Final Input Assumptions – Pathways to Decarbonization

The updated technical and policy assumptions that will form the basis for the IESO's Pathways to Decarbonization study have now been posted. Feedback from stakeholders and communities is an integral part of this work, and the IESO appreciates their perspectives and the valuable role they are playing in shaping this analysis.

The study is exploring potential scenarios to achieve reliable and affordable decarbonization of Ontario's electricity grid, and a broad range of input has been received around the policies, resources and technologies being considered to achieve Ontario's decarbonization goals. The IESO has incorporated evidence-based feedback in a number of areas, detailed below.

Policy assumptions:

- The IESO revised the proposed approach to carbon-pricing, based on feedback and other studies, to a $15/tonne increase to 2035 and increases linked to inflation thereafter.

Electricity demand assumptions:

- Refinements have been made for some building decarbonization technologies by including additional technologies and taking improvements over the course of the outlook period into consideration.
- Decarbonization timelines for both existing and new buildings have been revised.
- Sales and deployment targets for electric vehicles have been increased.
- Minor revisions have been made to projections within the mining and agriculture sectors.

Resource and technology assumptions:

- Additional cost and performance metrics for participation in demand response programs have been informed by IESO engagement and industry research.
- Research has also informed additional updated costing and performance details in a number of areas, including: renewable generation, new large nuclear, batteries and thermal retrofits.
- Modelling will now use actual proposed pumped storage projects in Ontario.
- The potential for imports from neighbouring jurisdictions has been modified based on third-party research.

While feedback reflected the knowledge and experience of stakeholders, and all comments were considered by the IESO, some suggestions fell outside of the scope of the study. In addition, some referenced technologies that, while promising, lack a sufficient level of supporting data to allow for modelling. Full details of the feedback received and the IESO's responses have been captured in the Stakeholder Feedback and IESO Response documents and the Study Assumptions document.

It's important to note that some of these assumptions may still change in response to evolving public policy, significant corporate announcements, or further insight into the potential advancement of emerging technologies. All final assumptions used in the analysis will be posted with the study results in the fall.

Stakeholder Feedback and IESO Response

The technical and policy assumptions for the Pathways to Decarbonization study entail detailed assumptions about carbon price and electrification of the economy, as well as a wide range of resources both established and in development, and how they would operate.

The evidence-based feedback received and detailed in this document will help the IESO better understand the potential performance of these resources and how in the future they could contribute to meeting both requirements for reliability and rising electricity demand.

Feedback Received

The IESO received over 40 submissions through its formal feedback process, as well as comments from residents via email, sharing their input on environmental policies and approaches to achieving Ontario's decarbonization goals. The IESO's response to feedback on assumptions has been broken out in themes below followed by general questions.

Policy Assumptions

Feedback received on policy assumptions is summarized below and specific questions are addressed in the table.

- Introduction of policies to support the adoption of Distributed Energy Resources (DER)s
- Adoption of Building and Housing retrofit codes to align with federal building codes
- Treatment of Carbon Capture, Use and Sequestration (CCUS) in the assumptions
- Revisit cost caps on energy efficiency programs and DERs
- Application of Border Carbon Adjustments
- Consideration of District Energy
- Impact of Clean Fuel Regulation

