Pricing framework review

April 9, 2020

Public

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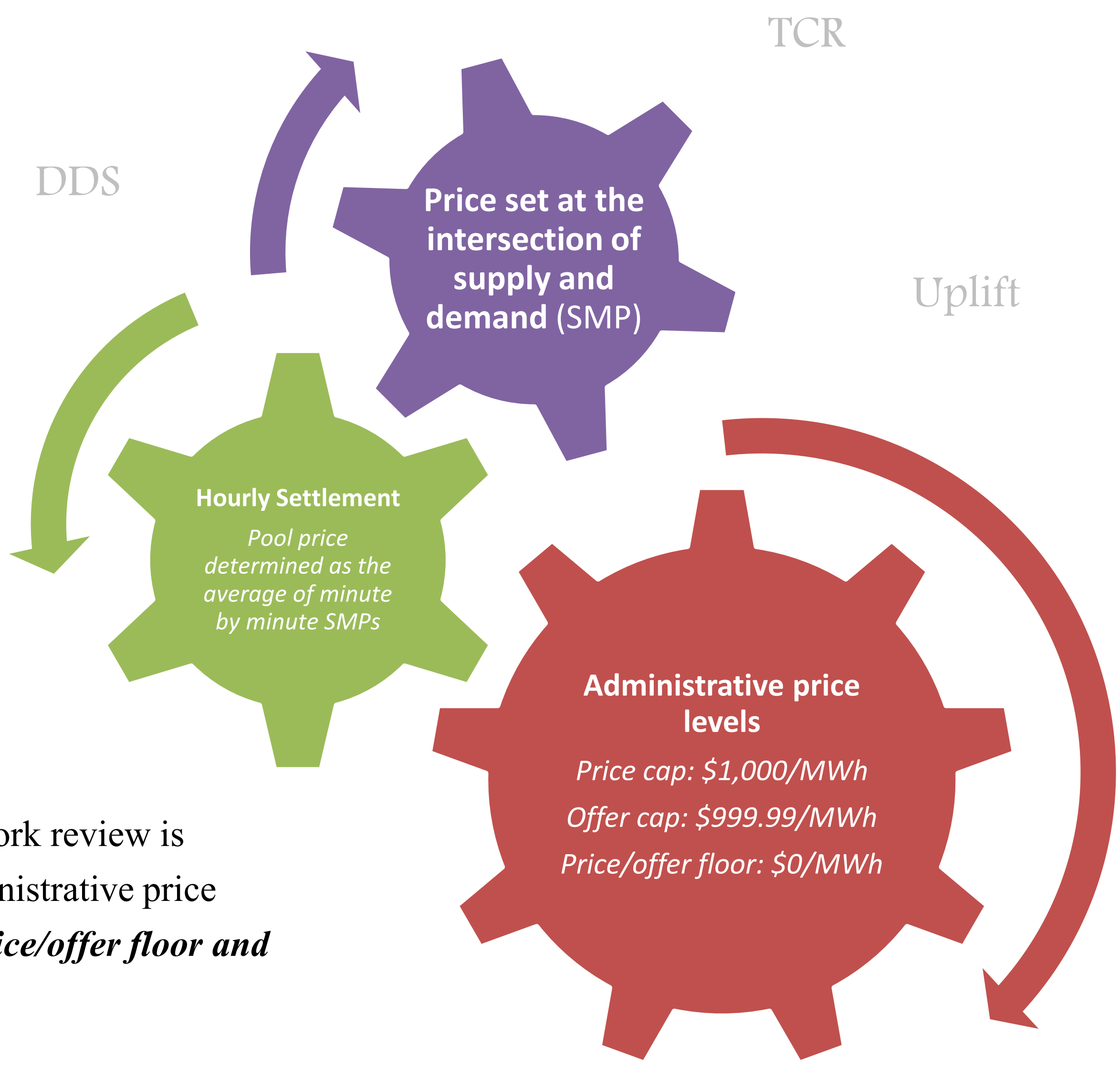
AESO Stakeholder Engagement Framework

Agenda

- Recap previous session
- Review efficiency of short-term market response during shortfall/surplus conditions
- Jurisdictional review

Session 1 Recap

Alberta's energy pricing framework



The pricing framework review is focused on the administrative price levels: ***price cap, price/offer floor and offer cap***

Session 1 recap

- Review of AESO's long term resource adequacy assessment
  - Found that Alberta's existing pricing framework did not appear to be a barrier to resource adequacy
  - No change to the ***offer cap*** required at this point in time
- Presented information on the intent of the pricing framework in Alberta
- Requested stakeholders to provide feedback – in response to the feedback received a few modifications to the purpose of the price cap and offer cap were made in the following slides

Purpose of offer cap

- Offer cap protects consumers
  - May help address potential market power issues resulting from concentration of generation ownership and relatively inelastic demand for electricity - a form of market power mitigation
- Allows suppliers the ability to reflect their variable operating costs
- In the current Alberta structure, allows for reasonable opportunity to recover fixed costs over the long term which include a return on capital
  - Mechanism for ensuring supply adequacy

The offer cap should provide a reasonable opportunity for the marginal generating asset to recover its fixed costs over the long term, and in the short term not prevent a resource from recouping its variable costs

Purpose of price cap

- Indicate that the market is in a shortage condition
- Limit excessive wealth transfer from consumers to producers
- Incent efficient demand response during shortage events
- Incent additional supply response during shortage events
- May also provide an administrative mechanism to allow for a portion of fixed cost recovery

Efficiency issues may occur if prices cannot reach levels sufficient to reflect the shortage of supply or the willingness-to-pay of demand

Purpose of price floor

- The level of the price floor can help to mitigate risk to producers of sustained negative pricing
- The price floor should allow for efficient pricing during supply surplus events

Efficiency issues may occur if the price floor impedes the ability of market based clearing in supply surplus events

Stakeholder feedback approach

- General alignment with the AESO's objectives
  - AESO should develop a longer term vision, or end state, for the energy-only market
  - Ensure that the market sends the right signals for flexibility
  - Consider aligning pricing framework with other jurisdictions
- Majority support the existing scope definition
  - Relies on assumption regarding market power mitigation
  - Some stakeholders would prefer a broader scope
    - Include SCUC, SCED, co-optimization, OR review in review
- Stakeholders would prefer to receive materials earlier in order to better prepare for meaningful discussion

Stakeholder feedback
pricing and revenue sufficiency

- General alignment with the descriptions of the offer cap, price cap, and price floor
  - Avoid arbitrary levels, identify an objective metric
  - Be aware of revenue sufficiency issues if negative prices are considered
  - Consider how prices impact the forward market liquidity
  - Be aware of impact on market risk and corresponding financing costs, especially relating to swaps
- General acceptance of the AESO’s forward-looking and historical resource adequacy assessments with exceptions
  - Difference of opinion regarding input assumptions, including volume of future renewables and emerging technologies
  - Be more transparent with modelling details

What are we trying to achieve through our pricing framework?

Energy pricing framework should ensure efficient and effective signals are provided to promote the following:

- Long term adequacy: through providing clear transparent signals on the need for capacity, and revenue sufficiency with reasonable expectations of recovery of capital and return on capital
- Efficient short-term market response: involves ensuring that the pool price creates the right signals for the market and administrative price levels do not hinder these signals, including:
  - Provide short term price signals to encourage flexibility and response from both supply and demand resources;
  - Provide self-commitment decision signals, and also provide a mechanism for the recovery of start-up and cycling costs;
  - Provide the signal for participants to import or export.

Efficiency during scarcity and shortage conditions

Establishing common language

- A supply **scarcity** situation occurs when available energy in the energy market merit order is greatly reduced or zero
- A supply **shortage** situation occurs when there is insufficient energy supply available to meet demand and maintain required reserve levels
  - Supply shortfall procedures are enacted per ISO rule 202.2
  - In these situations the system controller may use operating reserve to balance the system, or if required, shed firm load

Evaluating short-term response to scarcity and shortage conditions

- Hypothesis: The market operates more efficiently when participants can actively respond to price rather than when administrative mechanisms are used to clear the market. Prices must be allowed to rise high enough to ensure <u>short-term market efficiency and short-term supply adequacy</u>

Does the current *<u>price cap</u>* allow for efficient price signals to both supply and demand resources during scarcity/shortage events?

- Is the price cap high enough to allow:
  - Flexible demand to economically curtail;
  - Generators to commit/respond in short-term; and
  - Maximum import flow.

