NYISO ELCC Accreditation Analysis

Final Report

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PREPARED FOR

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Cypress Creek Renewables, LLC
Enel North America, Inc.
Natural Resources Defense Council (NRDC)
New York Battery and Energy Storage Technology Consortium (NY-BEST)
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TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

TABLE OF ABBREVIATIONS

CT	Combustion Turbine Generation
EFORd	Equivalent Forced Outage Rate Demand
ELCC	Effective Load Carrying Capability
GW	Gigawatt
ICAP	Installed Capacity
IRM	Installed Reserve Margin
ISO	Independent System Operator
LOLE	Loss of Load Expectation
MC	Marginal Cost
MMU	Market Monitoring Unit
MR	Marginal Revenue
MW	Megawatt
NYISO	New York ISO
PRM	Planning Reserve Margin
SERVM	Strategic Energy & Risk Valuation Model
UCAP	Unforced Capacity
WY	Weather Year

EXECUTIVE SUMMARY

The following report has been produced by Astrapé Consulting in response to the marginal ELCC capacity accreditation proposal put forward by the New York Independent System Operator (NYISO) and supported by their Market Monitoring Unit (MMU) for their forward capacity auctions. Astrapé Consulting principals have several decades of experience providing electric system planning services, resource adequacy studies, and effective load carrying capability (ELCC) studies for many of the largest utilities and regulators in the United States and Europe. Astrapé's client list includes MISO, ERCOT, SPP, AESO, Duke Energy, Progress Energy, Southern Company, TVA, Pacific Gas & Electric, Louisville Gas & Electric, Santee Cooper, CLECO, PNM, FERC, NARUC, EPRI, PJM, and the California Public Utilities Commission. In addition to consulting services, Astrapé owns and licenses the probabilistic simulation tool SERVM (Strategic Energy & Risk Valuation Model), which is the primary resource adequacy tool for a majority of the independent system operators (ISOs) in North America and has been used and vetted by public service commissions across the country for various risk and economic based analyses.

Capacity markets are designed with two key objectives: procure enough capacity to ensure system reliability and provide proper price signals to procure that capacity in an economically efficient manner. Unfortunately, as the composition of electric systems becomes more diverse, capacity market design becomes more challenging. In this context, the NYISO has proposed a marginal accreditation scheme which conflates pricing and reliability objectives. In order to disentangle these concepts, it is critical to introduce reliability planning fundamentals and how they apply to both pricing and reliability aspects of capacity markets. With an understanding of reliability planning in place, it will be clear that the most efficient design will ensure that reliability is procured in aggregate while pricing is set on the margin and that this can only be implemented with average ELCC accreditation.

To demonstrate the importance of proper capacity market design, Astrapé Consulting performed rigorous simulations of potential New York resource mixes on the horizon which provide a quantification of the difference between marginal and average ELCCs. As shown in this work and other work performed by various resource adequacy planning entities, the differences between average and marginal capacity accreditation are expected to be significant at most future penetrations for renewable and storage technologies. Accrediting capacity on the margin would therefore create large disconnects between the reliability contributions expected from specific resource classes and the share of capacity revenues those resources would receive. Given the large differences between marginal and average accreditation, this has potentially significant implications for system reliability. For instance, if NYISO procures enough storage to meet the recently announced New York State's Energy Storage Roadmap goal of 6 GW of storage by 2030 (as identified in the 2022 State of the State Report),[1] the reliability contribution expected from storage will be over 5 GW while the capacity will only be compensated for 3 GW.[2]

[1] Page 146, https://www.governor.ny.gov/sites/default/files/2022-01/2022StateoftheStateBook.pdf
[2] Average ELCC of 86% multiplied by 6 GW = 5.15 GW. Marginal ELCC of 53% multiplied by 6 GW = 3.17 GW.

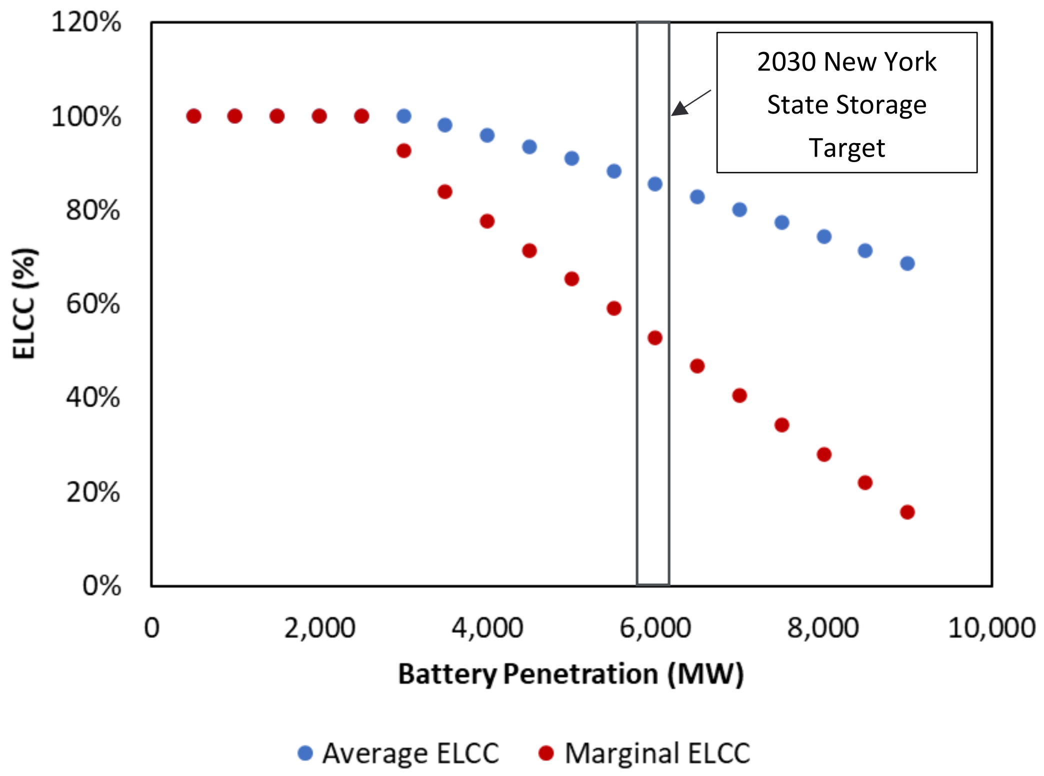


Figure ES1. Average and Marginal ELCCs as a Function of Battery Penetration

In summary, the proposed marginal ELCC accreditation by NYISO is inaccurate and poses potential reliability risks for the following reasons:

1. Underpays resources relative to their reliability contribution (i.e., does not accurately compensate variable energy resources for the value they provide towards meeting the capacity volume requirement). This has been incorrectly described as "savings" to consumers but is simply a reduction in compensation towards variable energy resources that does not correlate with any reduction in the actual reliability value being provided in aggregate. This may lead to risk of performance issues due to revenues not being commensurate with reliability value that NYISO is trying to procure.
2. Disproportionately selects resources with flat sloping ELCC curves, which are predominantly conventional gas and coal resources, and disadvantages resources with steeper ELCC curves, which are renewable and battery technologies. The marginal accreditation construct provides no technical or economic justification for why one portfolio with 5 GW of contribution to reliability should be paid differently from another portfolio that also provides 5 GW of contribution to reliability.
3. Conflates average ELCC accreditation with average ELCC pricing by arguing that average ELCC accreditation sends inefficient market signals. Average ELCC accreditation can be used in conjunction with marginal ELCC pricing to produce proper pricing signals and proper revenue determinations.
4. Utilizes an ex ante approach to determine the system resource mix, and therefore uses a static ELCC value for every resource class. This can result in both the wrong type and the wrong

quantity of resources clearing the capacity auction, resulting in economically inefficient and potentially unreliable procurement. While ex ante determinations of resource mixes have been approved in past proposals by other ISOs for capacity markets, this issue is only now becoming critical as the penetration of energy-limited and non-dispatchable resources is becoming significant.

I. EFFECTIVE LOAD CARRYING CAPABILITY

NEED FOR PLANNING RESERVES

Grid operators like NYISO must ensure that there are sufficient energy resources available to power the system at all times, even during times of peak demand, such as on the hottest days of summer and coldest days of winter. However, unexpected events can occur, such as significant weather events that cause widespread generator outages and high temperature days that cause higher than forecasted system load. Therefore, systems must procure more capacity than forecasted load to maintain the industry standard level of reliability known as 0.1 Loss of Load Expectation (LOLE). To do this, planners simulate a range of scenarios to identify the required level of reserves that results in fewer than 1 day with firm load shed in 10 years. This is commonly referred to as the Planning Reserve Margin (PRM). New York uses the synonymous term Installed Reserve Margin (IRM).

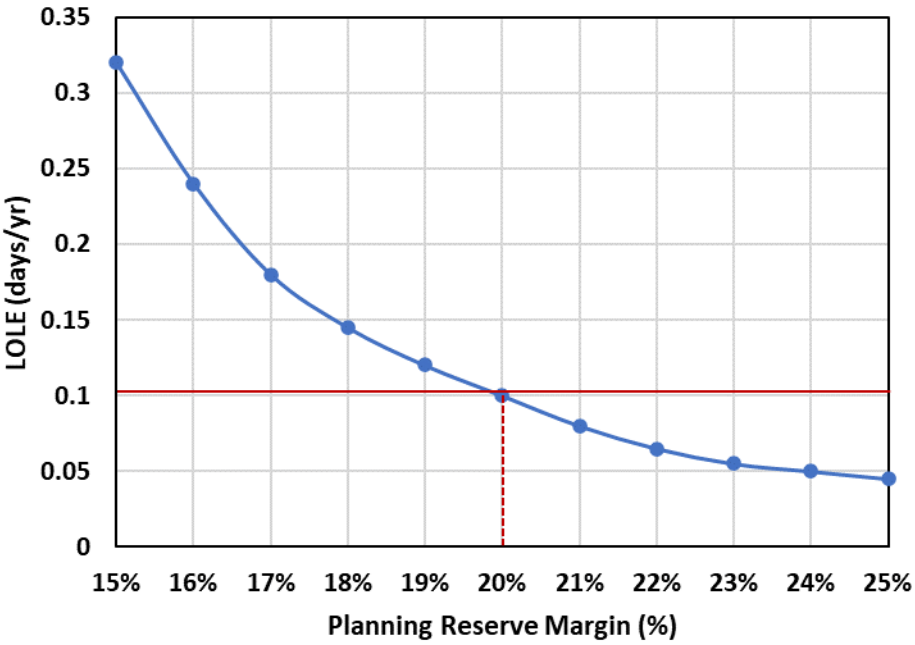


Figure 1. LOLE vs. Planning Reserve Margin (%)

RESOURCE ACCREDITATION

The PRM is designed to be technology-agnostic which requires that all resources be put on a comparable basis (or normalized) with regard to their reliability value. To determine the reliability value of conventional dispatchable resources like gas generators and coal plants, the only normalization required is based on forced outage rates associated with unexpected shutdowns or fuel supply constraints. A generator with a 10% forced outage rate provides roughly 90% of the reliability value of a generator with a 0% forced outage rate. This adjusted value (90% in this example) is typically referred to as a unit’s Unforced Capacity (UCAP) rating.

The normalization of reliability value is more challenging for resources with energy limitations or resources that cannot always be turned on when needed. Resources like batteries can exhaust their stored energy, and wind and solar are reliant on the wind blowing or the sun shining. The reliability value of these resources is determined via Effective Load Carrying Capacity (ELCC) studies which directly compare their reliability contribution to that of a perfectly available resource.[3]

If all resource technologies are normalized correctly, the PRM will remain static as the resource mix changes. A system that meets reliability with a 20% PRM with all conventional fossil generation should also meet reliability with a 20% PRM when reliability is served by 90% renewables and batteries. The renewables and batteries in this case will just have much lower ELCCs than 100% and so the system will need to procure more of them in order to accomplish this.

Resource accreditation is often a hotly contested process. Every class of generation often fights for the highest possible accreditation. However, maintaining a flat PRM provides a simple rubric for ensuring correct accreditation. If any resource class is given higher accreditation than appropriate, the PRM will increase as that resource class increases in penetration. If any resource class is given lower accreditation than appropriate, the PRM will decrease as that resource class increases in penetration.

