N/A	83%	88%	90%
CAISO	**93%**	**95%**	**97%**	**88%**	**90%**	**93%**
Average	**93%**	**93%**	**95%**	**88%**	**90%**	**93%**

Table 4. Ancillary Services Provisions (expressed as a percentage of interconnection capability)

CA-N Hybrid, 2030	Dispatch Heuristic[5]	1-Hour	2-Hour	4-Hour
Solar Hybrid	**Energy Only**	62%	90%	96%
	Energy and Ancillary Services	93%	95%	96%
	Ancillary Services Only*	100%	100%	100%
Wind Hybrid	**Energy Only**	55%	78%	80%
	Energy and Ancillary Services	86%	89%	93%
	Ancillary Services Only*	N/A[6]	N/A	N/A

*In the Ancillary Services Only dispatch heuristic, the hybrid is capable of providing grid services such as regulation up or spinning but will not provide energy unless during load shed

While modeling the hybrid resources with shorter duration, an updated storage scheduling methodology was adopted. The storage heuristic was updated for the hybrid resources with shorter durations as well as the hybrid resources with 4-hour duration. A detailed discussion of this change is included in this second report. Due to this change, the 4-hour duration hybrid resources ELCC values have been updated and are provided in this second report. The impact of this change results in significantly higher ELCC values for 4-hour wind hybrid resources. A comparison of the 4-hour hybrid resources' previous ELCC values and updated ELCC values is provided in the table (Table 5) below.

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[5] The resources are assumed to be capable of providing all services, but model settings are adjusted to utilize different dispatch heuristics for batteries in each respective case.

[6] The Ancillary Services Only dispatch heuristic was not assessed for wind hybrids.

Table 5. Report 1 and 2 Results for 4-Hour Hybrids (expressed as a percentage of interconnection capability)

4-Hour Hybrid Type	Region	2022		2026		2030	
		Original	Updated	Original	Updated	Original	Updated
Tracking PV Hybrid	CA-N	100%	100%	99%	100%	93%	96%
	CA-S	100%	100%	96%	100%	93%	97%
	AZ APS	99%	97%	96%	97%	91%	93%
	NM EPE	99%	96%	96%	96%	91%	92%
Wind Hybrid	CA-N	54%	96%	44%	94%	39%	93%
	CA-S	47%	96%	35%	95%	32%	93%
	AZ APS	78%	100%	79%	97%	63%	94%
	NM EPE	78%	100%	79%	97%	63%	94%
	BPA	57%	92%	53%	90%	52%	90%

Joint Utilities' Recommendations

Similar to the first report, the Joint Utilities recommend that, for any CAISO-located hybrid resource, the CAISO ELCC values for the respective technologies be used for any RPS evaluation purposes. While the ELCC study was performed across the seven regions, the geographic differences remain difficult to capture without significant time and effort. The Joint Utilities also recommend that the updated 4-hour wind hybrid and 4-hour solar hybrid ELCC values be adopted to incorporate the updated storage scheduling methodology.

REQUEST FOR COMMISSION APPROVAL

The Joint Utilities propose 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: Second ELCC Study Report

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 January 28, 2021, 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

Tara S. Kaushik
Managing Director, Regulatory Relations
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.: Pacific Gas and Electric Company (ID U 39 E)

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

Contact Person: Stuart Rubio
Phone #: (415) 973-4587
E-mail: PGETariffs@pge.com
E-mail Disposition Notice to: SHR8@pge.com

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

(Date Submitted / Received Stamp by CPUC)

Advice Letter (AL) #: 6041-E

Tier Designation: 2

Subject of AL: Joint Filing - Southern California Edison Company, San Diego Gas & Electric Company, and Pacific Gas and Electric Company's Second Effective Load Carrying Capability 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 #:
D.19-09-043

Does AL replace a withdrawn or rejected AL? If so, identify the prior AL: No

Summarize differences between the AL and the prior withdrawn or rejected AL: N/A

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: 1/28/21

No. of tariff sheets: N/A

Estimated system annual revenue effect (%): N/A

Estimated system average rate effect (%): N/A

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: N/A

Service affected and changes proposed[1]: N/A

Pending advice letters that revise the same tariff sheets: N/A

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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: Erik Jacobson, c/o Megan Lawson
Title: Director, Regulatory Relations
Utility Name: Pacific Gas and Electric Company
Address: 77 Beale Street, Mail Code B13U
City: San Francisco, CA 94177
State: California Zip: 94177
Telephone (xxx) xxx-xxxx: (415)973-2093
Facsimile (xxx) xxx-xxxx: (415)973-3582
Email: PGETariffs@pge.com

Name:
Title:
Utility Name:
Address:
City:
State: District of Columbia Zip:
Telephone (xxx) xxx-xxxx:
Facsimile (xxx) xxx-xxxx:
Email:

Clear Form

Advice 6041-E
December 29, 2020

Appendix A

Second ELCC Study Report

ASTRAPÉ CONSULTING
innovation in electric system planning

2020 Joint IOU ELCC Study

Report 2

12/11/2020

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 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 seven geographical regions (PGE Bay, PGE Valley, SCE, SDGE, AZ APS, NM EPE, and BPA)[2], detail the input 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 2: provide annual, marginal ELCC values for hybrid resources using 1[3]- and 2-hour duration storage, detail the input 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. As directed in the Decision, the 2017-2018 Preferred System Plan (PSP) was used as the basis for the analysis. ELCC values are reflective of the system studied and are not applicable to a system with a substantially different load and resource mix.

The major findings of this phase of the study are:

- While studying 1- and 2-hour hybrids, inefficiencies in the storage scheduling heuristics used in Report 1 were found and corrected in Report 2. Report 2 includes updated ELCC values for 4-hour wind hybrids and 4-hour tracking PV Hybrids. A detailed discussion of these findings is included in the "Charging Heuristics" sub-section within the "Input Assumptions" section.
- Battery and renewable hybrid resources of 1- and 2-hour duration are able to provide very high capacity value (92% or greater for all solar hybrid configurations, and 83% or greater for all wind hybrid configurations), where the assumed quantities of renewable resources and storage are each equal to the assumed interconnection capability, and capacity value is measured as a percentage of the assumed interconnection capability.
- The assumptions for short duration battery storage resources in this study - including when modeled as part of a hybrid resource - produce nearly maximal reliability benefit, with ELCC values approaching 100%. These assumptions include ancillary service eligibility with limited deployment and centralized dispatch that actively prioritizes by duration with almost immediate response from each resource. If these assumptions are not accurate for actual operations, the ELCCs will drop significantly. A sensitivity where the resources are modeled as energy only resources demonstrates that 1-hour duration storage is worth approximately 50%.

