Written Consultation | Dec. 16 to Jan. 31, 2022 – Stakeholder Comments

Posted | Feb. 1, 2022 [Updated: Feb. 4, 2022 – Suncor submission added]

1. Acciona Energy Canada Global
2. ADC – Alberta Direct Connect Consumer Association
3. AEEA – Alberta Energy Efficiency Alliance
4. Alberta Innovates
5. AltaLink Management Ltd.
6. AREA – Alberta Renewable Energy Alliance
7. ATCO Electric Ltd.
8. Big Spruce Law
9. BluEarth Renewables
10. BRC Canada – Business Renewable Center Canada
11. Calgary Climate Hub
12. Campus Energy
13. Canadian Nuclear Association
14. CanREA – Canadian Renewable Energy Association
15. Capital Power Corporation
16. COG – CANDU Owners Group Small & Medium Size Reactor Technology Forum
17. Direct Energy
18. Enbridge Inc.
19. Enfinite
20. ENMAX Corporation
21. EPCOR Distribution & Transmission Inc.
22. ESC – Energy Storage Canada
23. FortisAlberta Inc.
24. Friends of Science Society
25. FutEra Power
26. Greengate Power Corporation
27. Heartland Generation Ltd.
28. IPCAA – Industrial Power Consumers Association of Alberta
29. IPPSA – Independent Power Producers Society of Alberta
30. Ivan Purdy
31. Kineticor Resource Corporation
32. Montem Resources
33. MSA – Market Surveillance Administrator
34. Pembina Institute
35. PWX – Powerex Corporation
36. QUEST Canada
37. RMP Energy Storage
38. Shaffer Hastings Simon – University of Calgary
39. Solar Alberta
40. Solas Energy Consulting Inc.
41. Suncor Energy Inc.
42. TCE - TC Energy Ltd.
43. Technical Integration Ltd.
44. TransAlta Corporation
45. UCA – The Office of the Utilities Consumer Advocate
46. Voltus Energy Canada, Ltd.
47. WaterPower Canada

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Tracy Stoddard
Comments from:	Acciona Energy Canada Global	Phone:	312.673.3081
Date:	2022.1.31	Email:	tstoddard@acciona.com

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

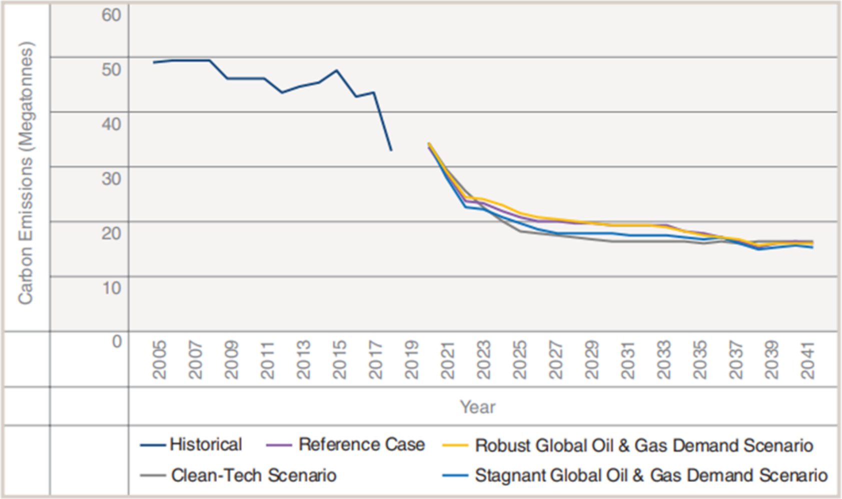
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	Acciona supports the AESO's development of a Net-Zero Emissions Electricity System Pathways report. Across markets, Acciona is seeing a growing number of jurisdictions assess the opportunities of net-zero electricity and begin to grapple with the system and market design reforms that will bring greater efficiencies in cost-effectively integrating non-emitting technologies. In many markets, this transition has begun regardless of system planning to accommodate it, driven by low renewable energy technology costs, large consumers' renewable energy targets, and a growing appetite for merchant exposure on some proportion of project capacity where developers are able to trust market fundamentals. There are likely scenarios that could prove more valuable to assess than a 100% renewable energy and storage scenario. Our understanding is that Alberta is well situated to take advantage of a number of energy options, many of which can compliment each other in a diverse, resilient energy system. In light of their highly competitive economics and strong resource availability in Alberta, wind and solar energy stand in very good stead to generate a large proportion of electricity in a net-zero grid that is

	Questions	Stakeholder Comments
		economically driven through market competition. There is no need to hardwire a 100% renewable scenario into the analysis.
	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?	
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?	
	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**	

Commented [BT1]: Note that I included this down in 5(a) as part of the articulation for why wind and solar are the best. I think it's fine for Acciona to leave comments on Alberta's economic prospects blank, but this is super relevant down there.

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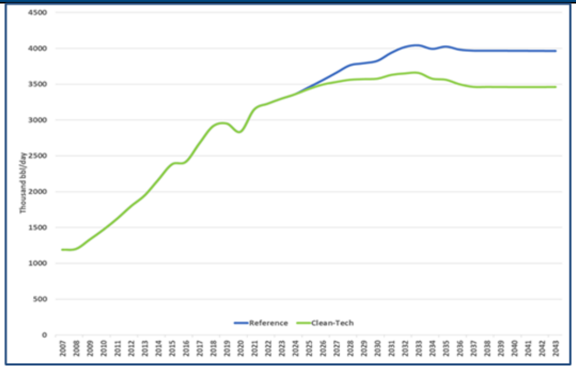
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	
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	Acciona's experience from private sector 100% renewable or net-zero targets is that corporate commitments commonly assume the use of verifiable offsets and credits to comply with commitments. To be credible, these instruments must create clearly additional emissions reductions and must be subject to verification and auditing processes.

	Questions	Stakeholder Comments
	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?	Acciona supports the schedule to $170/t by 2030 and anticipates that investors from all sectors will seek the regulatory certainty that comes with the province accepting or replicating this schedule. Beyond 2030, the analysis should assume a minimum of $170/t, with the possibility that carbon pricing will continue to rise in the 2030s.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	
	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.)?	
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
	d) Buildings	

	Questions	Stakeholder Comments
	- What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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)?	
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?	Wind and solar energy have proven to be the lowest cost options for new generation. The LCOEs for these projects are coming in below the marginal operating costs of efficient natural gas generation in many markets. Any path to a net-zero grid will include a healthy compliment of the most cost-competitive extant generation technologies, wind and solar energy, which also happen to be non-emitting. In fact, Acciona has entered offtake deals in US jurisdictions with buyers, like Amazon, that see greater NPV in contracting renewable energy versus wholesale hedges from the relevant market, even without considering the sustainability attributes that renewable energy brings for these buyers. The economics of transmission, including interconnection with other jurisdictions, tends to be very context specific, dependent on access to non-emitting supply in other jurisdictions that can integrate variable renewable generation, geographic distance, and local materials and construction costs. However, it can be a useful option and offer an important part of a national energy strategy. Battery storage costs are declining rapidly, driven by efficiencies in technology innovation, manufacturing, and supply chains realized by accelerating global deployment. This will continue over the coming

	Questions	Stakeholder Comments
		decade. It is also a highly flexible technology in terms of size and siting, averting development, timing, and merchant risks that are common in lumpier capital projects like interties, CCUS and hydroelectricity. This allows battery investments to respond quickly to the changing circumstances we can expect in a transition to net-zero electricity. With wind and solar deployment continuing to grow due to its attractive economics and other development attributes, Acciona anticipates that battery storage will become an attractive complement to these variable generation sources.
	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 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	Acciona appreciates Alberta's commitment to market outcomes and to avoid picking winners and losers in new generation development. anticipates that electricity consumers and capital markets will continue to choose wind and solar – increasingly paired with battery storage – to meet a substantial proportion of climate targets. Out-of-market capital subsidies for other technologies introduces some risk that could put a chill on project development and capital investment in this lowest-cost generation choice.
	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?	Acciona is increasingly active in pursuing green hydrogen developments, including both hydrolyzer deployment and the corollary renewable energy generation. Although Alberta's Hydrogen Roadmap emphasizes the potential for blue hydrogen development, the growing global interest in green hydrogen is likely to bring efficiencies and technology cost improvements for hydrolyzers. As such, any jurisdiction that pairs strong

	Questions	Stakeholder Comments
		renewable energy resources with a market and global market access for its hydrogen (as is envisioned in Alberta's Roadmap) is very likely to attract investment in hydrolyzers. This will further increase interconnections between renewable electricity generation and decarbonization in other sectors (including transportation and heavy industry) and facilitate the cost-effective integration of renewable energy in electricity grids.
	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.	
	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?	

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

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[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?	As noted above, we expect that battery storage costs will fall dramatically, driven by the nascent technology deployment curve that battery storage is currently ascending rapidly on a global scale. This will continue through the coming decade. Given their modular nature and the development of a competitive global market for components, battery storage will realize a similar cost decline as has been observed over the previous two decades in other non-emitting technologies, particularly solar PV. While batteries are on the steepest part of the cost curve, Acciona also sees steady, moderate LCOE reductions for wind and solar over the medium term and certainly within the 2035 timeframe. Once current supply chain issues are resolved, both technologies will continue to see improvement in technology and supply chain efficiencies, not at the same rate as in recent decades, but steadily through this decade. Already, solar energy is realizing lower capital costs than listed in the table, particularly in jurisdictions without tariffs on panel imports. The solar capital costs need to be adjusted from US EIA reporting to account for US tariffs on solar panel imports.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Colette Chekerda
Comments from:	ADC	Phone:	780-920-9399
Date:	2022/01/31	Email:	colette@carrmal.ca

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.
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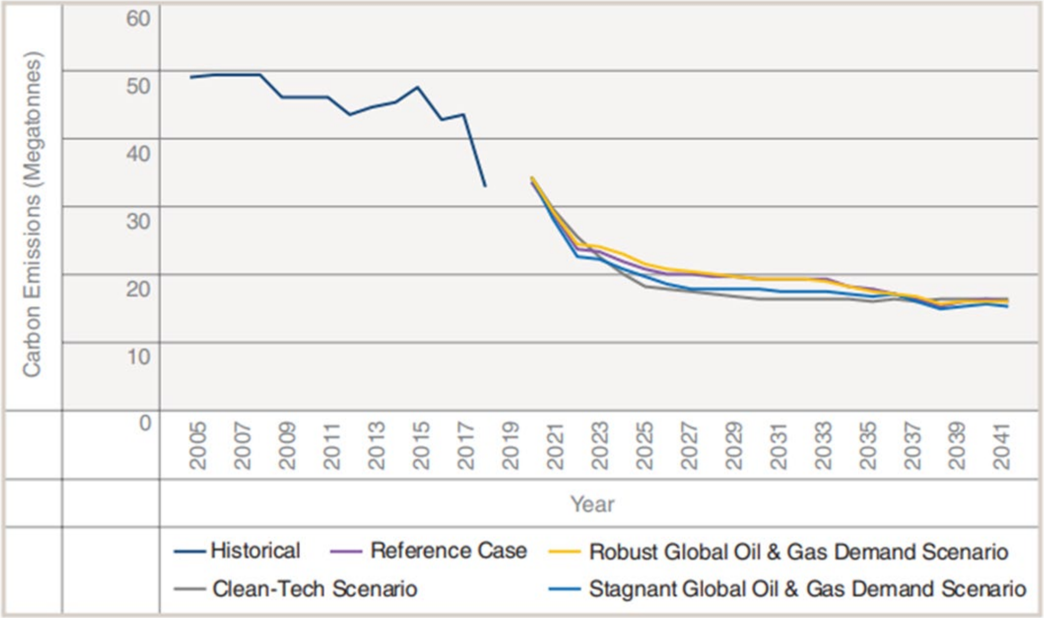
Alberta's electricity generation fleet has undergone significant transformation. Formerly a greenhouse gas intensive, primarily coal-fired generation fleet, Alberta's generation infrastructure has been converted and replaced with cleaner, less emissions intensive natural gas and renewable generation 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.

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?	At this time the ADC is focused on other key priorities. Any study needs to consider impact to Alberta competitiveness.
	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?	Many Alberta consumers are finding the delivered cost of electricity unaffordable. Any path needs to mindful of this.
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]	If the outcome of net zero is even higher electricity costs relative to other provinces, especially those such as Quebec, Manitoba, and BC which are already renewable, then we expect industry to migrate to these areas over time.

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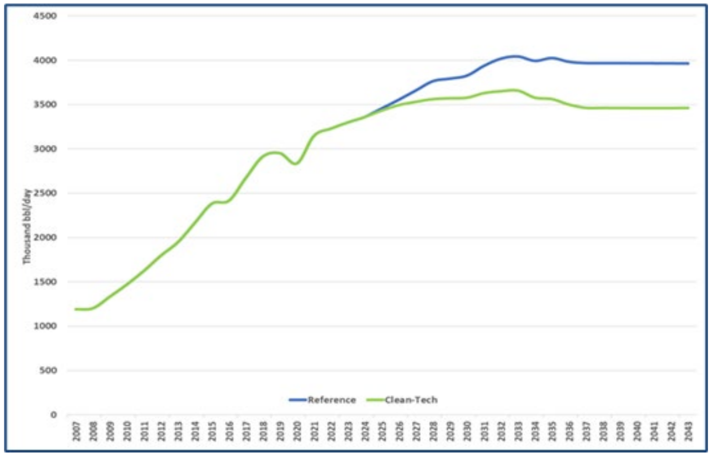
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

Questions		Stakeholder Comments
	a) What is your view on the economic impact of expected net-zero targets on this business-as-usual scenario?	
	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	ADC has no comment on the impact to the oil and gas sector.

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

	Questions	Stakeholder Comments
	scenario for analyzing the impact of net-zero policies on the oilsands sector and the subsequent impact on load growth?	
	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?	ADC has no comment on future 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	ADC has made no interpretation of the net-zero emissions target, however all mechanisms should comply with reduction targets.
	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?	No comment
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	No comment
	d) Are there any other related considerations that you would like to provide feedback on?	No comment
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?	Energy efficiency and conservation efforts are likely limited as projects with good economics have already been actioned. A different value proposition would be required to trigger more effort.

	Questions	Stakeholder Comments
	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.)?	No comment
	c) Transportation Sector - What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	No comment
	d) Buildings - What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	Expect further electrification as carbon cost of natural gas becomes cost prohibitive for heating/cooling.
	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)?	No comment. ADC members are currently at risk in Alberta given the high delivered cost of electricity. Further industrial expansion in Alberta will rely less and less on the grid in order to address cost and reliability concerns.
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?	No comment.

	Questions	Stakeholder Comments
	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 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	No comment
	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?	No comment
	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.	No comment
	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?	No comment

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

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[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 comment
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	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).	No comment
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	The ADC will follow this consultation, but at this time is a low priority for members given the timing with the AESO tariff application.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Jesse Row
Comments from:	Alberta Energy Efficiency Alliance	Phone:	403-483-4810
Date:	2022/01/31	Email:	jesse.row@aeea.ca

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

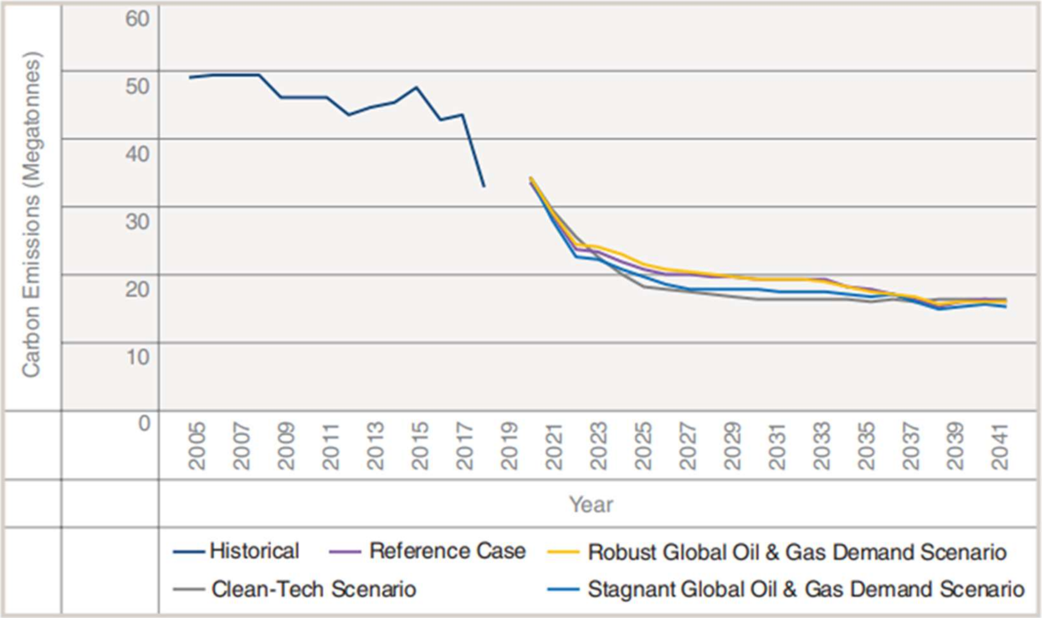
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	It is good to see demand-side management and energy efficiency included in this analysis as their inclusion is critical to reach net-zero targets at the lowest cost possible. The IEA, for example, estimates energy efficiency will meet 40% of emission reductions by 2040 in their Sustainable Development Scenario. Energy efficiency is presented as the "first fuel" within this work due to the strong economic return on investment associated with it. [Source]
	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?	The path to net-zero emissions will include changes to technology on both the demand and supply side of the system. The largest changes on the demand side will likely come from growing electricity demands as new technologies are increasingly adopted by consumers. The largest changes, and challenges, on the supply side will likely come through net-zero technologies that increase generation costs (e.g., CCUS) and technologies that increase the variability of generation. Comments on approaches to managing these challenges can be found in Question 5b.

	Questions	Stakeholder Comments
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?	The economic impact from net-zero targets will largely depend on how these targets are met. If high-cost mitigation approaches are only used, then it will increase business costs and reduce growth in areas that are highly sensitive to electricity prices. If lower cost mitigation approaches are prioritized (including energy efficiency and DSM), then impacts on economic growth will not be as great. Leveraging lower cost approaches as much as possible will be important to maximizing growth rates.
	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**	No comment

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

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

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
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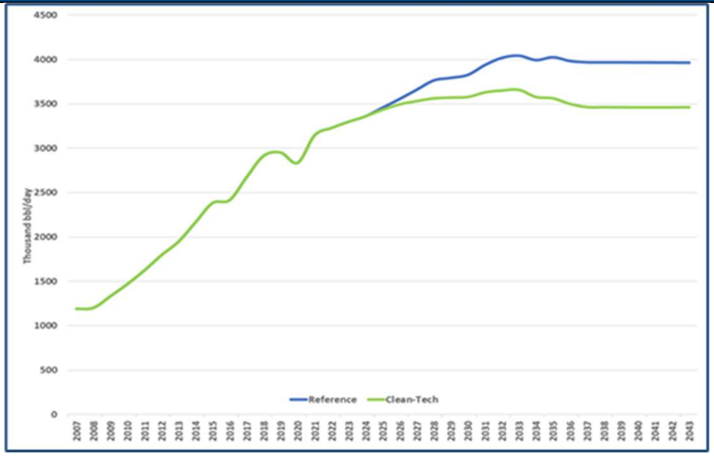

b) What is your view on the AESO adopting a similar approach to that used to develop the 2021 LTO Clean-Tech scenario for analyzing the impact of net-zero policies on the oilsands sector and the subsequent impact on load growth?</td><td></td></tr>
<tr><td></td><td>c) Current forward gas prices are in 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?</td><td>No comment</td></tr>
<tr><td>3</td><td>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</td><td>No comment</td></tr>
</table>

	Questions	Stakeholder Comments
	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?	Predicting exact prices can be challenging, but it's increasingly clear that there is a high probability that carbon prices of this magnitude (and higher) are certainly possible in the future. It is important to recognize, therefore, that there is value in mitigating that risk whether the price increases occur as currently scheduled or not. Modelling future carbon prices at levels stated in current policy is a useful scenario to consider as it provides an estimate of the value associated with reducing emissions in the sector whether those are the exact prices or not.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	No comment
	d) Are there any other related considerations that you would like to provide feedback on?	No comment
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?	A good resource for estimating the potential for energy efficiency improvements in electricity consumption is the annual ACEEE scorecard. The latest scorecard shows several states with an annual savings of over 2% of total retail sales. These savings are net (ie. over and above) of what is considered business-as-usual efficiency uptake as it is standard practice to incorporate net to gross (NTG) ratios for energy efficiency program savings to account for considerations such as free riders and spillover. It is also important to keep in mind that these savings accumulate year over year resulting in a noticeable reduction from business-as-usual over the course of 10 to 20 years. It should be noted that these savings are attributed to energy efficiency programs and are above the efficiency savings that occur through market price signals and/or regulations (eg. increased product efficiency standards). The Energy Efficiency and Small-Scale Renewables Potential Study for Alberta completed by Navigant in 2018 is a potential source of additional information in this area. The International Energy Agency has also published a report outlining energy efficiency potential in Canada that is a useful reference point for

Questions	Stakeholder Comments
	the potential that could be reached through a combination of programs, pricing and regulations.
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.)?	Net-zero goals have significant potential to increase distributed renewables, small scale storage, DSM, load aggregation and micro-grids, but the degree to which these occur will be dependent on the system's ability to incorporate and value their contribution. Consumers of various sizes, for example, would be able to incorporate renewable energy, battery storage, demand response and smart technologies into their buildings or industrial facilities, but the degree to which they install these technologies and enable their capabilities depends on how they're valued in the marketplace. Some consumers will be interested in actively shifting their load and/or storing electricity if effective economic signals are in place to value not only the direct benefits to them as a consumer, but the value they're providing to the system by reducing demand during tight supply-demand periods. Other consumers are generally not motivated by the potential for incremental future savings or revenues, but are open to receiving upfront support to install and enable DERs when making a larger capital investment (eg. an upfront incentive to participate in a smart charging program when installing an EV charger or an upfront incentive to install an advanced energy management system when building or retrofitting a building or industrial facility). The degree to which these different mechanisms are used to value DERs, and the amount of consumer engagement that occurs around these opportunities, will be a significant determinant to the level of uptake. We don't currently have figures to share on potential uptake scenarios, but have commissioned a DSM study that may be able to provide additional detail in this area. The study is expected to be completed in March. We'd be happy to share a copy once it's available.
c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger	The demand curve for electric vehicles has some similarities across jurisdictions. We would suggest looking at jurisdictions ahead of Alberta in terms of percent of new sales as potential scenarios for uptake in the province.

	Questions	Stakeholder Comments
	vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
	d) Buildings - What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	The green building community is very interested in electrification of heating. We're already seeing many of the net-zero energy new construction projects in the province incorporating air source heat pumps. While net-zero energy buildings remain a small number of new construction projects province-wide at this time, there is currently a goal to have all new buildings constructed after 2030 to be net zero energy or net zero energy ready. This would likely involve a ramp up of net-zero energy projects between now and 2030 to meet this goal with a significant number of those incorporating electric heat pumps. Of course, this is just one penetration scenario for electric heating in Alberta. Several factors could increase or decrease the rate at which this uptake occurs. Some uptake of electric heat pumps should also be assumed for existing buildings. Potential scenarios for this uptake can be found in Efficiency Canada's Retrofit Mission report that provides indication of how building retrofits would need to ramp up to meet net zero emission goals.
	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)?	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?	No comment

Questions	Stakeholder Comments
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 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	It should be noted that energy efficiency and DSM helps to counteract some of the weaknesses associated with various generation technologies. For technologies that are expected to increase costs (ie. CCUS, nuclear), energy efficiency and DSM initiatives can reduce demand compared with business-as-usual load growth and reduce the total amount of generation required from more expensive generation sources. For technologies with higher variability (ie. wind, solar), demand-side management can increase the flexibility of the load side of the system (including enhancing the use of consumer located storage) to better match available generation and reduce the amount of storage and/or other generation needed upstream. Energy efficiency initiatives can also be targeted towards measures that are most effective during peak demand times to reduce peak system loads and reduce the need for peaker plants. Energy efficiency initiatives would also be complementary to generating offsets in other sectors (eg. building heating) and could be a source of offsets for meeting net zero goals in the electricity sector.
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?	No comment
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.	No comment
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?	No comment

<table>
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<p><i>Net-Zero Generation Technology Costs</i></p>

<p>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 <i>Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies</i>[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.</p>

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	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 comment
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	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).	It should be noted that FortisAlberta's recent 2023 Cost of Service filing listed the levelized cost of delivered energy savings through energy efficiency programs as low as US$25 / MWh. Once again, it is standard practice for savings to be calculated net of business-as-usual activity (ie. taking into account both 'free riders' and 'spillover').
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	As mentioned, the Alberta Energy Efficiency Alliance is currently working with a consultant on a DSM study for Alberta that we would be happy to share once it is available.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Vanessa White
Comments from:	Alberta Innovates	Phone:	587-779-2916
Date:	2022-01-31	Email:	Vanessa.white@albertainnovates.ca

Instructions

1. Please fill out the section above as indicated.
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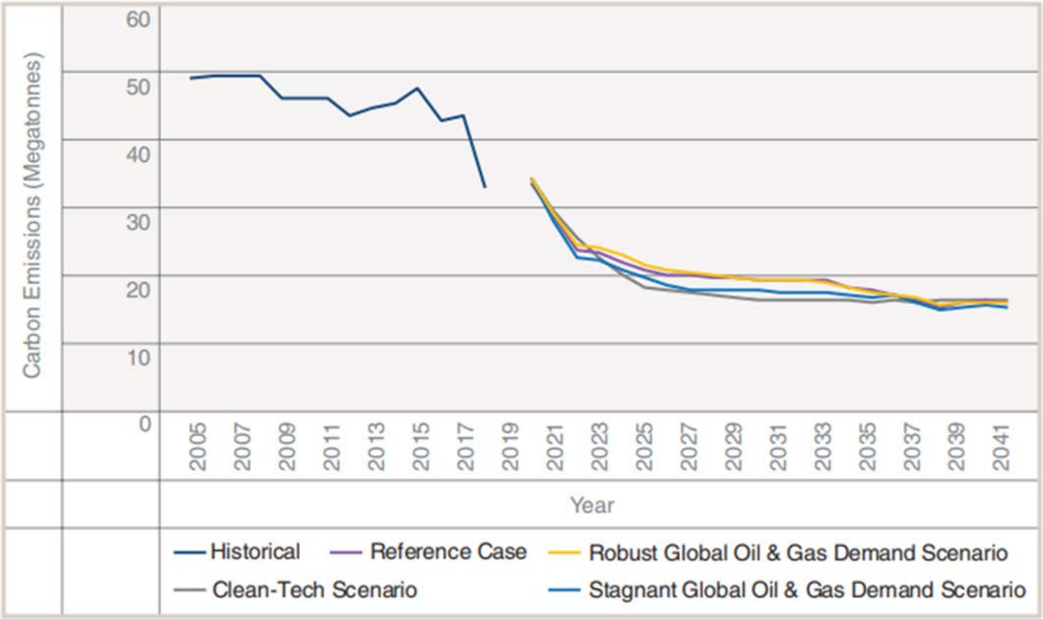

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	a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?	The transition to a decentralized grid also needs to be considered, as a one-way flow of electricity may not be as economical as decentralized resources. Broad analysis of decarbonization and electrification efforts need to be included across sectors deploying electricity. Global energy is increasingly based around electricity. That means the key to making energy systems clean is to turn the electricity sector, globally, from the largest producer of CO_2 emissions globally into a low-carbon source that reduces fossil fuel emissions in areas like transport, heating and heavy industry like petrochemicals and refining. SMRs (small modular nuclear reactors) are a huge part of the ability to achieve net zero. Nuclear isn't optional, it is a pathway to net zero and an opportunity for energy increasingly in remote, rural, indigenous communities, and difficult to decarbonize industries, like oil sands development.

	Questions	Stakeholder Comments
	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?	Aging infrastructure and the historical radial distribution of electricity may be one of the largest barriers to deploying new technologies without driving up the price to the consumer. Ensuring that Canada's and Alberta's energy transformation is authentically inclusive and is prioritized is challenging to achieve.
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?	Net-zero targets, coupled with growth will certainly have an impact on the cost of electricity.
	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 MMb/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**	While the oil sands are a significant factor in Alberta's load growth, what about other industrial users and how should their potential growth be considered in this exercise?

