2021 RFP Workshop:

Resource Adequacy
ELCC

August 31, 2021

Agenda

- Safety Moment
- 2021 IRP Resource Adequacy Analysis
  - Resource Adequacy Model (RAM)
  - Peak Capacity Credit – Effective Load Carrying Capability (ELCC)
- Climate Change Analysis
- RFP modeling
- Schedule and next steps

Electric resource adequacy

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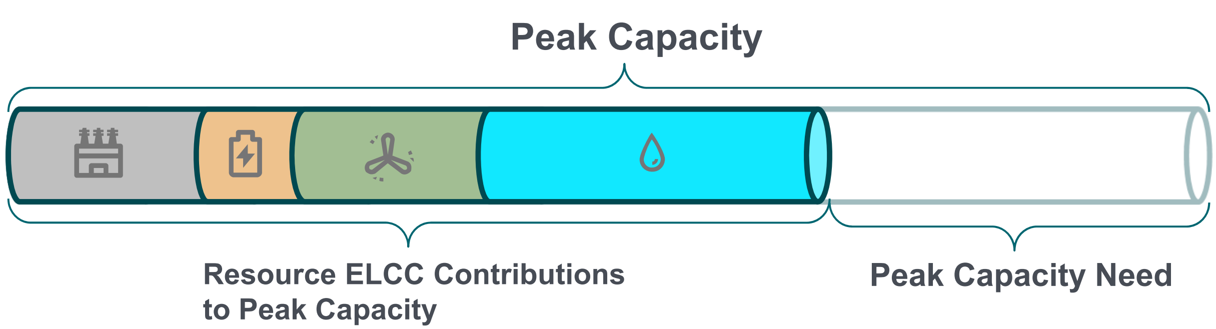
Modeling ELCC and peak capacity

- Maintaining an adequate resource mix is important to the functioning of any utility. In order to capture this importance, PSE uses the ELCC as a metric in the modeling process.
- The **ELCC** of a resource is a way to represent how much **Peak Capacity** is provided by a resource.
  1. The **Peak Capacity** is the energy needed by a utility system at the peak demand of a time interval. The energy is provided with the portfolio of resources at that time, or else a Loss of Load Event (LOLE) can occur.
  2. The **ELCC** is the contribution of a resource within a portfolio to contribute to **Peak Capacity** needs.



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Resource adequacy overview

- A system is "**Resource Adequate**" if it has sufficient capacity to serve load across a broad range of weather conditions, subject to a long-run standard for frequency of reliability events.
  - Resource adequacy analysis determines the amount of peak capacity needed to meet a reliability standard.

- **There is no mandatory standard for Resource Adequacy in the PNW.**
  - Each Balancing Authority establishes its own standard subject to oversight by state commissions or locally-elected boards.
  - North American Electric Reliability Council (NERC) and Western Electric Coordinating Council (WECC) publish information about Resource Adequacy but have no formal governing role.
- PSE is using **Loss of Load Probability (LOLP)**
  - LOLP is also used by the Northwest Power and Conservation Council (NWPCC) and Avista
  - Consistent with WUTC guidance in 2015 IRP

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Key resource adequacy (RA) metrics

Metric	Units	Meaning
Loss of Load Probability (LOLP)	%	In a given year, the probability that for any period of time (Load + Reserve Requirement) > Generation NWPCC uses an LOLP value of 5%.
Loss of Load Hours (LOLH)	$\frac{\text{Hours}}{\text{Year}}$	In a given year, the total number of hours where (Load + Reserve Requirement) > Generation
Loss of Load Expectation (LOLE)	$\frac{\text{Days}}{\text{Year}}$	In a given year, the total number of days where (Load + Reserve Requirement) > Generation
Expected Unserved Energy (EUE)	$\frac{\text{MWh}}{\text{Year}}$	In a given year, the total amount of generation missing when (Load + Reserve Requirement) > Generation
Effective Load Carrying Capacity (ELCC)	%	The percentage of a resource's capacity that can be relied on for system peak hours.

Resource adequacy model years

The 2021 IRP study period begins in 2022, but the RAM model examines periods that are five and ten years into the future.

PSE IRP start year: 2022

5-years from start: 2027 → modeled October 2027 – September 2028

10-years from start: 2031 → modeled October 2031 – September 2032

In order to preserve the continuity of the summer and winter hydro datasets, the RAM study periods are for "hydro" years (Oct-Sept), not calendar year. This practice is consistent with the NWPCC GENESYS Model and allows the full winter and summer seasons to stay intact for the analysis.

Resource Adequacy Model (RAM)

Step 1:

Data Collection for Inputs

- 88 Temperature Years
- 80 Hydro Years (BPA)
- Wind and Solar Draws (NREL)
- Resource Outages and Maintenance (AURORA)
- Regional Curtailments (GENESYS)
- Reserve Requirements (E3)
- Contracts
- New Resources (RFP)

Step 2:

Run the RAM Model

7040 Simulations

- Each simulation is for 8760 hours of the designated study year.
- "Perfect capacity" is added until a 5% LOLP is met.
- 5% LOLP aligns with current NWPCC reliability standards.

