Puget Sound Energy ELCC Workshop

Energy & Environmental Economics ELCC Review

August 31, 2021

Energy+Environmental Economics

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Contents

Scope of E3 Review

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- **E3 has extensive experience with ELCC estimation across various jurisdictions for different stakeholders, as well as resource adequacy analysis more broadly**
  - In addition to direct ELCC modeling, E3 regularly delivers presentations on ELCC topics including background, application, and ELCC methodology
- **In the context of Puget Sound Energy's 2021 All-Source Request for Proposals (RFP), E3 has reviewed Puget Sound Energy's (PSE's) ELCC methodology and the results of PSE's calculations**
- **In its review, E3 aims to answer the following questions:**
  1. Does PSE use industry-standard methodology for calculating ELCC?
  2. Does PSE use reasonable input data in its ELCC modeling?
  3. Does PSE appropriately capture regional dynamics in its calculation of ELCC?
  4. Does PSE's ELCC calculation methodology appropriately capture the interactivity between intermittent and energy-limited resources?
- **The ultimate goal of E3's review is to evaluate PSE's ELCC methodology, and specifically the reasonableness of PSE's calculations of ELCC for battery storage on its system in the context of its current RFP**

Data Reviewed by E3

- **To conduct its review of PSE's ELCC methodology, E3 analyzed PSE data used for its IRP forecasts and which are reflected in its RFP process, including but not limited to:**
  - Model input data:
    - 8760 profiles for load, solar, wind, and battery storage
    - Nameplate capacity of different resources
    - Hydro availability data
    - Mid-C capacity estimates
    - Generic battery storage operating characteristics
  - Model output data:
    - Hourly energy production estimates
    - Reliability metric results (e.g. LOLP, EUE, LOLE)
    - Outage duration and frequency results for January and February (the months with the most reliability events)
    - ELCC calculation results
  - Model input and output data was reviewed for the years 2027 and 2031 in the PSE forecast, each representing 7,040 combinations of 80 hydro years and 88 temperature years
- **In addition to this data, E3 and PSE held multiple calls to answer E3's questions, including detailed explanations of data and ELCC calculation methodology**
  - This included initial sessions to review methodology and a series of follow-up calls in response to E3's initial findings
  - PSE staff were available to provide additional data and respond to questions consistently throughout this review process, including additional data requests

E3 Review of PSE ELCC Methodology

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Key Issues Reviewed by E3

- **Each Key Issue E3 has reviewed is assigned 1 of 3 categories:**
  - **Green** ● no significant impact on ELCC results based on current review, unlikely to impact RFP process
  - **Yellow** ● some impact on ELCC results, area for future improvement but unlikely to materially impact RFP process
  - **Red** ● significant impact on ELCC results, likely requiring revision before applied to RFP process
- **In addition to the key issues covered in the slides that follow, E3's report will include a review of additional issues summarized later in this presentation**

Key Issue	Potential Impact on ELCC Results	Result of E3 Review
Is PSE's General LOLP Approach Reasonable for ELCC Purposes?	High	● (Green)
Does PSE's Treatment of Mid-C Market Availability Disadvantage Battery Storage ELCCs?	High	● (Red)
Are PSE's Generic Battery Storage Characteristics Reasonable?	High	● (Red)
Are the Resource Correlations Used by PSE Reasonable?	Medium	● (Yellow)
Is PSE's Temperature Input Data a Reasonable Basis for Forecasts?	Medium	● (Yellow)
Are Hydro Operations Captured Correctly?	Medium	● (Yellow)
Are Battery Storage Resources Dispatching Appropriately?	High	?

General LOLP Approach

Description of Topic

+ **E3 investigated whether PSE's application of the LOLP standard in its resource adequacy modeling is appropriate, and whether its approach for estimating battery storage ELCCs as an extension of this approach is reasonable**

PSE Methodology

+ **In general, PSE tunes its system to meet an LOLP standard**
  - PSE applies a 5% LOLP reliability target and uses LOLP to calculate ELCC
  - For storage, the additional step is then taken of adding storage capacity to a system that already meets the 5% LOLP standard and then removing perfect capacity until expected unserved energy (EUE) returns to its previous level
+ **In the starting calibrated portfolios that PSE used to calculate generic resource ELCCs that achieved a 5% LOLP, the corresponding LOLE was close to a 1-in-10 standard (~0.10 - 0.12 days/year LOLE)**

Industry Practice

+ **The LOLP approach is also commonly used across the Pacific Northwest region, and other utilities and stakeholders in the region apply a 5% LOLP standard**
  - Avista's 2021 IRP notes that its Aurora capacity expansion "model must also meet a 5 percent LOLP threshold for reliability when selecting new resources"(1)
  - The Northwest Power and Conservation Council (NPCC) stated in its most recent power plan (2016) that "A specific year's power supply extracted from an RPM analysis is deemed to be acceptably adequate if its LOLP ranges between 2 and 5 percent"(2)
+ **Outside the NW, the standard is 0.1 days of LOLE per year**

E3 Conclusion

+ **PSE's approach produces a portfolio that meets both the 5% LOLP standard and produces LOLE results that are close to the 0.1 industry standard, making the difference in methodology immaterial**
+ **Furthermore, given the LOLP approach and a 5% LOLP standard is used by other utilities in the region, PSE's approach is reasonable**