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

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

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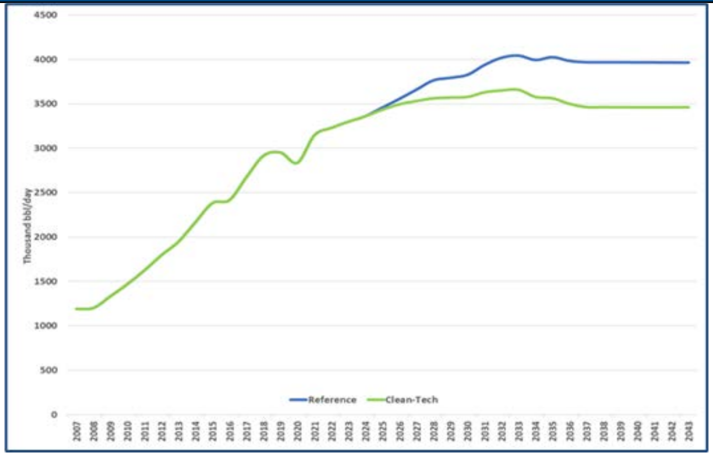
<tr><th colspan="2">Questions</th><th>Stakeholder Comments</th></tr>
<tr><td rowspan="2"></td><td>


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?</td><td></td></tr>
<tr><td>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?</td><td>Gas prices are not likely to sharply increase in the near-term, as there is still not enough forecasted capacity to ship LNG internationally.</td></tr>
<tr><td><i>3</i></td><td><i>Policy and Electricity Value Chain Impact</i>

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</td><td>Ultimately, the goal is to get to physical emissions reductions, but to encourage a transition of Alberta’s grid to net-zero will require offsets or credits within and external to the electricity sector.</td></tr>
</table>

	Questions	Stakeholder Comments
	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?	At carbon prices that exceed $170/t, many industries in Canada will be unable to compete in a global market. Our electricity infrastructure needs to be lower-emitting so that the competitiveness of Alberta industries is not eroded.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Clean Fuel Standards
	d) Are there any other related considerations that you would like to provide feedback on?	Alberta and Canada have an opportunity to use grid modernization to focus more than just on cost, reliability and safety and include more aspects like sustainability, equity, and access. We need to use grid modernization as an opportunity to drive technology development forward, deliver our connectivity for renewable, alternatives and emerging energy products, and implement creative solutions to allow for greater access to energy for all. We need to value equity in energy access.
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?	Energy efficiency isn't perceived as a benefit to customers. Much of the current bill in Alberta is fixed. Until the cost to the consumer can be significantly impacted by energy usage, energy efficiency measures will only be employed by a small percentage that are highly motivated to deliver net-zero goals.
	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.)?	DERs will definitely have a place in Alberta's grid as we move towards net zero. As articulated above, we need to use grid modernization as an opportunity to drive technology development forward, deliver our connectivity for renewable, alternatives and emerging energy products, and implement creative solutions to allow for greater access to energy for all. We need to value equity in energy access. As an example, energy storage and the corresponding technology development to enable it can

Questions	Stakeholder Comments
	contribute to energy independence, energy access, and energy equity, particularly for Indigenous and remote communities.
c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	The pace of vehicle electrification in Alberta will continue to be slower than other regions. The economics of electric vehicles, given Alberta's relatively low cost of gasoline and diesel, does not encourage transition to electrified vehicles. Incentives will be required. Additionally, a wide distribution of level 1 chargers will need to be in place for commercial vehicles. The main federal regulatory driver for EV adoption and deployment is the Clean Fuels Regulations (CFR). This regulation does not incent EV adoption in Alberta because our current grid has higher emissions than the Canadian average grid emissions of 180.4 tonnes/GWh. Therefore, grid-connected EV charging in AB will likely not qualify for significant compliance credits under the CFR until the Alberta (federal) grid emissions factor is on par with provincial grids with lower emissions. EVs charging directly from renewables (DER) would likely qualify. The grid carbon intensity (CI) issue may also limit Alberta's eligibility for federal EV infrastructure grants. A grid-based EV disincentive may push AB fuel switching towards DER-connected EV charging (depending on Alberta's DER implementation, impact may be nominal), liquid biofuels and hydrogen more than provinces with low CI grids.
d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	Natural gas is very inexpensive in Alberta. This will always be a challenge to electrification of heating. Switching to electricity may be driven by natural gas price increases, if global (Asia) demand for AB natural gas drives up prices for AB consumers. Electrification of appliances, such as cooking and water heating, will likely increase more rapidly than building heating and mass water heating (boilers). For example, induction heating is on a trajectory to replace gas-fired cooking. Easy integration with existing infrastructure (from household to distribution and transmission scale), cost and practicality of

	Questions	Stakeholder Comments
		retrofit/replacement of existing infrastructure, and rate new builds will all contribute to the conversion trajectory.
	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)?	As these industries continue to develop in Alberta, the load will continue to rise. There may be some facilities where "behind the meter' electricity is being used, but in general the load will need to be carried by the grid. Hydrogen is a critical part of Alberta's decarbonization future. Hydrogen is one of Canada's most exciting economic transformation opportunities to help businesses grow, dramatically reduce emissions in the industrial sector, and enable a new Canadian competitive advantage in a low-carbon economy. Alberta's Hydrogen Strategy, developed by Alberta Energy is housed in the Natural Gas Strategy and Vision. Alberta, and in particular the Greater Edmonton area is one of the largest production centres of industrial hydrogen – mainly used in petrochemicals and refining. Alberta is making a move to produce both low carbon intensity hydrogen and hydrogen technologies.
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?	Renewables and long-duration storage are a good potential option, but these technologies do not have the energy density of fossil fuels. The issue with these technologies are the other environmental trade-offs to produce significant electricity. Nuclear is an energy dense option, but SMRs are still in the technology demonstration stage. Ultimately, a diversified mix of energy sources will be needed to power Alberta's future grid. Land (and avian airspace) footprint of solar and wind will continue to face public pushback due to perceived or science-based impact on agricultural lands and biodiversity, as well as aesthetic and perceived health reasons, especially if wind/solar land footprint expands. The opportunity for DER or Microgeneration (MG) to facilitate dispersed generating capacity installed on buildings and other infrastructure is still a potential solution. For DER/MG, larger commercial installations need long lead times to address engineering requirements of new or retrofitted buildings to carry DER infrastructure. Technology innovation and regulatory "innovation" may help increase affordability of DER/MG.

	Questions	Stakeholder Comments
		Adding renewable natural gas produced from organic waste into natural gas will reduce grid intensity in natural gas burning power production plants. There are challenges with the feedstock availability and economy of scale. The main barrier is lack of incentive provided by the regulatory space as majority of planned RNG facilities under development in the province are going to export their RNG to other jurisdictions (e.g., British Columbia) with more robust regulations incentivizing natural gas CI reduction.
	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 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	(i) Post-combustion CCUS: CO_2 capture focus on developing novel capture alternatives to amine-based solvents, which remain challenged by high capital and operating costs. Metal organic framework is an emerging sorbent technology for CO_2 capture, but it is still at an early stage of development and key technology developers are unlikely to scale in the next 5 years. Growing momentum in the hydrogen economy incentivizes the use of CO_2 capture for hydrogen production with CCUS. The regulatory mechanisms for CO_2 capture are well-defined and in place, but too weak to incentivize mass-adoption. The drop in renewable electricity prices eliminates the need for CO_2 capture in the power industry. The lack of storage resources and new scalable application of CO_2 dampens the deployment momentum of CO_2 capture. CO_2 utilization for chemicals is at an early stage of development and highly energy-intensive – commercial viability requires securing cheap renewable energy. The falling renewable electricity prices brings down the cost of CO_2-based chemicals – access to cheap energy is essential. The market for CO_2-based methanol is reliant on the widespread availability of green hydrogen. CO_2 used for producing both liquid and gaseous hydrocarbon fuels such as jet fuel and methane. The adoption of the fuels sector for CO_2 utilization is severely limited due to a lack of regulatory support coupled with capital-intensive nature of the technology. Success in this sector focuses on the aviation sector

Questions		Stakeholder Comments
		taking unprecedent action to support the adoption of low-carbon fuels in its operations. The falling renewable electricity prices brings down the cost of CO$_2$-based fuels – access to cheap hydrogen is essential. Low carbon technologies require strong regulatory support for adoption, which is especially applicable to CO$_2$ utilization which is at an early-stage with expensive costs and strong competition from alternate technologies. A more structural approach is needed to help guide decisions in policy making and funding allocation for CO$_2$ utilization. Technology innovations will increase efficiency, securing a cheap source of renewable energy will go much further than efficiency improvements in bridging the price premium. (ii) Pre-Combustion CCUS: unable to comment. (iii) Oxyfueled Generation: unable to comment. (iv) Renewable generation including wind, solar, geothermal, and biomass - Renewables such as wind and solar have intermittency issues which challenge their applicability for base load. When combined with long-duration storage they have greater applicability. Environmental impacts regarding the land use for wind and solar are another concern. Renewables + new generation storage could be commercialized in the next 5-10 years. For geothermal, the biggest issue is that the Alberta geothermal resource is of relatively low quality in most areas of the province. With binary systems (like an ORC), the potential application improves, however the efficiency is likely quite low. New technologies are being investigated to be able to access Alberta's deep, high-temperature resources – but the commercial application of this technology is still 10 years off. Scope should consider both biomass and other waste-to-energy (organic or inorganic) including agri-forestry residues and waste, organic portion of municipal waste (liquid or solid), and other commercial/industrial/institutional wastes and residuals (e.g., hospital waste, food waste). Issues that may deter investment

	Questions	Stakeholder Comments
		include feedstock cost and supply chain risk, cost of transport, environmental risks. While feedstock pre-processing can increase energy density for transport and improve economics and CI of feedstock transport over longer distances, the economic balance point will tend to be between cost of transportation (distance, energy density) versus economies of scale (capacity). Feedstock pre-processing cost and who pays whom (supplier pays tipping fee or offtaker pays for feedstock) may also affect energy facility economics. Key opportunities for new capacity include: (A) biomass- or waste-based generation for Alberta that utilize feedstocks with no higher value use and highest intrinsic regulatory or other "problem" cost (e.g. toxic or contaminated waste, such as manures and meat processing remains), (B) Electricity and/or heat generation as a byproduct of new large biorefineries or other ag-for facilities are built, and (C) Converting biomass to renewable natural gas (RNG) for blending with natural gas for use in AB, leveraging existing regional NG transportation and distribution infrastructure. Cleaner, consistent biomass and wastes/residuals/co-products feedstocks will go to higher value uses (e.g., liquid biofuels, biomaterials, bio-based chemicals) or energy use in higher-paying markets (e.g., RNG, wood pellets). The current advantages of forest biomass (i.e., mill residues) for heat and electricity may erode as higher value uses emerge or mills reach their natural end of life. Increasing stringency of federally-adopted global sustainability standards for biomass may also constrain which feedstocks qualify for credits in regulated or voluntary carbon or ESG markets. (v) Hydroelectric Generation - The likelihood of new conventional hydroelectric in Alberta is very low. The potential could exist for run of river hydroelectric, but the output would be seasonal in nature and would not likely constitute a large resource. Most potential large-scale hydro locations are in remote undeveloped locations that are far from load and lack transmission infrastructure.

Questions	Stakeholder Comments
	(vi) Nuclear Generation - Nuclear, in the form of SMRs has the potential for base load power to replace fossil fuel generation or add capacity to the grid. It also has the potential for “behind the fence” generation for some of Alberta’s large industrial loads. Commercial deployment in Alberta would be 10-15 years away. (vii) Energy Storage - New long-duration energy storage technologies are being developed and is a solution to manage the intermittency of renewables. It also has the potential to capture and store electricity during low demand times and release the electricity, on demand, as required for peak shaving. Commercialization of new long-duration storage is 5-10 years from now. (viii) Transmission Connections with other Jurisdictions - Expanding Alberta’s interconnections with other jurisdictions that are producing net-zero power would help to accelerate Alberta’s transition. The more regular use of the intertie with Saskatchewan, as they complete their transition to nuclear could support Alberta’s energy transition to net-zero. Saskatchewan is planning to deploy SMRs by 2035. (ix) Offsets or Emissions Performance Credits - Offsets and emissions performance credits will help accelerate the transition to a net-zero grid.
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?	Electricity from industrial waste heat
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.	See commentary in sections (a) and (b).
e) Do you expect the accounting of net-zero emissions by 2035 in the electricity sector to require net-zero emissions	Carbon capture and storage will be the most economic method for emissions control at cogeneration facilities.

	Questions	Stakeholder Comments
	from cogeneration facilities? If so, what emissions control technologies do you believe can be most economically implemented at cogeneration facilities?	
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*	

Questions	Stakeholder Comments
	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

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[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?	As technologies become more mature and efficiencies are employed in the manufacturing process, the capital cost will continue to decline; pre-commercial technologies, like SMRs and fuel cells, will see cost reductions as their commercial market increases into the 2030s.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	No relevant retrofit cost data to share.
	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).	No additional comments.
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	Clean technology addresses sustainability while creating opportunity for economic diversification in Alberta. We need to consider more than just achieving net-zero, we need to establish a mindset and the tools to stay there. The conversation on net-zero is currently focused on strategies and tools; it needs to also focus on behaviours and values.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Richard Boulton
Comments from:	AltaLink	Phone:	403-850-5699
Date:	2022/01/31	Email:	richard.boulton@altalink.ca

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

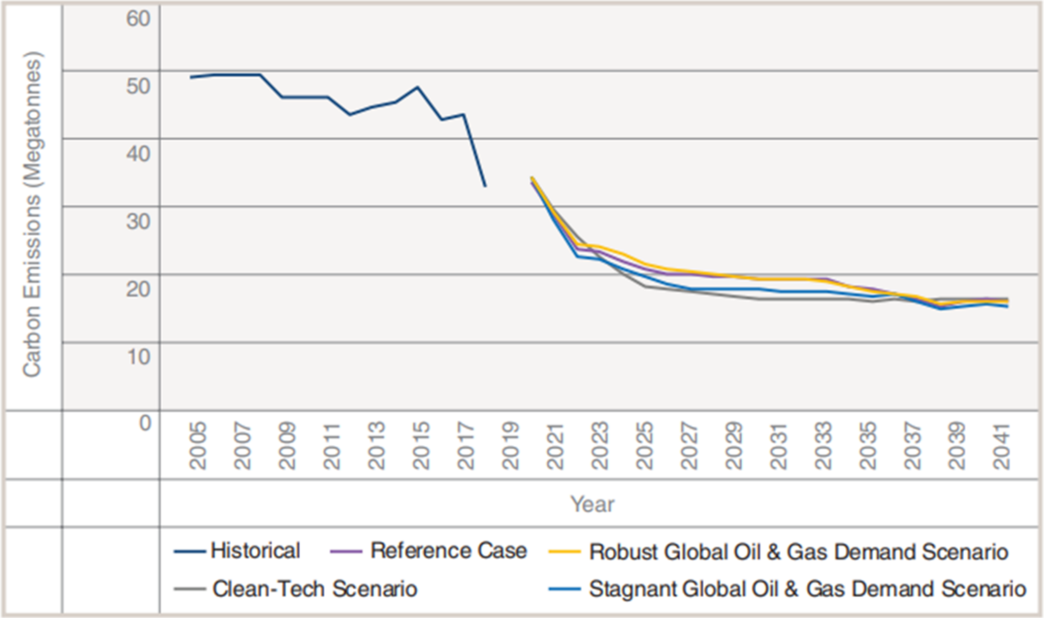
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	AltaLink commends the AESO undertaking the net-zero pathways study. Such a study will provide valuable information to inform policy makers, stakeholders, and the general public regarding the implications of net-zero goals on cost, reliability and GHG emissions. AltaLink encourages the AESO to consider the followings in developing scenarios and analyzing their implications: • Extend the scenario horizon to 2050. AltaLink agrees the focus should be on how the grid may achieve the 2035 net zero objective. However, the analysis needs to consider what will likely occur after 2035 when the broader economy transition to net zero by 2050 as envisioned by the federal gov't occurs. It is important to recognize that significant electrification will likely occur after achieving net-zero grid and as such the grid may see energy demand dramatically increase after 2035. Reaching the 2035 goal without this longer-term objective, could result in actions that maybe inconsistent with the ultimate 2050 goal, resulting in stranded investments and/or higher overall costs.

Questions	Stakeholder Comments
	- Consider broader set of scenarios. Given the large uncertainty on policies and technologies, it is desirable to explore a discrete set of scenarios instead of developing a single scenario that is the most economic based on a set of assumptions of cost, market and policies. AltaLink encourages the AESO to develop and assess additional scenarios after reviewing stakeholders' feedback. The scenarios to be assessed should not be constrained by current market/industry constructs so that the scenario analysis will provide insight on potential implications of net-zero pathways to inform policy makers, stakeholders, and the general public. - Explicitly consider a scenario to assess the role and value of interties in achieving net-zero. Many studies conclude that significant interties will play a large role in enabling decarbonization and the federal gov't has a strong interest in promoting regional interconnections as an important measure to enable net-zero to maximize the use of low-cost clean energy and capture regional diversities. The scenario should consider both maximizing the use of existing interties as well as new interties and assess their impact together with other scenarios. Once the scenario analysis is completed, it is recommended that further work is necessary to assess potential implementation issues such as a level playing field, cost to consumers, and to ensure Alberta is capturing its share of the benefits. - The analysis should be as quantitative as possible especially relative to costs. Quantitative analysis is ultimately required to provide confidence in policy direction. Given all the uncertainties, we recommend the AESO confirm key assumptions with stakeholders, test sensitivities and then document them in the final report. This will enable parts of the analysis to be repeated if key variables material differently.
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?	- Lack of policy clarity. The biggest impediment is the current lack of clarity of policy including the definition of net zero. - Short timeline. Given the timelines needed to permit and build any large infrastructure (including generation or wires), 13 years is not a lot of time to facilitate this transition.

	Questions	Stakeholder Comments
		- Maintaining affordability of the grid for customers. Regardless of the pathway, significant expenditures will be needed. Keeping the overall price of electricity affordable, will be very challenging but is a fundamental requirement of any viable pathway. - Maintaining the necessary reliability of the grid is essential but will be challenged given the magnitude of the change within this short period of time. i.e. 90% of all energy, which is now produced by carbon emitting sources, will need to come from non-emitting sources or have suitable offsets. A change of such a magnitude over a short period of time creates significant risk in maintaining grid reliability. - Sustainability of the current market framework. Alberta has relied on the energy only market over the last decade to attract private investment in generation while delivering competitive prices for consumers. The significant change in generation mix required to enable net-zero requires a significant amount of investment to occur in a relatively short period of time while large policy uncertainties exist. It is questionable that current energy only market remains to be the appropriate mechanism to facilitate required investment while meeting reliability and affordability objectives.
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?	- The energy transition driven by decarbonization and net-zero may have a positive impact on the Alberta economy in the short-term. Alberta 2021 GDP growth is estimated to be 6.1%. 2022 economic growth is forecast to be 5.1% by the government and most of the Canadian banks predict Alberta to lead other Canadian provinces in economic performance in 2022. Alberta's strong economic recovery benefited from strong oil and gas prices as a result of reduced capital flows into the oil and gas supply while global oil demand remained strong.

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

	Questions	Stakeholder Comments
		- Alberta's oil sands sector may benefit from this changing supply demand dynamics and resulted price volatility into the foreseeable future given its competitive advantages against others during the energy transition. - The long-term impact of a net-zero target on the Alberta economy will depend on how the Alberta economy adapts to the new energy system while diversifying its economy. - Successful decarbonization could be a significant competitive advantage for Alberta's oil and gas products. As such, they could be desirable in world markets for much longer.
	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**	- With high oil prices (which are expected to continue for the next decade of so), oil companies will look to add efficiencies within their operation to maximize production. - The investment community has been providing a disincentive for carbon-based projects and incentives for green projects. AltaLink believes this will likely prevent greenfield expansion. It will, however, incent investment in enhancements which increase efficiency, maximize production, and decrease carbon intensity of existing operations. - As a result, AltaLink believes the AESO's proposed approach seems reasonable for the study. - Although greenfield oil sands are unlikely, this does not mean that electricity consumption associated with oil sands production and processing will track based on historical rates. i.e. With short to intermediate term high prices, operators will look to maximize production. Also, carbon policy may drive changes such as

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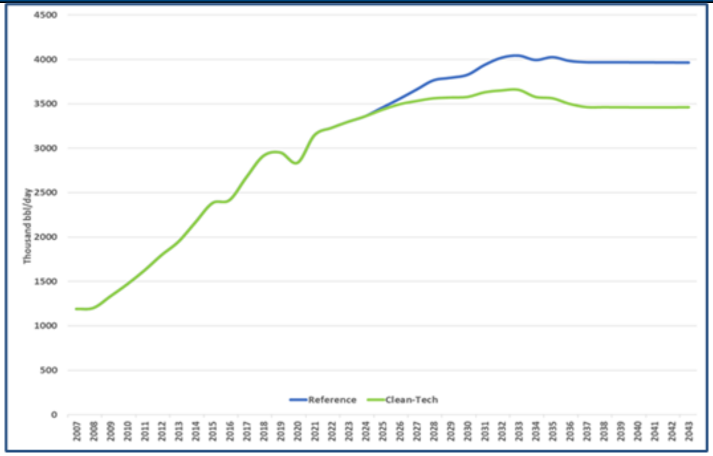
[2] https://ihsmarkit.com/research-analysis/canadian-oil-sands-running-above-prepandemic-highs.html

	Questions	Stakeholder Comments
	 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?	switching from gas to electric drives as a way of reducing emissions may occur.
	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?	• AESO should consult several different market forecasts. • A range of gas price assumptions is likely a sensitivity that should be included in the analysis to understand the implications.
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	• AltaLink expects the Federal Government will develop the specific rules relating to carbon accounting. These rules will ultimately need to align with international rules as well as support national policy and targets. i.e. As Net Zero Grid by 2035 is a national target, the Federal Government will define the parameters for what it means to achieve it including: • What emissions are attributable to the electricity grid? E.g. Only Scope 1 (direct emissions) by companies who the Federal Government designates as being part of the "Electric Utility" sector? Scope 1 and Scope 2 (indirect

	Questions	Stakeholder Comments
		emissions from the generation of purchased energy) associated with all electric power supply? Scope 1, Scope 2 and Scope 3 (all other indirect emissions)? Etc? • What offsets (if any) are acceptable relative to type and location. (e.g. Is it OK for not every province to be net zero providing the country as a whole is net zero?) • Currently, we believe the Federal Government has been accounting for electricity grid emissions as "only Scope 1 (direct emissions) by companies who the Federal Government designates as being part of the Electric Utility sector". It is unclear if they have been including any offsets. (Note: Individual provinces then may layer on their own requirements such as the need for the offset to be located within the province.) • Besides electricity, other sectors of the economy are expected to have intermediate term objectives. Oil & Gas is one such sector that will likely have such intermediate targets. Such policy targets will likely have knock-on impacts on the electricity sector (both supply and demand). • Unless carbon accounting rules are clarified before AESO commences their Net-zero study, AltaLink recommends the AESO assess different net-zero definitions as part of its scenario analysis to better understand their impact on affordability. This would be useful information for policy makers involved in setting the rules.
	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?	• AltaLink expects the carbon prices will follow the Federal Gov't's announced policy rising from $50/t to $170/t by 2030 • Post 2030, it is AltaLink's expectation that changes to the price of carbon will reflect how well the energy transition is progressing. i.e. If the targets are being met, there is no need to increase carbon taxes. However, if targets are being missed, then, increasing carbon taxes becomes a very likely lever to get targets back on track.

	Questions	Stakeholder Comments
		• Based on Canada's track record of not meeting carbon targets, it is reasonable to anticipate higher carbon prices are likely.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	• TIER. Currently, TIER "softens" the impact of the carbon tax by comparing emissions against intensity targets. Although this is done to protect customers from the impact of the carbon tax, it decreases economic signals. That said, this will not matter over the longer run as in a net zero world, the benchmark becomes zero. • Carbon accounting. The rules for attributing emissions will likely continue to evolve. This will include clarifications on the definitions of Net Zero. One potential change that would impact electricity is if Cogen emissions are at least partially attributed to the electricity sector (rather than to the host industry as they are today) • The design and implementation of federal Clean Electricity Standard as a enable mechanism for net-zero grid by 2035 • Energy efficiency, ZEV, ZEB, etc. incentive policies. • Public/consumer demand is increasing for green products and services. This is creating a pull, which in the end, may be much stronger than the push from governments to transition to 100% green. As electricity is a key input for all businesses, businesses are moving on their own to be green. This trend will likely continue to accelerate. • Political – change in US and/or Canadian Federal Governments resulting in a shift in climate change policies.
	d) Are there any other related considerations that you would like to provide feedback on?	
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,	• Energy efficiency improvements fall into two categories: ○ Reduction in final energy use (e.g. Better insulation, windows, and doors reduce the heat demand of a building)

Questions	Stakeholder Comments
commercial, and/or industrial)? What would trigger more energy efficiency or conservation efforts?	○ Efficiency gains through electrification (e.g. A ground source heat pump uses approximately 1/3 of the energy than a high efficiency natural gas furnace for the same heat output.) • Carbon prices, incentives, and regulation will continue to play an increasingly important role in driving energy efficiency improvements in all sectors. • The economics of electrification (or other technology changes) are highly sensitive to timing relative to the normal end-of-life replacement of the asset. (e.g. The economics transitioning from an ICE to an EV change dramatically depending if ones existing vehicle is at its normal end of life or not.) Stock turn-over will dictate the pace and scale of greater energy efficiency. • TIER is presently sheltering end consumers from the full impact of the carbon tax. As such, this softens the economic incentive for end users to conserve or invest in efficiency improvements. Changes to this policy could accelerate conservation and efficiency efforts.
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.)?	• Given 90% of Alberta's energy currently comes from carbon emitting sources, Net Zero is driving a largescale changeout of existing generation. In addition, longer term carbon reductions from other segments of the economy will drive electrification. As such, this will drive the need for many new energy resources. DERs will absolutely have a role along with transmission connected generation. Alberta will need all the resources it can get to meet this longer-term need. • As economies of scale apply to virtually all generation technologies, the quantity of DERs will likely depend heavily on the available subsidies. This is especially true for smaller scale DERs. Subsidies come in many forms including: ○ Direct subsidies (tax incentives, rebates, etc.) ○ Net metering (which offers an incentive equivalent to all or part of wire charges)

Questions	Stakeholder Comments
	- Without incentives, larger sized solar connected at distribution levels may continue to make economic sense. - With increased penetration of EVs, V2G likely could be a very viable way of driving efficiency into distribution networks.
c) Transportation Sector - What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	- Many predict that parity between ICE vehicles and EVs will occur in and around the 2025 timeframe. As such, even without government incentives, EV sales will naturally increase given electric vehicle target announcements from car manufacturers. Though, the entire fleet of existing vehicles in Alberta will take some time to completely change over. In Alberta, historically, approximately 4% of passenger vehicles get changed out each year. At this rate, the “natural” time to change out all vehicles would take about 25 years. AltaLink would expect, however, that the change-over may accelerate, particularly in the later years due to increasingly improved economics associated with zero emissions technology and likely worsening economics of hydrocarbons. - Expect hydrogen will play a role in eliminating emissions in transportation. EV and H2 have strengths and weaknesses. Thus, AltaLink would not expect either technology will fully dominate. Instead, AltaLink foresees both technologies will exist where it makes the most sense. E.g. EV will likely dominate for light passenger vehicles, especially the ones used for short trips. H2, however, appears to be the best technology for heavy transport, shipping, air travel and vehicles needed for long distances. - Another factor which could have profound impact on passenger vehicles is the potential shift away from personal vehicle ownership and towards more of a shared “transportation as a service” business model. Such a change, which has already been seen in other sectors such as the hotel industry, would not alter quantity of passenger kilometers, but would impact number of

Questions	Stakeholder Comments
	vehicles and, more importantly for the grid, where these vehicles are charged. - The current lack of charging infrastructure is likely an impediment to adoption of EVs in certain locations. Depending on how (& when) this is addressed will impact adoption rates.
d) Buildings - What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	- Eliminating emissions from buildings in Alberta's harsh climate will be challenging. AltaLink expects various approaches will be applied based on where they are most economical. Due to the large cost challenges of any pathway, suspect most changes will occur likely during the 2040s – though government incentives may drive some earlier changes when building owners existing heating systems normally need replacement. - Changes in Building Codes could drive changes for new construction. - Heating alternatives that will likely exist by the 2050 deadline will include: o Electrification particularly the use of ground-based heat pumps o District heating systems fed from centralized plants producing heat from H2. This likely makes the most sense for dense urban settings. o Continued use of natural gas and "negative" offsets - Challenges associated with safely distributing hydrogen will likely prevent it being directly used in most buildings.
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?	- AltaLink expects the majority of industrial energy needs will ultimately come from hydrogen. Most of the hydrogen will be "blue" produced from natural gas using technologies like Auto-thermal Reforming (ATR) + CCUS. Although this offers an economical approach to dramatically reduce emissions, it does not fully eliminate them. i.e. ATR may allow capture of up to 95% (but more likely 91-92%) of all carbon emissions. The

	Questions	Stakeholder Comments
	• 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)?	residual emissions are problematic when the goal is zero - given the quantity of negative carbon offsets is limited (unless one goes to extremely expensive technologies like direct air capture which quickly erodes the economics of this approach.) • ATR requires large quantiles of oxygen. Oxygen from cryogenic air separation units have a large electricity demand. In addition, CO2 compression is also needed to transport and send the CO2 into geological formations. As such, the electrical demand to support large scale blue hydrogen facilities could become significant. • Industries are being pressured by their customers to become 100% green. This is resulting for an increased desire from these industries to only procure green energy. • Some industries are very difficult to eliminate emissions (e.g. cement, agriculture). As such, this puts pressure on industries that can eliminate emissions to do so. i.e. The few negative offsets will be needed for these other industries. This is likely the biggest reason why electricity (which can get to zero emissions) to do so without needing any external offsets.
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?	• The technologies that will most likely form Alberta's decarbonization pathway are: ○ Wind and Solar ○ Hydrogen generation (CCGT & SCGT) ○ Interties ○ Energy Storage
	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 Carbon Capture, Utilization, and Storage • Expensive – large capital expenses would need to be added to each combustion-based generator. Alternatively, precombustion is much less capital intensive and, thus, ultimately much more economical. (i.e. One only needs to build out precombustion capacity to meet the average need,

Questions		Stakeholder Comments
	(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	assuming one has hydrogen storage and the ability to move the hydrogen to where the thermal generation is located which we would anticipate is adjacent or within these large-scale hydrogen production facilities. Likely locations of large-scale hydrogen facilities are identified within the Alberta Hydrogen Roadmap.) • Not Zero Emissions – cannot capture 100% of emissions • CO2 at low pressure – added CO2 compression required • CCUS remains controversial. Questions linger regarding sustainability and long-term safety (for systems which transport and sequester the CO2 underground at high pressure). (ii) Pre-combustion Carbon Capture, Utilization and Storage (hydrogen) • Most economical way to make low carbon hydrogen at scale is from a variety of feedstocks including Ng and biofuels • Not Zero Emissions – CO2 capture rates are in the 85-95% range. This is not an issue when burning biofuels any carbon capture results in negative emissions. When burning hydrocarbons, especially if done in high volumes, this slippage is a problem in achieving net zero. • CO2 and Hydrogen produced at reasonable pressure (e.g. 20 bar) which reduces compression energy requirement. • Some processes (like Auto-thermal reforming) are electricity intensive as they require large quantities of pure oxygen (iii) Oxyfueled generation • Not Zero Emission - Better than doing nothing, but far from enabling net zero • Very large electricity demand required to produce the oxygen needed. (iv) Renewable generation including wind, solar, geothermal, and biomass

	Questions	Stakeholder Comments
		• Wind and (grid-scale) solar is the lowest cost form of low/no carbon energy. In fact, overbuilding and accepting significant spilling is a lower cost alternative than other energy options. Intermittency is their greatest drawback and require some form of backup (storage, interties, thermal gen, etc). • Geothermal has potential and does not suffer from the intermittency problem. Costs, however, remain high • Biomass offers the opportunity when gasified and combined with CCUS to provide negative carbon emissions. As such, this will likely have a place in the future energy mix. (v) Hydroelectric generation • Alberta has some hydro potential in the far north. The biggest issues would be permitting any new larger scale hydro and permitting/building/cost of the transmission required to connect the generation into the transmission system (vi) Nuclear generation • Advanced Nuclear, especially, the small modular type currently being contemplated holds some promise. However, even optimistic costs are likely higher than other alternatives. • Although the waste of the advanced reactors is significantly less than the older technology, this still presents a long-term problem. • Public acceptance of nuclear is also a big hurdle. Chernobyl and Fukushima have formed public opinion. This would be difficult to overcome. • Although fusion will ultimately provide the worlds energy needs, development is slow. To prevent the 1.5C temperature rise, the world will have to do it without fusion. (vii) Energy Storage • Foresee large scale storage will have a role in helping to deal with the intermittency of wind/solar. The storage technology is

Questions	Stakeholder Comments
	less clear as there is a large range of choices – each with their strengths and weaknesses. Suspect that gravity-based systems (such as pumped hydro) currently holds the most potential for very large scale storage. • Foresee storage in specific applications. The biggest vale application involves using storage to increase the available capacity on the interties. (viii) Transmission interconnections with other jurisdictions • Ultimately, interties are the best way to deal with intermittent renewables. i.e. By integrating them over wide geographies, they become a reliable source of energy. This, however, requires very large capacities which are slow to build. • Expanding the existing interties can, however, be done relatively inexpensively and much faster using a variety of technologies. • The biggest issue with this approach is to design a mechanism for sharing the benefits of interties and dealing with structural differences (such as markets vs crown utilities) across jurisdictions to ensure fairness for all players (ix) Offsets or Emissions Performance Credits • When the goal is net 0 emissions, offsets (unless they are negative), won't help. As there is limited potential for negative offsets, AltaLink anticipates they will be kept for segments of the economy which are extremely difficult to mitigate emissions.
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?	• No. Although green technologies continue to advance rapidly, with the short time available before 2035, the technologies that exist today will need to be used.