Feedback	IESO Response
Emissions Performance Standard tapering to 0 tonne CO2e by 2035 for the Pathways Modelling should be 0 from today for both studies.	At this time, there has been no announcement to immediately reduce the Ontario Emissions Performance Standard for the electricity sector. Our assumption is that the OPBS/EPS will be reduced in the 2030s to align with the federal government's proposed Clean Electricity Standard.
The assumptions about carbon tax rates are incorrect. The Federal Government is committed to raising its carbon tax to $170/tonne by 2030. The IESO assumes that gas fired generation will only be subject to $50/tonne.	In both scenarios, We have used the Federal Government's carbon tax policy out to 2030, I.e. carbon taxes are rising $15/tonne CO2e/year in 2023-2030. In the Pathways scenario the EPS will remain in place until 2030 and then taper to 0 in 2035 In response to feedback, we have changed the the carbon tax assumption in the Pathways scenario; the tax will continue to increase by $15/tonne CO2e/year until 2035, and with inflation thereafter.
If differences in carbon policy result in modeled imports of large volumes of energy from jurisdictions that continue to generate using coal (e.g. MISO, PJM) it would be reasonable to assume that if that were to materialize in real life, Carbon Border Adjustment policies would be expedited.	The IESO agrees with this comment.
Will the IESO be considering the impact of changes in electricity rate structures as policy tools that could be used to shift system demand peaks, reduce peak capacity resource requirements, increase DERs, and/or provide incentives for broader electrification?	The assessment of electricity rate structures as policy tools are out of scope for this study.

Feedback	IESO Response
There are no assumptions regarding DER policy changes (e.g., Virtual Net Metering) that might encourage (or hinder) broader adoption of DERs. Will the study look at the role of DER policy, specifically in terms of what regulatory changes might facilitate broader update of these?	The purpose of the Pathways study is to identify a mix of non-emitting technologies that can reliably meet the power needs of Ontario. The scope of this study does not include testing policy or program approaches. The IESO is developing the DER Potential study and the results will be published in summer 2022. The preliminary results from the DER study will be an input into the Pathways study. In particular, behind the meter DERs will modify the demand scenario used in the study. The potential for DERs will help determine the amount of solar and storage from which the capacity expansion tool can select. The resource model will not distinguish between transmission and distribution-connected resources. The DER has a separate public engagement process: https://www.ieso.ca/en/Sector-Participants/Engagement-Initiatives/Engagements/DER-Potential-Study
The IESO should consider a scenario in which District Energy Systems (DESs) are implemented at large scale, with 5 percent of new and existing buildings (all sizes) being converted to DE each year, starting in 2028.	The Pathways Demand Scenario does not consider adoption of district energy systems as its opportunities and electricity demand savings are project specific and not able to be determined.
Carbon Capture, Utilization and Sequestration (CCUS) is an unproven and costly technology at this point, it does not seem viable to include in the study for validating the continued use of natural gas.	Based on feedback received and a review of the literature, the IESO has reached a similar conclusion. It appears that at this time CCUS is not likely to be used on Ontario's gas plants, which are often used for peaking purposes. For the purpose of this study, we will use hydrogen for low carbongas thermal plant fuel or abatement.
The IESO should consider aligning hydrogen-related assumptions with the Canadian Federal Hydrogen Strategy. This Hydrogen Strategy calls for 30% of the energy delivered today across the country to be provided by renewable and low carbon hydrogen by 2050, with this number reaching 6% by 2030.	The IESO will consider aligning the study assumptions to the Federal Strategy.

Feedback	IESO Response
There should be no cap on the price of energy efficiency programs procured by the IESO. To minimize our cost of decarbonizing our electricity grid the IESO must pursue all energy efficiency investments that can keep our lights on at less than the price it is paying OPG for nuclear electricity (e.g., 10.5 cents per kWh in 2022). It doesn't make sense to re-build our aging nuclear reactors or build a new Greater Toronto Area (GTA) nuclear reactor if energy efficiency investments can decarbonize our electricity grid at a lower cost.	The Pathways Demand Scenario will include the maximum achievable potential from the IESO and OEB's 2019 Electricity Conservation and Demand Management (CDM) Achievable Potential Study (APS) (https://www.ieso.ca/2019-conservation-achievable-potential-study). The maximum achievable potential represents all of the energy efficiency potential that is both cost-effective and achievable. Cost-effective potential means potential that comes from CDM measures that produce system benefits from both avoided energy and capacity costs that outweigh the measure costs. The values of avoided energy and capacity are calculated using assumptions developed through the IESO's Annual Planning Outlook and consider what resources would be needed to deliver additional energy or capacity if CDM programs were not implemented. Avoided capacity cost assumptions are based on the estimated Net Cost of New Entry of the anticipated lowest cost marginal resource in Ontario that would be developed when new generation is required. Based on analysis of available data from the Ontario market, CONE is equal to a gas combustion turbine (CT) plant at $570/MWUCAP-day (2021$). Achievable potential means potential from measures that are likely to be adopted given expected customer responses to assumed incentive levels and other non-financial factors that affect customer decision making. Levelized unit energy cost (e.g., $0.033/lifetime kWh for the maximum achievable potential scenario in 2030 or $0.039/kWh in 2038) is a reported metric for each potential scenario but is not used as a threshold or cap in the maximum achievable potential scenario. The Pathways Study will also incorporate preliminary findings of the IESO's Distributed Energy Resources Achievable Potential Study (DER APS). The study will determine the cost-effectiveness (from a system and GHG-emissions-mitigation perspective) of DERs using an advanced avoided cost framework that

