NERSC Phase 2

The Future of Ontario's Electricity Markets

UPDATED STUDY RESULTS

PREPARED FOR

Non-Emitting Resources Subcommittee

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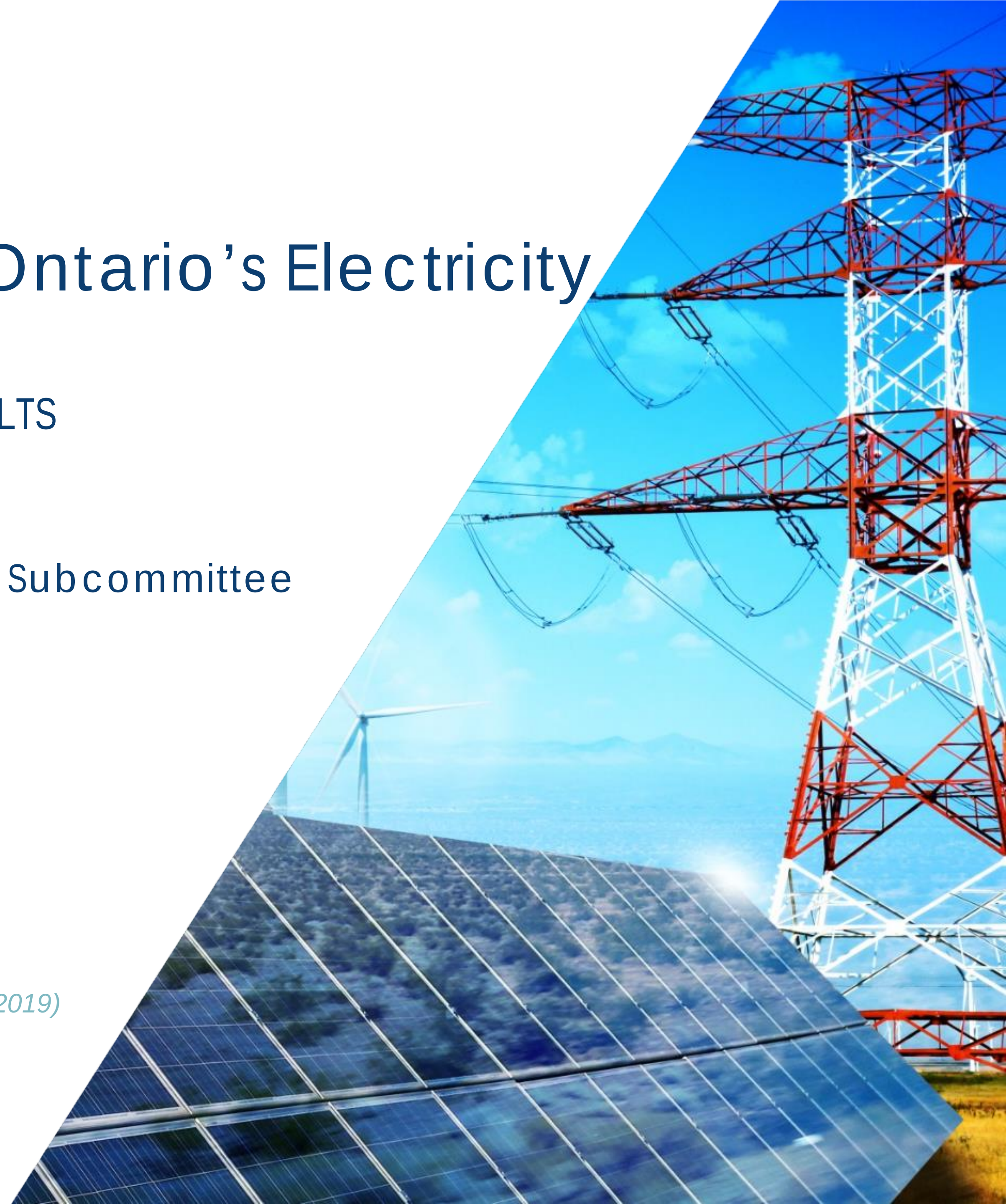


Agenda

- **Executive Summary**
- **Methodology**
- **Market Renewal and Enhanced A/S**
- **Clean Energy Market**
- **Decentralized Future**
- **Next Steps**
- **Appendix**

Study Objective and Scope

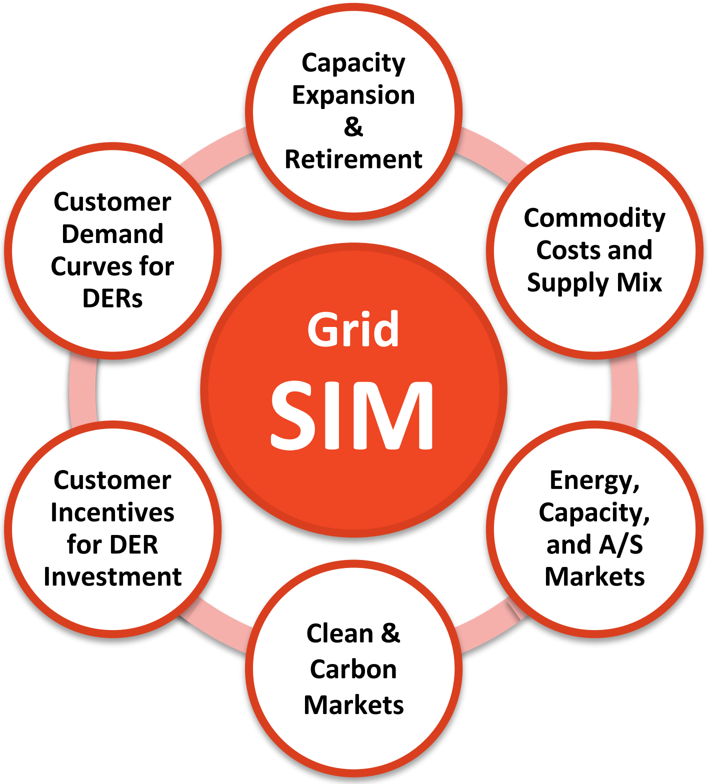
The objective of this analysis is to test the robustness of Ontario's new markets under a range of scenarios to understand:

- **Market Outcomes** and range of prices that could arise given current trends impacting the sector
- **Revenue Streams** that could be available to existing and emerging resource types with unbundled grid services
- **System Impacts** of foundational market reforms

Overarching Study Question: How will the new markets work together under a number of future scenarios?

Model Platform: Brattle's **Grid SIM**

We are using Brattle's **Grid SIM** platform to explore the range of potential outcomes after Market Renewal



Grid Scenario Impact Model

- Model is purpose-built to examine futures with high penetrations of non-emitting resources and distributed resources (DERs)
- Captures primary economic drivers for storage, hydro, DR, and traditional supply
- Traditional markets: energy, capacity, ancillary service
- Policy mechanisms and emerging markets: carbon markets, flexibility products, environmental attributes, customer demand curves for DERs

Markets Represented In Our Study

Grid SIM captures fundamentals and interactions across Ontario's markets

Markets	Essential Features
Energy	• Intraday economics of hydro, storage, DR, interties • Seasonal representations (high/low demand, freshet) • Locational (zonal) pricing
Ancillary Services	• Ancillary product needs and co-optimized pricing • Introduce new "enhanced" flexibility products* • Not captured: sub-hourly intermittency and flexibility needs
Capacity	• Entry and exit from least-cost supply under long-run equilibrium conditions • Annual, locational capacity market
Clean Attribute	• Markets for clean energy supply
Customer / Distribution	• Introduce revenue opportunities outside the wholesale markets for specific resource types (e.g. distributed storage and rooftop solar)
Contracts	• Share of resources under contract & associated size of Global Adjustment • Impact of contractual incentives on markets (e.g. FIT resource offers & negative pricing)

Included in Market Renewal

* The "Enhanced" Ancillary Services market is not currently envisioned under Market Renewal

Executive Summary

Scenario Overview

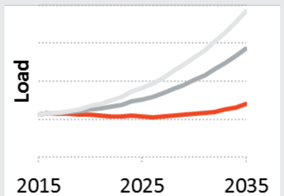
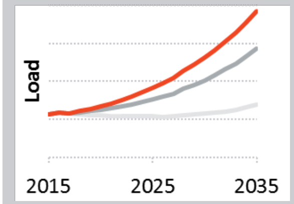
	Low Net Demand	Low Cost Clean Grid Driving Growth and Exports	Booming Economy & Electrification	Challenging Supply Conditions	Decentralized Future
					
Energy + Standard A/S + Capacity Markets	✓	✓	✓	✓	✓
Existing Contracts	✓	✓	✓	✓	✓
Enhanced A/S Market		✓	✓	✓	
Clean Attribute Market		✓			✓
Customer DER Premium					✓
	• Flat load growth and stable gas prices • Markets meet demand as contracts roll off • Without Clean Attribute market, fleet sees some re-carbonization after Pickering retirement	• Moderate load growth and stable gas prices • Low-cost clean technology and storage create opportunities for clean resources in Ontario	• Strong economy and electrification drive increased load • New investments required in generation to meet growth • Higher gas prices drive up customer costs	• High load growth coupled with expensive supply and gas prices put upward pressure on customer costs	• Customer demand drives significant DER investment • In one variant, DERs are integrated into wholesale markets • In another variant, DER investment is not visible or controllable by the IESO

Image Sources: https://www.smithsonianmag.com, https://www.finder.com.au/energy/home-battery

Findings Summary

Analysis indicates that Ontario's proposed markets are likely to cost-effectively meet system needs across a wide range of scenarios.

- A market-driven investment model reduces **customer commodity costs,** relative to the 2015-17 average, across all scenarios, even under challenging market fundamentals
- Markets create **opportunities for investment** across scenarios, attracting the resource types that best match with system needs
- A **clean energy market** could be used to **prevent re-carbonization**, while keeping **customer costs low**
- **Customers** would need to be **prepared to pay (or be paid) a high premium** to defect from the grid, which is unlikely under this future scenario

Agenda

- Executive Summary
- **Methodology**
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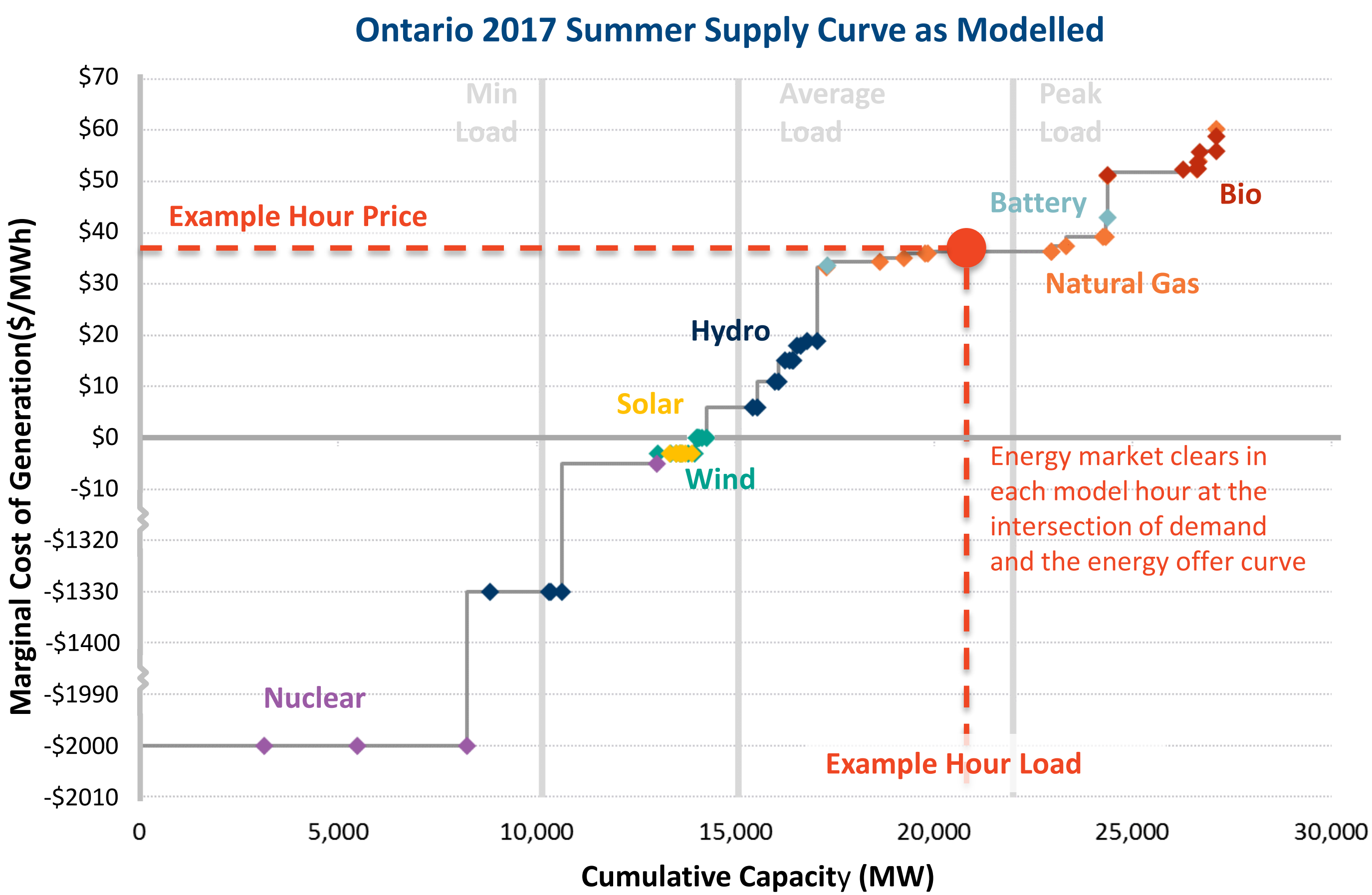
- Decentralized Future
- Next Steps
- Appendix

Energy Market Modelling

Grid SIM determines energy market clearing prices based on offers from all resources and demand



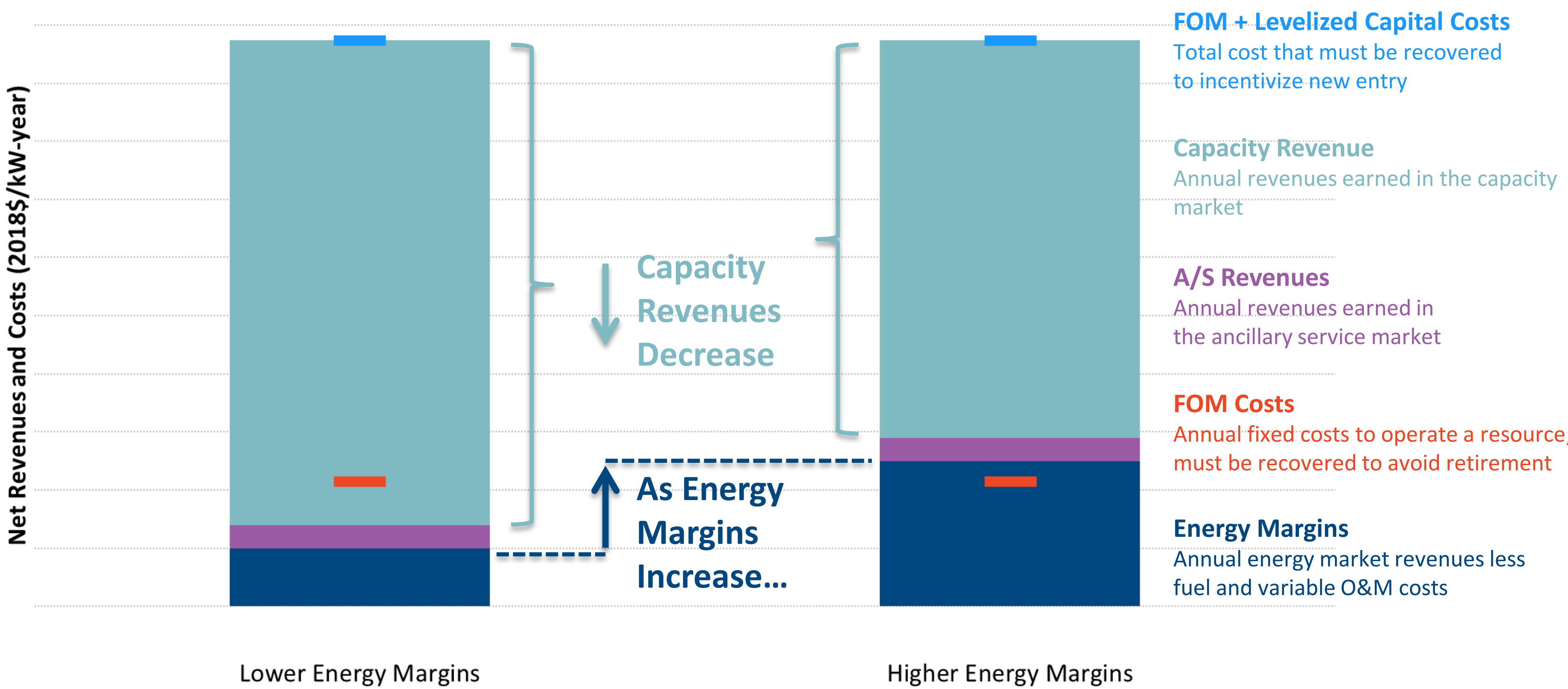
Notes: All marginal cost components (Fuel + VOM + Carbon Price) based on summer mid-day representative hour, assuming no imports or exports. Storage and energy-limited hydro marginal cost based on representative hour offer prices – in some hours energy-limited hydro offers will be higher or lower than shown. Wind and PV capacity de-rated by representative hour capacity factor. Conventional resource capacity de-rated to account for forced outages.