	Questions	Stakeholder Comments
	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.	• Although they are low cost, wind and solar are intermittent. As such, they need some form of backup. • Providing there is oxygen storage capacity, the large loads associated with blue hydrogen production may offer the electrical system flexibility in electrical demand and be used as a form of energy storage. i.e. Utilize excess renewable energy at times of surplus to produce oxygen and then withdraw from the oxygen storage to conserve electricity at times of higher demand. • What about the potential benefit of energy storage to the electric system?
	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?	• Ultimately, this is going to depend on the carbon accounting rules defined by the Federal Government. • AltaLink would anticipate that the emissions associated with exports to the grid will very likely need to be included in the grid's emissions. However, potentially, all emissions associated with electrical generation will need to be accounted for within the electrical grid. • The easiest and likely the most economical change to Cogen facilities to eliminate emissions would be to convert the gas turbines to use hydrogen.

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

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[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?	• Expect costs of key technologies (wind, solar, battery energy storage) will continue to trend downwards. However, the cost curves of all these technologies have been "flattening". Therefore, decreases may not be much more than to counteract inflation.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	• Adding CCUS on a generating plant does not make economic sense. The cost of such a change is almost equivalent to the cost of a hydrogen production facility which provides more operational flexibility (& requires overall less hydrogen production capacity). If existing generating plants continue to operate, expect they will be converted for hydrogen operation.
	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).	Missing costs are: • Simple-cycle hydrogen powered plants (needed for peaking). i.e. Like in today's world of natural gas powered generation, there is an optimal balance between combined cycle and simple cycle generation. • CCUS – i.e. Cost of capturing, transporting and sequestering carbon. • Hydrogen production facilities • Intertie enhancements • Other types of energy storage (like pumped hydro)
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	The economics of a technology change is highly sensitive to timing relative to the normal end-of-life replacement of the existing assets. (e.g. The economics transitioning from an ICE to an EV change dramatically depending if ones existing vehicle is at its normal end of life or not.) This is also true for the elements that make up the electric power grid (generators, wires, etc). i.e. Forcing a transition faster will result in higher costs. We would recommend that a sensitivity analysis be performed to see how costs change if the grid transitions to net zero slower than the 2035 target.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Ken Hogg
Comments from:	Alberta Renewable Energy Alliance	Phone:	403 463 9390
Date:	2022/01/31	Email:	

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

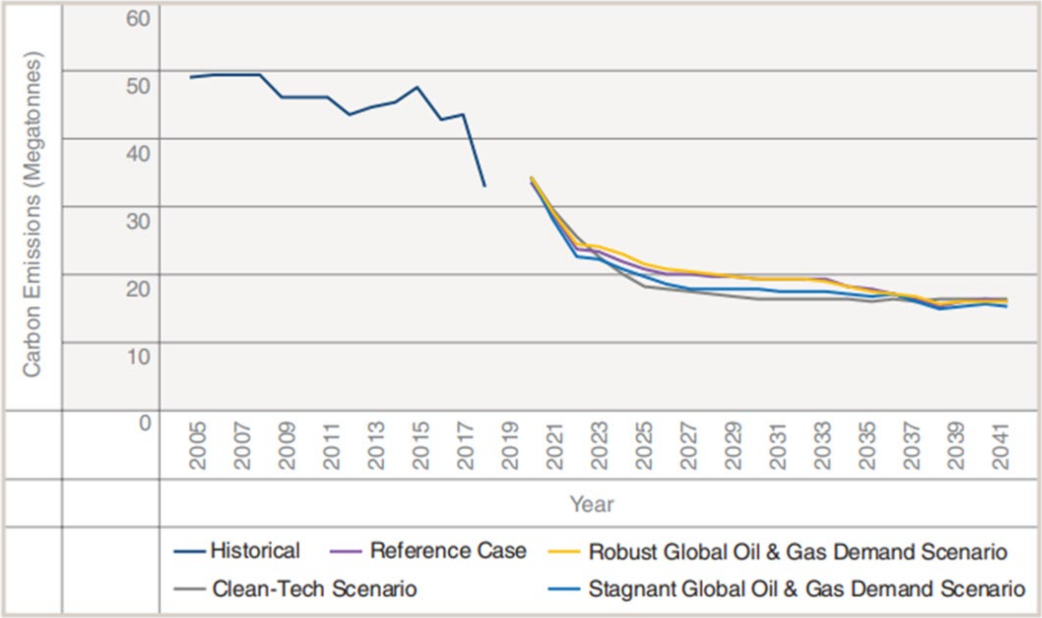
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	What defines 'Clean-Tech' generation? Alberta's generation intensity is currently 570 kg CO2e per MWh. Given the Federal 'clean' target of net-zero GHG electricity emissions by 2035, what might annual targets be for Alberta to achieve net zero by 2035?
	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?	Elimination of upstream fugitive emissions of methane in the oil and gas sector must be achieved as a priority if there is to be continued or increased use of natural gas for power generation and CCUS.
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]	Why would AESOs 2021 LTO forecast annual increase in generation (in both reference and clean tech scenarios) be a very conservative 0.67% resulting in 2030 generation to be 90,000 GWh? Increased electrification

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

	Questions	Stakeholder Comments
	a) What is your view on the economic impact of expected net-zero targets on this business-as-usual scenario?	of several sectors would suggest that annual growth should be at least 1% to 1.5%. Low-to zero carbon electricity generation can be achieved at speed and scale with renewable energy coupled with energy storage. Wind and solar LCOE is now less than natural gas generation. As the carbon price of GHG emissions escalates, renewable energy generation will not incur carbon costs and will benefit from revenues accruing from grid offsets.
	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**	

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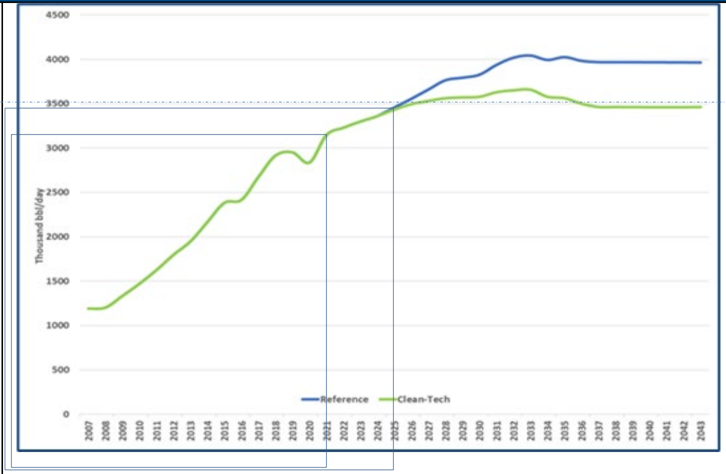
[2] https://ihsmarkit.com/research-analysis/canadian-oil-sands-running-above-prepandemic-highs.html

	Questions	Stakeholder Comments
	 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?	
	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?	
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	Offsets from low-to zero emission generation should continue to be registered within the electricity sector and retained within the Province of Alberta. Offsets should be adjusted annually to reflect the decreasing emission intensity of the Alberta grid.

	Questions	Stakeholder Comments
	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?	Carbon price on GHG emissions underpins the entire effort to reduce GHG emissions from power generation. Unless and until the carbon price is increased by at least $10 to $15 per tonne CO2e annually to 2030 and beyond, and related border adjustments are legislated, natural gas power generation will be allowed to continue unabated.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	The current Alberta TIER regulation on generation eliminates annual stringency on natural gas units below 370 kg CO2e per MWh. Federal regulations on new gas generation required an annual stringency of circa 10% such that allowable emissions from such units would be zero by 2030. Federal regulations should increase annual stringency on existing natural gas units to increase their carbon reduction obligation.
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	Archetype studies of energy use by residential, commercial, and institutional buildings should receive priority, and financial support. A common metric of GJ/square meter/occupancy should be used to provide comparison between high and low consumers of energy. Allowance for HDD and CDD should be factored into the metric. Specific knowledge of elevated consumption patterns, supplemented with Federal/Provincial incentives/rebates would trigger conservation efforts. Training of energy auditors must be a top priority.
	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.)?	Large scale deployment of wind, solar, geothermal and energy storage must be promoted immediately at a scale of gigawatts not megawatts/kilowatts. At least 13 GW of renewable/storage systems should be added to the Alberta grid by 2030 if net zero generation is to be achieved by 2035.
	c) Transportation Sector	The majority of new light duty vehicles (cars, trucks, buses) may be powered by batteries by 2030. Long range heavy duty trucks and rail

	Questions	Stakeholder Comments
	• What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	may be powered by electrolytic hydrogen. Hydrogen should be produced from electrolysis of water; electricity to power electrolysis and hydrogen compression should come from surplus wind and solar energy.
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	Electrification and retrofitting of the significant amount of current building stock (millions of buildings) will occur at a slower pace than a rapid transition of power generation with renewable energy.
	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)?	Any production of electrolytic hydrogen should come from surplus renewable energy. That is, any curtailment of excess wind or solar energy should be avoided. Any additional consumption of natural gas to provide the power for CCUS should be based on the assumption that fugitive emissions of methane must be eliminated. The 100 year GWP of methane of 25 should be updated and referenced to the 20 year GWP of 86, given the abbreviated time horizon available to reduce GHG emissions.
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?	GHG emissions from all generation technologies hinge on the carbon price legislated across Canada. If the carbon price escalates significantly this decade coupled with appropriate border adjustments, renewable energy generation will avoid high carbon penalties while realizing grid offset revenues and will offer the most economic pathway to decarbonization.
	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 Carbon Capture, Utilization, and Storage	CCUS should be evaluated at PILOT scales and supported with tax incentives. But unless fugitive emissions of methane can be eliminated, any CCUS encompassing additional combustion of natural gas will negate any gain from the exercise. The strengths of renewable generation/storage have been discussed in previous paragraphs.

Questions	Stakeholder Comments
(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	Small scale (up to 300 MW) nuclear generation should be evaluated for Alberta and not simply dismissed due to NIMBY resistance. Safety, radiation issues, and decommissioning problems and solutions should be disclosed. Energy storage of surplus renewable energy must be deployed at GW levels if Alberta is to transition off natural gas by 2035. Transmission interties with BC should be increased such that if surplus renewable energy is generated in Alberta, such surplus can be exported to BC; a reciprocal arrangement would apply for BC hydro. Offsets generated within Alberta for use within Alberta should be promoted.
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?	Geothermal power should be evaluated and deployed in Alberta. Drilling of deep wells to 5,000 meters can tap hot water (150 deg C) for Binary (Organic Rankine) cycle geothermal power generation. These plants can be operated for reliable generation or throttled for energy storage.
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.	
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 Aimplemented at cogeneration facilities?	Cogeneration emission intensity must be transparent and appropriately included in annual Federal NIR reports. The AESO 2021 LTO for 2030 forecasted cogeneration emission intensity of 120 kg CO2/MWh which is thermodynamically impossible. Cogeneration power delivered to the

	Questions	Stakeholder Comments
		Alberta public grid should be reported and assigned a more appropriate emission intensity of 300 kg CO2/MWh. Cogeneration, despite its relatively lower emission intensity, should be required to achieve net-zero emissions by 2035.
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*	

Questions	Stakeholder Comments
	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

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[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?	The variable O&M cost of Combined Cycle with CCUS of $7.36 per MWh should be explained more fully. What is the assumed price of natural gas and what is the assumed cost of CO2 access to the carbon trunk?
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	Premature to propose. As stated in 1 (f) "Subsequent analysis and reporting may focus on these more detailed metrics."
	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).	Binary geothermal Technology Costs should be researched by AESO and included in this table. Pumped Hydro Energy Storage Technology Costs should be researched by AESO and included in this table. If Hydrogen-Fired Combined Cycle is to be included in the table, technology costs for hydrogen produced from natural gas (Blue hydrogen), or electrolytic (green) hydrogen should be researched by AESO and included in this table.
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	Renewable generation can be deployed at speed and scale from 2022 to 2035. A target, mandated by the Alberta government, should require that renewable energy provide at least 50% of total generation in Alberta by 2030. 3,000 MW of coal units will be fueled by natural gas by 2023 and could provide reliable power generation during cold winter nights, if wind is absent for extended periods. Coal to gas units can operate with low capacity factors, but be called upon infrequently to offer reliable backup to wind and solar power. This availability of coal to gas generation could assist during the time period while renewable energy storage is being deployed.

	Questions	Stakeholder Comments
		Risks of stranded assets apply to any new large generating units fueled with natural gas which should be considered a barrier to their deployment.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Jenny Wang
Comments from:	ATCO Electric Ltd. (ATCO)	Phone:	(780) 292-2970
Date:	2022/01/31	Email:	Jenny.wang@atco.com

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

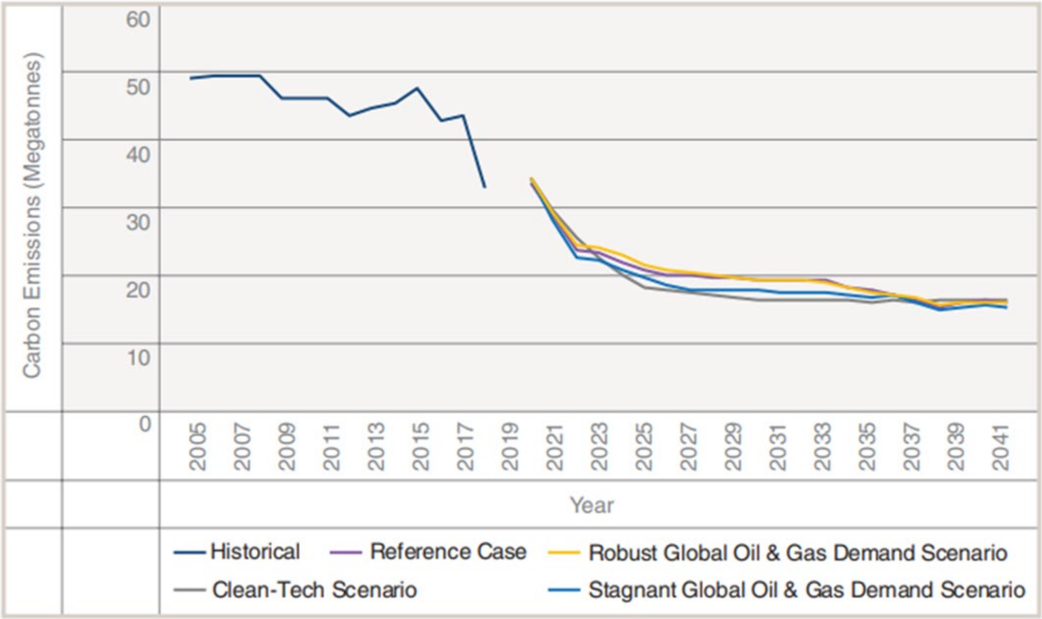
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	Energy systems are undergoing transition both globally and in Alberta. ATCO supports AESO's initiate on investigating how Net-zero pathways will shape in Alberta and the associated impact on the transmission system, upgrades required and future planning scenarios. Given the many uncertainties involved in how Net-Zero emissions will be achieved, ATCO suggests that in addition to seeking stakeholder opinions, a market analysis should be undertaken to provide more insight on the various paths that incorporates jurisdictional reviews as well as the Alberta specific detail. ATCO also suggests that AESO clearly state the following: - The scope of this initiative, and what components of the scope fall under AESO's legislated mandate. - How AESO will utilize the outcome of this initiative to fulfill its legislative mandate.

	Questions	Stakeholder Comments
	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?	ATCO views the largest challenges would come from the uncertainty around pace, changing technology and drivers (e.g., government policy) to get to net-zero.
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?	No specific comment for Question 2 a) to 2 c). A detailed market analysis should provide more insight.
	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**	Refer to above comments on 2 a).

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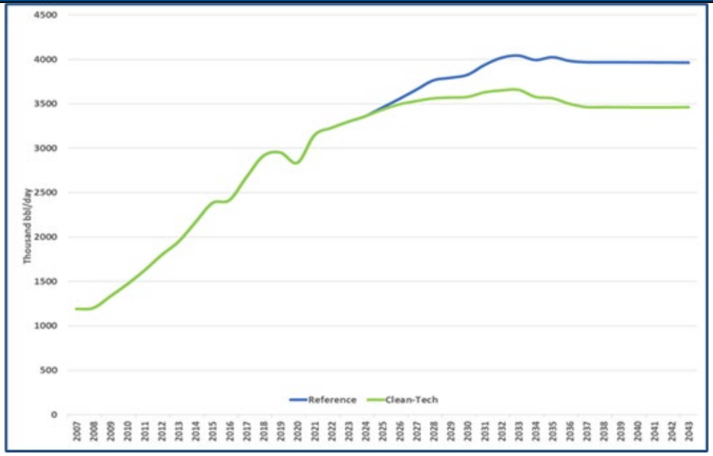
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	Refer to above comments on 2 a).
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	No specific comment for Question 3 a) to 3 d). This question is best addressed by policy making and will be driven by the drivers to change (e.g., government policy).

	Questions	Stakeholder Comments
	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?	Refer to above comments on 3 a).
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Refer to above comments on 3 a).
	d) Are there any other related considerations that you would like to provide feedback on?	Refer to above comments on 3 a).
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?	As seen in other jurisdictions energy efficiency programs has been playing a role for decades. ATCO does not see this being any different in Alberta. Over the past decade there has been continued growth in customer adoption of digital and other emerging technologies. Customer and societal expectations have changed and continue to evolve with corresponding changes in energy usage behaviours. The penetration and pace of energy efficiency will depend on the pace of adoption by various decision-making agencies and the development of effective efficiency programing.
	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.)?	In recent years, ATCO has seen increase in number and size of DER projects in its system. This trend is expected to continue and DERs are expected to increase due to improved affordability resulting from technology advancement and better prices (e.g., solar panels).
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	EV penetration is expected to increase driven by government policy and automaker commitments to eliminating combustible engines in the near future, some as early as 2025. This will have an impact on peak demand, for example when customers follow the same behavior patterns and charge at the same time (e.g., once arriving at home).
	d) Buildings	In ATCO's view, the mix and consumption between electricity, fossil fuels and natural gas will change overtime (e.g., EV's for commuting vehicles

	Questions	Stakeholder Comments
	• What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	and DER's). It is ATCO's view that emerging technologies such as RNG and Hydrogen will play a part in achieving Net Zero. In particular given the amount of consumption required (especially at peak) to heat buildings and the cost to get the electrical system upgraded to address that load.
	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)?	ATCO has not seen any major impact on its customers yet.
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?	ATCO is of the view that net-zero will involve mixed generation technologies and encourage advancement of technology to make decarbonization more economic.
	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 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	No specific comment on detailed generation technology. ATCO believes that transmission interconnections with other renewable-rich jurisdictions (in addition to the existing ones) is critical in strengthening the Alberta grid, enabling more renewables, and supporting the path to net-zero. More investigation should be undertaken.

	Questions	Stakeholder Comments
	(vi) Nuclear generation (vii) Energy Storage (viii) Transmission interconnections with other jurisdictions (ix) Offsets or Emissions Performance Credits	
	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?	Refer to above comments on Question 5b).
	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.	As stated in above comments on Question 5b), transmission interconnections with other renewable-rich jurisdictions provides critical benefits to the Alberta grid. Other conventional technologies such as hydro generation and nuclear generation are not expected to impose additional operational risks. Given the uncertainty of the various potential net-zero paths, it's important to ensure that the transmission system is adequately planned to accommodate the potential changes resulting from net-zero.
	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?	ATCO is of the view that whether cogeneration facilities should have net-zero emissions depends largely on policy requirements.

	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
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Hydrogen-Fired Combined Cycle	450	1,667	52.84	2.65	6.79

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[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 comment as ATCO is not an expert on generation costs.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	No comment as ATCO is not an expert on generation costs.
	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).	No comment as ATCO is not an expert on generation costs.
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	No further comments.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Michael M. Wenig
Comments from:	Big Spruce Law	Phone:	403-879-1006
Date:	2022/01/31	Email:	mike@bigsprucelaw.ca

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.**
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Introduction

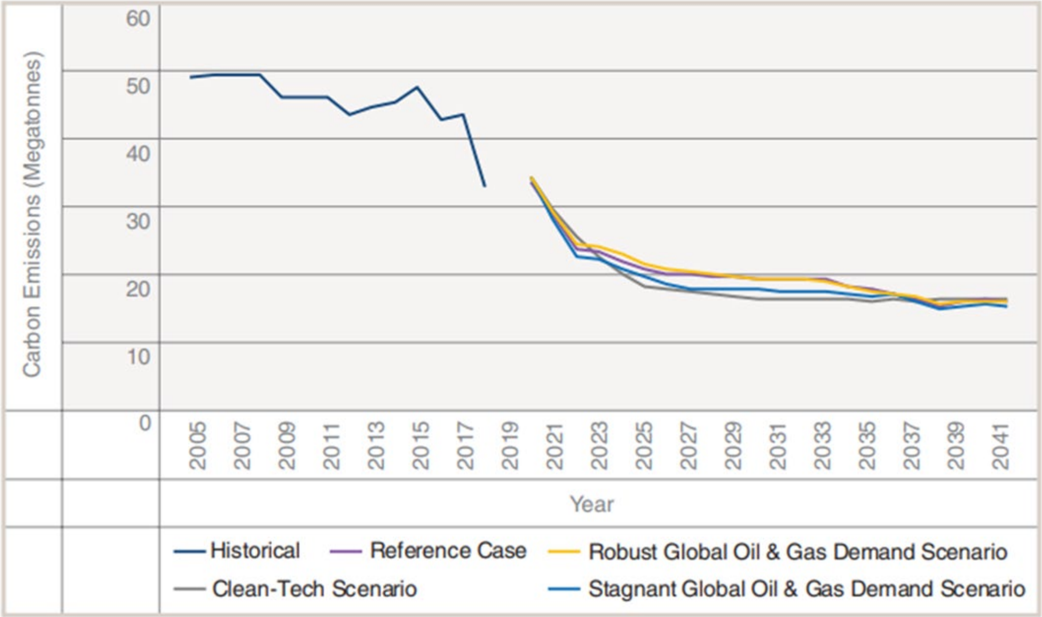
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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.

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td rowspan="3"><i>1</i></td><td colspan="2"><i>Net-Zero Analysis Scope</i>
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.</td></tr>
<tr><td>a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td></td></tr>
<tr><td>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?</td><td>Please see comments in part 7 below.</td></tr>
<tr><td><i>2</i></td><td><i>Macroeconomic Context</i>
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]</td><td></td></tr>
</table>

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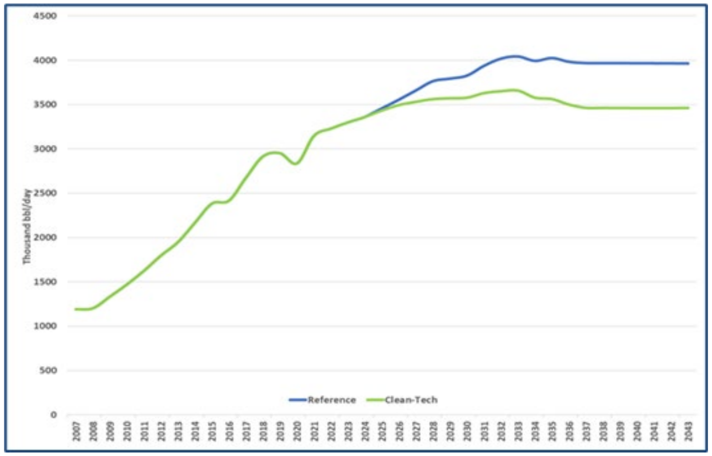
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

Questions	Stakeholder Comments
a) What is your view on the economic impact of expected net-zero targets on this business-as-usual scenario?	
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	

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

	Questions	Stakeholder Comments
	scenario for analyzing the impact of net-zero policies on the oilsands sector and the subsequent impact on load growth?	
	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?	
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	
	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?	
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	

	Questions	Stakeholder Comments
	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.)?	
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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)?	
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?	

	Questions	Stakeholder Comments
	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 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	
	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?	
	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.	
	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?	

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

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[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?	
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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.	It's unclear, from the AESO's Net Zero letter and on-line materials, what regulatory and grid management-related roles the AESO sees *itself* as playing in promoting or enabling a net zero pathway. It would be helpful if the AESO considers and discusses these potential roles with stakeholders and the public generally. Along these lines, it would be useful for the AESO to address—and inform the public of—what policy and legal tools the AESO has to promote net zero pathways and what discretion the AESO has under Alberta legislation to ensure that market rules and operating procedures will enable the electricity market to achieve a net zero pathway. This legal analysis should include the AUC's legal and policy tools in connection with its oversight of the AESO's decision-making functions.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	RMcMann
Comments from:	BluEarth Renewables	Phone:	
Date:	2022/01/28	Email:	

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

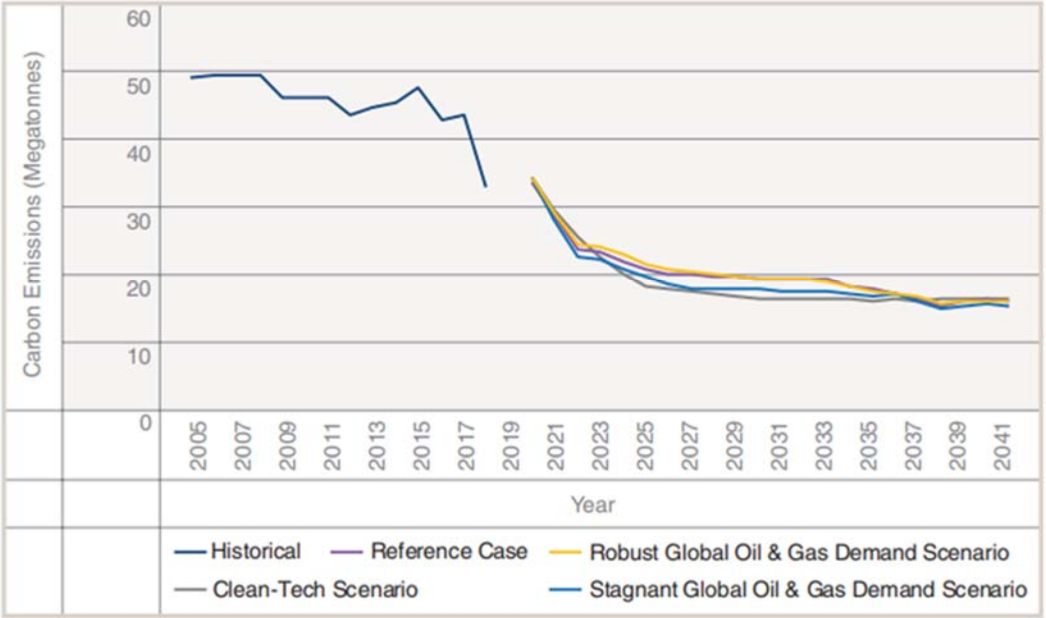
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	We commend the AESO on the decision to produce the first Net-Zero Emissions Electricity Pathways report. Many agencies over the past year, including the IEA, have agreed that the electricity sector must be at the forefront of any decarbonization strategy, and we are very supportive of AESO taking this first step. Regarding the scenarios, it would be beneficial to see multiple scenarios of renewables paired with storage. For example, in addition to 100%, look at 50%, 75%, 90% by 2035 scenarios. This can help inform what level of direct reductions vs. offsets would be appropriate to meet goals.
	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?	The biggest challenge would be navigating the transition to net zero (on both the supply and demand side) without clear decarbonization policy and forward carbon pricing that will allow both generators and consumers to plan for and participate in working towards a net zero grid by 2035. Alberta's large industrial load, including the current fleet of over 30 cogeneration facilities, representing 5GW of capacity and their specific role in oilsands industrial facilities should be carefully considered.