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

[2] Pacific Gas & Electric Bay, Pacific Gas & Electric Valley, Southern California Edison, San Diego Gas & Electric, Arizona Public Service, New Mexico Area and El Paso Electric, and Bonneville Power Administration, respectively

[3] Reference to storage duration means capacity in MW can be multiplied by duration in hours to determine max energy in MWh

Tables ES1 – ES3 provide the recommended ELCC[4] values by technology and region for the study years 2022, 2026, and 2030. The ELCC values for 4-hour hybrids in Tables ES1 - ES3 are an update to those originally shown in Report 1. Results shown have aggregated PGE Bay and Valley results together into the "CA-N", or California North region, and SCE and SDGE results together into the "CA-S" or California South region[5]. Northern and Southern California were aggregated since the underlying renewable profiles were more similar than suggested by the variability in raw simulation results.

Table ES1. Recommended ELCC Values for 2022[6] (expressed as a percentage of assumed interconnection capability)

Region	1-Hour Tracking PV Hybrid	2-Hour Tracking PV Hybrid	4-Hour Tracking PV Hybrid	1-Hour Wind Hybrid	2-Hour Wind Hybrid	4-Hour Wind Hybrid
CA-N	99%	100%	100%	88%	91%	96%
CA-S	99%	100%	100%	91%	93%	96%
AZ APS	95%	96%	97%	92%	95%	100%
NM EPE	95%	96%	96%	92%	95%	100%
BPA	N/A	N/A	N/A	86%	91%	92%
CAISO	**99%**	**100%**	**100%**	**90%**	**92%**	**96%**
Average	**97%**	**98%**	**98%**	**90%**	**93%**	**97%**

Table ES2. Recommended ELCC Values for 2026 (expressed as a percentage of assumed interconnection capability)

Region	1-Hour Tracking PV Hybrid	2-Hour Tracking PV Hybrid	4-Hour Tracking PV Hybrid	1-Hour Wind Hybrid	2-Hour Wind Hybrid	4-Hour Wind Hybrid
CA-N	94%	95%	100%	86%	89%	94%
CA-S	95%	97%	100%	91%	93%	95%
AZ APS	94%	94%	97%	90%	95%	97%
NM EPE	93%	91%	95%	90%	95%	97%
BPA	N/A	N/A	N/A	84%	88%	90%
CAISO	**94%**	**96%**	**100%**	**89%**	**91%**	**94%**
Average	**94%**	**94%**	**98%**	**88%**	**92%**	**95%**

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[4] 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.

[5] Report 1 also aggregated into CA-N and CA-S though the labels were PG&E for CA-N and SCE/SDG&E for CA-S

[6] Values for all three study years reflect post-processing to reduce statistical noise.

Table ES3. Recommended ELCC Values for 2030 (expressed as a percentage of assumed interconnection capability)

Region	1-Hour Tracking PV Hybrid	2-Hour Tracking PV Hybrid	4-Hour Tracking PV Hybrid	1-Hour Wind Hybrid	2-Hour Wind Hybrid	4-Hour Wind Hybrid
CA-N	93%	95%	96%	86%	89%	93%
CA-S	93%	95%	97%	90%	91%	93%
AZ APS	93%	93%	93%	90%	92%	94%
NM EPE	92%	91%	92%	90%	92%	94%
BPA	N/A	N/A	N/A	83%	88%	90%
CAISO	**93%**	**95%**	**97%**	**88%**	**90%**	**93%**
Average	**93%**	**93%**	**95%**	**88%**	**90%**	**93%**

Comparisons to results for Report 1 are shown in Table ES4. The charging heuristics used in the model in Report 1 assumed alignment between on-site renewable output and low net load periods. This assumption is reasonable for solar hybrids, but not for wind hybrids. Updated wind charging heuristics considered both net load and wind output forecasts and significantly improved capacity value for wind hybrids. Detailed explanation of the drivers of the difference is provided in the “Charging Heuristics” section of this report.

Table ES4. Report 1 and 2 Results for 4 Hour Hybrids (expressed as a percentage of interconnection capability)

4-Hour Hybrid Type	Region	2022		2026		2030	
		Original	Updated	Original	Updated	Original	Updated
Tracking PV Hybrid	CA-N	100%	100%	99%	100%	93%	96%
	CA-S	100%	100%	96%	100%	93%	97%
	AZ APS	99%	97%	96%	97%	91%	93%
	NM EPE	99%	96%	96%	96%	91%	92%
Wind Hybrid	CA-N	54%	96%	44%	94%	39%	93%
	CA-S	47%	96%	35%	95%	32%	93%
	AZ APS	78%	100%	79%	97%	63%	94%
	NM EPE	78%	100%	79%	97%	63%	94%
	BPA	57%	92%	53%	90%	52%	90%

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

	Tracking PV Hybrid	Wind Hybrid
PGE Bay	X	X
PGE Valley	X	X
SCE	X	X
SDGE	X	X
AZ APS	X	X
NM EPE	X	X
BPA	N/A	X

In Report 1[7], PGE Valley and PGE Bay regions were aggregated into PGE results, and SDGE and SCE results were aggregated into SDGE/SCE results. This aggregation is continued in Report 2, where ELCC for the PGE Bay and PGE Valley regions is reported for Northern California (CA-N), and the ELCC for SCE and SDGE regions is reported for Southern California (CA-S) regions.

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.[8] 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. LOLE was determined as the expected number of events where load and ancillary service requirements exceeded available generation, as measured over thousands of annual, chronological simulations. 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. A 0.1 LOLE level of reliability was determined by simulating the system as shown in Table 2.

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[7] Report 1 quantified the marginal ELCC by year for renewable technologies and 4-hour hybrid systems. Filed 07-01-2020 with the CPUC Energy Division

[8] 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 4-hour storage added*

MARGINAL 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 marginal ELCC value:

$$ELCC = \frac{Load\ Peak\ Increase\ (MW)}{Study\ Technology\ Resource\ Added^{9}\ (MW)} * 100\%$$

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. Marginal resource ELCC is typically analyzed assuming small increments of resources relative to system size. Figure shows an exaggerated visualization for clarity.

