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London Economics International LLC

Module B Study – Annex 3
Probabilistic Supply Adequacy Analysis

prepared for

Proceeding 28542: AUC Inquiry into the ongoing economic, orderly and efficient development of electricity generation in Alberta

February 7, 2024
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Agenda

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LEI's probabilistic supply adequacy analysis builds upon the foundation of the POOLMod and ConjectureMod modeling results

Simulation-based dispatch model that projects a single market-clearing price for each hour

POOLMod

- LEI's proprietary simulation dispatch model
- Consists of several key algorithms, such as maintenance scheduling, assignment of stochastic forced outages, hydro shadow pricing, commitment, and dispatch

Above SRMC offer behaviour provides an investment signal under the energy-only market

ConjectureMod

- Game theory module within POOLMod for the Alberta market
- Projects above short-run marginal cost ("SRMC") offers, replicating real-world outcomes; offers will be dynamic and change daily with evolving market conditions

Probabilistic assessment of weather-related factors

WeatherMod

- Assesses reliability and resource adequacy and tests the resiliency of the system to plant outages and varying weather conditions
- Allows for stochastic variation of generation outages, and consideration of weather patterns and their impact on load, intermittent renewable generation, as well as unplanned outages

Focus of this Annex

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The probabilistic supply adequacy analysis is conducted using the same tools as LEI's long term weather-normal modeling, but incorporates far more weather combinations

Inputs

Long term weather-normal modeling

- Hourly load pattern based on 2021 data
- Wind and solar hourly capacity factors based on 2021 data
- 10 "seeds" for random maintenance and outages

Probabilistic supply adequacy analysis

- Hourly load pattern, and wind and solar capacity factors from 5 historical years (2018-2022)
- 25 synthetic hourly weather patterns
- 50 "seeds" for random maintenance and outages

Common inputs

- Fuel prices
- Carbon prices
- Emissions policy
- Load growth
- Expected retirements
- New entry

LEI's propriety energy market simulation model, POOLMod

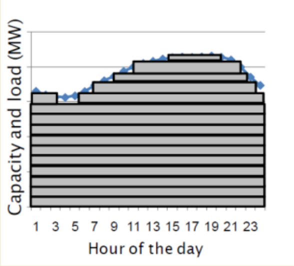
Stage 1: Commitment

Is plant available?

No → Not committed for dispatch

Yes → Review technical capabilities of units

Schedule hydro based on optimal duration of operation



Competitive bidding

Stage 2: Dispatch

Incremental offers are sorted from lowest to highest

Resources dispatched based on offer price

Market clearing price set equal to the bid of the most expensive dispatched resource

Outputs

Long term weather-normal modeling

- 20-year price forecast based on "weather-normal" scenario
- Focuses on average Pool Price and profitability of assets

Probabilistic supply adequacy analysis

- Only models specific years (2025, 2030, 2035, 2038, 2040)
- Each year is simulated 1,500 times under a combination of weather profiles and randomized maintenance/outages
- Focuses on frequency and distribution of unserved load events

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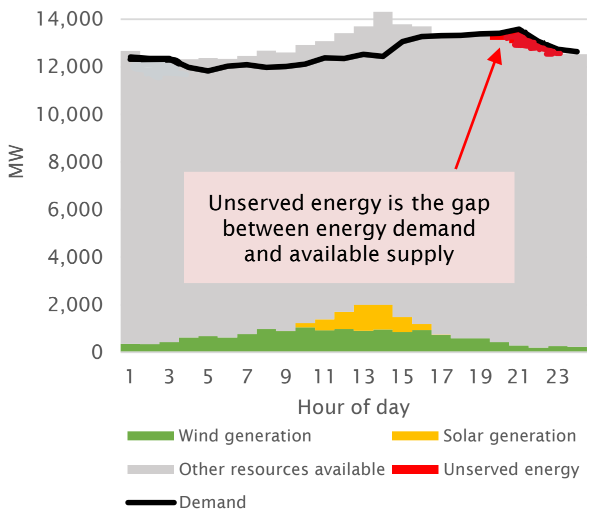
Supply adequacy is measured in terms of expected unserved energy ("EUE"), which is an industry standard metric in reliability analysis

- **Unserved energy refers to instances where not all customers' electricity demand can be met**
  - When the system runs out of available supply to provide electricity to all customers, AESO would have to shed some load, which means some customers will not have electricity for some period of time
  - In the industry, this is sometimes referred to as a "rolling blackout"
- **Expected unserved energy is a metric to estimate the level of supply adequacy of an electric grid**
  - EUE is the estimated average MWh of unserved energy in a year
  - EUE has also been adopted by the AESO in its long-term supply adequacy analysis

Illustration of unserved energy



- **In LEI's probabilistic supply adequacy analysis, the total unserved energy (in MWh) in each of the 1,500 runs for each modeled year is measured; EUE is the simple average of the unserved energy for those 1,500 runs**
- **Additional insights can be obtained through detailed analysis of modeled hours with unserved energy**

Distribution of unserved energy
- Which season has the highest risk?
- Which hour of the day has the highest risk?
- What are the causes of unserved energy?

Duration of loss of load events
- How many consecutive hours in a loss of load event?

Magnitude of loss of load events
- How many MWhs of unserved load in a loss of load event?
- Unserved energy as a % of demand in that hour

Analysis of severe loss of load events
- In the 5% most severe loss of load events, what is the typical duration or typical % of demand unserved?