Supply shortfall procedure

- Supply shortfall procedure is enacted when there is insufficient supply to meet demand and maintain adequate operating reserves
- AESO assesses short term adequacy to determine the likelihood of a supply shortfall event in upcoming settlement periods
- When triggered, AESO system controllers follow a set of steps to maintain regulating reserves and avoid shedding firm load
  - Energy emergency alerts (EEA) are a way for the AESO to communicate across coordinating agencies and control centers
  - 4 states: EEA1, EEA2, EEA3 & EEA0

Energy emergency alert 1

- EEA1 declared after all available resources in the energy market have been used to meet AIES firm load
- Sufficient operating reserves intact - still have about 500 MW reserves
- Energy is imported through the interconnections with BC and Saskatchewan as per schedules
- Energy exports are curtailed to zero
- At this point AESO would issue a directive to customers who have Demand Opportunity Service (DOS) contracts to lower their demand on the system
- Any transmission maintenance that results in generation constraints is cancelled
- System marginal price (SMP) is set at last offered MW

Energy emergency alert 2

- All steps under Alert 1 have been taken
- Power service is maintained for all firm load customers
- Contingency reserve are being used to supply energy requirements – regulating reserve is maintained
- Load management procedures have been implemented, which may include voltage reduction
- A public communication may have been issued to request customers to voluntarily reduce demand
- Emergency energy has been requested of neighbouring control areas
- System marginal price (SMP) is set at last offered MW

Energy emergency alert 3

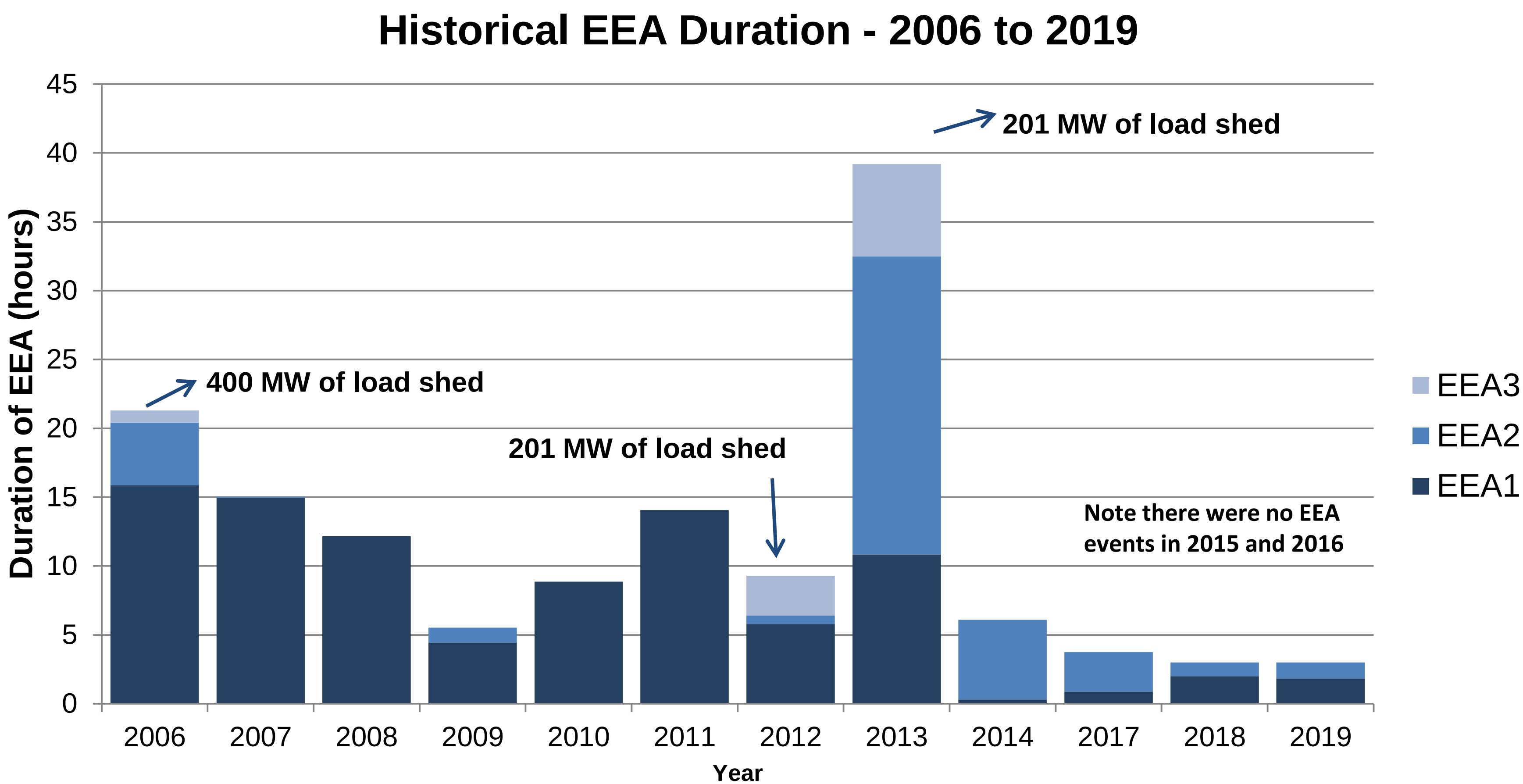
- All steps under Alerts 1 and 2 have been taken
- After receiving directives from the AESO system controllers, the transmission facility owners work with the distribution facility owners to curtail the directed amount of firm load
- Power service to some customers are temporarily interrupted to maintain the minimum required regulating reserve and the integrity of the overall system
- System marginal price (SMP) is set to $1000/MW

Energy emergency alert 0

- Termination of previous energy emergency alerts
- Energy supply is sufficient to meet AIES load and reserve requirements

Looking back frequency of EEA events

- From 2006 to now, there have been a total of 53 EEA events
  - 3 of these events saw firm load shed: 200 – 400 MW



Looking forward forecast tight supply hours

- The revenue sufficiency model was run for three representative future years: 2021, 2026 and 2031
  - In these years, expected unserved energy (EUE) events are comparable to past occurrences
- EUE results are on next slide, and compare to the threshold outlined in ISO Rule 202.6, 5(1)(a)

Forecast results

Scenario	EUE (MWh)	LOLH	Threshold MWh	Count of EEA Hours
2021 with DR	196	0.83	1,013	9.5
2021	486	2.01	1,013	19
2026 with DR	21	0.10	1,060	1.5
2026	61	0.27	1,060	3.8
2031 with DR	47	0.21	1,110	3
2031	120	0.55	1,110	6.7

- **Expected unserved energy (EUE):** magnitude (MWh) of expected load shed
- **Loss of load hours (LOLH):** expected number of hours within the simulation where firm load shed has been observed
- **Threshold MWh:** corresponds to the EUE threshold as outlined in ISO Rule 202.6
- **Count of EEA hours:** expected number of EEA hours, may not always correspond to firm load shed; hours with firm load shed are a subset of this field

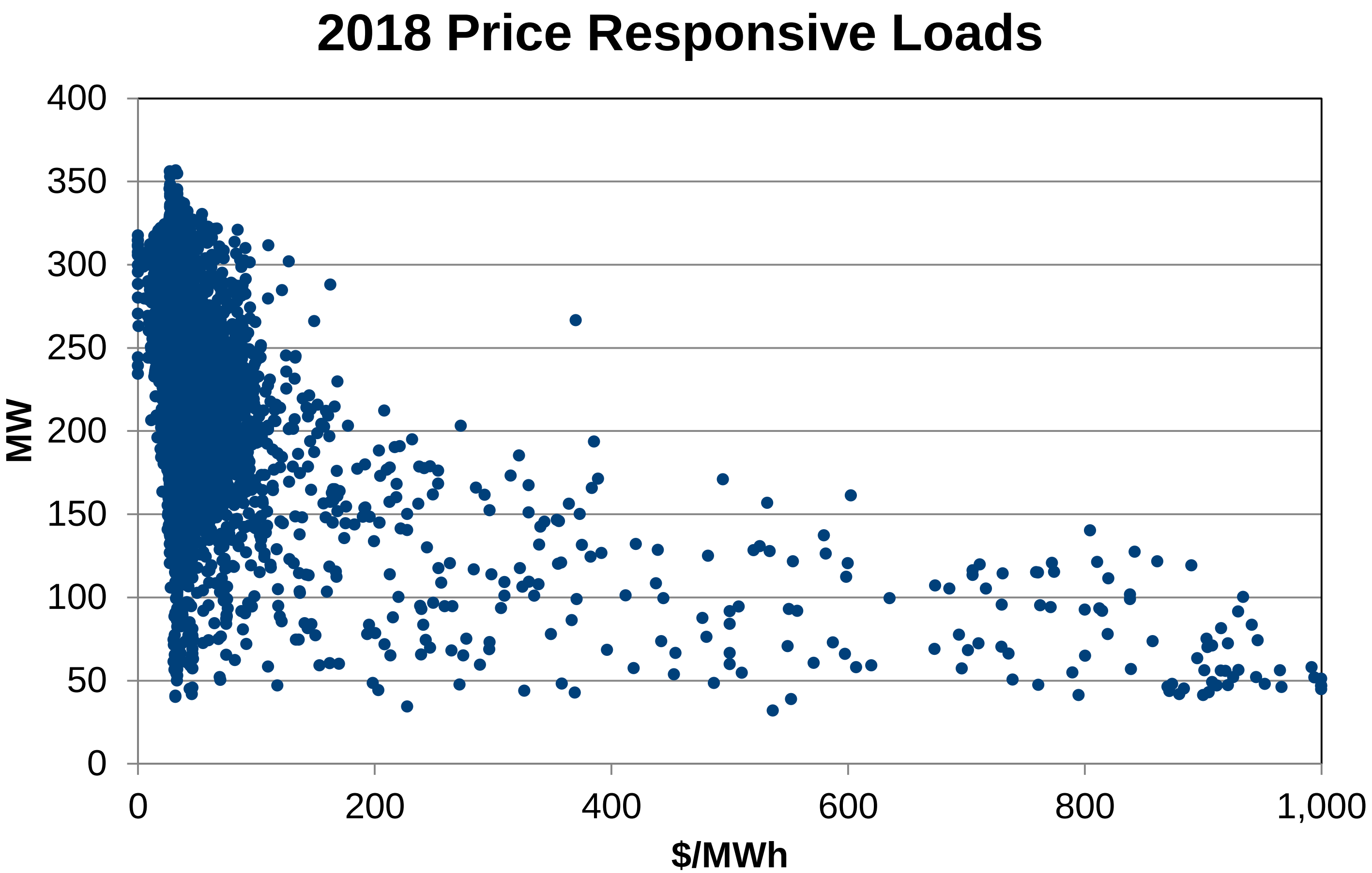
Demand response

Does the current price cap allow for efficient price signals for *demand* resources during scarcity/shortage events?

