CESA
CALIFORNIA ENERGY STORAGE ALLIANCE

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To: Patrick Young, CPUC (Patrick.young@cpuc.ca.gov)
Nathan Barcic, CPUC (Nathan.Barcic@cpuc.ca.gov)
Paul Douglas, CPUC (paul.douglas@cpuc.ca.gov)
Karolina Maslanka, CPUC (Karolina.Maslanka@cpuc.ca.gov)
Neil Raffan, CPUC (Neil.Raffan@cpuc.ca.gov)
Jimmy Nelson, E3 (jimmy.nelson@ethree.com)
Stefanie Tanenhaus, E3 (stefanie@ethree.com)

Subject: R.16-02-007: CESA's follow-up to July 9, 2019 hybrid resource modeling call

Re: CESA's informal comments on solar-plus-storage resource modeling as follow-up to July 9, 2019 hybrid resource modeling call

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Dear CPUC IRP Staff & E3 Modeling Team:

Thank you for the opportunity to speak with Energy Division and the E3 modeling team on July 9, 2019 regarding the approach to hybrid resource modeling and analysis. This email is the second partial follow up to that discussion focused on CESA's recommendations and response to your questions regarding solar-plus-storage hybrids. On July 15, 2019, CESA provided our first follow-up email regarding our recommendations on how to model gas-plus-storage hybrids.

Before addressing the specific responses, CESA would like to begin with our thoughts on the importance of IRP modeling of hybrid solar-plus-storage resources to show the reliability and cost benefits of such resources. Understandably, as the Commission observed, many stakeholders in this proceeding have focused on resource-specific issues related to IRP modeling and procurement when this proceeding should actually be focused on identifying the attributes needed to provide reliable service while achieving our state's renewable and climate goals. The Commission staff also expressed that the IRP modeling results should be directional in some ways, as modeling results and real-world activities will not always align.

CESA agrees but believes that solar-plus-storage configurations are important and prevalent resource types that will likely play a big role in the state's future. Even as the state is seeing contracting of solar-plus-storage resources as evidenced by the number of projects in the CAISO's interconnection queue and several early projects by a select number of LSEs, CESA believes that the IRP modeling results should demonstrate either explicitly via solar-plus-storage resource selection or implicitly via separate but co-optimized solar and storage selection in order to inform policy and procurement decisions. For example, depending on how the model is structured and/or the results are framed, the marginal ELCC results of the IRP modeling could show that ELCC reform or directed reliability-based procurement should encourage such solar and storage pairings and co-locations.

Furthermore, the central buyer framework as directed by the Legislature (*e.g.*, via AB 56) or as adopted by the Commission in the RA proceeding plays an important context in the IRP modeling results. Whether the Commission directs or guides procurement to address reliability and capacity issues, it will be informed by the IRP modeling results. If solar-plus-storage resources are shown to provide significant benefit, then buyers will have a clearer vision and pathway to comply with the needs of the grid as identified in the IRP models.

Finally, the IRP modeling results for certain resource types or attributes, such as solar-plus-storage, provide developers with a market signal on what the market needs. Even if the IRP modeling results are merely directional, they serve as a reference for both buyers and sellers alike on some of the resource types that are needed to ensure reliability and accomplishment of the state's various goals. While the resource mix can be different through procurement of different resources with similar attributes, sellers will still be informed of the resource types that will directly address grid needs by aligning with the model results.

With all that said, CESA appreciates the opportunity to provide informal comments on how solar-plus-storage hybrid configurations should be modeled in RESOLVE. Initially, CESA proposed in our comments on January 4, 2019 in R.16-02-007[1] that storage be modeled with low-cost sensitivities using the low cost range of the Lazard Levelized Cost of Storage (LCOS) Study v4.0[2] along with cost reduction estimates of 26% to 33% based on NREL's estimates of cost savings for shared infrastructure and facilities of co-located solar and storage resources.[3] Since then, CESA has evolved its views to a degree but maintains this view to a degree, given the way that RESOLVE models solar resources.

Overall, CESA appreciates the Commission's consideration of hybrid solar-plus-storage resources in the IRP modeling efforts for the 2019-2020 cycle. CESA is open to a follow-up conversation with the Commission's IRP modeling team and E3's modeling team upon further review of these responses and our previous comments. Additional follow-up calls may be needed, as the previous call did not provide sufficient time to answer questions and/or follow-up on some of the technical modeling details. Going forward, it may be productive to have separate calls for the gas-plus-storage and solar-plus-storage modeling issues.

[1] *Comments of the California Energy Storage Alliance to the Administrative Law Judge's Ruling Seeking Comments on Inputs and Assumptions for Development of the 2019-2020 Reference System Plan* filed on January 4, 2019 in R.16-02-007 at pp. 14-15. See link here.

[2] *Lazard's Levelized Cost of Storage Analysis Version 4.0*, published on November 2018. https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf

[3] *Evaluating the Technical and Economic Performance of PV Plus Storage Power Plants*, NREL, August 2017. https://www.nrel.gov/docs/fy17osti/68737.pdf

Responses to Questions

1. **What information does IRP need to provide to stakeholders to enable hybrids to compete fairly with other resource types and assess operational implications?**

A key near-term focus for solar-plus-storage resources is the impacts of the Federal ITC, which is scheduled to step down from 30% in 2019 to 26% in 2020, 22% in 2021, and 10% in 2022. This is a key consideration of solar-plus-storage resources as it presents the possibilities of significant reduced investment costs but also creates operational limitations for storage resources to only or mostly (greater than 75%) charge from the paired ITC-eligible solar resource for the first five years of operations.

To inform policy and procurement decisions on solar-plus-storage resources, CESA recommends that the E3 team conduct marginal and average ELCC calculations for solar only and then again for those resources that can be reasonably assumed to be paired with solar (*i.e.*, ITC Paired Storage and Non-ITC Paired Storage, as discussed further below). By conducting this ELCC analysis by zone,[4] the Commission can be informed of how ELCC values for solar are improved when paired with storage. At the same time, it is important to be careful in interpreting and discussing these results such that the Commission does not allocate the incremental ELCC boost of pairing solar with storage to solar as a resource class, which would not send the appropriate economic signal to developers to invest in these hybrid resources.