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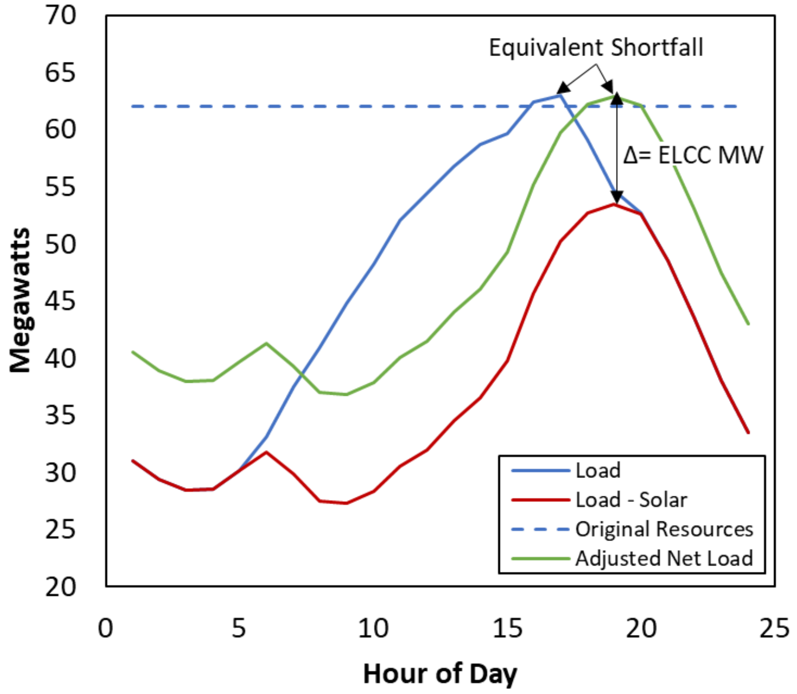
[9] Limited by interconnection capability for combined hybrid projects

Figure 1. Marginal 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:

- Arizona Public Service Company (AZ APS)
- Balancing Authority of Northern California (BANC)
- British Columbia Hydro Authority (BCHA)
- Bonneville Power Administration (BPA)
- Comisión Federal de Electricidad (CFE)
- Imperial Irrigation District (IID)
- Idaho Power Company (IPCO)
- Los Angeles Department of Water and Power (LADWP)
- Nevada Power Company (NEVP)
- NorthWestern Energy (NWMT)
- PacifiCorp East (PACE)
- PacifiCorp West (PACW)
- Portland General
- Public Service Company of Colorado (PSCO)
- Sacramento Municipal Utility District (SMUD)
- Sierra Pacific Power Company (SPPC)
- Salt River Project (SRP)
- Tucson Electric Power Company (TEPC)
- Turlock Irrigation District (TIDC)
- Western Area Power Administration – Colorado/Missouri Region (WACM)

- Western Area Power Administration – Lower Colorado Region (WALC)

The neighboring resources were assumed to be fully deliverable to CAISO subject to an 11,665 MW aggregated Maximum Import Capability limit (MIC).

All external regions described above were not explicitly modeled, instead North and South neighbor assistance was modeled as a proxy. Table 3 defines which Tier 1 (one tie away) neighboring entities were classified as North and which neighbors were classified as South.

Table 3. Region Definitions for Proxy Neighbor Assistance

Region	Tier 1 Entity
North	BANC BPA PACW TIDC
South	AZ APS CFE IID LADWP NEVP SRP WALC

A time series of imports into CAISO was developed for North and South Tier 1 neighboring entities separately and was based on historic interchange as a function of CAISO net load[10] by season, where net load is calculated as load minus wind, utility scale solar PV, and behind the meter PV ("BTM PV"). By assessing the imports with Tier 1 entities for 2019, the presence of Tier 2+ entities is also reflected, if not explicitly. 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.[11] Total imports were capped at 11,665 MW to reflect aggregate transmission MIC constraints. The average hourly imports as a function of net load is provided in Figure 2. As shown in the figure, imports increase as a function of net load, with the majority of imports from entities connected to the South region, however the incremental imports for each MW of net load becomes attenuated at higher net load periods.

Figure 2. Average Hourly Imports by Zone

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[10] Unless noted otherwise, net load will be defined as gross load less BTM PV, utility scale solar PV, and wind generation

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

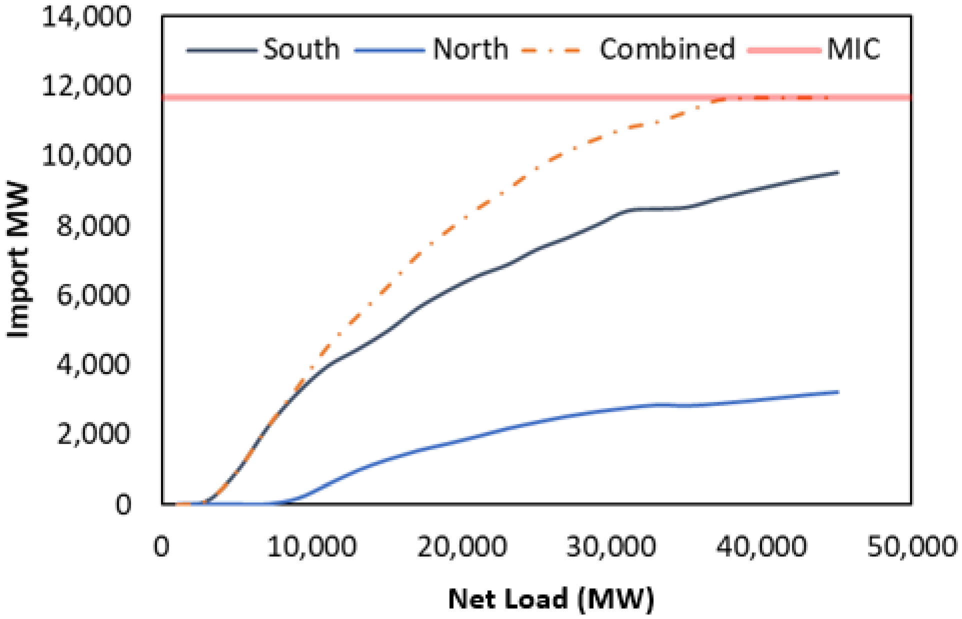
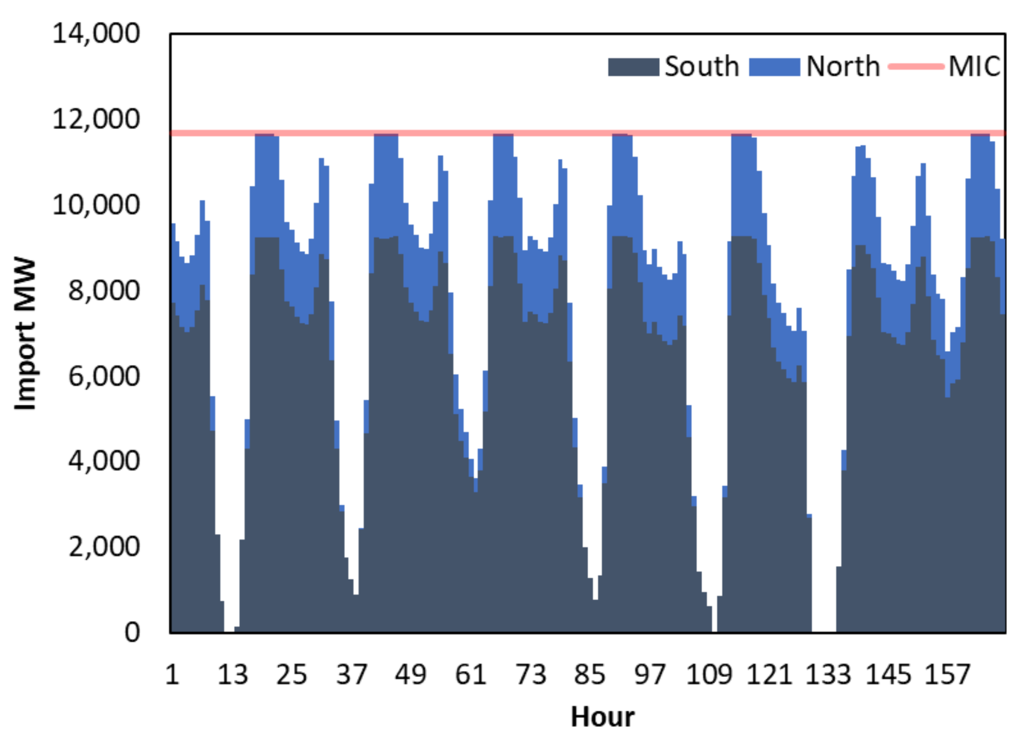