- Loads are sensitive to the delivered cost of energy
  - Includes both energy and tariff charges
- In Alberta, loads participate in the market through:
  - Voluntary price response to energy or tariff signals;
  - Participating in ancillary services: LSSi, Operating Reserves
- Voluntary load response to avoid tariff costs is observed with some loads in Alberta
  - Monthly coincident peak (12-CP)
  - Current bulk system charge is $10,524/MW/month

Historical price responsive load

- There are about 300 MW of load that currently respond within the existing pricing framework, suggesting that, at certain times, the value of their consumption may be below the current $1,000/MWh price cap



Methodology to determine demand response potential above $1,000/MW

- Analysis was performed using 2018 and 2019 data to identify sites that have been observed to respond to pool price and tariff signals (12-CP)
- Sites examined included all sites with average annual load of greater than 1 MW – over 450 sites
- Load sites that were responsive to both price and 12-CP were identified and studied through regression methods to determine the amount of load that is more responsive to the 12-CP price signal, and thus may reduce consumption in response to a higher price cap level

Demand response model results

- **Conclusion:** Approximately 40 MW of load at approximately 10 sites was identified as not responding to high price events but responding to 12-CP. This may be additional load that could respond at a higher price cap level.
- **Further analysis:**
  - Seek feedback on the effectiveness of a higher price cap to incent greater demand response during scarcity and shortage events
  - Response to tariff signals may not fully reflect response to the energy price
    - Tariff may be a weaker signal: Loads respond to the expected value of the coincident peak charge, not the nominal value (analysis may underestimate potential response)
      - *a load that reduces its consumption in 20 hours a month will face an average savings of $10,000/MWh / 20 hours = $500/MWh*
    - Tariff may be a stronger signal: Loads have the ability to hedge energy prices; they do not have the ability to hedge tariff costs (analysis may overestimate potential response)

Supply response

Does the current price cap allow for efficient price signals for *supply* resources to respond to scarcity/shortage events?

- Alberta has must offer/must comply requirements – physical withholding not permissible
- Assessment of amount of additional supply response at price cap determined through reviewing if additional response from long lead time assets (LLTA) or imports have been observed during previous scarcity and shortage situations to determine if price cap has been a barrier to additional supply response

LLTA historical response

Do LLTA's voluntarily enter the market in anticipation of or in response to price cap events if offline prior to the event?

- Long Lead Time Asset (LLTA): per ISO's consolidated authoritative glossary (CADG):
  - means a generating source asset that:
    - requires more than one (1) hour to synchronize to the system under normal operating conditions; or
    - is synchronized but has varying start-up times for distinct portions of its MW and which requires more than one (1) hour to deliver such additional portions of its MW; and
  - which is not delivering all of its energy for reasons other than an outage
- If price cap is a barrier, LLTA's may remain offline even when the price is at the cap because the price cap may provide insufficient revenues to cover costs/risk of starting
  - In this event, the AESO would need to resort to out of market tools to direct an LLTA into the market.

LLTA methodology

- To assess the historical response from 2015-2019, the analysis examined assets that exhibited long lead time behaviour in hours where:
  - Pool price was greater than or equal to $999.99/MWh; or
  - EEA events occurred.
- Available capability (AC) was compared at T-1 and T for a given high price ($999.99/MWh) or EEA event hour and classified as:
  - Online: unit had decided to run prior to the event and was available both before and during the event
  - Responded: unit made its LLTA energy available within 1 hour prior to or during the event
  - Did not respond: the unit was offline without an operational reason
  - Unavailable: unit was offline for maintenance or other operational reason

LLTA results

- From 2015 – 2019, there were 17 hours where pool price was greater than or equal to $999.99/MWh or an EEA event occurred
- During these events, LLTA's had an average availability of approximately 61%
- Reasons for being unavailable included:
  - Operational reasons which included forced or planned outages
  - Mothball outages

Conclusion:

- The current price cap does not appear to impede the operation of LLTA's. The analysis did not show any occurrences where an LLTA did not respond due to a reason other than an operational reason or mothball.

Considerations

- The AESO has never directed an LLTA online in the past – such a directive would need to occur well in advance to respect the start time for a given LLTA

BC & MATL import utilization

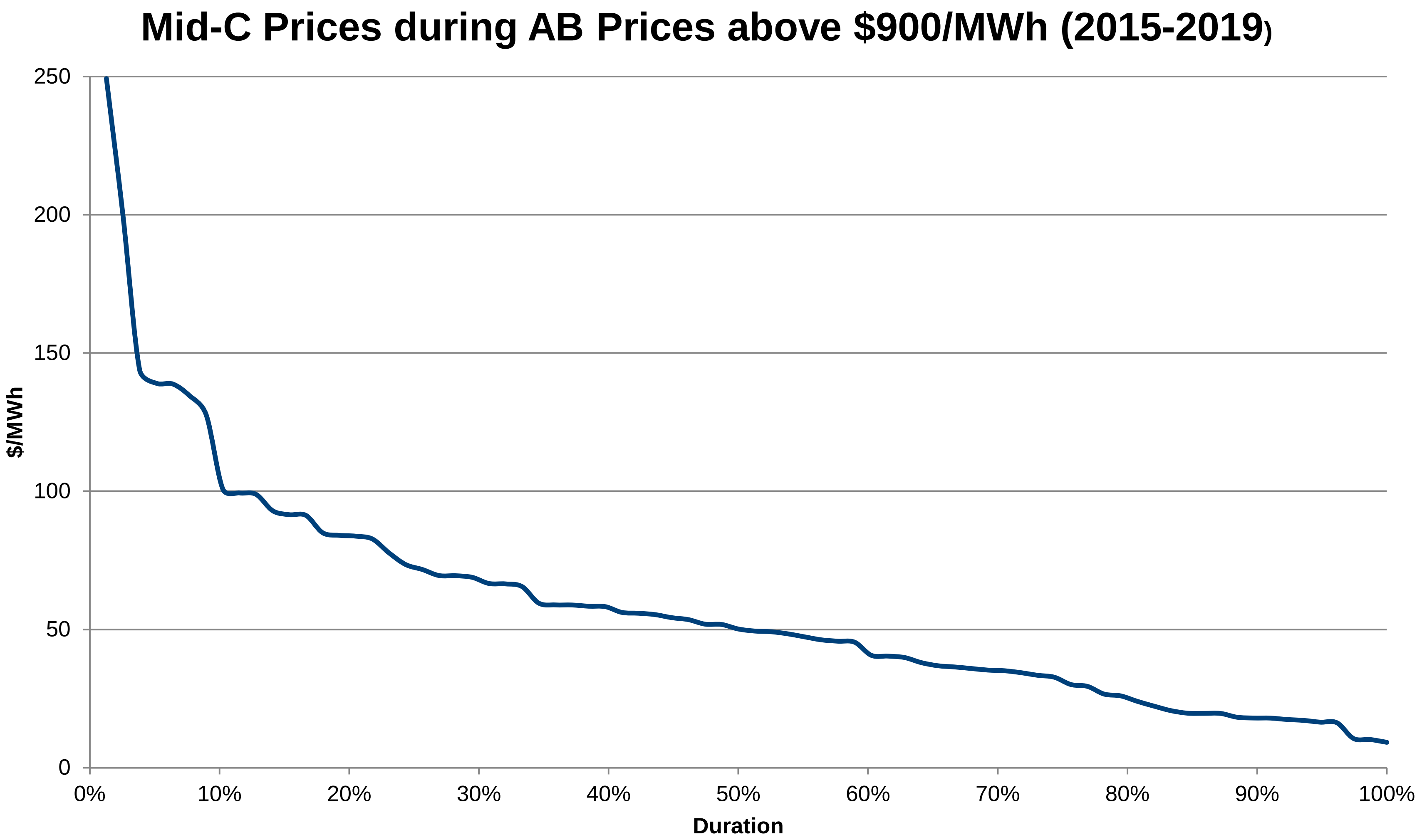
Does the current price cap provide sufficient incentive for the intertie to be fully utilized for imports during shortage or scarcity events?

Year	# of Hours		BC Average Utilization (%)		BC Import ATC (MW)		MATL Average Utilization (%)		MATL Import ATC (MW)	
	Total	w/ PP >= $900	w/ PP < $900	w/ PP >= $900	Max	Mean	w/ PP < $900	w/ PP >= $900	Max	Mean
2015	8760	28	20%	**95%**	780	667	24%	**98%**	295	258
2016	8784	0	10%	**N/A**	750	701	14%	**N/A**	295	268
2017	8760	4	23%	**72%**	750	691	21%	**25%**	295	258
2018	8760	29	44%	**97%**	750	656	56%	**92%**	295	238
2019	8760	17	23%	**99%**	750	697	40%	**100%**	295	272

Saskatchewan import utilization

Year	# of Hours		SK Average Utilization (%)		SK Import ATC (MW)	
	Total	w/ PP >= $900	w/ PP < $900	w/ PP >= $900	Max	Mean
2015	8760	28	23%	**79%**	153	124
2016	8784	0	6%	**N/A**	153	146
2017	8760	4	8%	**37%**	153	144
2018	8760	29	23%	**49%**	153	147
2019	8760	17	40%	**88%**	153	120

Mid-C real-time prices during high AB prices



Intertie conclusions

- There is typically a substantial margin opportunity when Alberta prices are high (above $900/MWh)
  - Transmission constraints and wheeling fees may limit the extent to which this opportunity can be captured
- Interties have high import utilization rates during these high price events

Conclusion

- Current price cap levels do not appear to impede imports

Efficiency during scarcity & shortage events: conclusions

- There may be opportunity for incremental demand response at prices higher than $1,000/MWh
  - Analysis has shown a potential for ~40 MW of additional response
- The price cap does not appear to overly impede supply response (intertie and LLTA in particular) during scarcity & shortage events:
  - Interties have high utilization rates during these events
  - LLTA's had an availability of ~61% during these events with unavailability due to operational reasons or mothball

Discussion questions

- Is this analysis comprehensive? If no, what else should the AESO examine?
- Is the price cap set at the right level to encourage sufficient supply and demand response during scarcity and shortage situations?