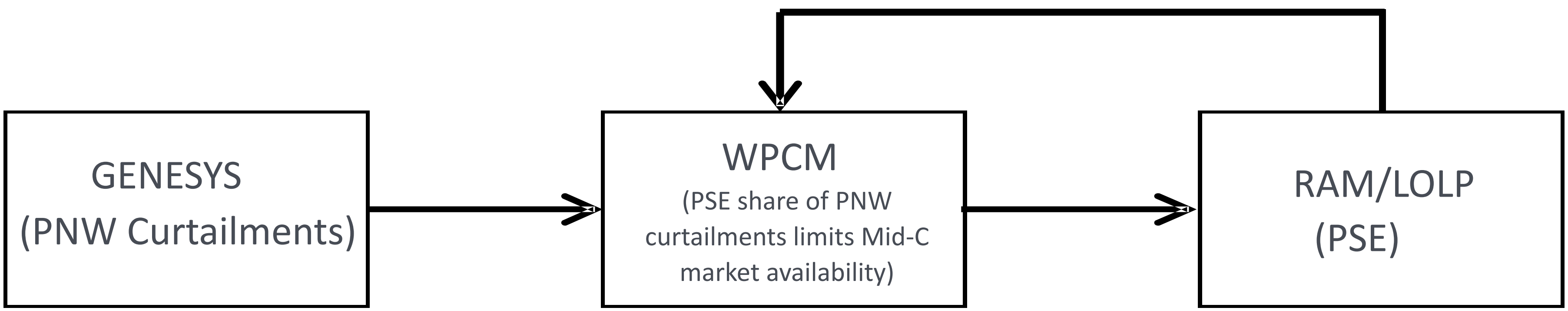
Step 3:

Query Results for Outputs

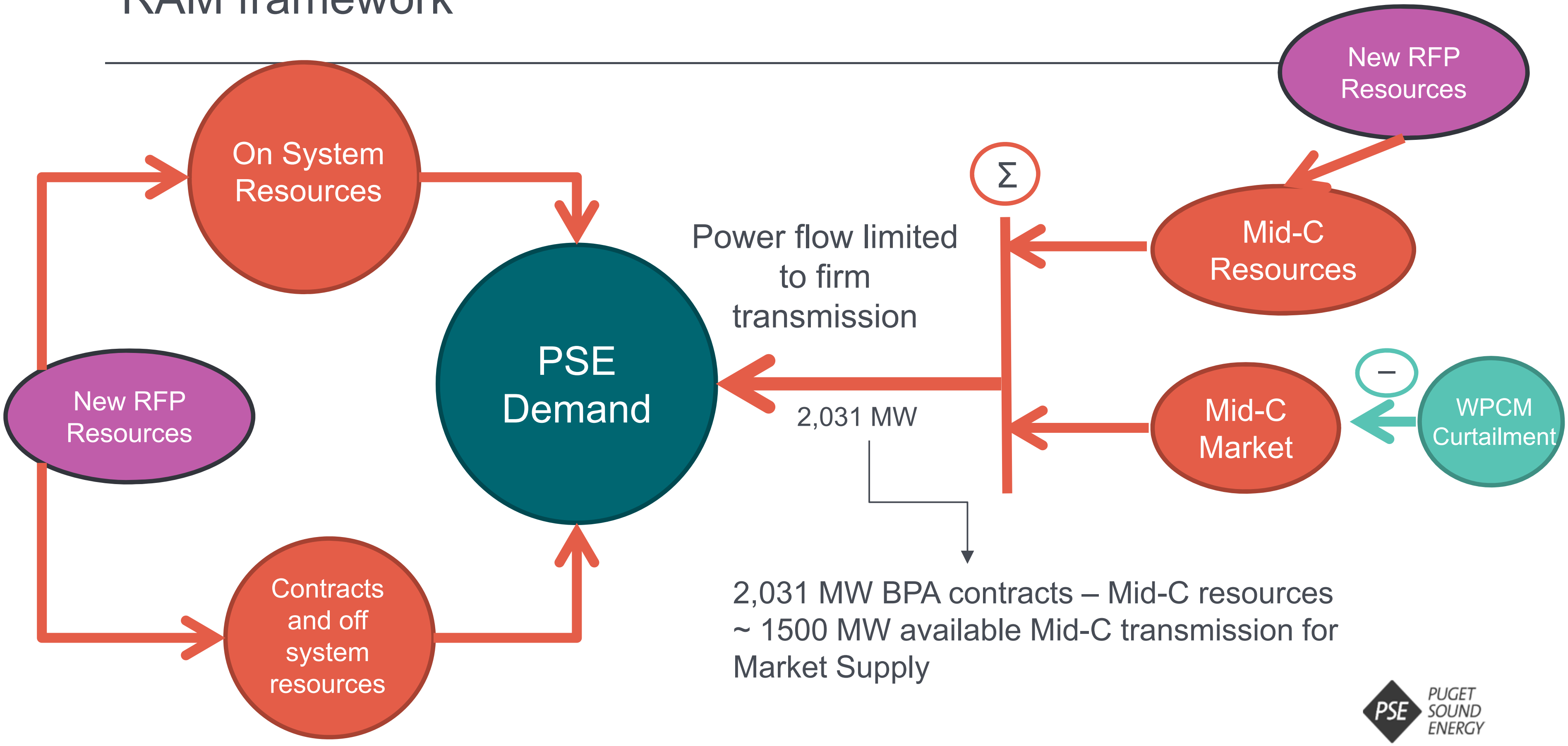
- Perfect Capacity Added
- LOLP
- EUE
- LOLH
- LOLE
- LOLEV