	Questions	Stakeholder Comments
		However, we should also note that when a target is set, such as the coal phase out, our sector has shown ability to exceed it; with coal phasing out 40 years ahead of 2015 schedule, now expected by 2023.
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?	Early, clear policy signals on the future of the TIER program and net zero targets will allow companies to make long term decisions aligned with Provincial goals.
	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**	This approach may require further discussion in consideration of the details of future net zero policy for the electricity sector and should be viewed from the aspect of how a net zero electricity sector could support further oilsands investment.

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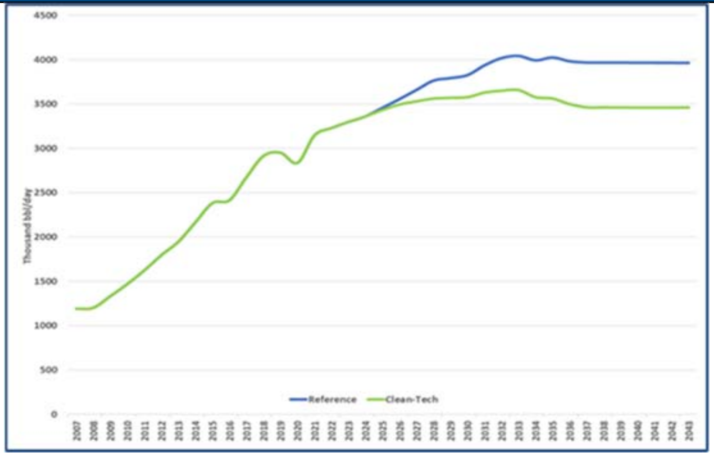
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	
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	We are not aware of the Government of Alberta setting a net zero target yet, however we are strongly supportive of this guiding policy. We also note that net zero targets for both 2030 and 2050 are common in other jurisdictions: 130 countries have net zero goals, 9/13 provinces/territories have net zero goals for 2030 (ref; Pembina report). Alberta is one of the provinces that does not have 2030 or 2050 goals, despite many of our major O&G players having them (covering 95% of the oil produced in the province through the oilsands pathway to net zero), and our major cities recognizing a need for action ie; City of Calgary has declared a climate emergency and City of Edmonton actively procuring renewables.

Questions	Stakeholder Comments
	Once Alberta sets net zero goals, we are confident that the decarbonization of the electricity sector will be one of the main pillars to meeting the broader provincial (and federal) goals, due to the opportunity for cost effective emissions reductions. In this case, we see offsets and credits within the electricity sector continuing to play a big role in driving reduction in the near term. In the longer term, offsets/credits will need to increasingly be replaced with physical emissions reductions. We also see net zero goals driving more economy wide electrification, making it imperative that the electricity sector is ahead of the curve on decarbonization.
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?	Prior to 2030 – we expect Provincial pricing to be in line with Federal pricing as all Federal parties in the recent election campaigned with a price on carbon and shared consensus that GHGs must decrease rapidly toward net zero in 2050, with interim targets. We see investors and industry already mobilizing capital with this view. Beyond 2030 we expect pricing to increase in line with global commitments on broader greenhouse gas reductions, driven by country/sector targets and corporate demand. In Canada specifically, the *Canadian Net-Zero Emissions Accountability Act* enshrines in legislation the Government of Canada's commitment to achieve net-zero greenhouse gas emissions by 2050 and set five-year targets to achieve it.
c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	• Global trends, for example: o Corporate commitments to net zero or 100% renewable as seen in both Canada (BRC deal growth) and the US (CEBA: a community of nearly 300 energy customers and partners committed to achieving a 90% carbon-free U.S. electricity system by 2030.) o Major shifts with investors toward ESG prioritization – for example, as captured by BlackRock's Larry Fink in his 2021 letter to CEOs "*We know that climate risk is*

	Questions	Stakeholder Comments
		investment risk. But we also believe the climate transition presents a historic investment opportunity.” o Demand – oil sands net zero commitments such as Oil Sands Pathways to Net Zero - Helping Canada achieve its climate goals • US Electricity sector policy such as the 100% Carbon Free Electricity by 2035 Biden Executive order. • Canadian Federal policy such the anticipated consultation on the Clean Electricity Standard and cap on oilsands emissions.
	d) Are there any other related considerations that you would like to provide feedback on?	As both the supply and demand sides of the electricity sector evolve, we need to look at how to move to thinking of the system more holistically – for example: • Effective location signals for distributed generation • Use of Non-wires alternatives in a competitive market • Evolving consumer behavior/participation resulting in two ways flows on the system such as with micro generation and EVs. In addition, as Alberta seeks to decarbonize the electricity sector, emerging global supply tightening in the renewable sector should be considered as early clarity will help to continue to attract investment to the Province over the long term.
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?	
	b) Distributed Energy Resources (DER)	With the cancelation of the DG credits there is no mechanism incenting appropriate siting of DG/optimization of siting generation closer to load. In

Questions	Stakeholder Comments
• 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.)?	order to achieve the fundamental goal of Alberta's Transmission Regulation "ensuring that consumers are served with reliable, reasonably price electricity, and to support continued economic growth in Alberta," the definition of "system" needs to evolve to include all wires and associated infrastructure in order to allow planning to be optimized. For example: storage and distributed generation are part of the "system" when considering alterative to wires. DERs, especially renewable DG should be encouraged to efficiently use the existing grid and reduce new transmission build and any net zero modeling should include looking at how DG can help reduce future cost for rate payers. In absence of accounting for how DG can reduce future transmission build out, the net zero scenarios will result than higher than necessary transmission built out.
c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
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	

	Questions	Stakeholder Comments
	(e.g., cryptocurrency mining, data centers, petrochemical facilities, cement, steel, others)?	
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?	Wind and solar are and will continue to be the most economic non-emitting resource in Alberta. We expect that with removal of current barriers to storage development in the province, coupling storage with renewables will provide the lowest-cost clean portfolio. The continued low-cost expectations for renewables and storage are presented in several external reports from BNEF, IEA and Lazard.
	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 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	Renewables and storage are proven low-cost technologies ready for deployment, as is the offset/EPC market that has been in place in the province since 2008. Although transmission with other jurisdictions could help transition to net zero, impact to Alberta's energy only market and realistic implementation timelines should be considered. In the case of large hydro and CCUS, we note that recent large scale projects of each of these types of facilities have resulted in large cost overruns (ie: Site C, Muskrat Falls and Boundary Dam CCS).
	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?	Further to the note above in 4b, Distributed generation should be considered as a pathway to meaningful reductions in GHGs and a way to reduce future large wires build out. Similarly, storage at both utility and distribution can provide both system flexibility and a non-wires alternative.

	Questions	Stakeholder Comments
	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.	It is important to remove barriers to storage development in the near term to unlock flexibility and grid efficiency benefits.
	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?	

	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
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[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?	We expect the cost of renewables and storage to continue to decrease over the forecast period, with some near-term price pressure due to supply chain tightening. Reference: Lazard V.15, BNEF forecasts.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	We would be interested in an AESO analysis that would identify any geographic limitations to siting CCUS or hydrogen projects ie; access to pipeline infrastructure or sequestration location capability.
	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).	The continued low-cost expectations for renewables and storage are presented in several external reports from BNEF, IEA and Lazard.
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	We commend the AESO for taking this important first step in the discussion of how the electricity sector can contribute to decarbonization. • As AESO continues to develop scenarios for this report, we request a continuous dialogue with stakeholders, similar to the 2021 LTO. It is requested that, prior to any modelling of the scenarios being proposed for this report, the AESO share details for comment, preferable through both a webinar presentation (including Q&A) and via written comments. • Consideration of generation and transmission cost (including any new pipeline infrastructure) will be important to consider in future iterations of this report. • Repowering: the ability to site renewable generation/storage on old gas should also be considered ie; Florida Power and Light's 409 MW Manatee Energy Storage Center is complete – pv magazine USA (pv-magazine-usa.com)

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

– Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Calvin Ng
Comments from:	Business Renewable Center Canada	Phone:	587-327-2662
Date:	[2022/01/28]	Email:	calvinn@businessrenewables.ca

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.**
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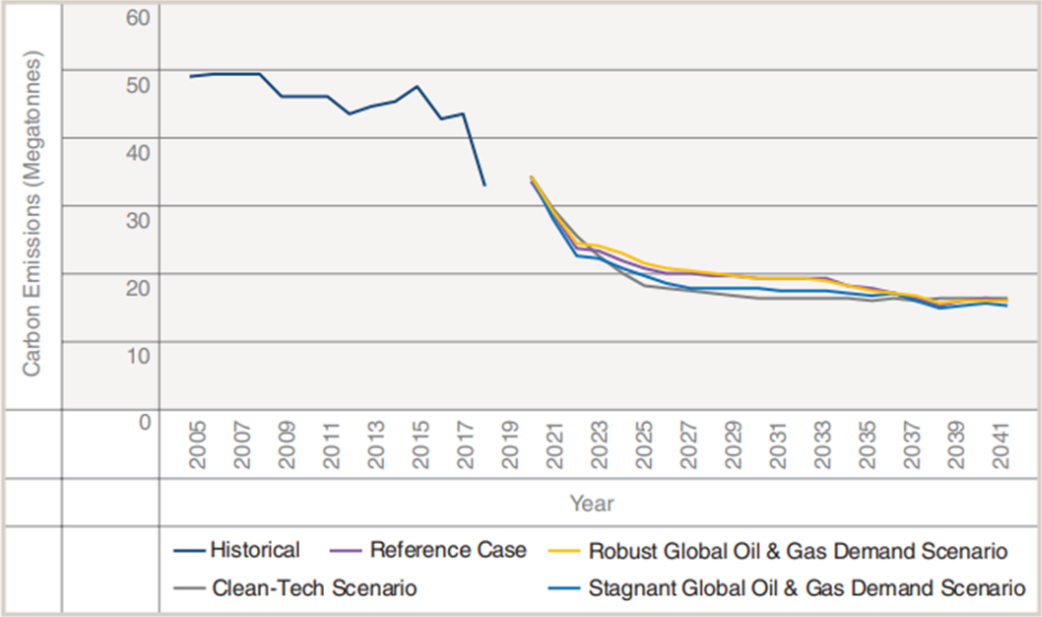
In 2022, the AESO will examine potential pathways to achieve a net-zero greenhouse gas emissions electricity sector in Alberta and the market, operational and cost implications of these pathways. The AESO intends to review and understand the most prominent zero and low-carbon emissions technologies, 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.

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?	BRC-Canada applauds the AESO's initiative to improve upon the 2021 LTO's Clean-Tech Scenario. It is also BRC-Canada's hope that this analysis will help to improve forecasting for the LTO's Reference Case Scenario. Forecasting efforts will benefit substantially by updating the shared understanding across stakeholders and the AESO about the economics of renewable energy, innovations that help to integrate higher penetrations of renewable energy, and the strong market pull for renewable generation. Accurate forecasting is important for decisions around the system, market and policy designs necessarily to best and most efficiently serve the electricity system to come. Prior LTOs have demonstrated some degree of inertia in forecasting, which has assumed that the mix of future generation additions would resemble prior additions. Renewable energy technology cost reductions combined with growing market demand for renewable energy has seen solar and wind development vastly outpace the forecasts in both the 2019 and 2021 LTOs, due to the result of many successfully contracted virtual power purchase agreements in the province. Both of these trends (cost reductions and market demand) were observable in other jurisdictions at

	Questions	Stakeholder Comments
		the time of the LTOs and were quickly adopted in Alberta, as BRC-Canada and its founding members anticipated in the lead up to the initiative's launch in 2020 and even back to the release of the Plugging In report in March 2018. BRC-Canada believes that renewable energy buyers and developers (many of whom are BRC-Canada members) have important insights on the renewables procurement market that can help to guide Alberta's forecasting and the corollary design decisions that flow out it. Currently, BRC-Canada comprises of 54 members, with 25 unique buyer members from industries ranging from oil and gas, telecommunications, food and beverage corporations, financial and banking institutions, and many more. There is every reason to believe that renewable energy will grow much faster than anticipated in the 2021 LTO even in the absence of any policy implementation of the net-zero 2035 targets referenced in the Introduction – indeed, it has already. Having said this, as far as we are aware, there is no stakeholder seeking a 100% renewable energy and storage outcome in 2035. While a growing number of large corporate consumers are committing to 100% renewable energy or net-zero emissions (including Scope 2) targets, these commercial and industrial buyers have demonstrated their ability to procure their renewable energy in Alberta through private markets. As such, we are not sure that there is value in assessing this scenario. There is a big gap between existing LTO scenarios (particularly the reference case) and a 100% renewable energy 2035 and there are more reasonable and likely scenarios to assess between those extreme ranges.
	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?	
	Macroeconomic Context	

	Questions	Stakeholder Comments
2	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?	
	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**	

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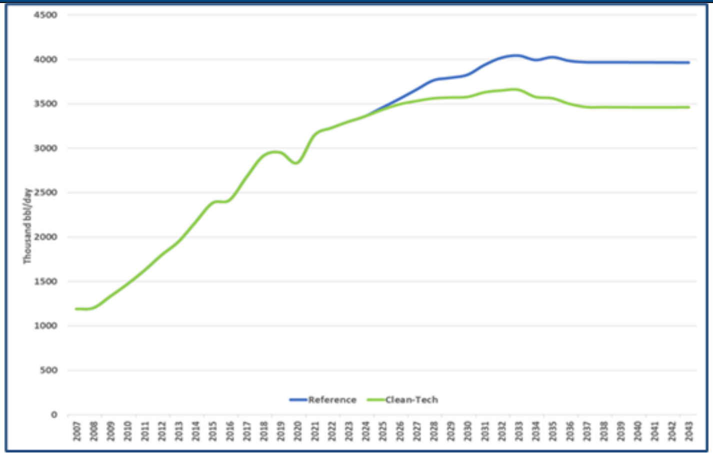
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	
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	

	Questions	Stakeholder Comments
	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?	
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	There is strong potential for the federal government to enable very high deployment of the most cost-effective non-emitting technologies by supporting renewable energy supportive investments like storage technology development and deployment and capital supports for transmission development. These potential public investments should be considered in the analysis of the supply mix and cost impacts of net-zero scenarios.
	d) Are there any other related considerations that you would like to provide feedback on?	There is some risk of policies being introduced that would resist further development of lowest-cost non-emitting generation in order to preserve existing system or market designs. This could include changes in open-access transmission policy, allocation of cost of transmission, or other market reforms to dissuade renewable energy development. Any such measures will only delay progress toward net-zero grids and aggravate the challenges and costs of the system and policy reforms necessary to embrace this inevitable transition.
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?	
	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.)?	

	Questions	Stakeholder Comments
	c) Transportation Sector - What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
	d) Buildings - What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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)?	Large corporate electricity consumers are increasingly interested in sourcing non-emitting electricity. There are examples where major commercial and industrial operations have sited new facilities and operations on the basis of the jurisdiction's amenability to renewable energy procurement. In fact, in some U.S. and Canadian jurisdictions with vertically integrated utilities, this has factored into the states' and utilities' decisions to enable commercial and industrial (C&I) procurement through sleeve deals and green tariff programs. Indeed, the nation-leading availability of C&I deals in Alberta was cited by Amazon as a key reason for choosing Alberta to host a new facility for Amazon Web Services. These are strong indicators that very low-to-non-emitting grids will attract stronger investment and economic growth from corporations facing increasing pressure to reach their own net-zero targets.
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?	We are in the midst of the market expressing its preferred choice of non-emitting generation: wind and solar energy. To-date, corporations and institutions have announced 1,703 MW of renewable energy deals, almost all of which have been announced since the start of 2019. Almost three-quarters were announced in the last year alone. With growing willingness from developers to take a merchant position for a portion of the project capacity, these deals are backing 2,277 MW of new wind and solar development in Alberta by 2023, blowing past the province's three REP

	Questions	Stakeholder Comments
		rounds and outstripping previous LTO reference cases, particularly for solar. Around half of the market demand announced to-date is voluntary, for ESG targets, purchased by operators in sectors that have no TIER compliance obligation. This strong market preference for non-emitting generation and, in particular, for wind and solar, reveals the competitive economics of these technologies, along with their other appealing attributes: strong developer familiarity, social licence, low development risk, no fuel price risk, etc.
	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 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	
	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?	

	Questions	Stakeholder Comments
	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.	
	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?	

	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

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[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?	
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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.	As a group, corporations that are active in procuring renewable energy are among the organizations that have put the most thought, analysis, and planning into net-zero approaches. BRC-Canada is available to facilitate further gathering of information and perspectives from these buyers to inform Alberta's net-zero analysis and planning.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Robert Tremblay Dr. Joe Vipond
Comments from:	Calgary Climate Hub	Phone:	1-403-903-6234 1-403-510-9236
Date:	2022/01/31	Email:	rob.tremblay@hotmail.ca jvipondmd@gmail.com

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

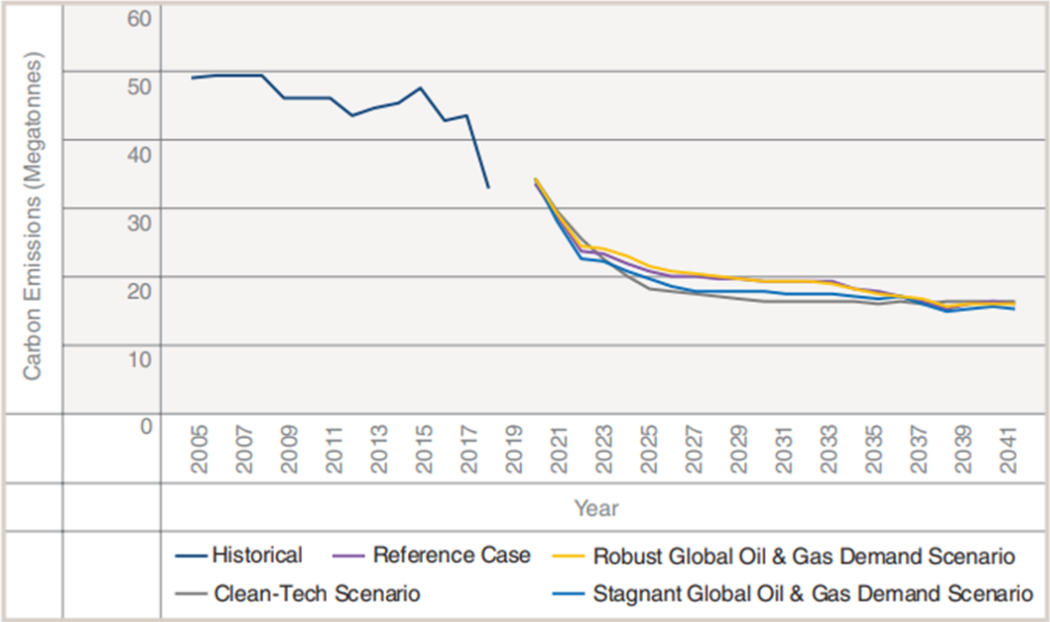
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	Within both scenarios, it is critical that the context of the Albertan electricity market connection of external markets and RTO's be explicitly stated. Examples of context are: - The Federal Minister of Natural Resources has been mandated with establishing a "Pan Canadian Grid Council" with the objective of, in part, connecting clean power grids (such as BC or MB) with high carbon grids (such as AB or SK).

- the impact of varying degrees and pace of climate policies, such as carbon pricing, the clean electricity standard, ZEV mandate, and new net-zero building codes. These policies all have stated paces now, but what would the impact be if the pace is sped up
- Declining oil demand and investment will likely coincide with increasing global vehicle electrification. The AESO should not assume that oil investment will grow at the same time as electric vehicles are more aggressively deployed

In previous reports such as the 2019 and 2021 Long Term Outlooks (LTO), the AESO has up to date data and policy implications which, in our opinion, have led to an underestimation in the development of clean electricity and an overstating of Alberta's future reliance on natural gas.

As an example, in 2019, the AESO made long term projections of solar installed capacity of ~400MW by ~2040 when much more than 400 MW was already under development, such as the Travers Solar project (400MW on its own) and numerous other medium and smaller installations. As of 2022, Alberta has an installed capacity of 736MW of solar, nearly double the projected capacity nearly two decades ahead when projected in 2019. There are now ~10GW in the AESO cue.

Additionally in 2021 the LTO's most aggressive climate policy scenario only considered a $50/tonne carbon price, even though a $170/tonne carbon price had already been announced. Obviously, this price is not guaranteed, but in our opinion the AESO is not providing valid bookend cases to the extent of climate policy which may develop and is presenting conservatively moderated climate policy as the bookend case for possible climate policy scenarios.

In the past, the AESO has underestimated the movement in climate policy relating to the Alberta grid. In leaving out details like these in the AESO has left Albertan policy makers and investors flat footed without adequate

		projections on the future of the Alberta Grid. This is likely lead to significant amounts of **stranded assets,** creating constituency that will oppose climate action due to their embedded economic interest.
	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?	Going forward, we view the largest challenges to the Alberta Grid as being: - market and regulatory difficulties in connecting the Alberta electricity market/grid to neighboring grids - the entrenched cultural and lobbying power of natural gas and gas generation facility corporations influencing climate and grid policy to protect their interests (via relatively unproven solutions like Carbon Capture and Sequestration or Blue Hydrogen) at the expense of the climate and the ratepayer - fugitive methane emissions remain a significant uncertainty in how natural gas plants compare to coal plants on GHG performance. Some research suggests that natural gas may indeed be more GHG intensive than coal if Alberta's gas grid more leaky than reported, which is likely - Industry groups, such as the Independent Power Producers Society of Alberta, may oppose lowest cost options, such as new interties and market integration with BC, out of their own economic interest. The AESO must act in the interest of Alberta ratepayers to consider a balance between the lowest cost options to get to net-zero, the fastest path to net-zero and avoid allowing the business interests of Alberta electricity generation asset owners, especially gas peaker owners
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?	- in general, we understand that economic growth in developed economies has been decoupled from electricity load growth for the past few decades, largely due to digitization and energy efficiency - In our opinion, we see economic growth being only loosely linked to load growth and not the dominant factor to consider when modeling Alberta's net-zero grid

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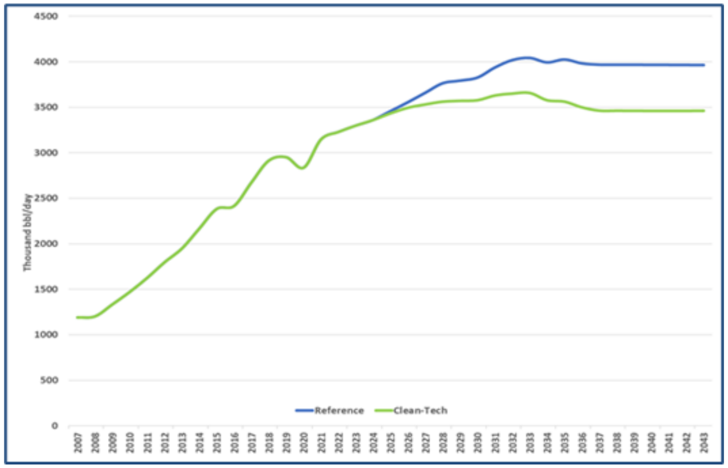
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

<table>
<tr><td></td><td>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?</td><td>As stated in 1a, it is critical that the there be a variety of "Clean-Tech" like scenarios including a bookend scenario with *climate policy more aggressive than currently mandated by the federal government*. It is very unlikely that 2022 will be the peak for aggression/ambition for climate policy and it is critical that the AESO not portray existing policy commitments as the most stringent possible climate policy scenario.

Just as climate policy may revert to the mean with ambition below the currently mandated goal, climate policy may increase in ambition and the AESO needs to provide Albertans and policy makers with quality information on what needs to be done to accommodate more ambitious climate action.</td></tr>
<tr><td></td><td>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</td><td>- We will capitulate to energy economists on the precise answer here. In general we understand that there may be a supply shortage of gas in the short to medium term as investment in</td></tr>
</table>

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

	rates? What do you see as key drivers of gas prices going forward?	natural gas extraction decreases while investment in renewables and clean electricity increases - We view natural gas a risk to Albertan's cost of living due to uncertainties around the pace of increases to carbon pricing and uncertainties an the future commodity price of the natural gas itself - If methane emissions are prices in at the consumer level similar to carbon pricing, for example, this may represent a *significant* cost to Alberta ratepayers
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	- In general, the only kind of offset we support are hard offsets that proveably result in either gaseous carbon dioxide or solid carbon (such as biochar or carbon black) permanently returning into the lithosphere - An exception is we do not consider captured carbon used in enhanced oil recovery validly offset carbon emissions
	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?	- We expect (and will work to realize) a higher than $170 carbon price as the constituency which the carbon price most effects (private and commercial vehicle owners and homeowners) electrify their transportation and heating assets, removing the carbon price's effect on them - It is critical the AESO investigate a range of carbon prices, both higher than and lower than $170
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	- The Federal Minister of Natural Resources has been mandated with establishing a "Pan Canadian Grid Council" with the objective of, in part, connecting clean power grids (such as BC or MB) with high carbon grids (such as AB or SK). - The Federal Ministers of Natural Resources and Environment and climate change have been tasked with implementing a "net zero by 2035" Clean Electricity Standar, likely amending the carbon intensity provision in the Canadian Environmental

		Protection Act (CEPA) to be “0t/MWh by 2035” from the current “400t/GWh by 2030” - The Federal Minister of Environment and Climate Change has been mandated with establishing a ZEV mandate of “50% of new light duty vehicles be ZEVs by 2030, and 100% by 2035” as well as “100% of medium and heavy duty vehicle sales be ZEVs by 2040” - New net-zero building codes will likely significantly affect the electrification of building heating - As mentioned above, the pace of all of the above must be considered at more aggressive paces to present a true bookend case
	d) Are there any other related considerations that you would like to provide feedback on?	- Declining oil demand and investment will likely coincide with increasing global vehicle electrification. The AESO should not assume that oil investment will grow at the same time as electric vehicles are more aggressively deployed
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?	- energy efficiency is poorly implemented in Alberta - updates to the National Model Building code and the upcoming Net Zero Building code will serve drive energy efficiency deployment in new builds - PACE style programs such as the Clean Energy Improvement Program (CEIP) in Calgary and Edmonton will also help deploy energy efficiency
	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.)?	- the push for net-zero and and economics of solar will likely result in an increased amount of DER deployment, especially rooftop solar - however in our understanding the upper limit of DERs in Alberta is not sufficient to provide for Alberta’s load and we recognize than many utility scale sources of clean electricity will need to be deployed, especially wind and solar.
	c) Transportation Sector	- we believe that the pace of electrification will outpace both projections and federal targets

	● What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	- costs are declining for EVs and significant deployment of EVs in Europe and China are likely to accelerate cost declines for EVs further
	d) Buildings ● What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	- to be on track for economy-wide net-zero by 2050, we essentially need to stop installing fossil fuel powered building heating now. Our position will be to advocate for the
	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)?	- on CCS, we emphasize that upstream methane emissions on any natural gas feedstock into the power plant, blue hydrogen steam methane reformer etc must be taken into account when considering the net-zero compatibility of a facility with CCS. CCS may be an important tool for net-zero but only if implemented with a holistic view of GHG emissions including methane emissions - we see green hydrogen in power-to-gas schemes being a potential candidate for true long term, long duration storage. This will however add significant need for capacity as the round trip efficiency of power-gas-gas is only ~50% - on electrified industries, such as crypto and data centers, we see an economic opportunity for low cost renewables in Alberta to attract industry looking for low cost electricity, especially if the electrified industry can take advantage of low cost in times of high renewable productivity - for emission intensive industries, such as steel or petrochemicals, low cost renewables may provide a low cost green hydrogen feed stock, *however* we again emphasize the methane emissions being taken into the GHG footprint of industry when considering net-zero
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?	-we perceive solar and wind being the main contenders when paired with increased interconnection and trade with hydro provinces, cheap short term battery storage and emerging long term storage schemes such as power-to-gas via green hydrogen