Break

Efficiency during supply surplus conditions

Evaluating short-term response to surplus conditions

- Hypothesis: The market operates more efficiently when participants can actively respond to price rather than when administrative mechanisms are used to clear the market. The price floor should allow for efficient pricing during supply surplus events, and should not overly impede market based clearing.

Does the current price floor allow for efficient price signals to both supply and demand resources during supply surplus events?

Supply surplus events

- Supply surplus is initiated when the supply of energy available at $0 exceeds system demand
- Steps used to balance system while in a state of supply surplus are set out in section 202.5 of the ISO rules

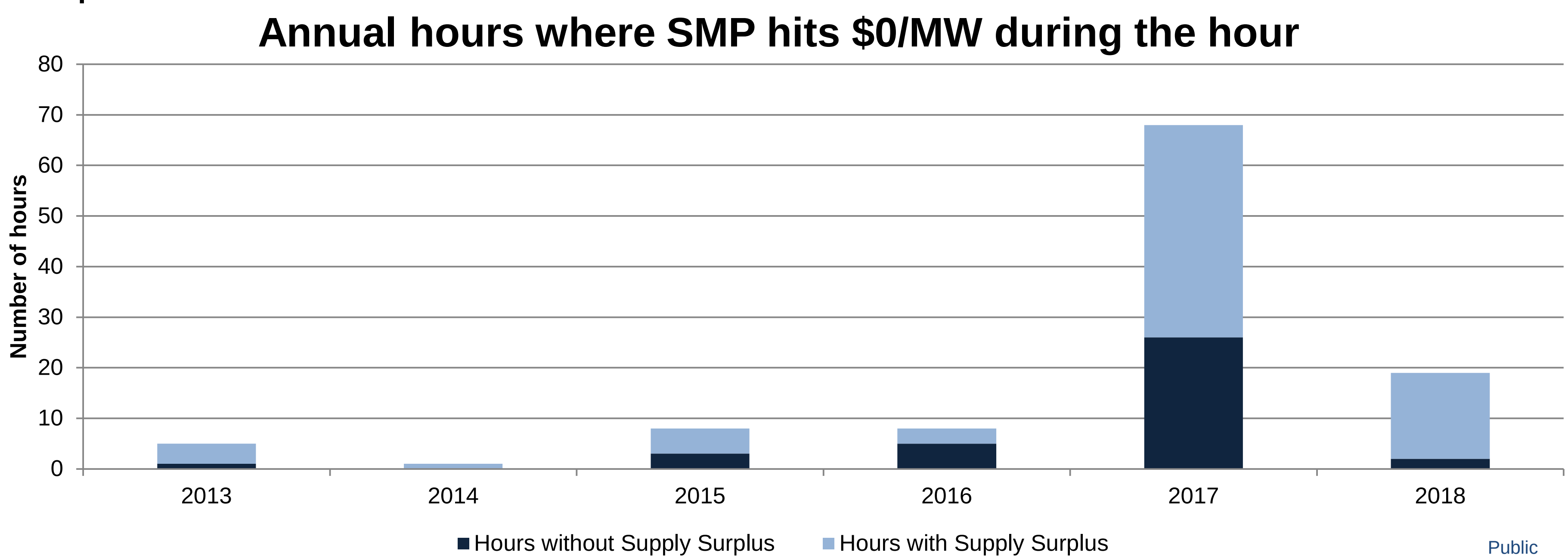
Supply surplus procedure

- If during current hour AESO determines that a supply surplus event is imminent, AESO will:
  - Initiate curtailment of imports
    - And allow participants to submit offers to decrease imports within T-2
  - Allow participants to submit bids to export within T-2
  - Permit participants to restate and reduce generating output within T-2
  - Issue, on a pro-rata basis:
    - Dispatches to generating units and aggregated generating facilities (AGFs) for partial volumes of flexible blocks on $0 offers
  - If there are generating units & AGFs with $0 offers greater than minimum stable generation (MSG), issue directives to curtail to MSG, starting with units with the greatest difference between current dispatch level and MSG
  - Direct any other necessary actions, including shutting down generating units and AGFs to ensure system reliability

Historical hours with SMP at $0/MW

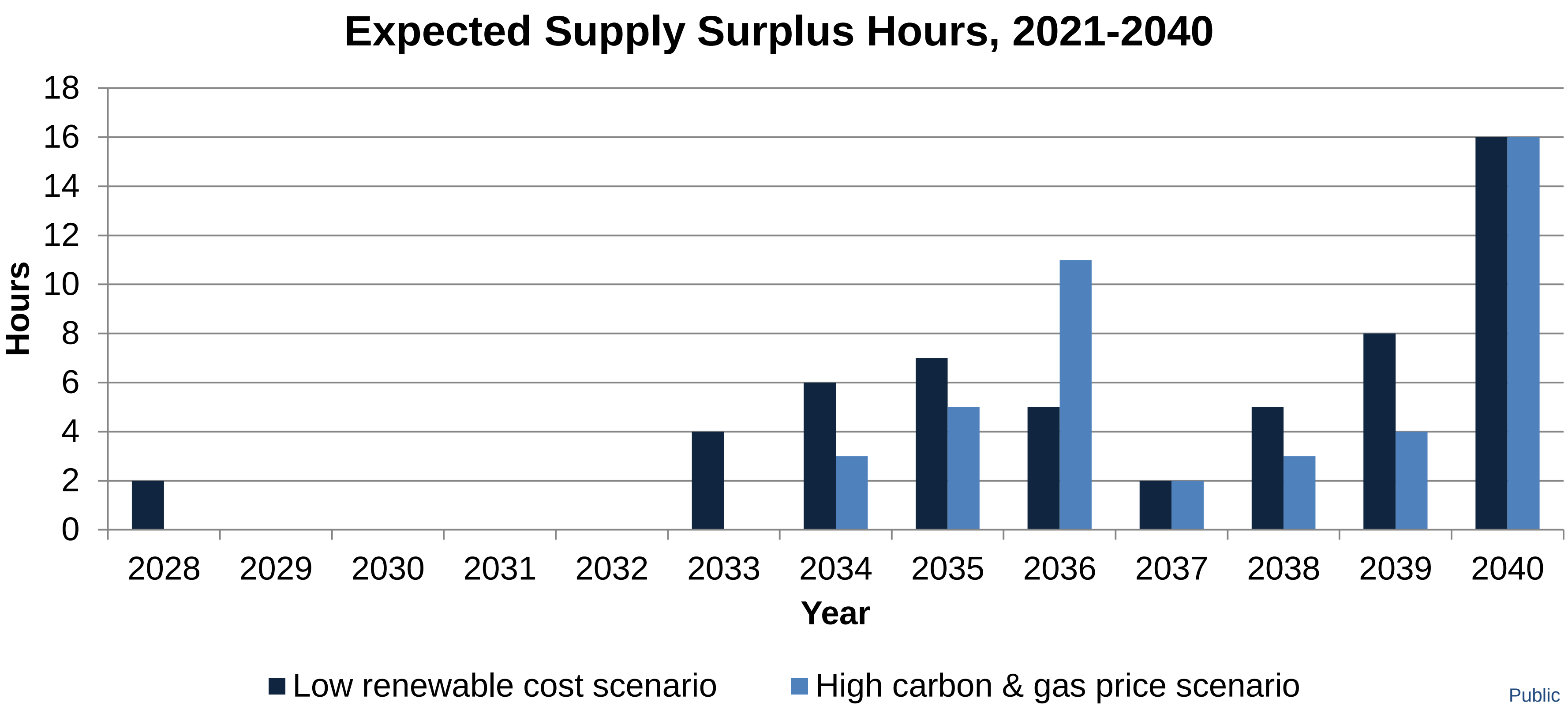
During past supply surplus events, has the price floor been a significant barrier to market based clearing?

- Supply surplus events occur when imports or generation curtailments must be performed
- Since 2013, there have been a total of 109 hours where SMP was $0/MW during the hour - 72 of these hours included supply surplus procedures



Forecast supply surplus events

- Results from the resource adequacy study suggest minimal expected supply surplus hours
  - only two scenarios see supply surplus events