Methodology

Capacity Market Price Formation

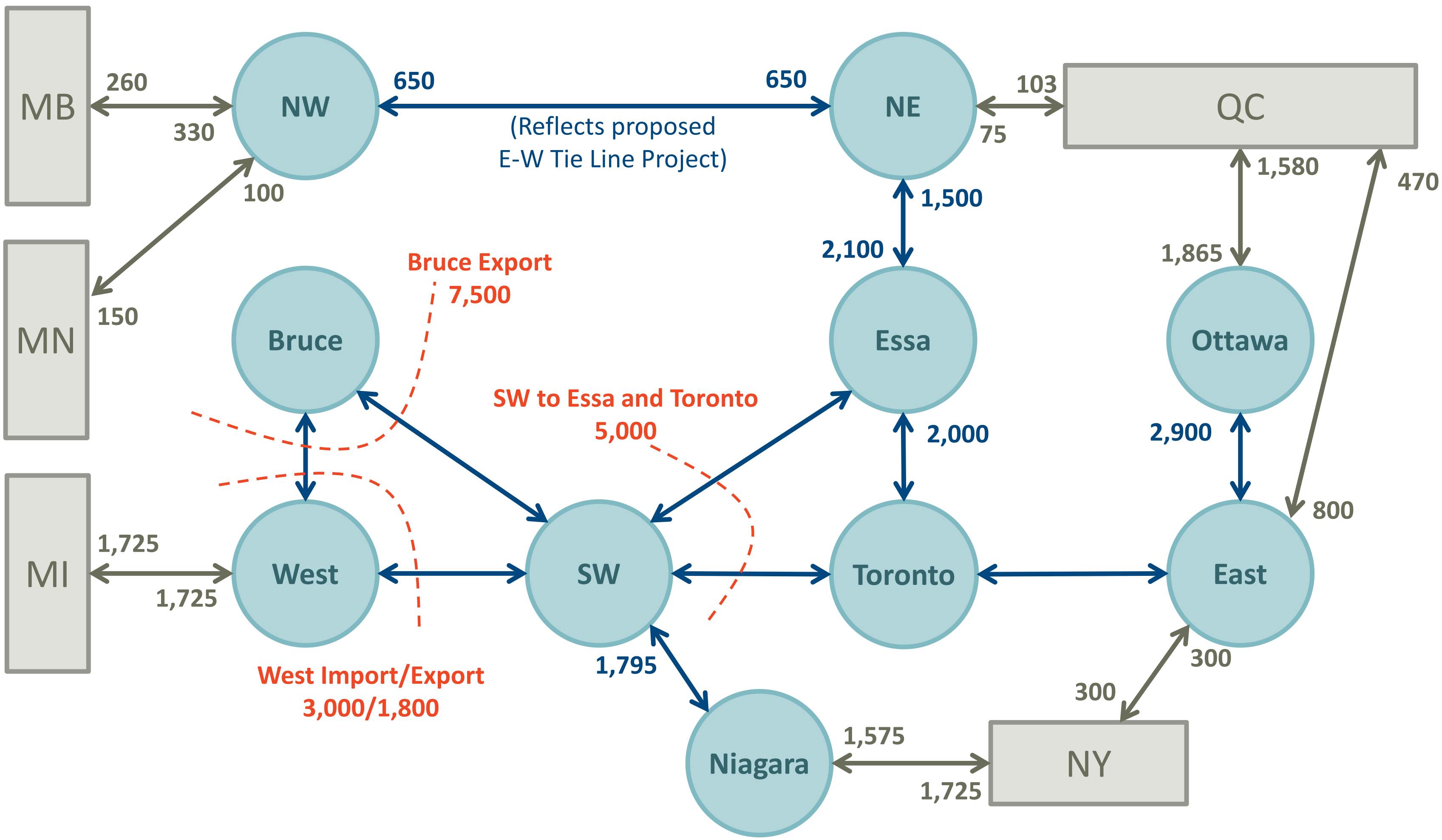
Grid SIM determines the capacity price necessary to attract investment up to the capacity requirement. The marginal resource for capacity will cover investment costs through energy margins, A/S revenues, and capacity revenues

Illustrative Revenue Stack for a Generator



Transmission

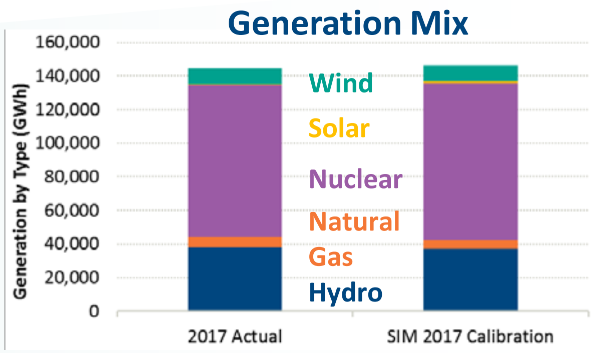
SIM uses a transmission model consistent with Ontario's zonal topology. NE to NW transfer capability is consistent with E-W Tie Line



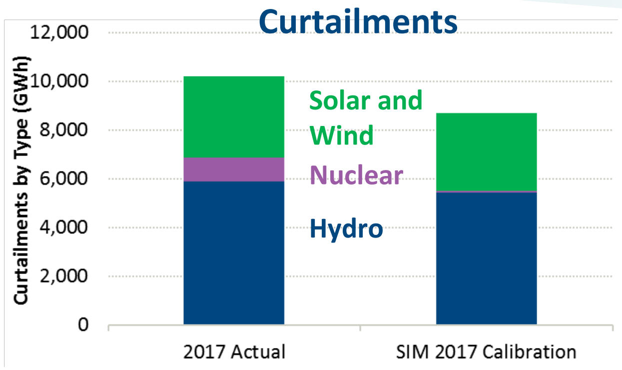
Sources and Notes: Based on transmission model from the June 22, 2017 Ontario Transmission System report. Line ratings based on average of summer and winter ratings. Model does not account for QC->Ottawa import contribution to the FIO limit.

Model Calibration Results

Grid SIM 2017 Calibration results are similar to 2017 actuals, indicating Grid SIM is realistically reflecting Ontario's electricity system:

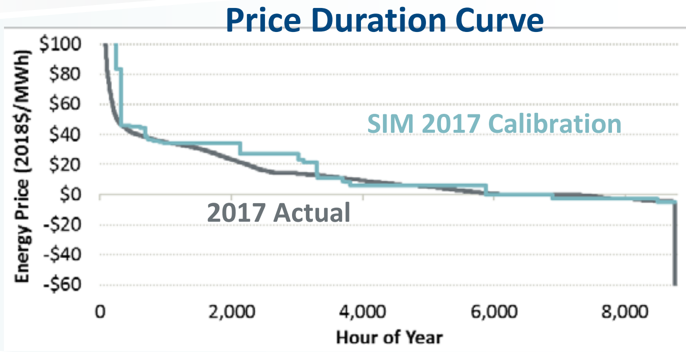


Generation Mix: Matches 2017 actuals, suggesting operating costs and existing resource mix are realistically modelled



Curtailments: Close to 2017 actuals, indicating that Grid SIM is correctly accounting for surplus baseload conditions

Energy Prices: Price duration curve is similar to 2017 actuals, indicating modelled price formation are accurate and lending credibility to market revenue estimates



Agenda

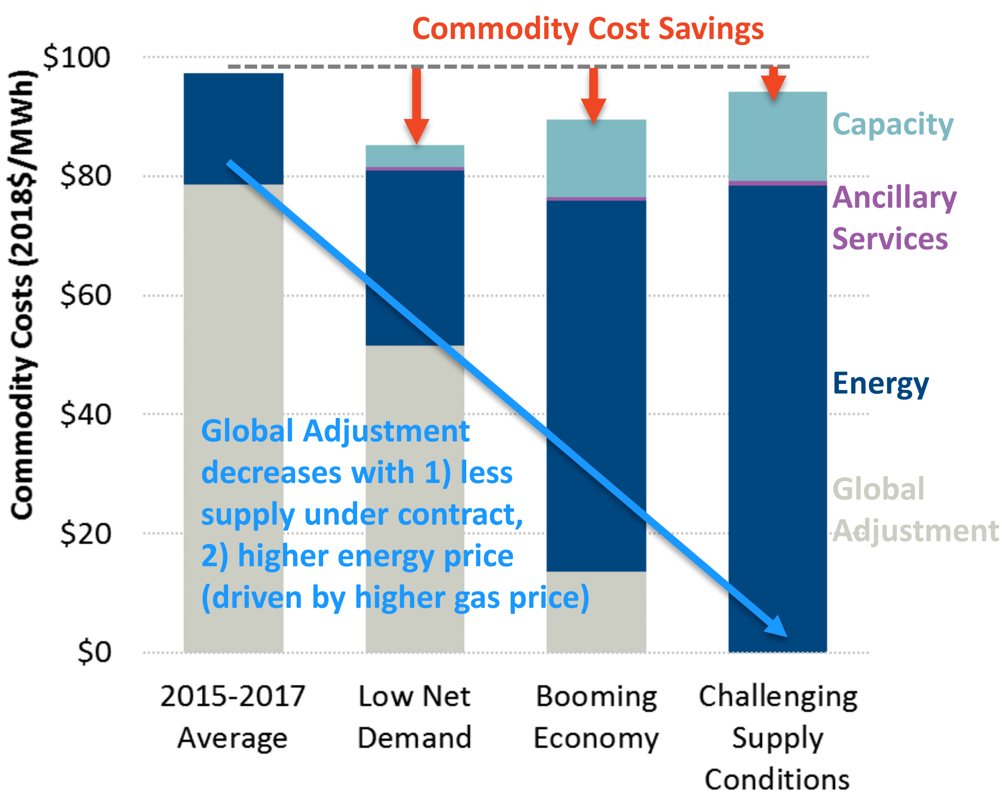
- Executive Summary
- Methodology
- **Market Renewal and Enhanced A/S**
- Clean Energy Market
- Decentralized Future
- Next Steps
- Appendix

Commodity Cost Savings

Under market renewal, customer commodity costs will be lower across a range of scenarios, driven by three mechanisms:

- **Right-sizing:** market forces better align supply and demand across capacity, energy, ancillary service, and other markets, whether load growth materializes or not
- **Competitive pricing:** market prices are set by the cost of the *most economic* resource able to meet the market's current need
- **Reduced curtailments:** improved, market-driven operational signals and right-sizing of the market reduce curtailment of low marginal cost resources

Customer Commodity Costs



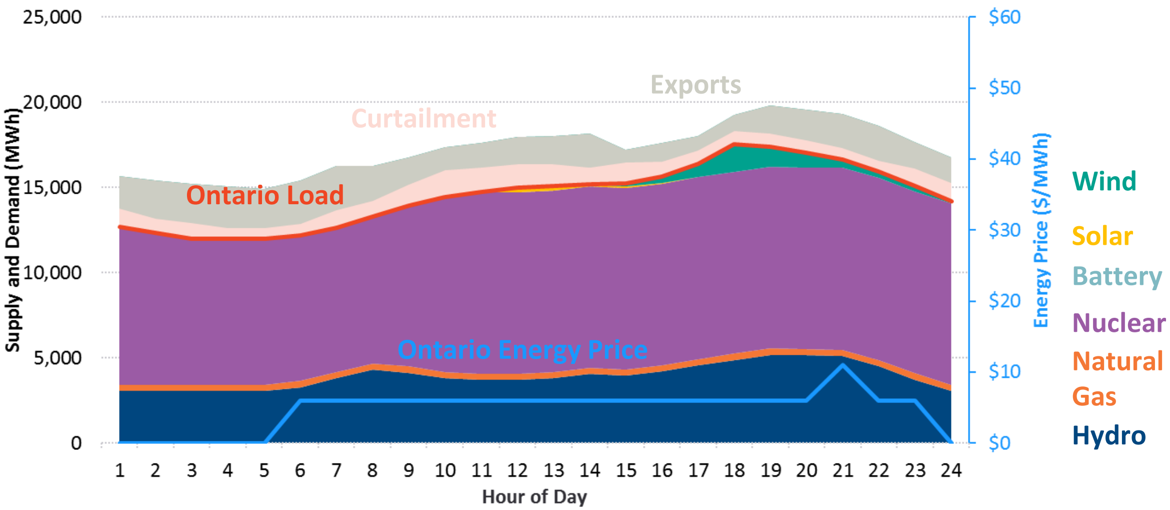
Note: Commodity costs under Challenging Supply Conditions *do not* include any potential additional costs that might be incurred on behalf of customers in the real world when existing contracted assets exit the market.

Impact of Pickering Retirement

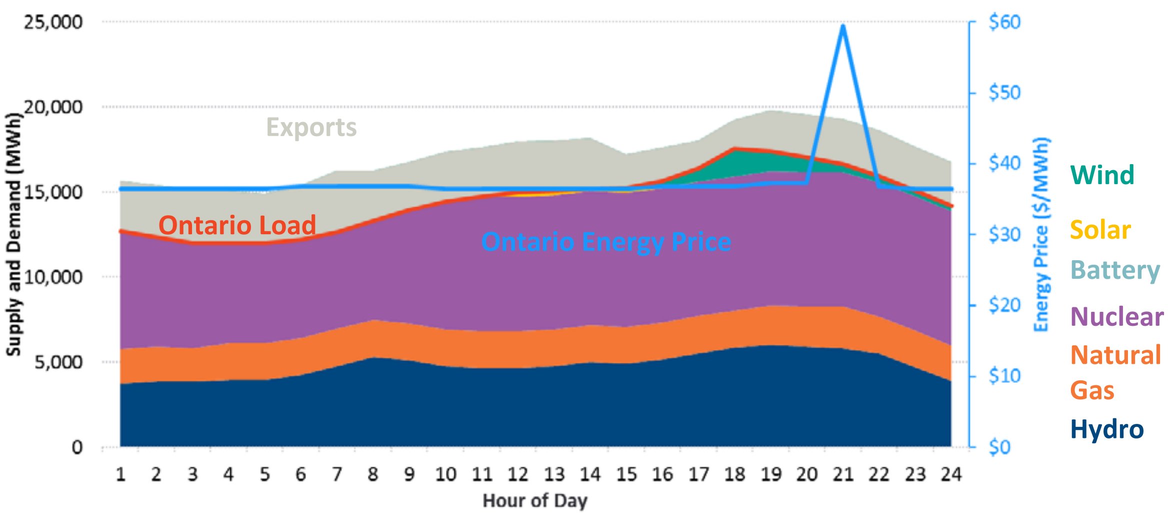
Pickering's retirement will have an impact on Ontario's market:

- **Customer Costs:** Pickering's retirement reduces average commodity costs by removing a large contributor to the Global Adjustment
- **Pricing:** A greater share of generator revenues will be earned in the wholesale energy market relative to today
- **Curtailments:** With substantial retirement of must-run supply, curtailment declines substantially

November 19th, SIM 2017 Calibration Case (Pickering Online)



