Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021, to Jan. 31, 2022**	Contact:	Justin W. Rangooni
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Instructions

1. Please fill out the section above as indicated.
2. Please respond to the questions below and provide your specific comments. We welcome your expertise and input and should some of the questions not be applicable to your area of expertise please feel free to leave those responses blank.
3. **Please submit one completed comment matrix per organization.**
4. **Stakeholder comment matrices will be published on aeso.ca, in their original state.**
5. Email your completed comment matrix to **forecast@aeso.ca by Jan. 31, 2022.**

Introduction

Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential transformation of the Alberta electricity system may occur at a faster pace and may involve technologies not considered in the 2021 LTO. Furthermore, this analysis will consider the technology review from the *AESO 2021 Technology Forward Publication* and the AESO Technology Summit 2021 – Power Tomorrow. The net-zero pathways analysis will inform and influence future long-term outlooks.

In 2022, the AESO will examine potential pathways to achieve a net-zero greenhouse gas emissions electricity sector in Alberta and the market, operational and cost implications of these pathways. The AESO intends to review and understand the most prominent zero and low-carbon emissions technologies, their cost and performance characteristics, and their impact to the grid, such that policy objectives may be achieved while minimizing disruptions to the existing market framework and maintaining a reliable electric system.

Alberta's electricity generation fleet has undergone significant transformation. Formerly a greenhouse gas intensive, primarily coal-fired generation fleet, Alberta's generation infrastructure has been converted and replaced with cleaner, less emissions intensive natural gas and renewable generation technology. Throughout this transformation, emissions have been reduced significantly, yet the AESO estimates that approximately 15Mt of emissions attributed to the electricity sector would need to be reduced by 2035 in order to achieve zero emissions. Placing a cost on carbon emissions via carbon taxes, and incentivization of clean generation via legislation and environmental and social governance practices have resulted in a significantly less carbon intensive electricity generation sector in Alberta. Further decarbonization ambitions have been announced by Canadian policymakers and industrial leaders intending to implement a net-zero emissions electricity generation target by 2035.

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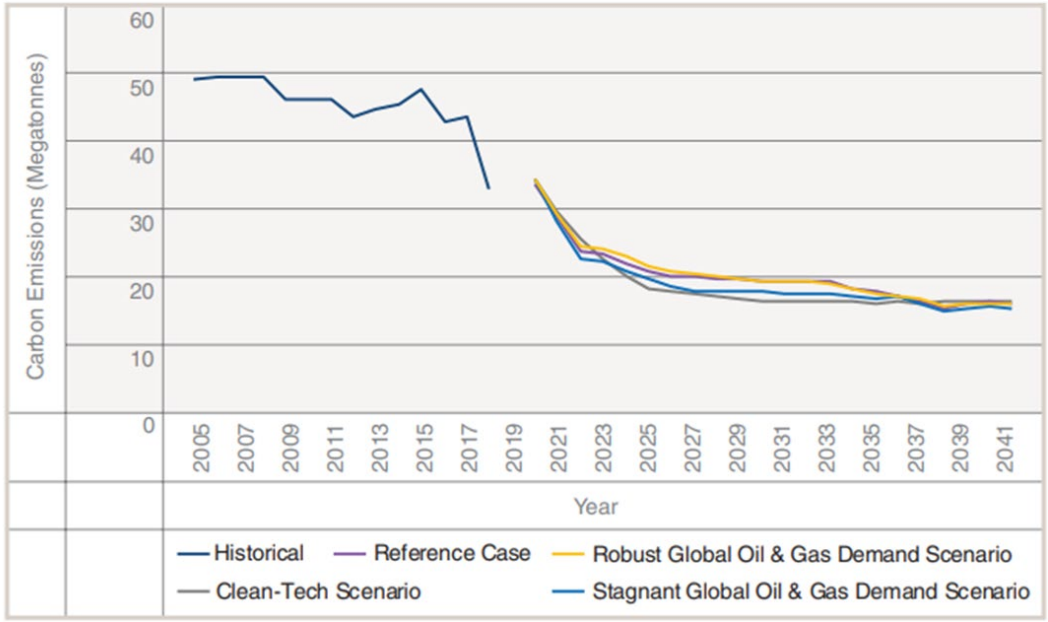
Electrification of high-emitting sectors and energy efficiency will also be key drivers along a pathway to net-zero outcomes. Mandates have been proposed for zero-emission vehicles, mentioned in the most recent federal election campaign and subsequent throne speech pledge, requiring at least half of all passenger vehicles sold in Canada be zero emission by 2030, reaching 100 percent in 2035. Support from various levels of government around energy efficiency from Emissions Reduction Alberta's Energy Savings for Business to the federal Canada Greener Homes Grants are anticipated to continue to grow and support the electrification transition, which will drive additional emissions reductions economy wide.