	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 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	- on CCS, we emphasize that upstream methane emissions on any natural gas feedstock into the power plant, blue hydrogen steam methane reformer etc must be taken into account when considering the net-zero compatibility of a facility with CCS. CCS may be an important tool for net-zero but only if implemented with a holistic view of GHG emissions including methane emissions. CCS may have strengths in industry support leading to faster deployment. We perceive CCS as being completely reliant on government subsidies and presenting a high risk due to a lack of evidence for CCS being deployed at energy transition scales. - in our understanding CCS with oxyfueld generation will also rely on government subsidies and not be a lowest cost option in a net-zero grid - we perceive wind and solar being the top contenders for the main sources of generation in a net-zero grid. Obviously generation is only part of the story and we will also need storage, backup and/or a more integrated grid/market to source energy from to accommodate wind and solar's variable nature. The significant subsidy free private investment in wind and solar in southern Alberta should give the AESO confidence that it needs to prepare for a reliable grid eventually dominated by wind and solar - we are supportive of geothermal but understand that it is not in the same cost tier as wind and solar. Geothermal may be well supported by deployment support programs, like wind was with the Renewable Electricity Program - we understand that biomass is technically near net-zero due to the combustion of biomass, but we are generally skeptical of the ability of biomass to scale without increased deforestation in Alberta. Biomass is an appropriate place for CCS deployment where a BECCS scheme can be carbon negative - traditional large scale hydro is likely both too costly and too politically fraught to be a significant net-zero technology. Building new pumped storage facilities or retrofitting existing facilities to be pumped storage assets may solve a significant amount of the "storage problem"

		- we don't see nuclear advancing quickly or cheaply enough to be a serious contributor to a net-zero grid in Alberta - Energy Storage is obviously critical to a net-zero grid and should be looked at in separate classes of short duration, medium duration and long term long duration. These categories are still evolving - we view increased transmission interconnectivity with hydro assets, particularly in BC, as a no brainer in a net-zero grid. We encourage the AESO to work with the federal government to find the best funding and market mechanisms to facilitate more clean electricity trade with Alberta's neighbors. In the long term, Alberta may be able to export renewable electricity to external markets as opposed to its current importer status - we are generally opposed to the use of offsets to achieve net zero. A net zero grid should be as close to zero emissions are possible
	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?	- Demand management has yet to be mentioned and shifting load, such as water heating or space heating (especially as these become electrified) can play a critical role in decarbonizing the grid and accommodating more variable generation profiles. The AESO needs to work with stakeholders in these areas (such as smart thermostat companies) to make sure they are able to properly participate in Alberta's electricity market
	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.	- nuclear generation can present operational risk during unplanned outages due to the typically large size of the nuclear plant
	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?	- yes, alternative fuel sources (such as nuclear for heat, green hydrogen, or biogas) may be needed. CCS may end up being implemented but again, upstream methane emissions must be considered - In general the market should allow the generation owners determine their best path to net-zero and avoid subsisdies

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

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?	- we will defer to energy economists for criticism on the numbers - please state in assumed LCOE for ease of comparison with mainstream sources such as Lazard

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

		- we expect solar and wind to continue to decline and battery and electrolyzer technologies to significantly decline
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	- high, subsidized and like to go over budget due to novel, relatively new (at scale) technology and nature of large projects
	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).	- we will defer to energy economists here
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	- it is critical work with groups like the federal Net Zero Advisory Body and relevant federal ministries - upstream methane emissions must be considered - the effects of more stringent than currently announced climate policy must be considered

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	C. Hughes
Comments from:	Campus Energy	Phone:	587-323-3750
Date:	2022/01/31]	Email:	Cameron.hughes@campusenergy.ca

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

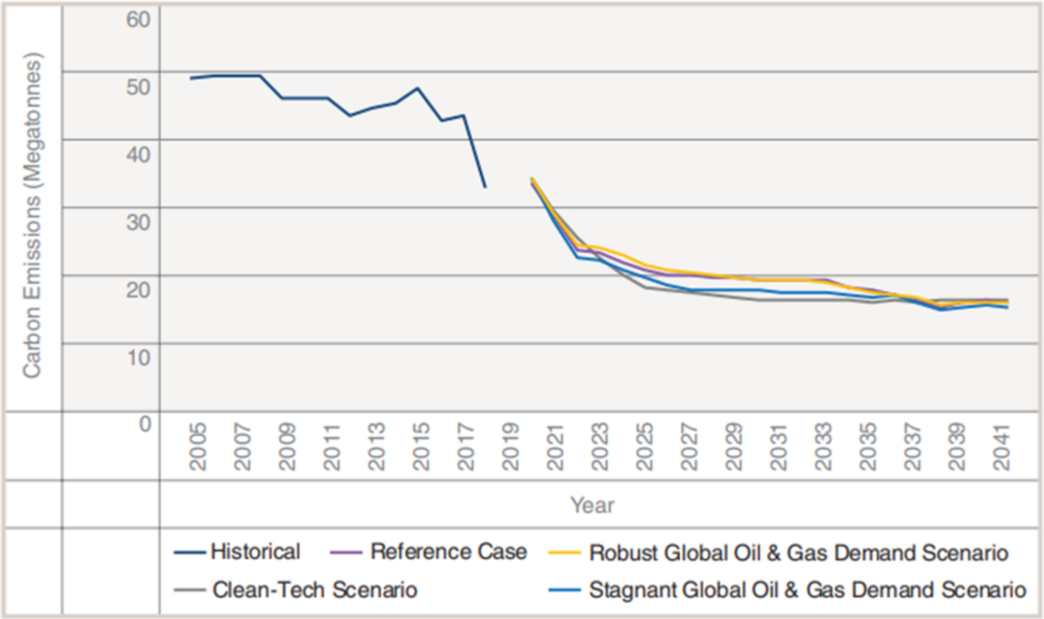
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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.

<table>
<tr><th></th><th colspan="2">Questions</th><th>Stakeholder Comments</th></tr>
<tr><td><i>1</i></td><td colspan="3"><i>Net-Zero Analysis Scope</i>
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.</td></tr>
<tr><td></td><td colspan="2">a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td>▪ Campus Energy has reviewed and supports the IPPSA submission.</td></tr>
<tr><td></td><td colspan="2">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?</td><td>Campus Energy has reviewed and supports IPPSA’s first four points, Campus adds two other challenges in this area for consideration:
1) Affordability
• Affordability of Net 0 by 2035 is a concern. Net 0 Trends will exacerbate the problem of wires costs. High voltage AC and DC wires are costly. Albertans could be better served by low voltage DER investment which is a significant trend in other markets.
2) Reliability
• Reliability is a legitimate concern if Net 0 by 2035 is the goal, but dispatchable DER investments, given their scale</td></tr>
</table>

	Questions	Stakeholder Comments
		and dispersed nature, could contribute to greater reliability than single large contingencies.
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?	Campus Energy has reviewed and supports the IPPSA submission.
	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**	Campus Energy has reviewed and supports the IPPSA submission.

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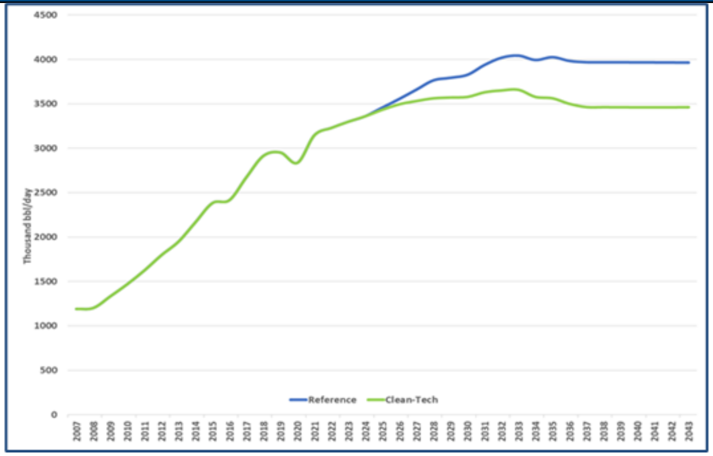
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	Campus Energy has reviewed and supports the IPPSA submission.
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	Campus Energy has reviewed and supports the IPPSA submission.

	Questions	Stakeholder Comments
	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?	Campus Energy has reviewed and supports the IPPSA submission.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Campus Energy has reviewed and supports the IPPSA submission.
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	
	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.)?	▪ The AESO's advocacy against DER in the AUC's DCG proceeding provides a chill to DER investment and could cloud any DER trends the AESO anticipates with net-zero. Failures to recognize savings and benefits of DER will mean that the trend of investment in expensive, long-distance high voltage transmission and high cost of delivered electricity will persist instead.
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	Campus Energy has reviewed and supports the IPPSA submission.
	d) Buildings	Campus Energy has reviewed and supports the IPPSA submission.

	Questions	Stakeholder Comments
	• What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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)?	Campus Energy has reviewed and supports the IPPSA submission.
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?	▪ Campus Energy agrees with IPPSA that wind, solar, lithium ion storage, carbon capture on existing supply and new NGCC + CCUS are the most likely and more economic. ▪ Campus Energy warns that any technology enabled by subsidy or awarded by happenstance to select participants will undermine the competitive market and further investment in Alberta Electricity could quickly unravel.
	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 Carbon Capture, Utilization, and Storage (ii) Pre-combustion Carbon Capture, Utilization and Storage (hydrogen) (iii) Oxyfueled generation	Campus Energy has reviewed and supports the IPPSA submission.

Questions	Stakeholder Comments
(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	
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?	
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.	Campus Energy has reviewed and supports the IPPSA submission.
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?	

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.

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	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?	
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
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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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Steve Coupland
Comments from:	Canadian Nuclear Association	Phone:	519-386-0704
Date:	Jan 31, 2022	Email:	couplands@cna.ca

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.
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Introduction

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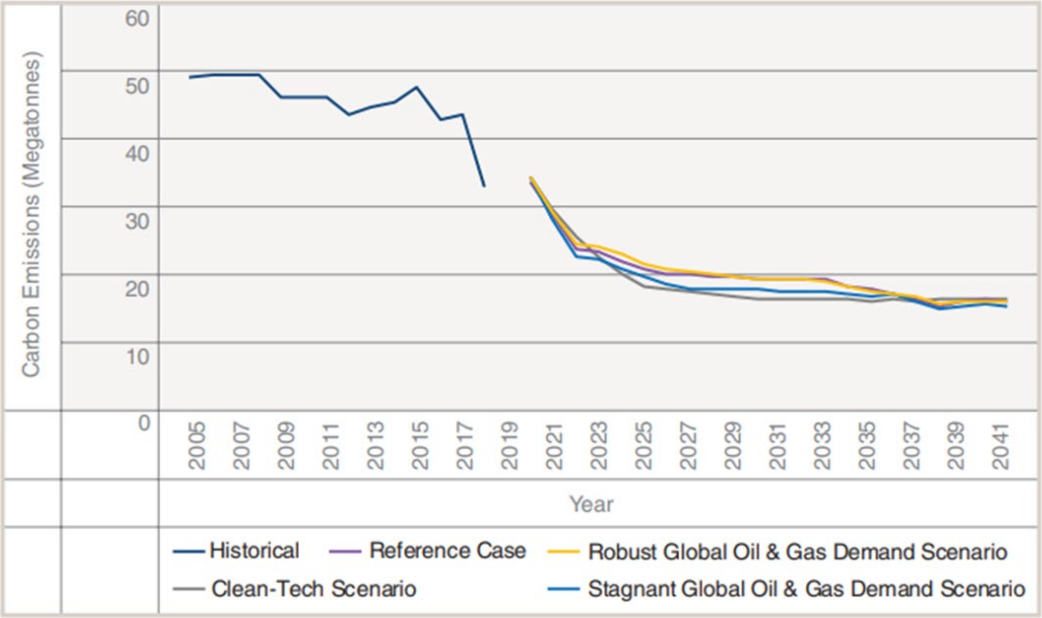
In 2022, the AESO will examine potential pathways to achieve a net-zero greenhouse gas emissions electricity sector in Alberta and the market, operational and cost implications of these pathways. The AESO intends to review and understand the most prominent zero and low-carbon emissions technologies, 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.

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



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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.

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.

Questions	Stakeholder Comments
a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?	When reviewing pathways to a net-zero grid by 2035, the AESO needs to pay particular attention to load growth. If Canada is to make its 2050 net-zero target, then electrification is going to play a significant role. Increased electrical load growth will start prior to 2035 (and accelerate after) so scenarios must include significant new generation. In the Canadian Nuclear Association's (CNA) view this makes the second scenario far more likely. It is the CNA's view that nuclear energy will need to play a vital role in creating a net-zero grid. Not only can nuclear energy provide baseload power to support the challenges of intermittency faced by but Small Modular Reactors (SMRs), have the ability to support co-generation with other energy innovation. High quality heat from these SMRs has the potential to produce hydrogen through steam methane reforming and their superior load following abilities have the potential to support integrated energy systems that include renewables.

	Questions	Stakeholder Comments
		Nuclear power is a proven carbon-free energy source; it is a flexible, economical, safe technology which will need to be part of the solution to achieve Alberta's net zero goals and meet increasing electricity demands.
	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?	In the CNA's view, Alberta's largest challenge will be to not only move existing generation to a net-zero basis but also add enough new non-emitting generation to meet growing electricity demand. This challenge will continue and likely accelerate in the post 2035 period. It is the CNA's view that this will require building a significant amount of new non-emitting generation as well as employing emissions reductions technologies such as CCUS Alberta Innovates (Deployability of Small Modular Nuclear Reactors for Alberta Applications (albertainnovates.ca)) has also identified other needs for Alberta. The development of SMRs gives Alberta the option of employing both large scale reactors for baseload power and SMRs to supply electricity, heat and high-quality steam for industrial purposes.
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?	Decarbonizing Alberta's electrical grid will be a significant challenge but also an economic opportunity as net-zero enabling technologies will require substantial new investment. Alberta will require a combination of net-zero technologies including nuclear, renewable integration systems, hydrogen and CCUS to meet 2035 targets – all of which will contribute to new economic activity. The macroeconomic impact of net-zero targets in the electricity sector are unclear at present as there is the potential that the transition to net-zero applies upward pressure on electricity prices which can reduce economic growth. It will be important for Alberta to prioritize reliability and affordability in this context as it prepares for 2035 and 2050.

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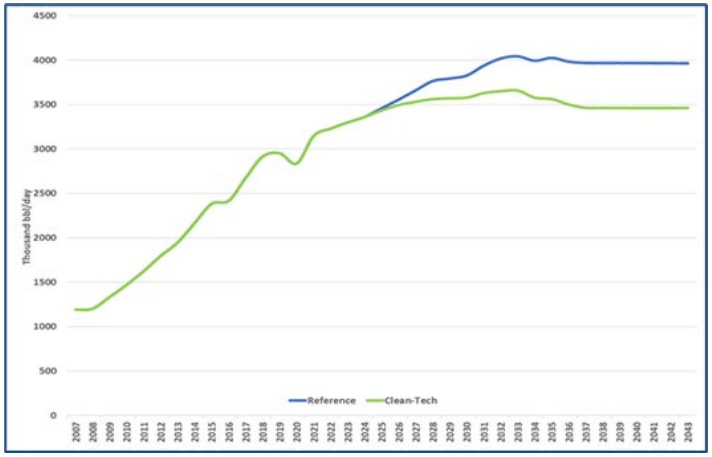
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

	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?	Adopting a similar analysis for net-zero targets and their impact on the oilsands sector as discussed in the 2021 Long-Term Outlook Clean-Tech scenario is appropriate however potential effects on Alberta internal load will need to be further assessed. Assuming no further greenfield expansion may be a prudent base case however that does not necessarily equate to no further sectoral growth as the oilsands industry still seeks to grow production on a net-zero basis largely through significant CCUS infrastructure. Large-scale CCUS infrastructure can have a potentially significant impact on load. Off-grid SMRs can enable large-scale CCUS, reduce carbon emissions from this application, and provides a pathway to reach net-zero in the oilsands sector in a manner that can mitigate corresponding demands on Alberta internal load.

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[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?	Over the medium to long-term, CNA believes the cost of natural gas will increase primarily as a result of increased carbon pricing and increased production costs associated with greater adoption of carbon abatement technologies.
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	The CNA views offsets or credits as a valuable tool in achieving net-zero targets. While the electricity sector has clear pathways to net-zero, there are some sectors where it is difficult to decarbonize. The ability to use offsets or credits allows those sectors the ability to achieve net-zero. In addition, offsets or credits will encourage fuel switching and enable additional emissions reductions in many industrial sectors.
	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?	The Government of Canada has promised the implementation of regulations that will require net zero from electricity generation by 2035. This federal policy is likely to create a dramatic increase in carbon penalties beyond the current $170/tonne target after 2030 or possibly earlier than 2030.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	One potential policy instrument available to the federal government is the legislated retirement of natural gas for power generation (which was the instrument used by the Government of Canada to force the retirement of conventional coal by 2030).
	d) Are there any other related considerations that you would like to provide feedback on?	The federal and Alberta governments need to consider how to harmonize their regulatory policies as much as possible. Major energy infrastructure projects take significant time to get through the regulatory process The existing federal regulatory processes will make net-zero by 2035 very challenging. If the federal government is not willing to find more efficient regulatory processes it will be challenging to make the 2035 timeline.
4	***Electrification and Electricity Demand Drivers in Alberta*** **a) Energy efficiency**	Energy efficiency is a valuable tool in reducing the amount of additional generation needed and should be encouraged wherever possible but the AESO needs to be careful not to overestimate the impact of energy

Questions	Stakeholder Comments
- 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?	efficiency as some provinces have. A net zero economy will still require significant new generation.
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.)?	The Canadian nuclear industry is developing a number of SMRs ranging from a few MW to 300MW per unit. These units are ideal for DER. These designs will have the ability to load follow making them a suitable backup for intermittent resources. In addition, their ability to produce high temperature heat and hydrogen make it possible to build DER for remote communities as well as large industrial users.
c) Transportation Sector - What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	The federal government has introduced policies to target significant increase in electrical vehicles by 2035. However, electrical vehicles only serve to reduce emissions if the electricity used is generated from non-emitting sources. It is the CNA's view that by 2035 these policies will create a significant increase in electrical demand and that Alberta will need to introduce significant new generation. It is also our view that hydrogen will also play a significant role in reducing emissions from transportation. Fortunately, nuclear energy is capable of producing vast amounts of both electricity and hydrogen and is therefore ideally suited to play a significant role in reducing emissions from the transportation sector
d) Buildings - What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	Similar to the transportation sector, a net zero economy by 2050 will require a significant increase in the use of electricity and hydrogen in buildings. This will also require a significant increase in electricity generation. As noted above, nuclear power is capable of producing the large volumes of non-emitting electricity and hydrogen necessary for such a shift.
e) Industrial Sectors	SMR technologies are best at directly providing baseload electricity. Hydrogen can be produced by nuclear and SMR technologies today, and

	Questions	Stakeholder Comments
	- 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)?	as noted above a large increase in use of hydrogen as a clean fuel would require an increase in baseload clean electricity for its production. Carbon capture on natural gas generation requires electrical and thermal energy which reduces the net electrical output of the power plant (parasitic load). If the electricity and heat required for CCUS is supplied by SMRs, the full electrical generation capacity of the natural gas plant is maintained and overall carbon emissions from the CCUS operations are reduced. In this application, the use of SMRs to support CCUS on natural gas will not increase industrial load but will reduce overall emissions from the operation of natural gas generation with CCUS. In addition, some SMR technologies have the potential to produce high temperature steam (not just electricity), which allows them to have co-generation capability for use with industrial applications including carbon capture and hydrogen production, potentially in a more efficient way [though not proven]. If SMRs are to be used for co-generation, the beneficial deployment of CCUS and hydrogen production could be enhanced through deployment of these technologies.
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?	As mentioned previously, nuclear energy can play a significant role in decarbonizing the electricity supply in Alberta. Larger nuclear facilities such as the ones operating in Ontario are capable of provide vast amounts of baseload non-emitting electricity to not only reduce emissions from existing generation but meet the rapid increase in demand resulting from increased electrification. In addition, there are a number of SMR technologies being developed that could serve the Alberta electricity market as well as being capable of providing high output steam that is ideal for co-generation applications for use in heavy industry, oil sands and for the production of hydrogen and synthetic fuels.
	b) What are the strengths and weaknesses associated with the following net-zero enabling technologies, within the	(vi) Nuclear generation

Questions		Stakeholder Comments
	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 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	Strengths: • Nuclear is a clean energy source that provides reliable, affordable electricity 24/7 without emitting any greenhouse gases in its operation. ○ The Canadian nuclear industry helped phase out coal in Ontario, resulting in the largest greenhouse gas reduction in North America. ○ Gram-for-gram, nuclear fuel contains one million times more energy than fossil fuels. ○ To generate the same amount of energy as nuclear, solar would require significantly more land area (estimates range from 100-220 times for solar and as much as 500 times for wind). • Nuclear energy can not only play a critical role in decarbonizing the electricity generation sector but can also play a significant role in reducing emissions and resource extraction and processing in Alberta's oil sands as well as other industrial processes. • Potential for hybrid energy systems that can integrate nuclear generation with wind or solar technology to decarbonize Alberta's grid and help phase out coal. • SMR deployment in Alberta would help offset the negative economic impact that will accompany the retirement of fossil generation. • SMRs are scalable to suit local needs and can be used to supply non-emitting, low-cost energy for off-grid application and for remote communities – particularly northern and Indigenous ones. • Some SMR designs have co-generation capability for use with industrial applications including carbon capture and hydrogen production. ○ The emissions from the CCUS process are further reduced when SMRs are used to provide electricity and heat, which would support a pathway in Alberta to net zero from the power grid by 2035.

Questions	Stakeholder Comments
	<u>Weaknesses:</u> • There may be challenges related to: ○ Establishing the necessary industry resources (human capital and supply chain) ○ Regulatory approval timelines ○ Public acceptance of nuclear in their vicinity (including interim storage of used fuel of radioactive waste and safe means of disposal of radioactive waste) <u>Development timelines</u>: Nuclear power is a well-known, proven technology that has been operating safely in Canada for decades. New designs are being deployed elsewhere in Canada, and will be deployable in Alberta within the timeframe of the regulatory process. For reference, the first SMR in Ontario is targeted to be operating as early as 2028, the first SMR in New Brunswick is targeted to be deployed as early as 2030 and in Saskatchewan by 2033-2034. Under the current regulatory regime Approximately 11-12 years should be the assumed deployment timeline for a first reactor in a new-to-nuclear jurisdiction like Alberta. It is expected that the timeline will shorten as additional reactors are deployed
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?	CNA believes that there is no one technology that will enable net-zero emissions but rather each available technology must be applied where it makes the most sense and work in concert with other technologies. For example: baseload nuclear generation enables greater use of intermittent wind and solar generation.
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.	See strengths of nuclear energy as outline in 5b for the benefits of nuclear power.
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	It is our expectation that cogeneration facilities will be required to meet net zero requirements. The CNA envisions CCUS playing a major role where feasible and offsets or credits being used until a transition to non-emitting sources like SMRs is viable.

	Questions	Stakeholder Comments
	technologies do you believe can be most economically implemented at cogeneration facilities?	
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*	

Questions	Stakeholder Comments
	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

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[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?	Existing nuclear power plants require significant upfront capital but they are capable of producing large amounts of electricity over a long period of time resulting in a competitive price for power. The CNA expects the price of nuclear generation to reduce as improvements are made in the regulatory process and greater standardization is applied. With respect to SMRs (Please note that SMRs have a power capacity of up to 300 MW) costs depend on size, technology, location and other factors. Please refer to the SMR Roadmap Economic and Finance Working Group report for capital cost estimates for on-grid and off-grid SMRs. Ontario Power Generation (OPG) has recently completed a technology assessment for on-grid SMRs, including analysis against other low-GHG options such as wind+batteries or solar+batteries, taking account of the over-build necessary for wind or solar to provide comparable capacity AND energy. SMRs are expected to be cost-competitive with these options. Such analyses should be performed for other Provinces contemplating the options in front of them.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	For many smaller and/or older thermal assets, retrofitting to support net-zero emissions will not be cost feasible. The economics of CCUS improve with larger units and combined with potential offsets and/or tax incentives can reduce retrofitting costs over time. However, even wide application of CCUS infrastructure on thermal assets will not fundamentally change the fact that Alberta will need to on-board significant non-emitting load to support a net-zero grid and broader electrification across sectors.
	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***	Nuclear energy is increasingly being acknowledged world-wide as an essential part to achieving net-zero and the CNA is pleased to see the AESO including nuclear in its list of options to achieve net-zero.

	Questions	Stakeholder Comments
	Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	The CNA would like to highlight the following points for consideration: Nuclear energy is a safe, clean, energy-dense and reliable source of non-emitting electricity generation. Nuclear energy has the flexibility to provide large amounts of baseload electricity as well as high quality heat and steam for industrial purposes. Nuclear energy creates minimal by-products and is the only energy source that accounts for all its by-products. The Canadian nuclear industry is not only one of the safest industries (by any metrics) but has heavy regulatory oversight by the Canadian Nuclear Safety Commission, one of the most respected regulators in the world.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Evan Wilson
Comments from:	Canadian Renewable Energy Association	Phone:	
Date:	2021/01/31	Email:	ewilson@renewablesassociation.ca

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

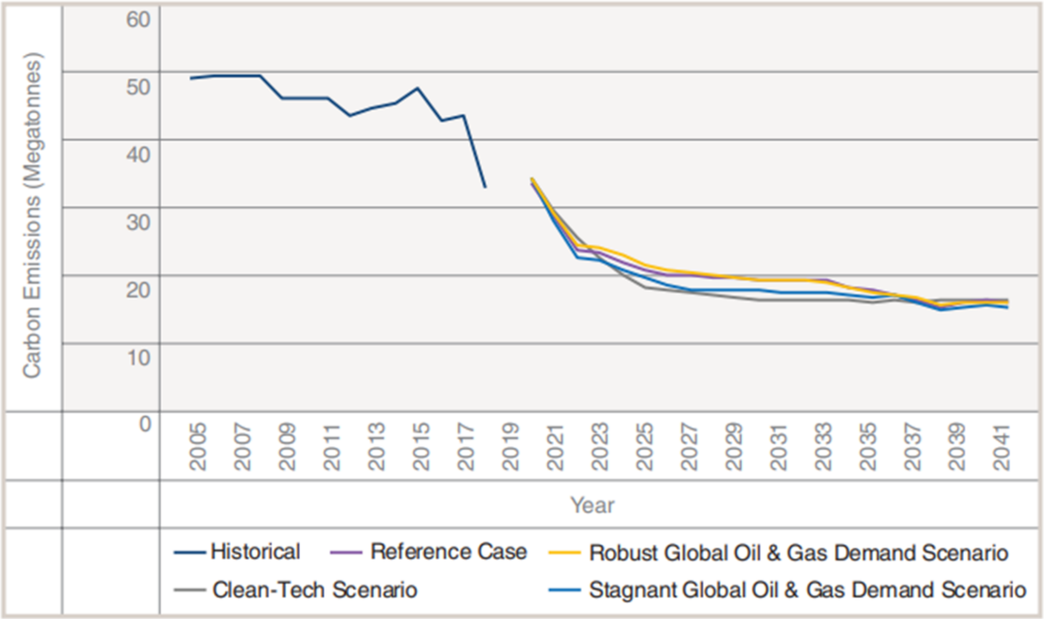
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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.

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td rowspan="2">1</td><td colspan="2">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.</td></tr>
<tr><td>a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td>We would like to commend the AESO for engaging with industry on the Net-Zero Emissions Electricity Systems Pathways report. As the market, various industries, and policy makers continue to drive the Alberta electricity grid forward toward decarbonization, it is critical that the AESO and market participants understand the potential impacts and can speak from a common set of facts about grid modernization and decarbonization. All following comments are offered in order to support the AESO in developing the best possible report on a range of scenarios and what to expect from various pathways toward the decarbonization of the system.
Firstly, we suggest that the AESO consider a broader range of supply scenarios for the decarbonization of the electricity sector. While wind, solar and storage technologies are extremely competitive, and we would expect for renewable energy grow exponentially to meet the demands of decarbonization, it remains unlikely that these technologies will make up 100% of the grid in such a short period of time.</td></tr>
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Questions	Stakeholder Comments
	Instead, we would recommend that the AESO provide analyses of scenarios in which renewables and energy storage meet 30% of demand, 50% of demand, 75% of demand, and 90% of demand by 2035. It is also recommended that various scenarios be used to determine the potential market and operational implications with and without increased interconnection capacity between neighbouring jurisdictions. Interprovincial interconnections have the potential to support grid decarbonization in Alberta, and it is recommended that this study provide some further context for support from neighbouring jurisdictions. Furthermore, any analysis of a net-zero economy should extend to 2050, as that is the year by which the *Federal Net-Zero Accountability Act* requires that Canada achieve a net-zero economy. This goal will necessitate both the decarbonization of the electricity sector, and a large increase of electrification of the economy. It is CanREA's position that this would require a decarbonized electricity system by 2035, along with a significant increase in electrification of the economy by 2050. Both factors should be considered in the timelines of the proposed scenarios.
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?	The biggest challenge to this analysis and the path to a decarbonized electric system will be the lack of clear decarbonization policies and pricing mechanisms. In the absence of these policies, stakeholders will continue to debate on the viability of a decarbonized grid. As we have seen from the coal phase out and the introduction of carbon pricing in Alberta, once the decision to move forward with decarbonization policy has been put into place, the market and market participants are able to move forward with significant emission reductions. Our sector has shown ability to exceed these goals, with coal phasing out by 2023, a full 40 years ahead of the initial schedule proposed in 2015. On a more technical note, the use of cogeneration in Alberta may result in significant challenges for decarbonization of the electricity sector by 2035. Currently, Alberta is home to over 30 cogeneration facilities, totaling 5 GW of system capacity. These facilities provide both steam and electricity for oil sands industrial facilities, the surplus of which is exported to the grid. Decarbonization of the grid would require decarbonization of these

	Questions	Stakeholder Comments
		facilities, while maintaining the heat and steam they provide for industrial processes.
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?	
	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**	

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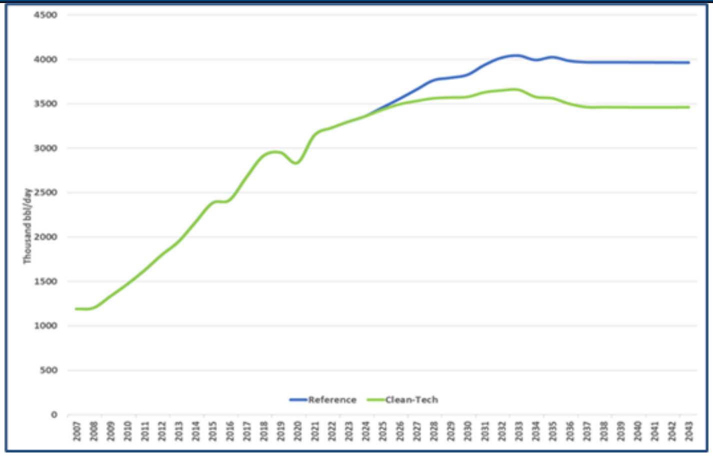
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

Questions	Stakeholder Comments
 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-zeT of ro policies on the oilsands sector and the subsequent impact on load growth?	
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?	Carbon pricing will be the key driver of gas prices going forward. To date, the federal government has committed to an increase to $170 per ton by 2030, and we expect that this figure will continue to grow out to 2035 and further to 2050.
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	While we await a formal definition of a net zero electricity grid from the upcoming federal policy announcements regarding the Clean Electricity Standard, we recommend that this study include separate scenarios for compliance mechanisms, one of which enables compliance via offsets or credits, and one which requires physical emissions reductions only.