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The purpose of the probabilistic supply adequacy analysis is to understand the risks faced by the electric grid given the current market design

1. **Results of LEI's supply adequacy analysis are based on the resource mix developed in the long-term analysis, which assumes continuation of the current market design**
   - The resource mix is based on AESO's preliminary 2024 Long-term Outlook ("LTO")
   - The current market design features an energy-only market with a $0/MWh price floor and $1,000/MWh price cap

2. **This analysis focuses on supply adequacy at the hourly level, and does not study reliability risk at the sub-hourly level of grid operations**
   - Unserved energy occurs when there are not enough resources to meet hourly demand
   - Sub-hourly level of grid operational risk, such as need for additional ancillary services, is not modeled

3. **LEI measures reliability risk in terms of energy, in the form of EUE; other costs of an unreliable grid are not modeled**
   - Other costs of an unreliable grid include, but are not limited to, economic losses (due to business productivity interruptions), increase in the cost of doing business in Alberta (due to need to install backup generation), decrease in the quality of life, or even loss of human lives

4. **There are options to reduce the EUE or limit the impact under the worst-case scenario**
   - For example, in its preliminary 2024 LTO presentation, AESO discussed the use of electric vehicle ("EV") load shifting (load management) to mitigate reliability risk; other demand response and controllable load programs could also be helpful
   - Modifications to the current market design could also result in a different supply mix, which may improve supply adequacy

5. **It is outside the scope of this study to identify methods or market designs to reduce the forecasted reliability risks**

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Key inputs for the probabilistic supply adequacy analysis are built using real world electric system data, instead of relying on assumptions related to distribution and correlation of weather events

Real world input data

- Inputs sampled from actual weather data, yielding realistic representations
- Can accommodate multiple stochastic drivers – planned plant maintenance and unplanned outages – that resemble real world behaviour
- Provides a detailed representation of potential market outcomes with realistic weather-driven impacts

Daily & hourly impacts

- Adjusts for generation outages, different patterns of load, and intermittent (weather-dependent) renewable generation
- Transmission outages were not explicitly considered, but their effect on system operations is partially captured in the other data relied upon, including the historical import/export data and the historical renewable generation data*
- Represents real-world outcomes with net load and supply cushion variations

Statistical analysis

- Yields a distribution of potential market outcomes – supporting various statistical analyses and confidence level testing
- By simulating a large number of plausible scenarios, we no longer need to make *a priori* assumptions on the underlying distribution

* Transmission system outages, including outages on interties, impact reliability outcomes. If imports are not available for some period of time, and that coincides with other factors that cause a tight supply-demand condition on the electric grid, that may cause supply adequacy to further deteriorate. However, intertie outages were not considered in LEI's supply adequacy analysis. LEI modeled interties based on market opportunities – with more imports in higher priced hours and more exports in lower priced hours, as discussed in Annex 1 *(Scenario Analysis: Long Term Weather-Normal Energy Market Forecast).*

Using 2018-2022 actual load patterns and renewable capacity factors, LEI developed 25 synthetic weather profiles for assessing supply adequacy

1 Develop weather profiles based on historical data and AESO's load modifier forecasts

Load pattern	▪ Uses 2018-2022 hourly load shape ▪ Peak demand and total load scale with AESO preliminary 2024 LTO forecasts to account for demand growth ▪ Add back AESO preliminary 2024 LTO load modifiers to weather-adjusted demand forecast for future years
Solar capacity factor	▪ Developed based on 2018-2022 hourly solar generation divided by installed solar capacity in the corresponding month
Wind capacity factor	▪ Developed based on 2018-2022 hourly wind generation divided by installed wind capacity in the corresponding month

2 5 actual weather profiles (2018-2022), split into weekly profiles

Weeks 1-52 in a year

2018 Profile	1	2	3	4	5	6	7	8	9	10	…	44	45	46	47	48	49	50	51	52
2019 Profile	1	2	3	4	5	6	7	8	9	10	…	44	45	46	47	48	49	50	51	52
2020 Profile	1	2	3	4	5	6	7	8	9	10	…	44	45	46	47	48	49	50	51	52
2021 Profile	1	2	3	4	5	6	7	8	9	10	…	44	45	46	47	48	49	50	51	52
2022 Profile	1	2	3	4	5	6	7	8	9	10	…	44	45	46	47	48	49	50	51	52

3 25 synthetic weather profiles based on randomized mix of weekly actual weather profiles

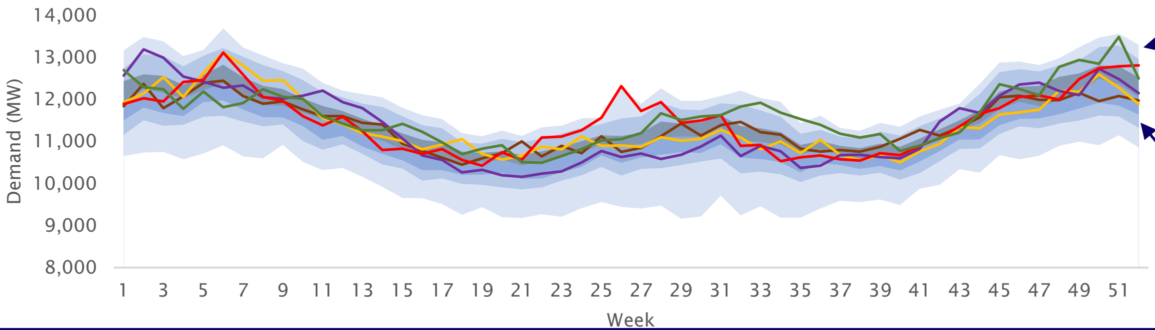
Synthetic 1	1	2	3	4	5	6	7	8	9	10	…	44	45	46	47	48	49	50	51	52
Synthetic 2	1	2	3	4	5	6	7	8	9	10	…	44	45	46	47	48	49	50	51	52
…										…										
Synthetic 24	1	2	3	4	5	6	7	8	9	10	…	44	45	46	47	48	49	50	51	52
Synthetic 25	1	2	3	4	5	6	7	8	9	10	…	44	45	46	47	48	49	50	51	52

4 50 maintenance and forced outage "seed" runs on each of the 5 actual weather and 25 synthetic weather profiles