FIGURE 34: Alberta Electricity Sector Emissions by Scenario



Request for feedback

The AESO is seeking feedback from interested stakeholders on their perspectives as it relates to the scope and input assumptions of the proposed net-zero emissions pathways analysis. Please be as specific as possible with your responses. Thank you.

Stakeholder engagement, dialogue, and feedback will be key to framing the AESO's analysis and calibrating modeling parameters to ensure that the information provided to stakeholders via this analysis is valuable. The AESO would like to thank stakeholders in advance for their ideas, thoughts, and perspectives related to electric system decarbonization in Alberta.

	Questions	Stakeholder Comments
1	***Net-Zero Analysis Scope*** The AESO intends to produce the first AESO Net-Zero Emissions Electricity System Pathways report, to be published in June 2022. The AESO's Pathways report will describe potential decarbonization pathways that can lead to a net-zero emissions electricity sector in Alberta by 2035. The report will include evaluation of supply-and-demand scenarios, which can result in decarbonization of the electricity system, and electrification of other emissions-intensive sectors. The initial report will review potential supply mix, market, supply adequacy and high-level cost implications. The report will not examine the full range of all potential operational impacts and related mitigation measures, the specific impact to consumers or provide quantitative analysis of all identified pathways. Subsequent analysis and reporting may focus on these more detailed metrics. The AESO intends to review load and generation scenarios that reflect current trends in decarbonization, with the intention of illustrating possible pathways to net zero. With respect to supply the AESO intends to review two net-zero emissions generation supply scenarios in greater quantitative detail to gain further insight on potential market and operational implications. These are: • Renewables paired with energy storage; and • An economically driven generation resource addition scenario that considers a range of potential zero-emission sources, such as those technologies listed in section 6, below. With respect to demand, the AESO intends to produce scenarios incorporating the impacts of significant electrification of transportation, buildings, and industrial activities, as well as the potential impact of demand-side management and energy efficiency initiatives.	
	a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?	First and foremost, ESC fully supports the AESO in exploring a pathway to net-zero analysis and believes the effort will result in many positive outcomes for the electricity sector as it navigates an uncertain future. A core foundation for any pathway to net-zero analysis is the definition and framework for what a "net-zero" future entail. In building scenarios, the AESO should define net-zero as it relates to the electricity sector and the broader economy. For example, is electricity expected to have negative emissions to offset positive emissions in other economic sectors (e.g., through export credits)? In addition, the pathway to net-zero should have some assumptions related to activities in neighbouring jurisdictions to determine potential positive and negative effects with intertie trading. The AESO should also be clear on what aspects of the analysis remain consistent and what areas are open to change. For example, will the AESO assume continued operation of an energy-only market design or will changes be considered? Will the AESO assume the existing transmission regulation remains intact or is adjusted to meet net-zero pathway objectives?

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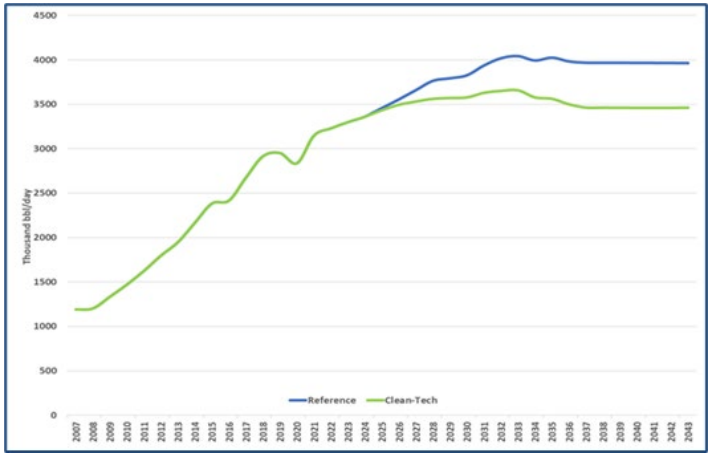
		In ESC's view, the framework and assumptions of the analysis are as important as the results and should be communicated clearly to stakeholders.
	b) What might be the largest challenges as well as the areas most impacted within the Alberta electric system on a path to net-zero?	ESC views four key challenges on a path to net-zero. 1. Current technologies and costs cannot achieve net-zero emissions and therefore any forecasting or planning will need to consider technology advances or cost reductions that are inherently uncertain. 2. Existing technology financial models and operations will need to be re-considered to reach net-zero. For example, it is reasonable under some net-zero scenarios that renewable generation would experience (and accept) a certain amount of curtailment without compensation. This will challenge system operation as well as resource adequacy assessments. 3. The closer to net-zero the electricity sector gets to, the harder it will be to model as extreme situations will determine whether the electricity system is capable of meeting net-zero objectives (e.g., does the electricity system have enough resources for extreme winter weather?). 4. Alberta's path to net-zero is not mutually exclusive from neighbouring jurisdictions therefore the impact of changes outside the control of Alberta will need to be considered.
2	***Macroeconomic Context*** The current economic outlook shows Alberta growing at an average of nearly five per cent in the near-term and returning to a long-term trend of slightly over two per cent.[1] a) What is your view on the economic impact of expected net-zero targets on this business-as-usual scenario?	ESC has no specific view on the economic impact of expected net-zero targets. ESC does note that government policy, regulatory design and financial incentives will play a significant role on the economic impact from net-zero targets (e.g., will the government provide incentives or compensation for industries that experience financial difficulty in the transition to net-zero?).