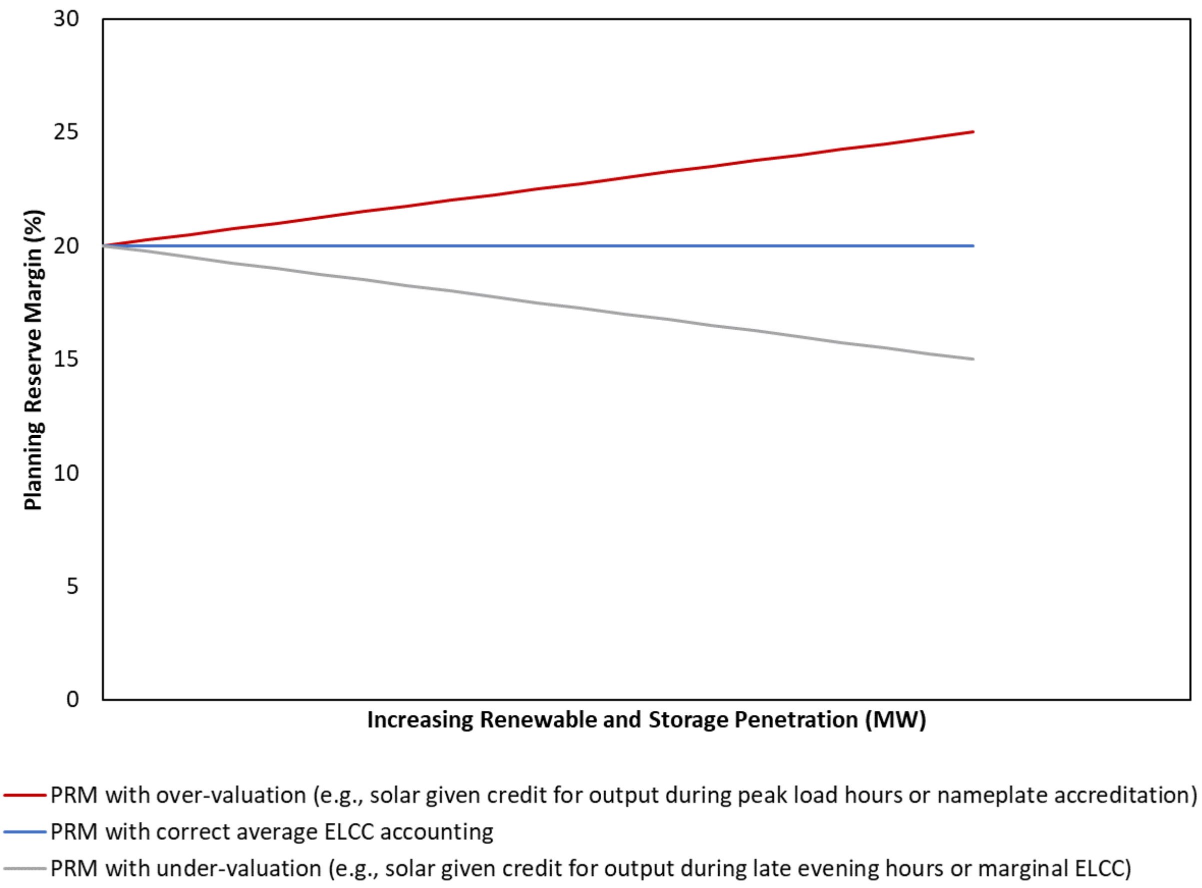


Figure 2. PRM Error with Increasing Renewable Penetration

[3] ELCC studies classically compare resources to additions of load but comparing to perfect resources is mathematically identical.

DECLINING ELCC

As the penetration of energy-limited and non-dispatchable resources increases, the per unit reliability value decreases. Each incremental MW of storage will be needed for longer duration and each incremental MW of wind or solar will have a smaller contribution to the net load peak.

As shown in Figure 3, the average and marginal ELCCs both decline, but intuitively the marginal ELCC declines faster since the first blocks of the technology supplied higher reliability value.

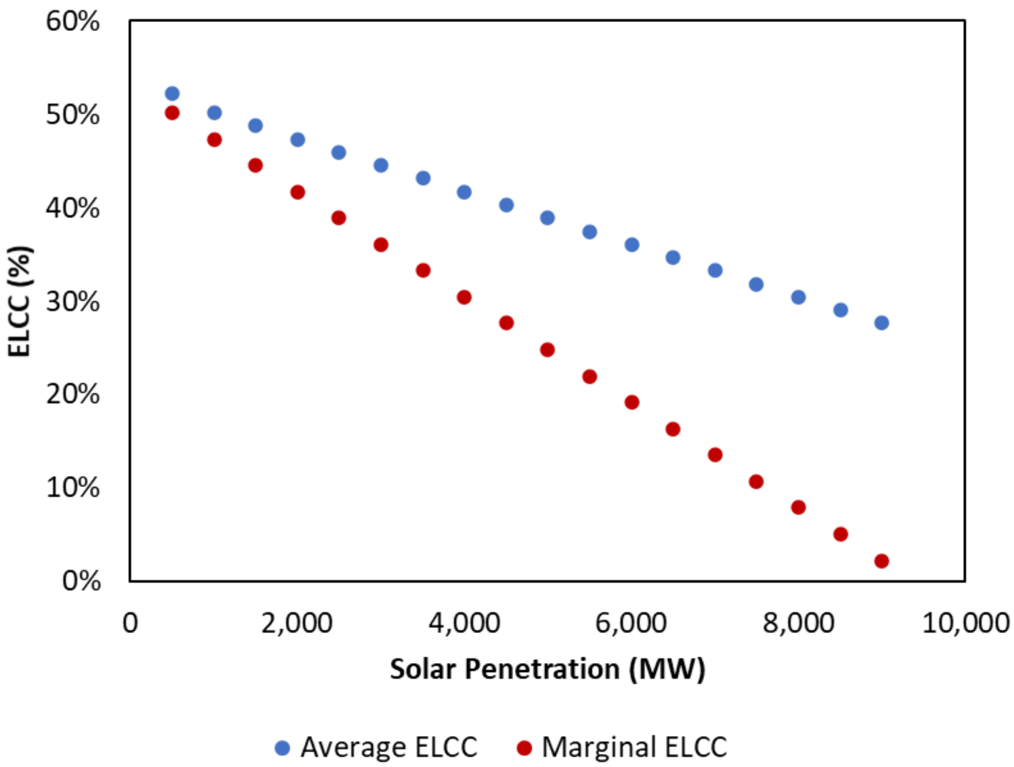


Figure 3. Declining Marginal ELCC Example (Solar)

The marginal ELCC then is used exclusively for marginal pricing. Vertically integrated utilities use marginal ELCC to normalize for reliability contribution in order to compare pricing among technologies when procuring future resources. Average ELCC is used exclusively for accreditation. Those vertically integrated utilities then calculate the average ELCC of all resources in their system to maintain a static PRM.

APPLICATION OF MARGINAL AND AVERAGE ELCC IN CAPACITY MARKETS

Capacity markets require the application of both marginal ELCC and average ELCC. Utilizing the marginal ELCC to calculate the marginal price signal ensures procurement is economically optimal. Utilizing average ELCC to procure a volume of capacity equal to the PRM ensures system reliability. Since NYISO has confused the application of marginal and average ELCCs, the next section will discuss efficient capacity market design principles as they relate to ELCC accounting.

II. EFFICIENT CAPACITY MARKET DESIGN PRINCIPLES

Capacity markets associated with the bulk electric system are designed to accomplish two primary goals for their service territories:

1. **Capacity Price Determination:** determine the price to be paid for each unit of capacity, which is established by the marginal resource price
2. **Capacity Volume Determination**: establish the total amount of capacity in aggregate required to meet a system reliability standard, such as 0.1 LOLE, regardless of the resource mix that is used to meet this reliability requirement.

CAPACITY PRICE DETERMINATION: PRICING SET ON THE MARGIN

First, marginal pricing is critical. The pricing signal sent to the market should incentivize the lowest cost marginal resource to participate. This is one of the first principles taught in Economics 101. Each incremental unit costs more to produce. Each additional unit of demand comes at a lower price. A profit maximizing firm will produce up to the point where marginal cost (MC) equals marginal revenue (MR).

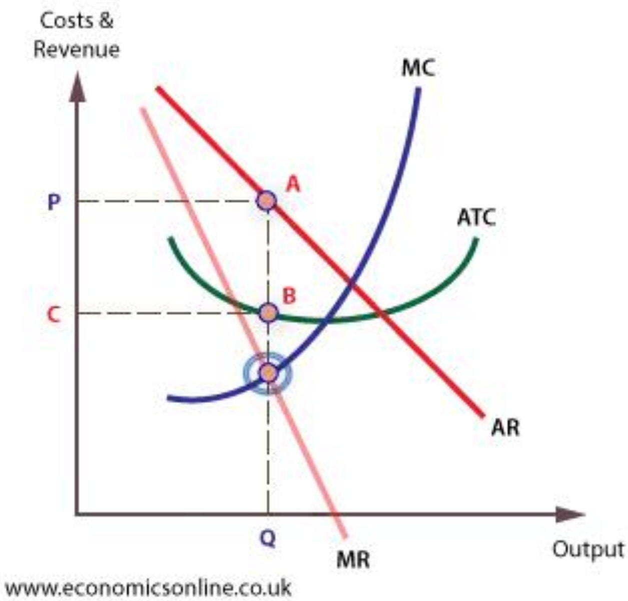


Figure 4. Marginal Cost and Marginal Revenue Curves

This is not inherently straightforward in electric systems though where there are many different technologies. Before marginal price can be identified, all technologies have to be normalized for their contribution to reliability. As discussed in the previous sections, resources are normalized for their reliability value utilizing UCAP or ELCC. When determining the price for a variable energy resource, the $/installed capacity MW would be divided by its marginal ELCC so that it can be compared appropriately as you move up the supply stack (starting with highest marginal ELCC value and descending down the marginal ELCC curve as more and more variable resources of the same technology class are added). The resource with the lowest effective bid price ($/installed kW-yr / marginal ELCC) where 0.1 LOLE reliability is satisfied should set the marginal price.

CAPACITY VOLUME DETERMINATION: ACCREDITATION IS DETERMINED IN AGGREGATE

To avoid load shed events, every system needs enough capacity to meet the highest load hour in the year. In systems with high renewable and storage penetration, however, reliability events do not always occur in hours where gross load is the highest. As shown in Figure 5, reliability problems could also be expected after sunset when the net load is the highest.

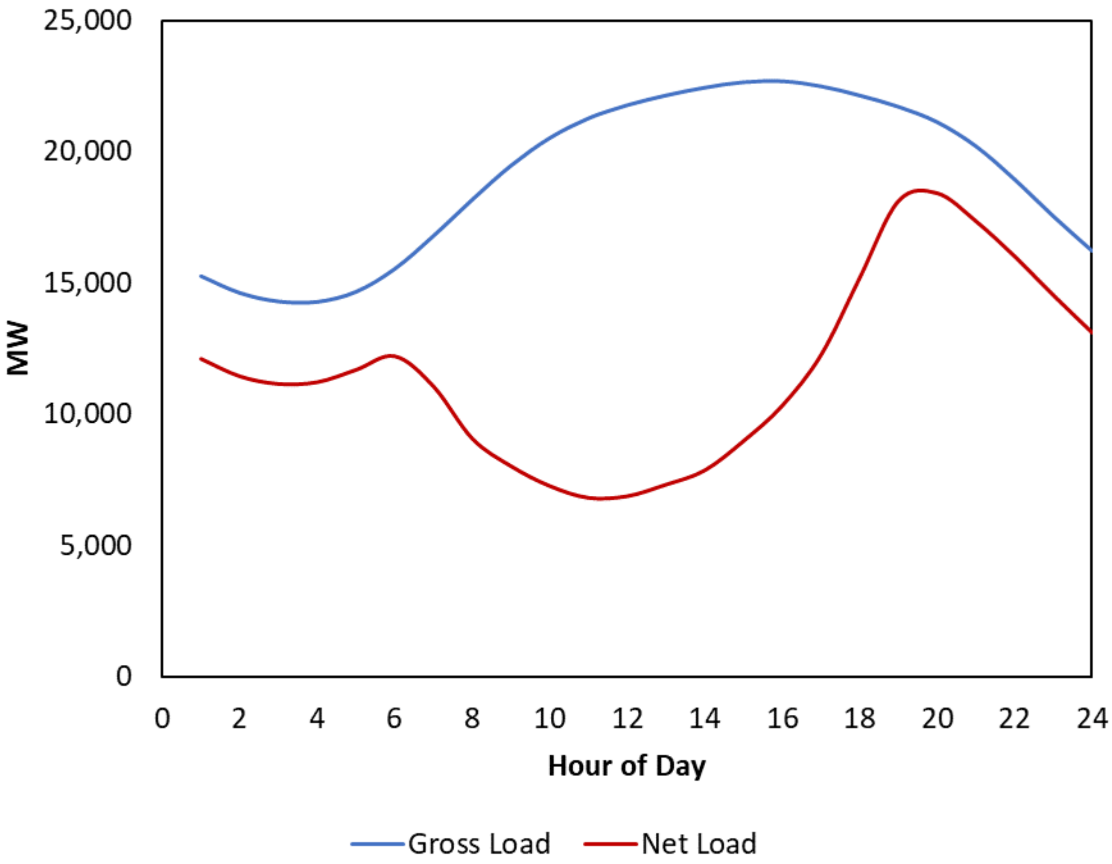


Figure 5. Gross Load vs. Net Load Peak Example

A critical component of the debate over marginal and average ELCCs is whether the capacity auction procurement volume should be determined based on the net load peak (when reliability events are most likely) or based on the gross load peak. As discussed above and recognized in the NYISO proposal,[4] accrediting capacity at less than its average ELCC will result in a declining PRM or procurement target. This means that by accrediting capacity with marginal ELCC, the volume of capacity targeted by the NYISO proposal is based on the net load in the late afternoon only. After all, energy produced at 12:00-3:00 PM (the original peak timing) often has limited value; producers sometimes even have to pay load to take the energy during those hours in high renewable systems. But the reduction of the gross load

[4] https://www.nyiso.com/documents/20142/24130223/20210830%20NYISO%20-%20Capacity%20Accreditation_v10%20(002).pdf/b12b55d4-7aa9-644a-d803-05ae8df1877c

peak is still a critical component of supplying reliability and should be recognized in the capacity market design. This principle is easiest to understand in the context of energy storage technology.