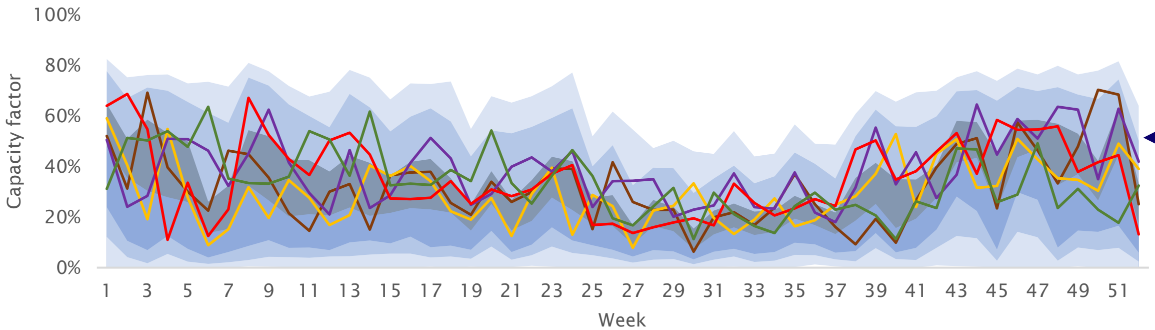
30 weather profiles x 50 outage seeds = 1,500 runs for each modeled year, allowing LEI to analyze the distribution of EUE events

The synthetic weather profiles result in a diverse but realistic range of load and renewable generation profiles, as opposed to using the load and renewable generation profile of any single year

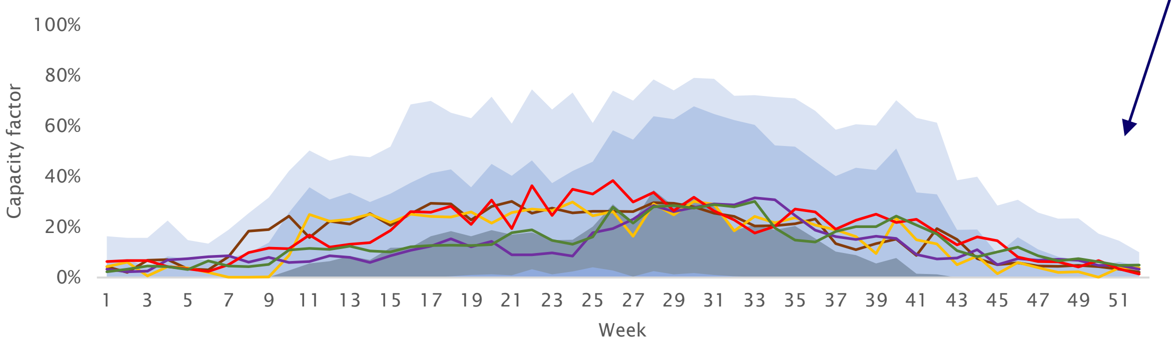
Modeled range of weekly average on-peak demand (2038)



Modeled range of capacity factors (by week) for existing wind



Modeled range of capacity factors (by week) for existing solar



The shaded areas represent the 10th to 90th percentile hourly value of the week

For the demand shape, the 2018-2022 weekly averages represent the hourly average on-peak forecasted demand if the load pattern follows 2018-2022 historical data, adjusted for new demand drivers such as EVs and electrification of space heating

For wind and solar capacity factors, the 2018-2022 weekly averages represent the hourly average of 24x7 actual historical data

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LEI performed the probabilistic supply adequacy analysis for 5 selected years out of the 20 years modeled in the long term weather-normal analysis

- **The probabilistic supply adequacy analysis is performed for selected years only due to the larger number of simulations required for each analyzed year**
- **Therefore, LEI performed the analysis at 5-year intervals (2025, 2030, 2035, and 2040), with one additional year (2038), as that is the year where all existing coal-to-gas units are assumed to retire**
  - For the Lower Demand Cases, only 2035 and 2038 are analyzed, as resource adequacy concerns as a result of demand shocks are expected to be minimal in 2025 and 2030

Years and scenarios for which LEI conducted its probabilistic supply adequacy analysis

Scenario	2025	2030	2035	2038	2040
2035 Base Case	✓	✓	✓	✓	✓
2050 Base Case	✓	✓	✓	✓	✓
2035 More Renewables Calibrated Case	✓	✓	✓	✓	✓
2050 More Renewables Calibrated Case	✓	✓	✓	✓	✓
2035 ~390 MW Lower Demand Case			✓	✓	
2050 ~390 MW Lower Demand Case			✓	✓	

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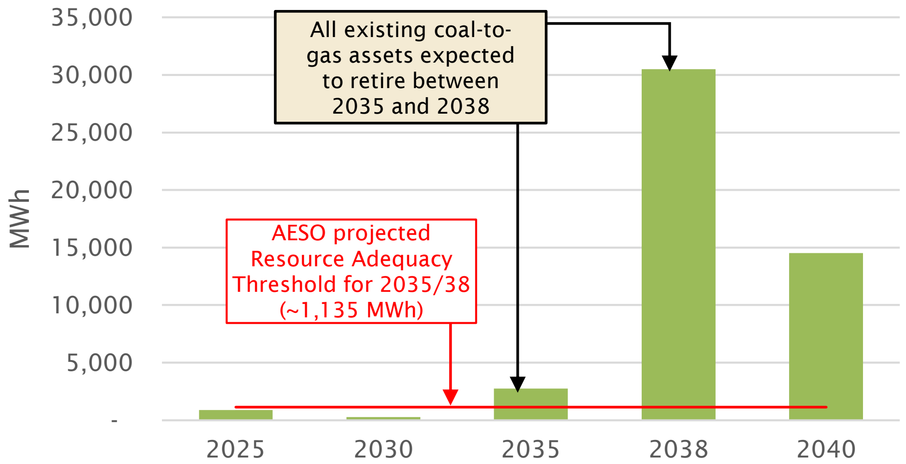
Under the 2035 Base Case, projected supply adequacy – in terms of EUE – reaches very high (unprecedented) levels in 2038 and 2040, indicating a high probability of load shed