[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

	Questions	Stakeholder Comments
	The current IHS Markit outlook notes that Alberta oil sands production has surpassed pre-pandemic levels and forecasts incremental growth out to 2030 to more than 3.6 MMMb/d.[2] Oilsands production is a key driver of Alberta's load growth. In the 2021 LTO, the AESO adopted an earlier version of the IHS outlook as the base for the Reference Case; for the Clean-Tech scenario, the AESO de-rated the outlook by removing greenfield expansions to represent a scenario with no further sectoral growth (see chart below). **Figure X: Oilsands Outlook Assumptions in the 2021 LTO**  b) What is your view on the AESO adopting a similar approach to that used to develop the 2021 LTO Clean-Tech scenario for analyzing the impact of net-zero policies on the oilsands sector and the subsequent impact on load growth?	ESC has no opinion on oilsands development and emissions profiles. As per comments above, assumptions on electricity sector emissions reduction interaction with other economic sectors are important assumptions for any path to net-zero analysis.

[2] https://ihsmarkit.com/research-analysis/canadian-oil-sands-running-above-prepandemic-highs.html

	Questions	Stakeholder Comments
	c) Current forward gas prices are in the $3/GJ range. Five years into the future, do you see gas prices remaining at this level, decreasing, or increasing beyond inflationary rates? What do you see as key drivers of gas prices going forward?	ESC has no comment on future gas prices. ESC does note that carbon pricing on natural gas prices is likely to have a growing impact on natural gas prices and could end up exceeding volatility in natural gas prices.
3	***Policy and Electricity Value Chain Impact*** a) Do you interpret net-zero emissions targets as enabling compliance via the following mechanisms? • Offsets or credits (generated outside the electricity sector) • Offsets or credits (generated within the electricity sector) • Physical emissions reductions only	ESC does not have an opinion at this time. ESC notes that offsets or credits should reflect real-time operation of the electricity sector as much as possible to capture fulsome emissions reduction potential.
	b) What are your expectations of carbon prices in the future? With federally announced carbon prices rising from $50/t to $170/t by 2030, how do you see carbon price policy unfolding prior to 2030 and beyond 2030?	ESC's most probable outlook for carbon pricing is to follow the federally announced carbon pricing from today to 2030. Beyond 2030, ESC believes broader policy decisions will influence net-zero pathway beyond carbon price. In other words, further increases to carbon pricing are likely to have a diminishing impact on lower carbon emissions compared to other legislation, regulation, or market dynamics.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	This question represents broad influences on the Alberta electricity sector and additional changes that could occur are too numerous to list. For example, when only considering changes to codes and standards for building design and transportation, the pace and magnitude of the changes could have an outsized role in determining demand growth for both sectors. Within the electricity sector, changes to market design, regulation and legislation could severely influence the path to net-zero (e.g., if Alberta significantly changes market design away from current energy-only design). Overall, ESC's recommendation is that the AESO clearly document assumptions used in scenarios and revisit those assumptions in future net-zero pathway outlooks.