Model interactions

- GENeration Evaluation SYStem Model (GENESYS)
  - Models entire Pacific Northwest region including imports from California
- Wholesale Purchase Curtailment Model (WPCM)
- Resource Adequacy Model (RAM)
  - The RAM/LOLP model and WPCM models are used iteratively, with the final output of the RAM/LOLP model used in the next WPCM modelling run.



RAM framework



2,031 MW BPA contracts – Mid-C resources
~ 1500 MW available Mid-C transmission for Market Supply

Establish resource needs

Resource Adequacy Analysis

Electric peak capacity need: 2027

907 MW resource need of perfect capacity for 5% LOLP

What is perfect capacity? Available all hours with perfect reliability

Reliability metrics at 5% LOLP:

Metric Name	Base System, 2027 No Added Resources	System at 5% LOLP, 907 MW Added
LOLP	68.84%	4.99%
EUE	5,059 MWh	430 MWh
LOLH	11.06 hours/year	0.83 hours/year
LOLE	12.58 days/year	0.12 days/year
LOLEV	2.49 events/year	0.14 events/year

Establish resource needs

Resource Adequacy Analysis

Electric peak capacity need: 2031

1,381 MW resource need of perfect capacity for 5% LOLP

Reliability metrics at 5% LOLP:

Metric Name	Base System, 2031 No Added Resources	System at 5% LOLP, 1381 MW Added
LOLP	98.45%	5.00%
EUE	19,243 MWh	419 MWh
LOLH	51.90 hours/year	0.86 hours/year
LOLE	11.25 days/year	0.12 days/year
LOLEV	13.80 events/year	0.17 events/year

Peak capacity credit - ELCC

Resource Adequacy Analysis

Effective Load Carrying Capability (ELCC) for 5% LOLP relative to Perfect Capacity

ELCC = $-(\text{Need}_2 - \text{Need}_1)$/Change

Example:

Step 1: Base case need = 500 MW

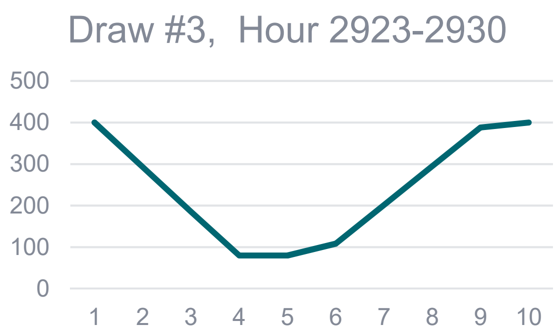
Step 2: Add 100 MW nameplate renewable, New Need = 475 MW
reduce perfect capacity to 475 MW to maintain 5% LOLP

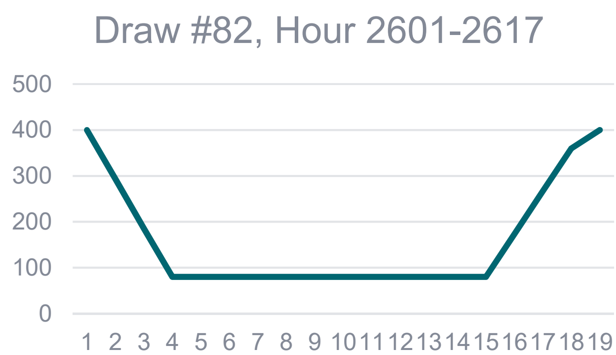
Step 3: ELCC = –(475 MW – 500 MW)/100 MW = 25%

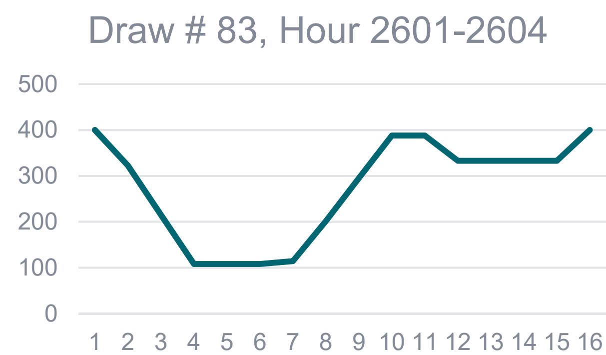
How batteries charge and discharge

- Examples

4 Hr 100 MW Battery 400MWh







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Why use EUE for the energy limited resources?

