

Ontario's Future Electricity Demand What Role for Nuclear?

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Marc Brouillette
Principal Consultant



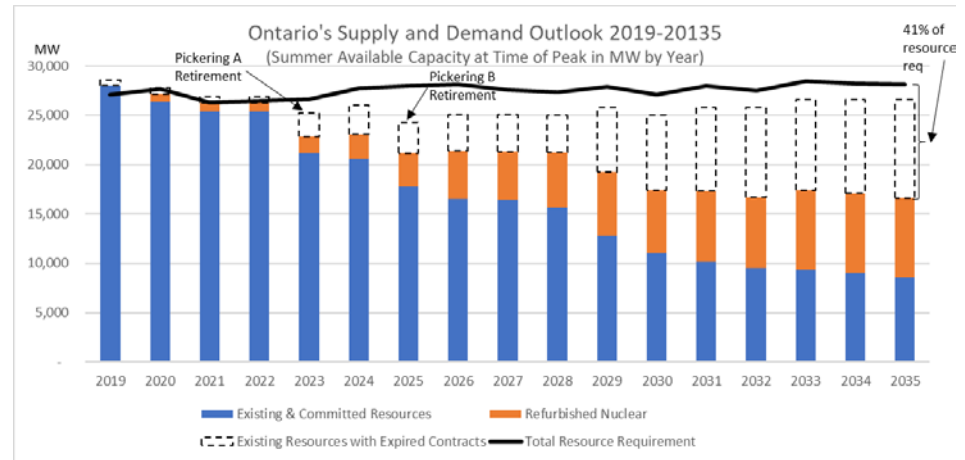
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Ontario to Replace Over 40% of Generation Capacity

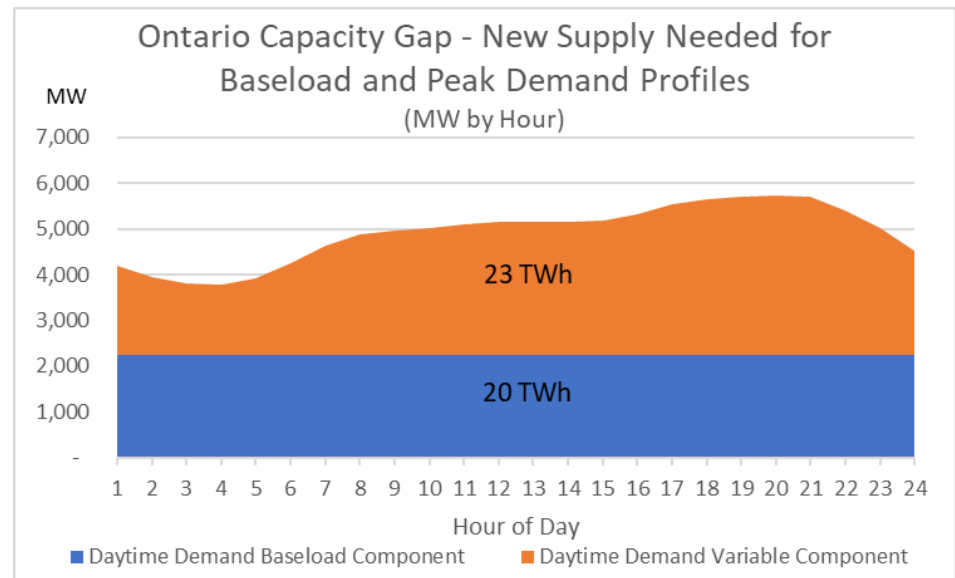
Ontario's power generation supply mix will change

- Contracted capacity is expiring and demand is growing
 - Mostly renewables and natural gas
 - 2,000 MW of baseload from Pickering's retirement



Expiring capacity supplies daytime demand

- Hydro and refurbished nuclear provide stable baseload
- 43 TWh demand above baseload to be supplied
 - 20 TWh of “baseload-like” demand
 - 23 TWh of daytime variable demand