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	d) Are there any other related considerations that you would like to provide feedback on?	As described by AESO, energy storage is a unique resource that requires different treatment from traditional load and generators. Energy storage is not an end-use customer but an intermediate resource that can increase the utilization and efficiency of the Alberta electricity system. Since energy storage does not produce new energy, but instead shifts it to higher value time periods, the ability to react to market dynamics requires adjustments to market design to inform storage when and when not to cycle. Further, any offset structure created for net-zero analysis should recognize the role energy storage would play and how the value of offsets should be partially allocated to energy storage.
4	***Electrification and Electricity Demand Drivers in Alberta*** **a) Energy efficiency** • What is your view on the potential penetration and pace of greater energy efficiency across sectors (residential, commercial, and/or industrial)? What would trigger more energy efficiency or conservation efforts?	ESC has no comment
	b) Distributed Energy Resources (DER) • How do you expect net-zero trends will impact DERs (e.g., gas-fired generation, solar, wind, small-scale energy storage systems, demand-side management technologies, load aggregator technologies, micro-grids, etc.)?	ESC believes that DERs can play a large role in the net-zero trend. DERs allow many customers to determine how they will use grid delivered energy to meet their energy needs; potentially avoiding higher priced hours or higher carbon intensive hours (if those hours are not aligned). Small-scale energy storage located behind the meter provides a unique option for customers to control their grid delivered energy quantities in a way that was not previously possible. Under a net-zero pathway, small-scale storage can allow customers to meet their specific emission reduction goals depending on the regulatory framework and market design. The role and participation of DERs is critical in any net-zero pathway analysis.
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger	ESC has no comment on the penetration and pace of electrification of the transportation sector other than to note that EV adoption is growing rapidly in many jurisdictions across the world.

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	vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	ESC believes pathway to net-zero analysis will need to consider the potential impact of Vehicle-to-Grid (V2G) capabilities in the future, either on an individual basis or aggregated for wholesale market participation.
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	ESC has no comment. ESC does note that small-scale storage can be used to help manage peak building loads during constrained electricity grid operating hours (i.e., either high prices or reliability issues).
	e) Industrial Sectors • Deployment of carbon capture, utilization, and storage (CCUS) and hydrogen production (especially if based on electrolysis) could increase industrial load. What is your view on the expected increase in load (either served on-site or from the grid) from these industrial processes? • What is your view on load growth and the impact of net-zero targets on other industries, sectors, or technologies (e.g., cryptocurrency mining, data centers, petrochemical facilities, cement, steel, others)?	ESC has no comment.
5	***Generation Technologies*** a) What net-zero enabling generation technologies do you perceive as being the most economic pathways to decarbonization of the electricity supply in Alberta?	ESC believes that a mixture of generation technologies is required to decarbonize the electricity supply in Alberta. Further, existing technologies and costs are not capable to meeting the net-zero objectives and therefore further evolution is required to determine the most economic pathway forward. Regardless of the generation technology, enabling energy storage resources will increase the effectiveness, efficiency and utilization of the generation technology and ESC believes energy storage resources will play some role in all net-zero pathway futures.
	b) What are the strengths and weaknesses associated with the following net-zero enabling technologies, within the context of transitioning to net-zero emissions in Alberta's electricity sector? What do you view as reasonable development timelines for these technologies?	(i) Post-combustion CCUS strength is the ability to continue operation of existing thermal generation resources. The weakness is the technology is costly and requires storage locations in conjunction with the generation technology. The post-combustion CCUS may also reduce operational flexibility for the thermal generation resource (ESC

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	(i) Post-combustion Carbon Capture, Utilization, and Storage (ii) Pre-combustion Carbon Capture, Utilization and Storage (hydrogen) (iii) Oxyfueled generation (iv) Renewable generation including wind, solar, geothermal, and biomass (v) Hydroelectric generation (vi) Nuclear generation (vii) Energy Storage (viii) Transmission interconnections with other jurisdictions (ix) Offsets or Emissions Performance Credits	believes energy storage could be used to retain the operational flexibility when paired). (ii) Pre-combustion CCUS has the potential to offer lower carbon intensive fuels to existing and future thermal generation units. The weakness is the cost of the pre-combustion process and the potential inability to completely remove all carbon emissions. (iii) ESC has no opinion on Oxyfueled generation (iv) Renewable generation offers the lowest cost new supply resources for a majority of jurisdictions, a major strength. Further, renewable generation costs are expected to decrease in the future providing growing benefit for their planned adoption. The key weakness for renewable generation is the variable energy production. In addition, renewable generation within a jurisdiction tend to be correlated and therefore increased installations decrease the value of energy overtime to the electricity system if demand growth is not present. ESC believes energy storage resources are a key partnership for renewable generation to shift energy production from low value hours to high value hours. (v) Hydroelectric generation is a highly flexible and established low emission generation technology. A key drawback is that hydroelectric generation requires specific geographic requirements (e.g., river flow). Pumped hydro storage can play an excellent complimentary role with hydro generation. (vi) Nuclear generation strength is significant amounts of carbon-free energy generation for a small footprint over a long lifetime. The major weakness is high cost, long construction timelines and inflexible operation. Energy storage can provide flexibility of operation by allowing nuclear generation to continue to operate even when demand is low. (vii) Energy storage is a versatile resource that has many different technology options to deploy (e.g., battery, pumped, compressed air, novel technologies, etc.). Energy storage can be paired with different generation technologies to address weaknesses of those generation