Batteries do not necessarily shift the net load peak. Since they can be dispatched to perfectly meet the net load peak, their contribution to reliability has a shaving effect as shown in Figure 6.

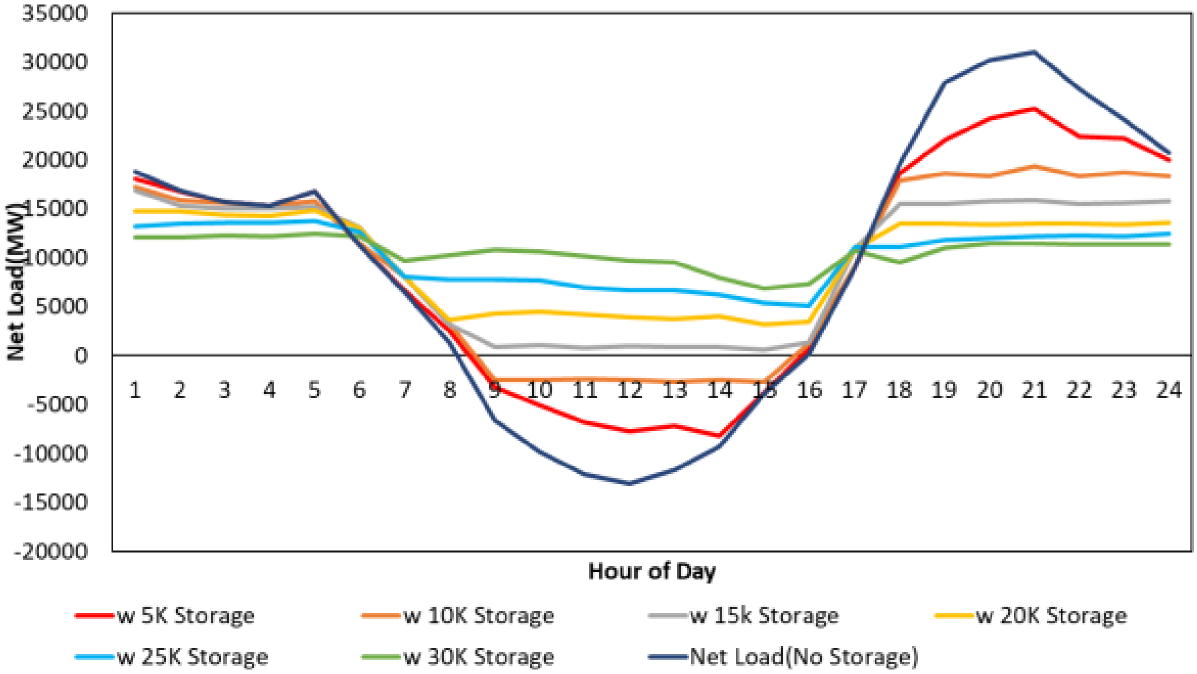


Figure 6. Net Load Peak at Various Storage Penetration Levels

A 30 GW battery portfolio reduces the net load peak from 30 GW to approximately 10 GW and nearly flattens the net load shape across the entire day. Reliability events are still concentrated in hours 20-21 since batteries continue to be dispatched until they are exhausted. In this example, since the flat load shape means there is no energy to charge incremental storage resources, the marginal value of 4-hour batteries is close to 0%. In a marginal ELCC accreditation construct then, none of the batteries would receive any capacity credit even though the battery portfolio effectively reduced the net load peak by nearly 70% and they are still producing at that level at the time of the reliability event. The only reason that solar appears to have less reliability value is that it shifts the timing of reliability events, but the same principle applies – any reduction in the peak load to be served should be accredited with capacity value since absent that resource class, there is no other mechanism to provide reliability in that period. Once the peak load has been shifted in the case of solar, further contributions to the gross load peak hour should not be given credit, but the initial contributions must be recognized.

Another implication of utilizing marginal ELCC for accreditation is that batteries (or other classes of resources with similar disconnects) that are expected to supply 70% of the energy during emergencies would receive none of the capacity revenue, and consequently would have minimal incentive to perform. Since capacity market performance obligations are enforced via adjustments to capacity market revenue, if there is no revenue to adjust, there is no mechanism to encourage performance. This concern holds at any level of disconnect between reliability supplied and capacity being paid for.

Therefore, there are reliability risks that stem from accrediting solar and storage at a low marginal ELCC even though in combination they are actually being used to reduce the gross load peak from 50 GW down to 10 GW. In an even more extreme scenario, this example could be extended such that solar and storage meet all reliability requirements. While the installed capacities required would be large, and the marginal ELCCs at target system reliability would be close to 0%, this is technically feasible. Further, this is the direction that many systems are headed. New York has goals of 70% renewable energy by 2030 and 100% zero-emission electricity by 2040. California will have greater than 10 GW of short duration storage by 2025 and greater than 30 GW of installed solar capacity. These edge cases where the resources supplying all, or nearly all, of the system's reliability needs, but receive little or none of the capacity revenue demonstrate that marginal accreditation is fundamentally inaccurate. And this principle applies not just for extreme cases. As soon as marginal and average ELCC curves diverge at all, which begins at modest penetrations, there is an inaccurate appropriation of revenue from that class of resource.

This issue is not simply with renewable or battery technologies. Winter reliability is becoming more challenging to supply in the Northeast due to fuel adequacy concerns. If the gas supply is already constrained with the existing gas portfolio, a new gas resource that bids into a winter season capacity market without firm fuel would provide 0% marginal ELCC. In this case, with the NYISO accreditation proposal, a gas portfolio that serves over half the load (per the NYISO 2021 Gold Book, gas resources make up approximately 57% of total installed capacity in 2030) during the time of peak would receive zero revenue from the capacity market.[5]

In all of these examples, under the proper market design, as the marginal ELCC approaches zero, the effective bid price will move drastically higher so that procurement decisions have the right economic signals. A 100 MW battery resource supplying 1% marginal ELCC has the same capacity contribution as a 1 MW perfectly available resource. The battery's effective bid price would then be 100x its nameplate bid (x$ bid divided by 1% marginal ELCC = 100x per effective MW). If that resource is going to be selected in the auction, its cost would have to be subsidized by state policies or other means, but it is important that the marginal economic signal accurately reflect its reliability value. This is why it is necessary to properly accredit any contribution to reducing the system peak load.

[5] Page 130, https://www.nyiso.com/documents/20142/2226333/2021-Gold-Book-Final-Public.pdf/b08606d7-db88-c04b-b260-ab35c300ed64

III. PROJECTED NYISO MARGINAL AND AVERAGE ELCCS

The MMU analyzed the implications of marginal and average accreditation in its Consumer Impact Analysis published on November 2, 2021. Their published technology specific capacity credit results when comparing average to marginal accreditation assumptions were potentially misleading. A snapshot of the results is shown in the table below.

Table 1. Capacity Credit Results from MMU Analysis[6]

		Capacity Credit by Case (%)			
Zone	Technology	Marginal	Average	Status Quo - Summer	Status Quo - Winter
A-F	Solar	7%	16%	9%	2%
A-F	Land Based Wind	10%	12%	22%	43%
A-F	2-Hour Storage	42%	43%	32%	32%
A-F	4-Hour Storage	64%	71%	64%	64%
A-F	6-Hour Storage	79%	86%	82%	82%
A-F	8-Hour Storage	87%	92%	100%	100%
G-I	Solar	14%	24%	9%	2%
G-I	2-Hour Storage	22%	31%	32%	32%
G-I	4-Hour Storage	52%	57%	64%	64%
G-I	6-Hour Storage	75%	80%	82%	82%
G-I	8-Hour Storage	90%	94%	100%	100%

The difference in capacity credit values for the storage resources between marginal and average accreditation appear to be small. In reality, this is due to significant differences in the assumed resource penetration values between the marginal and average case studies. For example, the marginal case study included only 1,150 MW of 4-hour battery compared to the average case study with 2,150 MW. If the marginal case study had assumed the same penetration at 2,150 MW, the marginal ELCC capacity credit would be much lower, following the marginal ELCC curve.

The capacity credit results from the MMU's preliminary analysis are also much lower than the values expected by Astrapé based on running solar and storage ELCC studies in a wide range of systems for the past 25 years. The low values purported by the MMU would suggest that solar and storage are unlikely to significantly contribute to reliability in New York and thus the concern over ELCC methodology is inconsequential. However, a more realistic analysis than the one conducted by the MMU demonstrates quite the opposite.

To probe the MMU's findings, Astrapé used the SERVM model to calculate NYISO specific marginal and average ELCCs for a range of solar and storage penetrations for the study year 2030. The SERVM model is a resource adequacy tool used by many of the largest utilities in North America as well as several of the ISOs in the U.S. and Canada. A base portfolio was developed for 2030 and a range of solar and storage penetrations were simulated to understand the magnitude of projected ELCCs as well as the relationships between marginal and average ELCC curves. Unless otherwise noted, the resource mixes

[6] Slide 42, https://www.nyiso.com/documents/20142/25835955/MMU%20ICAP%20Accreditation%20Consumer%20Impact%20Analysis%2011-02-2021.pdf/637ba21e-db75-a4c1-5b41-f770dd26e529

targeted in the scenarios matched scenarios from the NYISO Gold Book. Table 2 contains the resource mix used for the base case.[7]

Table 2. Base Scenario Resource Mix

Unit Category	2030 Goal Installed Capacity (MW)
Community Solar	8,334
Utility Scale Solar	8,583
BTM Batteries	493
PSH	1,407
Hydro	4,807
Land Based Wind	5,275
Offshore Wind	6,200
Conventional	21,168
EOPs	2,775

The penetration levels studied for storage and solar are defined in Table 3Table 2 and Table 4 below.

Table 3. Battery Penetrations Studied

Nameplate Capacity (MW)		
BTM Batteries	**Utility Scale Batteries[8]**	**Total Batteries**
493	507	1,000
493	1,507	2,000
493	2,507	3,000
493	5,507	6,000
493	8,507	9,000

Table 4. Solar Penetrations Studied

Utility Solar Nameplate Capacity (MW)
1,000
5,000
8,583
9,583

[7] The derivation of the values used for community solar, utility scale solar, BTM batteries, PSH, land based wind, and offshore wind can be found in Appendix A1.
[8] All batteries were modeled with a 4-hour duration.

These ELCC values were used directly in quantifying the issues between marginal and average ELCC accreditation to summarize the actual expected impact to the NYISO capacity market. A summary of the resulting ELCCs is provided in Table 5 below.

Table 5. Summary ELCC Results

Study Technology Capacity (GW)	Storage Average ELCC	Storage Marginal ELCC	Solar Average ELCC	Solar Marginal ELCC
1	100%	100%	50%	47%
2	100%	100%	47%	42%
3	100%	93%	45%	36%
4	96%	78%	42%	30%
5	91%	65%	39%	25%
6	86%	53%	36%	19%
7	80%	41%	33%	14%
8	74%	28%	30%	8%
9	69%	16%	28%	2%

As demonstrated from the ELCC results, the differences between the marginal ELCC and average ELCC can be significant, particularly for resources with steeper declining ELCC curves. In some cases, such as storage at 9 GW, the marginal ELCC drops to 16%, which would lead to minimal capacity revenues for all resources in that class, while the technology class would still be expected to supply 69% reliability value based on the average ELCC.

IV. REVIEW OF NYISO MARGINAL ELCC ACCREDITATION PROPOSAL

SUMMARY OF NYISO CAPACITY ACCREDITATION PROPOSAL

The NYISO marginal ELCC capacity accreditation proposal can be summarized in the following steps:

1. A NYISO wide Installed Reserve Margin (IRM) is determined each year utilizing a probabilistic hourly chronological simulation software based on achieving 0.1 LOLE reliability.

$$IRM = \frac{Installed\ Capacity\ Required\ to\ Acheive\ 0.1\ LOLE\ (MW)}{Peak\ Load\ (MW)}$$

2. The installed capacity requirement is then converted to a UCAP requirement by applying specific derating factors depending on the technology class.
    a. Conventional resources are converted to UCAP based on their equivalent forced outage rate demand (EFORd)
    b. Variable energy resources (solar, wind, battery, etc.) are converted to a UCAP value based on their marginal ELCC value
    c. Using the resulting total UCAP value, a system derating factor can be determined

$$UCAP_{Conventional} = ICAP * (1 - EFORd)$$

$$UCAP_{Solar} = ICAP * ELCC\%_{Marginal,Solar}$$

$$UCAP_{Requirement} = UCAP_{Conventional} + UCAP_{Solar} + \cdots + UCAP_n$$

$$System\ Derating\ Factor = \frac{ICAP_{Requirement} - UCAP_{Requirement}}{ICAP_{Requirement}}$$

3. Resources bid into the capacity auction, based on per unit accredited capacity (marginal ELCC rate for variable energy resources, UCAP for conventional resources)
4. The amount of cleared resources equals the UCAP requirement established in Step 2, with the marginal unit setting the market clearing price
5. Payments are allocated to each resource based on the market clearing price multiplied by their accredited capacity value.

Figure 7 summarizes the NYISO proposal where the total capacity accreditation of the cleared portfolio matches the sum of the conventional capacity and the marginal ELCC capacity to match the total gross load at the time of the net load peak.[9]

[9] The additional capacity that would be supplied above the gross load peak to meet the PRM is disregarded for simplification of the illustration.