Estimating an efficient floor in Alberta

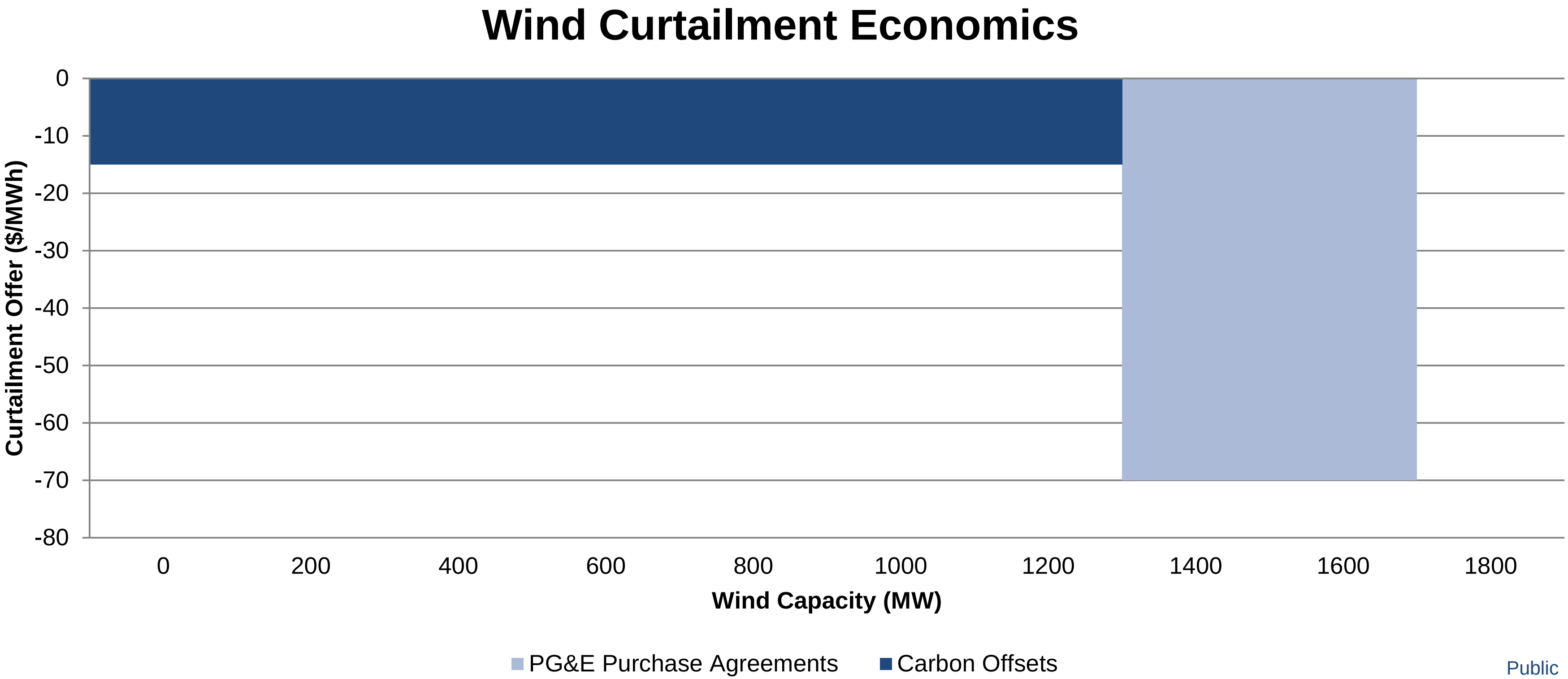
- Negative pricing may allow supply surplus events to be managed by market participants using the price signal to prioritize curtailments and incentivize system flexibility
  – Offer prices would signal an asset's willingness to produce during periods of supply surplus
- Currently wind and solar generation, imports and assets that incur high cycling costs are typically the suppliers that remain online during supply surplus events

Curtailment economics wind and solar resources

- Wind and solar resources have the ability to curtail generation with minimal cycling costs
- Curtailment thresholds may be a function of non energy market revenue from:
  - **Provincial carbon offsets:** value estimated at $15-16/MWh
    - Determined through multiplying the grid displacement factor[1] (t/MWh) by the carbon price ($/t) = 0.53 t/MWh*$30/tonne=$15.90/MWh
    - Note that above factors are set by the Government of Alberta, and will change over time
  - **Federal production incentives:** anticipated to end March 2021, provides a $10/MWh payment for 10 years of operation with a 35% capacity factor for wind and 20% capacity factor for solar[2]
  - **Renewable energy purchase agreements:** PG&E has 20 year contracts with two Alberta wind farms the value is estimated to be below the price cap of US$50/TREC (~C$66/TREC)[3]
- Non price responsive resources include Alberta REP and similar solar contracts
  - Indifferent to wholesale market price, *would likely continue to offer at the floor price to avoid market based curtailments*

Curtailment economics wind resources

- The following chart estimates a curtailment offer stack for wind resources – no solar included as volumes are minimal at this point in time
- Includes PG&E volume of 450 MW, and assumes that the remaining installed capacity of wind, ~1,300 MW, sell carbon offsets
- Assets that receive federal production incentives have been excluded from the assessment of curtailment costs as they are not anticipated to receive this incentive beyond 2021



Curtailment economics wind and solar resources

- **Conclusion:** nearly 1,800 MW of market based economic curtailment of renewable resources at price floor below negative $66/MWh
  - Includes provincial carbon offsets and offsets held by PG&E for Alberta based wind farms
  - Generous estimate, assumes that all wind not contracted through REP or PG&E will sell carbon offsets

Curtailment economics coal and combined cycle

- Costs of curtailing coal and combined cycle (CC) assets dependent on both cycling costs and lost opportunity costs
- Cycling costs are estimated as[4]:

Start type	Coal	Combined Cycle
Cold ($/MW/start)	154	117
Warm ($/MW/start)	95	82
Hot ($/MW/start)	80	52

  – Cycling costs encompass estimates of costs related to higher maintenance costs, deterioration, reduced lifespan etc.
  – These estimates do not include the opportunity cost of lost revenue, which is expected to be minimal

Curtailment economics coal and combined cycle

- **Conclusion:** the curtailment economics for coal and combined cycle facilities differ based on cycling costs for each of these asset types.
  - Coal assets may curtail at prices of -$80 to -$154/MWh depending on the start type
  - Combined cycle assets may curtail at prices of -$52 to -$117/MWh depending on the start type

Intertie economics imports and exports

- Decision to import or export into Alberta based on profit expectations relative to other markets
- Market based curtailment of imports rather than administrative would require priced interties and intra-hour dispatching of interties – currently being explored by AESO

BC & MATL export utilization

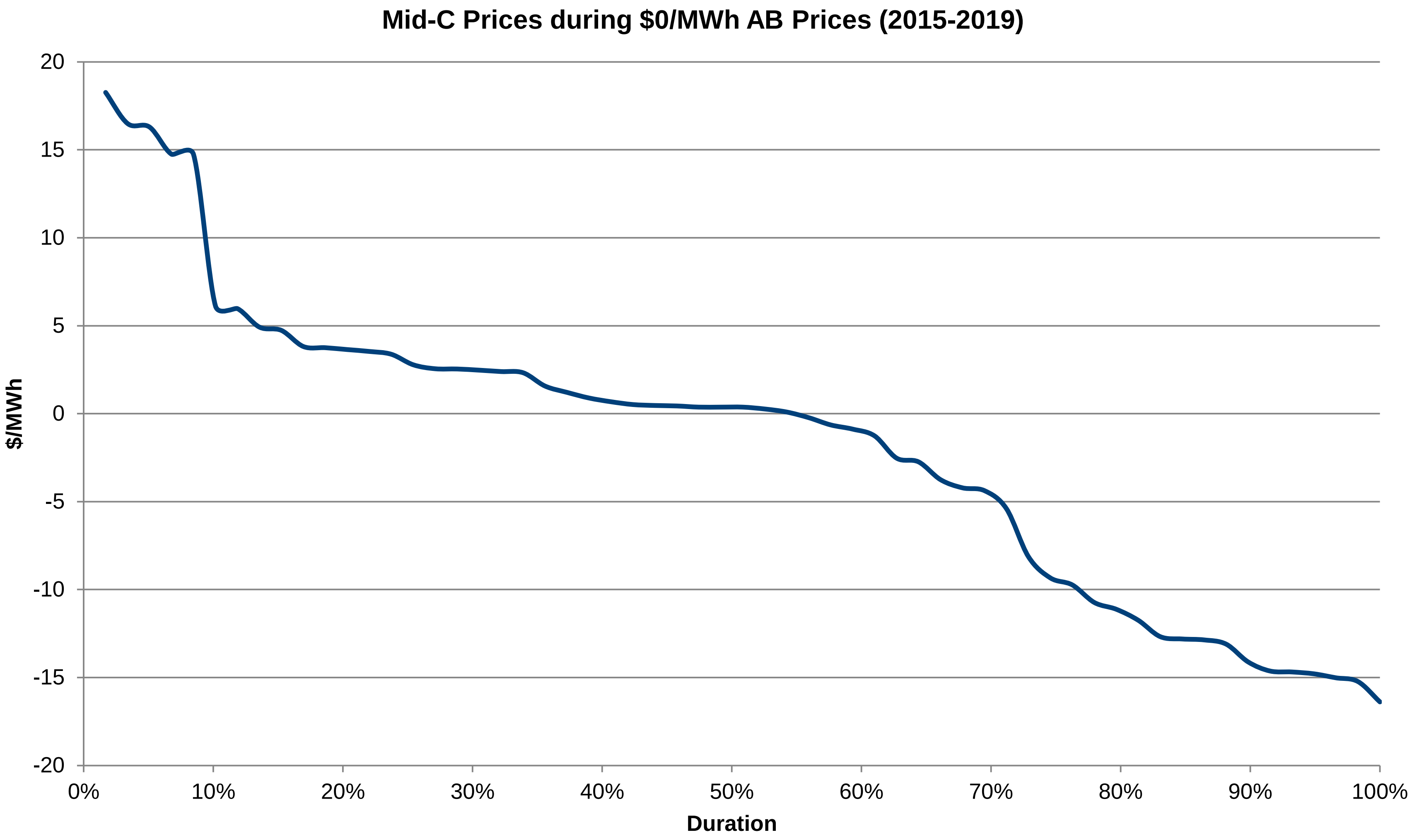
Does the current price floor provide sufficient incentive for the intertie to be fully utilized for exports during surplus events?