- **Under LEI's 2035 Base Case, in 2035, with unabated assets limited to 450 hours of operation, modeled EUE across 1,500 weather runs reaches 2,754 MWh**
- **In 2038, modeled EUE across 1,500 weather runs reaches 30,491 MWh**
  - This is materially worse than the AESO's projected Resource Adequacy Threshold of approximately 1,135 MWh in 2038*
- **In 2040, modeled EUE declines to 14,533 MWh due to additional entry, but is still materially above the AESO's projected Resource Adequacy Threshold**

Modeled EUE, 2035 Base Case with weather variability

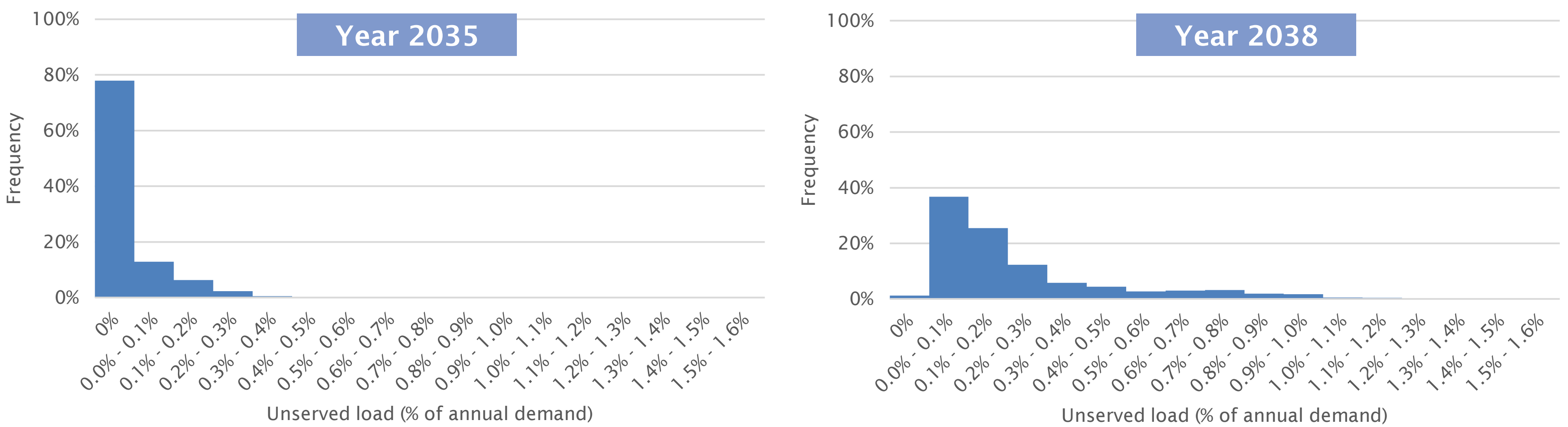


* Source: AESO. *2024 Long-term Outlook Preliminary Update.* November 15, 2023. The threshold is calculated as the 1-hour average Alberta internal load for a year divided by 10.

LEI also assessed the distribution of projected EUE under the 2035 Base Case, in order to better understand the severity of potential load shed in 2035 and 2038

- **In 2035, nearly 80% of the 1,500 model runs result in no unserved load**
  - Conversely, around 20% of the model runs result in some unserved load
- **However, in 2038, only 1% of the 1,500 model runs result in no unserved load; for 37% of the runs, unserved load as a % of annual demand is less than 0.1%**
- **Furthermore, in 2038, for 1.3% of the 1,500 model runs, unserved load could exceed 1% of annual demand**

Distribution of modeled unserved load under the 2035 Base Case with weather variability



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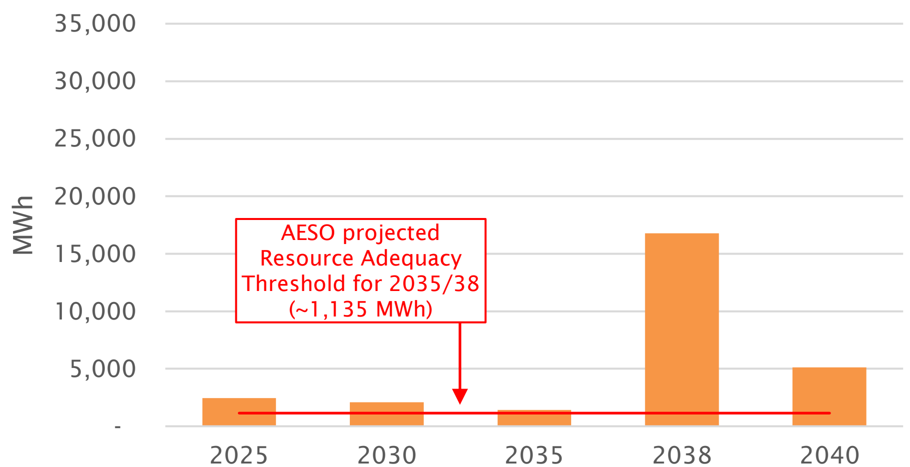
Under the 2050 Base Case, projected EUE for 2038 and 2040 are better (more reliable) than the 2035 Base Case, but are still at unacceptable levels

- **Compared to the 2035 Base Case, the 2050 Base Case has worse resource adequacy in 2025 and 2030, because 2 additional coal-to-gas units are assumed to retire before 2025 under AESO's Decarbonization by 2050 scenario (see next slide for more details)**
- **Under LEI's 2050 Base Case, in 2035, modeled EUE across 1,500 weather runs reaches 1,420 MWh**
- **In 2038, modeled EUE across 1,500 weather runs reaches 16,793 MWh**
  - 2050 Base Case has relatively better supply adequacy than the 2035 Base Case; however, still materially worse than the AESO's projected Resource Adequacy Threshold of approximately 1,135 MWh in 2038*
- **In 2040, modeled EUE is estimated at 5,127 MWh – still above AESO's projected Resource Adequacy Threshold**

Modeled EUE, 2050 Base Case with weather variability



* Source: AESO. *2024 Long-term Outlook Preliminary Update.* November 15, 2023. The threshold is calculated as the 1-hour average Alberta internal load for a year divided by 10.