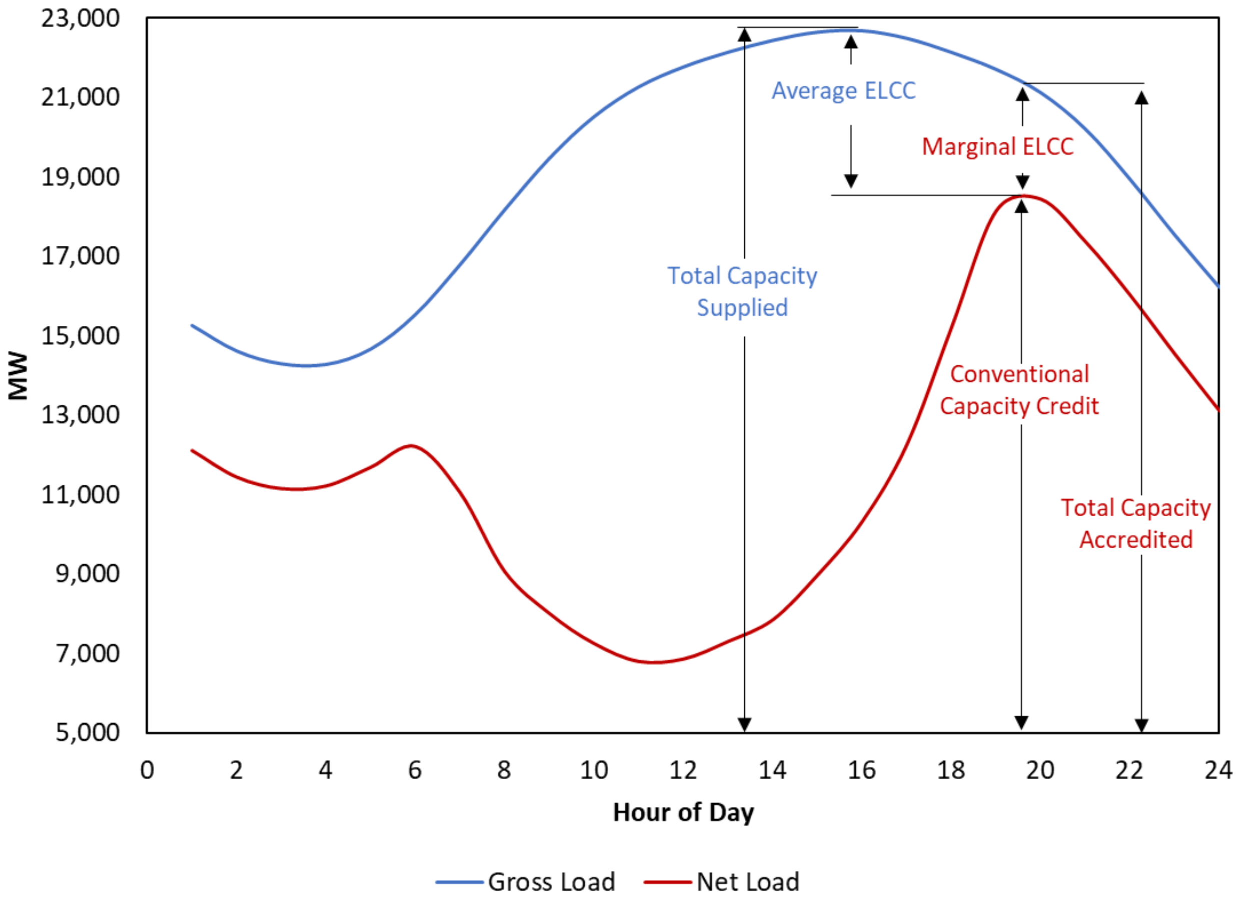


Figure 7. Marginal ELCC Accreditation Visualization

MARGINAL ELCC ACCREDITATION PROPOSAL ISSUES

ISSUE #1: MARGINAL ELCC RESOURCE ACCREDITATION DOES NOT ACCURATELY COMPENSATE RESOURCES RELATIVE TO THEIR RELIABILITY CONTRIBUTION

As established in the background section of this report, a key principle of a fair and efficient capacity market is that no resource that clears the market should be advantaged over another so long as that resource is providing the same value. Value is measured relative to a resource's capacity contribution towards meeting the capacity volume requirement, which is an amount set by maintaining the target system reliability. As such, each MW of perfectly available capacity equivalent that contributes to maintaining 0.1 LOLE reliability should receive the same amount of revenue set by the clearing price of the capacity auction.

Utilizing marginal ELCC to determine the capacity accreditation for variable energy resources unfairly underpays these resources relative to their actual reliability contribution as illustrated in Figure 7. It also results in discrimination between variable energy resources, where those with steeper declining marginal ELCC curves are more underpaid than resources with flatter marginal ELCC curves.

Table 6 below provides a detailed summary of the capacity payment discrepancies that arise in a marginal ELCC accreditation construct for each technology resource class under the 2030 Goals Scenario portfolio assumptions. Battery resources are underpaid 38% relative to their actual reliability contribution and solar resources are underpaid 83% relative to their actual reliability contribution, yet conventional resource revenues remain commensurate with their reliability contribution.

In developing the case for marginal ELCC accreditation, NYISO and the MMU incorrectly claimed that this underpayment to resources can be considered a cost savings to consumers,[10] when in reality this is an artificial revenue reduction to variable energy resources. When payments to resources are not commensurate with their reliability value, the potential for grid reliability risk can be increased. Further, this underpayment results in a potential cost risk that was not accounted for in the MMU's analysis. Existing variable energy resources that required renewable energy credits (RECs) to be developed were based on previous capacity accreditation assumptions. A drastic change to capacity payments, particularly for steeply declining ELCC resources where the marginal ELCC is much lower than the average, may result in resource owners with existing long-term contracts to provide capacity seeking to be made whole with the state of New York. Ultimately, these funds would come from taxpayers/ratepayers.

Table 6. 2030 Goals Scenario Capacity Payment Discrepancy Summary

	Conventional	Utility Solar	Utility Battery Storage	Formulas
Installed Capacity (MW)	21,168	8,583	6,000	[A]
Average ELCC/ UCAP (%)	95%	29%	86%	[B]
Marginal ELCC (%)	95%	5%	53%	[C]
Capacity Contribution (MW)	20,110	2,489	5,160	[D] = [A] * [B]
Capacity Accredited (MW)	20,110	429	3,180	[E] = [A] * [C]
%Delta - Capacity Payments	0%	-83%	-38%	[F] = ([E] – [D]) / [D]

Table 7 quantifies the impact of the potential discrepancy between capacity accredited and capacity supplied as the battery portfolio is built out over time. Critically, these values are based on SERVM simulations which reflect a larger reliability contribution than the values put forward by the MMU. So in the MMU's implementation, the disconnect would start at a lower penetration and increase more rapidly.

[10]https://www.nyiso.com/documents/20142/25835955/MMU%20ICAP%20Accreditation%20Consumer%20Impact%20Analysis%2011-02-2021.pdf/637ba21e-db75-a4c1-5b41-f770dd26e529

Table 7. 2030 Goals Scenario Capacity Accreditation Discrepancy Summary

Battery Energy Storage Installed Capacity (MW)	Average ELCC (%)	Marginal ELCC (%)	Actual Fleet Reliability Value (MW)	NYISO Accredited Fleet Value (MW)	% Delta
1,000	100%	100%	1,000	1,000	0%
2,000	100%	100%	2,000	2,000	0%
3,000	100%	93%	3,000	2,790	-7%
4,000	96%	78%	3,840	3,120	-19%
5,000	91%	65%	4,550	3,250	-29%
6,000	86%	53%	5,160	3,180	-38%
7,000	80%	41%	5,600	2,870	-49%
8,000	74%	28%	5,920	2,240	-62%
9,000	69%	16%	6,210	1,440	-77%

ISSUE #2: MARGINAL ELCC ACCREDITATION PROVIDES DISPROPORTIONATE ECONOMIC DISINCENTIVES FOR VARIABLE ENERGY RESOURCES

As seen in the Table 6 results above, marginal ELCC accreditation disproportionately underpays resources with steeper ELCC curves (e.g., solar, battery storage) relative to resources with flat sloping ELCC curves (e.g., conventional gas and coal resources) for the same reliability contribution. There is no technical or economic reason why 5 GW of contribution to the capacity volume requirement (i.e., perfectly available capacity equivalent) from conventional resources should get compensated more than 5 GW of contribution from battery and solar resources. In the absence of equal payment for equal contribution, there is a larger economic disincentive for battery and solar resources to participate in the capacity market. This disincentive is likely to lead to a lower selection of these types of resources than would otherwise exist and would work counter to the goals and objectives set forth by the state of New York in increasing overall renewable and storage penetration. This selection pressure would have to be made up for in an increase in REC payments or other market subsidies.

ISSUE #3: MARGINAL ELCC ACCREDITATION PROPOSAL CONFLATES AVERAGE PRICING WITH AVERAGE ACCREDITATION

The NYISO proposal justifies marginal ELCC accreditation by stating that it provides a more appropriate price signal as compared to using average pricing. However, accreditation is a separate issue from the establishment of the marginal pricing as established in the Efficient Capacity Market Design Principles section above. To help further illustrate why average pricing and average ELCC accreditation are not the same, and how marginal pricing and average ELCC accreditation can be used in conjunction to create both appropriate price signals as well as a market that provides compensate in proportion to value, the following analogy borrowed from basic economic theory is provided:

Smith Farms sells blueberries. Due to crop densities and other factors, picking the first blueberry is more efficient than picking the last blueberry. Everyone picks at the same rate, but with each additional worker, everyone's productivity drops. Therefore, the cost of production per gallon of blueberries picked rises as demand for blueberries rises.

Table 8. Smith Farms Supply Curve

Blueberry Demand (gallons)	Workers Required	Marginal Cost ($/Gallon)
1000	10	$2.35
1800	20	$2.75
3000	40	$4.10
4000	80	$15.46

An entrepreneur has developed a blueberry picking machine that picks at a constant rate regardless of crop density. He offers Smith Farms to pick at a fixed rate of $6/gallon. Smith Farms is looking for the most efficient mix of workers and machines to pick 4,000 gallons of blueberries. As such, the market clears at $6/gallon, with the machine displacing the workers whose cost per gallon is above $6/gallon, resulting in a mix of workers and machines to pick the fields.

Applying this same logic to capacity markets, NYISO is proposing to set the price according to the clearing logic above. Whatever mix of technologies results in the lowest marginal cost is appropriate. However, the NYISO proposal would then pay that price to a different quantity than the total capacity supplied. Using the analogy above, it can be assumed that the last worker hired reduced everyone's productivity such that total production increased by only 33 gallons. Smith Farms then uses the marginal production rate to calculate the payment to all the workers. So despite the fact that each worker produced 60 gallons, they only get paid for 33 gallons/day because of the effect that the last worker had on total production. Over time, this payment structure would provide strong incentives for all workers to produce less or leave Smith Farms. In the same way, NYISO proposes determining the cost of incremental capacity appropriately, but then proposes paying for a much smaller quantity of capacity than is actually procured, producing signals to produce less or exit the market.

Additional descriptions of how marginal pricing and average accreditation can be used in conjunction in capacity markets is summarized in Section V. Example Auction Design.

ISSUE #4: EX ANTE DETERMINATION OF ELCCS, WHETHER AVERAGE OR MARGINAL, CREATES THE POTENTIAL FOR RELIABILITY PROBLEMS OR OVERPROCUREMENT.

Under the NYISO proposal, the UCAP requirement is determined ex ante using a system derating factor from the installed capacity reserve margin requirement. Because the system derating factor utilizes the marginal ELCC to adjust the capacity contribution of the assumed variable energy resource penetration, the resulting UCAP requirement does not actually represent the true amount of perfectly available capacity equivalent that results in a system at 0.1 LOLE. This can be demonstrated by calculating the NYISO UCAP requirement and the actual quantity of perfectly available capacity equivalent for a system with a resource mix that differs ex ante and ex post. For instance, per the values in

Table 7, a capacity auction that cleared 35GW of UCAP capacity would be 2GW short of supplying 0.1 LOLE reliability if the auction clears 0GW of battery storage instead of the 6GW of battery storage assumed in the UCAP requirement development (difference between 5,160 MW of actual reliability contribution and 3,180 MW of NYISO accredited contribution).

NYISO has not provided clear methodologies for how it might deal with such discrepancies. To be clear, ex ante determination of ELCCs raises concerns whether the market uses marginal or average accreditation. An average accreditation framework could also result in reliability issues if the cleared resource mix varies from the modeled assumption. However, because the differences between the ex ante and ex post amounts can be significant, it is critically important that the methodology for reconciling these amounts be specified.

Table 9. Incorrect Ex Ante Resource Mix Assumption Outcomes

	Average Accreditation	Marginal Accreditation
Higher Renewable Than Assumed	Auction procures inadequate capacity leading to reliability issues	Auction procures too much capacity
Lower Renewable Than Assumed	Auction procures too much capacity	Auction procures inadequate capacity leading to reliability issues

V. EXAMPLE AUCTION DESIGN THAT SATSIFIES EFFICIENT CAPACITY MARKET DESIGN PRINCIPLES

In arguing against the marginal ELCC capacity accreditation put forth by NYISO, a distinction must be made between two different but related concepts: marginal pricing vs. marginal accreditation. Marginal pricing is the practice of establishing the price of a product based on the cost of producing the next, or marginal, unit of that product. The marginal price has long been utilized in determining the auction clearing price in capacity markets and sets appropriate price signals to resource owners and developers to make retirement/investment decisions for their generating assets. Regardless of how resources are accredited for their contribution towards meeting the capacity volume requirement, marginal pricing can and should be implemented to set the per unit cost of capacity to consumers.