Year	# of Hours		BC Average Utilization (%)		BC Export ATC (MW)		MATL Average Utilization (%)		MATL Export ATC (MW)	
	Total	w/ PP <= $10	w/ PP <= $10	w/ PP > $10	Max	Mean	w/ PP <= $10	w/ PP > $10	Max	Mean
2015	8760	109	**39%**	27%	950	682	**16%**	11%	300	275
2016	8784	41	**1%**	11%	950	899	**0%**	12%	300	277
2017	8760	105	**3%**	10%	950	904	**3%**	19%	300	275
2018	8760	30	**0%**	7%	950	905	**0%**	14%	300	263
2019	8760	7	**0%**	8%	950	908	**0%**	8%	300	283

Saskatchewan export utilization

Year	# of Hours		SK Average Utilization (%)		SK Export ATC (MW)	
	Total	w/ PP <= $10	w/ PP <= $10	w/ PP > $10	Max	Mean
2015	8760	109	**35%**	27%	153	122
2016	8784	41	**0%**	20%	153	146
2017	8760	105	**0%**	17%	153	145
2018	8760	30	**0%**	15%	153	147
2019	8760	7	**86%**	24%	153	120

Mid-C real-time prices during low AB prices



Intertie observations

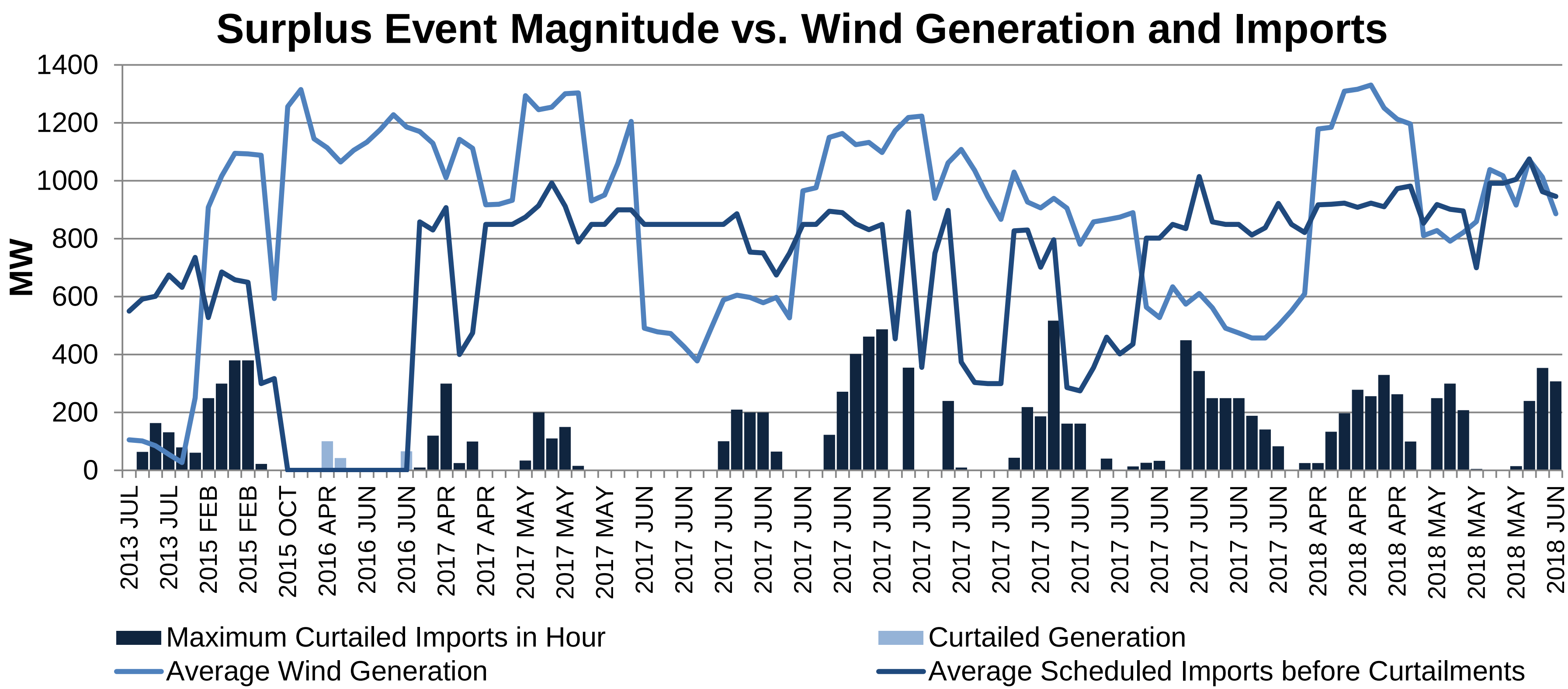
- **Conclusion:**
  - Exports: interties have low export utilization rates during low price events
  - Imports: the cost at which an import resource would curtail depends on opportunity cost of importing to Alberta relative to other markets like Mid-C. The lowest price observed in Mid-C hours when prices in Alberta settled at $0/MWh was -$20/MWh

- **Considerations:**
  - Market prices at Mid-C indicate that regional prices are often negative, including during AESO's surplus events
  - During historical supply surplus events the average import volume was 752 MW
  - The profit opportunity for exports during low prices (under $10/MWh) is less consistent than for imports during high prices (above $900/MWh)
    - Again, scheduling practices, transmission constraints and wheeling fees may further diminish this opportunity

Surplus event magnitude

- The chart in the next slide includes hourly surplus event magnitude (curtailed imports and curtailed internal generation) and compares the average wind generation in the hour and the average scheduled imports prior to any curtailments
- The graph shows that these events could have been managed through wind and import reductions, depending on the economics for each type of resource

Supply surplus events



- Maximum amount of generation or import curtailments have been approximately 500MW
- In the vast majority of hours, historical supply surplus events have been managed through import curtailments

Considerations for other resource types

- **Hydro:** subject to environmental regulations that may prevent curtailment due to minimum flow requirements
- **Cogeneration:** may have high curtailment costs and lost opportunity costs incurred by not generating during the entire minimum down time following a shutdown. These costs would likely be significantly higher than the curtailment costs of imports and renewables
- **Simple cycle:** typically peaking units are offline prior to reaching supply surplus conditions
- **Dispatchable load:** currently no dispatchable load participants. If dispatchable load were to participate, they could submit a negative bid to indicate a willingness to increase load at that price
- **Exports:** currently allowed to submit bids to export within T-2 in supply surplus conditions
- **Energy storage:** currently none in the province, however these resources may be in a good position to take advantage of negative pricing by charging during surplus events

Efficiency during surplus conditions: conclusions

- A negative floor of -$70/MWh may provide an incentive for market based curtailment
  - Wind and solar resources ~1,700 MW
  - Import resources depending on opportunity cost of importing to Alberta relative to other markets like Mid-C
  - This would provide a market based remedy for all historical and forecast supply surplus events
  - Coal assets are likely to remain on at this level due to higher costs of cycling
  - Combined cycle assets may curtail at prices of -$52 to -$117/MWh depending on the start type (per the current supply & demand page, there is 1,748 MW of installed capacity from combined cycle resources)

Summary

- Price Cap
  - Price cap does not seem to be a significant barrier to encouraging supply response
    - Imports and LLTA's have both had high availability when needed
  - The AESO's analysis indicates that there is potential for more demand response above $1,000/MWh
- Price Floor
  - Alberta has experienced past supply surplus events and is expected to experience supply surplus events in the future
  - Historic supply surplus events have largely been managed by curtailing imports
  - Lowering the price floor could allow future supply surplus events to clear based on market signals rather than administrative actions

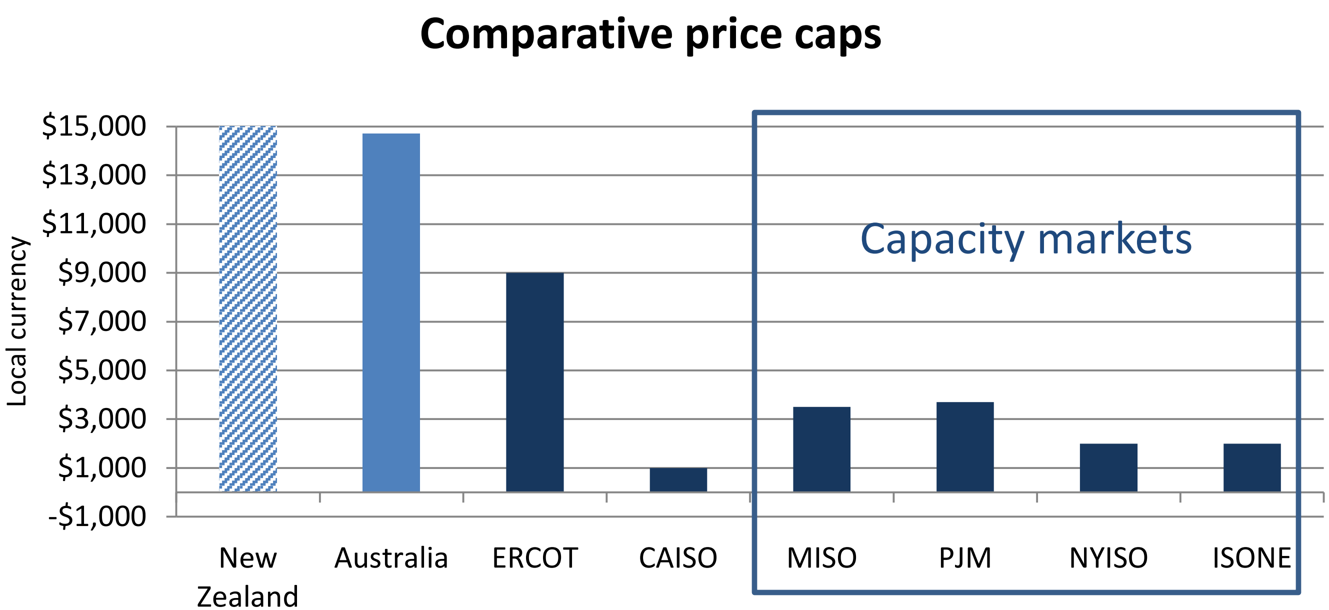
Jurisdictional review

Jurisdictional review price cap, price floor

- Why do a jurisdictional review?
  - Provides insight into what other markets have done and why
- While informative, caution in taking the information out of context. Design frameworks reflect the market's unique attributes such as:
  - Supply and demand situations of each market
  - Market power mitigation framework
  - Policies and risk tolerances from regulating bodies
- AESO has provided a summary of mitigation approaches and pricing frameworks in the Attachment 1 posted with this presentation
- Following slides provide a summary of price caps and floors and a deeper look into a few cap floor frameworks

