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Assessing Alberta's Future Reliability Challenges

July 12, 2017

DRAFT FOR DISCUSSION

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Outline of presentation

- Overview of the AESO's Straw Alberta Market (SAM 1.0) proposal
- Discussion of how adequacy is measured
- Overview of supply adequacy modeling
- Discussion on need for transparency in modeling inputs
- Discussion of Reserve Margin and how the appropriate standard is calculated
- Discussion of effective capacity: what is it, and why does it matter
- Overview of PowerEn's modeling results, and how they relate to history
- Conclusions

The AESO's Straw Alberta Market (SAM 1.0) proposal

- The AESO SAM 1.0 Proposal:
  - Resource Adequacy Criterion to be set by Government of Alberta
  - Assumed criteria will by physical resource adequacy criterion
  - AESO proposing Expected Unserved Energy or NEUE and Loss of Load Hours LOLH
- EUE/NEUE: Energy centric measure that measures unserved energy load.
  - Relates well to Value of Lost Load and cost to society of unreliability
- LOLH: No. of Hours during a time period where supply insufficient to meet demand.
  - Relates well to fixed cost recovery for generators.
- SAM 1.0:
  - **"AESO will use a probabilistic resource adequacy model to translate the LOLH and or EUE into a target volume for capacity."**
  - **"All resources, regardless of their eligibility to participate in the capacity market, will be included in the resource adequacy modeling to determine the total volume of capacity to be procured in the market."**

How is adequacy measured?

- **There are several ways to measure adequacy:**
  - Loss of Load Probability (LOLP) – likelihood of supply shortfall (%)
  - Loss of Load Expectation - expected # of supply shortfall events per year
  - Loss of Load Hours - expected # of supply shortfall hours per year
  - Loss of Energy Expectation (LOEE or EUE) – expected unsupplied load (MWh/yr)
  - Normalized Expected Unserved Energy(NEUE) – expected % of total load that is unserved
  - Reserve Margin – measure of supply cushion based on the ratio of installed capacity above peak demand to peak demand