Figure 3 provides an illustrative example of a week of imports for both the North and South zones.

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 originally 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 for all study locations 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 each of the studied regions. 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 for BPA were based on publicly available hourly wind data.[12] Wind profiles for other zones were synthetically developed from a combination of NREL profiles[13] and proprietary wind data.

Solar shapes in the 2017-2018 PSP were developed by downloading data from the National Renewable Energy Laboratory (NREL) National Solar Radiation Database (NSRDB) Data Viewer.[14] 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.[15] 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.

An indicative set of renewable profiles was selected for both CA-N and CA-S, which best represents the constituent regions. For the two aggregated 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.

Table 5. Average Capacity Factor for Renewable Profiles Used

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[12] https://transmission.bpa.gov/Business/Operations/Wind/

[13] https://www.nrel.gov/grid/wind-toolkit.html

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

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

	BTM PV	Solar Fixed	Solar Tracking Single Axis	Wind
CA-N	20.7%	25.9%	31.2%	27.5%
CA-S	21.0%	26.8%	33.3%	24.8%
AZ APS	N/A	27.6%	32.1%	30.2%
NME PE	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

TRACKING PV HYBRID

The tracking PV hybrid units used the tracking PV solar shapes and capacities defined in Table 6 below.

Table 6. Tracking PV Technology Assumptions

Region	Solar Shape	Capacity (MW)	Inverter Load Ratio (ILR)	Capacity Factor (%)
CA-N	PGE Valley Tracking	500	1.18	31.2
CA-S	IID Tracking	161.0	1.29	33.3
	SDGE Tracking	339.0	1.29	
AZ APS	AZ APS Tracking	500	1.11	32.1
NM EPE	NM EPE Tracking	500	1.11	31.1

Though solar shape 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.[16] The battery units were modeled with 1-, 2-, or 4-hour storage capability, 85% round trip efficiency, and used economic commitment and dispatch subject to the constraint that the battery 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 of Report 1.

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 the ability to fully charge prior to the highest net load peak periods. Figure 4 shows that during the highest CAISO net daily load peaks across the year 2022,[17] the coupled solar PV tracking component

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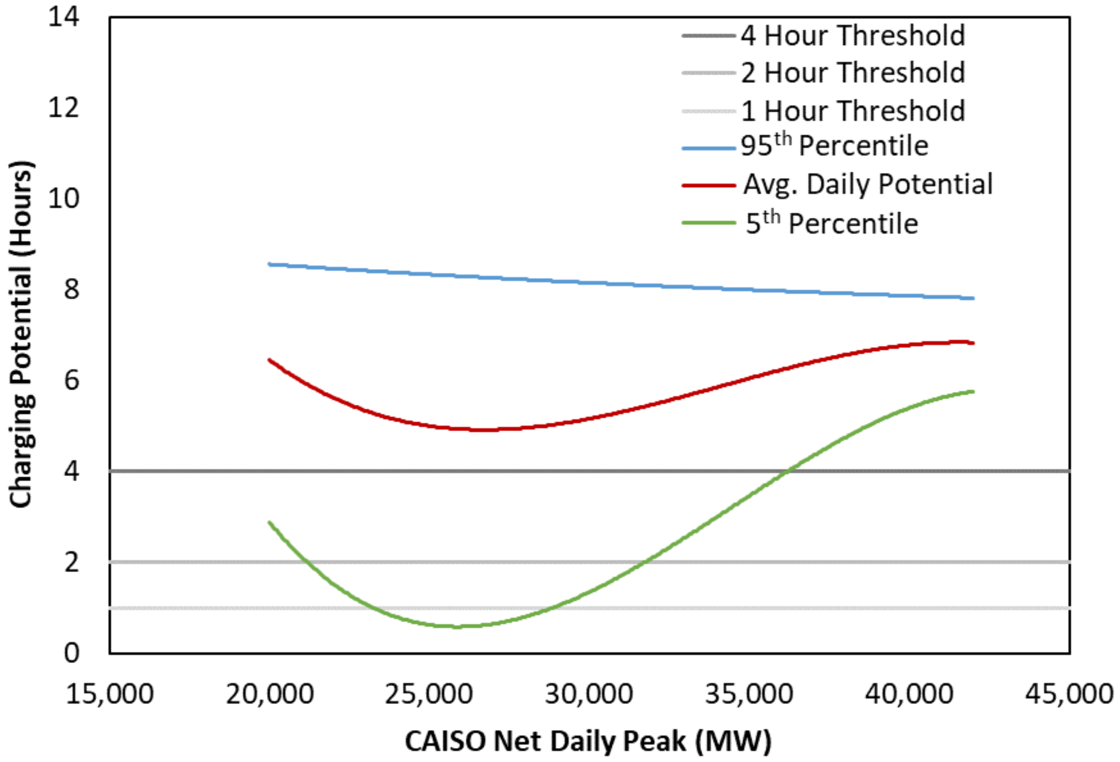
[16] See Appendix A in Report 1 for recommendation of maximum combined output.