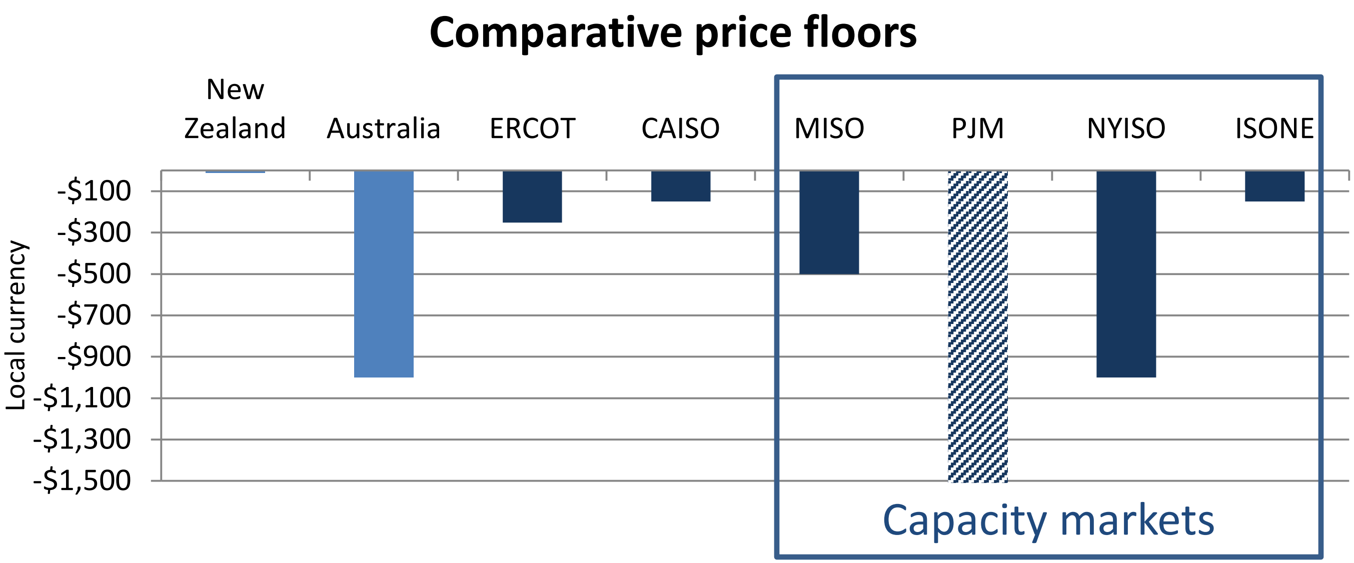
Price cap comparison

- Price caps range widely based on the structures of the markets
  - Energy only markets generally have higher price caps
  - ***Darker blocks*** indicate markets with ex ante mitigation programs
- Higher price cap markets have mitigating factors
  - New Zealand (no cap) and Australia have the ability to limit price levels after periods of sustained high prices
  - ERCOT: limits the ability for firms with greater than 5% of installed capacity to offer greater than marginal cost, no one firm can own more than 20% supply



Price floor comparisons

- Price floors range widely based on the structures of the markets
  - ***Darker blocks*** indicate markets with ex ante mitigation programs
  - Floor prices are less aligned with market structure and may reflect the frequency of surplus conditions due to significant base load generation
    - Note PJM does not have a floor price



Price cap approaches: ERCOT, PJM, Australia

- ERCOT, PJM and Australia all have scarcity pricing mechanisms but arrive at scarcity prices in a different manner
  - ERCOT uses a graduated Operating Reserve Demand Curve (ORDC)
  - PJM uses a stepped ORDC, with plans to move to a smoothed curve
  - Australia is based on offer levels up to the value of lost load
- PJM's approach complies with the 2016 FERC order 825 on scarcity pricing:
  - *"We…require that each regional transmission organization and independent system operator trigger shortage pricing for any interval in which a shortage of energy or operating reserves is indicated during the pricing of resources for that interval. Adopting these reforms will align prices with dispatch instructions and operating needs, providing appropriate incentives for resource performance."*

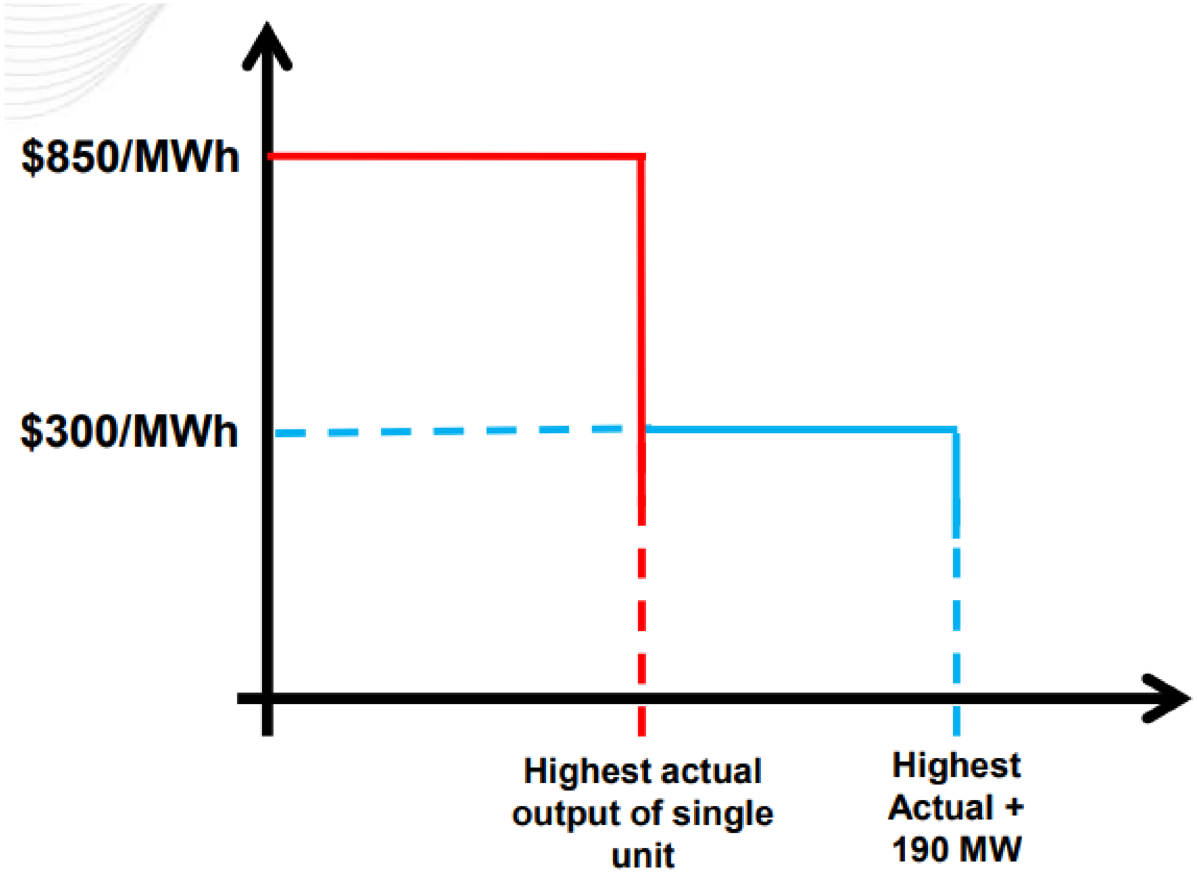
PJM shortage pricing
a stepped shortage curve

- ORDC originally implemented in 2012 as a single step demand curve – maximum price adder of $850/MWh
  - $850/MWh level was equivalent to some of the out of market payments and a compromise between PJM and stakeholders
- FERC 825 required ISO/RTOs to price transient shortages
  - PJM implemented a second step in their curve at $300/MWh
  - Had the effect of smoothing the transition to $850/MWh

PJM shortage pricing

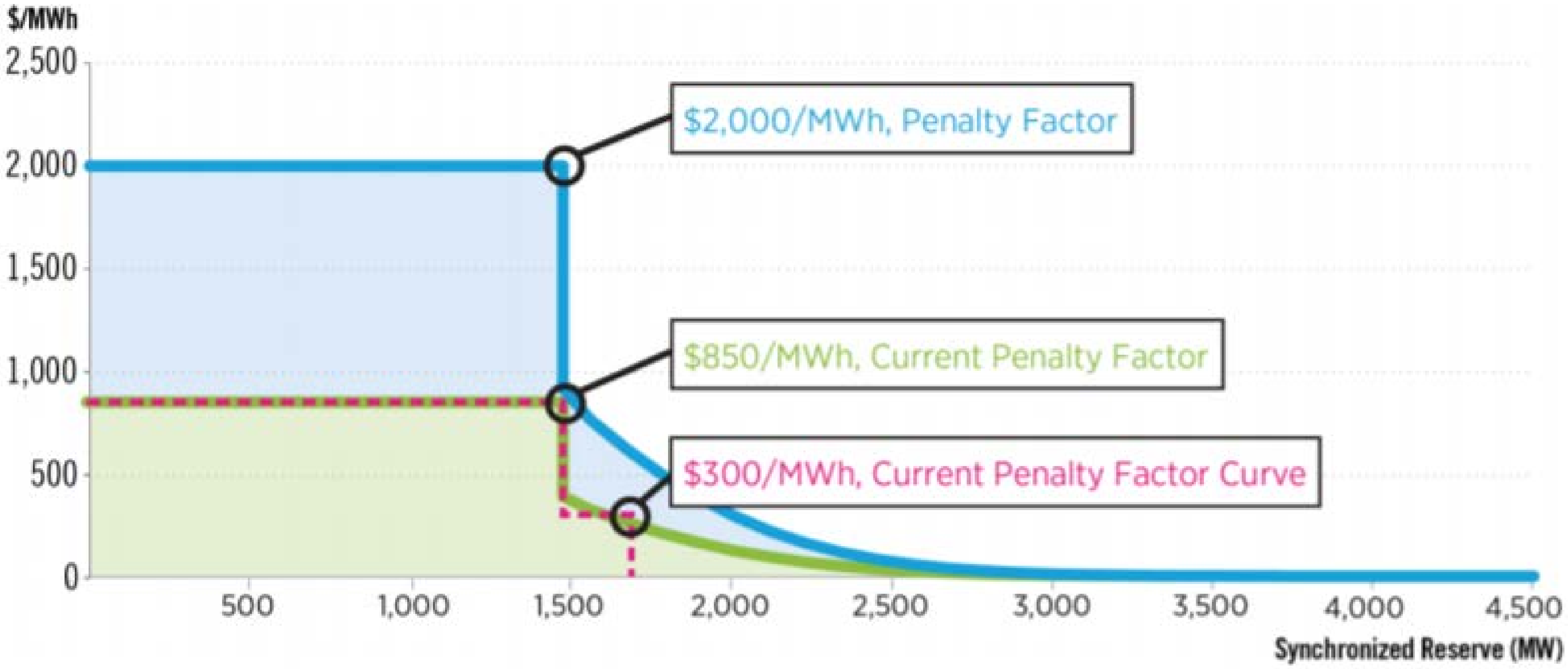
- Curve is triggered based on depletion of synchronized reserves and primary reserves (which includes synchronized and quick start reserves)
  - Each of these reserve requirements have a penalty factor of \$850/MWh, for a maximum penalty factor of \$1,700/MWh[5]
  - PJM's current energy price is capped at the energy offer cap + penalty factor for each of the reserves– would be triggered if they are short both primary and synchronous reserves
  - Current energy offer cap is \$2,000/MWh (verified costs)
  - Theoretical maximum price = \$2000/MWh+(2*\$850/MWh) = \$3,700/MWh