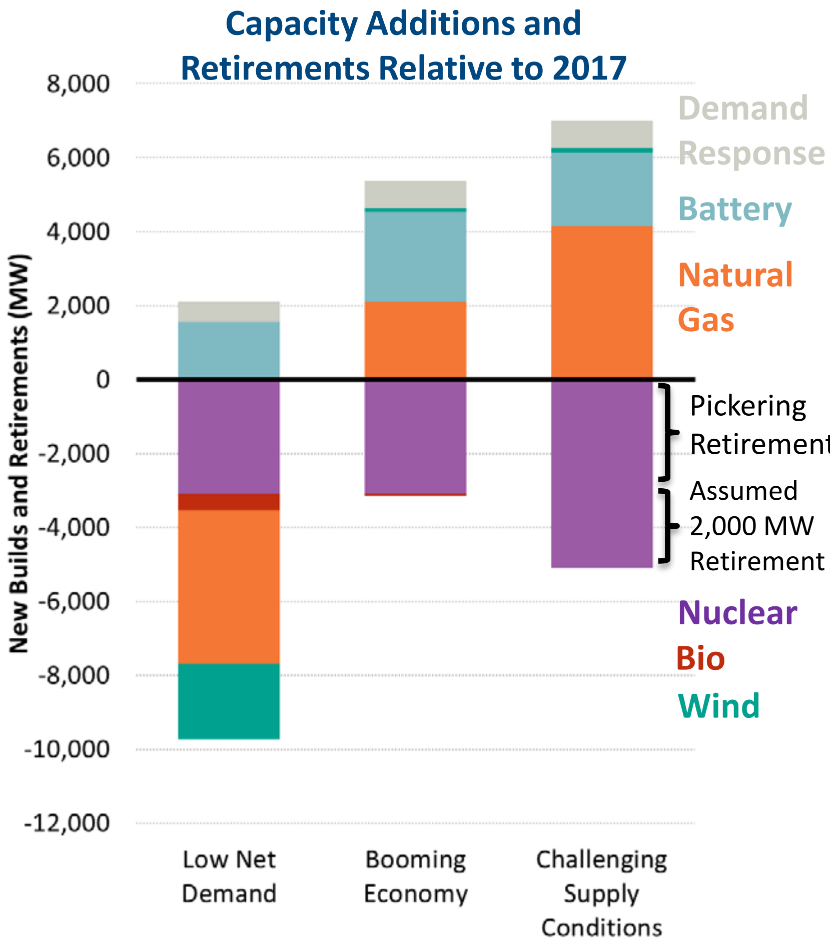
November 19th, Modified SIM 2017 Calibration (Pickering Retired)



Opportunities for Investment

Under Market Renewal, there are market-driven investment opportunities across scenarios and resource types:

- DR and short duration storage investment occurs in all scenarios, driven by capacity and A/S revenues
- Some natural gas resources coming off contract earn enough market revenue to remain online in all scenarios; new investment occurs under higher load growth scenarios
- Existing wind resources coming off contract are generally able to earn sufficient market revenues to remain online (except under Low Net Demand and Decentralized Future)
- The hydro and nuclear fleet are not expected to materially change under any scenario, except for the retirement of Pickering and the assumed unavailability of an additional 2,000 MW of nuclear supply under Challenging Supply Conditions

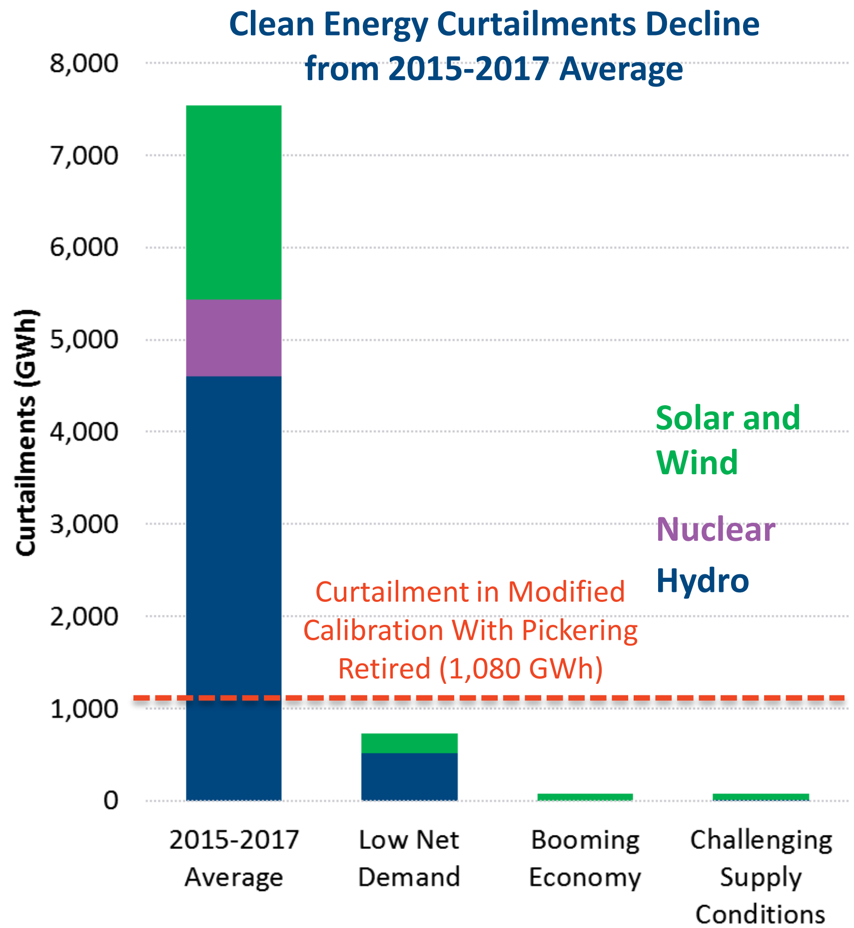


Curtailments of Clean Resources

Curtailments are reduced substantially relative to the 2015-2017 average across all scenarios

- **Pickering retirement** removes baseload from the system and alleviates surplus baseload generation
- **Exposure to market prices** for more resources helps improve coordination and right-size the market, further reducing curtailments
- **Higher load** under Booming Economy and Challenging Supply Conditions helps absorb additional curtailments

Note: we expect actual Ontario curtailments to exceed modelled levels due to sub-zonal transmission constraints (e.g., in the Northwest) not captured in Grid SIM

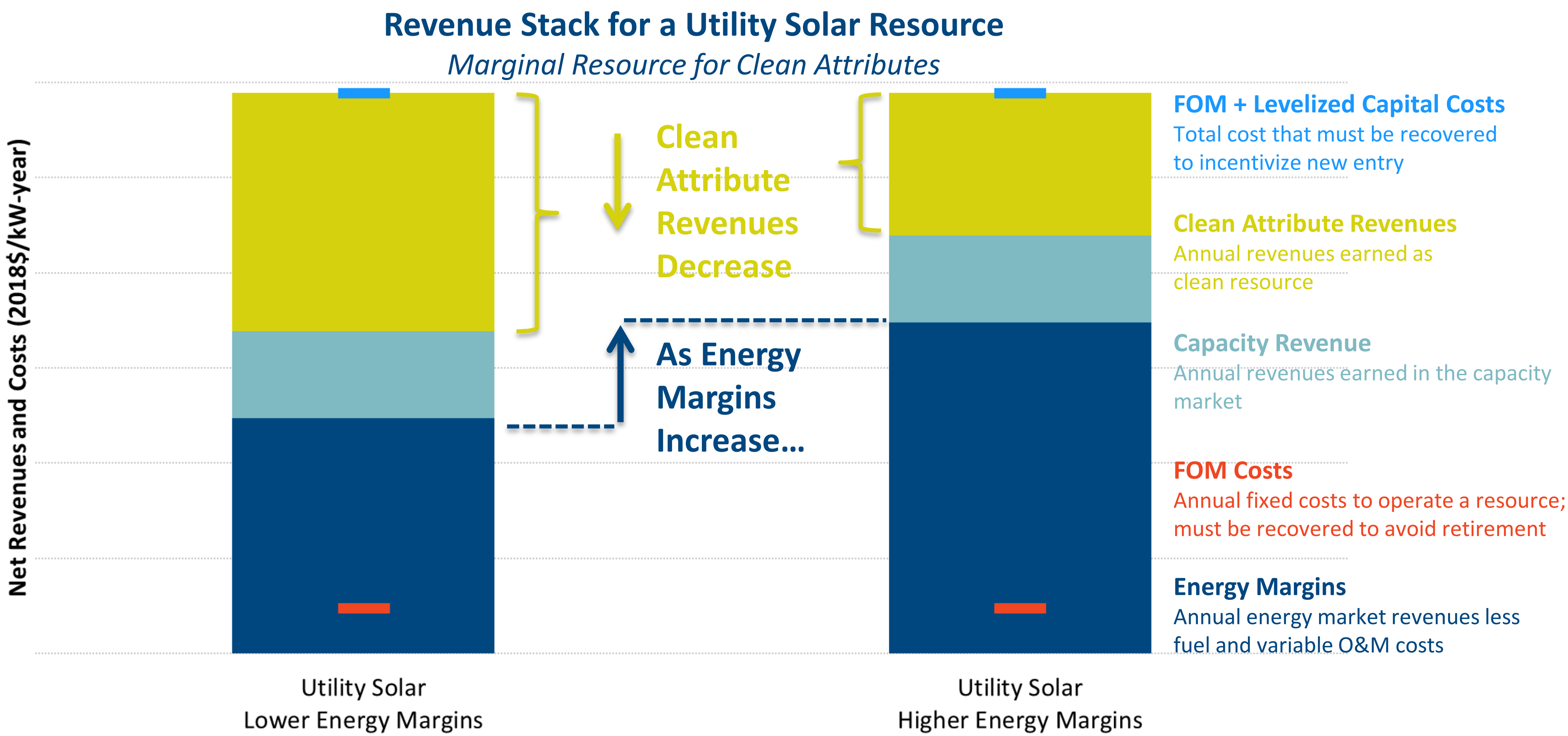


Agenda

- Executive Summary
- Methodology
- Market Renewal and Enhanced A/S
- **Clean Energy Market**
- Decentralized Future
- Next Steps
- Appendix

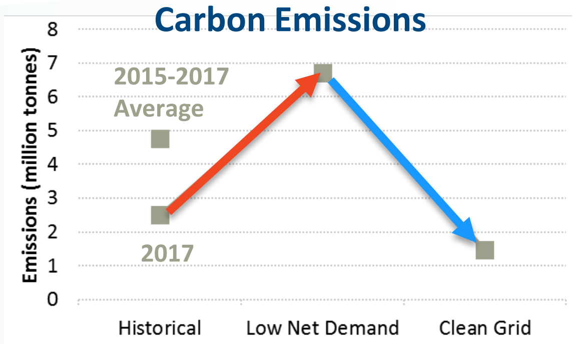
Clean Attribute Price Formation

Grid SIM determines the clean attribute price necessary to attract clean investment up to the requirement. The marginal resource for clean will cover investment costs through energy margins plus capacity and clean attribute revenues

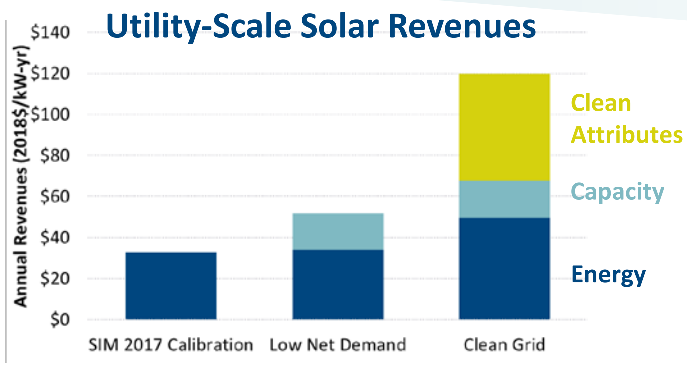


Clean Energy Market Results

A Clean Energy Market could avoid re-carbonization without increasing customer costs relative to today

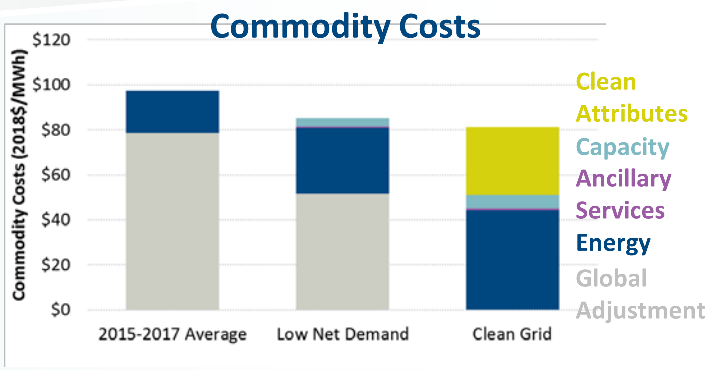


Carbon Emissions: A clean attribute market would prevent the market from re-carbonizing as contracts roll off in the absence of a carbon price



Clean Resource Revenues: It would also create an additional revenue stream for clean resources, attracting 1,250 MW of merchant solar (or low-cost wind if available)

Customer Commodity Costs: It would not increase commodity costs relative to today (and would actually decrease costs given our assumption of fewer contracts and inexpensive clean resources)



Agenda

- Executive Summary
- Methodology
- Market Renewal and Enhanced A/S
- Clean Energy Market
- **Decentralized Future**
- Next Steps
- Appendix

Decentralization and Grid Defection

In the Decentralized Future scenario, a key driver of investment in distributed resources is a customer's willingness to pay a premium for DERs *incremental to their market value.* This premium could be driven by several factors:

- **Environmental Value or Conspicuous Conservation:** Customers may value reducing their own carbon footprint and/or demonstrating to others that they are reducing their carbon footprint by adopting visible conservation measures. Conspicuous Conservation has been identified as a driver of hybrid vehicle purchases.[1]
- **Corporate Preferences:** Corporations may wish to source much or all of their electricity supply from zero-carbon resources, for branding purposes or as part of a hedging strategy. In the US non-utility renewables purchases in 2018 exceeded 3 GW as of August.[2]
- **Early Adopter Mentality**: As technology companies increasingly enter the electricity space, some customers may be willing to pay more based on their inclination towards adopting new technologies.

Sources:

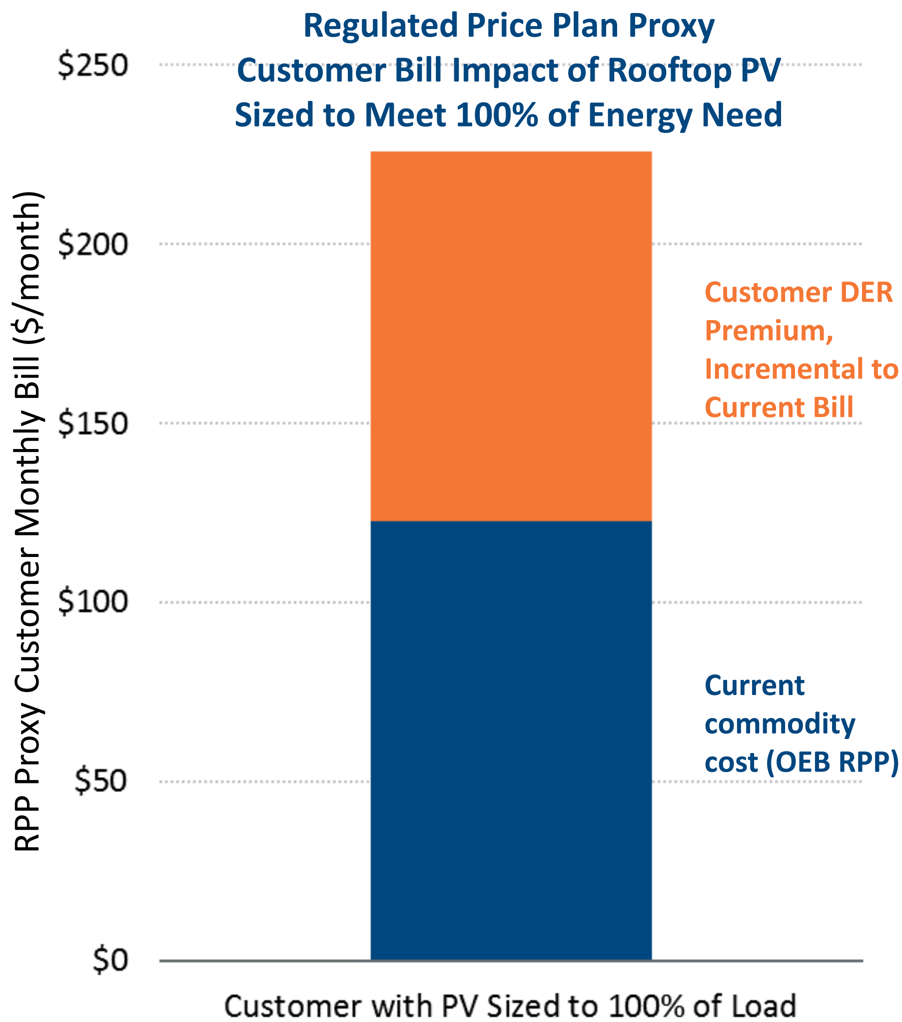
1. Sexton S. and Sexton A., "Conspicuous conservation: The Prius halo and willingness to pay for environmental bona fides," May 2014, Journal of Environmental Economics and Management
2. Pyper, J., "Corporate Renewable Energy Deals Smash Records in 2018," October 18, 2018, Greentech Media

Impact on Customer Costs

Our analysis assumes substantial customer willingness to pay (or be paid) for behind the meter resources, leading to nearly 8 GW of incremental rooftop solar installation

- A Regulated Price Plan (RPP) proxy customer with sufficient rooftop solar capacity to meet 100% of their 750 kWh/month load would see their bill nearly double to $226/month
- Approximately 1.25 million such customers would need to be prepared to pay this premium in order to reach 8 GW of rooftop PV province-wide

Given the size of these incremental payments, it would be unlikely to see this much behind the meter investment in the near term.