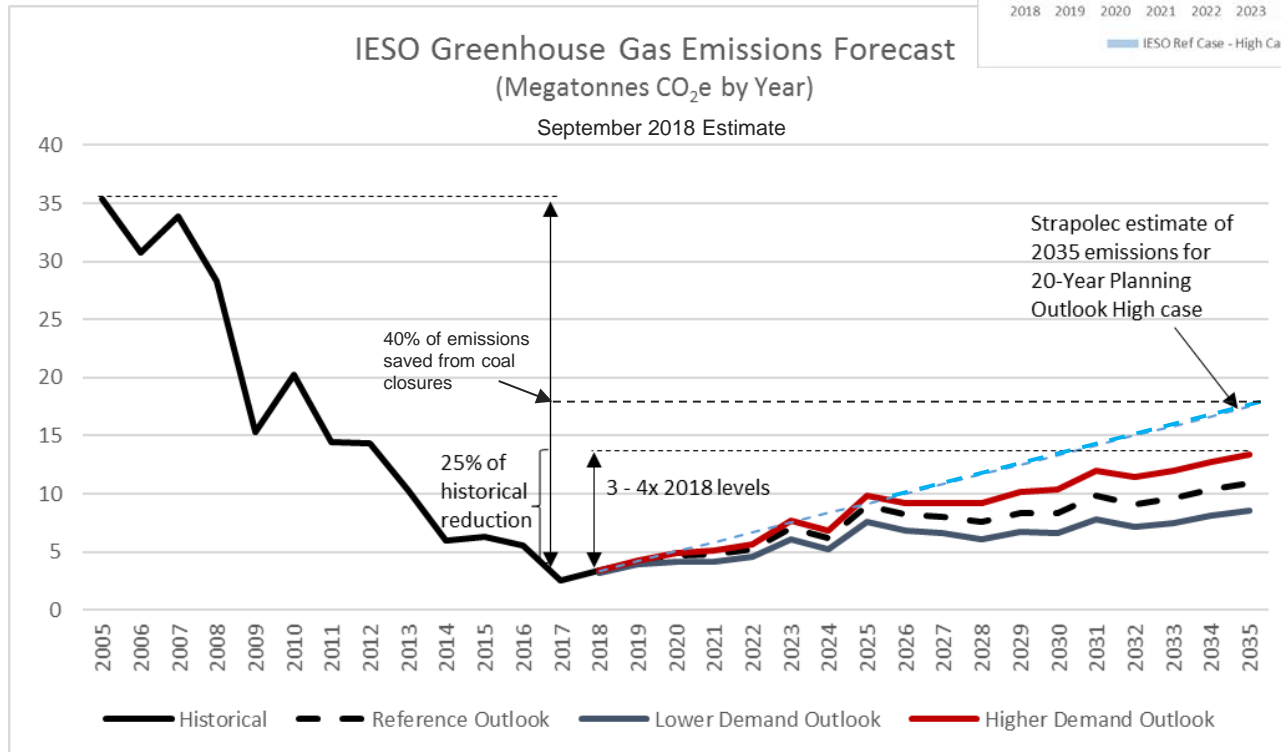
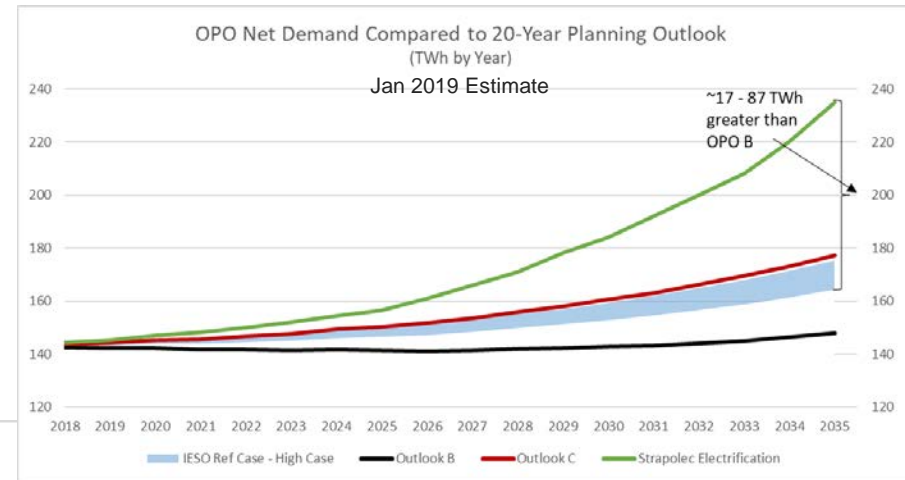
Sources: IESO 2018 Technical Planning Conference, Renewables-Based Distributed Energy Resources in Ontario, Strapolec Analysis

Emissions to Grow Under Current Plan

IESO Market Renewal Program (MRP) likely to procure natural gas-fired generation

With loss of clean baseload from Pickering NGS

- IESO MRP procurement leads to higher gas
- Increasing emissions to 3-4 times 2018 levels in 2035
 - Wiping out 25% of benefit of having closed coal plants
 - Potentially eradicating 40% of saved emissions
- Demand not reflecting electrification