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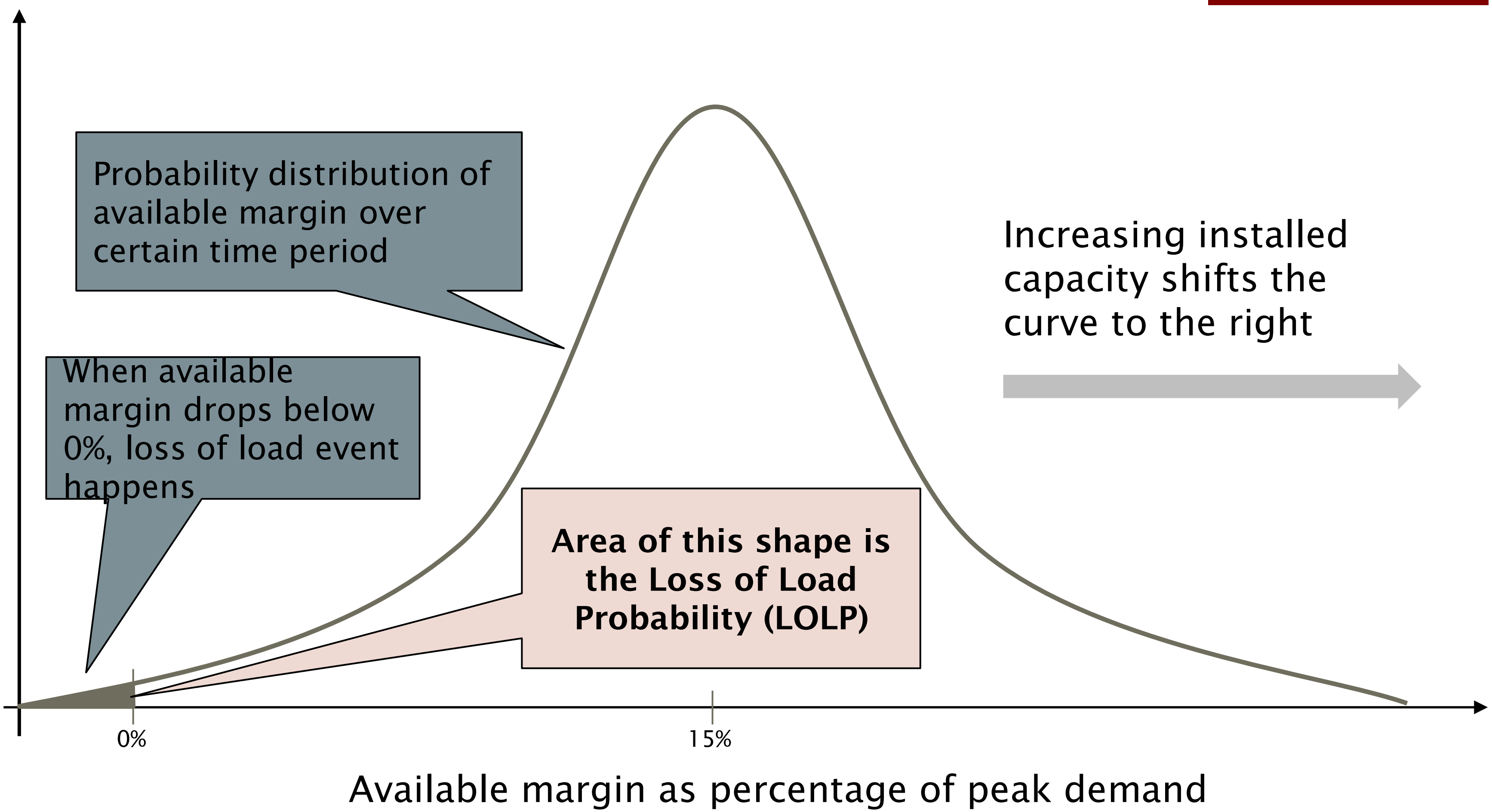
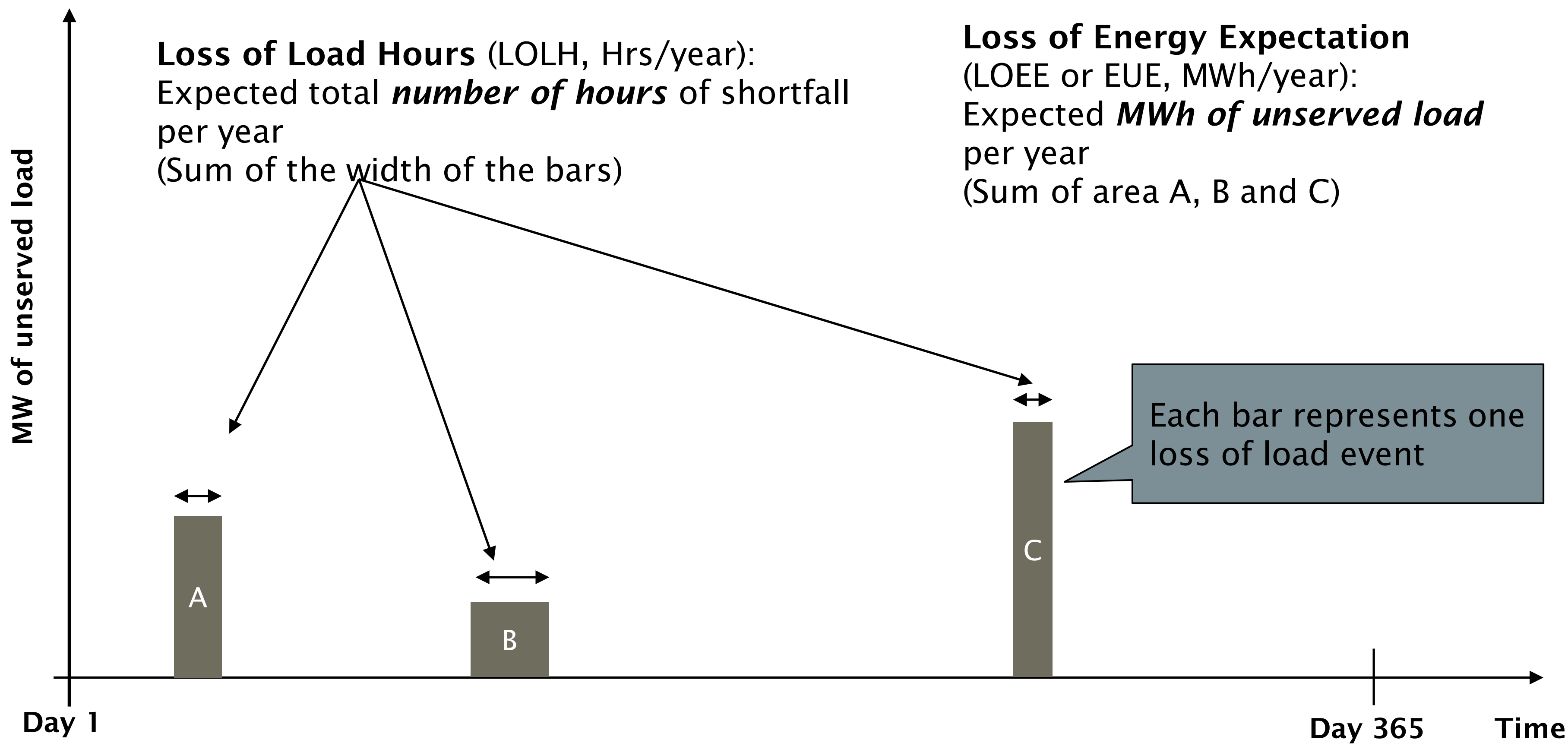
Loss of load probability (LOLP)



LOLH (hours/year) and LOEE or EUE, (MWh/year):



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Which adequacy metric should we use?