(1) Avista 2021 IRP, page 2-19. https://www.myavista.com/-/media/myavista/content-documents/about-us/our-company/irp-documents/2021-electric-irp-w-cover-updated.pdf
(2) NWPCC 2016, pg 11-4. https://www.nwcouncil.org/sites/default/files/7thplanfinal_allchapters_1.pdf

Treatment of Mid-C Market Availability

Description of Topic

- **E3 investigated how PSE's treatment of the Mid-Columbia (Mid-C) trading hub impacts its ELCC calculations in general, and whether it disadvantages battery storage ELCCs in particular**

PSE Methodology

- **PSE includes "short-term wholesale (spot) market purchases up to PSE's available firm transmission import capability from the Mid-C" as an existing resource in reliability planning, given its importance to PSE's system(1)**
  - PSE does not assume that reliability-driven capacity additions are made to the broader Pacific Northwest region to achieve a reliability standard. Instead, PSE assumes that the regional system's reliability degrades below accepted resource adequacy thresholds, in response to which PSE adds capacity to its own system
- **Fluctuations in energy from Mid-C are the largest contributor to outages in PSE's modeling and are the most frequent primary contributor (in MW) to the longer duration outages (5+ hours). These longer outages reduce ELCCs for battery storage resources**
- **Storage ELCCs calculated by PSE increase from 2027 and 2031 as additional capacity is added to the PSE system following declines in reliable capacity contributions from Mid-C**

Industry Practice

- **Typically, ELCC calculations assume that a utility tunes its own system to a reliability standard before running ELCCs, but does not necessarily assume that the external market is tuned to a reliability standard as well**
  - The unique nature of the NW hydro surplus makes this an important issue
- **Treatment of external markets varies across the industry**
  - Some utilities exclude the external market entirely in their resource adequacy planning, while others make simplified assumptions or create more nuanced forecasts
  - While other utilities in the industry omit interannual variability of market purchases for ELCC calculations, this may not be appropriate in a hydropower-dependent region

E3 Conclusion

- **PSE's current treatment of Mid-C disadvantages battery storage ELCCs**
  - There is no industry standard for how to address the issue of external market equilibrium
  - Whether it is appropriate to assume an adequate regional system is a real and difficult question
- **To assess the impact of changes in PSE's approach to Mid-C on ELCC values, E3 recommends an additional GENESYS model run assuming regional capacity additions such that the region meets a 5% LOLP standard before recalculating ELCC**
  - Adding capacity to the region would increase the reliability of the Mid-C resource but would also reduce the need for reliability-driven capacity additions to PSE's system

(1) (PSE 2021 IRP, pg 7 -11).

Generic Battery Storage Characteristics

Description of Topic

- **E3 investigated whether the generic operating characteristics and capacity contributions of battery storage resources reflected in PSE's ELCC calculations are reasonable**

PSE Methodology

- **PSE assumes round trip efficiency (RTE) of 82% - 87% for generic Li-ion battery storage resources**
- **PSE's application of the minimum state of charge (SOC) and one-way efficiency reduces the maximum and overall ELCC results for battery storage resources**
  - Minimum state of charge (SOC) for battery storage is 20% in PSE's modeling. This does not align with the minimum storage limits presented in PSE's HDR report. (1)
  - PSE assumes in its ELCC calculations that the maximum discharge for battery storage resources is calculated as (Nameplate Capacity) x (1 – One Way Efficiency)
    - This reduces the maximum capacity contribution of storage resources

(1) Source: PSE HDR Report. https://oohpseirp.blob.core.windows.net/media/Default/PDFs/HDR_Report_10111615-0ZR-P0001_PSE%20IRP_Rev4%20-%2020190123).pdf

Industry Practice

- **Typical practice is to apply a standardized MW value for battery storage throughout the ELCC calculation. This can be accomplished by applying nameplate capacity throughout the calculation (i.e. do not apply nameplate capacity adjusted for SOC and one-way efficiency in the denominator while full nameplate is applied in the numerator)**
  - This is often done under the assumption that RFP bidders will design their projects and bids whereby a 100 MWac battery resource can provide its full range of output (i.e. fully discharge its energy at 100 MW)

E3 Conclusion

- **PSE's round-trip efficiency assumptions are reasonable**
- **PSE's application of minimum SOC and one-way efficiency both impact battery storage's maximum and overall potential ELCC results as applied in the RFP context**
- **E3 recommends that:**
  - PSE restates its ELCC values for battery storage in a manner more aligned with industry standards
  - PSE aligns the presentation of ELCC values with the characterization of minimum, maximum, and nameplate MW values in its RFP documentation
- **If these recommendations are reflected, additional ELCC analysis is not required**

Resource Correlations

Description of Topic

+ **E3 investigated whether PSE applies appropriate correlations to different resources, between resources and load, and between weather and load in its modeling**

PSE Methodology

+ **Correlations applied:**
  - PSE preserves the correlation between solar and wind generation, and between weather and load
  - Expected PSE hydro output and short-term market purchases are correlated
+ **Correlations not applied:**
  - There is no direct correlation between weather and renewable (solar, wind) output, nor between load and renewable output
  - While hydropower and load are not correlated, load is permutated with hydropower output across PSE's 7,040 draws