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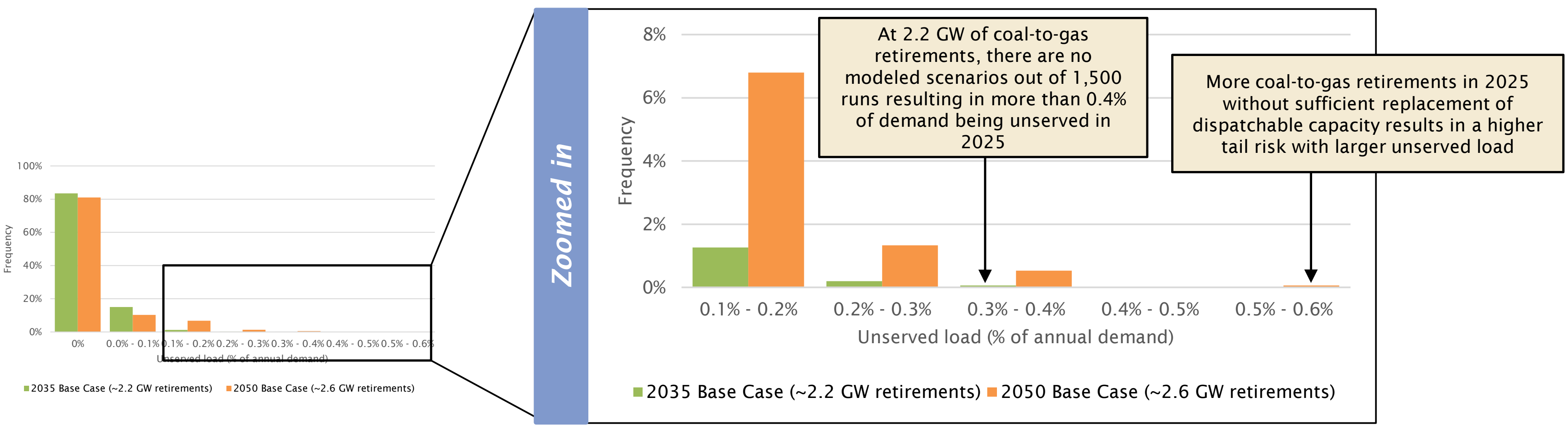
More coal-to-gas retirements in the near term without sufficient replacement capacity results in increased risk of unserved load (coupled with abnormal weather)

- **AESO assumes all coal-to-gas units (totaling ~4 GW) would retire by the end of 2037**
- **However, the schedule of retirements differs between AESO's Decarbonization by 2035 and Decarbonization by 2050 scenarios**
  - ~2.2 GW (56%) of these coal-to-gas units retire in 2024 under AESO's Decarbonization by 2035 scenario
  - In comparison, ~2.6 GW (66%) retire in 2024 under AESO's Decarbonization by 2050 scenario
  - Only 2 GW of new dispatchable capacity is added by 2025, consistent with the AESO's supply projections, resulting in a net loss in dispatchable capacity, and the Decarbonization by 2050 scenario has less capacity
- **Under the 2050 Base Case, LEI's modeled EUE in 2025 with 2.6 GW of coal-to-gas retirements reaches 2,450 MWh, exceeding both AESO's LTO Resource Adequacy threshold (1,135 MWh) and Two-Year Probability of Supply Adequacy Shortfall Metric from Nov. 2023 (2,005 MWh)**

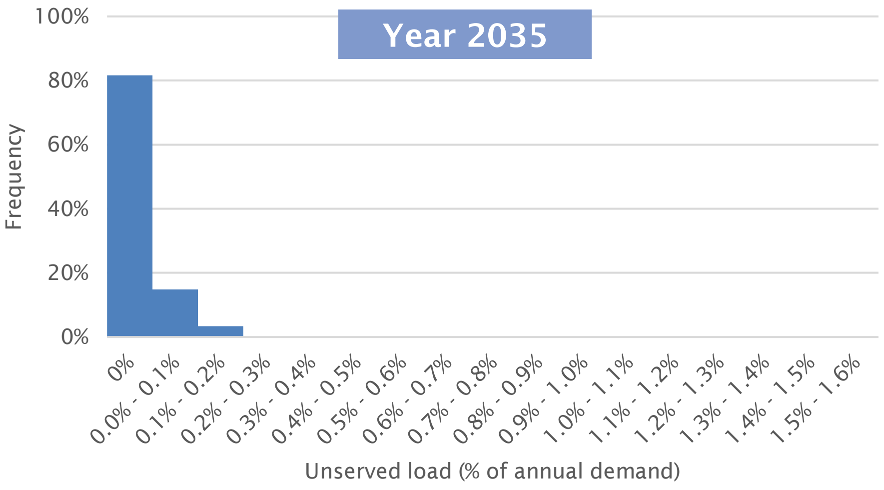
Distribution of modeled unserved load in 2025 under different coal-to-gas retirement schedules

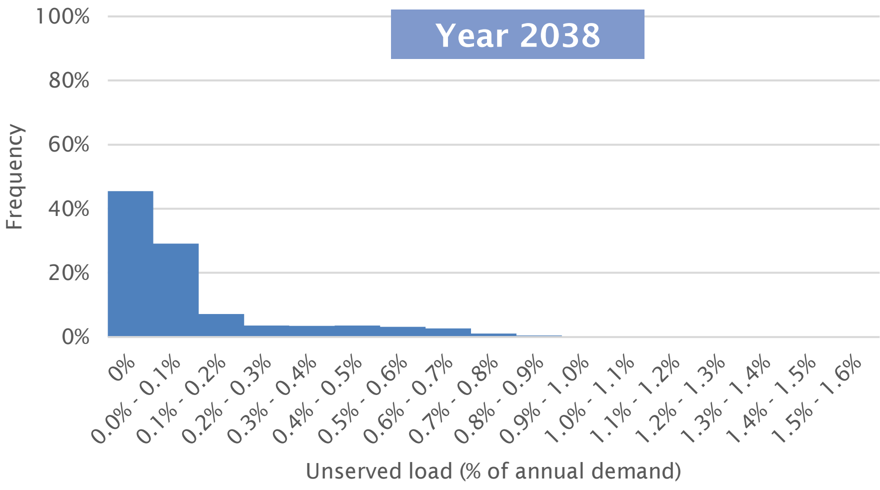


LEI assessed the distribution of projected EUE under the 2050 Base Case, which demonstrates less severe modeled unserved load in 2038 as compared to the 2035 Base Case