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

should be able to consistently charge the studied storage devices (1-, 2-, or 4-hours) with a 90% confidence interval, with an average charging potential of roughly 7 hours. The 90% confidence interval is shown as the difference in the 95th percentile and 5th percentile curves. Because the PGE Bay shape exhibits the lowest annual capacity factor of hybrid resources studied, other configurations are assumed to also have enough energy to achieve a full charge.

Figure 4. Charging Potential of PGE Bay Tracking PV Hybrid



WIND HYBRID

The wind hybrid units used the wind shapes and capacities defined in Table 7 below.

Table 7. Wind Technology Assumptions

Region	Wind Shape	Capacity (MW)	Capacity Factor (%)	Capacity Factor on CAISO Net Peak (%)
CA-N	Wind_PGE Valley	500	27.5	21.6
CA-S	Wind_SDGE	500	24.8	28.0
AZ APS	Wind_AZ APS/NM EPE	500	30.2	27.2
NM EPE	Wind_AZ APS/NM EPE	500	30.2	27.2
BPA	Wind_BPA	500	30.9	44.2

Though wind shape 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.[18] The battery units were modeled with 1-, 2-, or 4-hour storage capability, 85% round trip efficiency, used economic commitment and dispatch subject to the constraint that the battery could only charge from the corresponding wind unit.

Figure 5 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,[19] 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 coupled wind is even insufficient for 1- and 2-hour storage devices to consistently provide full charge, considering the 5th percentile is below 1 hour. The expected charging capability at the highest net load periods is expected to be less than 2 hours, with some days as low as a fraction of 1 hour. However, since this product is assumed to be capable of providing AS, its capacity value remains elevated. 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.

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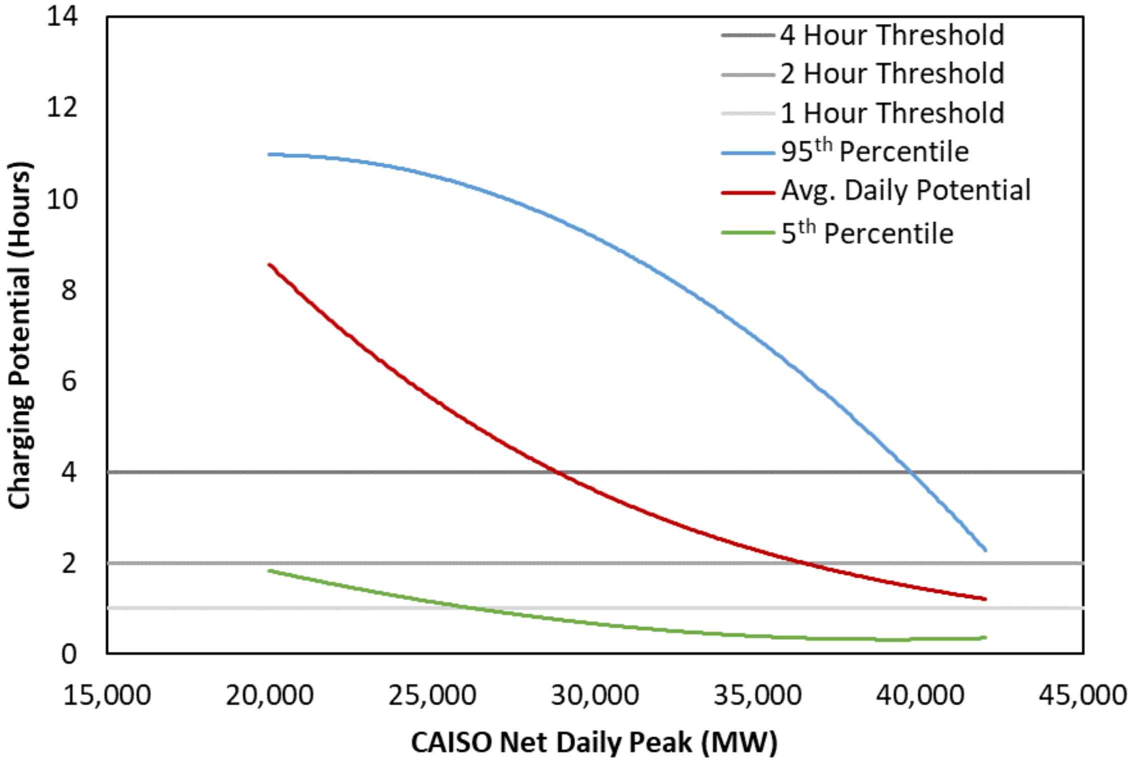
[18] See Appendix A in Report 1 for recommendation of maximum combined output.

[19] 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.