Industry Practice

+ **Correlations between weather and wind/solar output, or between load and wind/solar output, are traditionally used in resource adequacy system modeling, which helps capture conditions which may drive loss-of-load events**
  - In the Pacific Northwest, this would primarily result from intense cold weather driving increased demand and decreased renewable output
+ **Permutation of hydro and load is aligned with how other reliability forecasting models approach the same inputs (e.g. SERVM, E3's RECAP model)**

E3 Conclusion

+ **Correlations between wind/solar and between weather/load are reasonable, while permutation of hydro output and weather is reasonable and in line with common industry practice**
+ **Lack of correlated renewable and load shapes does not have a large impact on battery ELCCs**
+ ***<u>For future IRP cycles</u>*, E3 recommends utilizing weather-matched load that is aligned with wind and solar data for future analyses**
  - This will impact the ELCC results for wind and solar resources but impacts on battery storage will depend on resource-specific correlations

Temperature Data

Description of Topic

+ **E3 investigated whether the temperature data used by PSE as an input in its resource adequacy modeling is impacting its ELCC results in general, and battery storage ELCC results in particular**

PSE Methodology

+ **PSE synthesizes hourly temperature data from University of Washington daily high/low records for 1929-1947, after which more granular temperature data is available from Sea-Tac airport**
+ **Outage events in PSE's modeling are not evenly distributed across temperature input years:**
  - 33% and 35% of simulated draws with loss of load events in January 2027 and January 2031, respectively, occur with load data prior to 1948. This period represents only 21% of all weather years
  - ~94% of simulated draws with loss of load events in January 2027 and January 2031 occur with load data prior to 1972, the midpoint of the temperature year data

Industry Practice

+ **There is no prevailing industry standard for how utilities should account for climate warming trends in their temperature input data**
  - Furthermore, there is precedent in the PNW region for using 88 historical years of temperature data in GENESYS modeling
+ **Moving forward, PSE's winter peaks may be reduced relative to summer peaks based on more recent climate warming trends. This has the potential to impact PSE's resource planning**

E3 Conclusion

+ **PSE's synthesis of temperature data from the University of Washington appears reasonable based on data E3 has reviewed**
+ ***For future IRP cycles*, E3 recommends that PSE analyze the impact of the Temperature Sensitivity shown in its IRP on the current RFP and investigate potential modifications of the temperature data set to reflect a changing climate**

Hydro Operations

Description of Topic

+ **E3 investigated whether PSE's approach to modeling hydropower operations is impacting its ELCC results in general, and battery storage ELCC results in particular**

PSE Methodology

+ **In general, PSE models hydropower output as a shape, rather than a dispatchable (flexible) resource**
  - PSE shapes its Baker River hydropower output and contracted hydropower to PSE load
  - PSE assumes maximum available capacity in any hour of its hydropower output shape is the equivalent of the maximum of the day with the hydro year draw (80 total draws)

Industry Practice

+ **Hydro with dispatch capabilities (i.e. not run-of-river) is modeled as a dispatchable resource**
  - All else being equal, this reduces the ELCC estimates for battery storage by altering the operational capabilities of competing resources and lowering the need for reliability-driven capacity additions to begin the ELCC analysis
+ **Typically, hydro operations modeling accounts for limitations of energy availability to operate at maximum capacity through the entire day**

E3 Conclusion

+ **PSE's modeling of hydro resources as a shaped output without realistic energy availability limits leads to over-estimation of battery storage ELCCs, with potentially significant results**
+ ***For future IRP cycles*, E3 recommends that PSE update its modeling to incorporate hydro dispatch capabilities and hydro energy limitations**

Battery Storage Dispatch

Description of Topic

+ **E3 investigated whether the dispatch of the generic battery storage resources tested for ELCC calculations is reasonable**

PSE Methodology

+ **In PSE's Base Case, the 4-hour Li-ion battery discharges in only 146 of a total 7,040 simulation draws in 2027**
  - In January 2027 in the Base Case, there are 197 simulated draws with loss of load events
  - This shows that generic battery storage resources do not discharge in all hours with unserved energy
+ **E3 is continuing to investigate this issue in follow-up data requests and conversations with PSE**

Industry Practice

+ **Standard practice is for battery discharge to occur whenever possible during a loss of load event in utility resource adequacy modeling**

E3 Conclusion

?

+ **If there are issues with the reported dispatch of generic battery storage resources in PSE's modeling, this will have a material impact on battery storage ELCC results**
+ **However, specific conclusions require further investigation between the time of this draft submission and the ELCC workshop**