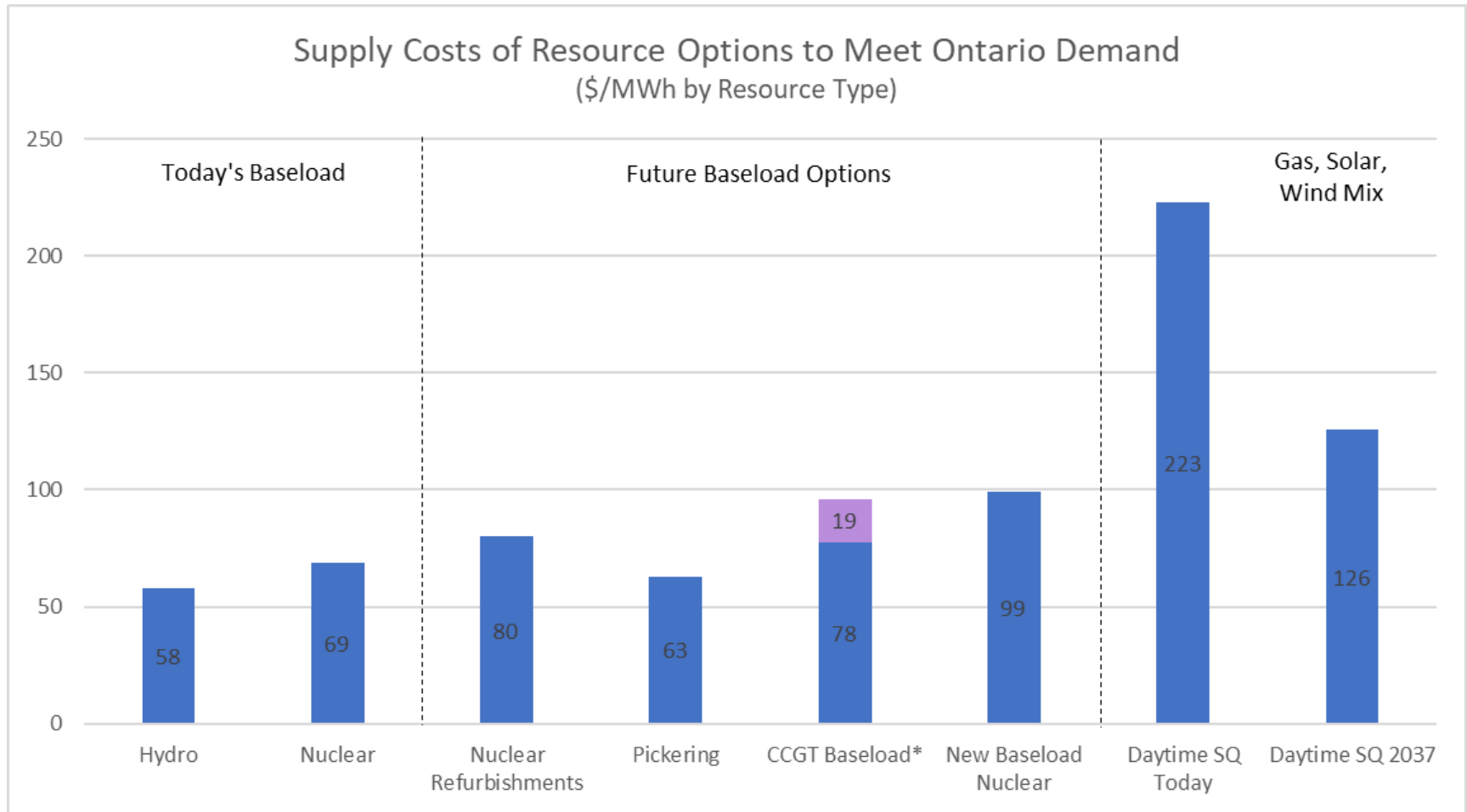
Sources: IESO 20 Year Planning Outlook, 2019, IESO 2016 OPO, Emissions and the LTEP, Strapolec Analysis

Note: Bottom of blue area is the high case from Sept 2018

Is this what we want?

Sources: IESO 2018 Technical Planning Conference, Strapolec Analysis

Cost of Resource Options in Ontario



*CCGT Baseload carbon price shown at \$50/tonne

Daytime SQ (Status Quo) represents the existing Ontario 2018 electricity supply mix to meet demand above baseload.

Daytime SQ 2037 is a similar supply mix used to meet 2037 demand based on OPO 2016 renewables cost assumptions for 2030 costs – Wind at \$86/MWh, Solar at \$90/MWh, substantially less than today

Sources: OEB RPP April 2017, FAO, Strapolec Pickering Report, OPO 2016, EIA 2017, Lazard LCOE Analysis 2017, Strapolec Analysis

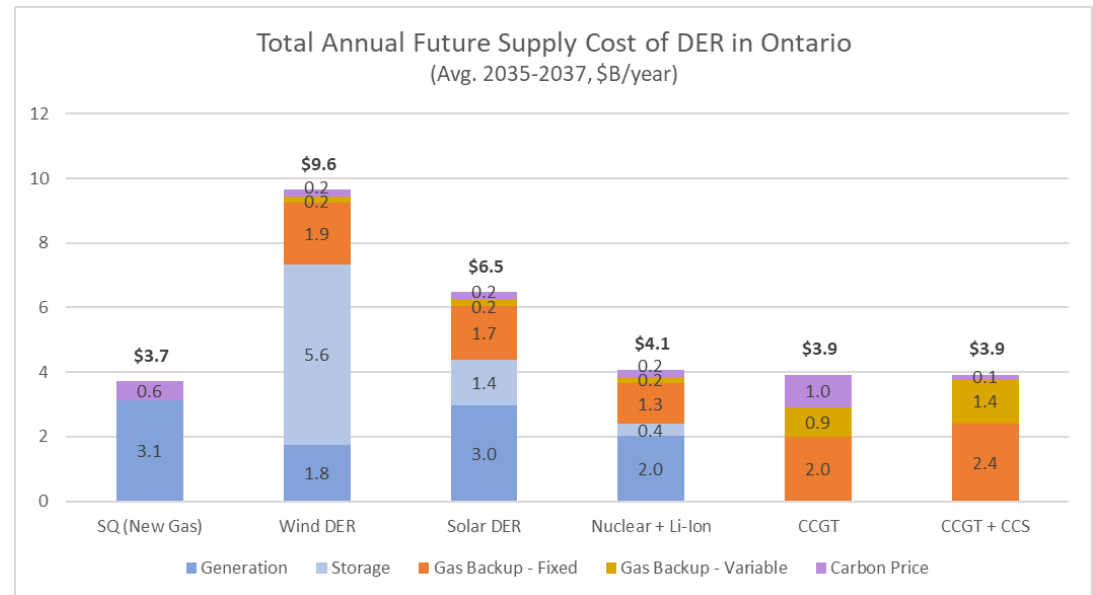
Renewables-Based Distributed Energy Resources (DER) are Costly