Figure 5. Charging Potential of SCE Wind Hybrid

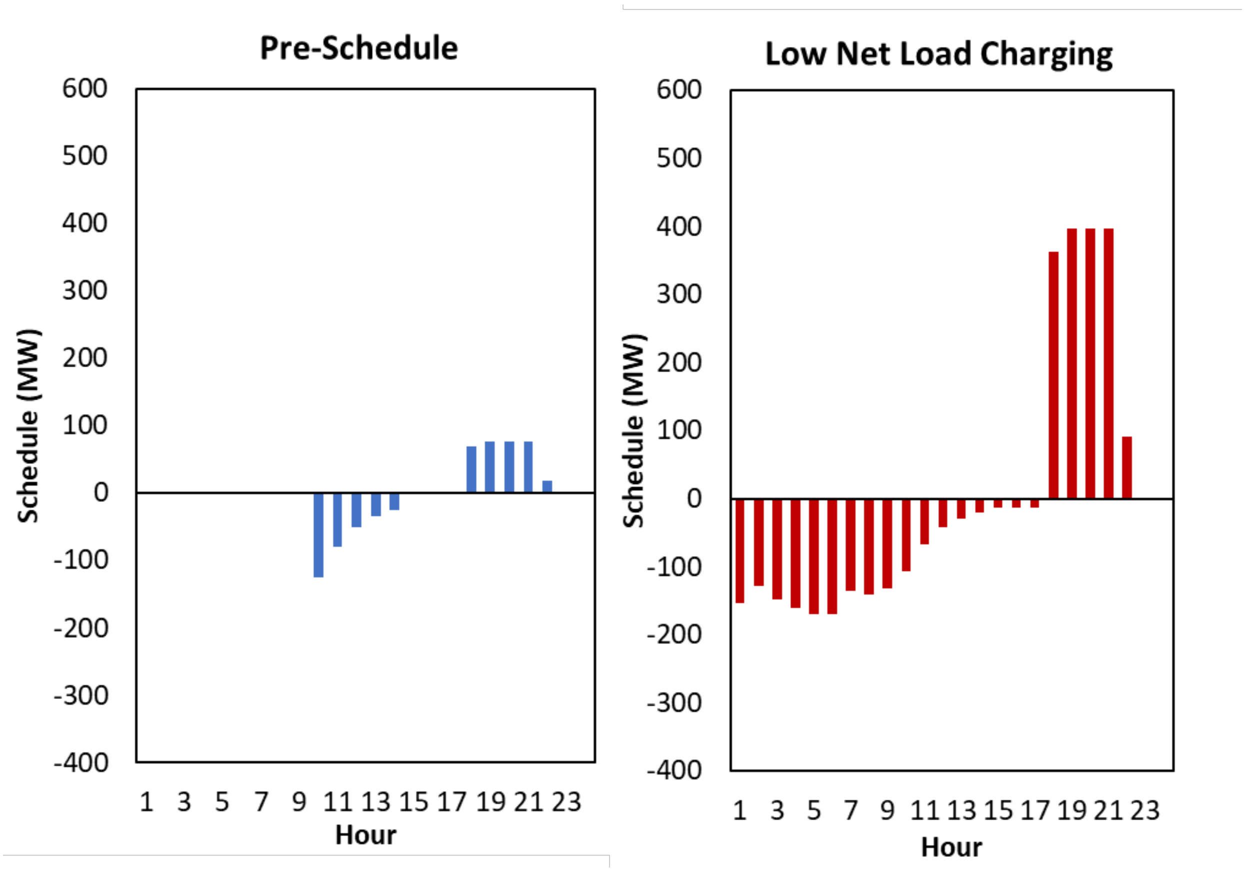


CHARGING HEURISTICS

Embedded in the results for Report 1 is the assumption that energy storage resources will schedule charging and discharging periods day-ahead based on the day-ahead forecast of net load, and then actually charge in real-time from the linked renewable facility at those pre-designated time periods. This assumes market participants would avoid charging at higher priced hours (which generally correspond with the highest net load hours), rather than scheduling charging to maximize state of charge. This was an error which presumed low net load periods (e.g., 10:00 am to 3:00 pm) and wind output would be correlated. This presumption results in inadequate state of charge in advance of high net load periods (e.g., 6:00 pm to 10:00 pm) when energy production is most valuable from a reliability perspective.

For Report 2, the charging heuristic used to schedule storage was updated. The new scheduling procedure assumes market participants will charge hybrid facilities as much as possible prior to the high net load period, prioritizing all lower net load periods in the charging schedule. An example of these two approaches is illustrated below. The prior scheduling heuristic assumed charging would be performed in pre-determined windows based on a day-ahead schedule.

Figure 6. Charging Heuristics (Wild Hybrid)



Pre-Schedule

Low Net Load Charging

The distinction between the two operating modes is less impactful for 4-hour solar PV tracking hybrids because low net load periods are highly correlated with solar output. Calculated 4-hour solar PV tracking marginal ELCC values have had a maximum absolute value change of three percent. Table 8 shows the results for 4-hour hybrid projects for each study year. As shown in the table, implementing this approach results in greater ELCC's for wind hybrids, attributable to more consistent charging.

Table 8. Report 1 and 2 Results for 4 Hour Hybrids (expressed as a percentage of interconnection capability)

4-Hour Hybrid Type	Region	2022		2026		2030	
		Report 1	Report 2	Report 1	Report 2	Report 1	Report 2
Tracking PV Hybrid	CA-N	100%	100%	99%	100%	93%	96%
	CA-S	100%	100%	96%	100%	93%	97%
	AZ APS	99%	97%	96%	97%	91%	93%
	NM EPE	99%	96%	96%	96%	91%	92%
Wind Hybrid	CA-N	54%	96%	44%	94%	39%	93%
	CA-S	47%	96%	35%	95%	32%	93%
	AZ APS	78%	100%	79%	97%	63%	94%
	NM EPE	78%	100%	79%	97%	63%	94%
	BPA	57%	92%	53%	90%	52%	90%

SIMULATION RESULTS

Astrapé performed simulations to determine the annual, marginal ELCC values for the defined hybrid resource classes and class subtype locations. Table 9 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 possible simultaneous output from the facility,[2,20] which is 500 MW based on the assumed interconnection capacity.[21] Additionally, the storage component cannot charge from the grid.

Table 9. 2022 Study Results[22] (expressed as a percentage of the interconnection capability)

Region	1-Hour Tracking PV Hybrid	2-Hour Tracking PV Hybrid	4-Hour Tracking PV Hybrid	1-Hour Wind Hybrid	2-Hour Wind Hybrid	4-Hour Wind Hybrid
CA-N	99%	100%	100%	88%	91%	96%
CA-S	99%	100%	100%	91%	93%	96%
AZ APS	95%	96%	97%	92%	95%	100%
NM EPE	95%	96%	96%	92%	95%	100%
BPA[23]	N/A	N/A	N/A	86%	91%	92%
CAISO	**99%**	**100%**	**100%**	**90%**	**92%**	**96%**
Average	**97%**	**98%**	**98%**	**90%**	**93%**	**97%**

The results for the 2026 study year are provided in Table 10.

Table 10. 2026 Study Results (expressed as a percentage of the interconnection capability)

Region	1-Hour Tracking PV Hybrid	2-Hour Tracking PV Hybrid	4-Hour Tracking PV Hybrid	1-Hour Wind Hybrid	2-Hour Wind Hybrid	4-Hour Wind Hybrid
CA-N	94%	95%	100%	86%	89%	94%
CA-S	95%	97%	100%	91%	93%	95%
AZ APS	94%	94%	97%	90%	95%	97%
NM EPE	93%	91%	95%	90%	95%	97%
BPA[23]	N/A	N/A	N/A	84%	88%	90%
CAISO	**94%**	**96%**	**100%**	**89%**	**91%**	**94%**
Average	**94%**	**94%**	**98%**	**88%**	**92%**	**95%**

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[20] 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.