- **There are historical LOLH targets (e.g., 1 day in 10 years or 2.4 hours/year).**
- **LOLH relates to frequency of price spikes and expected fixed cost recovery in energy market.**
- **The AESO has historically looked at Reserve Margin and LOEE/EUE.**
  - The AESO's most recent 2016 LTO was based on meeting a 15% reserve margin without consideration of interties. The 2014 LTO was based on 15% - 25%.
  - The AESO's Long Term Adequacy (LTA) has a LOEE threshold (~800 MWh/yr) is based on an LOLH of 1 day in 10 years.

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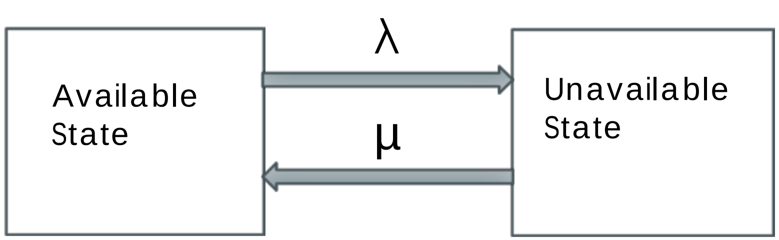
The models used to determine adequacy are highly complex

- **LOLH, LOEE, EUE and NEUE are probabilistic measures of adequacy and are outputs of stochastic models of future system operation.**

- **<u>LOLH, LOEE, EUE and NEUE are not independent measures.</u>**
  - Supplies can fail, be de-rated, be unavailable due to planned maintenance or other constraints and loads can be higher or lower than forecast or the hourly load profiles can differ from forecast
  - **<u>Markov models</u>** are used to model the random nature of generator forced and unplanned outages and create scenarios of the capacity that is available from each generator in each hour over a year.
  - **<u>Monte Carlo simulations</u>** create hundreds of possible (and equally probable) scenarios of hourly supplies and demand. Hourly supply is matched to hourly demand to predict the frequency, duration and magnitude of supply shortfalls over a year. LOLH and LOEE/EUE are <u>averages</u> of what is encountered after running many simulations.
  - Special models are needed for wind, hydro and other supplies that have special constraints on dispatch.

Two state Markov models of conventional generators

- In any hour each generator can be in one of two states: **available** or **unavailable**
- Transitions between available and unavailable states that are caused by forced or unplanned outages are random events.
- The probability that a generator that is available will become unavailable due to a forced or unplanned outage in the next hour is governed by the failure rate **(λ)** expressed in failures per hour.
- The probability that a generator that is unavailable due to a forced or unplanned outage will become available in the next hour is governed by the repair rate **(μ)** expressed in repairs per hour.
- The long term probability of being in the available state factoring in planned maintenance and adjusting for de-rates is the availability of the generator.
- Each generator is modelled with a separate Markov model



Monte Carlo simulations

- Conventional generators are modeled with two state Markov models that probabilistically transition between the available state and unavailable state in each hour over a year. Simulations create scenarios of possible hourly sequences of all generator states over a yr.
- If aggregate supply is less than demand in an hour a supply shortfall occurs
- No. of shortfall hours in each year is determined: Average over many simulations is LOLH
- Sum of energy shortfalls in each year is determined: Average over many simulations is EUE

Hour	G1 (100 MW)	G2 (200 MW)	G3 (50 MW)		Total Supply Available (MW)		Load (MW)		Supply Surplus
1	100	200	50		350		250		100
2	100	0	50		150		200		-50
3	100	0	50		150		150		0
4	100	200	0		300		200		100
5	100	200	50		350		250		100
6	0	200	50		250		220		30
7	0	200	50		250		220		30
8	0	200	50		250		260		-10
9	100	200	50		350		270		80
10	100	0	0		100		240		-140
11	100	0	0		100		160		-60
12	100	0	50		150		110		40
13	100	200	50		350		110		240
14	100	200	50		350		120		230
15	.	.	.		.		.		.
16	.	.	.		.		.		.
								LOLH: (Hrs)	4
								Unserved Energy (MWh)	260

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Since the models are complex with lots of inputs, transparency is critical

- **Models predict adequacy and capacity requirements based on many input assumptions that affect study results. Transparency is critical to test study results**
  - **Load forecast parameters:**
    - Annual energy
    - Peak demand
    - Hourly load profile (and any variations considered)
  - **Generator parameters**
    - Installed capacities, additions, retirements
    - Availabilities
    - Forced + unplanned Maintenance Outage Rates,
    - Mean Times To Repair, Repair rates
    - Seasonal de-rates and
    - Planned maintenance assumptions. (Durations and Schedules)
  - **Customized hourly models of wind and hydro and other supplies that have constraints on dispatch**
  - **Hourly models of Intertie Available Transfer Capabilities, capacity behind the interties and other constraints**
  - **Assumptions around transmission constraints**

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What is Reserve Margin?