But promoted by the LTEP and being pursued by utilities and IESO as viable alternatives

Study conducted to understand total system cost of DER coupled with storage

Four Scenarios

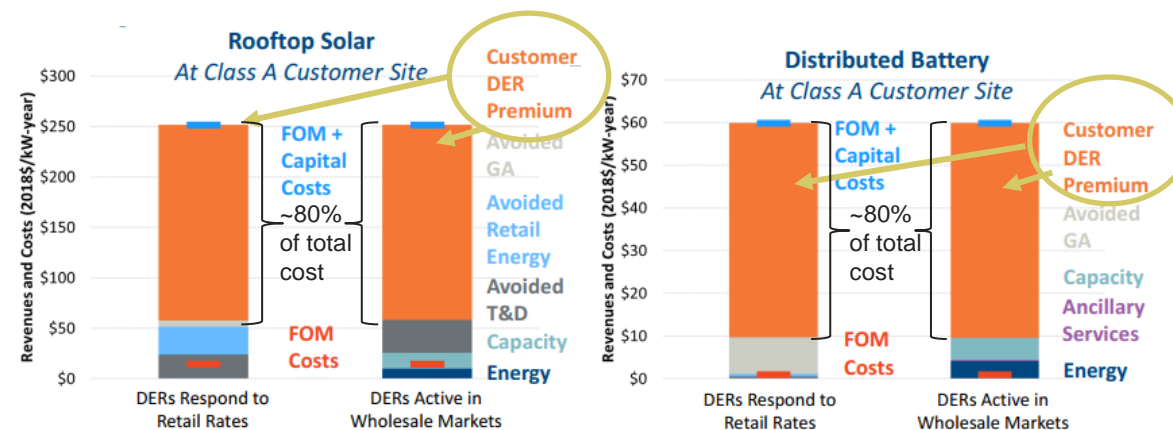
- Grid-scale wind with compressed air storage
- Distributed community scale solar with storage
- Grid scale nuclear coupled with distributed storage
- Natural gas fired CCGT for comparison



SQ = today's status quo supply mix deployed to meet 2035 demand

Residential scale solar DER is even more costly

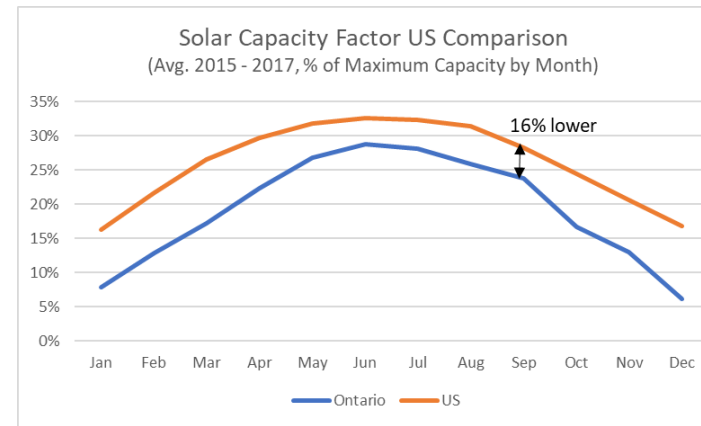
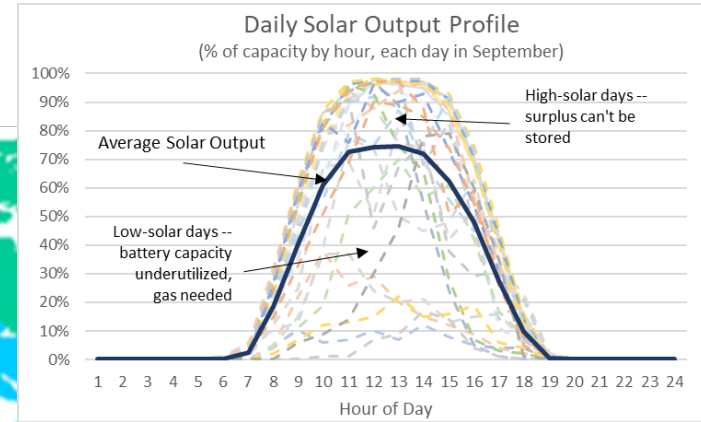
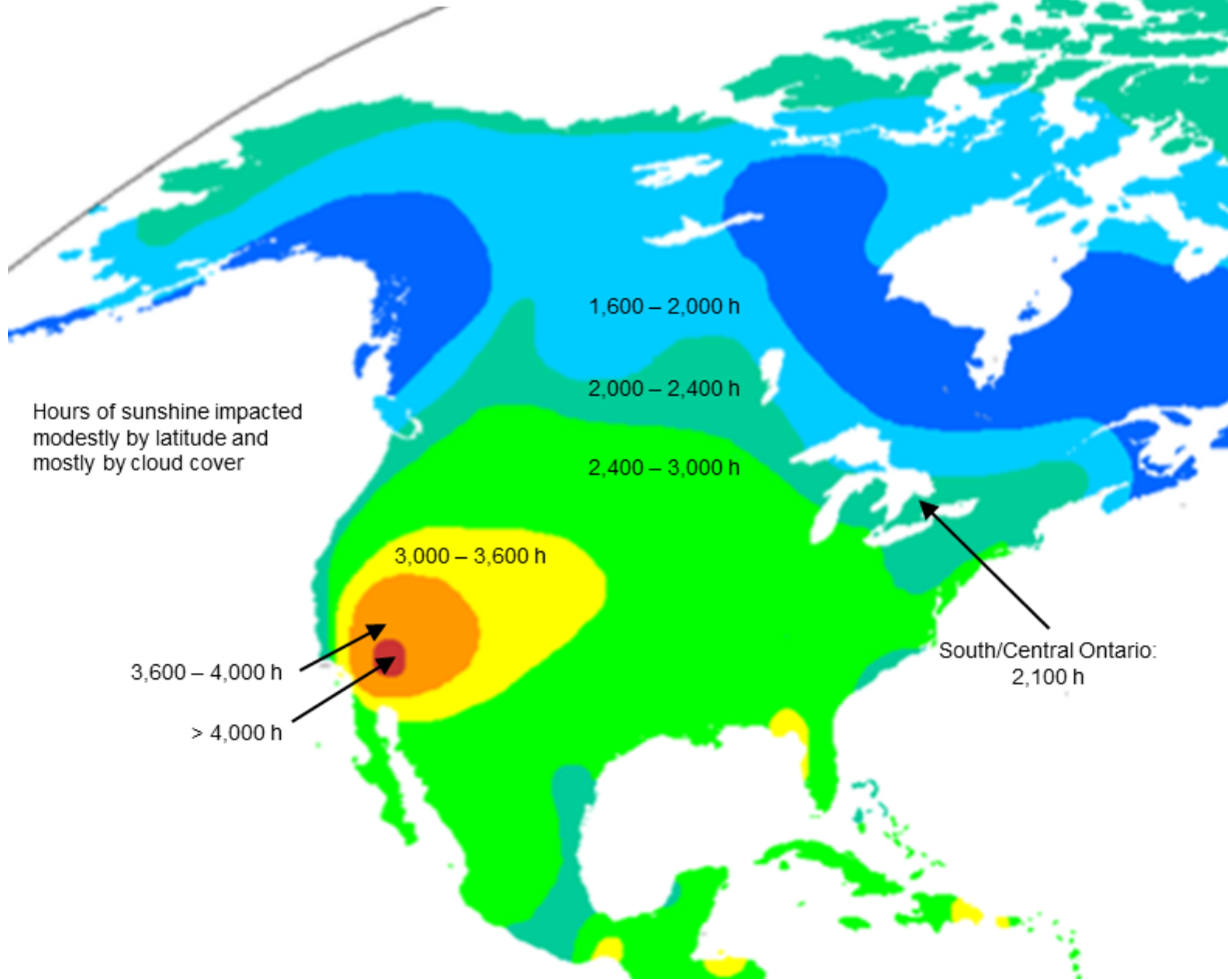
- Customers premium would be 4 times greater than the cost of electricity today