- **In 2035, over 80% of the 1,500 model runs result in no unserved load**
  - Conversely, around 20% of the model runs result in some unserved load
- **However, in 2038, only 45% of the 1,500 model runs result in no unserved load**

Distribution of modeled unserved load under the 2050 Base Case with weather variability





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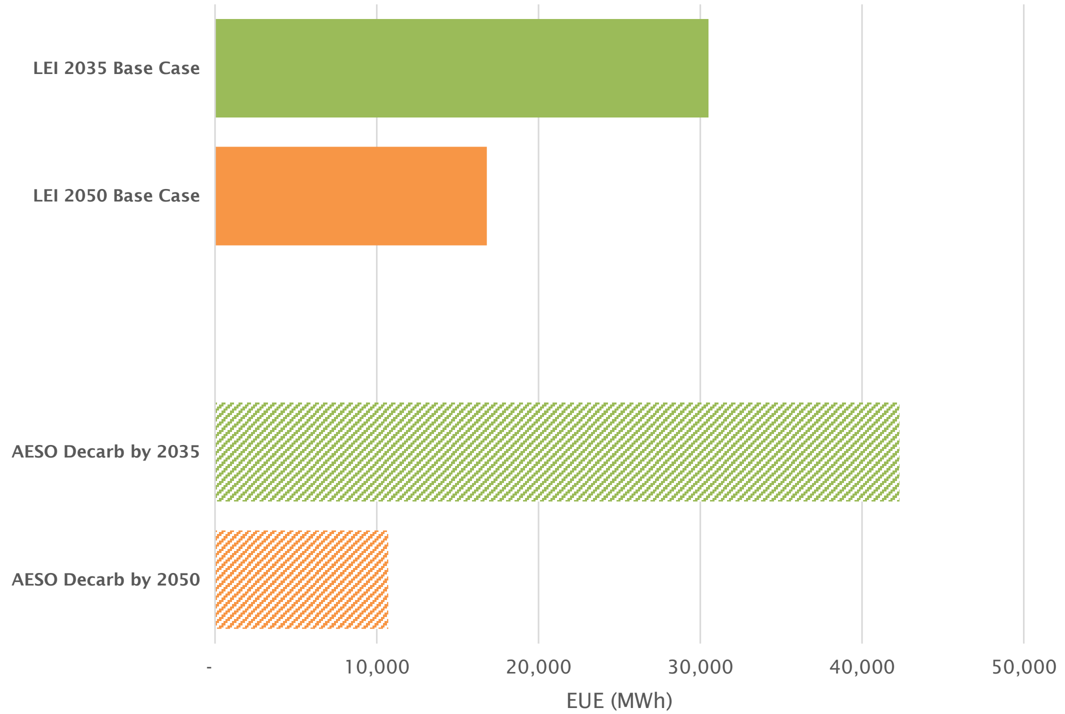
LEI's modeled EUE in both the 2035 Base Case and 2050 Base Case are comparable with the AESO's modeled EUE in its preliminary 2024 LTO

Forecasted EUE in 2038, LEI vs AESO preliminary 2024 LTO (MWh)



- **Some differences between LEI and the AESO's EUE results are to be expected – LEI and the AESO rely on different inputs related to weather, outages, and hourly demand shape**
- **Despite inherent differences in modeling inputs, LEI's results are aligned with the AESO's EUE results – both demonstrate increasing EUE from the 2050 scenarios to the 2035 scenarios; both also demonstrate similar levels of EUE across comparable supply-demand scenarios**

Source: AESO. *2024 Long-term Outlook, Preliminary Update.* November 15, 2023.

Alberta's system is forecast to have the highest unserved energy risk in winter evenings, with highest risk hours in December from 6-9 pm

- **In the 2035 Base Case, nearly 20% of unserved energy events occur in December (6-9pm)**
- **Unserved energy events occur when there is a combination of very low wind generation, no solar generation (during nighttime), high demand, and higher than average generation asset outages**

Monthly and hourly distribution of modeled unserved load in 2038 (2035 Base Case)

Hour of day

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
January	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.05	0.07	0.09	0.09	0.09	0.07	0.06	0.03
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.07	0.07	0.07	0.06	0.05	0.01
March	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
October	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
November	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.07	0.07	0.07	0.07	0.06	0.05	0.02
December	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.07	0.14	0.17	0.17	0.17	0.17	0.14	0.15	0.07

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In the top 5% worst situations modeled, an average of ~10% of demand would be unserved, with events on average lasting for almost an entire day (23 hours)

- **For reference, Storm Uri in 2021 resulted in an estimated load shed of up to 26% of demand in Texas; load shed lasted for ~72 hours**
  - The Electric Reliability Council of Texas ("ERCOT") estimated that 20,000 MW out of ~76,000 MW of demand was shed during the highest demand hour on February 15, 2021

Summary of average and 5% worst case EUE, MW of unserved load, and duration of unserved load

EUE (MWh)	2025	2030	2035	2038	2040
2035 Base Case	872	271	2,754	30,491	14,533
2050 Base Case	2,450	2,103	1,420	16,793	5,127
AESO forecasted Resource Adequacy Threshold*	2,005		1,135	1,135	

Average MW of unserved load during outage events (MW)	2025	2030	2035	2038	2040
2035 Base Case	292	256	410	473	408
2050 Base Case	357	356	335	430	344

Worst 5% event** average unserved load duration (hours)	2025	2030	2035	2038	2040
2035 Base Case	12.9	10.1	15.5	23.0	15.7
2050 Base Case	15.2	13.1	11.2	19.0	11.8