- The LOLP counts only draws with any outage event but not the magnitude, duration and frequency of events within each draw.
- When substituting a perfect capacity resource with an energy limited resource, it's possible to make conditions worse, which is not reflected in LOLP.
- The analysis starts from a portfolio of resources that achieves a 5 percent LOLP, then the EUE from that portfolio is calculated. Each of the storage resources is then added to the portfolio, which leads to lower EUE.
- The amount of perfect capacity taken out of the portfolio to achieve the EUE at 5 percent LOLP minus the peak capacity of the storage resource added determines the peak capacity credit of the storage resource.

Example:

Step 1: Base case

Base Need = 906.6 MW, LOLP = 4.99%, *EUE = 429.93 MWh*

Step 2: Add 100 MW nameplate 6 hr flow battery

New Need = 876.8 MW, LOLP = 3.97%, *EUE = 429.6 MWh*

Step 3: ELCC = –(876.8 MW – 906.6 MW)/100 MW = 29.8%

Energy storage capacity credit

Resource Adequacy Analysis

Peak Capacity Credit for Battery Storage Based on EUE at 5% LOLP

Energy Limited Resource	IRP 2019 ELCC 2022 EUE at 5% LOLP	IRP 2021 ELCC 2027 EUE at 5% LOLP	IRP 2021 ELCC 2031 EUE at 5% LOLP
Lithium-Ion Battery 2 hr, 82% RT efficiency	19%	12.4%	15.8%
Lithium-Ion Battery 4 hr, 87% RT efficiency	38%	24.8%	29.8%
Flow Battery 4 hr, 73% RT efficiency	36%	22.2%	27.4%
Flow Battery 6 hr, 73% RT efficiency	46%	29.8%	35.6%
Pumped Hydro Storage 8 hr, 80% RT efficiency	37%	37.2%	43.8%

Recall, in 2027, the ELCCs were calculated AFTER adding perfect capacity to maintain EUE, which creates surpluses to charge storage that do not otherwise exist

Hybrid resource capacity credit

Resource Adequacy Analysis

Peak Capacity Credit for Hybrid Resource Based on EUE at 5% LOLP

Energy Limited Resource	Capacity (MW)	IRP 2019 ELCC 2022 EUE at 5% LOLP	IRP 2021 ELCC 2027 EUE at 5% LOLP	IRP 2021 ELCC 2031 EUE at 5% LOLP
Generic WA Solar, lithium-ion, 25MW/50MWh, 82% RT efficiency	100	17.2%	14.4%	15.4%
Generic WA Wind, lithium-ion, 25MW/50MWh, 82% RT efficiency	100	NA	23.6%	23.0%
Generic MT East Wind, pumped storage, 8-hr, 80% RT efficiency	200	NA	54.3%	57.7%

Pumped storage hydro operation test

- 2021 IRP assumed a 88.5% operating range on PSH with a 11.5% minimum storage.
- Late in the IRP process, stakeholders had information on newer technology with a 100% operating range.
- This test looked at changing the minimum state of charge to zero.

Pumped Storage Hydro	Capacity (MW)	Peak Capacity Credit Year 2027	Peak Capacity Credit Year 2031
11.5% minimum state of storage	100	37.2%	43.8%
0 minimum, 100% operation range	100	39%	45.8%

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Climate Change Analysis

Climate change analysis

PSE is committed to continuing work on temperature trends and a climate change analysis for the 2023 IRP Progress Report.

Schedule

Mid-2022
Updated load forecast and RA analysis

⇩

Will be included in Phase 2 of the RFP

January 2023
Draft IRP Progress Report with updated CPA and portfolio analysis

April 1, 2023
Final 2023 IRP Progress Report

Analysis will include

- Temperature trends
- Hourly temperatures to create load draws for RAM, preferably a large data set with variations, not just the same pattern
- Hydro generation

Climate change analysis for resource adequacy

- The purpose of the resource adequacy model is to look at possible “what if” scenarios - and that includes extreme weather events.
- PSE will continue to model weather trends under different scenarios to better understand how summer extreme events can affect resource adequacy, but also to ensure that PSE continues to plan for winter extreme events.
- While average temperatures may be increasing over time due to climate change, extreme events (both hot and cold) may still occur.
- Further climate change modeling is needed beyond what was conducted in the temperature sensitivity to drive future resource planning changes.

How a different load can change the results

- In the 2021 IRP, PSE ran a temperature sensitivity that adjusted the demand forecast only and kept the exact same model and methodology.
- The temperature sensitivity is a way to begin to evaluate the impacts of climate change.
  - This temperature sensitivity is one model of possible weather changes and provides a preliminary view of a possible impact of warming temperatures as a result of climate change.
  - Since this was a preliminary view, information was missing in this analysis, including
    1. impacts to the conservation potential assessment,
    2. hydro stream flow data,
    3. extreme weather conditions,
    4. and variability in hourly temperature profiles.
  - By having a data set with a limited view and repeating patterns, we are unsure if the results of the resource adequacy model are reasonable.