- **Reserve Margin = (Effective Capacity – Peak Demand)/Peak Demand**
- Reserve Margin is a measure of supply cushion or amount of installed generation capacity over peak demand in relation to peak demand.
- Higher Reserve Margins are generally associated with lower LOLH, LOEE/EUE.
- Not all generation capacity is equally <u>effective</u> in changing LOLH, LOEE/EUE.
- Relationship between Reserve Margin and LOLH, LOEE/EUE, and NEUE is dependent on specifics of the supplies (generation mix, interties) and demand (hourly profile) on the system.
- **<u>What is appropriate for other jurisdictions may not be appropriate in Alberta</u>**
  - Higher Reserve Margins are often required to achieve comparable levels of reliability if;
    - Systems are small
    - Systems have a less reliable mix of generation sources.
    - Systems have high average loads relative to peak load

What is Effective Capacity and why is it important?

- Effective capacity measures an assets contribution to supply adequacy in terms of the installed capacity of an equivalent *fully dispatchable* generator.

- Effective capacity calculations are needed to determine contributions to system adequacy of suppliers which face special constraints on dispatch such as the interties, hydro and wind generators.

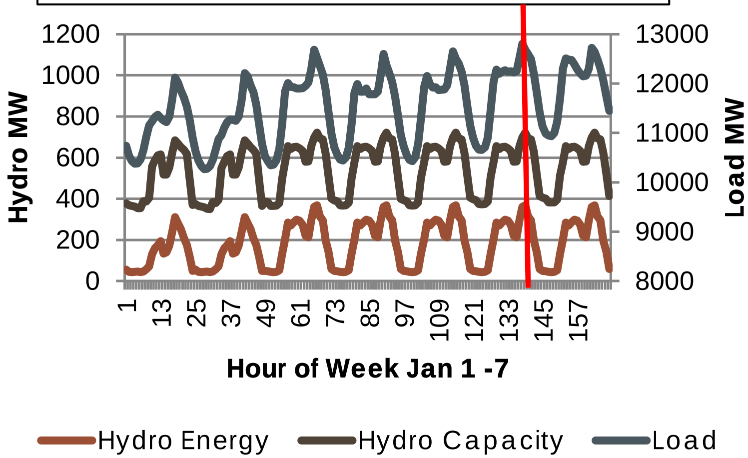
  - It is worth noting, the AESO's LTA assumes the effective capacity of large hydro is 75% of installed capacity and wind has no effective capacity**.**

- Effective capacity is determined by what *fully dispatchable* replacement generation would be needed to maintain reliability (LOLH) at a constant level if the asset were removed from the system.

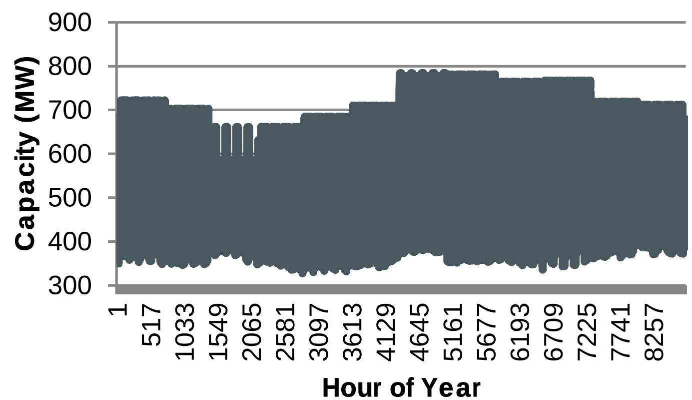
- PowerEN has tested the effective capacity of some key resources in Alberta

Effective Capacity of large hydro in Alberta

Hydro capacity aligned with demand



Hourly Hydro Capacity: Annual Energy Prod 1644 GWh

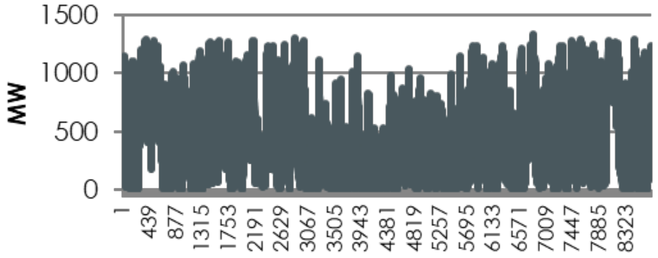


Installed Capacity (MW)	Effective Capacity (MW)	Effective Cap as Percentage of Installed Capacity
790	700 - 790	88% - 100%