2. **What improvements would you implement in modeling to fairly consider hybrid resources as a candidate?**

CESA understands that RESOLVE includes specific individual renewable projects to represent the current baseline resource inputs based on data provided by the Commission's IOU contract database, CEC's POU contract reports, data provided by the CCAs, and the CEC's Statewide Renewable Net spreadsheet. Nevertheless, solar, as a candidate utility-scale resource, is modeled based on simulations for two key configurations (single axis, fixed tilt) that are aggregated into a weighted average generation profile for one of the 11 representative locations in the state. Thus, when solar is selected within an optimal portfolio, it is not modeled as individual generating facilities or as individual solar projects such that the IRP modeling presents challenges in optimizing for hybrid solar-plus-storage pairings configurations by duration, storage sizing, and operational constraints. For example, as CESA understands it, when optimizing capacity investments, RESOLVE does not select four discrete 10-MW solar projects to add 40 MW of "Solano_Solar" but rather selects an aggregate 40 MW solar profile in that location. As a result, RESOLVE cannot optimize for different variations of storage pairings for selected discrete resources but rather for aggregate resources in the 11 representative locations within California and the four out-of-state locations. This approach also implies that selected solar will have a

[4] However, CESA believes that this may not be possible within the RECAP module within RESOLVE. CESA understands that RECAP calculates ELCC values at a system-wide level and cannot calculate these values with more locational granularity. CESA seeks to confirm this understanding with E3.

static, location-dependent capacity factor, thereby hindering considerably the ability of the model to assess the impact co-location could have on PV deliverability.

Candidate storage resources. Given that solar resources are aggregated by zone and do not have locational granularity to demonstrate the benefits of co-location, CESA recommends a simplified approach to approximate the benefits of co-location without having to figure out how to explicitly model the operational profile and constraints of specific solar-plus-storage resources.[5] This strategy also bypasses the issue of transmission costs and availability. In the current RESOLVE model, candidate resources selected receive an added cost in case transmission for their full deliverability is constrained. Modeling solar and storage as separate resources does not account for the shared facility savings and could, in fact, overstate the cost of adding these two resources. The benefits of co-located solar-plus-storage resources will not be captured in this zonal modeling structure, but co-location and ITC benefits can be modeled by optimizing for two types of paired storage resources and one standalone storage resource type. The below storage resources should be separate candidate resources or sensitivities to inform the Commission on whether policies or procurements should be directed toward co-located solar-plus-storage resources. By making these distinctions, the Commission will also gain insights into whether it is in ratepayer interests to direct or incentivize early procurement to take advantage of the ITC.

Candidate Storage Resource	NREL Shared Facility Cost Reductions (Y/N?)	ITC Benefit (Y/N?)	Charging Constraints
ITC Paired Storage	Yes	Yes	Yes, solar only charging allowed
Non-ITC Paired Storage	Yes	No	No
Standalone Storage	No	No	No

For ITC Paired Storage resources, we can assume solar-only charging to maximize the ITC benefit and limit the range of different charging profile differences, which can vary and complicate the optimize engine for the storage resource – *e.g.*, how do we optimize for 80% solar charging and 20% grid charging and compare ITC benefits and wholesale market price spreads? This would seemingly create another optimization within an optimization that may be unnecessary to provide the aforementioned directional guidance. As such, with solar-only

[5] CESA notes that there is a qualitative and quantitative difference between hybrid resources where both fuel types can inject into the grid at full output and those where they cannot. For example, CESA is aware that storage can be added after the interconnection studies are complete, so the output at the point of interconnection (POI) can be sized to match only the original resource. Alternatively, the hybrid resource can be designed from the start as something like 100 MW solar plus 100 MW storage but with greater than 200 MW maximum output at the POI. Where both fuel types can inject at full output, the modeling and RA assumptions can be more like standalone resources but more efficient because of the shared interconnection facilities (though "stand-alone" resources of any type like two solar projects can also share such facilities). The complications come where the maximum output at the POI does not allow for that simultaneous maximum output. This modeling exercise and our proposed simplification, however, does not delve into these technical interconnection details but we note this here as an important contextual piece of information on how hybrid solar-plus-storage resources may be operating in practice. Even in our simplified solar-charging scenarios, it may not fully capture how the storage resource could operate in practice.

charging, the charging and state of charge of the ITC Paired Storage would be limited by the amount and timing of solar generation within the zone it is located in for the first five years of operation. Such resources would also benefit from shared facility costs and the ITC. Thus, any storage resource that is selected with "yes" for each of the assumptions above in a given location, it can be assumed that the storage resource would be paired with any one of the solar resources selected in that location as well.

In *Solano_Solar*, for example, if 100 MW of solar is picked up along with 20 MW of ITC Paired Storage and 20 MW of Standalone Storage, we are assuming that zone has 20 MW of out of a total of 40 MW are paired with solar, though it is unclear how many MW of solar can be assumed to be paired.

In the short-term for the 2019-2020 IRP cycle, CESA recommends the above approach as a quick means to model solar-plus-storage resources and to inform Commission policy and procurement decisions.

Candidate solar-plus-storage resources. Our proposed short-term approach for modeling new candidate storage resources is limited in the sense that the RESOLVE model is not designed to select forced and co-optimized pairings of resources. To inform policy and procurement decisions on solar-plus-storage resources, the Commission should strive to develop solar-plus-storage generation profiles that could support the marginal ELCC calculation of these resources being added to the grid.

As CESA understands it, RESOLVE uses RECAP for its ELCC calculations that looks at the ELCC of solar and wind resources separately from storage, which would limit the calculation of the capacity benefits of solar-plus-storage resources. In other words, RESOLVE would interpret the inputs for separate candidate resources and not calculate a combined ELCC. The main issue of just relying on changing the operational constraints of storage (as proposed above) is that the results for ITC Paired Storage and Non-ITC Paired Storage will be interpreted and assumed as "paired" but the RESOLVE model will not actually pair them during optimization. The selected paired energy storage systems will still be modeled as following a central battery dispatch system but with operational constraints and/or cost reductions, which potentially optimizes these resources for a range of grid services.

However, CESA sees value in calculating the marginal ELCC values of solar-plus-storage resources to inform whether and how such resources provide greater reliability contributions. Over the past several months, CESA has conducted ELCC modeling using the RECAP model and "static" simulated generation profiles for solar-plus-storage and wind-plus-storage resources from two CESA member companies. These paired-storage generation profiles were forced into RECAP and represented as solar and/or wind in RECAP to generate our "separate resource class" ELCC values. In doing so, CESA aimed to see whether paired-storage resources would generate higher ELCC values as compared to its standalone counterparts and to evaluate whether there are trends for incremental ELCC value impacts for different variations of energy duration and sizing ratios of paired-storage resources. See our Appendix to view our methodology and findings on this modeling exercise.