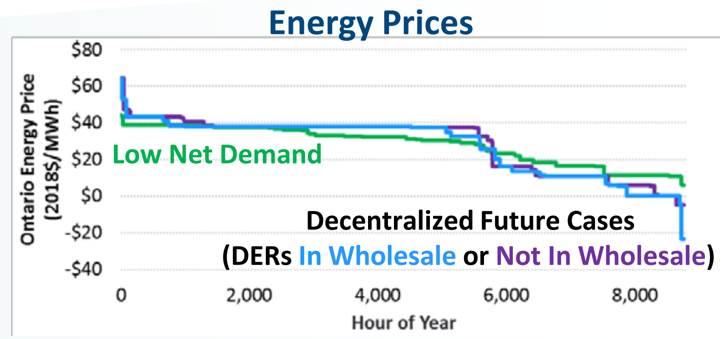


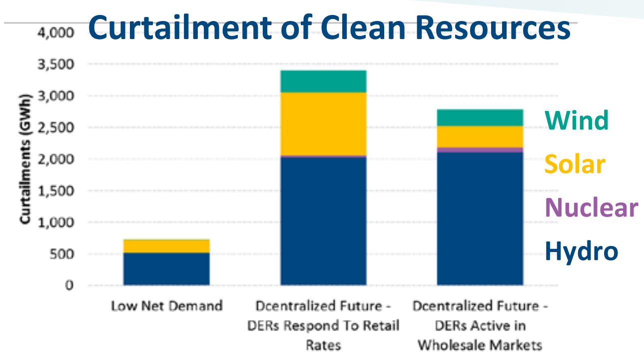
Source: Regulated Price Plan customer costs are based on a proxy customer with 750 kWh of monthly load, posted by Ontario Energy Board, April 2018.

Impacts on Wholesale Markets

DER penetrations at the high levels modelled in this scenario have collateral impacts on the wholesale electricity markets

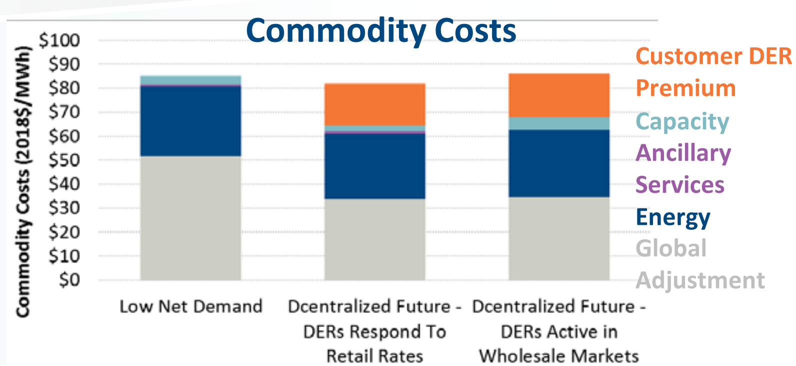
Energy Prices: At high penetrations, DERs can increase energy price volatility, increasing the highest prices and reducing the lowest prices





Curtailment of Clean Resources: More low-priced hours lead to higher levels of curtailments, particularly for rental charge-dispatch hydro resources

Customer Commodity Costs: Commodity costs remain approximately consistent with the Low Net Demand scenario, despite having fewer resources under contract



Considerations for Interpreting Decentralized Future Results

The analysis was developed to better understand the impact on wholesale markets of large-scale investment in behind the meter resources. It was not intended to assess the likelihood of this level investment actually occurring

- While this analysis shows that the cost of significant behind-the-meter investment is likely prohibitive for most residential consumers, some customers may be prepared to pay a premium
- Existing policies such as the Industrial Conservation Initiative have stimulated investment in the industrial and commercial segment
- Customer willingness to pay for distributed resources may increase as new products become available over time, similar to what has occurred in other industries, such as telecommunications, retailing, transportation, and food and beverages
- While large scale investment in behind the meter generation may not be economic for individual consumers, smaller scale investments are likely to occur, and the impact could still be significant
- More work is needed to understand how customer demand for electricity from different sources might change in the future and how this trend will impact wholesale markets

Agenda

- Executive Summary
- Methodology
- Market Renewal and Enhanced A/S
- Clean Energy Market
- Decentralized Future
- **Next Steps**
- Appendix

Next Steps

We will present the results of change cases, developed based on input from stakeholders, to evaluate the impact of individual drivers of market outcomes

Change Case	Changed Assumption in Change Case	Considerations	Applies to Scenario
Fully contracted market	Market remains approximately 100% regulated or under contract	Will any incremental investment be needed? How high will energy and capacity prices reach? What will be the impact on GA?	Low Net Demand
Lower Carbon Price	Carbon price reduced from $60 (consistent with NYISO adder) to $20/tonne (consistent with WCI)	Will investment in clean resources decline and carbon emissions increase? Will revenues shift from energy to environmental attributes market?	Low Cost Clean Grid
Lower Gas Price	Gas price reduced to $3.00/GJ, consistent with 2016-17	Will utilization of and investment in gas generation increase?	Low Net Demand
Nuclear Undergoing Refurbishment	Remove some nuclear supply to reflect tighter supply conditions during the 2020s	How might markets perform differently in the nearer term before refurbishments are complete?	Low Net Demand, Low Cost Clean Grid
Opportunities for Small Hydro	Include an additional 300 MW of Southern Ontario hydro potential, improved accounting of Northern vs. Southern and Greenfield vs. Brownfield	Will additional hydro resources be developed given greater supply availability?	Booming Economy

Agenda

- Executive Summary
- Methodology
- Market Renewal and Enhanced A/S
- Clean Energy Market
- Decentralized Future
- Next Steps
- **Appendix**

Appendix

Detailed Scenario Assumptions

	1. Low Net Demand	2. Low Cost Clean Grid Driving Growth and Exports	3. Booming Economy & Electrification	4. Challenging Supply Conditions	5. Decentralized Future
Ontario Net Demand	No net load growth (130 TWh, 23 GW peak, shape/location informed by Outlook A)	Moderate net load growth (150 TWh, 25 GW peak, informed by Outlook B)	High net load growth (175 TWh, 29 GW peak, informed by Outlook C)	High net load growth (175 TWh, 29 GW peak, informed by Outlook C)	No gross load growth, net load decreases (120 TWh, 19 GW peak)*
Fuel Prices	$3.50/GJ (Indicative of Current Dawn Hub prices)	$3.50/GJ (Indicative of Current Dawn Hub prices)	$6.00/GJ (Indicative of 2015 Dawn Hub prices)	$8.00/GJ (Indicative of 2014 Dawn Hub prices)	$3.50/GJ (Indicative of current Dawn Hub prices)
Carbon Prices	None	Consistent with NYISO Proposed Carbon Adder ($60/tonne)	Consistent with modest WCI price ($20/tonne)	Consistent with modest WCI price ($20/tonne)	Consistent with modest WCI price ($20/tonne)
Scope of Markets to Evaluate	MRP Only	MRP + Clean Attribute Market + Enhanced A/S	MRP + Enhanced A/S	MRP + Enhanced A/S	MRP + Clean Attribute + Customer Demand for DERs
Non-Emitting Resource Costs	Cost reductions relative to current levels, PV-Utility: 15%, PV-Rooftop: 30%; Wind: 2%; Storage: 25%	Cost reductions relative to current levels, PV-Utility: 20%; PV-Rooftop: 45%; Wind: 10%; Storage: 40%	Cost reductions relative to current levels, PV-Utility: 15%, PV-Rooftop: 30%; Wind: 2%; Storage: 25%	Costs of PV, wind, and storage consistent with current levels	Cost reductions relative to current levels, PV-Utility: 15%, PV-Rooftop: 30%; Wind: 2%; Storage: 25%
Contracted / Regulated Resources	60% of Current Fleet remains under Contract or Regulated (25% nuclear, 5% gas, 30% non-emitting)	40% of Current Fleet under Contract or Regulated (25% nuclear, 0% gas, 15% non-emitting)	60% of Current Fleet under Contract or Regulated (25% nuclear, 5% gas, 30% non-emitting)	50% of Current Fleet still contracted/regulated; 2,000 MW nuclear supply retired	40% of Current Fleet under Contract or Regulated (25% nuclear, 0% gas, 15% non-emitting)
Additional Notes					Two variants: 1) DERs participate in wholesale markets, 2) DERs simply avoid retail rates

*Reflects total load net of generation from new Behind the Meter resources that are attracted under the Decentralized Future scenario

Assumptions Summary

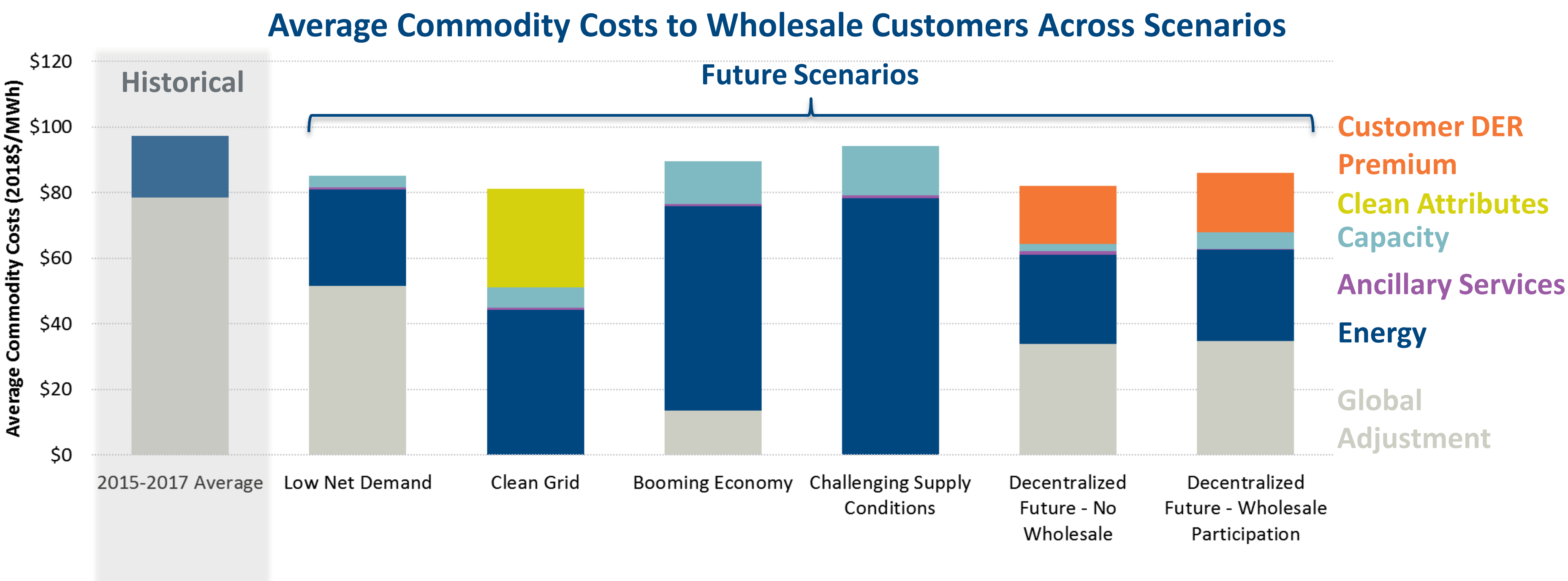
Model results across scenarios are driven by some fundamental assumptions:

- **Planned Retirements:** Pickering is retired in all scenarios, as is Thunder Bay. Challenging Supply Conditions has an additional 2,000 MW of nuclear retirement
- **Markets Modelled:** ICA, energy, and A/S (all scenarios); clean attribute, and customer value (some scenarios)
- **Market Offers:** Energy offer prices vary by resource type driven by cost fundamentals and contract/regulation-driven incentives. Capacity offers based on fixed costs net of energy and A/S margins
- **Resource Costs:** Capital and fixed costs based on National Renewable Energy Laboratory (NREL) data with Ontario-specific adjustments for regional capital costs, gas delivery costs, and Dawn hub basis
- **Hydro Modelling:** Three hydro resource-types developed in consultation with IESO staff: must-run, use charge-dispatch (offering based on Ontario's gross revenue charges for hydro facilities), and energy-limited
- **Imports and Exports:** Energy imports and exports are based on supply curves at major interfaces, modelling assumes modest capacity imports across all scenarios
- **Transmission:** Consistent with Ontario's zonal topology, with the East-West tie line assumed to be operational

Full set of assumptions can be found on the [Non-Emitting Resources Subcommittee website]()

Average Commodity Costs

Under market renewal, commodity costs are likely to decline relative to the past few years, across a range of scenarios despite a range of challenges, including high load and fuel prices, and maintaining de-carbonization



Note: Commodity costs under Challenging Supply Conditions *do not* include any potential additional costs that might be incurred on behalf of customers in the real world when existing contracted assets exit the market.

Market Opportunities by Scenario

Ontario's markets will provide opportunities for a variety of resources under a wide range of potential future market conditions

Average Market Prices by Scenario

	1. Low Net Demand	2. Low Cost Clean Grid Driving Growth and Exports	3. Booming Economy & Electrification	4. Challenging Supply Conditions	5a. Decentralized Future *(DER Wholesale Participation)*	5b. Decentralized Future *(No DER Wholesale Participation)*
Capacity *($/UCAP kW-year)*	$60 (Toronto $87)	$61 (Toronto $103)	$143 (Toronto $196)	$143 (Toronto $188)	$53 (Toronto $95)	$51 (Toronto $51)
Energy *($/MWh)*	$28	$43	$62	$78	$28	$29
A/S *($/MWh)*	$6	$4	$4	$7	$1	$7
Clean Attribute *($/MWh)*	N/A	$38	N/A	N/A	$0	$0
Customer Value – PV *($/ICAP kW-year)*	N/A	N/A	N/A	N/A	$193	$193
Customer Value – Storage *($ICAP/kW-year)*	N/A	N/A	N/A	N/A	$50	$50

Energy and capacity prices are high enough to retain existing supply if load remains flat

Environmental attribute payments provide opportunities for clean resources under Low Cost Clean Grid

A/S markets provide incremental revenue to flexible resources. Modelled A/S prices are very conservative as they do not account for reserve deployment

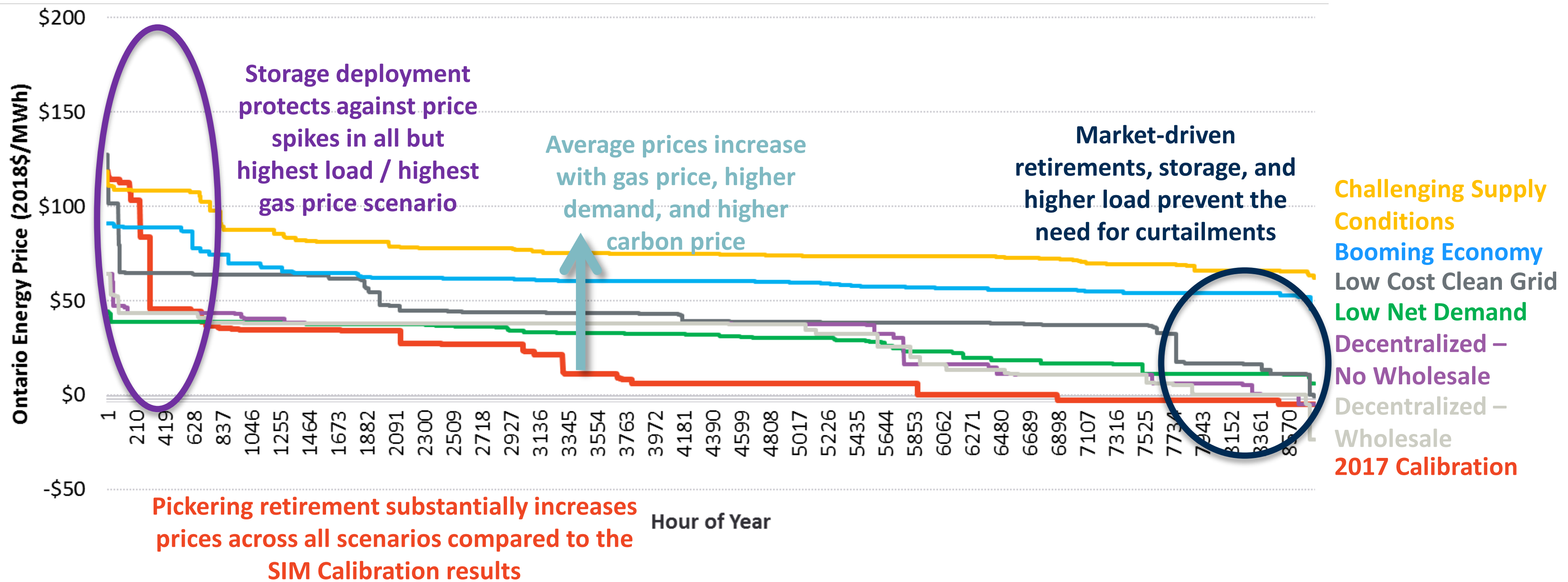
Attractive energy and capacity prices support entry under Booming Economy and Challenging Supply Conditions