Sources: OPO 2016, EIA 2017, Lazard 2017, Renewables-Based DER in Ontario, Modelling Ontario's Future Electricity Markets Brattle Group report to IESO NERSC, Strapolec Analysis

Geography and Weather Impact Renewables Output

Annual Hours of Sunshine by Region



Sources: Renewables-Based Distributed Energy Resources in Ontario, Strapolec Analysis

Made in Ontario Provides Enhanced Economic Benefits

Total rate payers costs for nuclear is \$50B less than for solar and \$120B less than wind

- Nuclear would, however, cost \$3B more than gas
 - after the carbon tax

Economic benefits arise from domestic spend

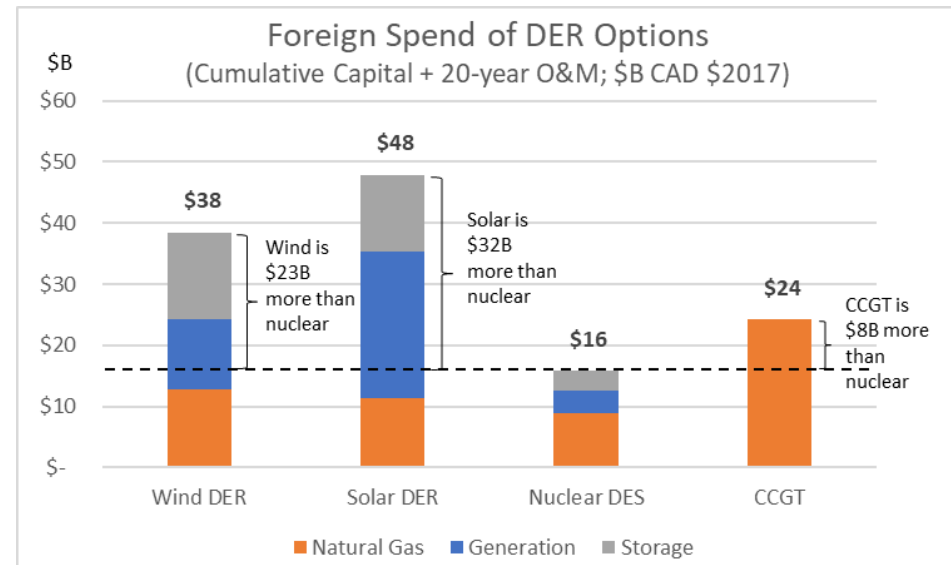
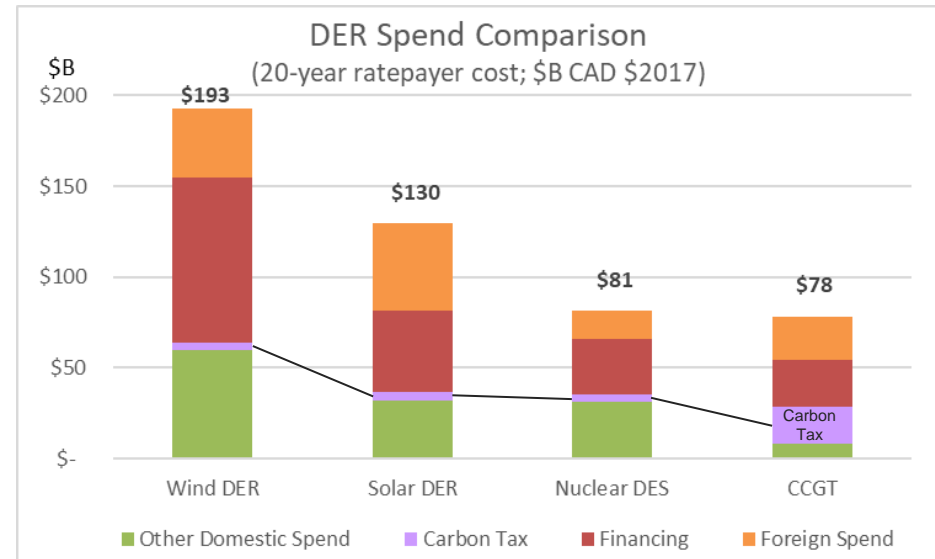
- Nuclear domestic spend is \$27B,
- Natural gas fired CCGT has only \$8B
 - With a carbon tax, the domestic spend for the CCGT becomes \$30B