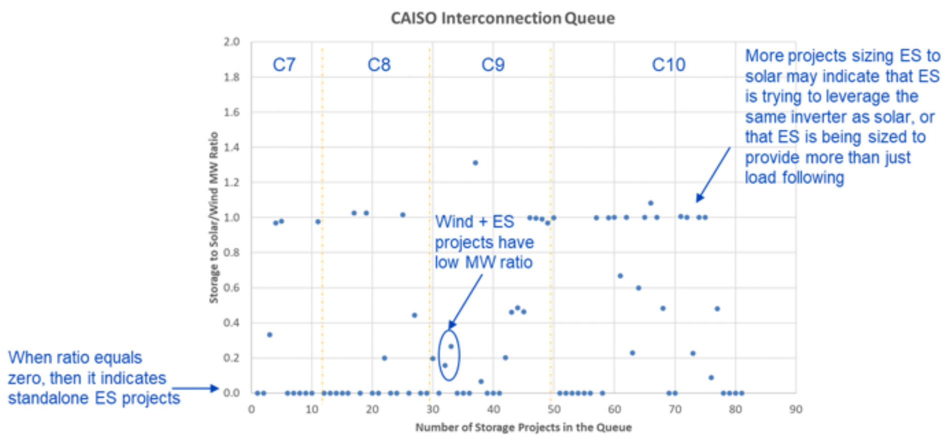
Similarly, CESA wonders whether similar types of solar-plus-storage resources, and even wind-plus-storage resources, could be forced into RESOLVE with simulated or representative generation profiles. This approach would likely limit the ability of such solar-plus-storage resources to be economically dispatched as a non-generator resource (NGR), which could be the case for certain solar-plus-storage resources in the field. On the other hand, candidate solar-plus-storage or wind-plus-storage resources would provide insights into the ELCC values of hybrid resources and may inform Commission direction on ELCC methodologies in the RA proceeding, procurement directives, and/or RPS Program changes.

The challenge with this approach is that there are many variations of how solar-plus-storage resources could be configured and sized in terms of capacity (MW) and duration (MWh). In CESA's analysis, we looked at a range of hybrid resource variations, which would likely be infeasible to add to RESOLVE as different types of candidate resources and likely do not represent the most economic configurations from the perspective of developers. Instead, to narrow the focus of solar-plus-storage resource types to represent as a separate candidate resource in RESOLVE, CESA recommends that the Commission either solicit paired generation profiles via an RFI to stakeholders and look at hybrid projects being procured or developed today. Such real-world projects represent those that have been reasonably vetted by stakeholders as being economically and financially viable and preferred or needed by buyers.

Some notable procurement from LADWP and the CCAs provide some reference of the solar-storage sizing ratios that could be explored in modeling. We also provide some additional data points on notable in-development solar-plus-storage projects from the 2018 LSE Plans submitted in the IRP in August 2018. With these projects being viable and contracted today or in the near future, there is some indication that these configurations are economically viable.

LSE	Counterparty	Solar (MW)	Storage (MW)	Storage-Solar Sizing Ratio	Storage Duration (Hours)
East Bay (CCA)	EDP Renewable	100.0	30.0	0.30	4
SVCE-MBCP (CCA)	Recurrent Energy	150.0	45.0	0.30	4
SVCE-MBCP (CCA)	EDF Renewables NA	128.0	40.0	0.31	4
BVES (SMJU)	[*In Development*]	8.0	5.0	0.63	4
RCEA (CCA)	[*In Development*]	2.3	2.0	0.87	4

Beyond actual and planned procurements, the interconnection queue may be insightful in terms of how developers are sizing storage projects when paired with solar (or wind), which could also inform how solar-storage sizing ratios could be explored in modeling. Notably, in Cluster 10, CESA observes that more solar-plus-storage projects are being sized to a 1.0 ratio. Though these projects may not all be procured by an LSE off-taker and may not materialize, this data supports potential configurations that developers find economical and that buyers may be indicating is preferred or needed.



Based on the data points above, CESA recommends that the Commission explore three variations of energy duration (1, 4, and 8 hours) and three storage-solar sizing ratios (0.3 and 1.0). These variations should represent the majority of projects today as well as providing some bookend analysis on different sizings and durations. Furthermore, CESA believes that additional operational constraints would not be needed in these cases, as we can assume that paired storage resources only charge from

In summary, CESA proposes two approaches modeling hybrid solar-plus-storage resources. At minimum, the Commission should pursue our proposed candidate energy storage approach, which will only require some immediately implementable modeling changes to RESOLVE. Alternatively, CESA recommends that the Commission may wish to incorporate solar-plus-storage and wind-plus-storage resources as separate candidate resources, though this would require additional information gathering from the developer community to receive generation profiles of a select range of hybrid resource configurations and durations. This information can be readily attained by the Commission given CESA's experience in being able to solicit and attain these profiles from our members. The Commission should have similar success if it chose to issue an RFI to solicit this information. Finally, our focus of these informal comments has been on solar-plus-storage resources but either approach could be reasonably applied to wind-plus-storage resources as well.

3. **How would you model operational constraints from hybrids and how would you expect that to affect candidate selection and operational results?**

As mentioned above, under our proposed candidate storage approach, the only operational constraint would be established for ITC Paired Storage. For Non-ITC Paired Storage and Standalone Storage candidate resources, the storage should be able to charge and dispatch freely within the model from either the grid or solar generation at any time when it is economic. Under our proposed candidate solar-plus-storage approach, there would be no operational constraints as the generation profiles for the hybrid resources would be represented in the model as standalone solar or wind resources with firmed or shifted generation profiles.

Conclusion

CESA appreciates the opportunity to provide these informal comments and hope these responses are helpful. Please do not hesitate to reach out if you have any follow up questions or would like to discuss further.

Sincerely,

Jin Noh
Policy Manager
CALIFORNIA ENERGY STORAGE ALLIANCE (CESA)
jnoh@storagealliance.org

cc: Alex Morris, CESA (amorris@storagealliance.org)
Shannon Eddy, LSA (eddyconsulting@gmail.com)
Colin Meehan, First Solar (Colin.Meehan@FirstSolar.com)

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Appendix A:

CESA's Solar-Plus-Storage and Wind-Plus-Storage Effective Load Carrying Capacity (ELCC) Modeling Analysis Using RECAP

CESA's Solar-Plus-Storage and Wind-Plus-Storage Effective Load Carrying Capacity (ELCC) Modeling Analysis Using RECAP

Introduction

In 2017, the Legislature mandated the use of the Effective Load Carrying Capacity (ELCC) via the signing of SB X1-2to determine the qualifying capacity value of wind and solar resources because of how it more accurately represents likely conditions than the exceedance methodology at the time. Rather than comparing the individual facility to a standard, the ELCC was viewed as reflective of the capacity value to the system. Since then, the California Public Utilities Commission (Commission) has calculated and applied the ELCC values of solar and wind for 2018 and 2019 to determine their contributions to reliability and Resource Adequacy (RA) capacity.