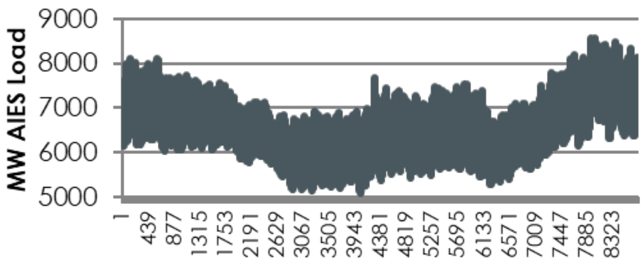
Average Energy Output (MW)	188
Average Capacity (MW)	540
Maximum Capacity (MW)	784

Effective Capacity of aggregate wind in Alberta

2015 Aggregate Wind Generation

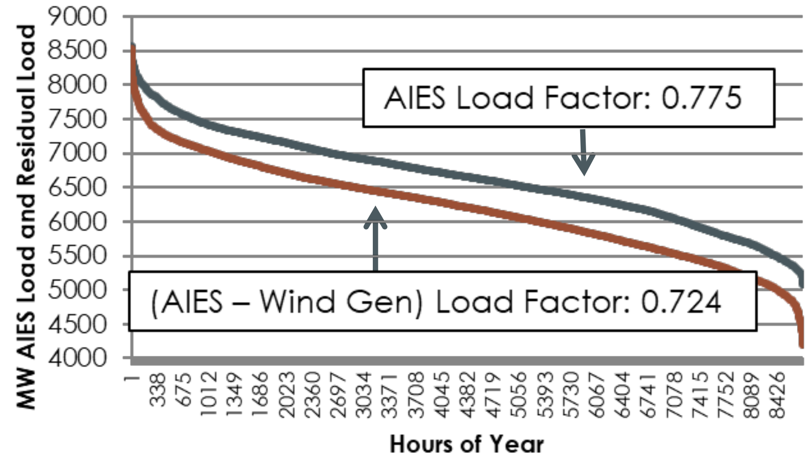


2015 Hourly AIES Load



Wind generation is a modifier of residual demand

2015 AIES Load Duration and AIES –Wind Duration



Year	Modeled Aggregate Installed Wind Gen (MW)	Effective Capacity (MW)	Effective Cap as % of Installed Capacity
2021	2425	265 - 289	11% - 12%
2026	3625	384 - 388	11%
2031	3925	405 - 457	10% - 12%

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Effective Capacity of interties

- Is limited by (1) Available Transmission Capability, and (2)the availability of generation behind interties.
- BC/MATL joint constraint modelled.
- May be further limited by need to carry additional contingency reserves if imports become larger than the contingency reserves normally carried for internal generation and load.

Year	All Interties	BC Intertie	MATL Intertie	Sask Intertie
2021	740-744 MW (45% TTC)	644 – 650 MW (54% TTC)	12 - 15 MW (4% TTC)	150 – 153 MW (100% TTC)
2026	761 – 777 MW (46% TTC)	644 – 650 MW (54% TTC)	8 – 12 MW (3% TTC)	115 – 118 MW (76% TTC)
2031	743 – 780 MW (46% TTC)	631 – 650 MW (53% TTC)	6 – 12 MW (3% TTC)	85 – 107 MW (63% TTC)

Intertie	Assumed Generation Capacity behind Tieline	Assumed Availability of Generation behind Tieline
BC	650	95%
MATL	300	Wind with 35% Cap. Factor
Sask	153	100%