Summary

Key Issue	Potential Impact on ELCC	Result of E3 Review	E3 Conclusions and Recommendations
General LOLP Approach	High		+ PSE's approach produces a portfolio that meets both the 5% LOLP standard and produces LOLE results that are close to the 0.1 industry standard, making the difference in methodology immaterial + Given the LOLP approach and a 5% LOLP standard is used by other utilities in the region, PSE's approach is reasonable
PSE's Treatment of Mid-C Market Availability	High		+ PSE's current treatment of Mid-C disadvantages battery storage ELCCs, but whether it is appropriate to assume an adequate regional system is a real and difficult question + To assess the impact of changes in PSE's approach to Mid-C on ELCC values, E3 recommends an additional GENESYS model run assuming regional capacity additions such that the region meets a 5% LOLP standard before recalculating ELCC
PSE's Generic Battery Storage Characteristics	High		+ PSE's round-trip efficiency assumptions are reasonable + PSE's application of minimum SOC and one-way efficiency both discount battery storage's maximum and overall potential ELCC results as applied in the RFP context + E3 recommends that PSE restates its ELCC values for battery storage in a manner more aligned with industry standards, and that PSE aligns the presentation of ELCC values with the characterization of nameplate capacity (MW) values in RFP documentation
Resource Correlations Used by PSE	Medium		+ Correlations between wind/solar and between weather/load are reasonable, while permutation of hydro output and weather is reasonable and in line with common industry practice + Lack of correlated renewable and load shapes does not have a large impact on battery ELCCs + For future IRP cycles, E3 recommends utilizing weather-matched load aligned with wind and solar data
PSE's Temperature Input Data	Medium		+ PSE's synthesis of temperature data from the University of Washington appears reasonable based on data E3 has reviewed + For future IRP cycles, E3 recommends that PSE analyze the impact of the Temperature Sensitivity shown in its IRP on the current RFP and investigate potential modifications of the temperature data set to reflect a changing climate
Hydro Operations	Medium		+ PSE's modeling of hydro resources as a shaped output rather than a dispatchable resource and as a resource without energy limitations both lead to over-estimation of battery storage ELCCs, but ultimate impact is likely minor + For future IRP cycles, E3 recommends PSE update its modeling to reflect hydro dispatch capabilities and hydro energy limitations
Battery Storage Resource Dispatch	High	?	+ If there are issues with the reported dispatch of generic battery storage resources in PSE's modeling, this will have a material impact on battery storage ELCC results + However, specific conclusions require further investigation at this time

Additional Topics Under Review

E3 Will Address the Additional Questions Below in its Forthcoming Report

General

1. Why are PSE's ELCCs lower than that of other utilities such as PGE and California utilities?
2. Are the operating data for different non-storage technologies reasonable?
3. Are the load shapes used in PSE's analysis reasonable?

Pumped Storage Hydro

1. Is it unreasonable for PSE to limit pumped storage resources' operating range (or "state of charge") to 70% of the resource's storage capacity?

Hybrid Resources

1. Does PSE unreasonably limit hybrid resources by only allowing them to charge from renewables over the entire lifecycle of the resource?

Market Limitation

1. Does the reduction in availability of market purchases in PSE's IRP artificially constrain the ability of storage resources to meet PSE's capacity needs?
2. Does the IRP impose a market import limitation across the full 24-hour window on all days in January and February instead of only during "super-peak" and "heavy-load" hours?
3. How does PSE's analysis reflect transmission constraints?

Battery Storage

1. Are the ELCCs for "Li-ion – 2-hour" and "Li-ion – 4-hour" overly conservative, considering that the resources are stand-alone and charging and discharging schedules will not be constrained by a co-located renewable generation resource?
2. Does PSE's IRP portfolio modeling preference for two-hour battery storage conflict with an industry-standard of four-hour battery?
3. Is the modeling limitation on storage resources' depth of discharge (DoD) overly conservative?
4. What changed between the cases utilized in 2020 and amended in 2021 that resulted in a decrease in the assessed ELCC of energy storage?

Other

1. Are PSE's ELCC estimates inclusive of the possibility of forced outages during a peak event?
2. How did the temperature sensitivity scenario in the 2021 IRP impact PSE's resource plan?

In addition to the topics above, E3 will provide context on Northwest Power Pool efforts where relevant to the discussion of PSE's ELCC calculations .

E3 Conclusions

+ **E3 finds that PSE's general approach to ELCC calculation is reasonable**
  - However, E3's investigation of certain specific issues is ongoing, and E3's forthcoming report will contain more analysis and information on this topic
+ **E3 recommends that PSE do the following before evaluating RFP bids:**
  1. Conduct an additional GENESYS model run assuming regional capacity additions such that the region meets a 5% LOLP standard before recalculating ELCC
  2. Restate ELCC values for battery storage in a manner more aligned with industry standards, and align the presentation of ELCC values with the characterization of minimum, maximum, and nameplate MW values in RFP documentation
+ **E3 recommends that PSE do the following in future IRP cycles:**
  1. Utilize weather-matched load that is aligned with wind and solar data for future analyses
  2. Analyze the impact of the Temperature Sensitivity shown in its IRP on the current RFP to inform future planning, and investigate potential modifications of the temperature data set to reflect a changing climate
  3. Update modeling to incorporate hydro dispatch capabilities and hydro energy limitations
+ **E3 expects that even in the context of the recommendations above, battery storage ELCCs are likely to be relatively low in a hydropower-dependent region like the PNW compared other regions**
  - To confirm this judgment, however, E3 recommends the additional steps above

E3 Report Outline

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E3 Report Outline

1. **Introduction**
   i. Status of PSE's IRP and All-Source RFP
   ii. E3's Review and Scope of Work

2. **Background on ELCC**
   i. Defining ELCC and Applications
   ii. ELCC's Importance for Assessing Resource Adequacy

3. **Industry Approaches to ELCC**
   i. Diversity of Practices Among Utilities in the Industry
   ii. Emerging Best Practices in Capacity Credit Calculation
   iii. Northwest Power and Conservation Council's (NPCC's) RA Committee and Modeling