Questions	Stakeholder Comments
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?	At a minimum, carbon pricing will match \$170/ton by 2030. Beyond 2030, it is difficult to determine the price due to a lack of information, though it is reasonable to expect that the price will continue to grow. However, the electricity sector will also be subject to additional policies, such as a Clean Electricity Standard, that may require the retirement of any facilities that continue to emit carbon, rather than exposing them to a new, increased carbon price. Environment and Climate Change Canada will be engaging in a consultation on the Clean Electricity Standard and the treatment of electricity facilities under OBPS throughout Q1. Any analysis of federal pricing/impacts should include at least the policies proposed at the beginning of this consultation process.
c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	There are several additional trends that should be considered beyond these policies, as they may accelerate the decarbonization that we are seeing in Alberta. These include: • Growing Interest in Corporate Power Purchase Agreements – the Business Renewables Centre Canada has reported 1,262 MW in renewable energy contracts announced in 2021 alone. These contracts have been signed not only by buyers with compliance obligations under the Technology Innovation and Emissions Reduction regulation, but also those with ESG-driven net-zero commitments. As more companies announce net-zero commitments, interest in these contracts will grow. • US Net-Zero ambitions – since Joe Biden was elected President of the United States, he has issued several executive orders that direct the federal government to support achievement of net-zero goals, including “100 percent carbon pollution free electricity by 2030”. This will have an impact on technology improvement, price reductions and competition for investment, each of which will have different implications for Alberta.
d) Are there any other related considerations that you would like to provide feedback on?	

	Questions	Stakeholder Comments
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?	Overall, we request more detailed information regarding how the AESO is treating the electrification and electricity demand drivers prior to the beginning of this modelling exercise. CanREA is of the opinion that decarbonization and grid modernization will have a significant impact on how factors such as energy efficiency, distributed energy resources and energy storage will lead to evolutions in the electricity system. While the system currently operates on the basis of one-way flows of electricity, these tools are expected to increase trends toward more efficient, two-way flow of electricity as both generation and load become more responsive to market signals. This coming evolution must be reflected in any modelling for 2035 and beyond.
	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.)?	As mature technologies, wind and solar, also have the advantage of potentially being developed in a more distributed manner (e.g. DER). This allows these technologies site in locations closer to the customer (on the distribution system) which affords further benefits. As a result, we expect growth of renewables on the distribution system as the system decarbonizes.
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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	

	Questions	Stakeholder Comments
	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)?	
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?	Wind energy and solar energy will provide the most economic foundation for any pathways to decarbonization of the electricity supply in Alberta. This is evident in numerous studies, including recent ones from Lazard, Bloomberg, and the International Energy Agency. Any additional technologies that are used to provide flexibility or capacity to the grid will do so to support wind and solar energy, which currently provide the lowest cost energy to the grid in Alberta.
	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 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	The AIES and the energy-only market could provide opportunities for all of these non-emitting technologies. However, it is critical to recognize that the 2035 timeline provides limited time to prioritize the development of any new technology over the deployment of proven, mature technologies, which includes energy storage. It is critical for the AESO to recognize that for technologies like wind and solar energy, energy storage and, potentially, transmission interconnections with other jurisdictions, are ready for deployment. Any net-zero emissions pathways analysis should base deployment timelines for these technologies based on carbon pricing, market rules and other market signals, rather than waiting for any further technological improvements. We also recommend that the AESO consider different energy storage technologies in the models, as different technologies provide support for different time durations. For instance, batteries provide for durations as short as one hour, whereas pumped hydro can provide support for as long as two weeks. Both technologies will be deployed in Alberta on the road to 2035, and both should be treated separately in this analysis.

Questions	Stakeholder Comments
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?	We encourage the AESO to consider the roles that distribution connected renewable generation will play in low-cost, meaningful reductions in GHG emissions in Alberta. As mature technologies, wind and solar, also have the advantage of potentially being developed in a more distributed manner (e.g. DER) – this allows these technologies site in locations closer to the customer (on the distribution system) which affords further benefits. Likewise, energy storage technologies will play a role in creating meaningful, low-cost emissions reductions in Alberta, both as a provider of flexibility for the grid, as non-wire alternative that can reduce overall system costs, and as a tool supporting the time-shifting of renewable generation.
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.	Energy storage is the one net-zero enabling technology listed above that will bring additional benefits to the electric system in Alberta. Not only is energy storage capable of firming non-emitting renewable energy generation, but will also provide additional support for enhanced system reliability by providing numerous other services including capacity value, fast frequency response and voltage support. Storage can also reduce system costs by delaying or replacing investments in expensive transmission and distribution wires. The National Renewable Energy Laboratory (NREL) has projected that four-hour battery costs will decline between 20% and 60% between 2020 and 2030. As these costs continue to fall, energy storage is likely to be deployed aggressively across the province, where it will enhance system reliability and reduce costs for all ratepayers.
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?	

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

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[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?	CanREA expects that the costs of energy storage will drop over the coming years to 2035, especially as there is more experience with the deployment of these projects both in Alberta and across the globe. This is supported by research from NREL, cited above. Likewise, wind and solar costs are expected to drop between now and 2035, though not necessarily at the same rate as we have seen over the past decade. Furthermore, it is recommended that end of life site remediation costs be more explicitly included in the modelling of any project costs. AESO should extend the set of storage technologies included in the analysis to include technologies such as batteries and pumped hydro storage. These technologies will come with different costs, and their inclusion will require further consultation with project proponents on reasonable cost assumptions.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	CanREA would be interested in an AESO analysis that would identify any geographic limitations to the siting of CCS projects, relating either to access to infrastructure or to proximity to the geology required for sequestration.
	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.	Again, we would like to show support for the AESO's decision to move forward with the development of this report. During the development of the 2021 LTO, the AESO provided stakeholders with details regarding the scenarios that they were developing. It is requested that, prior to any modelling of the scenarios being proposed for this report, the AESO share details for comment, preferable through both a webinar presentation (including Q&A) and via written comments. Furthermore, we offer the following commentary for consideration:

	Questions	Stakeholder Comments
		• The opportunity for wind and solar project repowering should be considered by the model as the AESO is determining the location of any projects. It is expected to be more economic for projects to be developed where there is already access to connection capacity, land owner and community agreements in place, and proven renewable resource. • There may also be opportunities to site some wind, solar or energy storage projects where there is capacity from retired natural gas plant infrastructure. • Consideration for storage siting should include areas where battery storage could be used as a non-wire alternative that would defer investment in new transmission or distribution lines.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Matthew Davis
Comments from:	Capital Power	Phone:	403.540.6087
Date:	2022/01/31	Email:	mdavis@capitalpower.com

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

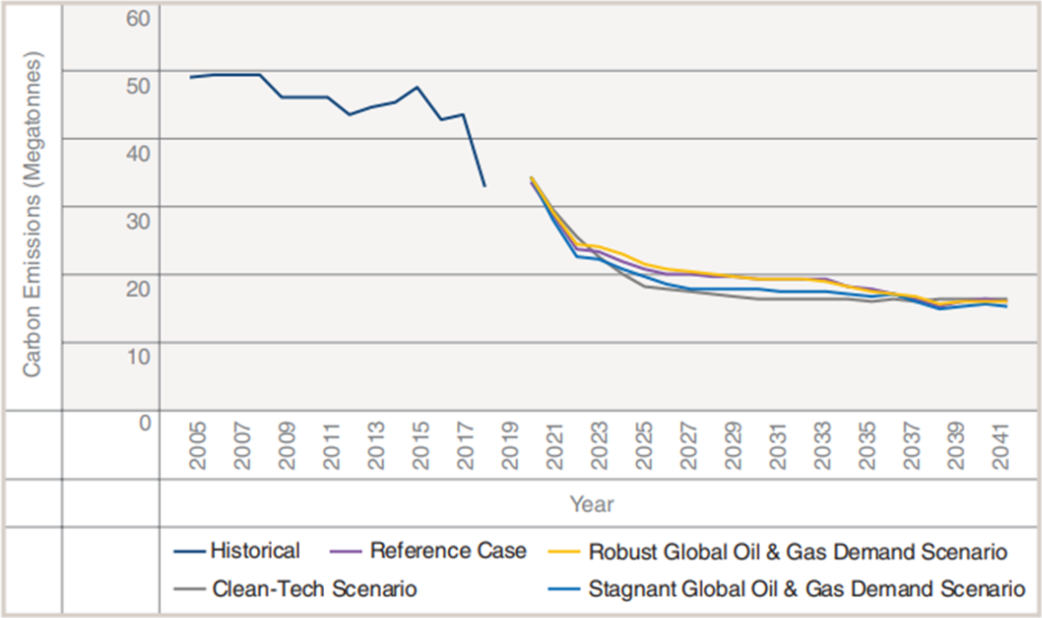
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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.

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td><i>1</i></td><td colspan="2"><i>Net-Zero Analysis Scope</i>
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.</td></tr>
<tr><td></td><td>a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td>Capital Power supports the AESO undertaking this initiative. The AESO is uniquely positioned to assess potential implications that decarbonization and pathways to net-zero present for Alberta, particularly with respect to operational and reliability impacts.
The AESO notes on page 1 that it will undertake the pathways analysis with intention of understanding how policy objectives can be met while “minimizing distortions to the existing market framework and maintaining a reliable electricity system.” We agree that the continuation of the existing market framework should be assumed for the purposes of the pathways, and that the analysis focus on viable pathways that can work within the framework (or limit disruptions to it). Adding discussion and analysis regarding alternative market designs would needlessly complicate the analysis and add an unnecessary level of uncertainty.
The system operations and reliability implications of different pathways is a critical aspect of the pathways analysis that the AESO is uniquely positioned to address. Given this, we believe there should be some high-</td></tr>
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	Questions	Stakeholder Comments
		level discussion in the initial report of how the AESO at least intends on defining and addressing these issues, rather than deferring the entire discussion to later reports as seems to be suggested. This would be consistent with the Ontario IESO's approach to its Natural Gas Phase Out Paper where the significant adverse reliability impacts of phasing out natural gas at an accelerated pace were prominently highlighted. At minimum, the AESO should include in the first report a discussion of the scope of technical and reliability issues that it believes are relevant to the net-zero assessment, and that will be subject to more detailed analysis and modeling in subsequent phases. Examples that Capital Power would view to be important for industry and policy makers include net-demand variability studies to assess ramping requirements and an assessment of system inertia / primary frequency response as many of the technologies that may have a more prominent role under net-zero pathways do not possess the same attributes as traditional sources of generation. Similarly, the AESO notes the initial report will address "high level cost implications" associated with the supply-mix changes modeled in the scenarios. These should include high-level costs relating to transmission system requirements to the extent possible. With respect to transmission costs, the pathways should assume continuity of Alberta's existing transmission policy and legislative framework, and particularly the requirement for a congestion-free transmission system. With respect to the two scenarios that the AESO has outlined, it is unclear how the AESO will frame the "renewables paired with energy storage" scenario – will the scenario maintain a residual amount of dispatchable capacity on the grid for 2035, or is the scenario more focused on only new builds being wind / solar / storage, or is it something else? Further details would be useful in better understanding the AESO's plans for this scenario. Further, the plausibility of this scenario being able to evolve within the existing market framework is highly questionable, and we would suggest that the AESO outline what potential evolutionary changes would be required to the market for it to work. Given the nature of the work the AESO is conducting, it is important to explain that any greenhouse gas (GHG) policy assumptions included in

	Questions	Stakeholder Comments
		the scenarios do not reflect the views of Governments. The Government of Alberta will review TIER in 2022 as part of the evaluation of the equivalence of Alberta's frameworks with the Federal backstop framework. In addition, the Government of Canada will be consulting on a potential Clean Electricity Standard (CES) to achieve a net-zero clean electricity grid by 2035. Given the AESO's net-zero analysis will run concurrently with these policy discussions, the AESO should be clear where its carbon policy assumptions reflect its own projections being made for modeling purposes versus which ones may reflect any direction provided by government(s).
	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?	Decarbonization in the electricity sector needs to consider and accommodate objectives relating to sustainability, affordability, and reliability. Achieving net-zero by 2035 is an ambitious timeline that, all else equal, will limit the suite of technologies that might be commercially available and proven for deployment, and which will present additional challenges for affordability and reliability. The transformation of the electricity system on a path to net-zero will come with challenges to: - market design and investment signals (including carbon policy certainty), - system planning and operations to ensure reliability, and - infrastructure costs paid by ratepayers. **Markets** Alberta has a different resource endowment than most other provinces and limited interconnections with adjacent markets. Alberta's market and carbon pricing framework, and declining costs of renewable technologies, have already driven a significant shift in Alberta's resource mix. Alberta's market framework will continue to drive investment and innovation in renewable generation and in decarbonization technologies such as Carbon Capture, Utilization and Storage (CCUS). Increasing intermittent, zero-variable cost generation, along with changes to demand due to electrification will impact price formation in Alberta's market. Capital Power supports the AESO's intention to evaluate

	Questions	Stakeholder Comments
		pathways that minimize distortions to Alberta's market design but also believes that it would be useful for the AESO to comment on how the pathways it analyzes may impact the energy and ancillary services markets that form the basis for generation investment. While evolutionary changes to the energy market may be necessary, carbon policy certainty is also necessary to support investments in support of net-zero. Alberta has had a carbon pricing framework for the electricity sector in place since 2007. In 2018, the Government of Alberta introduced the carbon price with output-based allocations based on good as best gas performance. Under Alberta's GHG system, all electricity generators must meet a 0.37 tCO_2e/MWh benchmark. The province's carbon pricing policy and electricity benchmark decreased the utilization of coal power facilities and accelerated the transition plans to phase-out coal by 2023 instead of the initial date of 2030. Capital Power believes that the goal of GHG policies to advance a net-zero grid should be focused on achieving desired emission reductions – regardless of technology – and not specifying certain technologies and fuel types. Preserving technology neutrality will avoid introducing unnecessary uncertainty that may disincentivize near-term investments that will be critical to achieving 2030 and 2035 goals. Investment in technologies like CCUS, hydrogen blending, and Direct Air Capture (DAC) today, will reduce the cost of longer-term technologies such as hydrogen (distributed in a dedicated network) that may play a greater role in the medium to long-term decarbonization. **System Planning & Operations** While power systems are constantly evolving, future changes to grid composition as we advance toward net-zero are expected to be more substantial than in the past and to occur at an accelerated pace, given the current array of technologies and pace of change. As such, system planning and operations will need to be responsive to changes so that reliability is maintained, and innovation and development is not needlessly impeded.

	Questions	Stakeholder Comments
		For example, historically, base-loaded thermal generation such as coal has supplied important reliability attributes such as inertia (which provides intrinsic system support and flexibility). Wind, solar, and smaller distributed generation sources do not necessarily possess the same reliability attributes that system planners and operators are familiar with having in abundance. As such, it will be critical for the AESO in its role as a system planner and operator to perform reliability and operability assessments on net-zero pathways. **Infrastructure Costs** As identified in the AESO's CEO Roundtable materials provided in December 2021, additional infrastructure costs for the wires necessary to facilitate a net-zero future must be considered as part of this assessment. These include transmission developments to connect new loads and the generation developed to serve it, along with distribution network improvements to support the two-way flow of electrons. The AESO should ensure that its net-zero pathways assessment consider not only the impact to energy prices, but the impacts for overall delivered cost of energy inclusive of transmission and distribution costs as affordability is an important aspect of any pathway to a net-zero future.
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?	Given the broad reaching implications of net-zero policy beyond the electricity sector, there will be impacts to the business-as-usual scenario and particularly with respect to changing the drivers of Alberta's load. When the AESO presents their final assumptions and results it will be useful for the AESO to articulate all the modifications to its macro-economic assumptions it is making in developing its scenarios.
	The current IHS Markit outlook notes that Alberta oil sands production has surpassed pre-pandemic levels and forecasts	Net-zero for the electricity sector cannot be evaluated without understanding how broader net-zero policy will impact other industries. The approach outlined by the AESO in the past green-tech scenario and

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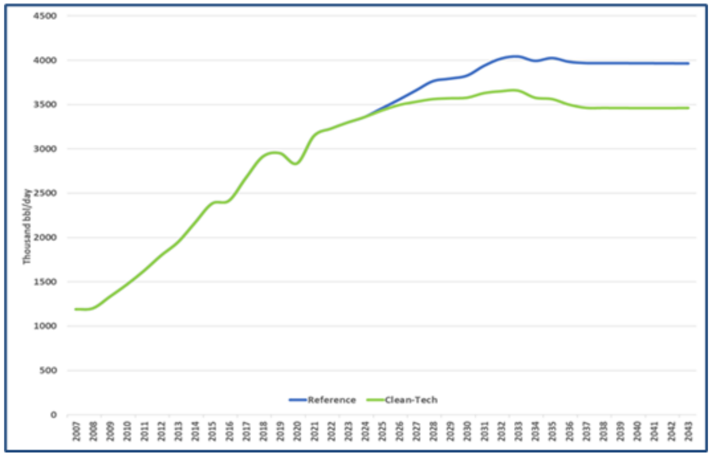
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

	Questions	Stakeholder Comments
	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?	further extended to evaluate how broader net-zero policy would/could result in a decline in oilsands production ensuring that the AESO's net-zero scenarios are internally consistent. Overall, it would be reasonable to assume for the purposes of a net-zero pathways assessment that some form of declining emissions cap will occur for the oil and gas sector. One potential approach for developing any adjustment would be to bookend the adjustment based on industry (*e.g.* CAPP, Oilsands Pathways to Net-Zero Alliance) and environmental non-governmental organizations and institutes (*e.g.* Pembina, Clean Prosperity) potential pathways for the sector.
	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	The current forward market for natural gas prices is in the $3/GJ range, though market liquidity for natural gas futures is low in the later years.

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

	Questions	Stakeholder Comments
	rates? What do you see as key drivers of gas prices going forward?	Demand for Alberta natural gas is expected to continue to grow, even under a net-zero future given current uses, global demand for liquified natural gas, and the development of “blue” hydrogen. As such, maintaining natural gas prices in the $3/GJ range in real-dollar terms is a reasonable assumption, though Capital Power would suggest that the AESO frame this assumption with third-party fundamental forecasts. Further, Capital Power suggests that the AESO consider evaluating a stress case assessing the potential implications to baseload generation and the market under a combination of an increase in natural gas prices with higher carbon 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	Net-zero by definition includes allowance for a volume of physical carbon emissions being fully offset by an equivalent amount of removals of carbon emissions from the atmosphere. Given the divergent processes required with respect to carbon removal and sequestration, the term is normally considered on a broader national/global scale. Capital Power has established a target to achieve net carbon neutrality within our portfolio by 2050. We intend to achieve this through a three-tiered approach that prioritizes achieving physical emissions reductions to the greatest extent practical, supplemented by deployment of direct air capture to generate offsets within our own portfolio, with market purchased offsets being procured as the residual. With respect to net-zero within Alberta’s electricity sector by 2035 (or any period), it will need to incorporate compliance through all three of the mechanisms the AESO notes. A narrow interpretation that limits compliance to only physical reductions would not be viable or practical. The Government of Canada has defined the 2050 net-zero objective as: Achieving net-zero emissions means our economy either emits no greenhouse gas emissions or offsets its emissions, for example, through actions such as tree

	Questions	Stakeholder Comments
		planting or employing technologies that can capture carbon before it is released into the air.[3] In addition, the federal OBPS Regulations allow the use of offsets as a compliance option. While the Federal OBPS is not in effect in Alberta, its recognition of the role for offsets is nevertheless instructive. As such, Capital Power believes that offsets will play a role in meeting net-zero objectives, though to what extent is not known at this time as policy uncertainty does exist. As offsets and Emission Performance Credits (EPCs) are broader than the electricity market, can be banked for a period of time, and are limited in providing compliance through programs such as TIER, it is important for the AESO to have an understanding of the broader market for these environmental attributes. Capital Power submits that the AESO provide in its assumptions as much detail as possible on how it views the offset / EPC protocols in its net-zero study. Capital Power has provided additional commentary around individual offset and EPCs in response to question 5.b.ix.
	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?	In the pre-2030 period, Capital Power expects Alberta will continue to maintain its own TIER carbon pricing framework for large emitters with pricing following the federal carbon price trajectory to reach \$170/tCO_2e by 2030. It is reasonable to expect that this would be assessed as meeting the Federal equivalency criteria. With respect to stringency in the electricity sector, Capital Power is of the view that the current benchmark of 0.37 tCO_2e/MWh should be maintained at least through 2030. Maintaining the stringency at this level, in combination with the escalating carbon price, will continue to provide an increasing effective carbon price under TIER that will continue to impact investment and dispatch decisions towards lower emitting resources, while avoiding more significant pricing and market impacts that we believe would result under a scenario

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[3] https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html

	Questions	Stakeholder Comments
		involving more aggressive reductions in the stringency level in the pre-2030 period. The Government of Canada has not announced a carbon price trajectory after 2030 but it is reasonable to expect that increases should moderate over time. Capital Power would appreciate the AESO clearly publishing its post 2030 assumptions on carbon.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Capital Power expects there will be ongoing consideration of various policy mechanisms and approaches intended to advance provincial and/or Federal carbon policy objectives that stand to potentially impact Alberta's electric system to varying degrees. Notable areas of focus include the following: • Capping emissions from the oil and gas sector at current levels and requiring that they decline at the pace and scale needed to get to net-zero by 2050. • Reducing oil and gas methane emissions by at least 75% below 2012 levels by 2030. • Changes to residential and small commercial demand profiles as a result of federal, provincial and municipal rebates/programs for rooftop solar, behind the meter storage, and electrification technologies such as heat pumps. • Mandating the sale of zero-emission vehicles so that 100% of new light-duty vehicles (cars, pick-up trucks, etc.) sold in Canada are zero-emission by 2035 and at least by 50% by 2030. • Developing emissions standards for heavy-duty vehicles that will require that 100% of selected categories of medium- and heavy-duty vehicles be zero-emission by 2040. • Alberta CCUS Hub. Impacts for load on system-wide basis, and deployment of CCUS within power sector to provide near-zero emission dispatchable capacity that can provide key reliability support. • Ongoing Federal/provincial funding for CCUS, hydrogen and other decarbonizing technologies to advance to commercial-

	Questions	Stakeholder Comments
		scale deployment, and support for build-out of Electric Vehicle infrastructure. Also, the Government of Canada remains interested in providing support for expanded interprovincial interties. While this may be appropriate for some provinces as part of developing a net-zero future, it is not appropriate or warranted for Alberta for numerous reasons. Specifically, expanding interties is first and foremost a long-term option given permitting and jurisdictional seams issues. These later issues are critical to consider given Alberta's unique market structure relative to neighbouring provinces. Finally, expanded interties are not subject to must offer, must comply, and may not deliver energy when needed the most.
	d) Are there any other related considerations that you would like to provide feedback on?	Capital Power is supportive of the AESO's intention to focus on pathways that minimize disruption to the current market framework and believes that the AESO should clarify and extend this principle to transmission policy framework principles. Current and future investments are based on the full suite of policies that underpin the market, and timely access to an unconstrained grid is essential to support future development of generation. Considering that Capital Power does acknowledge that there are real costs associated with developing the transmission grid – particularly should generation develop away from the transmission system – this is most acute for intermittent renewables. The AESO should provide additional insights on how transmission costs may be impacted under different scenarios.
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?	Capital Power has no specific comments to the AESO on energy efficiency potential and uptake at this time. It will be appreciated if the AESO provides details on their energy efficiency estimates and other demand response expectations through this process. It would be reasonable to expect that a combination of avoided commodity costs and policy driven programs will drive increases in energy efficiency efforts, though these may only offset future electrification drivers.
	b) Distributed Energy Resources (DER)	Capital Power expects to continue to see increases in DER technologies due to net-zero trends and technology price curves. Alberta has a strong

Questions	Stakeholder Comments
- 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.)?	solar resource that will likely see smaller installations at customer sites (rooftop PV) and a continuation of smaller, but utility scale (~1 MW and greater), distributed connected installations. The former will look more like a reduction in net demand, while the latter is more in line with wholesale market sizing. Net-zero trends may drive more uptake in both options due to policy and pricing incentives though it is important that the AESO continue to monitor and support a level playing-field between DER and transmission-connected developments.
c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	Capital Power has no specific comments on the impact of electrification of the transportation sector and buildings at this time but re-iterates that these electrification loads may offset energy efficiency gains though the timing may differ.
d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
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)?	Post-combustion carbon capture technology will require significant steam and power loads to operate. Loading levels for CCUS, regardless of carbon capture method (amine-based, or even some of the newer adsorbent technology), come from two components: 1) steam requirement for capturing the CO_2 and 2) electrical load for compressing the CO_2. It is rational to expect that CCUS loading on power generating facilities would appear as station service (though there may be tariff issues depending on interconnection configurations), reducing the net-to-grid output of the facility. Similarly, if hydrogen is produced on-site at a generating facility, this may again look similar to other station services, but may require further contemplation by the AESO as these changes to power plant configurations add complexity to the production of power that is beyond what has previously been contemplated.

	Questions	Stakeholder Comments
		For other industrial applications where CCUS and/or the production of hydrogen is drawing from the grid it would be subject to normal costs for industrial demand. Capital Power would suggest that in terms of performance benchmarks for increased loading for CCUS, the AESO should look to publicly available research such as from the US Department of Energy.[4] While costing will have evolved, there should be sufficient information to develop a high-level estimate of a MWh per tonne of CO_2 abated. Overall, Alberta's competitive marketplace makes it attractive for energy intensive industries as they are able to secure corporate power purchase agreements (PPAs) that can be structured to meet individual's needs (pricing, flexibility, ESG considerations, etc…). These though are premised based on the ability to connect and deliver energy from projects that are developed in support of these PPAs. Finally, it is important to note that some future loads (*e.g.* cryptocurrency mining) may be much more controllable (not required to have firm delivery) and capable of participating more fully in the market should the right signals exist.
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?	Capital Power views a portfolio of technologies providing the most efficient decarbonization pathway in Alberta. Wind and solar generation provide cost effective energy but require firm generation backup. Capital Power views the use of CCUS and hydrogen as the most viable technologies available in the pre-2035 period to provide the firm, dispatchable capacity necessary to ensure resource adequacy. Energy storage, particularly batteries, are emerging first as providers of ancillary services and short-duration energy arbitrage, but as costs decline may also be coupled with intermittent renewables to act closer to baseload / dispatchable facilities.
	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	(i) **Post-combustion CCUS** has the benefit that it can be integrated into operations at existing and future natural gas-fired facilities reducing stranded asset risks and leverage brownfield advantages

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[4] https://www.netl.doe.gov/projects/files/CostandPerformanceBaselineforFossilEnergyPlantsVolume1aBitCoalPCandNaturalGastoElectRev3_070615.pdf

Questions	Stakeholder Comments
electricity sector? What do you view as reasonable development timelines for these technologies? (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	at existing sites to realize cost efficiencies, including transmission infrastructure. Further, new business models have emerged (industrial hub model) and the investment environment has improved resulting in significant interest to deploy CCUS technologies. Deployment of CCUS on dispatchable generation technologies provides firm, reliable capacity as the grid transitions to net-zero. As the technology can be deployed at existing generation sites, incremental transmission costs are not necessary. While CCUS technology is proven at scale, there are currently a limited number of projects that capture CO_2 from a power plant. Other investment considerations include a higher capital cost, continued uncertainty on carbon policy, and unclear and potentially unlevel tariff treatment depending on the type of permitting and site configuration for the necessary load required for the process. Capital Power views this technology as central to decarbonization of Alberta's electricity sector in the next 10 years. (ii) **Pre-combustion Carbon Capture, Utilization and Storage** Capital Power understands to refer in general to "blue" hydrogen fuel production. In addition to "blue", alternative sources for hydrogen include "green" production via the use of electrolysis. In general, hydrogen fuel blending provides an alternative zero-emissions fuel-source for gas-fired turbines which provide the dispatchable capacity that is required to ensure resource adequacy. Existing natural gas infrastructure may be utilized for hydrogen blending; however, industry standards will be required to be developed to effectively implement. Estimates by turbine manufacturers have indicated that a 10% to 30% blend may be achievable with modest investments to upgrade ancillary systems. This limits the ability to deploy hydrogen in much of the existing gas fleet in Alberta. It is important to note that the relationship between hydrogen blending and emission reductions is not linear, and the physical properties of the fuel limit the associated reductions that are realized at lower blends. A 30% hydrogen blend by volume will achieve an associated emissions reduction of approximately 10-15%; at a 75% blend the emission reductions approach 50%.