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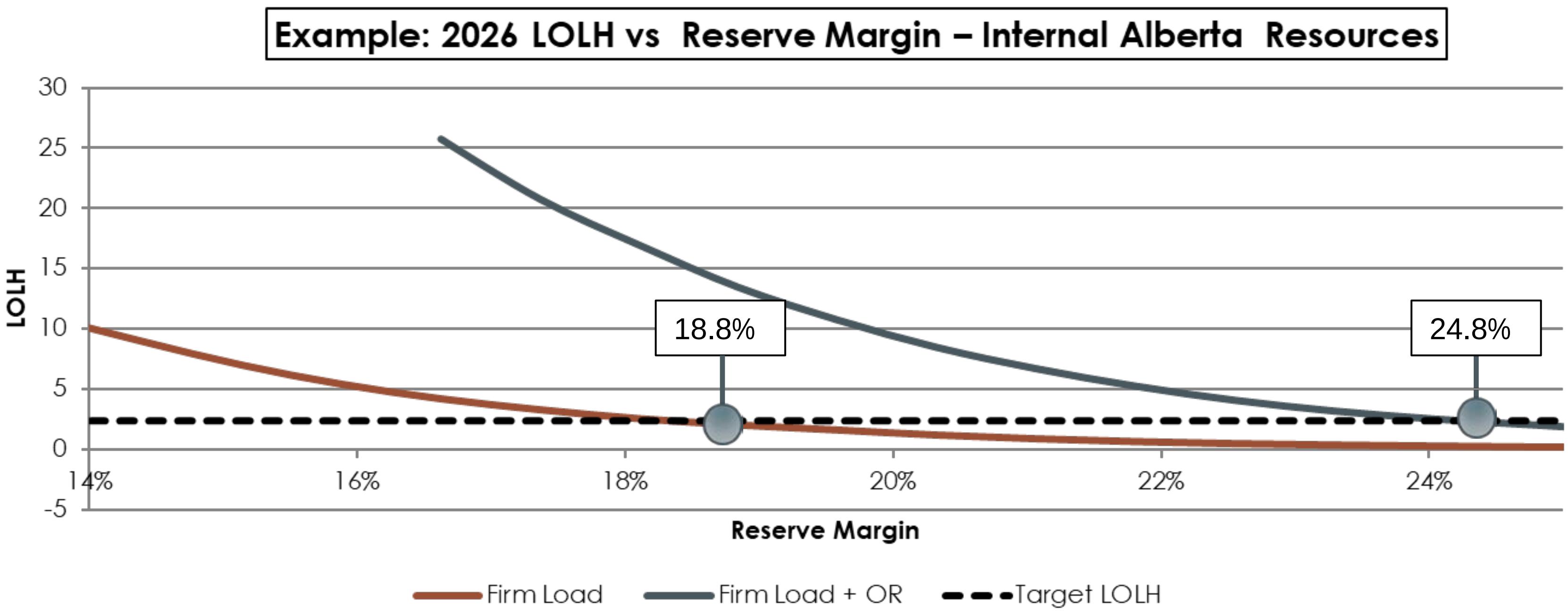
LOLH and Reserve Margin do not have a linear relationship

- LOLH increases more on a reduction in Reserve Margin than it decreases for an equal increase in Reserve Margin.



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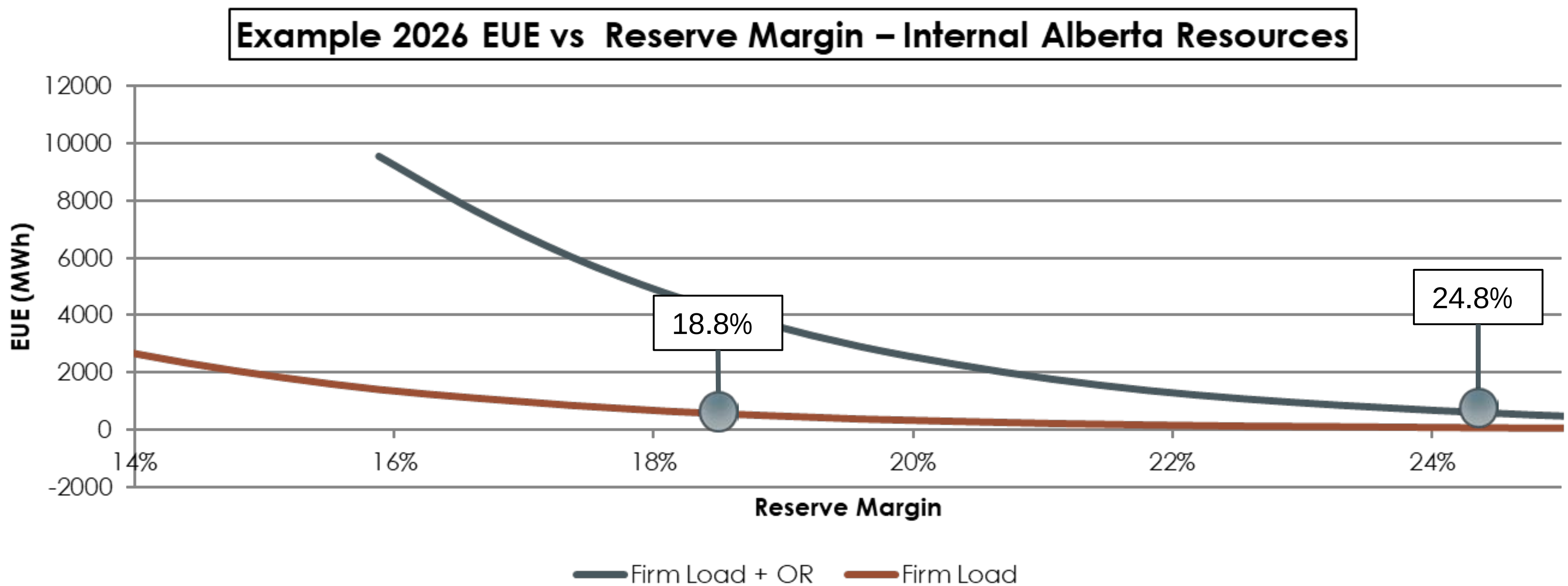
EUE at LOLH target of 2.4 hrs/yr approx. 700 MWh/Yr

- EUE increases more on a reduction in Reserve Margin than it decreases for an equal increase in Reserve Margin.