Foreign spend on imports

- Nuclear-based DES system would be \$8B less than the natural gas-fired option.

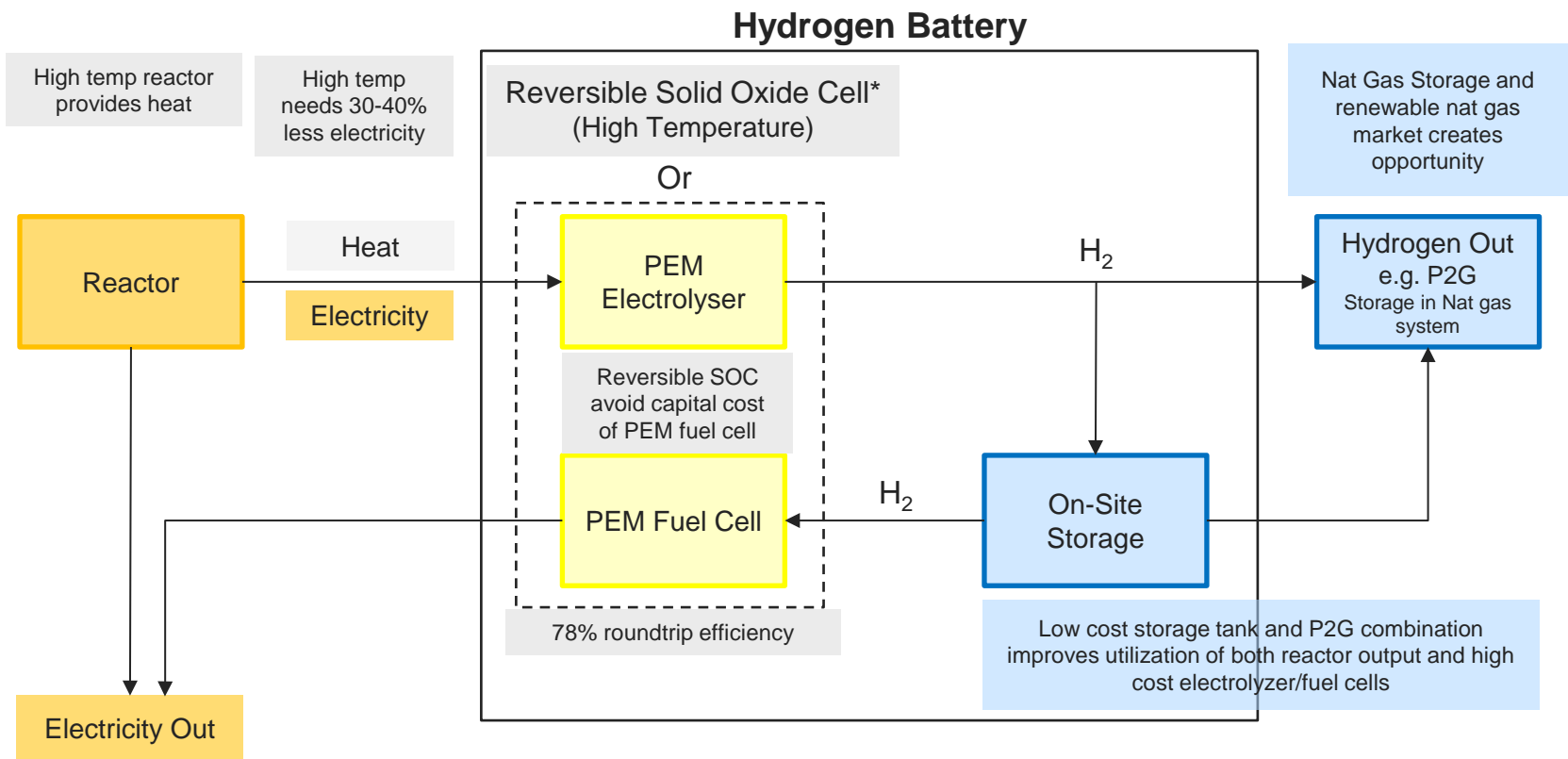
Repatriating this \$8B into the economy:

- Generate \$10B in GDP
- Adds \$1.8B to government revenues
- Helps sustain 2,300 nuclear-based DER jobs per year
- Reduce the tax burden on Ontario's residents.