4. **Reviewing PSE's ELCC Approach**
   i. Summary of PSE Approach
      – Differences With Neighboring Utilities
      – Regional and PSE-Specific Characteristics
   ii. Input Data
   iii. Output Data
   iv. Reliability Metrics
      – Interactive Effects Among Intermittent and Energy-Limited Resources
   v. Technical Findings
      – PSE Treatment of Mid-C
      – Battery Storage Characteristics
      – Resource Correlations
      – Temperature Data
      – Hydro Operations
      – General LOLP Approach

5. **Conclusions and Recommendations**

Thank You

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Appendix:
Daily Dispatch Plots From PSE Base Case

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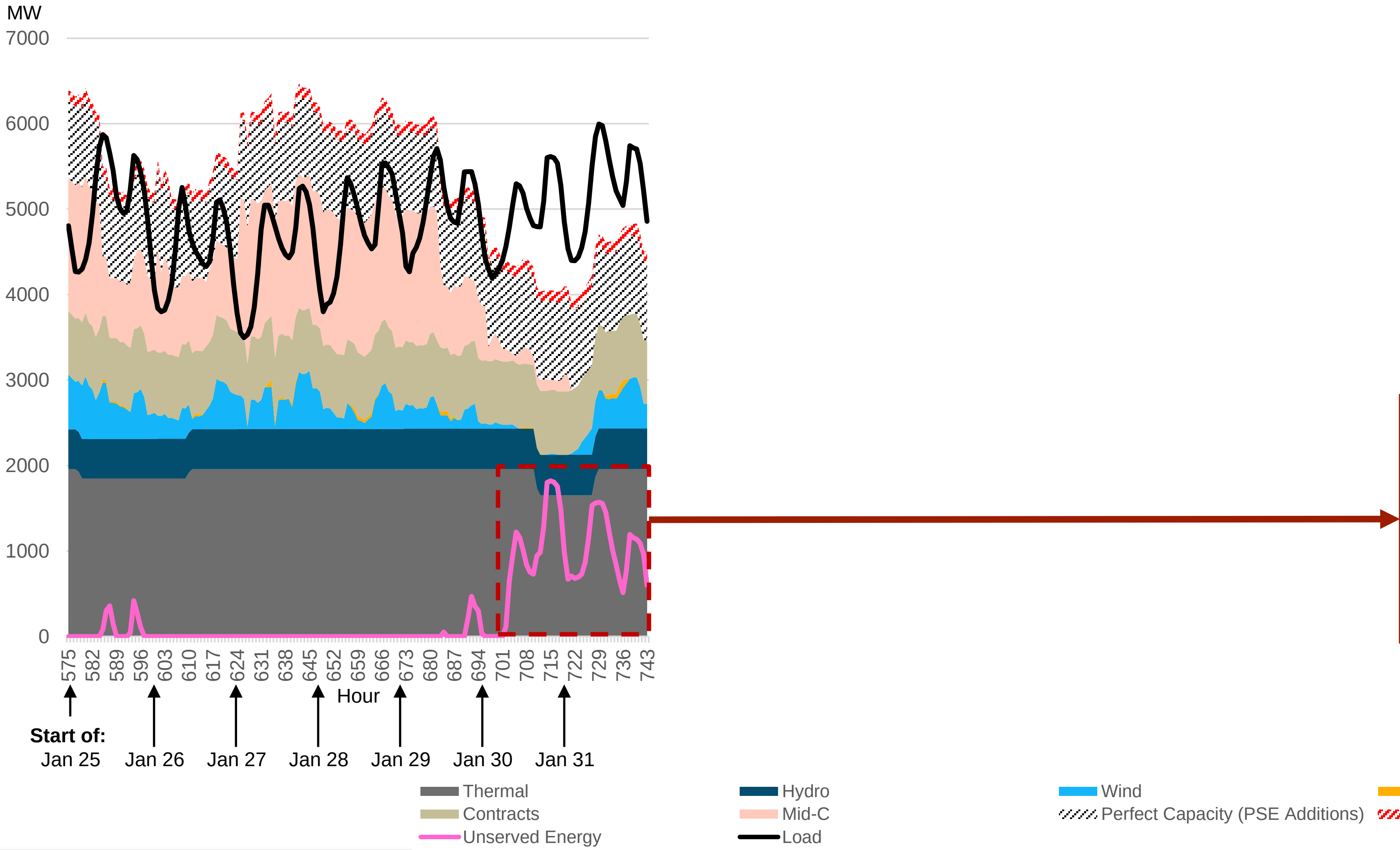
January 2027 Dispatch Plots

- **On the slides that follow, E3 has generated illustrative charts to reflect the potential impact of modifying the energy output from Mid-C and hydro resources in PSE's Base Case, draw 1687**
  - Draw 1687 represents the combination of hydro year 19 out of 80 (calendar year 1947, 0th percentile) and temperature year 15 out of 88 (calendar year 1943)
- **To estimate the impact of modifying Mid-C output, E3 focused on the week of January 25**
  - The week of January 25 is the focus because of a 42-hour outage that occurs during this week in draw 1687
  - E3 modified the PSE Base Case so that 500 MW of additional capacity is available from Mid-C during unserved energy events, reflecting PSE's share of illustrative regional capacity additions. In tandem, E3 reduced the perfect capacity additions assumed on the PSE system by 500 MW
- **To estimate the impact of modifying PSE's hydro modeling, E3 focused on January 14 – 16**
  - This period contains multiple shorter-duration outages that illustrate the impact of flexible hydro dispatch
  - PSE Base Case hydropower resources are modified to operate with energy limitations (50% capacity factor, pmin of 25%) and dispatch capabilities (i.e. output can be increased to pmax when there is unserved energy)
- **Modifying the PSE Base Case so Mid-C output is increased by 500 MW during unserved energy events does not reduce the duration of the 42-hour outage, illustrating the impact of Mid-C on the outage characteristics against which battery storage is tested**
- **Modifying hydro resources so they are energy-limited and dispatchable illustrates the ability of hydro to meet unserved energy needs over shorter-duration periods (e.g. 4-6 hours)**