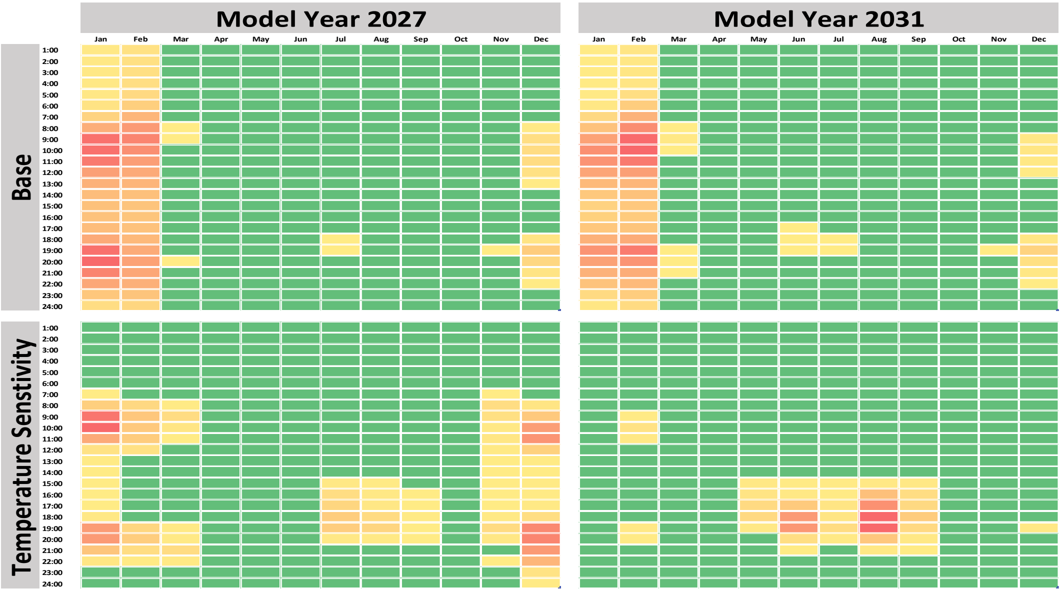
There are three components to the temperature sensitivity analysis:

1. An updated energy demand forecast;
2. An alternative resource adequacy analysis; and
3. A portfolio sensitivity using the Aurora Long Term Capacity Expansion portfolio model.

Temperature sensitivity results

- The temperature analysis results showed more loss of load events in the summer caused by inadequate supply while in the base analysis, most loss of load events occurred in the winter season
- This shift in loss of load events from the winter to summer affects the peak capacity credit of resources.
- Resources with higher capacities in the summer, such as solar, now have higher peak capacity credit while those with strong winter generation become less effective with a lower peak capacity credit.

Frequency of Loss of Load Events by Month and Hour of Day for Model Years 2027 and 2031, Base Scenario and Temperature Sensitivity
(red indicates more loss of load events, green indicates zero loss of load events)



Temperature Sensitivity results continued

Selection of ELCC results from temperature sensitivity

Peak Capacity Credit for 5% LOLP

		ELCC Year 2027		ELCC Year 2031	
WIND AND SOLAR RESOURCES	**Capacity (MW)**	**Base Scenario**	**Temp. Sensitivity**	**Base Scenario**	**Temp. Sensitivity**
Generic MT East Wind1	350	41.4%	28.5%	45.8%	28.1%
Generic MT East Wind2	200	21.8%	13.1%	23.9%	17.7%
Generic MT Central Wind	200	30.1%	23.1%	31.3%	20.9%
Generic WA East Wind	100	17.8%	7.8%	15.4%	12.0%
Generic WA East Solar	100	4.0%	21.6%	3.6%	45.6%
Lithium-ion, 2-hr, 82% RT efficiency	100	12.4%	34.2%	15.8%	36.0%

The temperature sensitivity is included in the 2021 IRP. The full results from the RA analysis is included in Chapter 7.

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RFP ELCC Use Cases

RFP evaluation process and timeline

Bids due Sept. 1, 2021

Intake

- New proposal submission web portal
- New proposal data collection through Exhibit B

Sept. 2021 – March 2022

Phase 1 individual proposal screening

- Quantitative evaluation (70%) - Automated inputs from database for energy and financial modeling; proposals compared by Portfolio Benefit / MW[1]
- Qualitative evaluation (30%) - Evaluation is cross-functional, thorough and spotlights CETA benefits
- Phase 1 candidate list - Represents resources among the lowest costs and highest commercial values of each technology group, and meets at least 150% of the RFP resource needs

April 2022 – June 2022

Phase 2 portfolio of proposals optimization

- Optimal portfolio mix of resources with maximum portfolio benefits
- Sensitivity analysis will be performed for optimization under different economic settings such as levels of carbon costs and load growth; may include analysis of portfolio that maximizes CBIs
- Creates the short list for negotiation and contracting

July 2022 – Dec. 2022

Negotiation and contracting

- Improved efficiency by including prototype term sheets with pre-specified non-negotiable terms
- Compliance report filed with WUTC within 90 days of the conclusion of the RFP

[1] Portfolio benefit includes social cost of carbon as a cost adder, consistent with PSE's 2021 Integrated Resource Plan and the requirements of RCW 19.280.030(3).