PJM current ORDC



PJM proposed ORDC

- PJM is proposing a new penalty factor of \$2,000/MWh$_6$ for each reserve type, up from the previous \$850/MWh

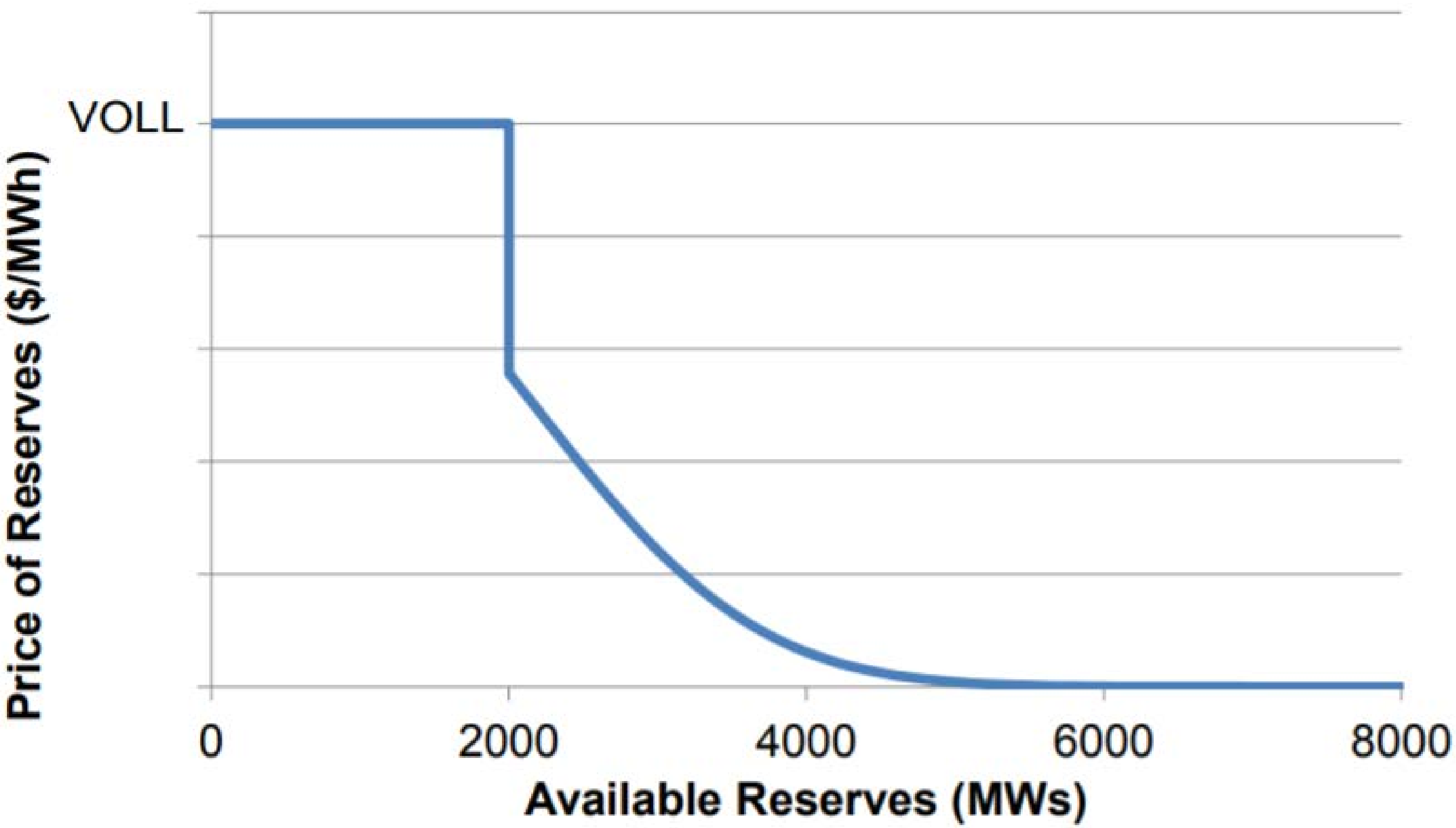


ERCOT
a graduated shortage curve

- ORDC first implemented on June 1, 2014 in order to improve scarcity and shortage pricing by reflecting the marginal value of available reserves (or supply cushion) in real-time energy prices
  - Marginal value of available reserve determined as product of value of lost load (VOLL) and loss of load probability (LOLP)
- The ORDC also helps to address resource adequacy concerns by providing adequate generator revenue through scarcity and shortage pricing
- ERCOT did not want to build a system that relied on high offer prices to properly reflect the value of energy in real time

ERCOT shortage pricing model

- Price cap is set administratively at $9,000/MWh[7]
- Prices increase to price cap when available reserves fall below minimum contingency level (2,000 MW)



Australia value of lost load

- Australia's national electricity market is a real time, energy only market
- Price cap is set at the value of lost load, and increased by inflation each year
- There is no formal shortage pricing mechanism
  - Price cap and offer cap both currently set at $14,700/MWh AUD
  - Price mitigation regime: if the sum of settlement prices for the previous 7 days exceeds the cumulative threshold of $221,100, entire trading day will have an administered price threshold of $300/MWh applied

Lessons learned from other jurisdictions price cap and shortage pricing

- Price cap frameworks are varied, with goals generally being
  - Provide scarcity price signals to the market
    - Incent demand to respond when system conditions are tight
    - Allow for revenue sufficiency for generators
  - Balancing the need for adequate consumer protection through differing market power mitigation frameworks

Price floors

- Most jurisdictions use a negative price floor to enable market based clearing in supply surplus conditions
- Renewable attribute sales
  - Even at $0 energy prices, the value associated with renewable credit sales or production tax credits will compel renewable generation sources to continue production
  - The costs associated with cycling base load generation exceed a price floor of $0
- CAISO has moved from a -$30/MWh floor price to a -$150/MWh floor price to ensure price signals were adequate to allow for market based curtailment.[8] Other markets have moved to even greater negative values.

Cautions on price floors

- While enabling market based clearing, negative price floors may introduce revenue sufficiency concerns
- 2017 PJM stated

  The negative offers, encouraged by [the production tax credit], negatively impact all resources by distorting price signals and eroding revenue streams.[9]

- In 2017 the US Department of Energy made similar observations and noted that negative prices were most prevalent in regions that feature large amount of variable or nuclear generation: PJM, CAISO and ERCOT[10]

Lessons learned from other jurisdictions price floor

- Negative pricing can promote more market based clearing compared to administrative clearing approaches
  - Floor prices should be set low enough to promote sufficient depth in the merit order
- However, careful consideration must be taken when establishing floor prices to ensure negative revenue sufficiency and resource adequacy implications are avoided

Closing remarks competing drivers

- Changes to the pricing framework must balance competing drivers
  - Urgency for change
    - What's the need for change now, do the efficiency gains outweigh the administrative efforts and costs to market from the change
  - A robust market that over the long time provides the competitive pricing signals needed for efficient market clearing
    - The Alberta power system is undergoing substantial physical changes
      - *Coal to gas conversions and eventual retirements*
      - *Increased renewable generation additions*
      - *New market participants that range from distribution and locally connected supply to new forms loads that are more active than traditional industrial load*

Are there modifications to the pricing framework that can be implemented in Alberta to ensure an efficient and effective market in the future?

Next steps

- Next session will be held in May
- Objective of the next session will be to explore possible options to improve the pricing framework, and discuss the pros and cons of each
- Further discussion on determining the efficient price cap and price floor in Alberta while ensure stability and robustness of design
- Comment matrix has been posted
- There will be an opportunity for stakeholders to present analysis or options in the fourth stakeholder session in late May or early June. Please indicate in the comment matrix if you are interested in doing this

Discussion questions

- Is this analysis comprehensive? If no, what else should the AESO examine?
- Is the price floor set at the right level to encourage sufficient supply and demand response during supply surplus situations?

- Any other questions as needed

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