January 2027 Dispatch Plots: Week of 1/25

PSE Base Case
No Modifications



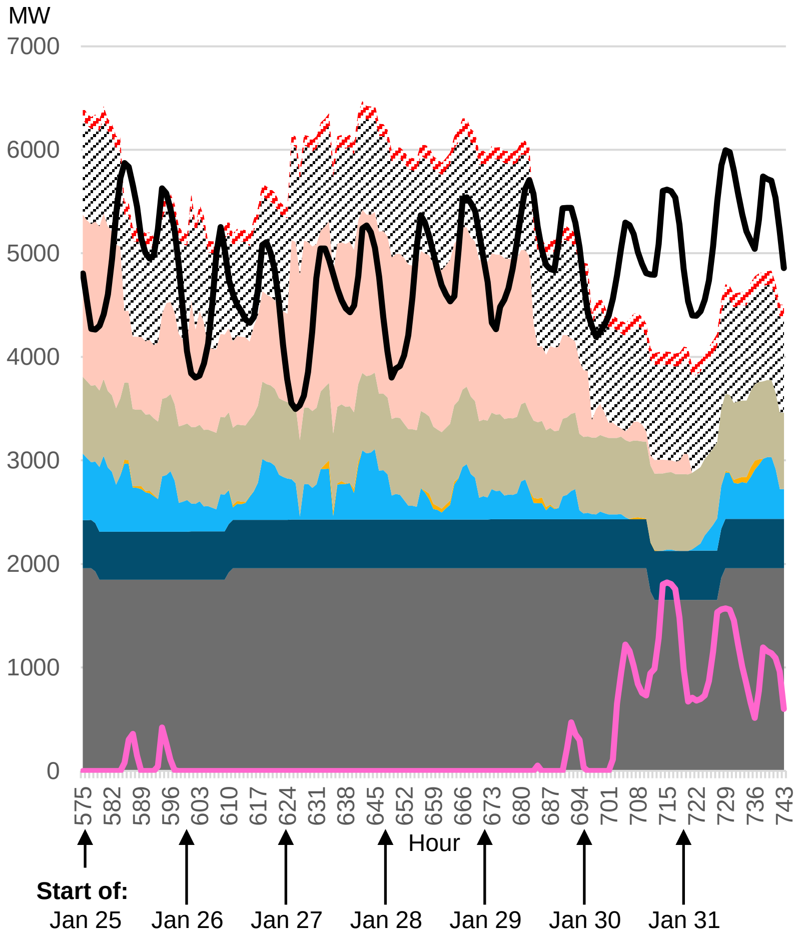
Outage Event: 1/30 – 1/31

- **Outage duration (continuous) = 42 hours**
- **Maximum unserved energy = 1,821 MW**
- **Minimum unserved energy = 110 MW (hour 702)**
- **Mid-C output during outage = 61 MW (avg)**

January 2027 Dispatch Plots: Week of 1/25 (cont'd)