One misconception related to average ELCC accreditation methodology is that the average ELCC must also be used in determining the price signal to the capacity market for a given technology class. To illustrate how marginal pricing can be used in conjunction with average accreditation, the following market clearing example is presented below.

CAPACITY AUCTION EXAMPLE

Suppose that a bulk electric system achieves 0.1 LOLE reliability when it procures the equivalent of 33,000 MW of perfectly available capacity equivalent. A capacity market is constructed where resources must provide bids based on a per unit of perfectly available capacity equivalent basis (i.e., UCAP value for conventional resources, ELCC for variable energy resources). A supply stack can be easily constructed for conventional resources, as their individual UCAP values are known in advance and are not dependent on other resources in the market. The conventional resources are priced according to the chart below.

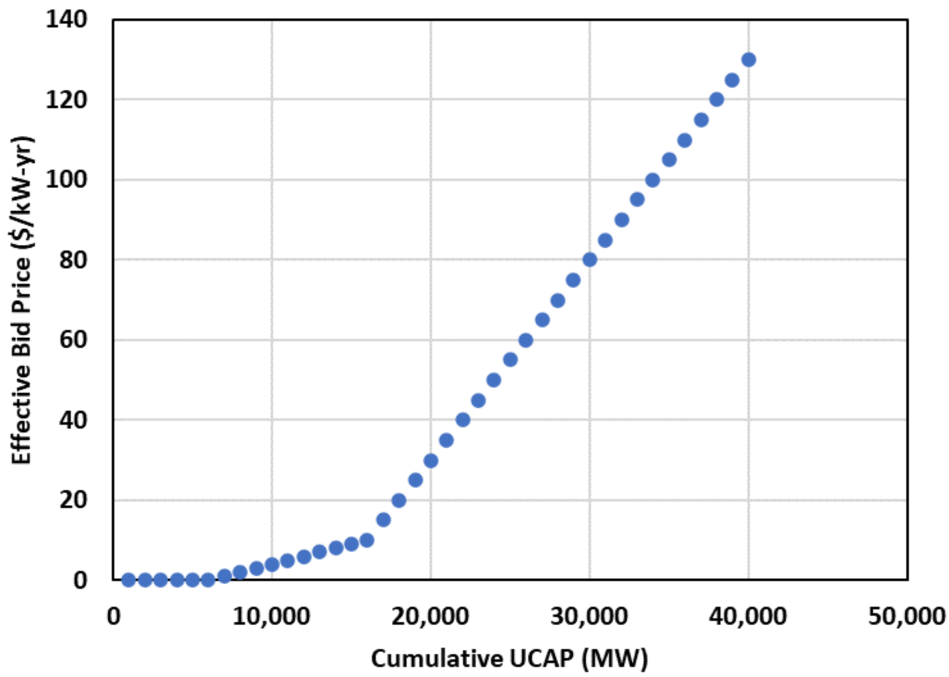


Figure 8. Conventional Resource Supply Stack

For resources like solar and storage however, their perfectly available capacity equivalent is dependent on their resource class penetration. Because the market is designed to clear the lowest cost resources first, the lowest cost resource of a given technology class would receive the highest marginal ELCC rating to determine its perfectly available capacity equivalent. Subsequent resources would get the next marginal ELCC rating, following a predetermined technology specific declining ELCC curve. This would continue through all bids received for the auction.

The supply curves for solar and battery resources are shown in Figure 9 and Figure 10 below, where 20 GW of solar is initially bid at a flat price of $20/kW-yr (installed capacity basis) and 10 GW of 4-hour storage is bid at a flat price of $50/kW-yr (installed capacity basis). These bids are then adjusted for each MW of perfectly available equivalent capacity supplied, following the declining marginal ELCC curve for each technology. As more bids are received and the marginal ELCC decreases, the adjusted price per unit of perfectly available capacity equivalent will increase to reflect its true marginal value to the system.

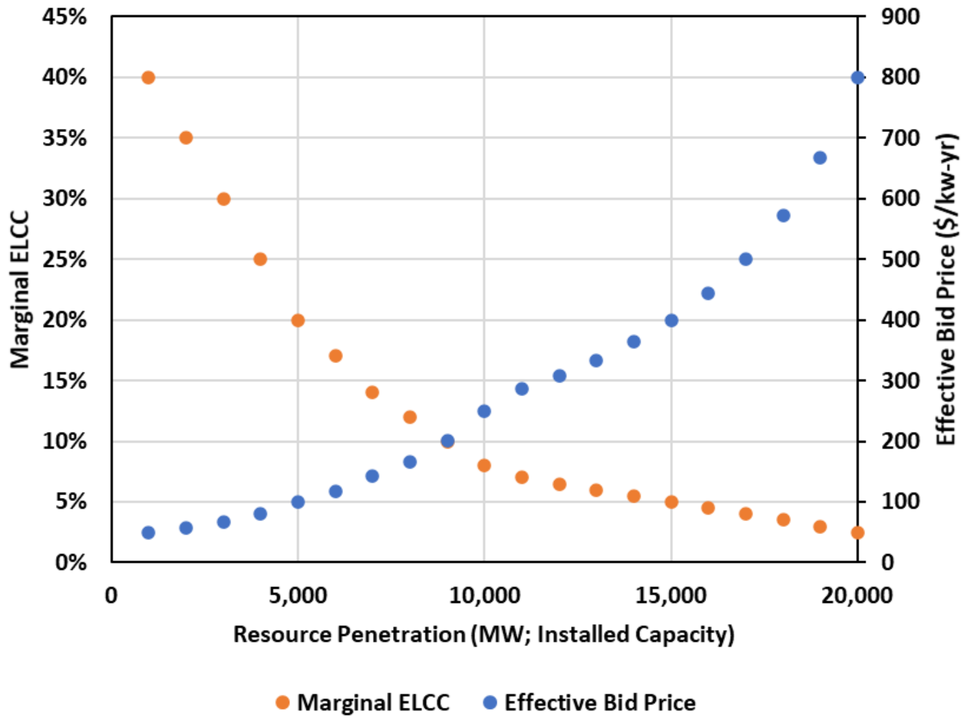


Figure 9. Adjusted Bid Curve and Marginal ELCC Curve (Solar)

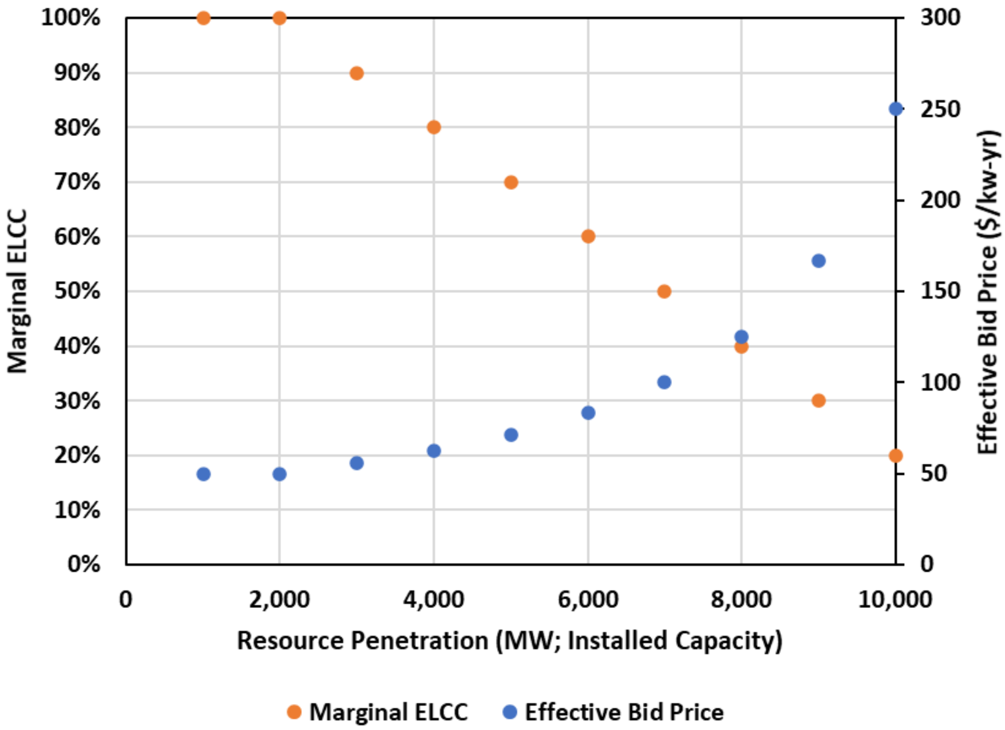


Figure 10. Adjusted Bid Curve and Marginal ELCC Curve (Battery)

With the adjusted bid prices of solar and storage, all resources can then be sorted by their effective bid price to produce the following supply stack. At 33 GW of perfectly available capacity equivalent, the supply stack yields a clearing price of $83.38/kW-yr with 29 GW of conventional, 4 GW of solar, and 6 GW of storage cleared (installed capacity).

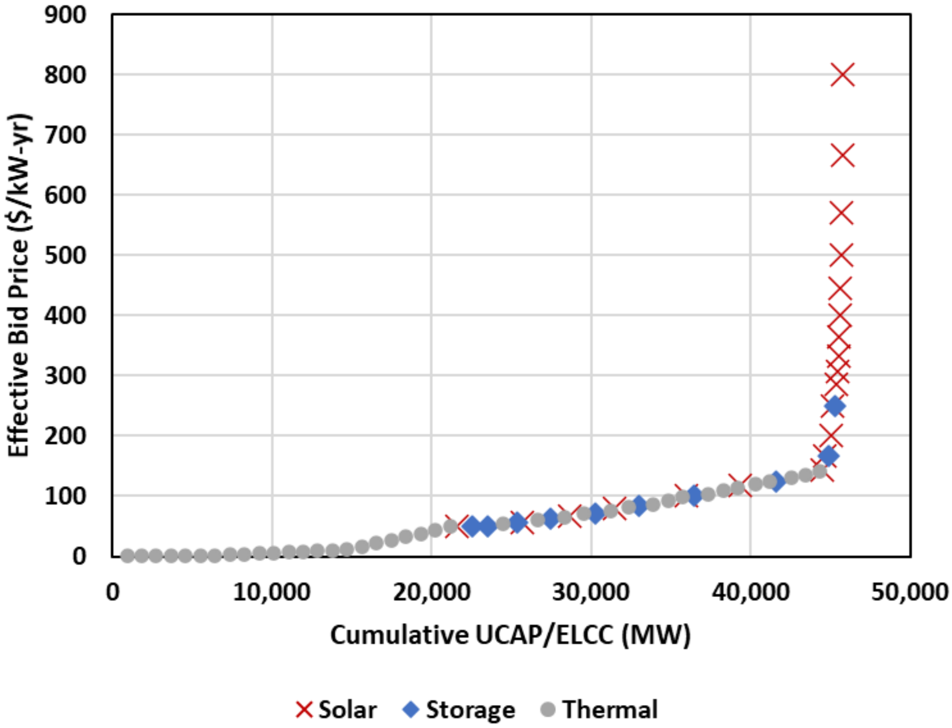


Figure 11. Total System Supply Stack

After the volume of capacity to be procured and clearing price are determined, resources must now be accredited based on their reliability contribution. In total, precisely 33 GW of perfectly available equivalent capacity has been procured. While the first solar and first storage resources that cleared had higher marginal ELCC values than subsequent resources, this is simply due to how the resources were sorted according to price and not reflective of how they contribute to reliability in the aggregate. Therefore, all solar and all storage should receive the average ELCC based on the total value of capacity that cleared for each respective technology class. For solar this is 33% and for storage this is 83%.

In summary, 29 GW of conventional resources is accredited at 92% (based on an 8% EFORd), 4 GW of solar is accredited at 33%, and 6 GW of storage is accredited at 83%. The sum product yields 33 GW of effective capacity.

ADDRESSING ARGUMENTS AGAINST AVERAGE ELCC ACCREDITATION

NYISO and the MMU have put forward the following main argument against average ELCC accreditation throughout the stakeholder process of developing the marginal ELCC accreditation proposal: average ELCC accreditation leads to inefficient incentives for investment and leads to excess consumer costs.

If the penetration level of a variable energy resource, and thus its expected average ELCC value, is determined before the capacity auction is cleared, it is possible that over procurement can occur for resources with steep declining ELCC curves (e.g., solar resources). In this case, the capacity price signal reflects a relatively high average ELCC value, and the incremental contribution is a relatively low marginal ELCC value. However, as demonstrated by the capacity auction example above, this is an inappropriate use of average ELCC accreditation, which should not be determined ex ante. If the proper marginal ELCC values are utilized to adjust bid prices ex post, average accreditation does not impact the marginal price signal.

Even in a case where solar developers are seeking to manipulate their bids to ensure they clear the market and receive full average accreditation, market outcomes are beneficial to consumers. In theory, solar developers looking to guarantee they are not the marginal unit due to very high effective bid prices could all decide to bid $0/kW-yr. All solar resources would then clear, even those that provide very little marginal value. However, this would only lead to a depression in the market clearing price, and therefore a reduction to consumer costs relative to a scenario where all bidders bid at their true marginal cost. Reliability would not be impacted, and the lower clearing price would reflect a more efficient market. However, this depressed market price may not cover the costs of certain solar developers, even when utilizing the average accreditation method. If solar producers were forced to bid at cost, then the marginal unit would have a very high effective bid price and not clear the market, with its capacity replaced by more efficient resources.