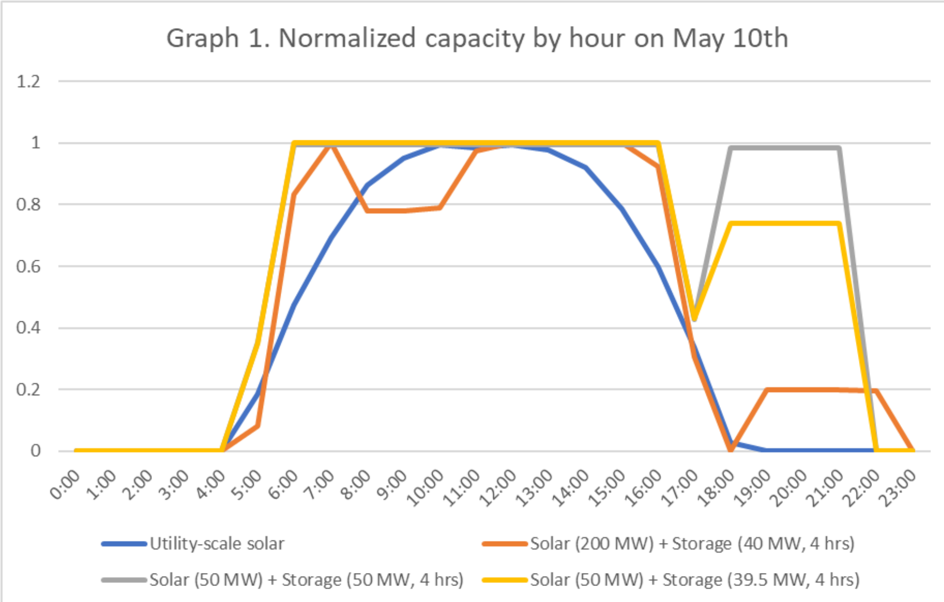
However, the California Energy Storage Alliance (CESA) believes the current ELCC methodology does not accurately measure the capacity value or provide the economic signals to sellers to procure solar and wind resources paired with energy storage. Not only does the ELCC methodology not account for technological and locational differences, but it also does not differentiate the ELCC calculation for standalone variable generators with those that are paired with storage under the resource class approach. In the RA and Renewable Portfolio Standards (RPS) proceedings (R.17-09-020, R.18-07-003), CESA has advocated for a revised ELCC methodology to be developed, one allowing for numerous technology categories and sub-classes that would more fairly capture the capacity value of variable generation paired with energy storage. Assessing the capacity value of paired resources in a more accurate and granular fashion will incentivize the procurement of preferred resources to fulfill RA requirements in the coming years.

In order to support this hypothesis, CESA conducted an analysis of capacity values for an array of actual paired-storage generation profiles, provided to us from two member companies. In the following white paper, CESA shares our methodology and approach and examines the findings and limitations of this analysis.

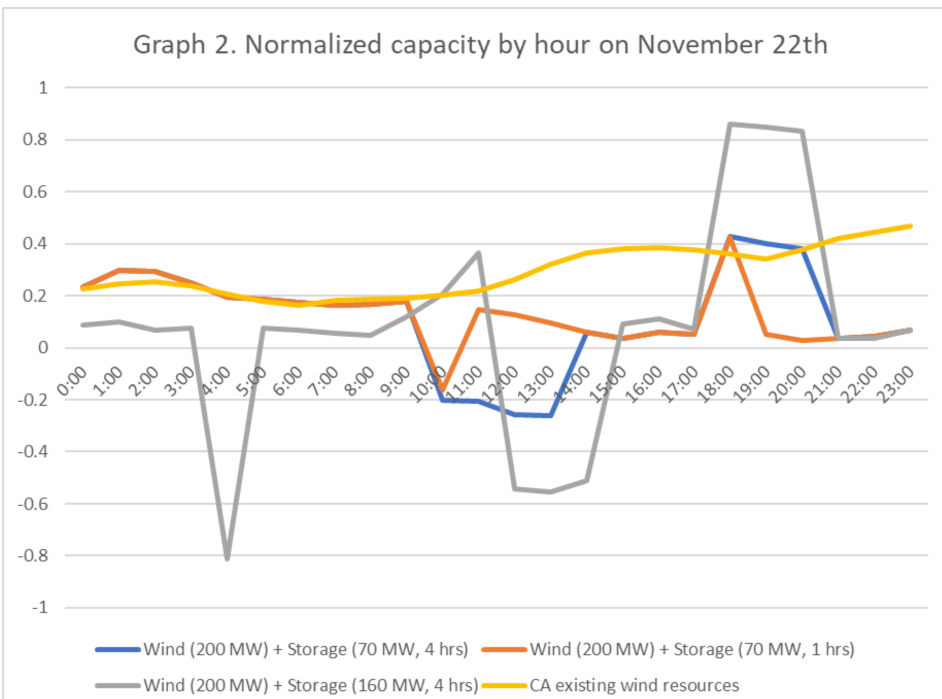
Methodology & Approach

For this evaluation, CESA relied on the latest publicly-available version of the Renewable Energy Capacity Planning (RECAP) model developed by Energy + Environmental Economics ("E3"). CESA used RECAP to compare the annual and monthly marginal capacity values of 27 actual, hourly generation profiles for co-optimized solar and wind resources paired with storage and compared those results with that of the system-wide fleet of wind and solar photovoltaic (PV) resources. The aforementioned profiles were provided by CESA members. Notably, CESA strived to solicit different variations of pairings to glean insights from the results. The overall system-wide generation, including dispatchable and variable resources, were already included in the RECAP model.

Our examination is motivated by the fact that co-optimized storage effectively changes the generation output of intermittent resources. Graph 1 illustrates the hourly differences between co-optimized *solar* generation profiles and existing generation during the same, non-weekend day.



Meanwhile, Graph 2 illustrates the hourly differences between co-optimized *wind* generation profiles and existing generation during the same, non-weekend day.



Both figures above show that co-optimized resources are likely to shift output from low demand to high demand times. This ability to shift production allows generators to effectively turn an intermittent resource into a more dispatchable one, which, at least theoretically, increasing its capacity value.