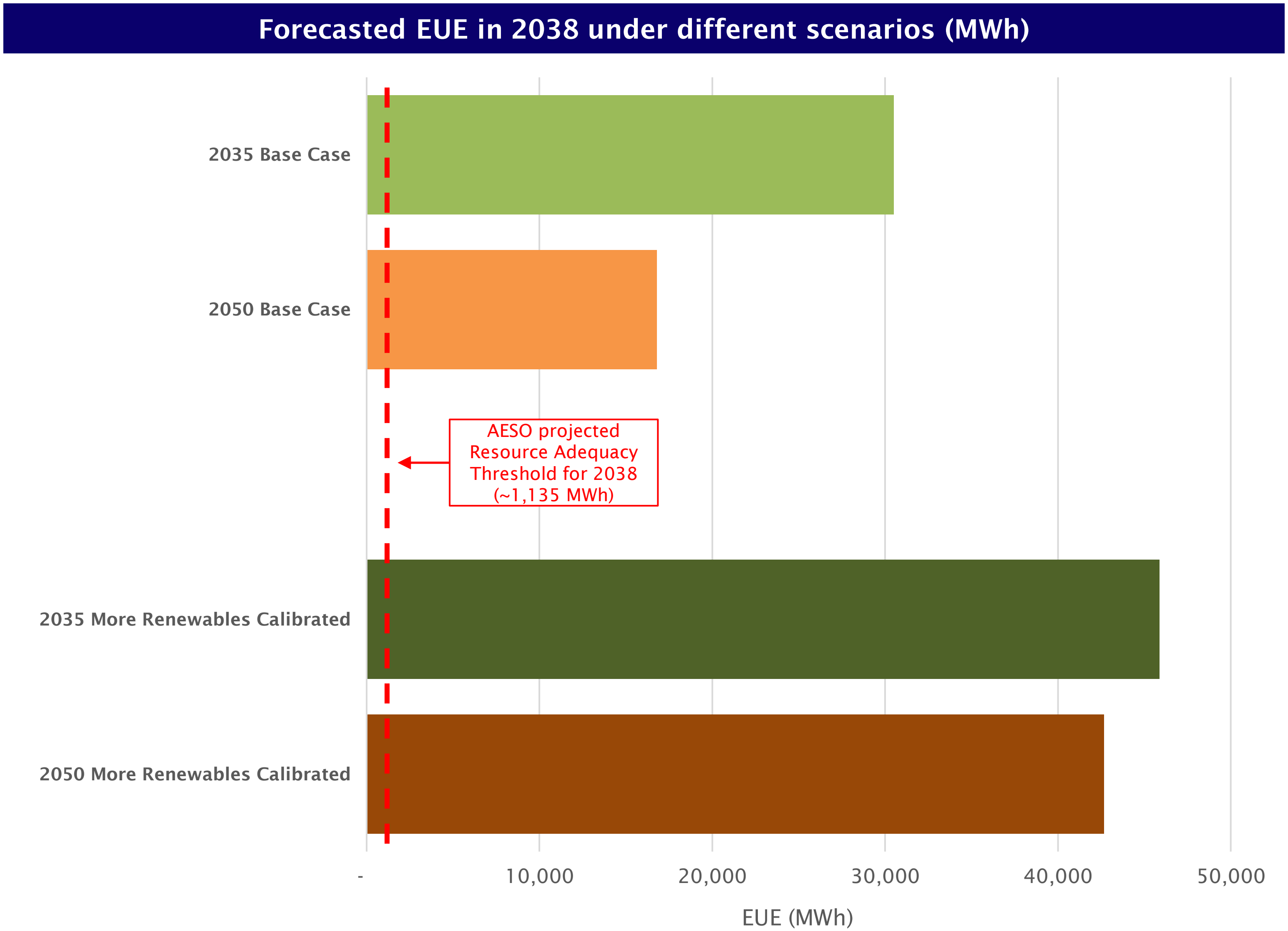
Worst 5% hours** average unserved load (MW)	2025	2030	2035	2038	2040
2035 Base Case	981	815	971	1,034	985
2050 Base Case	1,088	1,045	1,043	1,245	1,208

Worst 5% hours** average % of demand unserved (%)	2025	2030	2035	2038	2040
2035 Base Case	8.3%	6.7%	7.5%	7.9%	7.2%
2050 Base Case	9.3%	8.7%	8.1%	9.4%	8.7%

* Note 1: In 2025, modeled EUE for the 2050 Base Case is higher than the threshold value published in the AESO's November 2023 Long-Term Adequacy ("LTA") Report – this is because LEI's 2050 Base Case assumes over 3 GW of coal-to-gas unit retirements by 2025, while AESO's November 2023 LTA only assumes 820 MW of coal unit retirements.

** Note 2: The 5% worst events are measured for average unserved load duration, average unserved load MW, and % of demand unserved; these do not necessarily correspond to the same events – some events may be long but with small MW unserved, other events may be short but with large MW unserved.

LEI's More Renewables Calibrated Cases are projected to result in lower levels of supply adequacy (higher levels of EUE), because lower profits in the energy market result in less CCGT new entry / earlier retirements