Phase 1: Evaluation of the capacity contribution of RFP resources

- In Phase 1, quantitative evaluation will approximate the ELCC value of each proposed RFP resource using that of a comparable generic resource from PSE's 2021IRP:

  Resources will be classified into subgroups based on technology and location.

  Note:

  - As-generated VERs delivered to Mid-C will not receive a capacity credit and will get a reduced transmission evaluation adder
  - Resources delivered to COB/Malin or John Day during non-winter months will receive a limited capacity credit and will get a reduced transmission evaluation adder
  - Visualization and statistics of 8760s will be compared within subgroups to assure comparability

Resource Type	Resource	ELCC
Thermal Resources	CCGT[13]+Duct Firing	100.0%
	Peaker - Frame	100.0%
	Peaker - Reciprocating	100.0%
Renewable Resources	WA Wind Offshore	48.4%
	WY Wind East	40.0%
	WA Wind	17.8%
	MT Wind East	21.8%
	Biomass	95.0%[14]
	MT Wind Central	30.1%
	East WA Solar	4.0%
Capacity-Only Resources	Li-Ion 2-hour	12.4%
	Li-Ion 4-hour	24.8%
	Flow 4-hour	22.2%
	Flow 6-hour	29.8%
	Pumped Storage	37.2%
Hybrid Resources	WA Solar, Li-ion, 25MW/50MWh, 82% RT efficiency	14.4%
	WA Wind, Li-ion, 25MW/50MWh, 82% RT efficiency	23.6%
	MT East Wind, pumped storage, 8-hr, 80% RT efficiency	54.3%

Note: Source per 2021RFP document, the precise ELCCs used in Phase 1 will be aligned with 2021 IRP final generic resource ELCCs.

Phase 2: Evaluation of the capacity contribution of RFP resources

- Phase 2 portfolio optimization will utilize resource-specific ELCC values based on:
  - Independent energy assessment to verify generation shape (8760)
  - Exact location of the resource and 250 draws of NREL data @ the location
  - Ability to dispatch
  - Duration of output
  - Availability of firm delivery to PSE's load center
  - Other resource-specific operational characteristics, such as:
    - ➢ Determination of the availability of firm fuel supply for biomass
    - ➢ Determination of the ability to charge during a loss of load event for storage
    - ➢ Capacity and hours available to call for a capacity call option
    - ➢ Historical operational data for a hydro/run-of-river resource
    - ➢ Availability of calls per day and hours per day for a demand response
    - ➢ Shaped hours and capacity for a shaped VER
    - ➢ Forced and maintenance outages and determination of firm fuel supply of a thermal resource
- Phase 2 analysis will run shortlist portfolio ELCC to assess resources correlations and ELCC saturation and ensure meeting PSE's resource need
- Phase 2 analysis will run temperature sensitivity scenario using updated needs, load shapes, and ELCCs

An illustration example of how ELCC may impact the RFP evaluation by two otherwise identical Wind Projects with slightly different ELCC

	100 MW WA Wind with 20% ELCC	100 MW WA Wind with 21% ELCC
Avoided capacity unit cost per 2021 IRP	$95.27/kw-yr	$95.27/kw-yr
Capacity contribution	20 MW	21 MW
NPV of Avoided capacity	$1.9M/yr =($95.27 x 1000 x 20MW) **$19.6M NPV** for a 20yr PPA @7.39% discount rate	$2.0M/yr =($95.27 x 1000 x 21MW) **$20.6M NPV** for a 20yr PPA @7.39% discount rate
Relative portfolio benefit NPV		**+$1.0 M**