To test this hypothesis, CESA used the RECAP model to calculate and compare the annual and monthly marginal capacity values of the profiles provided by CESA members. RECAP is a state-based RA model designed to make the best possible use of incomplete and often non-coincident load and variable generation time-series datasets. The RECAP framework has been built around the need for bootstrapping to produce the most accurate results possible. RECAP works by comparing probability distribution functions of supply and demand by month, hour, and day-type (weekend, weekday) to find loss-of-load probability (LOLP) by each time slice. RECAP accounts for historical load, renewable generation, and generator forced outage data to establish relevant correlations between variables. CESA used E3's recommended values for all calculation settings, only adding the generation profiles provided by CESA members.[6]

Table 1: Scenario Inputs

Input Category	Input Name	Description	Value used by CESA
Regions	Region	The main region for analysis	CAISO
Load Inputs	Analysis Year	Populates recommended annual energy and peak load numbers used to scale load	2020
	Scale by	This feature scales the given load profile(s) to a future year based on either energy alone or energy and median peak load.	Energy and 1-2 Peak Load *
Operations	Operating Reserves (up)	Increases load requirements by a user-specified percentage due to operating reserve requirements	0%
Transmission & Imports	Imports limited to	The user can specify whether system reliability metrics will use the capacity of either the system's full import capability or just contracted resource imports. The user may want to run different types of analysis given that many balancing areas have import capabilities that greatly exceed their contracted resource imports.	Contracted resources only *
	Simultaneous Import Limit (MW)	Maximum import capability	13,308 *
Hydro & Thermal Inputs	Analysis Year (Hydro & Thermal Inputs)	Used to determine which hydro and thermal power plants (from the generation inputs) are active based on commission/retirement dates.	2020
Load Profiles	Profile name	This profile name must match a file of the same name in the 'profiles' folder. The file must contain at least a full annual hourly load shape.	Caiso_load_1950_2012 *
	Zone	The primary balancing area in the analysis. A load profile must be included for the primary zone.	CAISO

[6] Parties interested in replicating results or calculating marginal capacity values for their own profiles can do so. In this analysis, CESA mostly used values recommended by E3. Values marked with a star (*) represent those where CESA followed E3's recommended approach. For dispatchable generation, for example, CESA maintained all the parameters already predetermined within the CAISO examination of the RECAP model.

Input Category	Input Name	Description	Value used by CESA
	Annual Energy	Used to scale the load profile to the analysis year. The recommended value below the load profile inputs box uses a look-up of a preloaded load forecast to assist the user.	220,240,679 *
	1-2 Peak Load	Used to scale the load profile to the analysis year. The recommended value below the load profile inputs box uses a look-up of a preloaded load forecast to assist the user.	45,256 *

Table 2: Calculation Settings

Input Category	Input Name	Description	Value used by CESA
Data Outputs	Output intermediate results	If TRUE the model will output underlying distributions for load, net-load, supply-resources, and net-generation. The default value is FALSE to speed up the calculations and limit the size of the outputs.	False *
PRM Calculation	Primary reliability metric	ALOLP – Annual probability of having lost load (%) LOLE – Loss of load expectation (hours/year) EUE – Expected unserved energy (MWh/year) EUENORM – expected unserved energy normalized by annual energy The model uses the primary reliability metric and its value to determine capacity need and planning reserve margin	LOLE *
	Metric value	The metric value is used in the calculation of planning reserve margin and for determining capacity need.	0.1 *
	Method for adjusting system capacity	The model must initially calibrate to the specified metric value of the PRM. It can do this by either adding or subtracting fixed load or by altering the generator stack by removing dispatchable generation in the order of nearest retirement.	Flat load carried
	Determine target PRM	Determines whether RECAP calculates a target planning reserve margin.	True
	Peak load month for PRM determination	PRM is defined as [(Resources / Peak Load) – 1] the peak load month is used to determine the quantity of capacity resources used in the numerator in the PRM calculation	8

Input Category	Input Name	Description	Value used by CESA
	Perform calculations by month	Determines whether RECAP performs ALL model calculations separately for each month	True
Capacity Value	Calculate marginal renewable capacity value	Determines whether RECAP calculates marginal renewable capacity value for each profile in the variable generation tab	True
Maintenance & outage	Maintenance schedule	'Ideal' maintenance takes the user specified maintenance rates for each month and spreads them out over the course of the month to mitigate impact on the system. Random maintenance takes the user specified rates and distributes them randomly without regard for impact on reliability.	Ideal *
Demand Response Calculator	Write DR Input File	Determines whether the user wishes to output hourly loss of load probability corresponding to the input load data. The output file is needed to calculate the ELCC of DR in a separate model.	False
Load Binning	Distribution Type	The model creates a distribution for each month/hour/day type. The model can either use the 'Raw Data' directly from the load profile inputs or match the data to an idealized distribution. The 'Normal or Gumbel Distribution' option matches either a normal or gumbel distribution to bin, whichever is a better fit. The 'Normal Distribution' option matches only normal distributions to each bin. A gumbel distribution is often a better fit in distributions with a high probability of deviation above the mean (shoulder months and low load hours). See appendix **Error! Reference source not found.** for more information on fitting normal and gumbel distributions to raw load data.	Raw data *
	Fraction of distribution determining fit	The distribution of best fit is determined by only high load points, or the top fraction of the load distribution. This input specifies that fraction. This option is only valid if the user selects 'Normal or Gumbel Distribution' for distribution type. See appendix **Error! Reference source not found.** for more information on fitting normal and gumbel distributions to raw load data.	0.1 *
	Distribution cutoff (# Std.)	The model cuts off any idealized distribution at either this specified distribution cutoff (# of standard deviations) or the maximum load value, whichever is smaller.	3.1 *

Input Category	Input Name	Description	Value used by CESA
Load Correlation Bins		There is often a correlation between load and renewable energy output, namely that wind output tends to drop as load increases due to factors such as temperature and air pressure. These bins specify the fraction of high/low load hours the load distribution to create separate renewable generation distributions. For instance .2/.8 would create two distributions of renewable energy – one for the top 20% of load hours and one for the bottom 80%. See appendix **Error! Reference source not found.** for more information on load correlation bins.	0.0, 0.8, 0.9
Advanced Settings	Convergence Threshold	The convergence threshold for the metric value of the primary reliability metric. The model uses gradient decent to solve for the capacity needed to achieve the target reliability.	0.0005 *
	Ignore load less this % of 1-2 peak	To save memory and increase computing efficiency, the user can specify that the model ignore load less than a certain % of 1-2 peak. This feature will only work correctly if there is a negligible LOLP for the load levels that are being ignored.	50% *
	Scale entire power system	This factor scales up the entire system (load and generation). For small systems, the user will often want to scale up the system size; otherwise the 1 MW capacity increments used in the model may be insufficient precision. Scaling the system increases runtime and the amount of memory needed in the calculations.	2.0 *
Capacity Value Calculation	Marginal capacity value calc method	To calculate capacity value, the user must specify a calculation method. 'Adjusted system capacity' decreases conventional power to return to the original level of system reliability after the addition of a new variable generation source. 'Flat load carried' increases load after the addition of a new variable generation resource until system reliability returns to the level prior to the variable resource addition.	Flat load carried
	Marginal capacity value step size	Specifies the size of a variable generator to be added. Since the system increments load and generation in units of MW, a large step size will be more accurate in terms of %, but less accurate as a true 'marginal' value.	100