	Questions	Stakeholder Comments
		To develop a dedicated hydrogen network, significant dedicated transmission and storage infrastructure will have to be developed. Alternatively, on-site hydrogen production may be possible prior to combustion in new hydrogen ready turbines which manufactures are now deploying that with additional engineering will allow up to 100% hydrogen. As with post-combustion CCUS, there has to be the capability to sequester the carbon though the process. Capital Power views both green and blue hydrogen as an essential part of net-zero development with likely deployment post-2030. (iii) **Oxyfueled generation** or Allam Cycle generators are novel natural gas power plants that could theoretically provide emission-free dispatchable capacity. While there is one operating facility in Texas, the technology is in its infancy, as such Capital Power does not view it as part of a suite of core technologies for net zero electricity grid development in the near to medium term. (iv) **Renewable generation** including wind, solar, geothermal, and biomass. The first two technologies listed here are proven emission-free generation options in Alberta. They provide cost effective energy, but being intermittent, they require firm, dispatchable generation backup. Wind generation is economic on its own in Alberta's market and would be considered an energy resource with a relatively low capacity value as wind production typically is low during highest load levels in Alberta. As such, some firm backup is necessary, and the AESO's pathway analysis will be informative in identifying the potential reliability and cost issues raised under more aggressive scenarios for wind investment and penetration. Solar generation is economic on its own in Alberta's market and while it provides a predictable on-peak generation profile, significant additions will dramatically change the overall shape of net-demand that the market serves and may create ramping challenges as during certain periods of the year solar will ramp down just as load ramps up for the evening peak. As with wind, solar production does not match with Alberta's highest demand periods (winter super peak) thus will also require some form of firm backup.

	Questions	Stakeholder Comments
		Geothermal appears most likely to provide low grade heat and may provide small amounts of electricity but is not expected to form the basis of significant renewable additions in the province. Biomass generation is constrained based on feedstock locations relative to the generator. While some existing biomass facilities exist in Alberta, the costs of transporting the feedstock adds to the overall cost making it an unlikely alternative fuel for re-fueling relative to natural gas. (v) **Hydroelectric generation** developments have a long history of cost over-runs, and long development timelines (12+ years to develop / permit / construct). These developments are infeasible in the current or any other competitive market design without significant government guarantees. Also, large hydro would come with significant transmission investment(s) required and would be challenged due to the potential for significant environmental impact to facilitate required reservoir creation. As such, Capital Power does not view large hydro developments as a reasonable resource option in Alberta in the near to medium term. (vi) **Nuclear generation** suffers from the same challenges with respect to long-lead development and cost over runs as hydro (for conventional nuclear). Alberta is a signatory of a memorandum of understanding with Saskatchewan, Ontario, and New Brunswick to evaluate the potential for small modular reactors (SMRs). While efforts are being made to develop initial investments before 2030 in Ontario, the technology and regulatory approval processes are uncertain, and the significant capital cost associated would still be challenged to be made by private investors at this time. (vii) **Energy Storage** with a short-term discharge (1-4 hours) is viable today for targeted applications in Alberta, and costs are continuing to come down which will lead to further development in storage in Alberta. As the net demand variability increases (with additional wind and solar installation) then so does opportunity for energy storage applications either as a stand-alone project looking to arbitrage price / participate in ancillary services markets, or as a hybrid facility, co-located with intermittent generation. While shorter-term storage may displace some applications for peaking

	Questions	Stakeholder Comments
		generation, there are regularly periods where peaking capacity is required for longer durations, upwards of days at a time should wind not be blowing. While longer-term storage would provide additional firming capabilities, the technology is more expensive at this time (though new technologies are being explored vigorously), as such Capital Power views longer-term storage with renewables as a potential future baseload configuration in the future (post 2030). (viii) **Transmission interconnections** with other jurisdictions are relatively challenging to permit given the multiple jurisdictions that must provide approvals and would require special consideration in Alberta given significant market seams issues. As discussed above in response to 3.c., incremental interconnections create new resource adequacy risks (*e.g.* hydrological) and do not guarantee self-sufficiency. In fact, BC Hydro's 2021 Integrated Resource Plan shows that there is very little surplus energy in the 2030s,[5] as such it is questionable with BC's own electrification and net-zero objectives whether there would be significant energy available to be delivered to Alberta. Capital Power notes that the AESO's own assessment in the CEO roundtable materials reflects that the development timeframe for any future interconnections would be between 5 – 15 years. Given the complexity of the issues that any intertie expansion would raise from a policy, market, permitting and construction perspective, the actual timeline for any development would be toward the longer end of the range. As such, the reasonableness of assuming further interties as part of the pathways to 2030/35 is not clear. (ix) **Offsets or EPCs** are instruments representing environmental attributes that could play a role in net-zero developments (see the response to question 3.a. above). Given their potential role, it is important to have a strong understanding of the various protocols and how they are valued.

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[5] https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/regulatory-planning-documents/integrated-resource-plans/current-plan/integrated-resource-plan-2021.pdf

	Questions	Stakeholder Comments
		Under TIER, CO_2 Capture and Permanent Storage (CCS) in Deep Saline Aquifers along with renewable generation (wind, solar, geothermal, and biomass) have offset protocols and can generate offsets. The CCS offset credit generation period is set at 20 years, with the possibility of ongoing five year extension. For renewable generation, offsets are generated based on the electricity grid displacement factor (EGDF), currently 0.53 tCO_2e/MWh and the offset credit generation period is set at 8 years, with the possibility of ongoing 5-year extension or one time of 10 years. In 2022, the EGDF for renewable generation will be re-calculated and is expected to decline quickly (highly likely will be below the 0.37 tCO_2e/MWh benchmark in the second half of the decade which may lead developers to elect to produce EPCs). EPCs can also be generated for production of electricity that is not participating in another program based on the difference between the emission intensity of the generating facility and the 0.37 tCO_2e/MWh benchmark. Under TIER, only up to 60% of a regulated facility's compliance obligation can be met through EPCs and offsets. These environmental attributes are expected to retain value due to shadow pricing of the carbon price trajectory. The majority of Alberta credits (EPCs and offsets) created will be sold at 10-30% discount rate below the carbon price, allowing value to be retained when credits are used for compliance. Currently, Alberta has ~ 27 $MtCO_2e$ of banked offsets and EPCs and while annually old vintage offsets must be used or lost (*e.g.* 4.7 $MtCO_2e$ from the 2016-2015 vintage expected to retire this year) there is the potential for there to be sufficient supply of credits to achieve net-zero in the electricity grid as its emissions obligation drops. In addition, TIER may allow the federal Clean Fuel Regulations (CFR) to stack EPCs and offsets. Should stacking be accepted, more CCUS projects at refineries could be developed due to the significantly different carbon price under the CFR. **Direct air capture (DAC)** technologies extract CO_2 directly from the atmosphere. The CO_2 can be permanently stored in deep geological

Questions	Stakeholder Comments
	formations thereby achieving negative emissions or carbon removal. These physical reductions could be used to offset emissions at generating facilities that may not suit other emission capture technologies. As DAC technology has yet to be demonstrated on a large scale, the future cost of DAC is uncertain. Capture cost estimates are wide-ranging, from \$USD 100/tCO$_2$e to \$USD 1,000/tCO$_2$e. In 2018 Carbon Engineering released peer-reviewed research showing that capture costs of \$USD 94/tCO$_2$e to \$USD 232/tCO$_2$e were achievable depending on financial assumptions, energy costs and specific plant configuration.
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?	While there are several other technologies that are underdevelopment, the above listing is representative of those that hold the most promise on enabling net-zero pathways in Alberta, and includes several that are discussed, but that Capital Power views as less likely to play a major role – particularly in the near to medium term.
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.	It is well understood that wind and solar generation are intermittent and as their penetration increases will result in continued increases in net-demand variability (NDV). In real-time, a higher NDV will likely require system operations to evaluate faster ramping products to manage the more variable nature of the resources. Additional wind and solar will also have impacts on how generators commit units which may have further reliability implications (such as inertia). These, and similar types of changes to how the grid will be operated will require the AESO to contemplate the current set of ancillary services, and how the AESO approaches operations to maintain reliability. Over the long term, changes to NDV will impact price formation in the market and will create pressure to evolve the current market design so that the market remains capable of attracting adequate resources. Larger firm generating sources such as combined cycle with CCUS or fired with hydrogen provide many benefits to the grid. These include dispatchable capacity and system inertia. These investments though are challenged with current uncertainty with respect to the AESO's potential MSSC limit. The investment required for these technologies are significant and benefit from economies of scale that the AESO may not realize.

	Questions	Stakeholder Comments
	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?	It is unclear, but likely not as emissions from cogeneration facilities that produce steam or electricity for on-site use are reallocated from electricity sector to the relevant economic sector. The relevant economic sectors include Natural Gas Production and Processing, Oil Sands, Mining, Pulp and Paper, Chemicals and Fertilizers, Service Industry, and Light Manufacturing. According to the modelling performed for the Federal Government's December 2020 "A Healthy Environment and a Healthy Economy" plan, the projected emissions in 2030 from Canada's electricity sector are 11 $MtCO_2e$, which do not include cogeneration. This may create challenges in how the AESO characterizes the grid relative to how the emissions are accounted for at a national and sub-national level as cogeneration plays a major part only in Alberta's electricity market and not in other Canadian electricity markets.

	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*[6], 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

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?	In general Capital Power would comment that when normalizing costs from a more generic source such as the EIA, additional adjustments to reflect the costs of development specifically for Alberta must be made (*e.g.* labour and productivity rates, winterization, etc…). Further, the AESO must develop rational financing assumptions that reflect developer's

	Questions	Stakeholder Comments
		experience in financing projects. The AESO has previously engaged consultants to provide them this level of detail for cost normalization. While financing assumptions are not presented here, Capital Power has through previous engagements with the AESO identified the need to improve the AESO's understanding and assumptions on what is necessary to finance a power project in Alberta. It will be useful for the AESO to publish further details on their cost normalization and financing assumptions through this process. In addition to the technology costs, Capital Power would remind the AESO that for a comprehensive assessment, estimated transmission costs should be included in the AESO's assumptions. While not included in the levelized cost of energy, various technologies do have differing expectations on transmission costs. The AESO's CEO Roundtable materials provides a reasonable assumption for the incremental cost of transmission. On nuclear, SMRs have no precedent to determine actual capital and variable costs in Canada. For traditional CANDU nuclear facilities, the last new construction was completed in the 1990s and subsequent refurbishments have exceeded their budgets in both timeline and cost estimates. From the general comments on this technology above, there may not be significant value in developing costs for this technology given that it is less viable than other technologies, particularly in the near-term. For hydro developments, Capital Power submits that the AESO's estimate is significantly under the realized costs of three projects recently developed in Canada (Muskrat Falls (824 MW), Keeyask (695 MW), and Site C (1,098 MW) are estimated to cost $32.1 B for a total of 2,617 MW, avg. $12,265/kW-installed). Capital Power does not foresee costs for large hydro projects materially changing over time.

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

	Questions	Stakeholder Comments
		On energy storage, Capital Power would note that costing for these projects is based on a combination of the costs of inverters (capacity, $/kW) and the cost of the storage of energy ($/kWh). Technology cost curves of each are evolving differently, with the costs of energy storage declining at a faster rate than the cost of inverters. Capital Power's own experience with wind facilities indicate that the AESO's capital cost estimate on the lower end of the costs for projects developed in Alberta. For solar though, the AESO's capital costs may be slightly higher than Capital Power's experience. While the combined cycle with CCUS costs appear reflective of the additional cost of CCUS infrastructure on-site (*i.e.* capture technology, but not any further sequestration costs such as a pipeline, and injection wells), the hydrogen-fired combined cycle option appears to have not included any costs for on-site hydrogen production and appears more in-line with network delivered hydrogen as a fuel source. As such, Capital Power suggests that the AESO make clear its assumptions on the scope the capital cost outlay covers and also its views on hydrogen costs. Finally, for hydrogen-fueled options, there is an increase in NO_X that would likely result in an increase in capital costs to install NO_X emission controls (*e.g.* Selective Catalytic Reduction or SCR). It is not clear if that has been included in this estimated cost.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	While individual projects may differ, Capital Power's plans to install CCUS on its repowered Genesee units (1,432 MW) has an estimated capex of $1.8-$2.0 B. Capital Power views CCUS as more economic on higher capacity factor units, whereas hydrogen may become more of an interest as a fuel-source for peaking capacity depending on the development of a distribution network for hydrogen.
	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).	While the AESO appears to have presented a combined cycle that draws from network delivered hydrogen (which would have to be developed), it has not included a peaking unit. The costs on and operational characteristics would be similar and would align with conventional peaking capacity.

	Questions	Stakeholder Comments
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	As the AESO develops its scenarios, Capital Power would support the AESO continuing to engage with stakeholders in a transparent manner. This way the AESO has the opportunity to gain the insights of developers and other market participants who are making long-term, significant investments where considerations such as net-zero are key.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Sonia Iqbal, CANDU Owners Group
Comments from:	CANDU Owners Group (COG) Small & Medium Size Reactor Technology Forum	Phone:	437-290-9515
Date:	[2022/01/31]	Email:	Sonia.Iqbal@CANDU.ORG

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

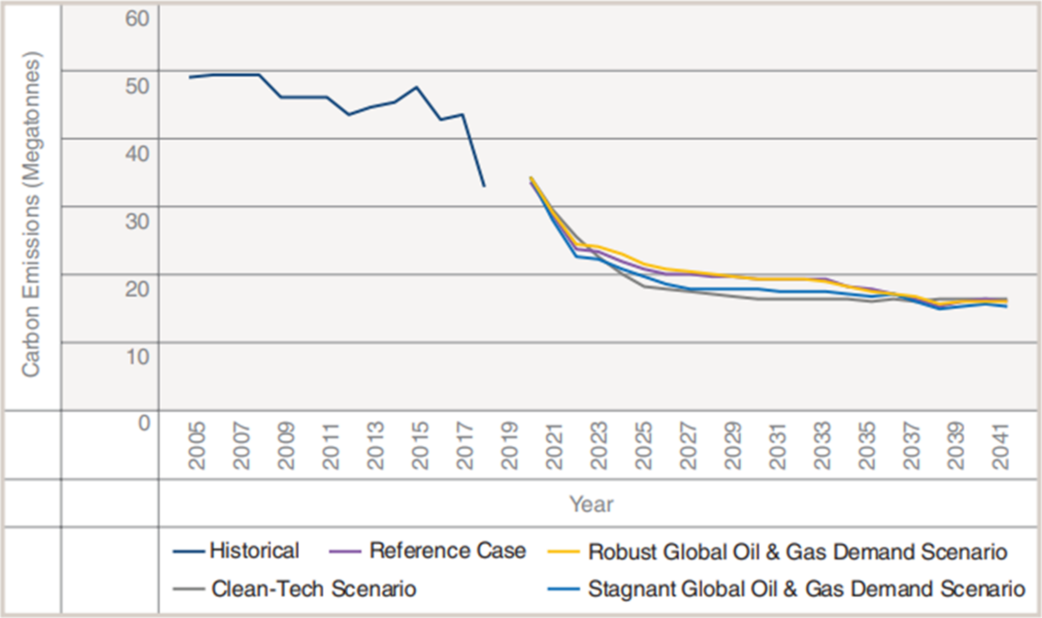
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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 Nuclear is a clean energy source that provides reliable, affordable electricity 24/7 without emitting any greenhouse gases in its operation. 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.

Questions	Stakeholder Comments
a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?	To meet the climate change objective of net zero, Canada and all countries will need nuclear power. Nuclear will be critical in providing baseload power, particularly in areas where renewables face intermittency issues. While nuclear has the capacity to provide baseload power, Small Modular Reactors (SMRs) in particular, have the potential to support co-generation with other energy innovations, and support intermittent power sources such as renewables. The high quality heat from these SMRs has the potential to produce hydrogen through steam methane reforming and their superior load following abilities have the potential to support integrated energy systems that include renewables. Nuclear power is a proven carbon-free energy source; it is a flexible, economical, safe technology which is a necessary part of the solution to achieve Canada's net zero goals and meet increasing electricity demands. International expert bodies such as the International Energy Agency have done in-depth modelling to demonstrate this (Nuclear Power in a Clean

	Questions	Stakeholder Comments
		Energy System – Analysis - IEA, and Net Zero by 2050 - A Roadmap for the Global Energy Sector (windows.net)).
	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?	Alberta's largest challenge will be changing its electric system from a largely emitting based system to a net zero system in a very short period of time. It is important to note that the expected increase in electrification will also increase the needed generation. This will require building a significant amount of new non-emitting generation as well as employing emissions reductions technologies such as CCUS. Nuclear power is capable of producing large volumes of non-emitting electricity as well as supporting the intermittent power sources such as wind and solar generation. Alberta Innovates (Deployability of Small Modular Nuclear Reactors for Alberta Applications (albertainnovates.ca)) has also identified other needs for Alberta. The most viable option to meet all the needed applications in Alberta is nuclear power, specifically with the deployment of small modular reactors (SMRs).
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?	
	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	

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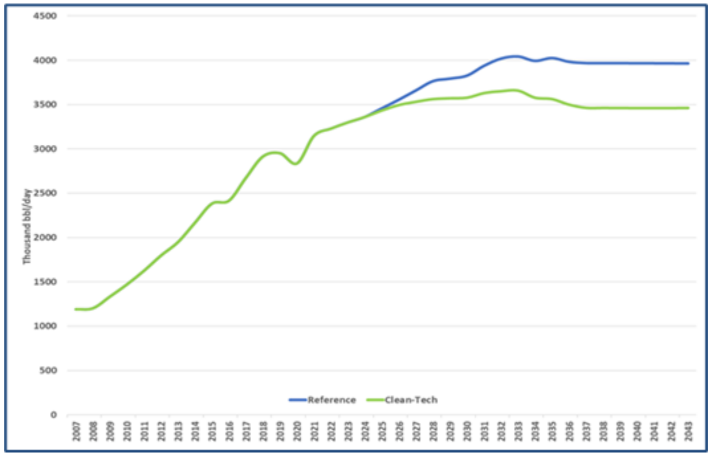
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	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?	
	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?	
3	***Policy and Electricity Value Chain Impact*** a) Do you interpret net-zero emissions targets as enabling compliance via the following mechanisms?	It is our expectation that all of the technologies employed by the electricity sector will be subject to life cycle analysis. Consequently, even low-carbon emitting nuclear power plants are aiming to eliminate or offset the small amounts of carbon that they emit (What Net Zero 2027 means for

	Questions	Stakeholder Comments
	• Offsets or credits (generated outside the electricity sector) • Offsets or credits (generated within the electricity sector) • Physical emissions reductions only	Bruce Power), including indirect emissions from the generation of purchased electricity or other energy (heating steam) that they consume.
	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?	The Government of Canada has promised the implementation of regulations that will require net zero from electricity generation by 2035. This federal policy is likely to create a dramatic increase in carbon penalties beyond the current $170/tonne target after 2030 or possibly earlier than 2030.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	A potential policy instrument available to the federal government is the legislated retirement of natural gas for power generation (which was the instrument used by the Government of Canada to force the retirement of conventional coal by 2030).
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	From an industrial perspective, new and innovative nuclear reactor technologies have the potential to improve energy efficiency through improved load following. New and innovative SMR technologies have the ability to respond in seconds to changes in demand. Certain technologies have also incorporated battery banks to accommodate load swings.
	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.)?	The smallest of the SMRs – the micro reactors (1-20 MWe) – are especially portable. They are consequently being targeted at off-grid applications at mines and in remote communities. Their portability, and their ability to produce high temperature heat, have the potential to make these energy systems, and the hydrogen energy innovations that they support, distributed.

Questions	Stakeholder Comments
	Certain SMR technologies produce high quality heat (>600ºC) that can be used to displace the heat used to produce steam and to reform the natural gas / steam mixtures in the steam-methane reforming production of hydrogen.
c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	Transportation can make up approximately 20% of the total GHG emissions in a jurisdiction (more or less depending on location, industry, etc.) In order to reach net-zero, clean fuel (e.g. hydrogen or synthetic fuels produced by non-emitting energy like nuclear, hydro, wind or solar) or else non-emitting electricity available on-demand (generally only nuclear and hydro can provide this) needs to be put in place to electrify the transportation sector. It should be assumed that this transition occurs by 2040, so that in the 2040's the focus can be shifted to the harder-to-de-carbonize sectors of the economy.
d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	Similar to c) above, though perhaps on a 2040's timeline, depending on the amount of government subsidies to enable consumer transition. It should be noted that any significant increase in electrification in buildings will require a significant increase in electricity generation. Nuclear power is capable of producing the large volumes of non-emitting electricity necessary for such a shift.
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)?	SMR technologies are best at directly providing baseload electricity. Hydrogen can be produced by nuclear and SMR technologies today, and a large increase in use of hydrogen as a clean fuel would require an increase in baseload clean electricity for its production, which would drive a need for more clean power. Carbon capture on natural gas generation requires electrical and thermal energy which reduces the net electrical output of the power plant (parasitic load). If the electricity and heat required for CCUS is supplied by SMRs, the full electrical generation capacity of the natural gas plant is maintained and overall carbon emissions from the CCUS operations are reduced. In this application, the use of SMRs to support CCUS on natural gas will not

	Questions	Stakeholder Comments
		increase industrial load but will reduce overall emissions from the operation of natural gas generation with CCUS. In addition, some SMR technologies have the potential to produce high temperature steam (not just electricity), which allows them to have co-generation capability for use with industrial applications including carbon capture and hydrogen production, potentially in a more efficient way [though not proven]. If SMRs are to be used for co-generation, the beneficial deployment of CCUS and hydrogen production could be enhanced through deployment of these technologies. Growing demand for data centres and similar are likely to contribute to a slow increase in the net overall electricity demand, so it is not sufficient to just imagine replacing current GHG-emitting baseload electricity, rather we need to build these into an increasing demand forecast, leading to a need to build more than the existing infrastructure capacity.
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?	As noted in the Feasibility of Small Modular Reactor Development and Deployment in Canada, energy generated by SMRs in Ontario and Saskatchewan is expected to be economical compared to other low-carbon alternatives and could be used to support reduction in carbon emissions and meet new energy demands. By extension, it is expected this would also apply for Alberta. There are a number of SMR technologies being developed in North America that could serve the Alberta electricity market as well as being capable of providing high output steam that is ideal for co-generation applications for use in heavy industry, oil sands and for the production of hydrogen and synthetic fuels. One such example is the ARC-100 reactor being developed in New Brunswick with an expected deployment at Point Lepreau around 2030 is expected to also be cost competitive with other low carbon alternatives. . It has also been recently demonstrated through feasibility studies that certain of the micro reactor designs are cost-competitive with diesel generation (Study Concludes eVinci™ Micro-Reactors A Real Solution For

Questions	Stakeholder Comments
	Clean Energy in Canada and https://www.opg.com/documents/smr-economic-feasibility-and-cost-benefit-study-for-remote-mining/). These technologies will be instrumental in reducing the GHG footprint at off-grid mines and in remote communities, taking Canada the rest of the way to net zero by 2050. **Note:** The intent of the SMRTF is not to identify an SMR technology recommendation for Alberta (as this is not our role). The examples listed above identify only some of the existing SMR technology projects underway in Canada, recognizing that other SMR technology options exist. It should be noted that the choice of SMR technology and speed of commercialization will play a significant role in the cost of deployment (refer to the response to question 6a)). The Feasibility of Small Modular Reactor Development and Deployment in Canada further notes that deployment of SMRs in Saskatchewan starting in the early 2030s could substantially offset the negative economic impact in Saskatchewan of the Government of Canada's mandated phase-out of conventional coal fired power generation. It is expected that if Alberta were to deploy SMRs in the same timeframe, it could reap the same benefits as Saskatchewan.
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 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 Strengths: • Nuclear is a clean energy source that provides reliable, affordable electricity 24/7 without emitting any greenhouse gases in its operation. ○ The Canadian nuclear industry helped phase out coal in Ontario, resulting in the largest greenhouse gas reduction in North America. ○ Gram-for-gram, nuclear fuel contains one million times more energy than fossil fuels.

Questions		Stakeholder Comments
	(vi) Nuclear generation (vii) Energy Storage (viii) Transmission interconnections with other jurisdictions (ix) Offsets or Emissions Performance Credits	○ To generate the same amount of energy as nuclear, solar would require about 100-200 times and wind about 400-500 times more land area. • SMRs can play a critical role in decarbonizing the electricity generation sector and resource extraction and processing in Alberta’s oil sands ○ SMRs have the ability to meet heat, electricity and steam requirements of in situ extraction of bitumen and oil sands mining. • SMRs are scalable to suit local needs and can be used to supply non-emitting, low-cost energy for off-grid application and for remote communities – particularly northern and Indigenous ones. • Potential for hybrid energy systems that can integrate SMRs with wind or solar technology to decarbonize Alberta’s grid and help phase out coal. • SMR deployment in Alberta would help offset the negative economic impact that will accompany the retirement of fossil generation. • Some SMR designs have co-generation capability for use with industrial applications including carbon capture and hydrogen production. ○ The emissions from the CCUS process are reduced when SMRs are used to provide electricity and heat, which would support a pathway in Alberta to net zero from the power grid by 2035. Weaknesses: • There may be challenges related to: ○ Establishing the necessary industry resources (human capital and supply chain) ○ Regulatory approval timelines ○ Public acceptance of nuclear in their vicinity (including interim storage of used fuel of radioactive waste and safe means of disposal of radioactive waste)

	Questions	Stakeholder Comments
		Development timelines: Nuclear power is a well-known, proven technology that has been operating safely in Canada for decades. New designs are being deployed elsewhere in Canada, and will be deployable in Alberta within the timeframe of the regulatory process. For reference, the first SMR in Ontario is targeted to be operating as early as 2028, the first SMR in New Brunswick is targeted to be deployed as early as 2030 and in Saskatchewan by 2033-2034. Under the current regulatory regime approximately 11-12 years should be the assumed deployment timeline for a first reactor in a new-to-nuclear jurisdiction like Alberta. It is expected that the timeline will shorten as additional reactors are deployed.
	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?	
	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.	
	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?	

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td><i>6</i></td><td colspan="2">
<i>Net-Zero Generation Technology Costs</i>
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 <i>Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies</i>[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.
<table>
<tr><th>Generation Type</th><th>Plant Capacity, MW</th><th>Capital Cost, $/kW</th><th>Fixed O&M Costs, $/kW-yr</th><th>Variable O&M Costs, $/MWh</th><th>Heat Rate (HHV) or Efficiency, GJ/MWh or %</th></tr>
<tr><td>Fuel Cell</td><td>10</td><td>8,442</td><td>38.78</td><td>0.74</td><td>6.83 GJ/MWh</td></tr>
<tr><td>Advanced Nuclear Fission Reactor</td><td>2,156</td><td>7,612</td><td>153.27</td><td>2.99</td><td>11.19 GJ/MWh</td></tr>
<tr><td>Small Modular Reactor – Nuclear Fission</td><td>600</td><td>7,801</td><td>119.70</td><td>3.78</td><td>10.60 GJ/MWh</td></tr>
<tr><td>Hydroelectric</td><td>100</td><td>6,698</td><td>37.62</td><td>-</td><td>-</td></tr>
<tr><td>Battery Energy Storage</td><td>50 (200MWh)</td><td>1,750</td><td>31.25</td><td>-</td><td>80% round trip efficiency</td></tr>
<tr><td>Wind Generation</td><td>200</td><td>1,594</td><td>33.19</td><td>-</td><td>-</td></tr>
<tr><td>Solar Photovoltaic Generation</td><td>150</td><td>1,654</td><td>19.22</td><td>-</td><td>-</td></tr>
<tr><td>Combined Cycle with CCUS</td><td>377</td><td>3,126</td><td>34.78</td><td>7.36</td><td>7.52</td></tr>
<tr><td>Hydrogen-Fired Combined Cycle</td><td>450</td><td>1,667</td><td>52.84</td><td>2.65</td><td>6.79</td></tr>
</table>
</td></tr>
</table>

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[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?	Small Modular Reactor – Nuclear Fission * Please note that the specified plant capacity is for large nuclear reactors; SMRs have a power capacity of up to 300 MW. The SMR costs will depend on size, technology, location and other factors. Please refer to the SMR Roadmap Economic and Finance Working Group report for capital cost estimates for on-grid and off-grid SMRs. Ontario Power Generation (OPG) has recently completed a technology assessment for on-grid SMRs, including analysis against other low-GHG options such as wind+batteries or solar+batteries, taking account of the over-build necessary for wind or solar to provide comparable capacity AND energy. SMRs are expected to be cost-competitive with these options. Such analyses should be performed for other Provinces contemplating the options in front of them.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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.	Nuclear power plants have been safely providing clean, reliable and affordable electricity to Canadians for over 50 years. Nuclear energy is an important part of Canada's non-emitting energy mix and will play an important role in achieving Canada's low-carbon future. All told, nuclear energy provides 15% of Canada's electricity supply (approximately 60% in Ontario and 33% in New Brunswick) and avoids over 50 million tonnes of carbon dioxide every year in Canada (A Call to Action: A Canadian Roadmap for Small Modular Reactors (smrroadmap.ca)). As of 2018, the nuclear sector contributed $6 billion to the economy annually, providing 30,000 direct jobs. The SMR Roadmap notes the

	Questions	Stakeholder Comments
		potential economic benefits of SMRs to Canada include an estimated 6,000 new jobs supporting a high-skill labour force, and adding up to an estimate $10 billion to Canada's GDP between 2030 and 2030. In Saskatchewan, the impact of deploying 1,200 MW of nuclear power from SMRs between 2033 and 2043 is estimated to be approximately $1.6 billion between 2022 and 2033 and $8.8 billion over the operating life of the SMR fleet. In Ontario, the impact of deploying a 300 MW SMR in 2028 is estimated to be $2.6 billion, with the operation and manufacturing/construction phases accounting for 49% and 45% respectively of the GDP generated in Ontario (A New Power: Economic Impacts of Small Modular Nuclear Reactors in Electricity Grids (conferenceboard.ca)).