VI. CONCLUSIONS

In conclusion, the proposed marginal ELCC accreditation by NYISO results in inaccurate resource compensation that has potential risks to system reliability for the following reasons:

1. Underpays resources relative to their reliability contribution (i.e., does not accurately compensate variable energy resources for the value they provide towards meeting the capacity volume requirement). This has been incorrectly described as "savings" to consumers but is simply a reduction in compensation towards variable energy resources that does not correlate with any actual reduction in the actual reliability value being provided in aggregate. This may lead to risk of performance issues due to revenues not being commensurate with reliability value that NYISO is trying to procure and creates an economic discrepancy between conventional resources and variable energy resources.
2. Disproportionately selects resources with flat sloping ELCC curves, which are predominantly conventional gas and coal resources, and disadvantages resources with steeper ELCC curves which are renewable and battery technologies. The marginal accreditation construct provides no technical or economic justification for why one portfolio with 5 GW of contribution to reliability should be paid differently from another portfolio that also provides 5 GW of contribution to reliability.
3. Conflates average ELCC accreditation with average ELCC pricing by arguing that average ELCC accreditation sends inefficient market signals. Average ELCC accreditation can be used in conjunction with marginal ELCC pricing to produce proper pricing signals and proper revenue determinations.
4. Utilizes an ex ante approach to determine the system resource mix, and therefore uses a static ELCC value for every resource class. This can result in both the wrong type and the wrong quantity of resources clearing the capacity auction, resulting in economically inefficient and potentially unreliable procurement. While ex ante determinations of resource mixes have been approved in past proposals by other ISOs for capacity markets, this issue is only now becoming critical as the penetration of energy-limited and non-dispatchable resources is becoming significant.

VII. CERTIFICATION

Exhibit A.1: Appendix

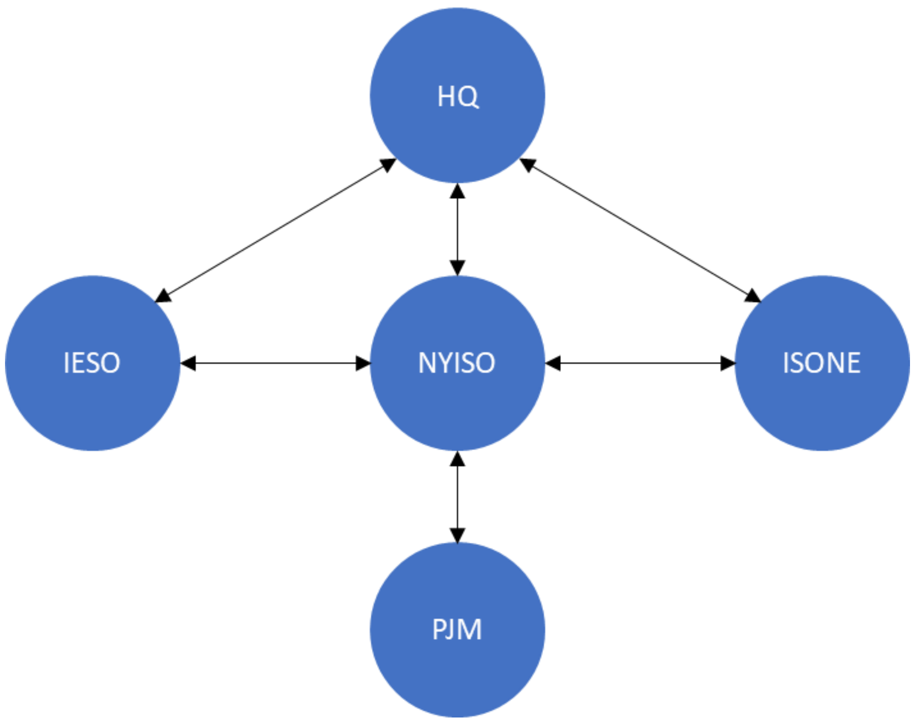
EXHIBIT A.1: APPENDIX – MODELING ASSUMPTIONS

SERVM is a system-reliability planning and production cost model designed to analyze the capabilities of an electric system during a variety of conditions under thousands of different scenarios. SERVM uses a full economic commitment and dispatch model that results in a higher degree of accuracy of system reliability due to more realistic resource operational characteristics. The SERVM model chronologically simulates the economic commitment and dispatch of the system across all pre-defined scenarios, calculating numerous economic and reliability metrics for each. This process provides insight into risks and costs during these periods as well as the expectation of being able to meet peak load under various conditions. Understanding the results of the model helps a user understand and determine the amount of reserves an electric system requires to adequately meet peak demand. The model is also used for many other analyses including ELCC studies, fuel back up studies, Equivalent Forced Outage Rate (EFOR) improvement studies, and capacity valuations for upcoming peak seasons.

STUDY TOPOLOGY

To capture the system reliability, Astrapé modeled the load and generator outage diversity that a system has with its neighbors. For this study, the NYISO system was divided into 11 zones. The neighboring regions modeled included 8 ISO-NE zones, 3 PJM zones, IESO, and Hydro Quebec. All of the zones were simulated at 0.1 LOLE with their expected 2030 resource mix. Figure A1 shows a simplified representation of the topology used in this study.

Figure A1. Study Topology

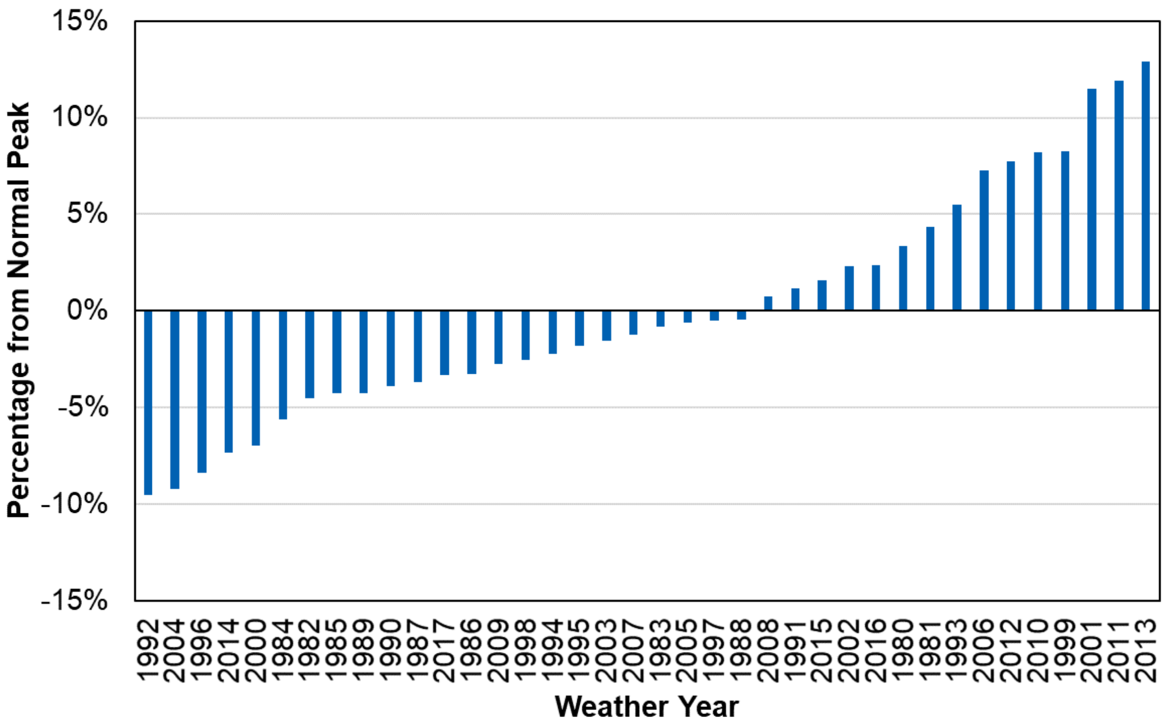


UNCERTAINTY FRAMEWORK

LOAD MODELING

The two primary load uncertainties that are modeled in SERVM are weather-related uncertainty and economic load growth uncertainty. To model the effects of weather uncertainty, 38 weather years were developed to reflect the impact of weather on load. Based on the 2010 to 2018 historical weather and load, a neural network program was used to develop relationships between weather observations and load. Different relationships were built for each season and for each zone to ensure that proper weather diversity was captured. These relationships were then applied to the last 38 years of temperature profiles to develop 38 load shapes for 2030. Equal probabilities were given to each of the 38 load shapes in the simulations. Figure A2 ranks all weather years by summer peak load and shows variance from normal weather. In the most severe weather conditions, the peak for the NYCA can be as much as 12.9% higher than under normal weather conditions.

Figure A2. 2019 Peak Load Rankings for All Developed Synthetic Loads



Loads for each external region (Hydro Quebec, IESO, PJM (Mid-Atlantic, West, and South), and ISO-NE (CT, ME, NEMASSBOST, NH, RI, SEMASS, VT, and WCMASS)) were developed in a similar manner as the NYISO loads.[11] A relationship between hourly weather and publicly available hourly loads was developed based on recent history, and then this relationship was applied to 38 years of temperature data to develop 38 load shapes. Table A1 summarizes the peak load for the NYISO Balancing Authority and the load diversity relative to the interconnected regions.

[11] Hydro Quebec hourly load data was not available. The load shapes for IESO were used for HQ but adjusted so HQ demand peaked in the winter. HQ load diversity is not shown since its exports were limited primarily by transmission and not by generation and load balance.

Table A1. Regional Load Diversity

	Peak Load (MW)	Load Diversity (% below non-coincident 50/50 peak)	
	Non-Coincident Peak Load	**At System Coincident Peak**	**At NYISO Coincident Peak**
NYISO	30,639	-8.1%	0.0%
PJM	154,483	-1.4%	-3.7%
ISONE	24,025	-7.9%	-2.5%
IESO	26,618	-7.8%	-16.1%
System	259,276	0.0%	-2.7%

ECONOMIC LOAD FORECAST ERROR

The non-weather drivers of load forecast errors differ from weather-related forecast errors because they increase with the forward planning period, while weather uncertainties remain relatively constant and are in general independent of the forward period.

The non-weather load forecast error multipliers were developed by reviewing the Congressional Budget Office (CBO) GDP forecasts 3 years ahead and comparing those forecasts to actual data. A standard deviation was calculated, and a normal distribution was developed for economic load forecast error. Because electric load grows at a slower rate than GDP, a 40% multiplier was applied to the raw CBO forecast error.

Table A2 shows the economic load forecast multipliers and associated probabilities used in this study. The table shows that 6.1% of the time, it is expected that the load will be under-forecasted by 4% 3 years out. The load forecast multipliers were applied to all regions.

Table A2. Economic Load Forecast Error Multipliers Used in SERVM

Load Forecast Multiplier	Probability (%)
0.96	6.1
0.98	24.2
1.00	39.4
1.02	24.2
1.04	6.1

SERVM utilized each of the 38 weather years and applied each of the 5 load forecast error points to create 190 different load scenarios. While the economic load forecast error distribution follows a normal distribution where each point has a different weighting, each weather year was given equal probability of occurrence.

RESOURCE MODELING

CONVENTIONAL RESOURCES

Existing resources included in the 2030 study are consistent with the resources listed in the 2021 Load and Capacity Data Gold Book.[12] To accurately reflect the flexibility of the NYISO system, each resource was modeled with detailed unit variables and all operational constraints were respected by SERVM in the simulations. Resources were selectively retired in the analysis in order to achieve 0.1 LOLE for the each of the base cases.

SOLAR RESOURCES

The solar profiles, one for each zone, were developed from data downloaded from the NREL National Solar Radiation Database (NSRDB) Data Viewer.[13] Data was downloaded for the 11 different locations for the available years, 1998 to 2020. 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 Advisory Model (SAM) for each year and location to generate the hourly solar profiles based on the solar weather data for a fixed and tracking solar PV plant.[14] Inputs in SAM included the DC to AC ratio of the inverter module and the tilt and azimuth angle of the PV array. The azimuth was set to maximize project value by having higher output in late afternoon hours. Data was normalized by dividing each point by the input array size. Solar profiles for 1980 to 1998 were selected by using the daily solar profiles from the day that most closely matched the peak load out of all the days +/- 2 days of the source day for the 1998 to 2020 interval. The profiles for the remaining years 1998 to 2017 came directly from the normalized raw data. The previous steps for selecting a profile were completed for each of the 11 locations. Figures A3 and A4 show the August average daily solar profiles for utility scale plants for 1980 to 2017 for fixed and tracking technologies.