Input Category	Input Name	Description	Value used by CESA
Batch Capacity Value Calc	Run batch marginal capacity value	This TRUE/FALSE option specifies whether the user wants to individually calculate a marginal capacity value for the different profiles in the 'batch_marignal_capacity_value' folder.	False
	Add or subtract marginal profile	'Add marginal profile' assumes that the profiles in the 'batch_marginal_capacity_value' folder do not exist on the system, so the model adds them to the system. 'Subtract marginal profile' assumes that the profiles already exist on the system so it calculates a marginal capacity value by removing them from the system.	Add marginal profile
Capacity Value Table	Create capacity value table	Specifies whether the model calculates a table of capacity values for the portfolio specified in the input table below. Each resource in the input table represents a different dimension in the capacity value table output. *Note: this calculation can take a long time as it needs to perform the number of calculations listed below the table in blue*	False
	Create Capacity Value Table ONLY	If True, the model will only perform the capacity value table calculation	False
	Marginal capacity value at each step	Specifies whether the marginal capacity value is calculated for each resource (using the marginal capacity value step size) at each point in the capacity value table.	True
	Output generator stack changes	Specifies stack changes to account for conventional power retirements due to an increase in variable generation capacity value	False
	Table delineation	Specifies whether the 'step' and 'stop' values in the user input table below are installed capacity (MW) or penetration by energy (%)	Penetration by Energy
	Maximum energy penetration	If the user inputs 'Installed Capacity' for the table delineation input, enter FALSE. Otherwise, enter the maximum energy penetration %.	False

Table 3: Variable Generation

Input Category	Description	Value used by CESA
Profile Name	This value should correspond to a file of the same name in the profiles folder. This file should contain historical hourly production data from the variable generation resource for as many years as possible.	Several, one per profile added

Input Category	Description	Value used by CESA
Zone	The balancing area containing the variable resource. This information is pertinent when evaluating both local capacity requirements and import constraints.	CAISO
Capacity (MW) or Energy (MWh)	The capacity or annual energy production of the resource. Resource profiles must be normalized to this value, and capacity or energy should be chosen based on how the resource profile is given. For instance, electric vehicle load growth may be given in annual energy while behind-the-meter PV may be given in capacity.	Depends on profile
PRM Accounting	This indicates whether the variable resource is supply side or demand side. For instance, behind-the-meter PV would be supply resource while EV charging would be demand modifier.	Supply resource *
Load Correlations	Specifies whether the variable resource should be correlated with load for each month/hour/day type. Generally, this is only a good idea if the user has an intuition for some correlation between the load and resource. If the user selects TRUE without basis, the resulting disaggregated distributions will not be as rich.	True *
Do Weekends Matter	Specifies whether the day type affects the output of the variable resource. For instance, electric vehicle charging would likely be affected due to differences in customer behavior on weekdays vs. weekends.	False *
Commission Date	The in-service date of the resource used to calculate whether the resource is active or not	01/01/2000 *
Retirement Date	The retirement date of the resource used to calculate whether the resource is active or not	01/01/2050 *

Note: CESA included the profiles shared by its members following the instructions for the RECAP model.

Table 4: Imports

Input Category	Description	Value used by CESA
Transmission Line	The name of the transmission pathway. The model does not actively use this field; it is there to aid the user	Line2 *
Pathway Start	The balancing area where the transmission pathway begins	Ext *
Pathway End	The balancing area where the transmission pathway ends	CAISO *
Maximum Capacity	The maximum capacity in MW of the transmission line. Note that this value may change by month, so the user should try to use a number that best approximates the maximum capacity in the high load months.	1 *
Transmission Availability Distribution	The top line of the chart lists fractions from 0 to 1 in increments of 0.05. These represent the fraction of maximum transmission capacity that is available. The user should input under each value the fraction of time that the transmission line will exist in that state. The sum of these user input values should sum to 1.	1 at 1 *

To take advantage of the RECAP model, CESA faced several challenges and compromises. Importantly, this analysis required CESA to have overlapping load and generation data to establish load correlations – a fundamental factor when modeling intermittent resources. The load information included in the latest publicly-available version of RECAP goes from 1950-2012 while the 27 co-optimized profiles provided by CESA members covered 2014-2018. To solve this challenge, CESA tried expanding the load file in RECAP. However, CESA was advised by people within E3's RECAP development team that such an approach would not yield results since RECAP's pre-compiled code would not allow an expansion of the load file. Thus, following this advice, CESA decided to modify the dates of the profiles provided by CESA members in order to have an overlap with the load profile. Therefore, all of the profiles in this analysis end on December 31, 2012. This compromise has two main implications on the results.

- **Load correlations and weather-related effects:** Since there is no load profile that overlaps with the generation profiles, this approach can only approximate load correlations by assuming similar loads and weather for the same day a few years back. CESA believes that this will have a detrimental yet minimal effect on the order of magnitude of these results.

- **Resource saturation:** Since the latest publicly-available version of RECAP is only updated up to 2012, this approach is also constrained in terms of the intermittent system-wide installed capacity. The fact that this analysis is not considering the current state of renewable generation might actually slightly increase the calculated annual and monthly marginal capacity value of system-wide variable generation since current resource saturation is higher than the one in 2012.

Results

As shown in the following table, CESA found that the annual marginal ELCC capacity values for the co-optimized profiles estimated by RECAP generally exceeded the ones calculated for the system-wide standalone PV and wind resources. This effect was also evident for most months.