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Our forecast of Reserve Margin to meet a LOLH target of 2.4 Hrs/Yr

- Reserve Margin required from resources internal to Alberta

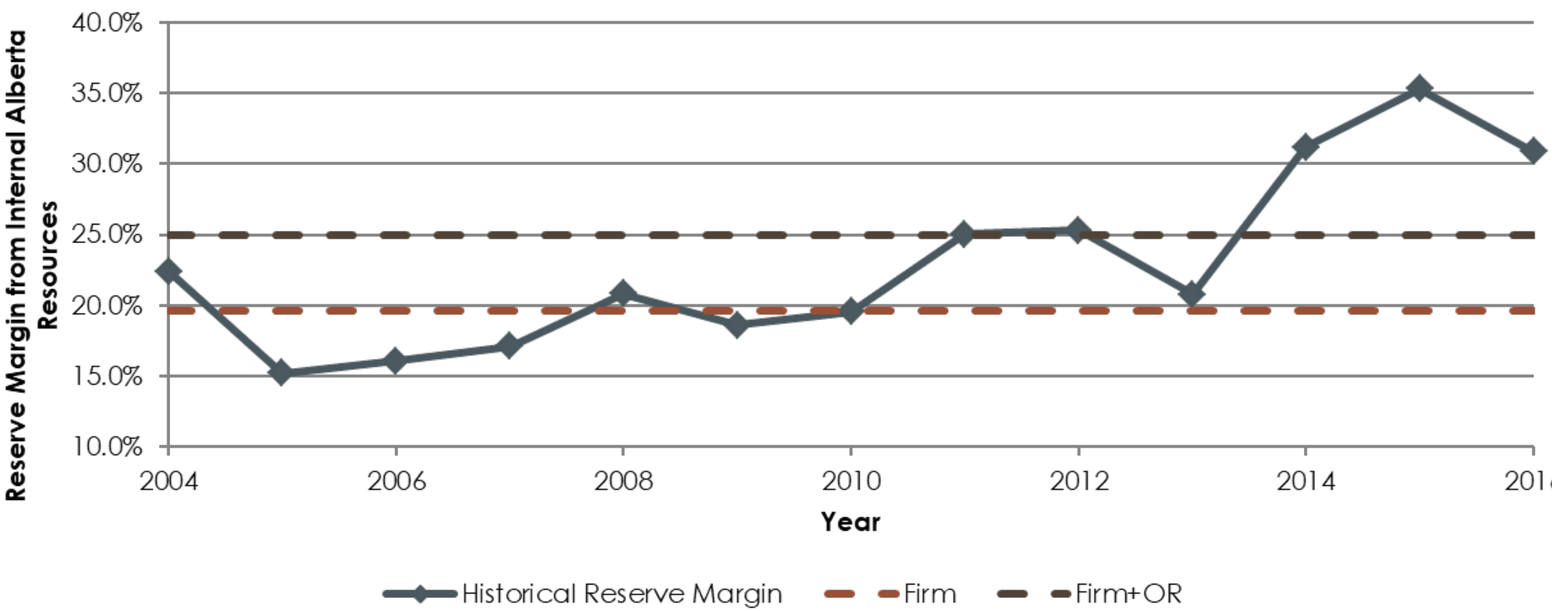
Year	Reserve Margin to meet Firm Load	Reserve Margin to meet Firm Load + Oper. Reserve
2021	19.8%	Approx. 19.8% **+6%** = 25.8%
2026	18.8%	Approx. 18.8% **+6%** = 24.8%
2031	20.4%	Approx. 20.4% **+6%** = 26.4%

- Reserve Margin required from interties and resources internal to Alberta

Year	Reserve Margin to meet Firm Load	Reserve Margin to meet Firm Load + Oper. Reserve
2021	25.6%	Approx. 25.6% **+6%** = 31.6%
2026	24.5%	Approx. 24.5% **+6%** = 30.5%
2031	25.8%	Approx. 25.8% **+6%** = 31.8%

How does this compare to historical values?