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10-minute break

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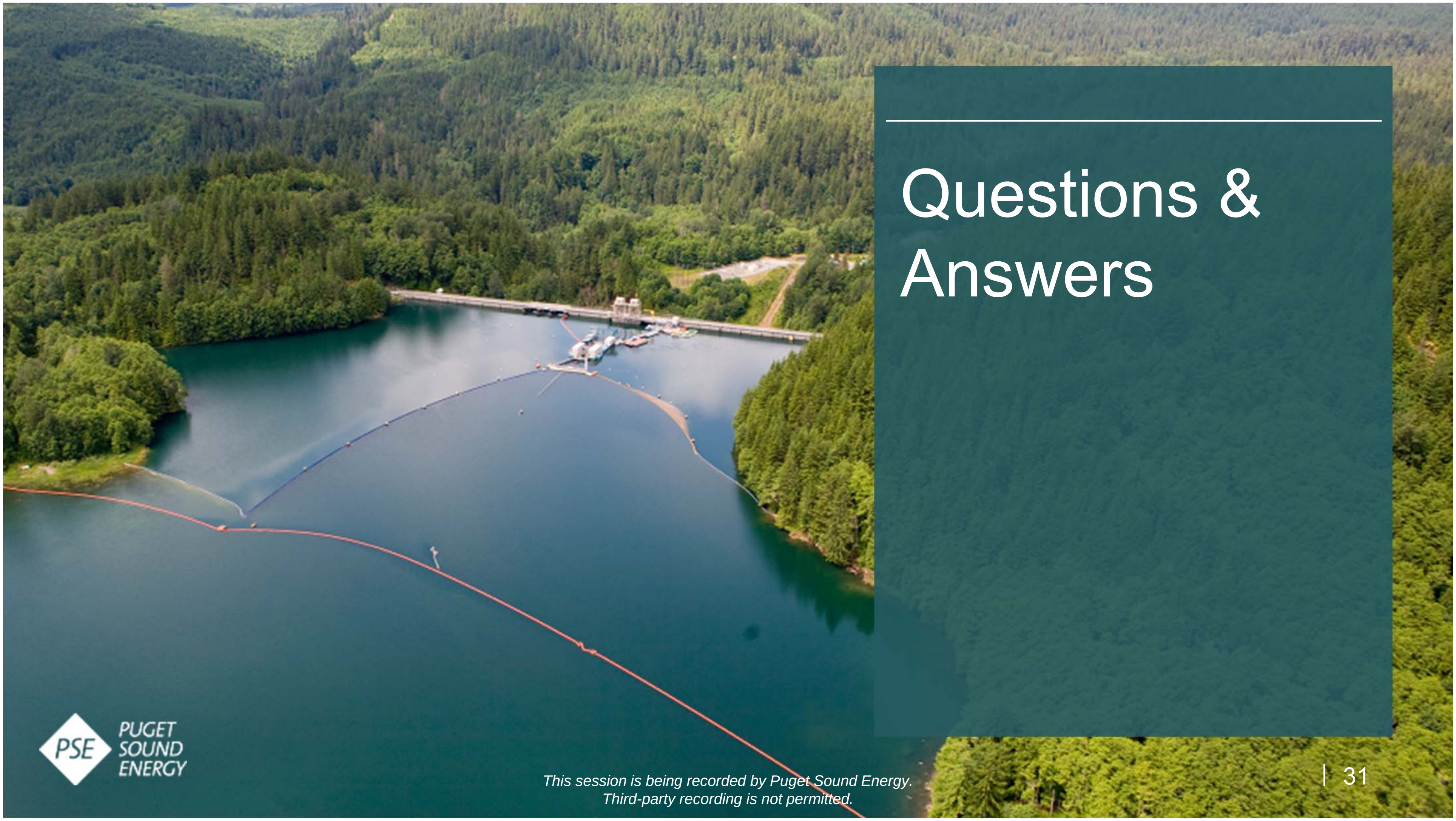
Questions &
Answers
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E3 Evaluation

Independent Review of PSE’s ELCC Methodology

- PSE received various comments and questions from stakeholders during the RFP public comment period on the approach to calculating ELCC, in particular for energy storage (WUTC Docket 210220)
- Working through its Independent Evaluator, PSE engaged **E3** (Energy+Environmental Economics) to conduct an independent review of PSE’s ELCC methodology and evaluate the reasonableness of PSE’s calculations of ELCC for energy storage in its system
- PSE presented the stakeholder comments to E3, which then undertook to address the following main questions:
    - Does PSE use industry-standard methodology for calculating ELCC?
        - If not, are any deviations from industry-standard methodology warranted?
    - Does PSE’s data reflect the relevant correlations between intermittent renewable resources (i.e. wind and solar) and load?
        - Are the operating data for relevant technologies reasonable?
        - Are the load shapes used in PSE’s analysis reasonable?
    - Does PSE appropriately capture regional dynamics in its calculation of ELCC?
        - Is the impact of bilateral trading markets captured appropriately?
        - Is the role of hydropower generation in the region captured appropriately?
    - Does PSE’s ELCC calculation methodology appropriately capture the interactivity between energy storage and intermittent renewables (wind and solar), as well as the role of hydropower in its system?
- **The ultimate goal of E3’s analysis is to evaluate the reasonableness of PSE’s calculations of ELCC for energy storage in its system.**