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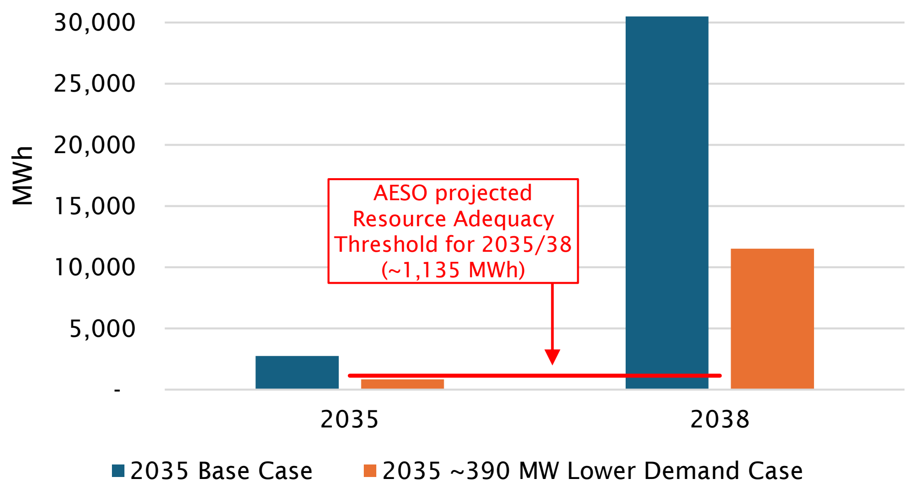
Holding supply conditions constant, lower demand results in better reliability; however, in 2038, the 2035 ~390 MW Lower Demand Case still results in reliability that is worse than the AESO's current standard

- **A negative demand shock of 3.5% reduces the EUE in the Decarbonization by 2035 scenario materially**
- **In 2035, EUE decreases from 2,754 MWh to 857 MWh, bringing the EUE in the 2035 ~390 MW Lower Demand Case to below AESO's projected Resource Adequacy Threshold**
- **In 2038, EUE decreases from 30,491 MWh to 11,524 MWh under the 2035 ~390 MW Lower Demand Case, which is still significantly higher than the AESO's projected Resource Adequacy Threshold**
  - An estimated additional 800 MW of demand reduction over the 2035 ~390 MW Lower Demand Case (i.e., ~1,200 MW over the 2035 Base Case) is needed to reduce the EUE to below the Resource Adequacy Threshold

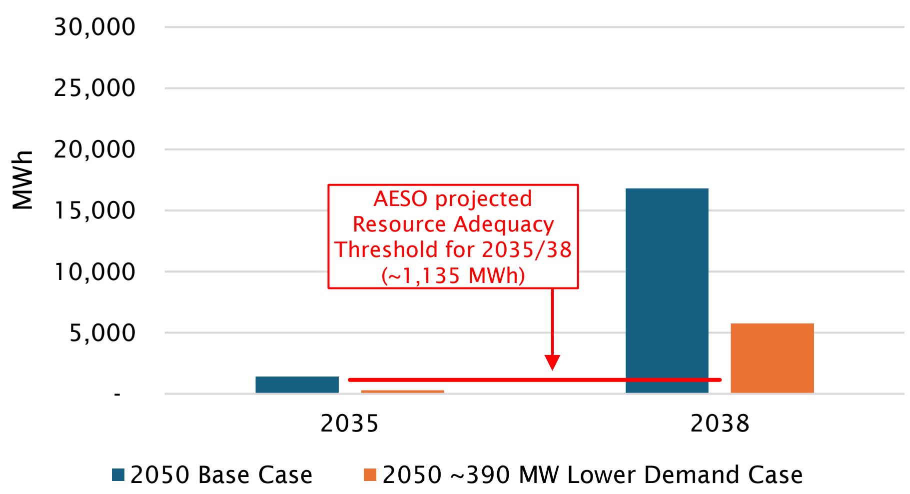
Modeled EUE, Decarbonization by 2035 (MWh)



Similarly, in 2038, the 2050 ~390 MW Lower Demand Case still results in reliability that is worse than the AESO's current standard

- **In 2035, EUE decreases from 1,420 MWh to 308 MWh, bringing the EUE in the 2050 ~390 MW Lower Demand Case to below AESO's projected Resource Adequacy Threshold**
- **In 2038, EUE decreases from 16,793 MWh to 5,755 MWh under the 2050 ~390 MW Lower Demand Case, which is still significantly higher than AESO's projected Resource Adequacy Threshold**
  - An estimated additional 550 MW of demand reduction over the 2050 ~390 MW Lower Demand Case (i.e., ~850 MW over the 2050 Base Case) is needed to reduce the EUE to below the Resource Adequacy Threshold

Modeled EUE, Decarbonization by 2050 (MWh)



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Glossary of key terms

AESO's Resource Adequacy Threshold: The AESO develops a Long Term Outlook every two years to forecast electricity demand and generation over a 20-year horizon to inform its long-term plans. The LTO monitors resource adequacy through a Resource Adequacy Threshold. This analysis is conducted for information and planning purposes only – there is no mechanism for the AESO to procure new generation even if reliability risk is found to exceed the threshold.

AESO's Supply Adequacy Shortfall Metric: While the Alberta energy-only electricity market has no mandated reliability targets, the AESO is still required to report on long-term (2 year) resource adequacy metrics on a quarterly basis. If the AESO identifies a two-year probability of supply adequacy shortfall, the AESO may take specific preventative actions, including procuring load shed services, back-up generation, or emergency portable generation.

Expected unserved energy ("EUE"): EUE is a metric to estimate the level of supply adequacy of an electric grid. It is the estimated average MWh of unserved energy in a year.

Load shed: As a result of unserved load, a system operator would have to shed some load – which means that some customers will not have electricity for some period of time. In the industry, this is sometimes also referred to as a "rolling blackout".

Rolling blackout: A rolling blackout entails the system operator intentionally cutting electricity to some customers in order to balance supply and demand. A rolling blackout is therefore a partial outage of the electric system – in contrast with a system-wide blackout, where the entire system is on outage.

Supply adequacy: Supply adequacy is having enough electricity generation supply to meet hourly demand, taking into account planned and unplanned outages and other factors that may impact demand or supply. Supply inadequacy is one cause of poor system reliability.

System reliability: System reliability is broader than supply adequacy and includes elements such as inertia and frequency support. In other words, supply adequacy is a component of system reliability. Other components of system reliability include the ability to continuously balance supply and demand and maintain adequate inertia and frequency on the grid.

Unserved load/unserved energy: Unserved load (or unserved energy) refers to instances where not all customers' electricity demand can be met, regardless of price. It can be measured in MWh or % of annual demand not met, which is the amount of demand that is not served when the system runs out of available supply to provide electricity to all customers.

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