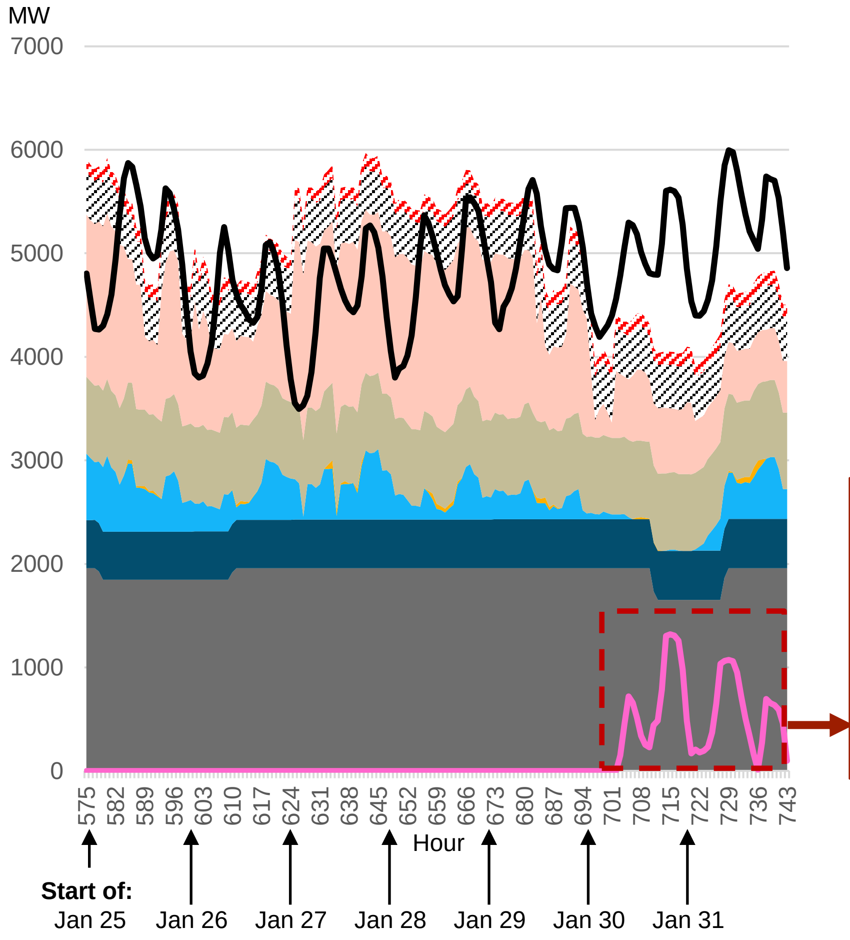
PSE Base Case

No Modifications



PSE Modified Base Case

500 MW Capacity Added to Mid-C During Outage,
500 MW of Perfect Capacity Removed



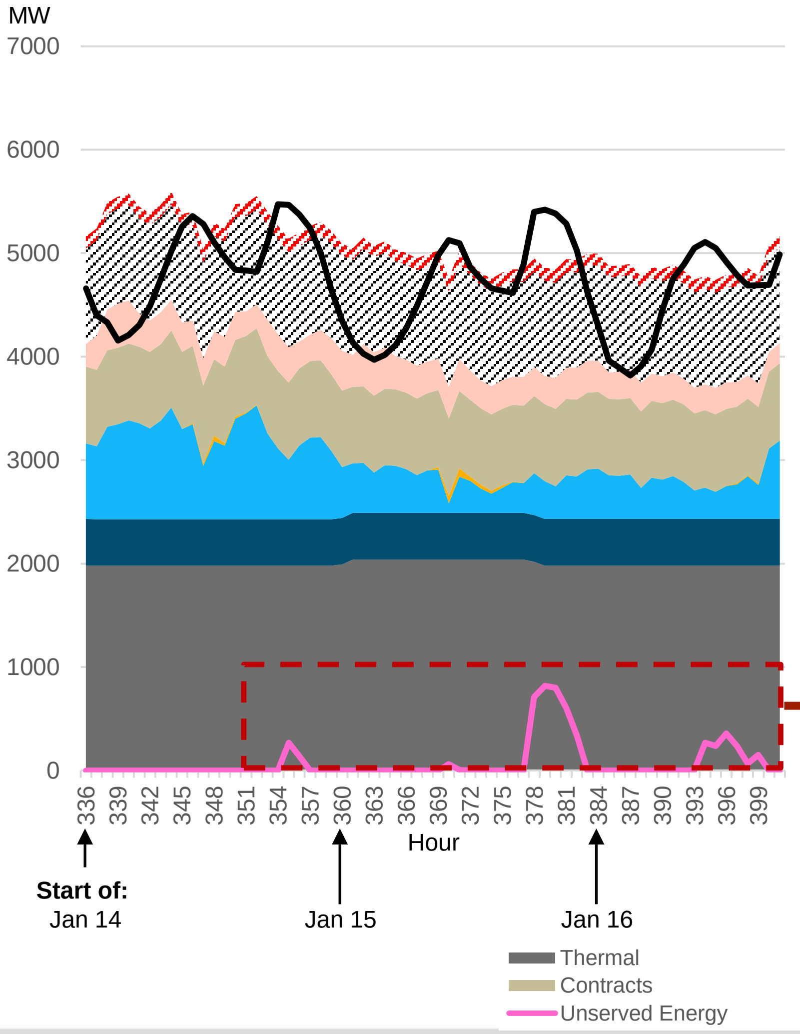
Outage Event: 1/30 – 1/31

- Outage duration (continuous) = 41 hours
- Maximum unserved energy = 1,321 MW
- Minimum unserved energy = 13 MW (hour 736)
- Mid-C output during outage = 561 MW (avg)