Customer Value demand attracts new Behind the Meter investment under Decentralized Future

Wholesale Energy Price Duration Curves

Wholesale energy prices increase across all scenarios due to reduced curtailments, higher load, higher gas prices, and increased reliance on imports. Higher energy prices ***do not*** translate into higher overall commodity costs

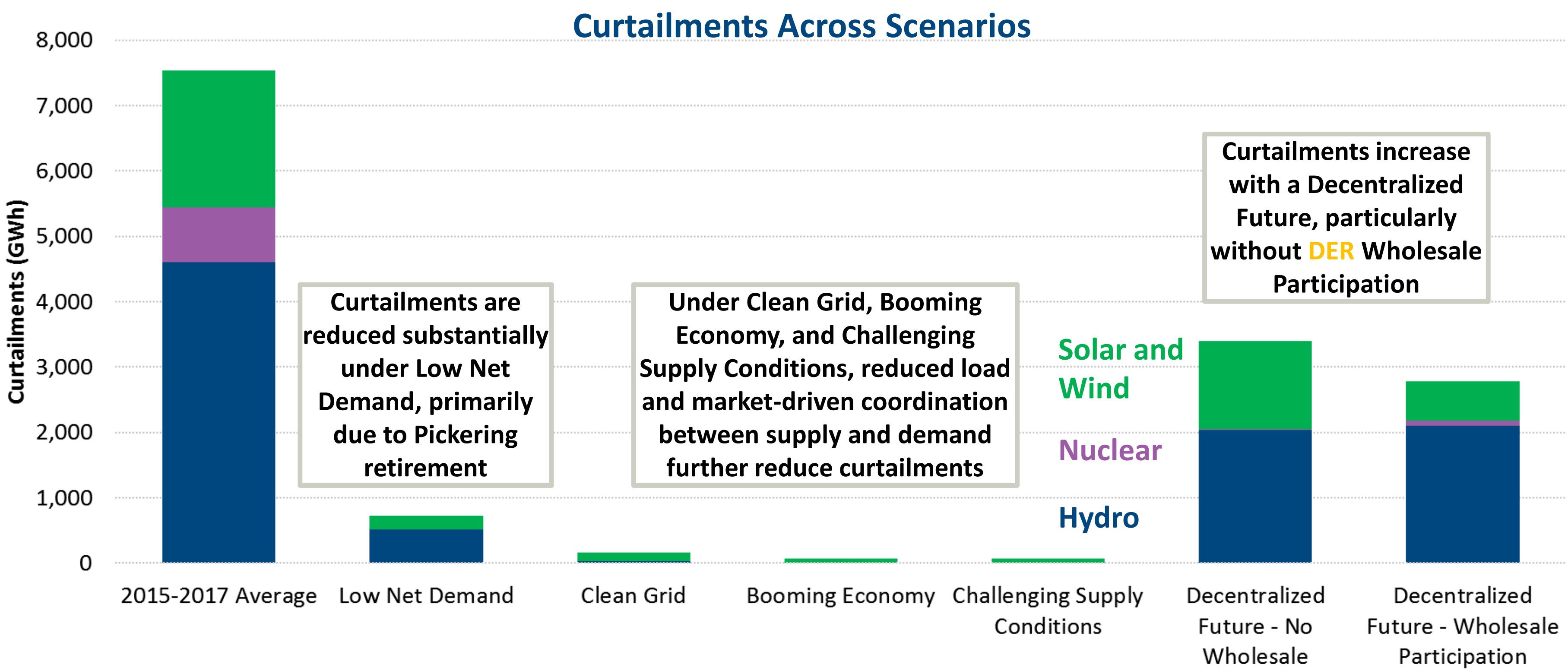
Price Duration Curve Across Scenarios



Appendix

Clean Energy Spilling & Curtailments

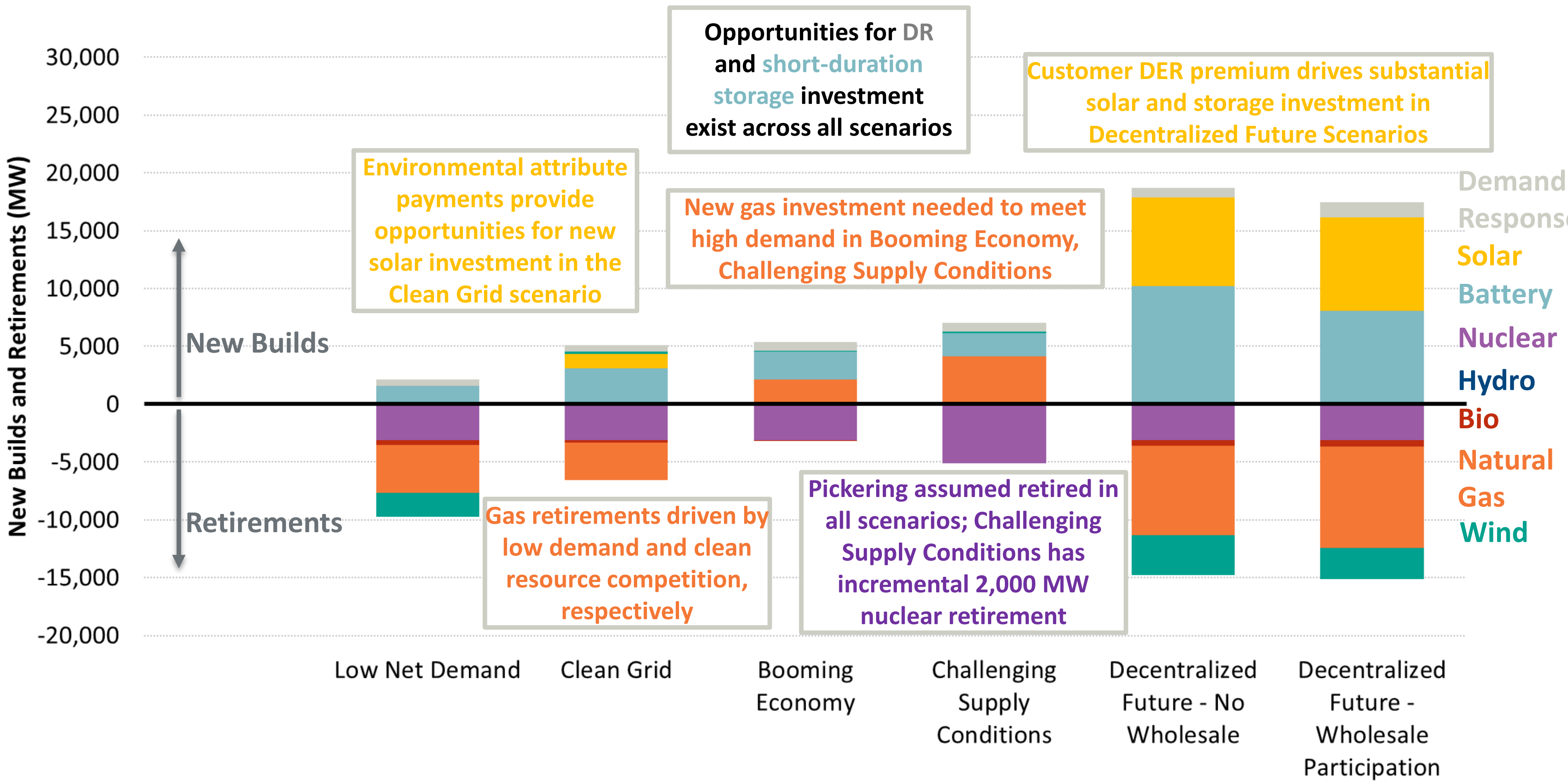
Curtailments are reduced substantially relative to recent conditions across all scenarios, largely due to Pickering retirement, higher load, and market-driven co-ordination between supply and demand



Appendix

Capacity Additions and Retirements

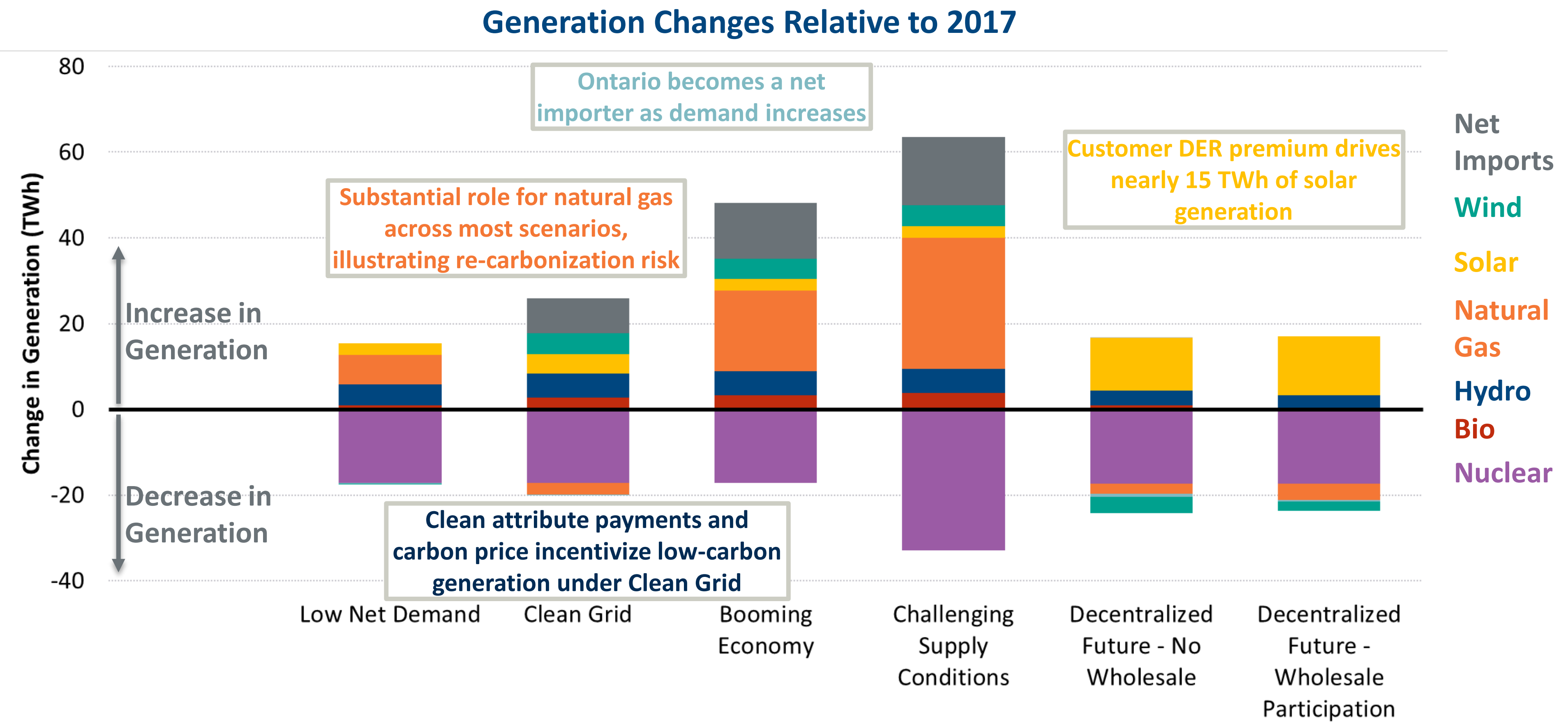
Capacity Additions and Retirements Relative to 2017



Notes: All scenarios include 1,000 MW of capacity imports into Ontario. Pickering and Thunder Bay Generation Station are retired in all scenarios.

Appendix

Generation Changes Across Scenarios

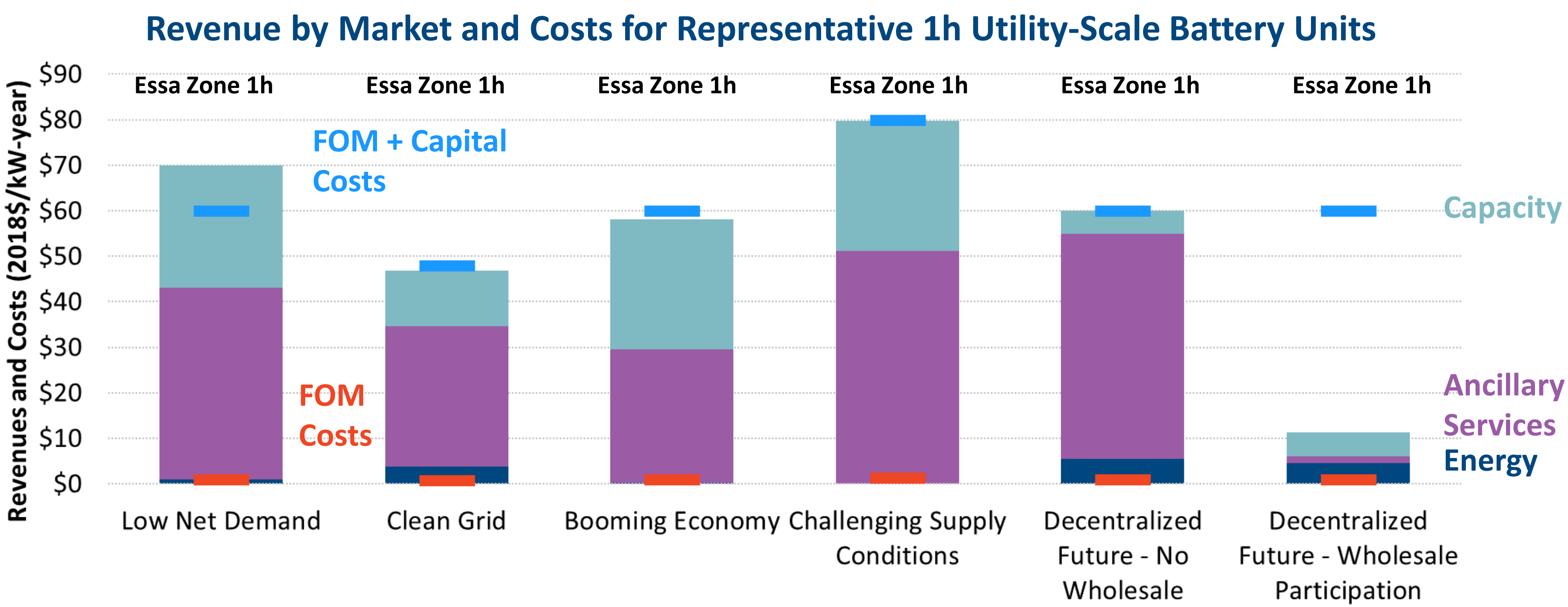


Notes: Energy imports and exports are based on a price-responsive supply curve in each scenario. The cost of imports increases in the higher gas price scenarios. Ontario exported 14 TWh of energy in 2017. This decreases to nearly 12 TWh of exports in Low Net Demand, and then Ontario becomes an importer in Clean Grid, Booming Economy, and Challenging Supply Conditions.