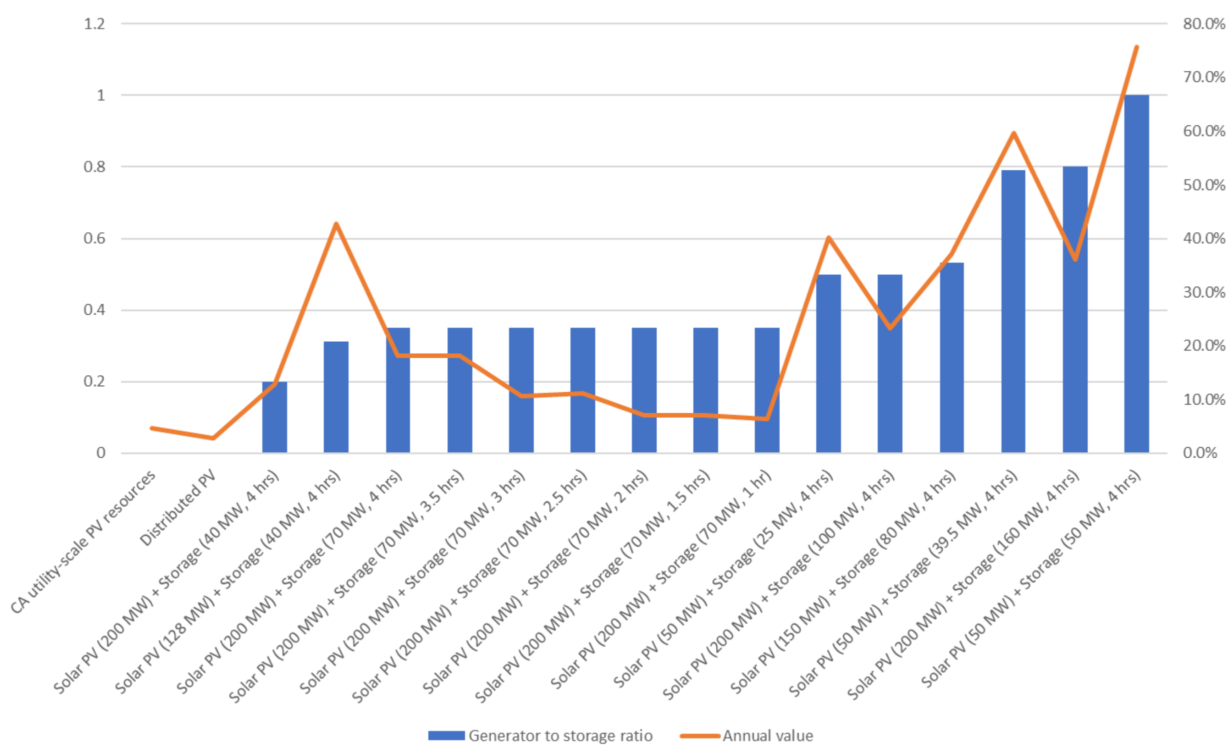
Table 5: RECAP Results on Monthly & Annual Capacity Values

Marginal capacity values derived from the RECAP model														
Generator	Generator to storage ratio	Annual value	January	February	March	April	May	June	July	August	September	October	November	December
Wind (200 MW) + Storage (100 MW, 2 hrs)	0.50	42.1%	12.1%	38.3%	16.8%	43.8%	45.2%	22.7%	52.0%	36.2%	42.5%	28.3%	29.7%	5.4%
Wind (200 MW) + Storage (100 MW, 4 hrs)	0.50	55.6%	12.2%	39.3%	23.1%	40.4%	62.1%	49.3%	67.0%	58.1%	56.0%	32.9%	36.4%	13.9%
Wind (200 MW) + Storage (160 MW, 2 hrs)	0.80	44.0%	12.3%	39.5%	16.4%	43.7%	45.0%	26.9%	56.8%	39.2%	43.0%	28.3%	28.5%	6.6%
Wind (200 MW) + Storage (160 MW, 4 hrs)	0.80	62.1%	12.3%	40.3%	26.0%	34.7%	67.9%	68.9%	75.5%	71.2%	60.6%	35.2%	37.7%	19.0%
Solar PV (50 MW) + Storage (25 MW, 4 hrs)	0.50	40.1%	47.2%	48.9%	7.5%	3.8%	49.1%	51.5%	52.7%	51.1%	38.6%	12.0%	33.8%	48.9%
Solar PV (50 MW) + Storage (39.5 MW, 4 hrs)	0.79	59.7%	71.1%	73.5%	11.2%	14.1%	74.5%	76.0%	77.1%	76.0%	58.2%	16.6%	54.5%	74.1%
Solar PV (50 MW) + Storage (50 MW, 4 hrs)	1.00	75.7%	94.5%	97.8%	14.3%	26.7%	98.6%	99.0%	98.4%	98.5%	73.7%	17.5%	78.7%	97.8%
Solar PV (128 MW) + Storage (40 MW, 4 hrs)	0.31	42.8%	30.2%	33.9%	15.5%	3.4%	13.0%	39.5%	44.7%	35.0%	43.6%	15.4%	32.7%	31.4%
Solar PV (150 MW) + Storage (80 MW, 4 hrs)	0.53	37.2%	48.4%	50.0%	6.8%	15.4%	49.5%	48.7%	49.4%	49.0%	36.1%	2.3%	32.6%	49.8%
Solar PV (200 MW) + Storage (40 MW, 4 hrs)	0.20	12.8%	-0.1%	2.0%	4.7%	3.4%	10.5%	16.1%	18.3%	15.9%	10.7%	9.2%	7.1%	4.1%
Solar PV (200 MW) + Storage (100 MW, 4 hrs)	0.50	23.3%	0.4%	3.9%	8.5%	2.2%	23.0%	31.2%	33.9%	35.9%	20.9%	11.6%	14.5%	10.2%
Solar PV (200 MW) + Storage (160 MW, 4 hrs)	0.80	36.0%	0.3%	6.2%	12.5%	3.4%	33.9%	53.1%	61.9%	55.0%	32.1%	13.7%	20.1%	15.2%
Wind (200 MW) + Storage (40 MW, 2 hrs)	0.20	40.5%	12.4%	38.0%	16.8%	43.9%	43.7%	17.3%	44.7%	32.2%	41.5%	28.6%	29.3%	4.7%
CA Existing wind resources	NA	28.9%	19.8%	26.9%	17.1%	34.0%	50.1%	53.4%	55.5%	46.3%	26.6%	17.6%	14.4%	20.2%
CA New wind resources	NA	18.1%	19.0%	8.1%	4.9%	17.8%	20.0%	32.9%	36.9%	25.9%	12.3%	10.9%	11.1%	11.6%
CA utility-scale PV resources	NA	4.7%	-0.4%	0.7%	4.5%	0.6%	3.7%	5.0%	5.3%	3.0%	2.6%	4.1%	0.7%	-0.3%
Distributed PV	NA	2.8%	-0.4%	-0.3%	0.0%	0.0%	0.6%	2.5%	2.3%	1.0%	2.0%	3.5%	0.7%	-0.1%
Solar PV (200 MW) + Storage (70 MW, 4 hrs)	0.35	18.1%	0.3%	2.7%	6.9%	2.2%	16.9%	24.0%	26.2%	26.3%	16.0%	10.4%	11.1%	7.4%
Solar PV (200 MW) + Storage (70 MW, 3.5 hrs)	0.35	18.1%	0.3%	2.7%	6.8%	2.2%	16.9%	24.0%	26.2%	26.3%	16.0%	10.4%	11.1%	7.4%
Solar PV (200 MW) + Storage (70 MW, 3 hrs)	0.35	10.7%	0.0%	2.1%	2.9%	0.9%	10.9%	11.4%	22.5%	11.0%	10.1%	8.2%	1.8%	1.2%
Solar PV (200 MW) + Storage (70 MW, 2.5 hrs)	0.35	11.2%	0.0%	2.0%	3.8%	0.8%	11.1%	11.6%	22.2%	11.0%	10.4%	7.5%	1.6%	1.4%
Solar PV (200 MW) + Storage (70 MW, 2 hrs)	0.35	7.1%	0.5%	0.7%	0.6%	0.8%	3.5%	9.9%	18.9%	8.6%	5.6%	7.5%	0.8%	1.4%
Solar PV (200 MW) + Storage (70 MW, 1.5 hrs)	0.35	7.1%	-0.3%	0.7%	1.0%	0.8%	3.5%	9.9%	17.9%	6.2%	5.5%	7.5%	0.8%	1.4%
Solar PV (200 MW) + Storage (70 MW, 1 hr)	0.35	6.4%	-0.2%	0.1%	0.8%	1.0%	3.2%	8.9%	13.6%	6.4%	4.7%	6.8%	0.6%	1.0%
Wind (200 MW) + Storage (70 MW, 4 hrs)	0.35	51.7%	12.3%	39.0%	21.5%	42.1%	57.3%	38.8%	59.8%	51.7%	52.0%	31.6%	35.3%	11.2%
Wind (200 MW) + Storage (70 MW, 3.5 hrs)	0.35	49.5%	12.4%	38.6%	21.7%	47.0%	57.0%	39.2%	59.5%	44.9%	50.3%	31.4%	34.4%	5.1%
Wind (200 MW) + Storage (70 MW, 3 hrs)	0.35	45.0%	12.4%	38.6%	20.5%	44.0%	52.7%	24.6%	52.7%	36.8%	46.1%	28.9%	30.4%	5.1%
Wind (200 MW) + Storage (70 MW, 2.5 hrs)	0.35	45.0%	12.4%	38.9%	20.4%	44.2%	52.4%	22.4%	51.8%	37.0%	45.7%	28.9%	29.7%	5.1%
Wind (200 MW) + Storage (70 MW, 2 hrs)	0.35	41.6%	12.4%	38.1%	15.8%	43.8%	44.5%	20.1%	48.8%	34.6%	41.9%	28.8%	29.3%	5.1%
Wind (200 MW) + Storage (70 MW, 1.5 hrs)	0.35	41.3%	12.4%	37.9%	16.4%	43.9%	44.1%	18.7%	47.2%	32.3%	41.8%	28.4%	28.9%	4.8%
Wind (200 MW) + Storage (70 MW, 1 hr)	0.35	41.3%	12.4%	37.2%	16.3%	43.9%	44.1%	17.1%	44.0%	32.3%	41.1%	28.4%	28.9%	4.8%