Schematic of Hydrogen Battery Concept

Could be a ReSOC to a PEM-based electrolyser and fuel cell



Notes:

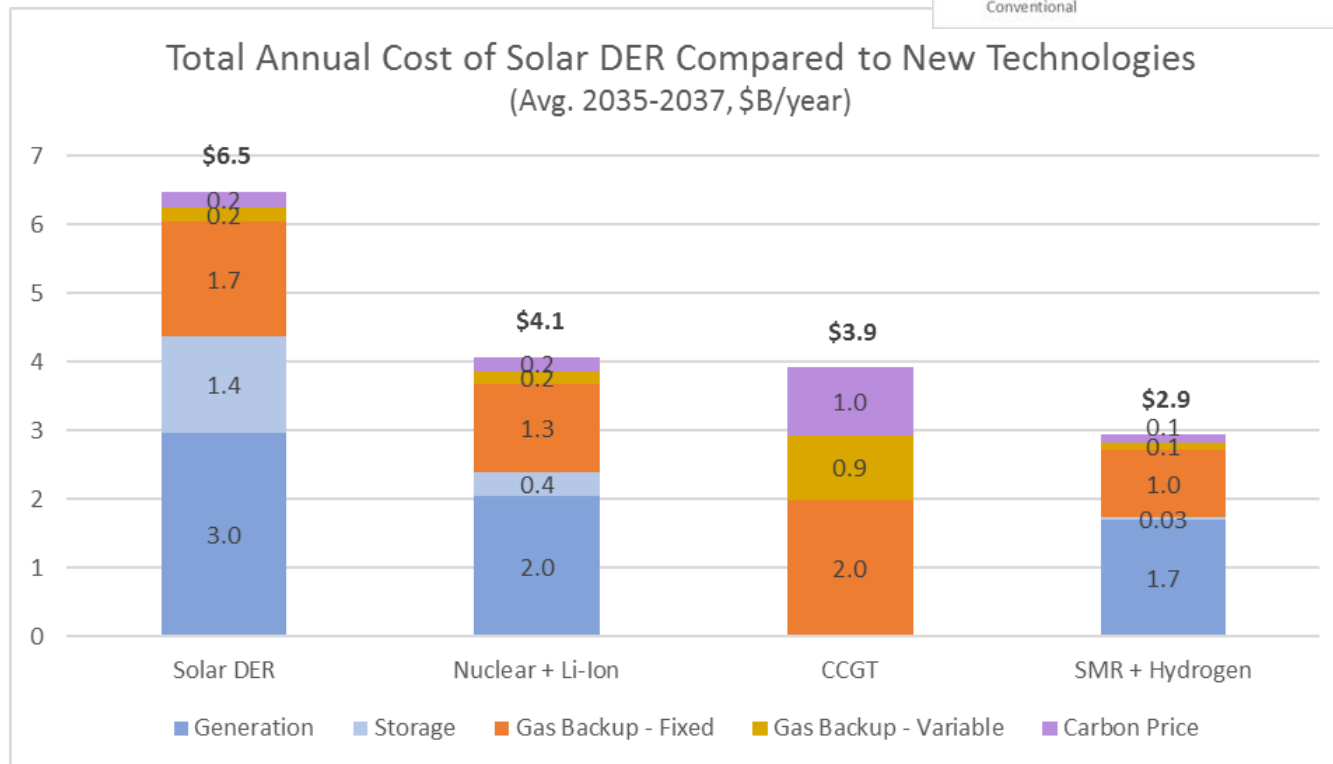
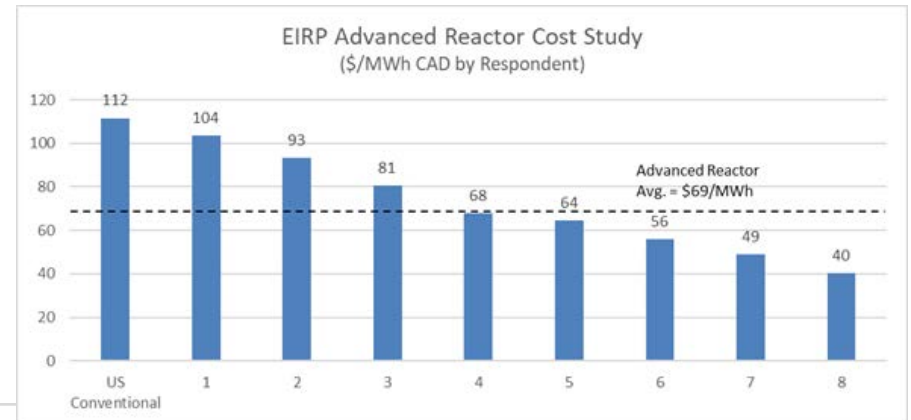
- Commercializable ReSOC still in development stage, parameters are theoretical potential
- There are other candidate high temperature technologies in development
- Li-Ion batteries have an 86% round trip efficiency