Appendix

Revenue Opportunities: Utility-Scale Battery

Short-duration (particularly 1h) utility-scale batteries are attractive across most scenarios, primarily due to capacity and A/S sales. Most utility-scale storage additions are in Toronto



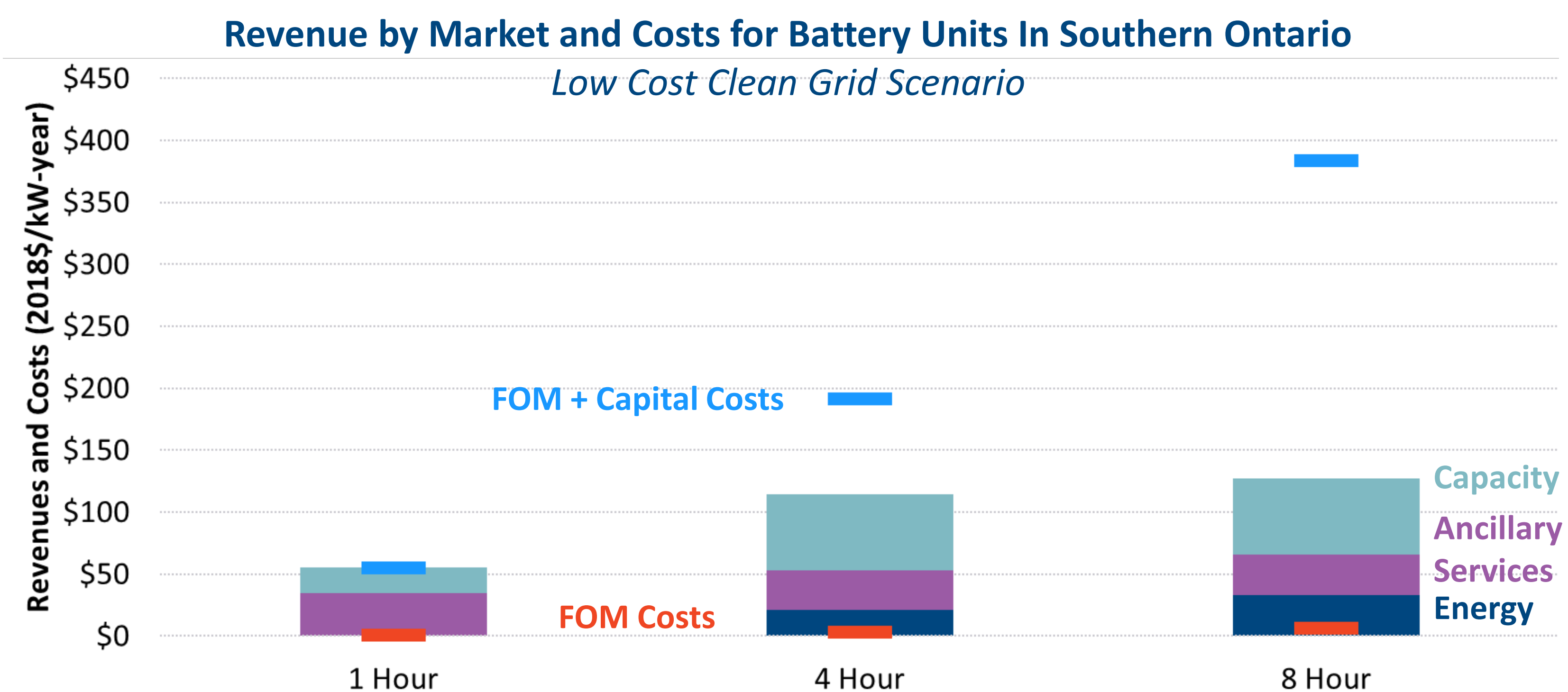
Additions (MW)	1,504	2,994	2,428*	1,992	10,209	8,000
Retirements (MW)	0	0	0	0	0	0

Notes: *Storage additions under Booming Economy occur only in Toronto. Additions and Retirements reflect all battery durations, behind the meter and wholesale-connected, though all additions are 1-2 hour duration. 1-hour storage investment under Low Net Demand and Challenging Supply Conditions is equal to the maximum quantity that can be developed at 45% capacity value. Net revenues exceed capital + fixed O&M costs at 45%, but are not sufficient to attract additional storage at the 20% capacity value for incremental supply.

Appendix

Revenue Opportunities: 1, 4, and 8h Battery

Capacity, ancillary service, and energy revenue streams are sufficient to attract 1-hour battery investment across most scenarios, despite the lower capacity revenues. Additional revenues are not sufficient to justify the additional cost for 4- and 8-hour batteries in any scenario

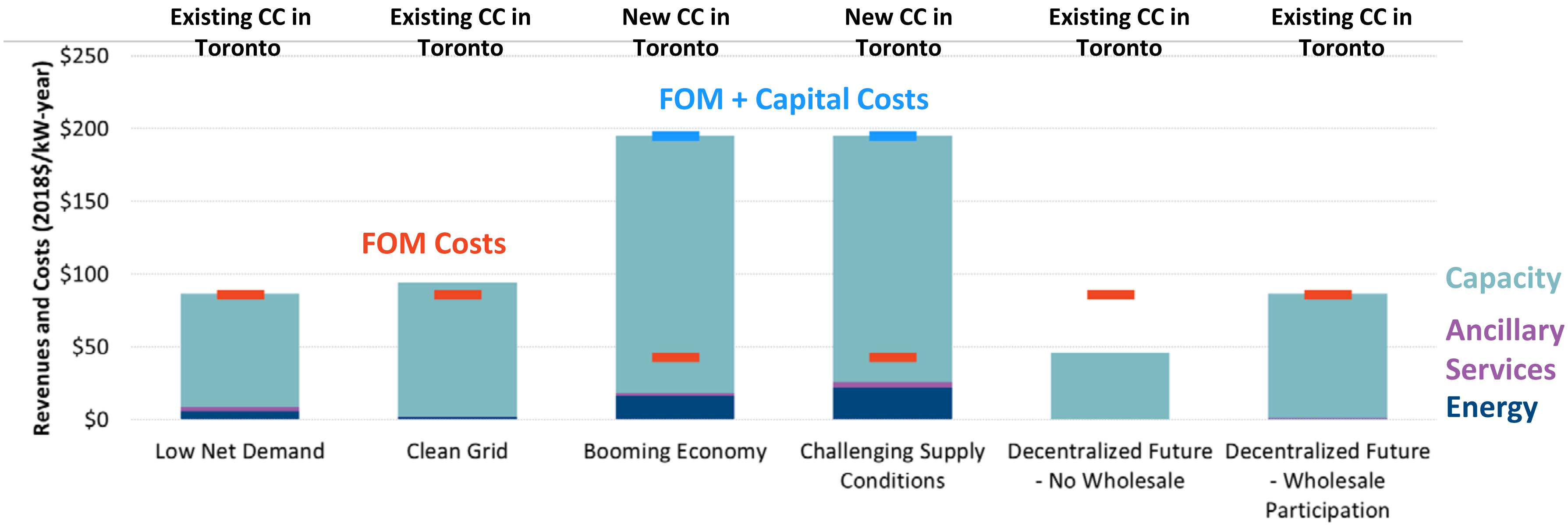


Appendix

Revenue Opportunities: Natural Gas

Capacity payments attract new CC investment (in Toronto) and uprates (across the province) under Booming Economy and Challenging Supply Conditions. Under other scenarios, Lennox retires, as does additional CC and CT supply across the province, while revenues are sufficient to retain some gas units

Revenues by Market and Costs for Representative Natural Gas Units

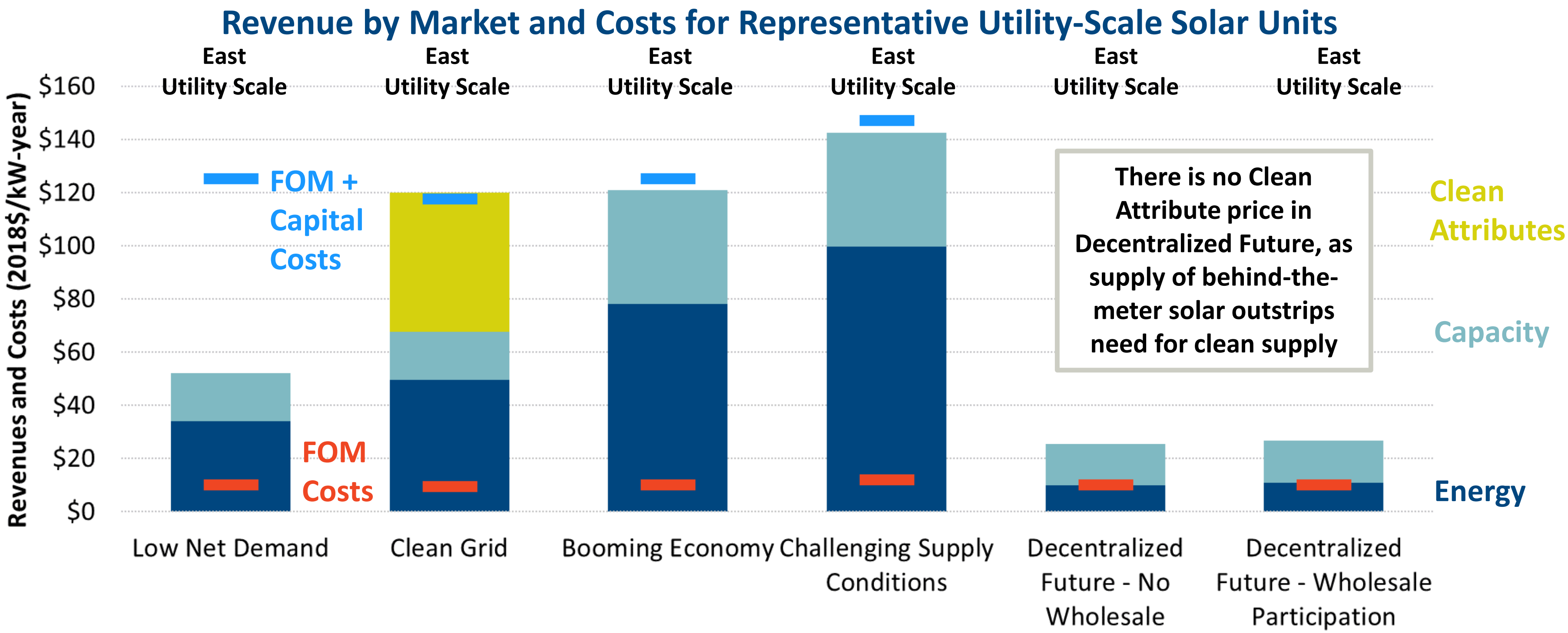


Uprates(MW)	50	66	303	313	0	52
Additions (MW)	0	0	1,768	3,781	0	0
Retirements (MW)	4,160	3,265	0	0	7,763	8,752

Notes: Additions/Uprates and Retirements reflect all gas resource types. New natural gas resources are on the margin for capacity under Booming Economy and Challenging Supply Conditions scenarios and these resources will receive exactly FOM + Capital Cost across markets. Under Low Net Demand, Clean Grid, and Decentralized Future, older existing Gas CCs with higher fixed O&M are on the margin for capacity.

Revenue Opportunities: Utility-Scale Solar

Clean attribute payments attract new utility solar investment in Southern Ontario under Low Cost Clean grid; energy and capacity payments retain existing solar in other scenarios

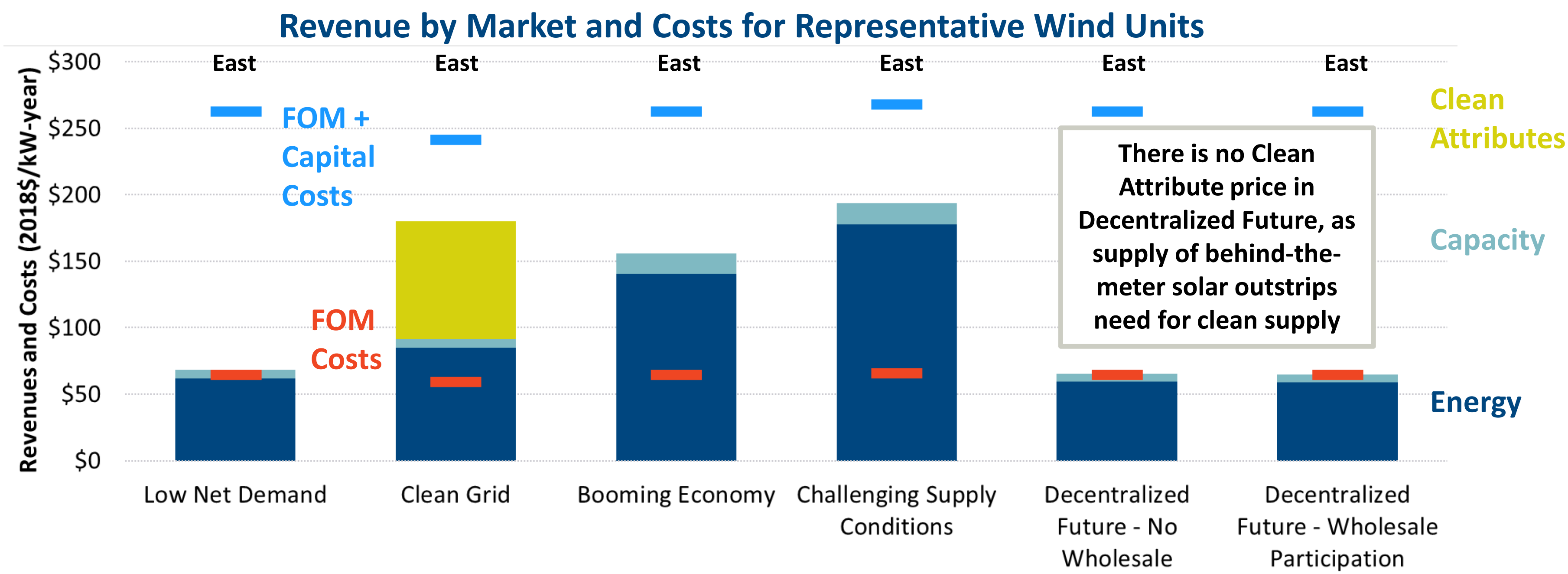


Additions (MW)	0	1,246	0	0	0	0
Retirements (MW)	0	0	0	0	0	0

Notes: Additions and retirements reflect utility solar. Decentralized Future scenarios include over 7,000 MW of rooftop solar investment in addition to the utility-scale solar shown above.

Revenue Opportunities: Wind

Market revenues retain existing wind and incentivize uprates under Low Cost Clean Grid, Booming Economy, and Challenging Supply Conditions. Wind resources retire across the province under other scenarios



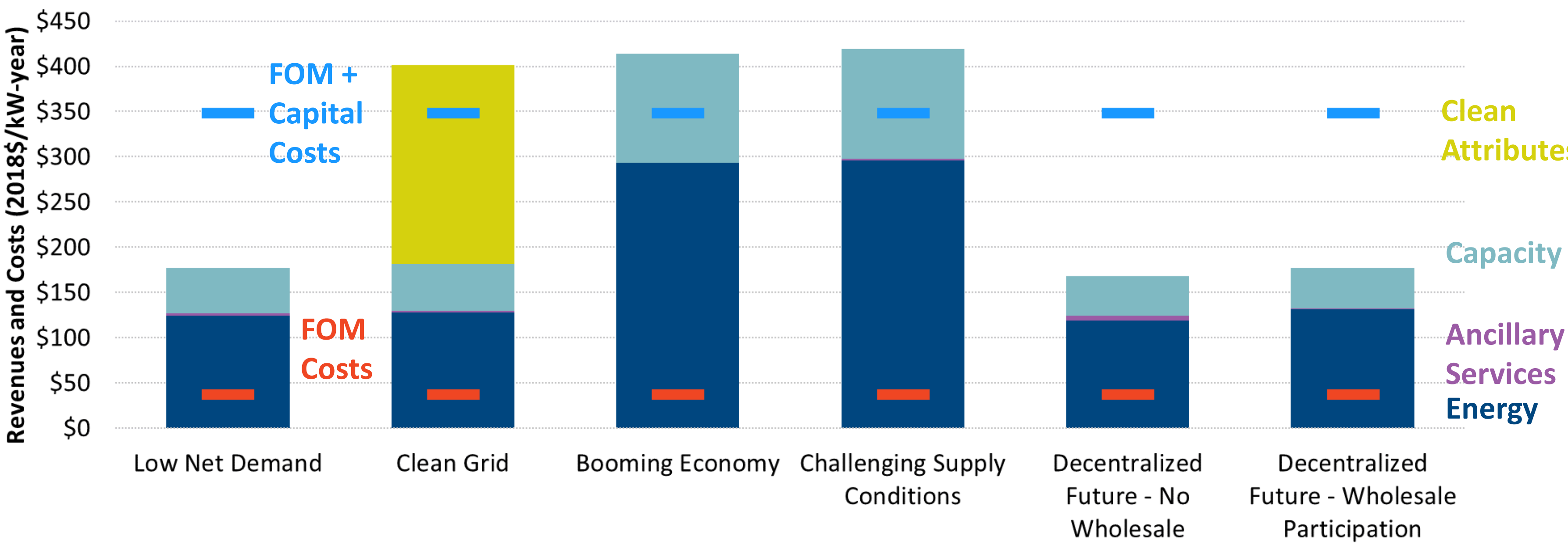
	Low Net Demand	Clean Grid	Booming Economy	Challenging Supply Conditions	Decentralized Future - No Wholesale	Decentralized Future - Wholesale Participation
Additions (MW)	0	0	0	0	0	0
Uprates (MW)	0	189	90	117	0	0
Retirements (MW)	2,042	0	0	0	3,416	2,715

Notes: Under base case assumptions, market prices (for energy, capacity, and clean attribute) are high enough to attract uprates at existing wind facilities (up to 3.5% additional capacity is assumed to be available at existing facilities) under several scenarios, but not high enough to attract new entry.