In CESA's analysis, the results demonstrated that standalone PV had very low marginal capacity values within RECAP, around 5% annually and negative in some months. This, in contrast, is not always the case for PV resources paired with storage since they are able to provide more stable output and the grid is not yet saturated by PV resources. Storage actively changes the shape of generation outputs, making the paired-storage resources substantially different from their standalone counterparts. The fact that paired resources have not been considered in current ELCC methodology has limited their procurement; hence, saturation is not a concern as it is for standalone projects.

Secondly, the capacity value of solar-paired-storage projects is largely dependent on the storage-to-generation ratio. As shown in the following graph, CESA found a positive correlation between storage-to-generation ratio and annual marginal capacity value – *i.e.*, the higher the ratio of storage to generation led to higher annual and monthly capacity values of PV resources co-optimized with storage. This signals that any shift in generation output from solar projects, regardless of its duration (*i.e.*, 1 hour or 4 hours), is valuable in terms of marginal capacity. This finding is consistent with the fact that solar generation profiles are highly consistent with each other during the year. Thus, the ability of a particular project to shift its output to hours where standalone PV does not generate is always impactful.

Graph 3. Annual marginal capacity value for PV projects, by generator to storage ratio.



Generally, wind generators paired with storage also produced higher annual and monthly marginal capacity values relative to standalone wind generators. This may be due to the fact that less wind generation is already in place relative to PV generation; thus, saturation is less of a concern. In addition, for wind resources paired with storage, the energy duration of the paired storage resource (*i.e.*, 1 hour versus 4 hours) was more relevant than the storage-to-generation ratio.[7]

[7] For each of the above RECAP results, readers who are less familiar with ELCC should interpret the numbers in terms of equivalent "perfect" capacity to the system. For example, for the first row in Table 5, readers should

Conclusion

CESA acknowledges the limitations of this study. In theory, if only focused on ELCC value, a solar or wind resource would increase the relative size and energy duration to increase this value. This does not account for the incremental costs associated with adding power or energy capacity, which could render such resources as economically unviable and unlikely to be procured.

However, CESA intended for this analysis to be directional and seeks to inform the Commission and other decision-makers on recognizing the added reliability value of solar-plus-storage and wind-plus-storage resources to the degree that policy actions are taken to not only model these resources separately from standalone solar or wind, but also to develop and establish new ELCC counting methodologies for projects with the desired pairing configurations to encourage sellers and buyers to pursue such projects.

The difference in the order of magnitude of our results must not go unnoticed. Real-world applications of co-optimization of solar-plus-storage and wind-plus-storage resources are increasingly becoming more economical. Nevertheless, an incorrect assessment of capacity value could eliminate the incentives of co-optimization, thus rendering the pairing as less cost-effective. These results should inform the Commission on considering reforms to the current ELCC methodology. A methodology that captures technological and locational differences at a project and resource level in its assessment of ELCC values would prove effective in incentivizing the procurement of preferred resources for capacity and reliability purposes. The creation of such categories is not only feasible but necessary given the State's overarching policy goals and the rapid transformation the electric grid has gone through in the last decade. CESA hopes this analysis is useful for the Commission as it discusses potential changes within the RA proceeding.

understand that an additional megawatt of this resource (200 MW of wind paired with 100-MW, 2-hour storage system) would contribute 0.421 MW of equivalent capacity on an annual basis given all other dispatchable and renewable generation profiles in the model that are operating in the system.