Source: Discussion with Prof. Olivera Kesler, Lazard Levelized Cost of Energy Storage 2017, Strapolec Analysis

SMR-Powered Hydrogen Battery Concept Lowest Cost Option

Surveys of SMR vendors suggest levelized costs would be about \$69/MWh (USD)

Advanced SMR paired with hydrogen battery could be less costly than CCGT option for supplying daytime demand



Source: EIRP Advanced Reactors Cost Study

Source: Emissions and the LTEP, Renewables-Based Distributed Energy Resources in Ontario, DOE Hydrogen and Fuel Cell Program Record 2016 & 2018, CH2M Hydrail Study 2018

SMR Roadmap

Published by the Canadian SMR Roadmap Steering Committee

Committee undertook a 10-month initiative to help Canada become leader in SMR tech

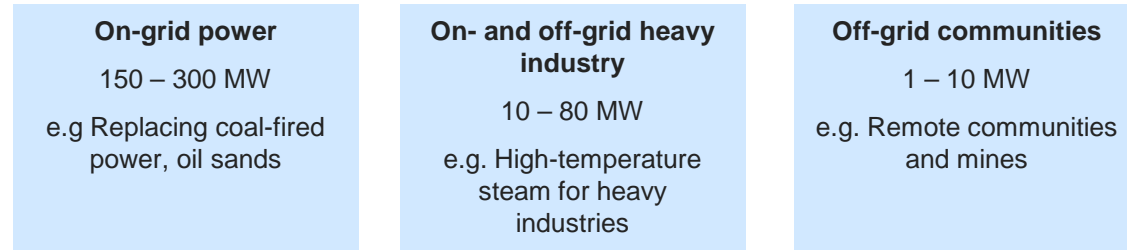
- Voting members
 - Industry: Alberta Innovates, Bruce Power, New Brunswick Power, OPG, Qulliq Energy Corp., SaskPower
 - Governments: New Brunswick, Northwest Territories, Ontario
- Non voting members
 - NRCAN, AECL
- Identified
 - Markets
 - Key Enablers
- Recommendations under 4 thematic pillars

Next steps for turning Roadmap into action

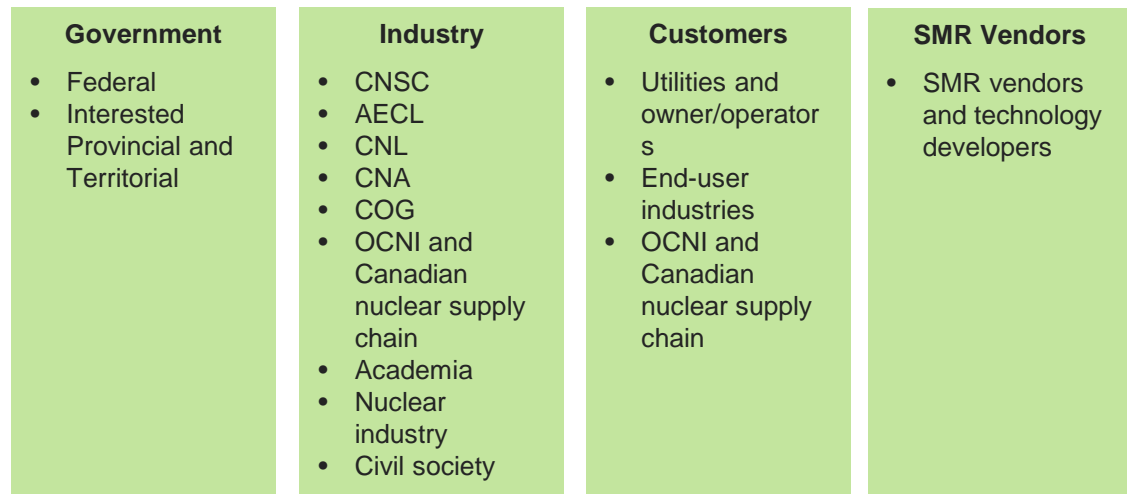
- Key organizations to take early action
 - on priority recommendations
 - with commitments to further concrete action
- Industry and governments to co-create Canada's Nuclear Energy Advisory Council
 - to review progress annually and discuss ongoing strategic priorities for future

NRCAN is independently advancing Canada as a supportive nuclear nation

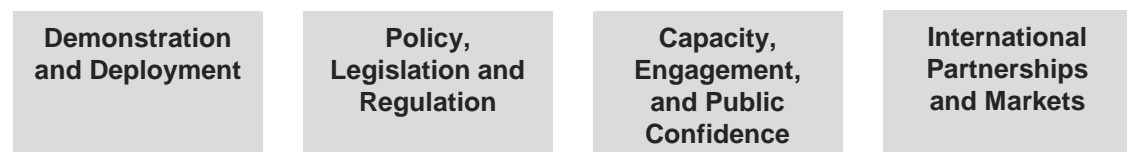
Distinct Markets



Key Enabling Organizations



Recommendation Pillars



Not clear how next steps are being pursued

Source: SMR Roadmap, NRCAN Small Modular Reactors for Mining Presentation March 2019

Discussion