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[12] https://www.nyiso.com/documents/20142/2226333/2021-Gold-Book-Final-Public.pdf/b08606d7-db88-c04b-b260-ab35c300ed64

[13] https://nsrdb.nrel.gov/nsrdb-viewer

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

Figure A3. August Daily Fixed Solar Profile

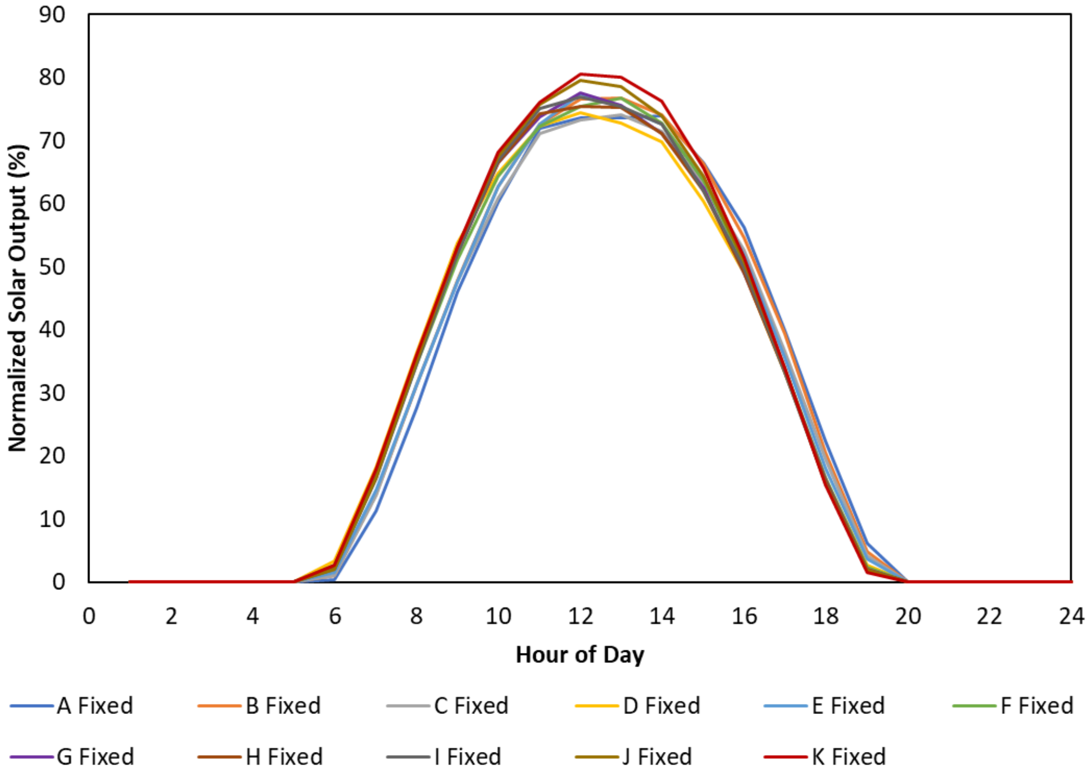
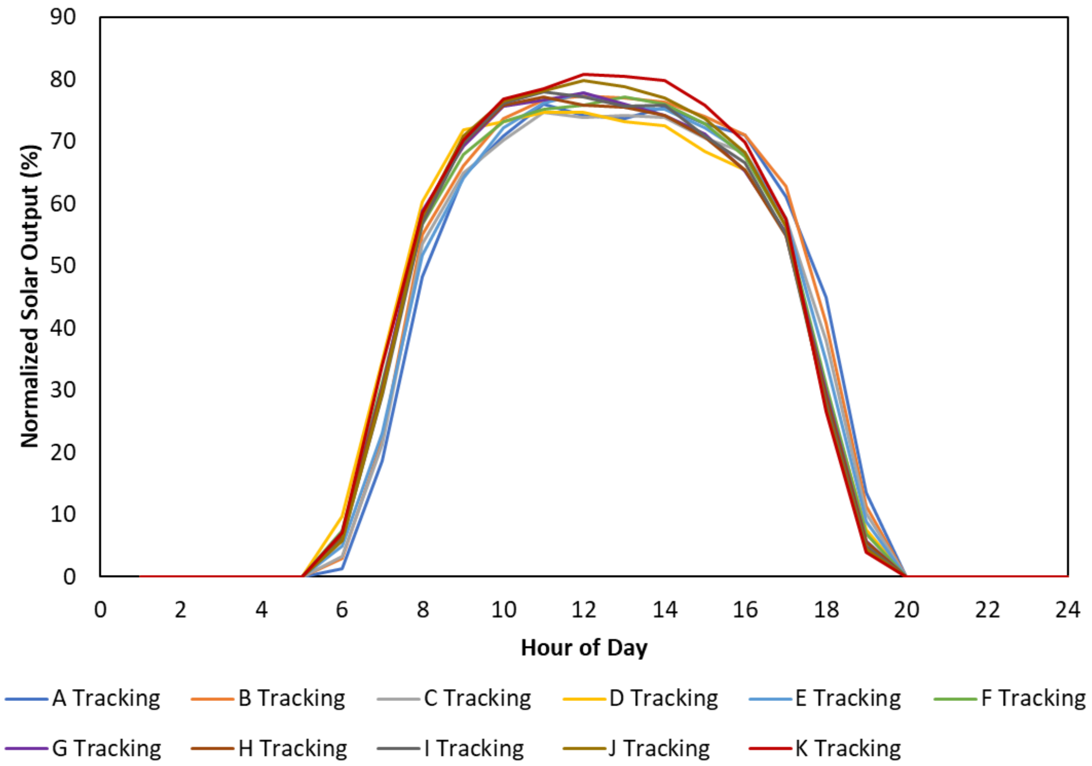


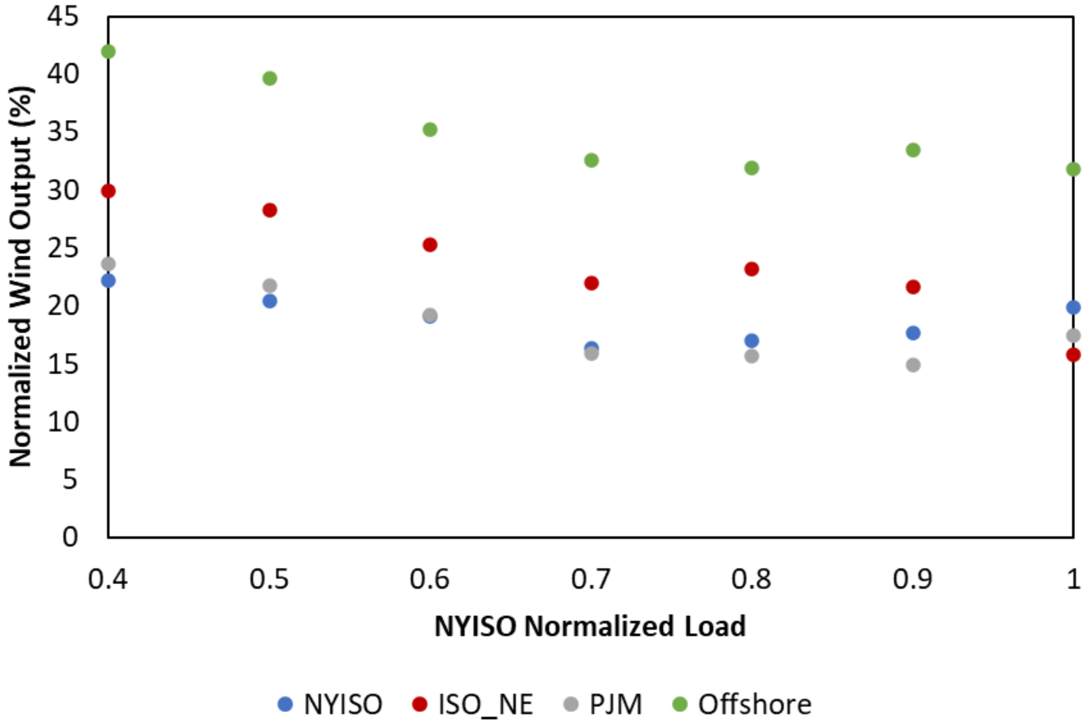
Figure A4. August Daily Tracking Solar Profile



WIND RESOURCES

Wind profiles were produced using hourly data for 2016 to 2018 found for NYISO, ISO-NE, and PJM, found on their respective websites. To construct wind shapes back to 1980, random days were selected from the 2016 to 2018 dataset based on the aggregate NYISO load. To maintain correlation between wind output and load in the different regions, shown in Figure A5, the same day was used for each region being captured. Offshore wind profiles were based off projects found off the New Jersey coast.[15]

Figure A5. Average Summer Wind Output as a Function of NYISO Load



ENERGY STORAGE RESOURCES

The batteries tested in the study were modeled with 4-hour storage capability, were allowed to charge from the grid, 90% round trip efficiency, used economic commitment and dispatch, and could serve ancillary services.

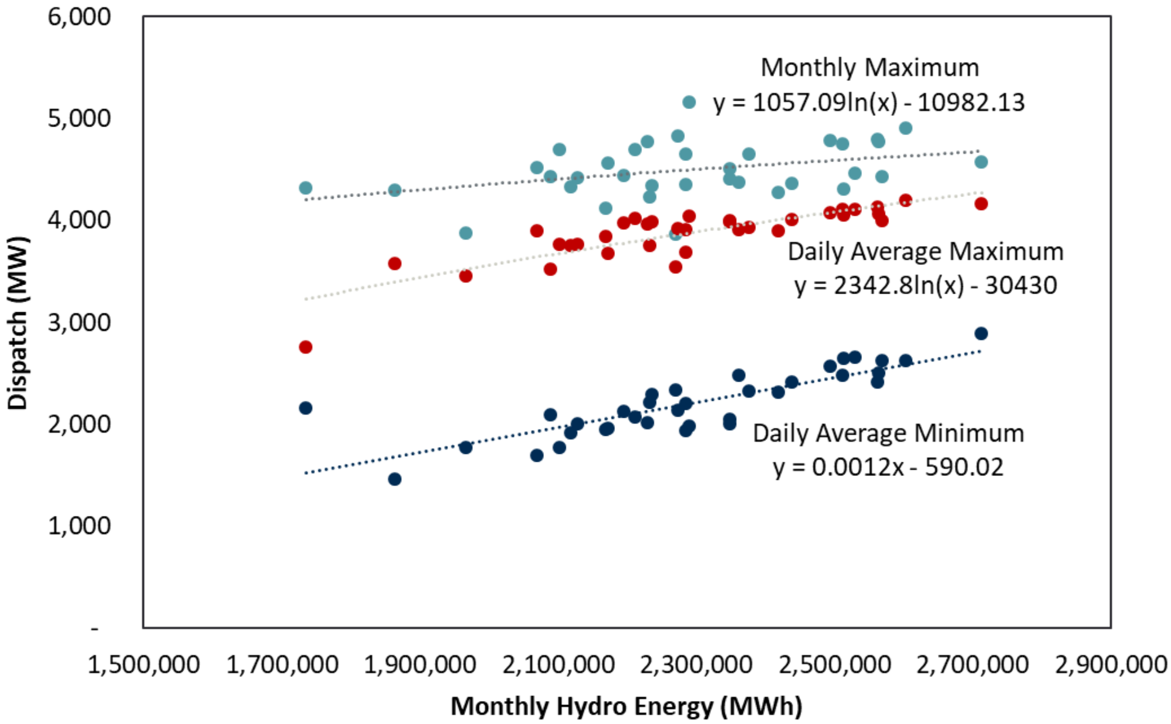
HYDRO RESOURCES

Available hydro data from 1980 to 2017 was collected from the U.S. Energy Information Administration Form 923. The projects in all of the zones modeled were assigned to their appropriate regions for all 38 weather years. Using the aggregate actual hourly data provided by NYISO from 2016 to 2018, inputs were developed to be used by the proportional load following algorithm for the proper NYISO zones.

The average daily minimum and maximum dispatch levels, the total monthly energy, as well as the monthly maximum dispatch level was identified from the historical hourly data for NYISO. Minimum and maximum daily dispatch levels are monthly maximum dispatch levels were defined as a function of monthly total energy as shown in Figure A6.

[15] https://www.pjm.com/planning/resource-adequacy-planning/effective-load-carrying-capability

Figure A6. NYISO Hydro Dispatch Levels



The curve fit equations were then used to apply to historical energy from the monthly energies calculated in the EIA form. SERVM optimally schedules the hourly hydro energy while respecting these constraints. The daily maximum and minimum dispatch and monthly maximum dispatch in conjunction with the total monthly energy are parameters that go into the determination of the hourly hydro schedule. The daily minimum hydro dispatch is scheduled at the minimum load hour of the day, and the daily maximum hydro is scheduled at the maximum load hour of the day. The monthly maximum hydro is scheduled at the max load hour of the month.

Scheduled hydro units are modeled with maximum capacity, total energy, daily average energy, and the schedule flow range. The total energy is the total amount of hydro that will be produced in a given month. This value cannot be greater than the total maximum hydro capacity multiplied by the number of hours in the month. The simulation logic will not allow the unit to simply run at the maximum hydro capacity for all hours because the monthly hydro energy constraint will be violated. After the minimum weekly flows are taken into account, the remainder of the month’s energy is scheduled as peak shaving.

SOURCES FOR BASE CASE RESOURCES SELECTED IN THE STUDY

Table A3. Base Portfolio Sources

Unit Category	Capacity (MW)	Link	Additional Notes
Offshore Wind	6,200	https://climate.ny.gov/Our-Climate-Act/Draft-Scoping-Plan	Annex 2
Land Based Wind	5,275	https://climate.ny.gov/Our-Climate-Act/Draft-Scoping-Plan	Annex 1
PSH	1,407	https://www.nyiso.com/documents/20142/2226333/2021-Gold-Book-Final-Public.pdf/b08606d7-db88-c04b-b260-ab35c300ed64	Base Gold Book
BTM Storage	493	https://www.nyiso.com/documents/20142/2226333/2021-Gold-Book-Final-Public.pdf/b08606d7-db88-c04b-b260-ab35c300ed64	Base Gold Book
Utility Solar	8,583	https://climate.ny.gov/Our-Climate-Act/Draft-Scoping-Plan	Annex 1
BTM PV	8,333	https://climate.ny.gov/Our-Climate-Act/Draft-Scoping-Plan	Annex 1

ELCC CALCULATION METHODOLOGY

Table A4 contains the resource mix used for the base case.[16] A base case of the system was first established by calibrating the NYISO to a reliability level of 0.1 Loss of Load Expectation (LOLE) for each system by retiring conventional generation.