Feedback	IESO Response
	captures the dynamic capabilities of DERs to maneuver in response to system conditions.

Demand Assumptions

- Consider the impact of newer technologies such as EVs with bidirectional chargers
- The IESO should consider including both natural gas demand and non-gas fossil fuels demand as part of the industrial fossil fuel demand
- Publishing year-by-year cost assumptions, with direct linkages to the source data, rather than ranges for specific costs
- Consider on-site solar PV by residential, commercial and industrial load customers

Feedback	IESO Response
The inputs for conservation programs from the 2019 Integrated Ontario Electricity and Natural Gas Achievable Potential Study are inconsistent with the Pathways Scenario timeline. The 2019 study extrapolates potential until 2038, while the Pathways Scenario ends in 2050, leaving 12 years of modelling inputs unaccounted for. It is unclear from the assumptions document how this period will be managed in the model.	The IESO and OEB's 2019 Electricity Conservation and Demand Management (CDM) Achievable Potential Study (APS) (https://www.ieso.ca/2019-conservation-achievable-potential-study), covers the period of 2019-2038. The Pathways Demand Scenario will also include assumptions of the level of annual electricity conservation and demand management maximum achievable potential in the period of 2039-2050 extrapolating based on average growth rate during the final years of the APS outlook period
How is the Achievable Potential Study being updated and what new measures or circumstances are being considered in the update, i.e., a shift to a winter electrical peak.	It is not possible to update the Achievable Potential Study in time to inform the modelling work in the Pathways study. As noted above, we will be using the maximum achievable potential from the 2019 study in Pathways. The IESO is currently refreshing the APS. Once IESO's 2022 CDM APS refresh is complete the IESO intends to speak to any changes in the Pathways to Decarbonization project final report, and to use refreshed APS results for any future assessments.

Feedback	IESO Response
Regarding DERs, it is not clear how "This incremental energy resource potential will be considered as an option that competes with other Potential Resource Options" It is not possible to provide proper feedback on DER assumptions without seeing the costs, performance and penetration assumptions of the DER Potential Study which will not be completed until July.	The analysis performed in the DER study will be an input into the Pathways study. The potential for DERs will help determine the amount of solar and storage from which the capacity expansion tool can select. The resource model will not distinguish between transmission and distribution-connected resources. The DER Potential Study has a separate public engagement process: https://www.ieso.ca/en/Sector-Participants/Engagement-Initiatives/Engagements/DER-Potential-Study
The industrial fossil fuel demand should include both natural gas demand and non-gas fossil fuels demand.	The Pathways Demand Scenario assumes a portion of fossil fuel consumption in industrial sector production processes will be converted to the electricity equivalent. It is understood that not all fossil fuel consumption can be converted, as a portion of the total amount is used as chemical inputs rather than energy and the total Ontario industrial sector fossil fuel consumption is difficult to determine while natural gas consumption data is widely available.
What reference is being used for the assumptions governing building envelop efficiency improvements.	Building envelope efficiency improvements are generally modelled through the Ontario Building Code conservation regulation. Further details are provided in the IESO 2021 Annual Planning Outlook Demand Forecast Methodology Module available at: https://www.ieso.ca/en/Sector-Participants/Planning-and-Forecasting/Annual-Planning-Outlook