Revenue Opportunities: Hydro

There are opportunities for low-cost, small-scale hydro under the Low Cost Clean Grid, Booming Economy, and Challenging Supply Conditions scenarios

Revenue by Market and Costs for Small-Scale Hydro Resources

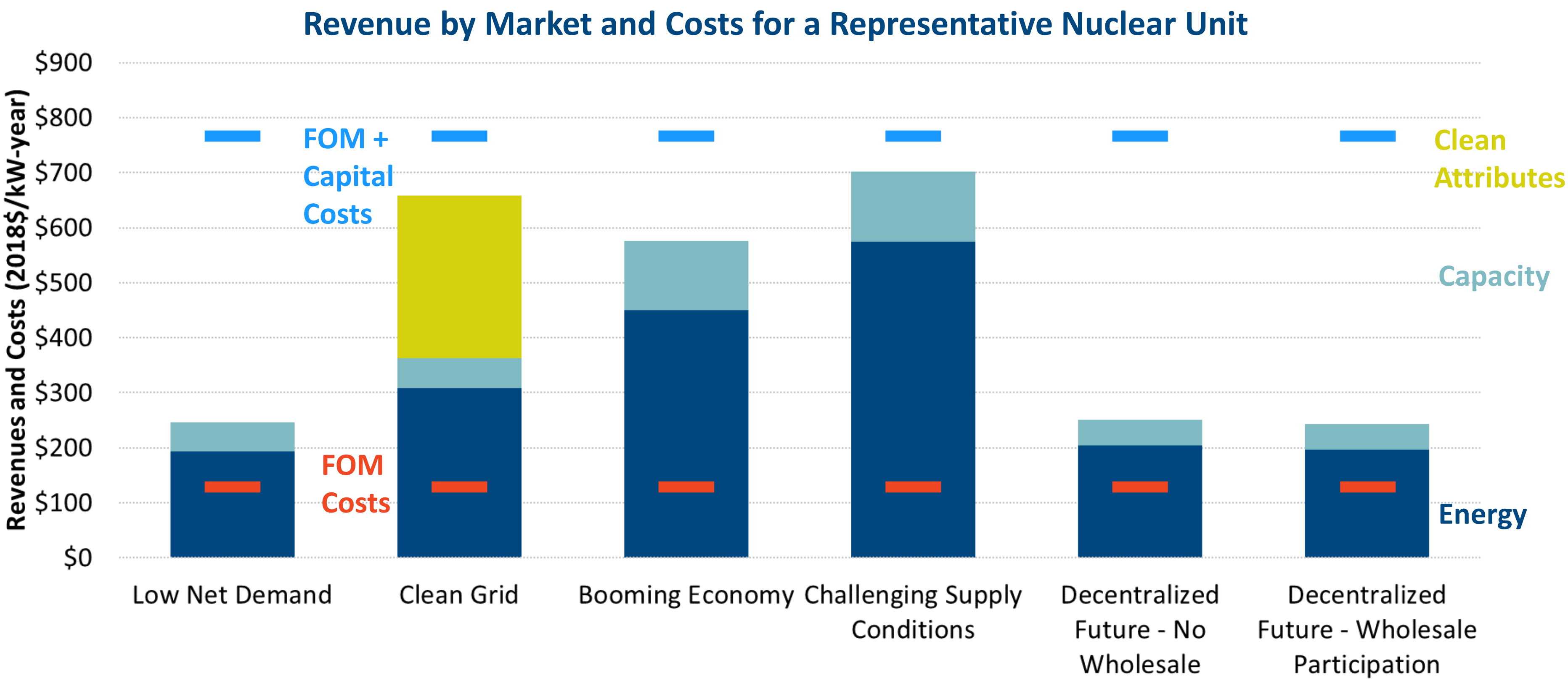


Additions (MW)	0	30	15	30	0	0
Retirements (MW)	0	0	0	0	0	0

Notes: All hydro additions are small-scale, lower-cost hydro resources. There may be additional opportunities for small-scale hydro development in the province, including at Brownfield sites in the South. If additional lower cost supply were available, hydro additions might exceed the levels shown here. See the “Opportunities for Small Hydro” change case.

Revenue Opportunities: Nuclear

Energy and capacity payments provide enough revenue to keep existing nuclear plants (after Pickering retirement) economic across all scenarios

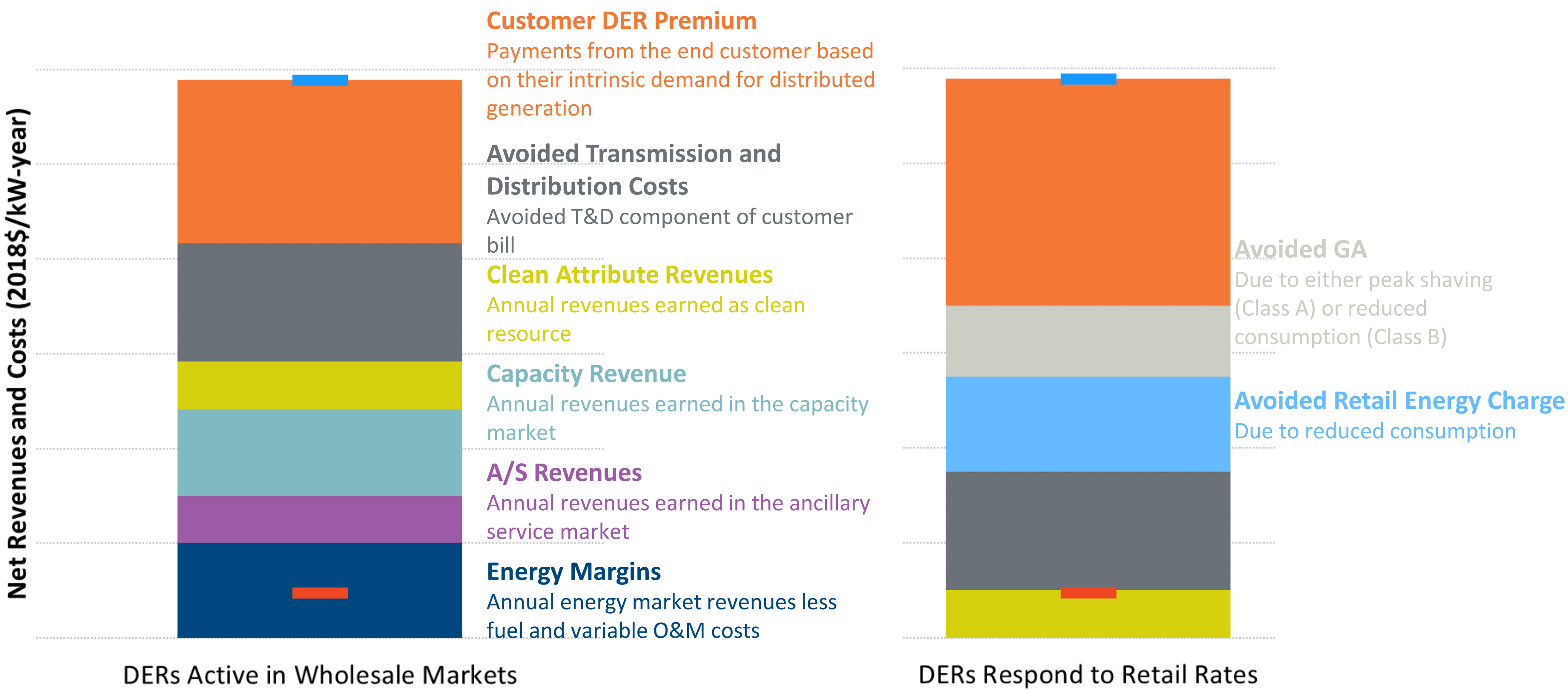


Note: Pickering is retired in all scenarios. Challenging Supply Conditions has an additional 2,000 MW of nuclear retirement

Appendix

Distributed Resource Business Models

In the decentralized future scenario, distributed resources could capture value using a range of different *potential* business models



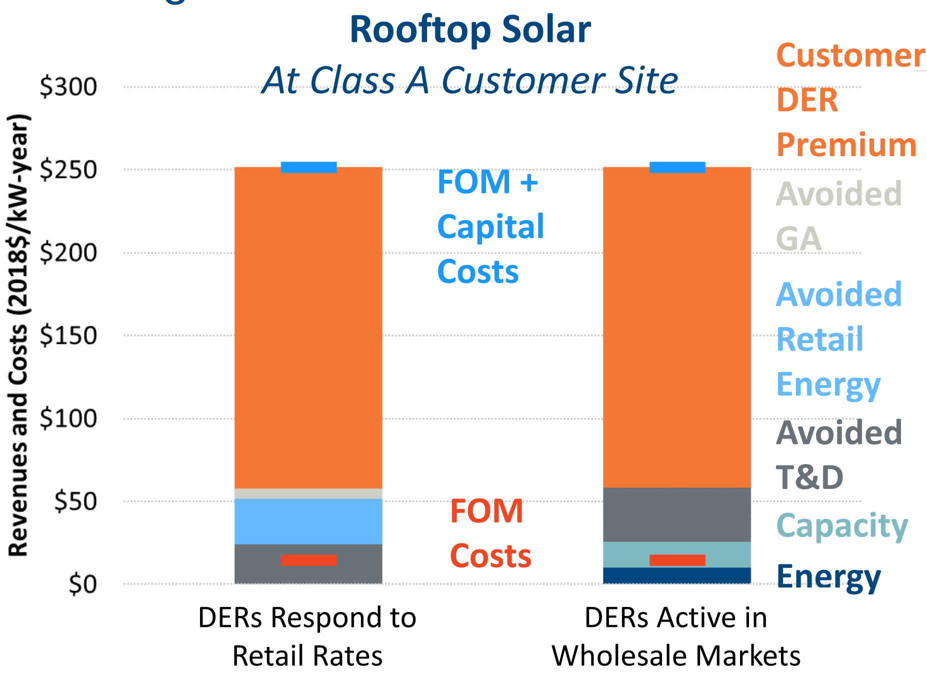
If distributed resources actively participate in wholesale markets, they can earn the same revenue streams as grid-connected resources, plus avoided T&D and customer DER premium

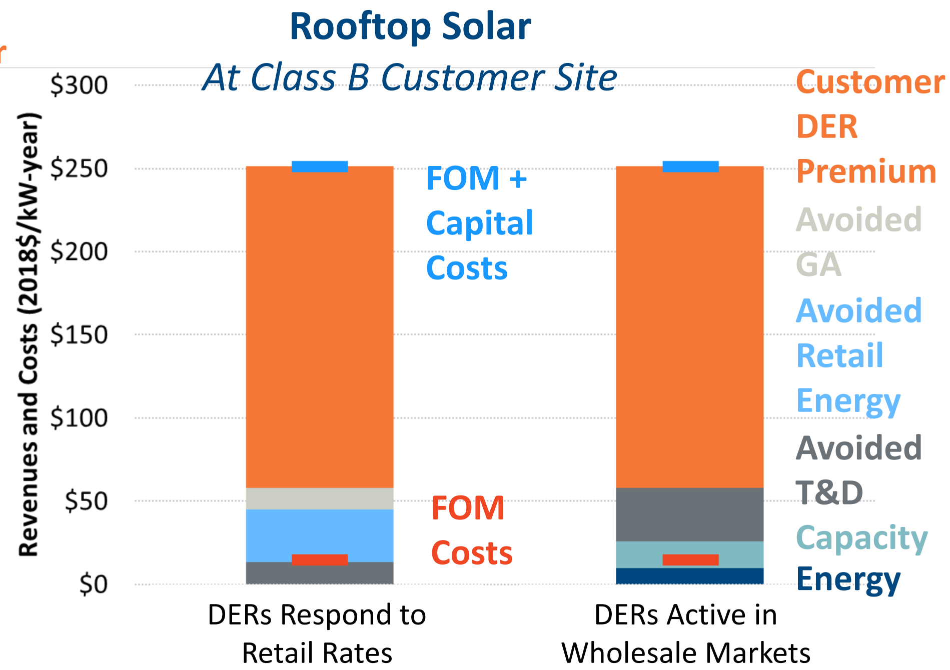
If distributed resources do not participate in wholesale markets, they can earn avoided T&D, avoided retail energy charges, avoided GA and customer DER premium

Note: These figures illustrate different value streams a distributed resource *could* capture, but results may show any combination of these value streams.

Revenue Opportunities: Rooftop Solar

In the Decentralized Future scenarios, solar investment is predominantly driven by a customer DER premium and avoided transmission and distribution charges





Reduced curtailments under Wholesale Participation increase Avoided T&D for Class A and B resources

Class B solar resources avoid modest amounts of either volumetric or peak-allocated GA

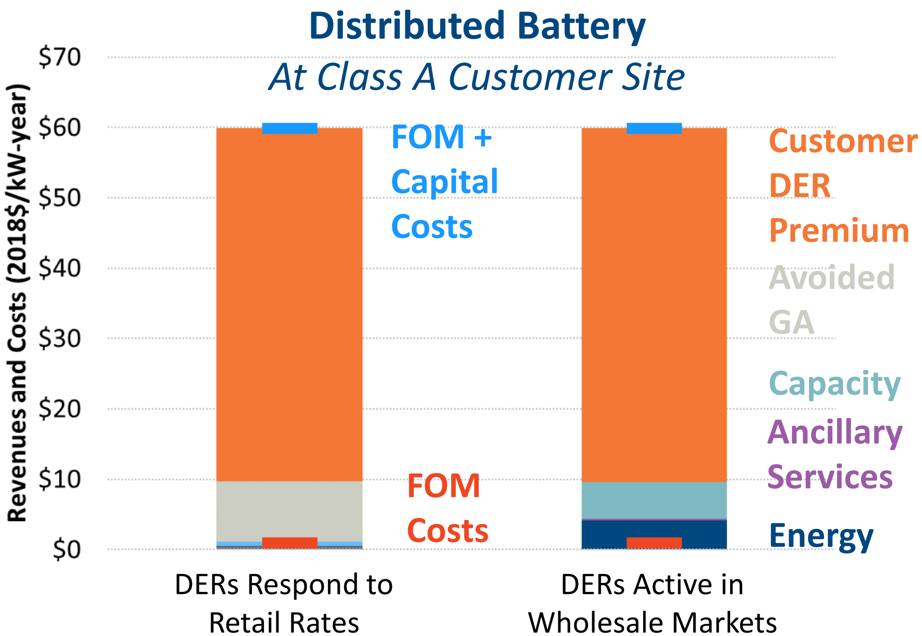
Without wholesale participation, solar can avoid retail energy payments

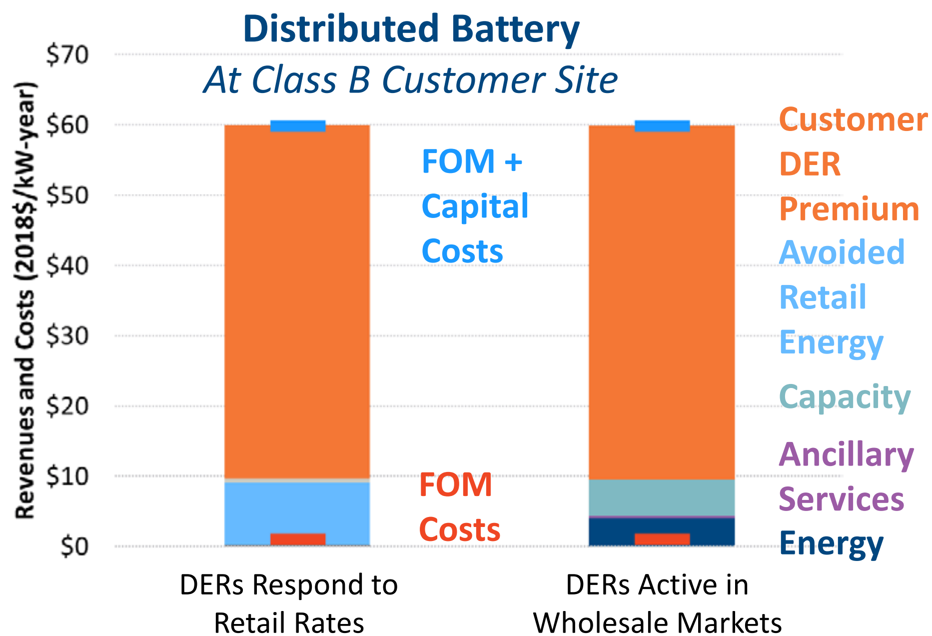
Customer DER premium covers a considerable portion of rooftop solar costs