January 2027 Dispatch Plots: January 14-16

PSE Base Case

No Modifications

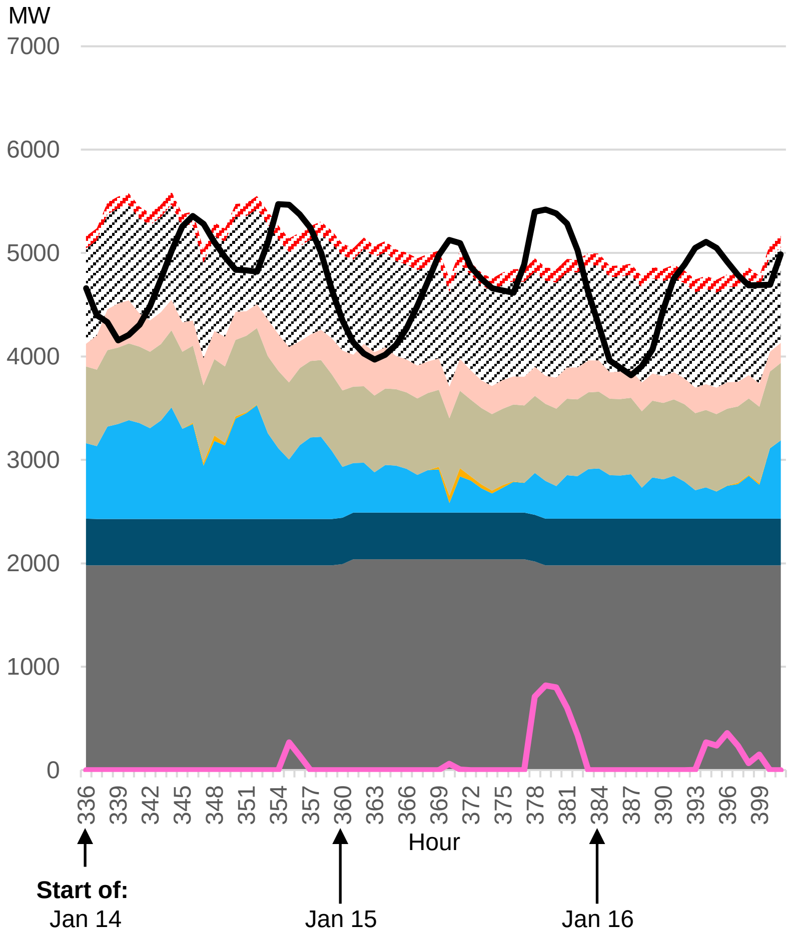


Outage Events: 1/14 – 1/16

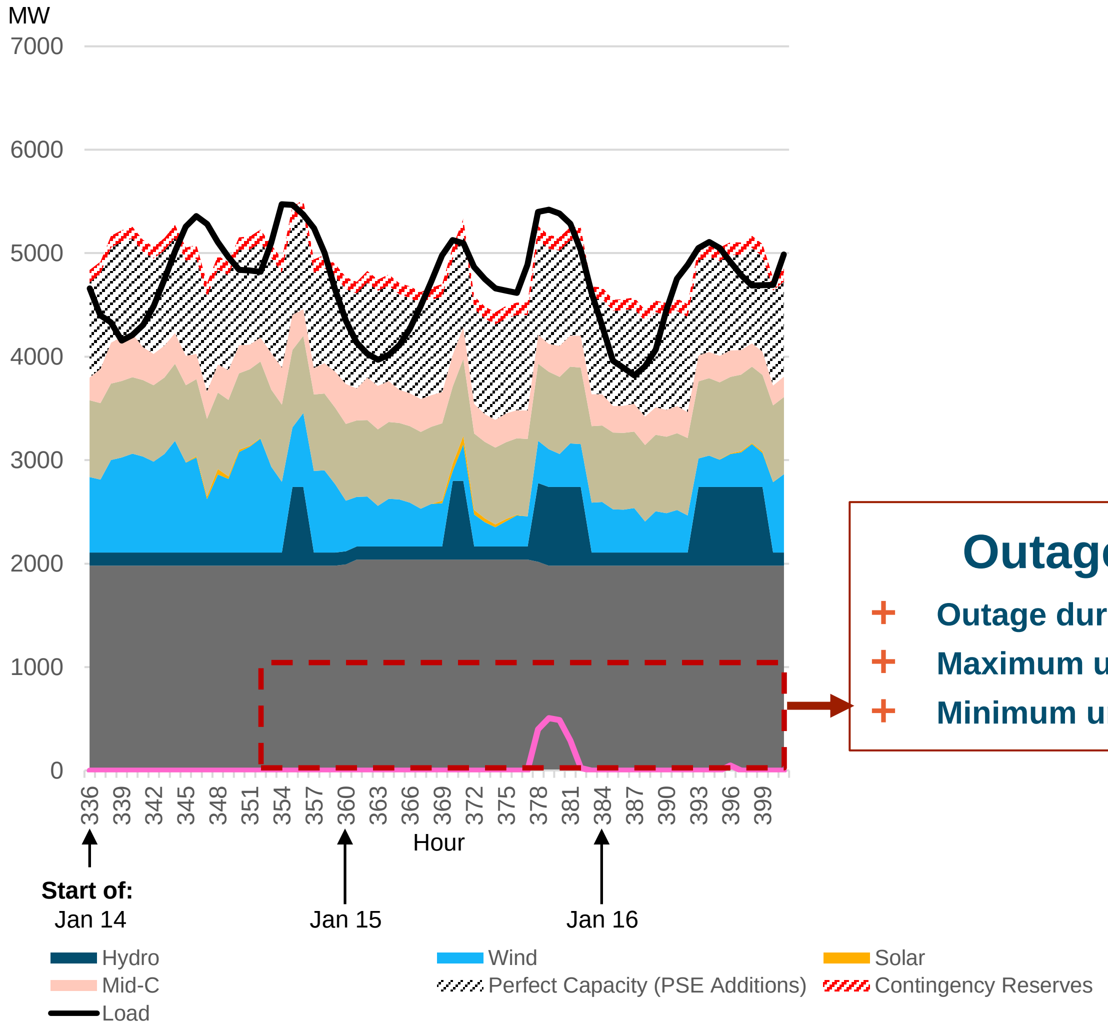
- Outage duration (longest) = 7 hours
- Maximum unserved energy = 818 MW
- Minimum unserved energy = 2 MW (hour 393)

January 2027 Dispatch Plots: January 14-16 (cont'd)

PSE Base Case
No Modifications



PSE Base Case
Dispatchable Hydro



Outage Events: 1/14 – 1/16

- Outage duration (longest) = 5 hours
- Maximum unserved energy = 507 MW
- Minimum unserved energy = 25 MW (hour 382)