Feedback	IESO Response
Is the decarbonization of heavy trucks considered, including how Mega Chargers (not yet developed) might be accommodated on the grid. The IESO should consider how this greater power should be modeled, developed, and deployed in remote areas along the major highways.	The Pathways Demand Scenario accounts for the electricity charging demand of heavy trucks as part of an "other electric mobility" category, which is assumed to have an electricity demand equivalent to 5% of light duty battery electric vehicles. The Pathways Demand Scenario transportation electrification forecast focuses on the provincial system level. Mega Chargers and their regional impact are out of scope of the Pathways Demand Scenario.
The potential for community energy solutions that capture and distribute energy locally, reducing peak loads and creating storage environments appear to be missing from models.	The model functions at the bulk level, and does not address distribution level issues. The IESO will engage with municipalities to discuss their priorities for decarbonization. Load flexibility from district energy systems is captured in the P2D modelling of demand response resources
The IESO should include the impact of newer alternatives such as use of electric vehicles (EVs) with bidirectional chargers as well as thermal storage options such as thermal storage bricks.	In the model, bidirectional EV charging and thermal storage are considered as behind-the-meter resources that could support load participation in Demand Response initiatives.
Pipeline companies may ask the IESO to change this assumption to include renewable natural gas ("RNG") and hydrogen for space and water heating. The IESO should not accede to this request. There are three reasons why RNG and hydrogen are inappropriate for space and water heating: (a) electrification is far less expensive, (b) limits on RNG feedstocks and hydrogen blending rates mean these cannot significantly decarbonize space and water heating, and (c) these fuels must be reserved for the hardest-to-decarbonize sectors, such as aviation or industrial processes that require energy dense fuels.	The IESO is not including modelling low carbon fuels for heat in this study.

Resource Assumptions

- Revisit the capacity values for wind in summer
- Refer to Canada's Hydrogen strategy for costs
- Consider carbon negative sources such as hydrogen from biomass and RNG
- Consider minimum cost shocks to ratepayers
- Explore further integration with Quebec for imports
- Consider engaging with banks that finance power projects in Ontario for resource costs
- Consider impact of international resource supply chains and resource security

Feedback	**IESO Response**
The IESO's assumptions indicate three activations/year for hourly demand response (DR): Is that throughout the outlook period? With more electrification and technology adopted with DR potential, does the IESO not anticipate the installed capacity of DR increasing over time and, as a result, the acceptable number of activations?	In response to stakeholder input, the IESO has significantly revised the modelling assumptions for DR to better segment different types of loads capable of providing demand response to reflect differences in acceptable activation frequency and activation cost (which impacts the frequency with which resources are activated). The IESO has updated the acceptable number of activations per year for hourly demand response provided from industrial processes from three to five, and introduced new categories (e.g. hourly demand response provided by business HVAC and lighting controls) with a greater number of acceptable activations.
Why are there no costs for SMR's or retrofitting SCGT's – or volumes of CO2 utilization or storage potential	Some sections, such as the cost of SMRs or of retrofitting Natural Gas Generation were purposely left blank as the IESO has not found any public sources available as reputable as the NREL ATB.
Regarding project life, recent studies indicate that the useful project life for a solar project is between 25 to 40 years (see: NREL and Berkeley Lab).	The life-span of solar has been updated to 25 years.
Assumptions for DERs consider only capital and operating expenses, indicating that the	The model functions at the bulk level. The assessment process focuses on reliability, operability

Feedback	IESO Response
economic benefits of their grid reliability services will not be considered in the analysis. Similar to conservation programs the economic benefits of distributed energy resources, through cost savings to electricity consumers, should be included if cost-benefit analyses of decarbonization pathways will be evaluated in the modelling.	and cost. These numbers can then be used to estimate economic DER uptake: DER projects with similar economics as transmission level resources would also be economic. This is where the reader would be able to include localized distribution benefits to assess the economics of their specific DER project. Cost savings to electricity consumers are entirely program/rate structure based and represent a transfer. This study intends to capture the overall cost of resources and transmission; rate structures/programs are not considered.
It is unclear from the assumptions document if or how the IESO model will consider future changes in technology costs (solar, wind, storage) and capacity factors, all of which have experienced dramatic improvements over the last decade.	The ranges posted in the resource assumptions document include anticipated reductions in cost and increases in capacity factor, based on the NREL ATB.