[21] 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 possible simultaneous output as the denominator was most appropriate for this report. The implications of hybrid configuration on ELCC are further explored in Appendix A in Report 1.

[22] Values for all three study years reflect post-processing to reduce statistical noise.

[23] Solar PV Hybrids were not studied for BPA

The results for the 2030 study year for each duration of hybrid resource studied are shown in Table 11.

Table 11. 2030 Study Results (expressed as a percentage of the interconnection capability)

Region	1-Hour Tracking PV Hybrid	2-Hour Tracking PV Hybrid	4-Hour Tracking PV Hybrid	1-Hour Wind Hybrid	2-Hour Wind Hybrid	4-Hour Wind Hybrid
CA-N	93%	95%	96%	86%	89%	93%
CA-S	93%	95%	97%	90%	91%	93%
AZ APS	93%	93%	93%	90%	92%	94%
NM EPE	92%	91%	92%	90%	92%	94%
BPA[23]	N/A	N/A	N/A	83%	88%	90%
CAISO	**93%**	**95%**	**97%**	**88%**	**90%**	**93%**
Average	**93%**	**93%**	**95%**	**88%**	**90%**	**93%**

ANCILLARY SERVICES PROVISIONS

Since ancillary services must be maintained during a load shed event, hybrid resources are expected to be able to provide those products at some level, increasing their overall capacity value. By providing spinning or regulation up service, the battery component of the hybrid allows a conventional resource to produce energy, rather than ancillary services. Hybrids were modeled with the ability to provide energy or AS, subject to the maximum interconnection limit of the hybrid facility. To understand the capacity value the provision of AS provides, 2 additional operating heuristics were simulated for the CA-N hybrids for the year 2030. In the "Energy Only" scenario, hybrid resources were exclusively energy arbitrage resources. Energy was scheduled to be dispatched at the expected net peak demand hours. In the "Ancillary Services Only" scenario, hybrid resources did not participate in energy arbitrage. The battery component of the hybrid facility is capable of providing grid services such as regulation or spinning but will not provide energy unless during load shed. "Ancillary Services Only" is not expected to be an actual operating mode a market participant would elect, and is intended to capture the ceiling of possible ELCC. Further, the capacity value of providing AS is expected to decline once battery penetration exceeds the total system AS obligation.

Results for this analysis are shown below in Table 12. The AS heuristic provides more capacity value to wind hybrids, due to the state of charge. Referring to Figure 5, wind hybrids would be expected to be energy limited more than solar resources. As such, the ability to conserve energy by providing AS allows more grid services to be provided during high load periods (e.g. a wind hybrid with 1 hour of charge could provide spinning reserves for 2 hours, then discharge, providing 3 hours of total grid services). This shows more value than an energy only hybrid system, where a wind hybrid with 1 hour of charge would discharge, resulting in 1 hour of total grid services.

Table 12. Ancillary Services Provisions (expressed as a percentage of interconnection capability)

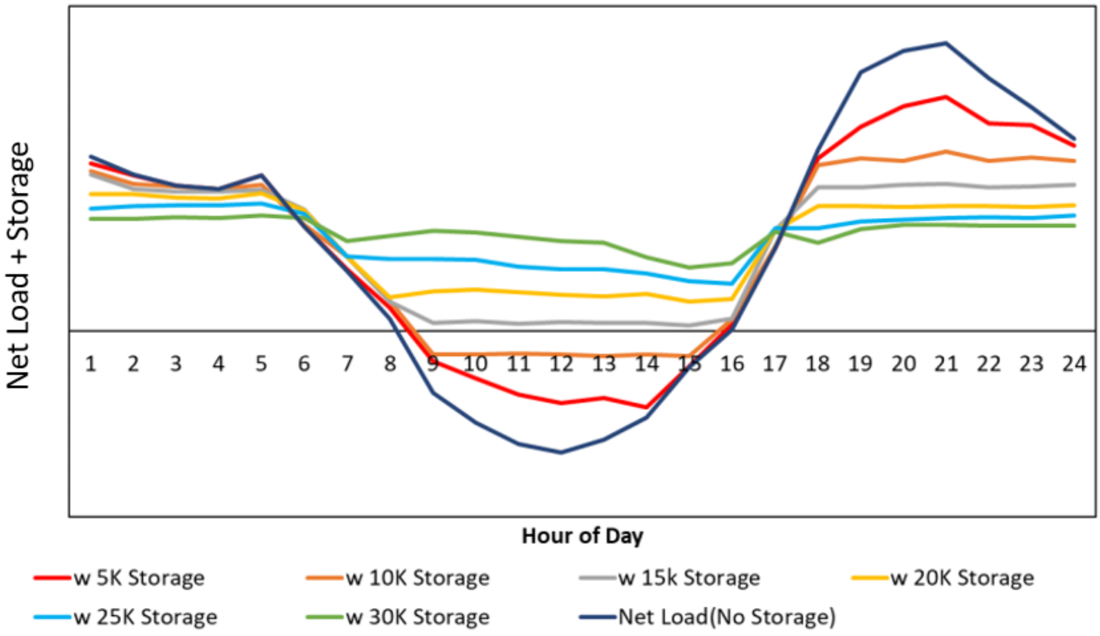
CA-N Hybrid, 2030	Dispatch Heuristic[24]	1-Hour	2-Hour	4-Hour
Solar Hybrid	Energy Only	62%	90%	96%
	Energy and Ancillary Services	93%	95%	96%
	Ancillary Services Only*	100%	100%	100%
Wind Hybrid	Energy Only	55%	78%	80%
	Energy and Ancillary Services	86%	89%	93%
	Ancillary Services Only*	N/A[25]	N/A	N/A

*In the Ancillary Services Only dispatch heuristic, the hybrid is capable of providing grid services such as regulation up or spinning but will not provide energy unless during load shed

RESULTS DISCUSSION

The decline seen in hybrid marginal ELCC can be attributed to increased storage penetration within the CAISO footprint. An extreme version of this concept is shown in Figure 7. As storage penetration increases, the overall load shape flattens. This limits the opportunity for incremental storage, leading to a diminished capacity value.

Figure 7. Impact of Storage on Net Load Shape (Illustrative)



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[24] The resources are assumed to be capable of providing all services, but model settings are adjusted to utilize different dispatch heuristics for batteries in each respective case

[25] The Ancillary Services Only dispatch heuristic was not assessed for wind hybrids

This concept, to a lesser degree, is shown for results of this study. The increased battery 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. Based on the charging potential described earlier in this report, the variable generation portion of the hybrids studied have sufficient energy to fully charge a 1-, 2-, or 4-hour duration battery, and additional energy would not be expected to provide much additional value. Within the analysis, energy clipped by the hybrid inverter is not dispatched to the grid and based on the inverter loading ratios used, clipped energy does not exceed 1.5% on an annual basis for the studied hybrid resources.