- **Historical Reserve Margin <u>from Internal Alberta Resources</u>: 15% to 35%**
- Required to meet LOLH target (2.4 Hr/Yr)for <u>firm load</u> shortfalls: **19% - 20%**
- To meet LOLH target for <u>firm load and operating reserve shortfalls</u>: **25% - 26%**



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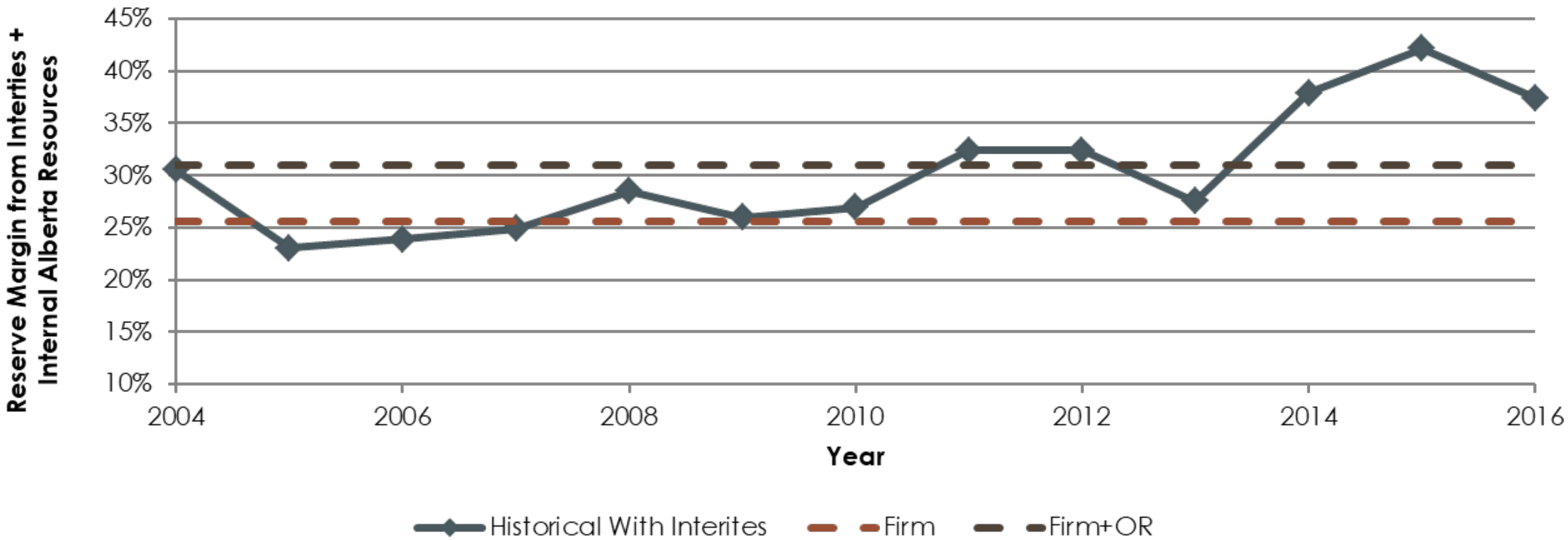
How does this compare to historical values?

- **Historical Reserve Margin from <u>Interties plus Internal Alberta Resources</u>: 23% to 42%**
- Required to meet LOLH target (2.4 Hr/Yr)for <u>firm load </u>shortfalls: **25% - 26%**
- To meet LOLH target for <u>firm load and operating reserve </u>shortfalls: **31% - 32%**



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Conclusions

- Determining what the appropriate 'effective capacity' is for suppliers which face special constraints on dispatch such as the interties, hydro and wind generators is critical.
  - Our modeling suggests the Effective Capacity of both hydro and wind is higher than the AESO's LTA assumptions.

- We used LOLH as a metric for system adequacy and assumed a '1 day in 10 year' reliability standard (i.e. 2.4 hours of demand interruptions on average per year).

- This suggests a reserve margin reliability standard, i.e. target reserve margin, of 19-20% from resources internal to Alberta and 25-26% for the combination of internal and external resources.

- The target reserve margins would be approximately 6% higher to limit shortfalls of operating reserves to 2.4 hrs/yr on average.

- Historically, the actual reserve margin from resources internal to Alberta has fluctuated between 15-35% since 2004. The actual reserve margin from the total resources, both internal and external to Alberta, has fluctuated between 23-42% since 2004.

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PowerEn modeling assumptions

- AESO 2016 LTO low load forecast/ 2015 AIL Load shape
- Generation additions: Existing + Under construction
- New generation needed to meet LOLH targets: CCGT with 85.5% availability
- Retirements: SD1,SD2,BR3,BR4,HRM – Other coal converted to gas
- Generator availability: Existing coal: Estimated, Other Thermal: NERC stats for similar generator types
- Planned maintenance schedule: Estimated Proxy Schedule
- Wind: Installed Capacity in 2026: Assumed to be 3625 MW
- Wind generation capacity factor 35%
- Large hydro: Long Term average water year of 1644 GWh
- No transmission congestion
- Intertie Available Transmission Capability – similar to 2015
- Reserve Margins Calculated as ((Total Installed Capacity – Hydro – Wind + 11% of Installed Wind Capacity + 95% of Large Hydro + 750 MW Capacity on Tielines)- Peak Demand)/Peak Demand