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		technologies. Energy storage can be scaled to meet local, regional, or bulk system needs. Energy storage is capable of value stacking multiple electricity services from a single facility. Finally, energy storage can offer the ability to take raw emissions free energy production and process into standard energy blocks for sale into wholesale and retail markets. A key drawback for energy storage is the resource requires energy from other generation technologies to work, and costs vary demand on duration and capacity. (viii) Transmission interties can offer access to other markets where excess emission free energy production can be exported for a credit within Alberta. Transmission interties also offer access to larger regional pools of renewables and other geographic driven resource potential. Larger geographic areas have been shown to reduce renewable energy production correlation between different generation sites. Drawbacks of interties include negative economic impact on Alberta-based resources if fair and equal access to markets in neighboring jurisdictions are not established. Further, net-zero pathways in neighbouring jurisdictions can reduce the value of new transmission interties over time if the expectation was to receive credits for exporting to those jurisdictions. (ix) ESC notes that offsets or credit should reflect real-time operation of the electricity sector as much as possible to capture fulsome emissions reduction potential. Treatment of energy storage in credit or offset programs should be considered carefully to ensure energy storage is not unfairly punished for storage emissions free power for use during high-value times.
	c) Are there generation or emissions control technologies other than those listed in (b), which you believe can contribute to meaningful reductions in greenhouse gas emissions, and enable a pathway to net-zero emissions in Alberta?	ESC has no comment

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	d) Do any of the net-zero enabling technologies in (b) or (c), above, impose operational risks, challenges, or benefits to the electric systems in Alberta? If so, please identify.	ESC has no comment at this time
	e) Do you expect the accounting of net-zero emissions by 2035 in the electricity sector to require net-zero emissions from cogeneration facilities? If so, what emissions control technologies do you believe can be most economically implemented at cogeneration facilities?	ESC has no comment at this time.

	Questions	Stakeholder Comments

6 ***Net-Zero Generation Technology Costs***

The following table contains select net-zero enabling generation technologies and operational specifications on potential future generation developments. The data herein has been primarily derived from the US Energy Information Administration's *Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies*[3], then converted to Canadian dollars using an exchange rate of 1.26 CAD/USD. Hydrogen-fired combined cycle costs were derived from the cost estimates for publicly announced combined-cycle generation costs, assuming that the costs for hydrogen-capable generating stations will be similar to advanced combined-cycle plants.

Generation Type	Plant Capacity, MW	Capital Cost, $/kW	Fixed O&M Costs, $/kW-yr	Variable O&M Costs, $/MWh	Heat Rate (HHV) or Efficiency, GJ/MWh or %
Fuel Cell	10	8,442	38.78	0.74	6.83 GJ/MWh
Advanced Nuclear Fission Reactor	2,156	7,612	153.27	2.99	11.19 GJ/MWh
Small Modular Reactor – Nuclear Fission	600	7,801	119.70	3.78	10.60 GJ/MWh
Hydroelectric	100	6,698	37.62	-	-
Battery Energy Storage	50 (200MWh)	1,750	31.25	-	80% round trip efficiency
Wind Generation	200	1,594	33.19	-	-
Solar Photovoltaic Generation	150	1,654	19.22	-	-
Combined Cycle with CCUS	377	3,126	34.78	7.36	7.52
Hydrogen-Fired Combined Cycle	450	1,667	52.84	2.65	6.79

[3] https://www.eia.gov/analysis/studies/powerplants/capitalcost/

	Questions	Stakeholder Comments
	a) Do you believe that these are representative of the costs associated with potential future Alberta net-zero generation technologies? How do you expect the cost of these technologies to change by 2035?	No, ESC believes that costs published by the US EIA are dated and do not reflect current market realities. Further, exchange rates for total costs are not accurate when considering the unique Canadian and Alberta market conditions. ESC expects the cost of energy storage to decline from today to 2035. Further, energy storage notes only one energy storage technology is provided, there are many others that should be considered by the AESO in addition to battery energy storage (i.e., pumped, thermal, compressed air, hydrogen storage etc.).
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	ESC has no comment
	c) Please share any additional views on technologies and specifications that are not included within the table (please include the cost and operational characteristics applicable to the net-zero generation technology in the format of the provided table).	
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	

Thank you for your input. Please email your completed matrix to: forecast@aeso.ca