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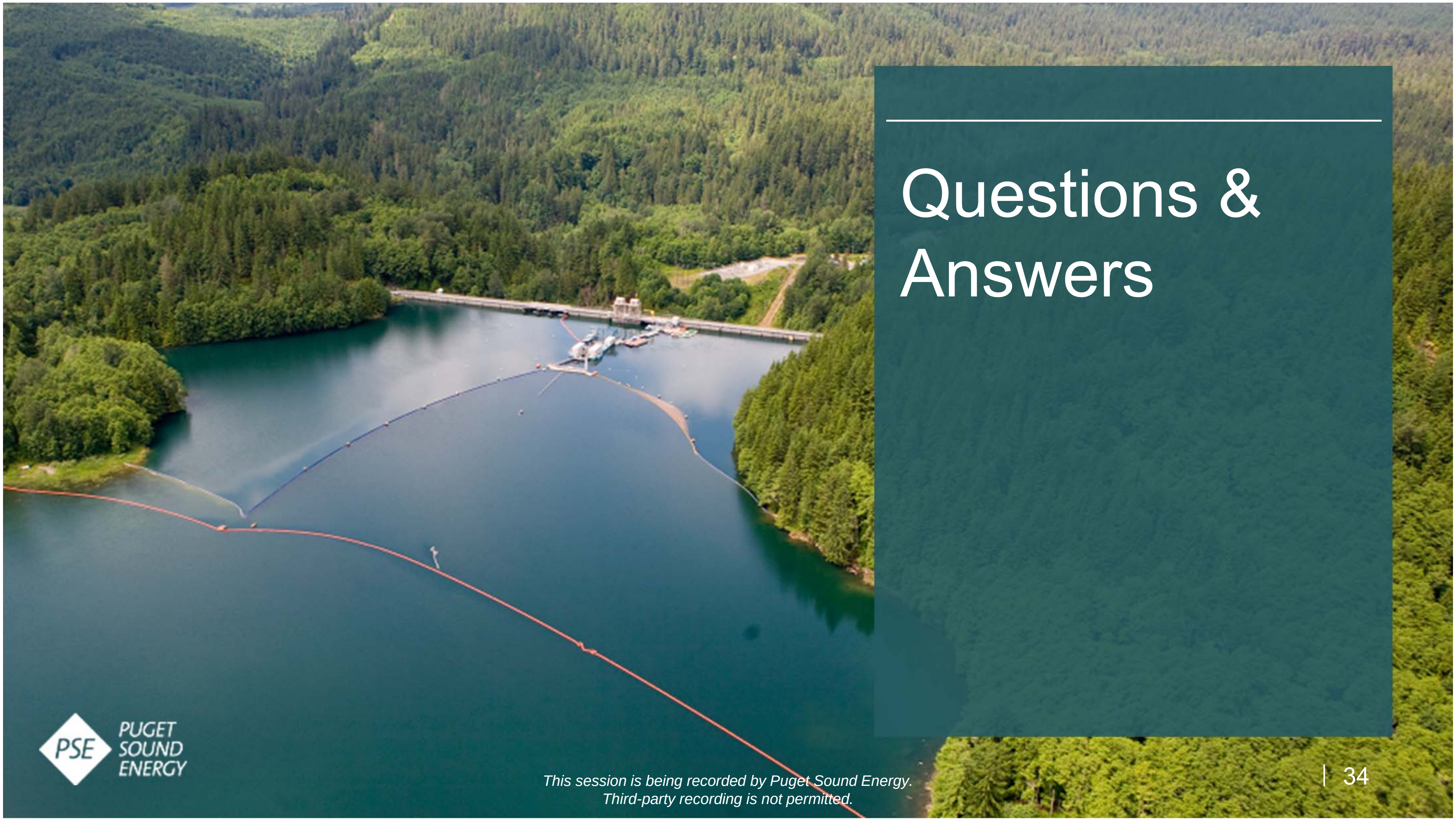
Questions & Answers



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Next steps

- Submit written comments to PSE by **September 30, 2021.**
- A recording and the chat from today's webinar will be posted to the website in 5-7 business days**.**
- PSE intends to respond to stakeholder comments prior to incorporating any potential updates into the ELCC values that will be used in Phase 2 of the All-Source RFP

Thank you for your attention and input.

Thank you for your participation in PSE's 2021 RFP!

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Appendix

Regional view from GENESYS

- NWPCC Adequacy Assessment for 2023 GENESYS base case is used for the 2021 IRP, Updates PSE made to GENSYS includes:
  - Updated coal plant retirements with retirement years
  - Increased the year 2023 demand forecast using the escalation rate of 0.3 percent to the year 2027 and 2031. The escalation rate is from the NPCC demand growth after conservation.
  - Added planned resources from PSE's portfolio: Skookumchuck Wind (131 MW) and Lund Hill solar (150 MW).

- Key assumption in regional model:
  - Economics drive joint coordination of resources in the Pacific Northwest
  - No consideration of firm transmission rights
  - All PNW transmission resources can be fully utilized up to modeled limits by any entity
  - Assumes 3400 MW California import limit

Major Updates from 19 IRP process to 21 IRP

- Updated study years
- Updated demand forecast
- Updated transmission assumptions
- Updated Wholesale Market Purchase model
- Updated contracts
- Updated wind & solar NREL data
- Updated balancing reserves
- Updated outage draws and resource capabilities
- Updated GENESIS with load growth and coal plant retirements

Please find more details in 2021 IRP Report Chapter 7
https://pse-irp.participate.online/2021-irp/reports