Table A4. Base Scenario Installed Capacity

	2030 Goal Installed Capacity (MW)
Community Solar	8,334
Utility Scale Solar	8,583
BTM Batteries	493
PSH	1,407
Hydro	4,807
Land Based Wind	5,275
Offshore Wind	6,200
Conventional*	21,168
EOPs	2,775

* Includes the Conventional Generation Removed to Calibrate the System to 0.1 LOLE

The ELCC of each resource type was then calculated. The battery or solar under study was added to the system, and load was added until the system returned to 0.1 LOLE. The calculation of the ELCC for each study resource was performed as:

[16] The derivation of the values used for community solar, utility scale solar, BTM batteries, PSH, land based wind, and offshore wind can be found in Appendix A1.

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

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

1. Add a 30 MW solar resource to a system calibrated to 0.1 LOLE
   a. LOLE decreases to 0.08, indicating an improvement in reliability
2. Add 10 MW of load every year
   a. 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

After calibrating the system to 0.1, ELCCs were calculated for multiple storage penetrations defined in Table A5.

Table A5. Battery Penetrations Studied

BTM Batteries (MW)	Utility Scale Batteries (MW)	Total Batteries (MW)
493	507	1,000
493	1,507	2,000
493	2,507	3,000
493	5,507	6,000
493	8,507	9,000

Solar ELCCs were calculated at the penetrations defined in Table A6 for the 2030 Goal scenario.

Table A6. Solar Penetrations Studied for the 2030 Goal Scenario

Utility Solar Nameplate Capacity (MW)
1,000
5,000
8,583
9,583

Exhibit A.2: Curriculum Vitae of Kevin Carden

Kevin Carden | Director, Astrapé Consulting, LLC

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Hoover, AL 35224
(205) 988-4404
kcarden@astrape.com

With a background in production cost simulations for risk analysis and reliability planning for power supply options, coupled with more than twenty years of diverse utility management experience, Mr. Carden possesses the technical background needed to successfully execute a wide range of resource adequacy studies. Under Kevin's leadership, Astrapé Consulting has provided consulting services to ISOs, RTOs, utilities, regulators, and developers worldwide. For the Southern Company, he led the redevelopment of SERVM, an industry leading Resource Planning tool which is currently owned and licensed by Astrapé. Additional responsibilities have included project financial analysis, RFP independent evaluation, target reserve margin studies, renewable capacity valuation, demand side management program development and contract management for many large capital projects. Kevin holds a B.S. in Industrial Engineering from the University of Alabama.

Experience

Modeling and design for assessment of power supply options
Intensive power modeling experience in multiple applications, including software design
Developed proprietary generation reliability and dispatch model for electric utilities
Demand forecasting, demand-side option management, and optimal reserve margin targets
Evaluation, procurement, and administration of long-term power purchase contracts
Demand-side options pricing and evaluation
Bid preparation for power purchase RFPs
Managing Director, Astrapé Consulting, LLC
Generation Reliability Manager, Southern Company Services
Holds U.S. patent in Generation Reliability Modeling techniques (#7698233)

Major Clients

Southern California Edison	Portland General Electric Company	Southern Company Services
Duke Energy	SMUD	AESO
LCRA	Tennessee Valley Authority	Tenaga Nasional Berhad
Santee Cooper	ERCOT	CPUC
MISO	Terna	SPP
Pacific Gas & Electric	Public Service Company of New Mexico	

Education

B.S. Industrial Engineering, The University of Alabama

Relevant Experience

Redevelopment of SERVM

Company Name: Southern Company Services - Resource Planning.
Mr. Carden has been responsible for the redevelopment, management, and use of a proprietary dispatch model used by the Southern Company for over two decades. This model is used primarily for reliability risk analysis and provides key insights into the value and need of capacity in both the short-term and long term. Kevin identified the need for the development of market modeling algorithms, new hydro logic, updated transmission modeling, economic dispatch criteria, reliability dispatch rules, and other key factors which contribute to reliability risks. Kevin wrote the majority of the logic for these additions based on his extended experience in resource planning. Using the model to run studies for the Southern Company, Kevin has recommended risk mitigation strategies that balance the cost of new capacity with the reliability benefits of those resources.

Resource Adequacy Assessments

Southern Company Services: Maintain SERVM for Southern Company and assist in all resource adequacy studies. All reserve margin studies have been filed with regulators. Performed Production Costs and LOLE Based Reserve Margin Study in 2007, 2010, 2013; Performed Interruptible Contract evaluation; Performed Various Other Resource Adequacy Assessments and Product Cost Studies.

Tennessee Valley Authority: Performed Various Reliability Planning Studies including Optimal Reserve Margin Analysis, Capacity Benefit Margin Analysis, and Demand Side Resource Evaluations using the Strategic Energy and Risk Valuation Model (SERVM) which is Astrapé Consulting's proprietary reliability planning software. Recommended a new planning target reserve margin for the TVA system and assisted in structuring new demand side option programs in 2010. Performed Production Costs and Resource Adequacy Studies in 2009, 2011, 2013, and 2015.

PPL - Louisville Gas & Electric and Kentucky Utilities: Performed Reliability Studies including Reserve Margin Analysis for its Integrated Resource Planning Process. This study included the probabilistic simulations regarding load uncertainty, generator performance, and weather uncertainty. Planning Reserve Margin to Company based on lowest cost and risk to customers. Reserve margin study was filed with Kentucky State Commission.

CLECO: Performed resource adequacy studies for CLECO to determine optimal reserve margin and assist in other resource adequacy decisions. Performed Production Costs and LOLE Based Reserve Margin Studies. Performed 2016 Reserve Margin Study.

Pacific Gas and Electric (PG&E): Performing flexibility Requirement Study 2015 – 2017. CES Study for Renewable Integration and Flexibility 2015 – 2016.

California Energy Systems for the 21st Century Project: Performed 2016 Flexibility Metrics and Standards Project. Developed new flexibility metrics such as EUE flex and LOLE flex which represent LOLE occurring due to system flexibility constraints and not capacity constraints.

Testimony

Application of Cleco Power LLC Regarding the Costs and Benefits of Continued Participation in the Midcontinent Independent System Operator, Inc. Regional Transmission Organization, Docket No. U-34501, Direct Testimony on behalf of Cleco Power, LLC, June 19, 2017.
https://lpscpubvalence.lpsc.louisiana.gov/portal/PSC/ViewFile?fileId=uVo6s1fRmdk%3d

In re: Petition for a Certificate of Convenience and Necessity by Alabama Power Company, Docket No. 32953, Rebuttal Testimony on behalf of Alabama Power Company, January 27, 2020.
https://www.pscpublicaccess.alabama.gov/pscpublicaccess/ViewFile.aspx?Id=1c997c6b-7e1d-40c0-b490-c488e26d9250

In re: Application of Public Service Company of Colorado for Approval of its 2021 Electric Resource Plan and Clean Energy Plan, Proceeding No. 21A-0141E, Hearing Exhibit 115, Direct Testimony on behalf of Public Service Company of Colorado, March 31, 2021.
https://www.dora.state.co.us/pls/efi/EFI_Search_UI.search

In re: Application of Public Service Company of Colorado for Approval of its 2021 Electric Resource Plan and Clean Energy Plan, Proceeding No. 21A-0141E, Hearing Exhibit 131, Rebuttal Testimony on behalf of Public Service Company of Colorado, November 12, 2021.
https://www.dora.state.co.us/pls/efi/EFI_Search_UI.search

Published Articles

National Association of Regulatory Utility Commissioners 2015, *A Study on Probabilistic Risk Assessment for Transmission and Other Resource Planning*, accessed 16, March 2021,
https://pubs.naruc.org/pub.cfm?id=536DCE1C-2354-D714-5175-E568355752DD

Exhibit A.3: Curriculum Vitae of Alex Dombrowsky

Alex Krasny Dombrowsky | Consultant, Astrapé Consulting, LLC

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Mrs. Alex Krasny Dombrowksy is a consultant at Astrapé Consulting. As a consultant, Alex has performed and assisted with various reserve margin studies, renewable integration studies, and ELCC studies for clients across the U.S. and internationally. She is an active participant in industry groups concerned with reliability and resource adequacy, including the NERC Probabilistic Working Group and the IEEE Loss of Load Expectation Working Group. Alex holds a B.S. in Chemical Engineering from the University of Alabama.

Experience

Consultant at Astrapé Consulting (2016 to Present)
Manage and Assist Resource Adequacy Studies
Manage and Assist Renewable Integration Studies
Manage and Assist ELCC and Capacity Value Studies
Develop and Manage Eastern Interconnection Database
SERVM Model Quality Assurance
Develop Study and Project Proposals
Marketing and Sales of the SERVM Model
Redesign and Maintain the SERVM Manual and Supporting Documents

Major Clients

ERCOT	Duke	TVA
AESO	PGE	Malaysia
Southern Company	CPUC	

Industry Specialization

Resource Adequacy Planning	Capacity Value Analysis	Renewable Shape Development
Renewable Integration		

Education

B.S. Chemical Engineering, The University of Alabama **- Cum Laude**

Relevant Experience

California Energy Systems for the 21st Century Project: Assisted Flexibility Metrics and Standards Project (2016).

Malaysia (TNB, Sabah, Sarawak): Assisted in Resource Adequacy Studies for 3 different Malaysian entities (2016 – 2018).

Southern Company: Developed load, solar, wind, and hydro shapes for Southern's neighbor utilities (2016 – 2021).

AESO: Performed Resource Adequacy Study (2018).

ERCOT: Assisted in Economic Optimal Reserve Margin Studies in cooperation with the Brattle Group in 2018. The report examined the total system costs, generator energy margins, reliability metrics, and economics under various market structures. Performed a Probabilistic Risk Assessment for the North American Electric Reliability Corporation (NERC) (2018).

Duke: Assisted in Capacity Value and Ancillary Service Studies (2018).

TVA: Supported Renewable Integration Study (2018).

NYBEST: Assisted Energy Limited Capacity Value Study in NYISO (2019).

US ESA and NRDC: Assisted Capacity Value of Energy Storage in PJM (2019).

TVA: Performed Reserve Margin Study (2019).

AECI: Supported Reserve Margin Study (2020).

PSCO: Assisted in Planning Reserve Margin Study (2020).

CA Joint IOU: Performed 2020 and 2021 Joint IOU ELCC Study (2020 and 2021).

ERCOT: Performed Economic Optimal Reserve Margin Study Update. Performed Probabilistic Risk Assessment for NERC (2020).

California Public Utilities Commission (CPUC): Performed Incremental ELCC Study for Mid-Term Reliability Procurement (2021).

Industry Involvement

Member of the NERC Probabilistic Working Group
Member of the IEEE Loss of Load Expectation Working Group

Exhibit A.4: Curriculum Vitae of Trevor Bellon

Trevor Bellon | Consultant, Astrapé Consulting, LLC

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(936) 828-6790
tbellon@astrape.com

Trevor Bellon is a consultant at Astrapé Consulting. He has experience in utility planning activities including Integrated Resource Plan (IRP) development, resource adequacy assessments, and reliability modeling. Prior to joining Astrapé Consulting, Trevor developed on-the-ground industrial experience as the Consulting Department Manager at VaCom Technologies. At VaCom, Trevor successfully managed the development and implementation of several industrial refrigeration energy efficiency projects at large food and beverage manufacturing plants in California, including detailed system design, project economic analyses, and field installation management. Additional experience includes utility planning activities as a supply planning analyst at Entergy Services.

Education

B.S. Nuclear Engineering, Texas A&M University – Summa Cum Laude

Experience

Consultant at Astrapé Consulting (2021-Present)
SERVM reliability modeling
Renewable and battery effective load carrying capability (ELCC) assessments
Capacity market assessments

Consulting Department Manager at VaCom Technologies (2016-2021)
Developed energy simulation models for energy efficiency assessments of industrial systems
Performed over 30 commercial and industrial onsite energy audits
Managed field installation of industrial equipment at food manufacturing plants
Performed load and capacity balance calculations for industrial refrigeration system design
Lead technical writer for California Energy Commission grant applications ($14M awarded)

Supply Planning Analyst at Entergy Services (2015-2016)
Project management of integrated resource plan activities
Resource adequacy assessments as related to ISO market requirements
New generation site selection analyses
SERVM reliability modeling

Industry Specialization

Utility Resource Planning	Energy Efficiency Modeling	Project Financial Analysis
Reliability Planning	Mechanical System Design	Technical Writing
Field Project Management		

Relevant Experience

For **Entergy New Orleans:** Project manager of the 2015 Integrated Resource Plan for the City of New Orleans, coordinating financial analysis, resource mix scenario analysis, and report development for required regulatory filings.

For **DTE Electric Company:** Co-author of 2021 ELCC study, calculating the marginal and average ELCC values for wind, solar, and battery storage resources located in MISO LRZ7.

For **Evergy:** Lead reliability model developer, performing planning reserve margin calculations and ELCC values for variable energy resources for the study years 2025 and 2030 in SERVM for Evergy utility service territory.