Note: Avoided T&D refers to Avoided Transmission and Distribution charges

Revenue Opportunities: Distributed Battery

In the Decentralized Future scenarios, distributed battery investment is dominated by a customer DER premium, with GA playing a role for Class A customers and avoided retail energy charges for Class B





Batteries owned by Class A customers are able to avoid peak-allocated GA and avoid some T&D and retail energy charges, taking advantage of surplus distributed solar generation

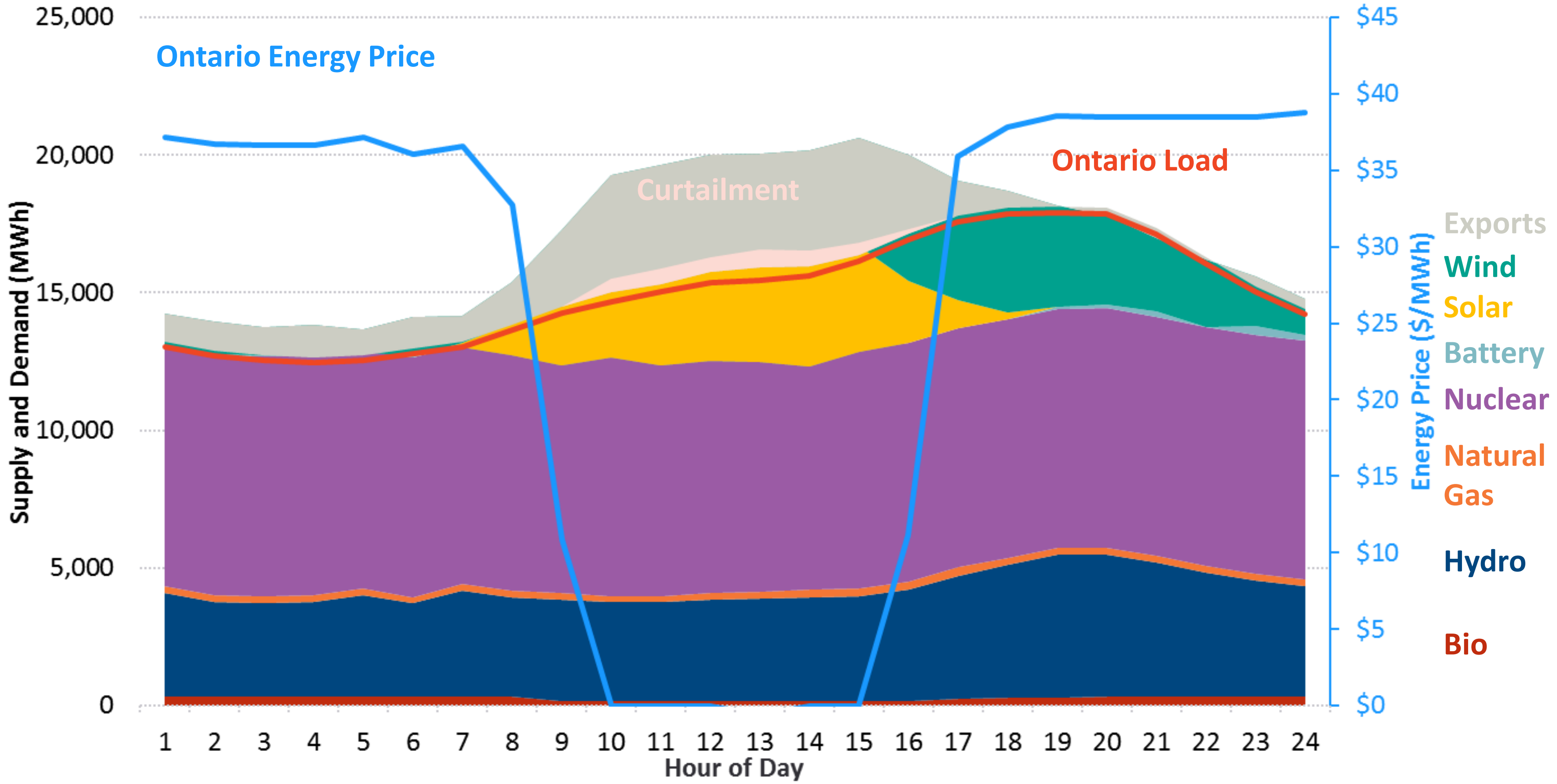
Customer DER premium covers the majority of distributed battery costs

Batteries owned by Class B customers predominantly avoid retail energy charges and also take advantage of surplus distributed solar

Note: Avoided T&D refers to Avoided Transmission and Distribution charges

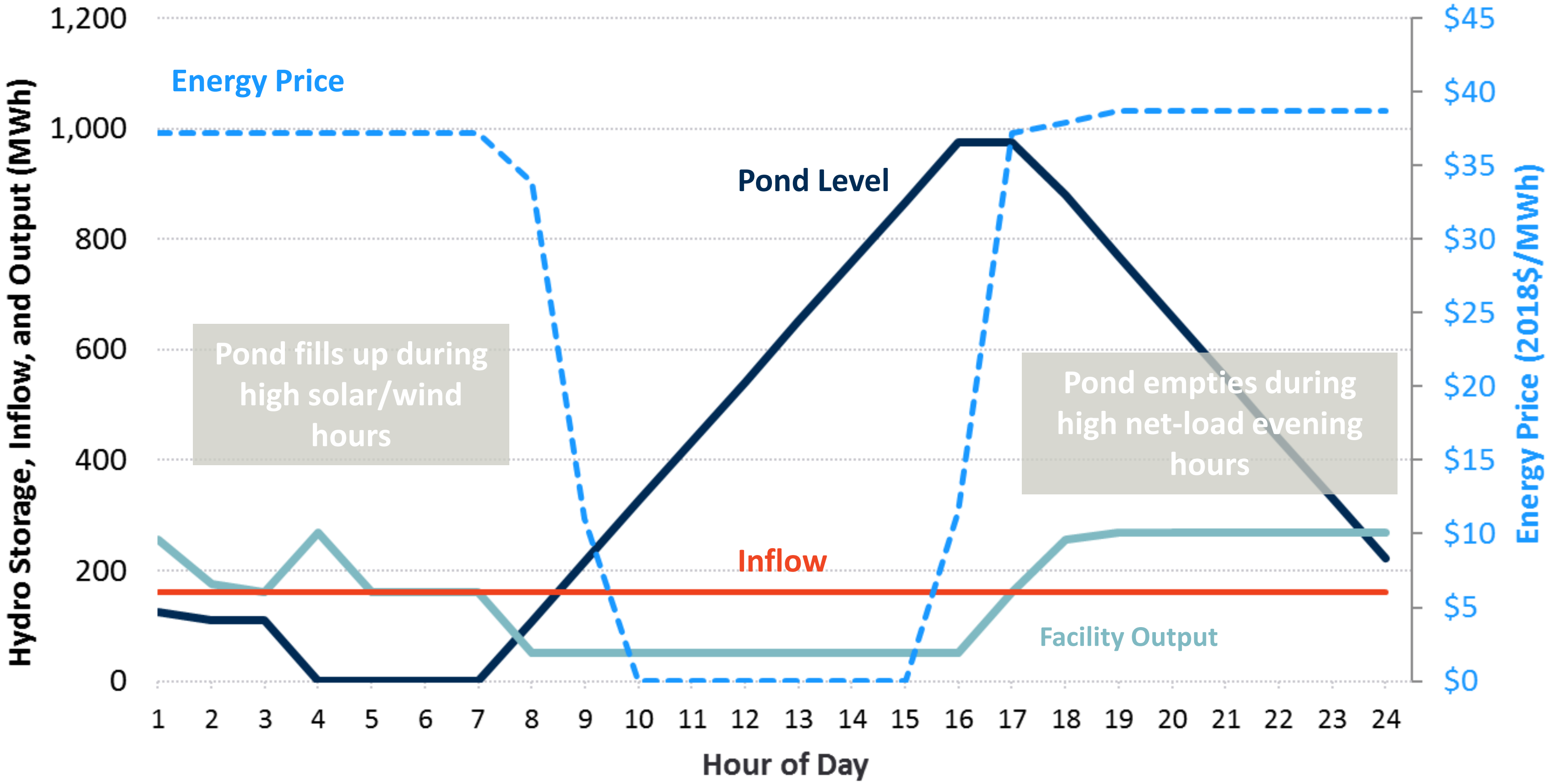
Hourly Generation Mix: Duck Curve

September 4th, Low Cost Clean Grid: Ontario manages a "duck curve"- like renewable ramp by backing off hydro, increasing exports, and small amount of "economic dispatch" hydro curtailment



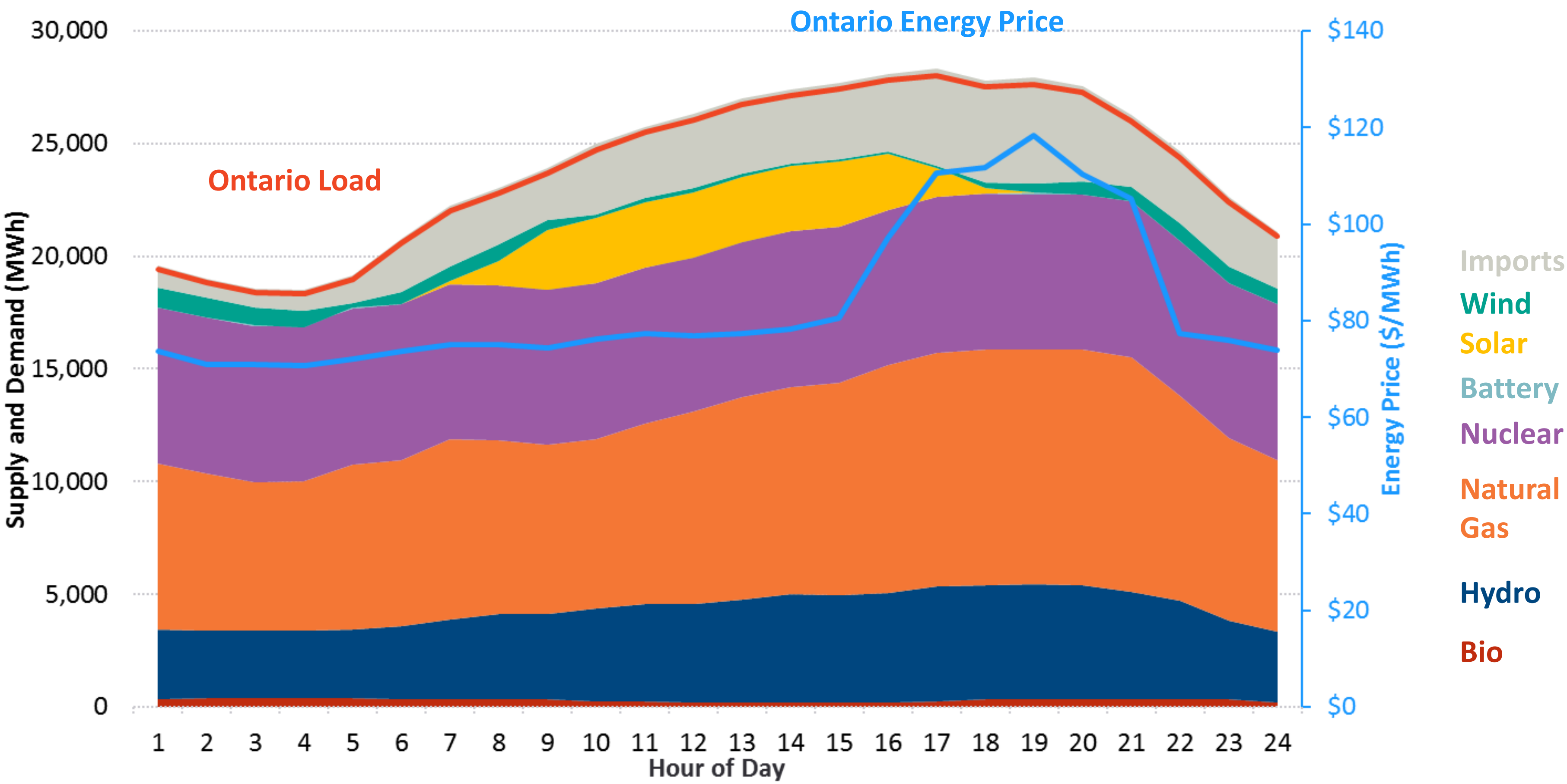
Hourly Operations: Energy-Limited Hydro

September 4th, Low Cost Clean Grid: Energy-limited hydro in the East zone fills pond when solar/wind output peaks, then ramps up in the early evening



Daily Operations Details: High Peak

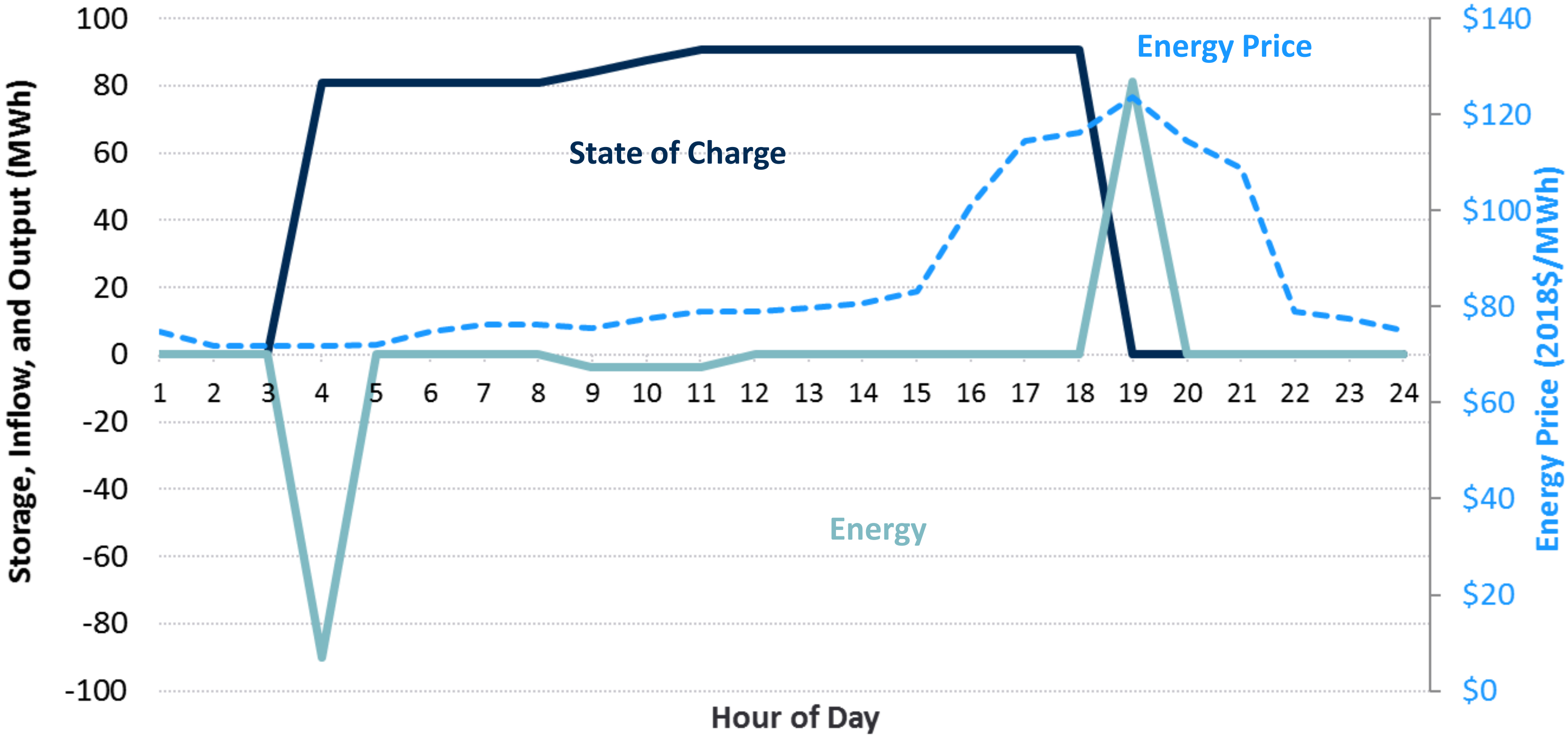
September 25th, Challenging Supply Conditions: Ontario manages an early evening net load peak using gas and hydro peakers, battery discharge, and increased imports



Note: Total battery generation reaches 85 MWh in hour 19 during peak energy price.

Hourly Operations: 2h Battery

September 25th, Challenging Supply Conditions: 2h battery in Toronto charges early in the morning, provides reserves throughout the day, and discharges during the highest peak hours



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