The impact of standalone storage penetration on the marginal ELCC of wind hybrids is more pronounced than for solar PV hybrids of the same nameplate capacity. This is because wind hybrids can be thought of as having shorter duration storage than solar PV hybrids for the same nameplate capacities. As shown in Tables 9-11, lower duration storage hybrids have lower marginal ELCC values, all else being equal. The results also show that the marginal ELCC of a hybrid in 2030 is less than that of the same hybrid in 2022 due to increased penetrations of standalone battery storage which result in a flatter net load peak. For these reasons, increasing storage penetration will diminish the marginal ELCC of wind hybrids more rapidly than solar PV hybrids of the same nameplate capacity.

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 resources types as storage and renewable penetration increases in the CAISO footprint. Wind hybrid ELCC values fall slightly faster than solar hybrid ELCC values as these resource types are able to charge less prior to CAISO net load peak periods, rendering them shorter duration devices, and consequently more sensitive to the higher storage deployment in the 2026 and 2030 study years. Despite these differences, wind hybrids retain high ELCC values into 2030 with 1-hour duration, primarily due to the participation in AS.

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. Data quality for out-of-state wind profiles needs to be similar to that for in-state wind profiles to ensure comparisons of the resulting ELCCs are valid.
3. Hybrid results are dependent upon the expected operating mode and charging practices implemented. For Report 2, an improved storage scheduling routine was implemented which is expected to be more consistent with operation of hybrid resource types.
4. The impact of standalone storage penetration on the marginal ELCC of wind hybrids is more pronounced than for solar PV hybrids of the same nameplate capacity.
5. Shorter duration storage devices’ (1- and 2-hour) reliability value is dependent on discharging behavior (i.e. provision of ancillary services).

APPENDIX – REPORT 1 UPDATES

Shown below are the final Report 1 values, which include updates to hybrid resources based on updated charging heuristics as covered in Report 2.

Table A1. ELCC Values for 2022 (expressed as a percentage of assumed interconnection capability)

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
CA-N	4.3%	5.4%	6.9%	100%	21.8%	96%
CA-S	3.6%	4.6%	5.4%	100%	18.0%	96%
AZ APS	N/A	4.6%	5.4%	97%	38.8%	100%
NM EPE	N/A	4.6%	5.4%	96%	38.8%	100%
BPA	N/A	N/A	N/A	N/A	32.7%	92%
CAISO	**4.0%**	**5.0%**	**6.2%**	**100%**	**19.9%**	**96%**
Average	**4.0%**	**4.8%**	**5.8%**	**98%**	**30.0%**	**97%**

Table A2. ELCC Values for 2026 (expressed as a percentage of assumed interconnection capability)

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
CA-N	1.3%	2.1%	3.4%	100%	17.9%	94%
CA-S	0.6%	1.2%	1.9%	100%	17.8%	95%
AZ APS	N/A	~0.0%	1.9%	97%	30.8%	97%
NM EPE	N/A	~0.0%	1.9%	95%	30.8%	97%
BPA	N/A	N/A	N/A	N/A	32.8%	90%
CAISO	**1.0%**	**1.7%**	**2.7%**	**100%**	**17.9%**	**94%**
Average	**1.0%**	**0.8%**	**2.3%**	**98%**	**26.0%**	**95%**

Table A3. ELCC Values for 2030 (expressed as a percentage of assumed interconnection capability)

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
CA-N	0.4%	1.3%	3.4%	96%	20.5%	93%
CA-S	~0.0%	~0.0%	~0.0%	97%	17.4%	93%
AZ APS	N/A	~0.0%	~0.0%	93%	30.2%	94%
NM EPE	N/A	~0.0%	~0.0%	92%	30.2%	94%
BPA	N/A	N/A	N/A	N/A	28.2%	90%
CAISO	**0.2%**	**0.7%**	**1.7%**	**97%**	**19.0%**	**93%**
Average	**0.2%**	**0.3%**	**0.9%**	**95%**	**25.3%**	**93%**

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AT&T
Albion Power Company

Alta Power Group, LLC
Anderson & Poole

Atlas ReFuel
BART

Barkovich & Yap, Inc.
California Cotton Ginners & Growers Assn
California Energy Commission

California Hub for Energy Efficiency Financing

California Alternative Energy and Advanced Transportation Financing Authority
California Public Utilities Commission
Calpine

Cameron-Daniel, P.C.
Casner, Steve
Cenergy Power
Center for Biological Diversity

Chevron Pipeline and Power
City of Palo Alto

City of San Jose
Clean Power Research
Coast Economic Consulting
Commercial Energy
Crossborder Energy
Crown Road Energy, LLC
Davis Wright Tremaine LLP
Day Carter Murphy

Dept of General Services
Don Pickett & Associates, Inc.
Douglass & Liddell

East Bay Community Energy Ellison Schneider & Harris LLP Energy Management Service
Engineers and Scientists of California

GenOn Energy, Inc.
Goodin, MacBride, Squeri, Schlotz & Ritchie
Green Power Institute
Hanna & Morton
ICF
IGS Energy
International Power Technology
Intestate Gas Services, Inc.
Kelly Group
Ken Bohn Consulting
Keyes & Fox LLP
Leviton Manufacturing Co., Inc.

Los Angeles County Integrated Waste Management Task Force
MRW & Associates
Manatt Phelps Phillips
Marin Energy Authority
McKenzie & Associates

Modesto Irrigation District
NLine Energy, Inc.
NRG Solar

Office of Ratepayer Advocates
OnGrid Solar
Pacific Gas and Electric Company
Peninsula Clean Energy

Pioneer Community Energy

Redwood Coast Energy Authority
Regulatory & Cogeneration Service, Inc.
SCD Energy Solutions
San Diego Gas & Electric Company

SPURR
San Francisco Water Power and Sewer
Sempra Utilities

Sierra Telephone Company, Inc.
Southern California Edison Company
Southern California Gas Company
Spark Energy
Sun Light & Power
Sunshine Design
Tecogen, Inc.
TerraVerde Renewable Partners
Tiger Natural Gas, Inc.

TransCanada
Utility Cost Management
Utility Power Solutions
Water and Energy Consulting Wellhead Electric Company
Western Manufactured Housing Communities Association (WMA)
Yep Energy