Resource Considerations	IESO Response
Recommend that hydrogen storage be considered in the decarbonization pathways analysis as a resource available in the long-term, and as part of the technology deployment policies considered.	The use of hydrogen as a fuel is being considered as an option within the capacity expansion tool. In addition, we expect to have a discussion in the study regarding the supply and consumption of blue and green hydrogen.
Direct Ontario Power Generation (OPG) to put its five large gas-fired power plants on standby reserve from 2030 to 2040 so that they can provide emergency back-up power to our electricity grid if we temporarily have insufficient carbon-free electricity resources to meet our needs due to extreme events	For the moratorium, we plan to allow participation by existing gas subject to the impact of rising carbon tax. For the pathway, we will consider the possibility of unabated gas to address some issues, e.g. long duration heat/cold events.
The IESO should specifically model the cost (including $/kW) and potential (MW) that could	The shape of the daily demand profile does have a material impact on the appropriate supply mix.

Resource Considerations	IESO Response
be achieved from thermal storage. Thermal storage can flatten the demand from electric heating by using electricity to generate and store heat at night (e.g. in special bricks) and release it during daytime peak hours. It is best when coupled with heat pumps. Nova Scotia and Quebec are providing incentives for thermal storage units, including residential units that can be coupled with a heat pump.1 There are units on the market now that can provide over 80,000 BTU/hr during the day based on a 12-hour nighttime "charge."2 They are also capable of utility control if desired. This can reduce the electricity used to heat almost any home during the peak daytime hours almost to zero.	Thermal storage has the capability of better aligning residential and commercial heating consumption with energy availability. Unfortunately, it would require a more comprehensive approach to modeling to fully capture its value: a simple 12-hour nighttime charge concept would likely underestimate the value of such a program as it would appear to the power system as a large inflexible load (when the idea is obviously to use this to increase flexibility). This is a resource/program concept that should be revisited in future pathways activities.
The IESO's Assumptions file appears to suggest that it will only consider electricity imports from Manitoba and Quebec if they are available during every single hour of the year despite the fact that it is willing to consider Ontario generation options (e.g., nuclear) that are not available during 100% of the hours of the year. For example, on average, the Darlington Nuclear Station has only produced electricity during 83% of the hours of the year. If the IESO wishes to import electricity from Hydro Quebec during every single hour of the year, it should meet with Hydro Quebec to discuss how Hydro Quebec could meet such a request by: a) increasing the energy efficiency of its domestic customers to free up more of its existing heritage waterpower capacity for export; and/or b) building new wind or solar generating stations. It this context, it is important to note that wind and solar, not waterpower, are Quebec's lowest cost options for new electricity supply.	IESO has hired a consultant to look at the availability of energy and capacity in neighboring jurisdictions, not the cost to Ontario of expanding our transmission infrastructure. We will consider the cost of transmission needed to enable any available (or new build) resources in Quebec.

Comments from Targeted Outreach

The IESO conducted targeted outreach with over 50 organizations, facilities, and associations throughout the energy sector during March and April, 2022. These early discussions helped to inform the study approach and key considerations. The comments and feedback received are similar in nature to those submitted through written feedback and are summarized into key themes below:

- Alignment of assumptions with Federal strategies
- Future consideration of Hydrogen
- Concern over impact of fluctuating electricity prices
- Promote a clear understanding of definition of Net Zero and what's in scope
- Industry concern over supply chain issues
- The future use of energy storage
- Cost of SMRs to be considered