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Nicole Black
Comments from:	Direct Energy	Phone:	403-463-3520
Date:	2022/01/31	Email:	nicole.black@nrg.com

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

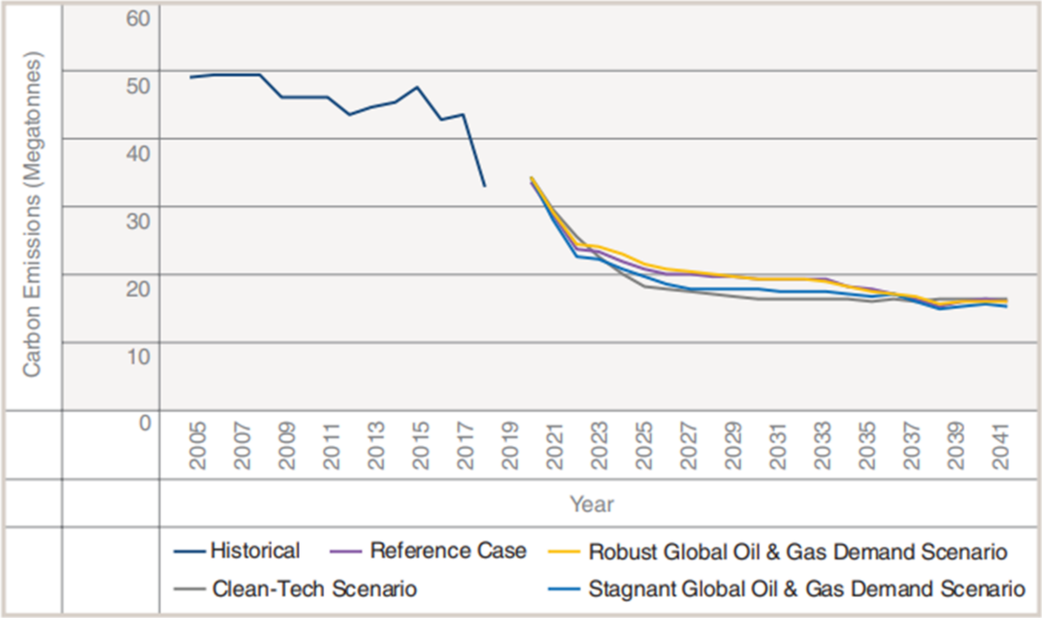
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	Consideration should also be given to: • Cost for each scenario • Public perception and feedback • Preservation of the competitive market including the role of competitive retailers in energy supply
	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?	Challenges: • Reliability of renewables • Volatility of hourly prices • Capital costs – double building generation to accommodate the intermittent renewable generation and additional connection costs • Consideration for other options to build more generation • Incentives that preserve the competitive energy market • Energy only price might not be sufficient to send the right price signals for investment

	Questions	Stakeholder Comments
		- Lasting supply chain issues - Two-way flow on distribution network from EVs - Transformer needs for neighborhoods – high consumption, high density - Lack of smart meters limits innovation and end-user control which is an incentive for consumers to help manage load
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?	- Increased prices for generation will lead to higher costs for the end consumer. - It is critical that there are offsets of costs with carbon tax reductions/ government rebates for net-zero consumption
	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**	Negative load growth should also be considered. There is a disconnect between forecasting increased load from the oil and gas sector while expecting mass EV adoption and electrification globally.

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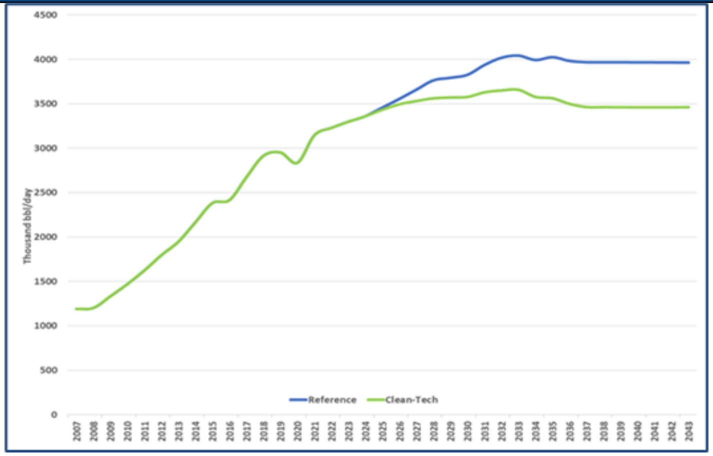
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	• Natural gas prices should be stable in the medium term as drilling has increased to compensate for low storage and the resultant higher prices • Long term, the prices could increase given the lower incentive to drill (increasing carbon pricing) and difficulties in obtaining financing plus corporate ESG goals • The demand for natural gas for heating purposes is not expected to be replaced in the medium term
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)	A pathway to net-zero emissions should consider all three mechanisms

	Questions	Stakeholder Comments
	• Physical emissions reductions only	
	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?	The carbon price will increase in the near to medium term and will stabilize in the long term. Policies, either provincial or federal, should provide guidance and certainty on how to reach the targets and should consider the impact of the offset credits on the electricity market. The fast adoption of renewables will increase costs on the system as early adoption is expensive.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Impacts: • Differences between the Technology Innovation Emissions Reduction (TIER) and the Output-Based Pricing System (OBPS) regulations • Zero-emissions vehicles / clean fuel standard vehicles could be a potential disruptor to the Alberta electric system • Price caps for wholesale or retail market • Policies to credit renewables to offset natural gas generation • Development of renewable portfolio standards (RPS)
	d) Are there any other related considerations that you would like to provide feedback on?	Political parties with different policy views lead to investment risk
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?	Energy efficiency considerations: • Smart meters are required • Large customers already have interval meters and adjust their consumption to prices • EV charging at night could lead to flatter load shape • Tools to help load shape and change customer behaviour are required • Retailer and customer access to hourly data could lead to increased energy efficiency • Energy efficiency trends should account for future government policies

Questions	Stakeholder Comments
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.)?	The view is that: • Expect more interest in net-zero DERs, especially two-way charging for EVs • An economic case should be required for an increase in DERs • There is a natural conflict of interest for building out infrastructure to support DERs – user pay versus socialized costs Other considerations: • Allow voluntary participation in the energy market for small DERs, defined temporarily as DERs under 1 MW. AESO should consider reducing the threshold to 0.1 MW, which is accepted in many other jurisdictions • Lower the asset qualification thresholds to provide operating reserves for regulating reserve, spinning reserve, and supplemental reserve from the current requirement of 15 MW, 10 MW and 5 MW, respectively, to 1 MW • Allow small DER participation in the Operating Reserve market without a requirement to submit offers in the energy market • Make changes to AESO's current operating/real-time forecast to enable forecasting of under-5MW resources at the point-of-delivery, particularly rooftop solar
c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	High levels of EV adoption and distributed solar will have a big impact on the distribution system in terms of flows reversing and worker safety issues with deenergizing lines. Pace of EV adoption will be dependent upon available infrastructure and the cost of the EV alternative. Currently the manufacturers are outpacing the capabilities of the infrastructure. With the potential increase of the electrification of the transportation sector there will be an overload to residential transformers which will result in increased costs for customers and the system. Separate incentives for EV specific infrastructure build will be required to support the electrification of the transportation sector.

	Questions	Stakeholder Comments
	d) Buildings - What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	Incentives are required to drive innovation which will increase adoption
	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)?	Considerations: - Hydrogen production it is very costly - Cryptocurrency mining and data centers might have a positive impact on prices as they could shift energy consumption between locations in other jurisdictions based on price signals. Steel, cement and petrochemical facilities are far less flexible.
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?	Nuclear generation technologies will be most economic and helpful in achieving the decarbonization of the electricity supply in Alberta, especially considering future technology improvements and the locational flexibility of SMRs.
	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 Carbon Capture, Utilization, and Storage (ii) Pre-combustion Carbon Capture, Utilization and Storage (hydrogen) (iii) Oxyfueled generation	Strengths (S) and Weaknesses (W): i) W: Unproven, expensive technology, increased infrastructure costs and transportation build costs ii) W: Unproven, expensive technology and increased infrastructure costs iii) No comment iv) W: Wind and solar are intermittent resources so require back up generation

	Questions	Stakeholder Comments
	(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	S: Proven technology v) W: Expensive with environmental impact to be considered vi) S: No need for back-up generation and net-zero emissions, proven technology W: Currently has a negative public perception vii) W: Extremely expensive with technology limitations viii) S: Additional transmission interconnections with other jurisdictions are strongly encouraged to share low carbon generation W: Current market rules limit competition ix) S: Incentivizes low carbon generation
	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?	
	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.	• An increasing percentage of intermittent renewable generation will be an operational risk for the grid. • Nuclear generation is a reliable net-zero emission source of baseload that does not have the weaknesses present with other renewable sources of generation (wind and solar). • NIMBY challenges will continue.
	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?	The emissions control technologies should be the same as for the rest of the grid.

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

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[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?	Expect the cost of nuclear to decrease over time due to increased interest and focus - similar to what has occurred with solar costs - solar costs have dropped about 70% since 2010.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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).	Interconnections should also be considered as access to low carbon power from other jurisdictions would help Alberta meet net-zero. Compressed air storage seems to be building traction and there are a couple of interesting Hydrostor projects being developed in California. Alberta could potentially use depleted gas wells as compressed air storage facilities.
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	The role of competitive energy retailers should be considered in order to encourage competitive market solutions. The expansion of utility monopolies should be limited as much as possible.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Laura Jehn
Comments from:	Enbridge Inc.	Phone:	(437) 234-3499
Date:	2022/01/28]	Email:	Laura.jehn@enbridge.com

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

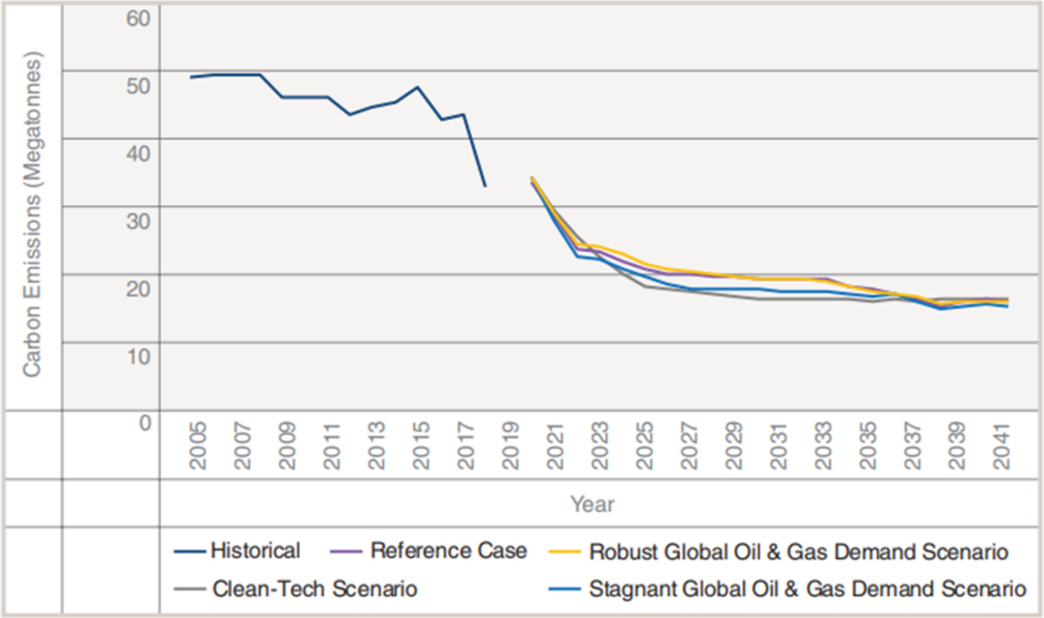
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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.

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td>***1***</td><td colspan="2">***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.</td></tr>
<tr><td></td><td>a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td>Enbridge appreciates the opportunity to provide comments on AESO’s net-zero emissions pathways analysis. As Alberta moves toward net-zero policies, it is critical that changes are made, and policies developed, in a way that continues to maximize the benefit of Alberta’s resources and its diverse, competitive electricity market.
The cost of electricity and its related emissions are key inputs for many industries, and Alberta’s electricity supply should achieve net-zero while continuing to be reliable and low-cost. Enbridge submits this is best achieved by making the best use of all options available including adding significantly more wind and solar and incorporating carbon capture utilization and storage (CCUS), RNG, and blue and green hydrogen, along with enabling offsets and credits that meet high standards of verifiability and additionality.
We look forward to participating in future consultations as AESO develops its pathways to net-zero.</td></tr>
</table>

Questions	Stakeholder Comments
	Enbridge submits that AESO should focus on the second net-zero emissions generation supply scenario described above and variables within that approach. While renewables are likely to dramatically increase their share of Alberta's electricity sector in the coming years – due to the increasing affordability of wind, solar, and power storage and due to power purchasers' adoption of voluntary Environmental Social and Governance (ESG) targets – renewables are unlikely to be the sole source of electricity on Alberta's grid by 2035. As a result, it would be a more efficient use of AESO and participants' resources to focus analysis on a variety of scenarios under a diversified economically driven generation resource addition model. Scenario variables that should be considered under this model include: - Renewables (plus power storage) providing 30% of demand, 50% of demand, and/or 75% of demand by 2035. - Consideration for each of the renewable contribution scenarios listed above, beyond 2035, including up to 2050 when Canada aims to have a net-zero economy. - Under the scenarios above, we submit AESO should also consider varying degrees to which the sectors it listed are/can be electrified by 2035. For example, scenarios where 10%, 20% and/or 30% of buildings and/or transportation are electrified by 2035. - AESO should take a whole energy sector approach where contributions from Renewable Natural Gas (RNG) and green and blue hydrogen are factored into the analysis. For example, hydrogen production can play a role in determining generation forecasts and planning, even where the hydrogen itself is not used for power generation (i.e., used instead for heavy transport or blending into natural gas for home heating). - AESO should, under each scenario, seek to understand the cost impacts associated with reliable electricity supply in Alberta, including electricity, transmission tariffs and other economic impacts to the consumer both individual and industry, as opposed to only the $/MWh of generation.

	Questions	Stakeholder Comments
		- Finally, Enbridge submits that Carbon Capture Utilization and Storage (CCUS), particularly on lower-emission natural gas generation sources, should be considered in each scenario analyzed, with consideration for its longer development timelines as compared to renewables.
	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?	Enbridge submits that Alberta's competitive market is likely to overcome any challenges where there are clear forecasts and price signals from AESO. The recent growth in Alberta's renewable energy sector indicates that resources are ready to compete in economically driven markets and that Alberta can move rapidly toward a lower-carbon grid. This trend can continue where there are clear decarbonization policies and pricing mechanisms for generation assets, including those that enable distributed energy and power storage, among other grid enhancing technologies.
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?	Electricity supply and associated costs are a significant driver of competition for new industry and investment. Any Net Zero goal should strive to keep costs competitive relative to other markets in North America.
	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	

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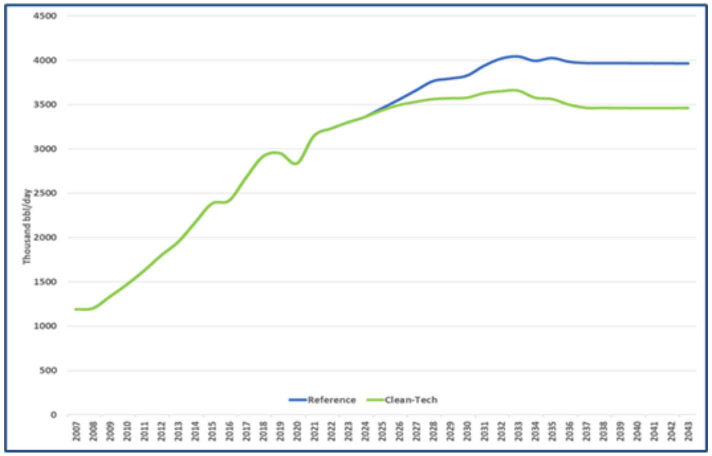
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	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-zeT of ro policies on the oilsands sector and the subsequent impact on load growth?	
	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?	Enbridge submits that carbon pricing will continue to be a driver of gas prices. At this time, the federal government has proposed an increase to $170/t by 2030.
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)	Enbridge supports the use of market-mechanisms, including offsets and/or credits, to achieve regulatory compliance or voluntary emissions reduction targets. We interpret the achievement of a net zero emissions target through a multiple pathway approach which includes not only physical emissions reductions, but also the use of credits or offsets generated

Questions	Stakeholder Comments
- Offsets or credits (generated within the electricity sector) - Physical emissions reductions only	across a portfolio of sectors and linked with the other markets to balance residual emissions. For example, Enbridge has set clear ESG targets, including reducing emissions intensity of our operations – which include gas transmission pipelines – by 35% from 2018 levels by 2030. Where Enbridge and other upstream service provides are able to reduce emissions of those upstream operations, via renewable energy BTM/FTM power, CCUS, efficiency upgrades, etc., and receive an economic return on those investments, it encourages others in the electricity supply chain to make similar investment decisions, which can reduce emissions of the electricity sector as a whole. Credits and offsets should be required to meet clear verifiability and additionality standards to ensure there have been real emissions reductions and could be limited as to number/percentage each generator is allowed to use. However, it would not be in Alberta's interest to limit paths to zero emissions only to physical emissions reductions.
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?	
c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Federal decisions regarding a potential Canada-wide Clean Energy Standard and standards for passenger and light vehicles sold in Canada could impact demand for electricity generally and for emission-free electricity. At the same time, provincial and/or federal investments in electric vehicle charging infrastructure, in hydrogen transportation, and in heavy transportation's (including public transit) adoption of hydrogen could all enable increased demand for emissions-free electricity generation and green hydrogen production. Increasing carbon pricing – beyond $170/t – at the federal or provincial level could also drive some heating toward electrification, though this

	Questions	Stakeholder Comments
		could be mitigated by Alberta establishing enabling frameworks for green hydrogen and/or RNG production and blending. In addition, ongoing demand from entities with ESG targets will continue to support demand for Corporate PPAs for renewable energy generation. Within Alberta, the increasing stringency of facility benchmarks under the Technology Innovation and Emissions Reduction (TIER) Regulation is expected to continue a reduction in the emissions intensity of the electricity grid. In turn, it is also expected to drive further investments in CCUS and renewable electricity and storage to meet compliance requirements. Finally, a range of federal and provincial funding and lending programs are expected to impact the Alberta electric system, specifically, and broad-based decarbonization, more generally. These include, but are not limited to, the Canada Infrastructure Bank, the Strategic Innovation Fund's Net Zero Accelerator, the Clean Fuels Fund, the Smart Renewables and Electrification Pathways Program, and the Investment Tax Credit for CCUS.
	d) Are there any other related considerations that you would like to provide feedback on?	There is considerable uncertainty regarding all of the public policies and potential market changes described above. AESO has not provided visibility under this consultation into what legislative changes and new policies from the Federal and/or Provincial governments it expects to incorporate into its assumptions for scenario analysis. Enbridge submits that the jurisdictions that will emerge most successful in meeting their electricity needs at reasonable, competitive costs, while also reducing emissions, will be those that cut through the uncertainty to provide clear forecasts and pricing signals to potential market participants and to end users. Where AESO is able to take a whole energy sector approach, provide a clear outlook toward 2035 that may include specific targets (e.g., a Clean Energy Standard), and establish enabling regulations with competitive, transparent, and fair procurement and pricing mechanisms, Alberta will be well positioned to lead in this transition to a lower-carbon economy.

	Questions	Stakeholder Comments
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?	Enbridge submits that grid modernization will be key to enabling meaningful energy efficiency. For example, clear frameworks for distributed energy and power storage will enable both generation and load to respond to market signals and participate in the electricity market. This will incentivize energy efficiency practices and ensure a more efficient use of the existing grid and any new transmission builds.
	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.)?	Net-zero trends and corporate ESG targets are already driving investment in solar and power storage, as well as demand-side management technologies. In its analysis, AESO should account for the impact of grid modernizations and voluntary ESG targets in facilitating participation of and demand for these technologies.
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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	Enbridge anticipates significant new investment in CCUS and green/blue hydrogen production in the coming years in Alberta which could certainly increase industrial load. Further, the development of CCUS and hydrogen solutions, we anticipate, could underpin significant new investments in low-carbon or net-zero industries, like petchems and cement. CCUS and hydrogen proponents are working with industrial partners to install solutions that could access the existing electric system <u>or</u> involve more integrated, behind-the-fence power systems. As these projects

	Questions	Stakeholder Comments
	(e.g., cryptocurrency mining, data centers, petrochemical facilities, cement, steel, others)?	materialize and further develop, the AESO will need to carefully monitor impacts to the electric system.
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?	Bloomberg NEF has consistently said in recent years that wind and/or solar are the lowest cost electricity generation technologies in North America, including in Alberta which has strong wind and solar resources. Power storage is rapidly declining in its cost per MWh, such that solar + power storage is already less expensive than natural gas in many jurisdictions. Wind and/or solar plus power storage are both less expensive today than coal and/or natural gas plus CCUS. Further reducing costs, existing wind and solar assets could be repowered, providing new power beyond the anticipated project lifecycle with minimal impact to land use, communities, and/or transmission needs. Power storage can also help reduce the need for new transmission. Enbridge submits that, as the renewable energy capacity is built and the grid modernization work is undertaken to enable two-way flow of power between load and generation, the province’s natural gas generation will nevertheless remain an important part of Alberta’s electricity sector. Gas-based pathways to reduce emissions should be considered as part of the decarbonization pathways, including CCUS, RNG, and blue and green hydrogen blending.
	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 Carbon Capture, Utilization, and Storage (ii) Pre-combustion Carbon Capture, Utilization and Storage (hydrogen) (iii) Oxyfueled generation	Many of these net-zero enabling technologies have the ability to contribute to long-term emissions reductions and net-zero targets. When considering the 2035 target timeframe, and practical development timelines for these technologies, Enbridge submits that wind and solar plus power storage provide the lowest-cost, quickest to develop technology options. Alberta’s grid is heavily coal and gas-based power resources and can take on additional renewables. As Enbridge noted above, other enabling technologies such as CCUS, RNG, and green/blue hydrogen should also be considered as contributing pathways to a net-zero grid by reducing emissions of natural gas-fired generation but the development timelines may extend closer to and

Questions	Stakeholder Comments
(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	beyond 2035, particularly by the time enabling frameworks, forecasts, and pricing signals are established. These development timelines should be considered when AESO analyzes potential paths to net-zero by 2035 and beyond. Finally, Enbridge submits that offsets and/or emissions performance credits, outside and within the electricity sector can be invaluable in directing investment resources efficiently and in supporting emissions reductions further up and down stream in the energy sector. These offsets and credits should be verifiable and additional, and may be limited in the degree to which generators can rely on them to ensure real emissions reductions.
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?	Enbridge submits that transmission within Alberta, and distributed energy and other grid modernization technologies will help support the adoption of the technologies described in part (b), in addition to making better use of low-carbon resources already connected to the grid.
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.	Energy storage will bring additional benefits to the electric system in Alberta. It supports the deployment of non-emitting renewable energy generation while also improving system reliability. Power storage can also delay or replace investments in certain transmission and distribution wires. As energy storage costs continue to fall and enabling frameworks are established, energy storage will be deployed across the province, where it will reduce costs for all ratepayers. For newer technologies, including blue/green hydrogen and CCUS, the public policy uncertainty is a significant challenge to development, e.g., generation of TIER credits, federal ITC/PTC and CFR credits. These technologies will play a crucial role in the net-zero grid and development of clear policies will unlock their potential.
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	

	Questions	Stakeholder Comments
	technologies do you believe can be most economically implemented at cogeneration facilities?	
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*	

Questions	Stakeholder Comments
	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
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Combined Cycle with CCUS	377	3,126	34.78	7.36	7.52
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[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?	Enbridge anticipates the cost of wind and solar, with and without power storage, will continue to fall in the coming years. In particular, power storage is expected to decline in cost rapidly as the technology is deployed in larger numbers internationally. Hydrogen and CCUS are in the early stages of technology development and deployment, so it is likely that related costs will also decline, but not until closer to or after 2035. In particular, clear permitting and regulatory frameworks, along with establishment of offtaker demand, in transit, blending, and other uses, will help mitigate development risk which will make projects less expensive to finance.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	Regardless of the economic outlook for retrofitting generators for hydrogen-fired generation, hydrogen should be considered a valuable component of a lower-carbon grid. For example, green hydrogen projects can use renewable energy that might otherwise have been curtailed and/or provide a secondary offtaker, in support of additional new renewable energy generation, to produce emission-free hydrogen in Alberta. This hydrogen can be used in heavy transportation and blended into natural gas heating for commercial and residential buildings, while maximizing renewable energy participation in the electricity sector. Enbridge submits that AESO should consider these non-electricity-based offtaker benefits as part of the whole energy sector view when performing its scenario analysis.
	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***	Enbridge appreciates the opportunity to provide comments at this stage of AESO's analysis. We submit that the analysis could be further aided if

	Questions	Stakeholder Comments
	Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	AESO were to share details on its proposed scenarios, for comment, prior to performing its modelling work.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Jessica Halland
Comments from:	Enfinite	Phone:	403-615-7594
Date:	2022/01/29	Email:	jhalland@enfinite.com

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

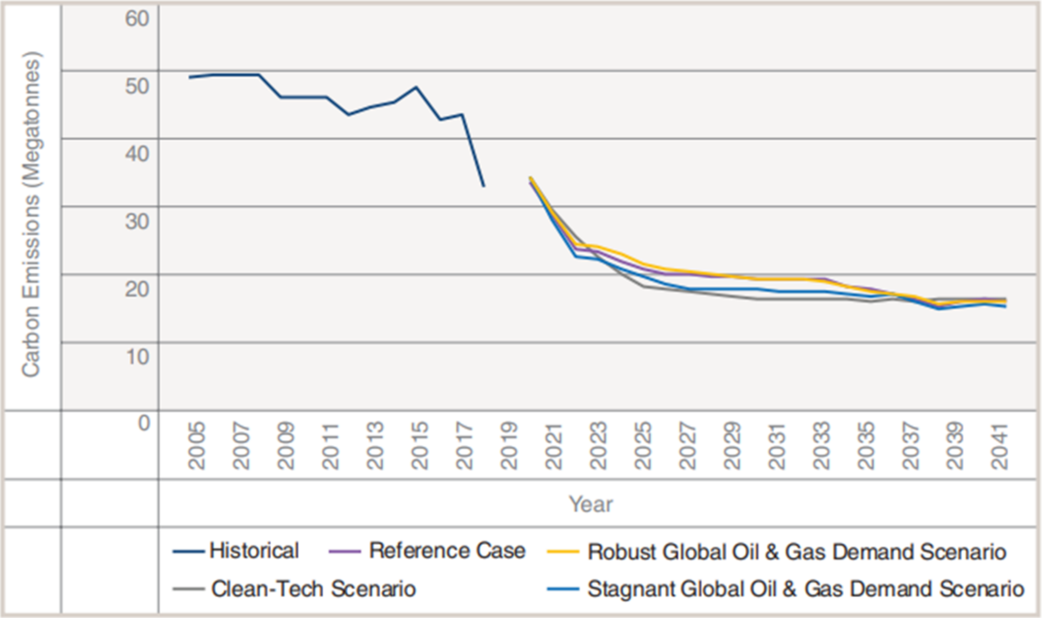
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	Enfinite thanks the AESO for the opportunity to submit comments on this significant matter. As a leader in energy storage, Enfinite is supportive of the intended scenarios and analysis that the AESO has identified, particularly in terms of renewables paired with energy storage. Energy storage is incredibly versatile and plays a critical role on the pathway to net-zero. Decarbonization of the grid in Alberta is not possible without energy storage. This is particularly due to the relative uniqueness of utility-scale storage including its flexibility in switching between load and supply, potential portability and the variety of competitive services energy storage can supply makes it an essential component of decarbonization. Storage can provide transmission services at a much lower cost and have less environmental impact than that of traditional transmission builds. Storage is also a vital component in enabling renewable energy on a larger scale. Without the ability to store energy from products such as solar and wind, the issue of intermittency will remain. Climate modeling and energy system assessment studies have shown that an electricity sector with net-zero emissions, and an increasing share

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	of electricity in the end-use fuel mix, is a cornerstone of an energy system in a carbon neutral world and the most economical way to achieve this is the pairing of renewables with energy storage. Further, reducing peak demand is a significant benefit for ratepayers as electricity costs are increasingly becoming a key focus of the market.
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?	Energy storage faces several regulatory and policy barriers to deployment on a large scale. Enfinite submits that the largest challenge on the path to net-zero is the lack of policy signals from the government regarding storage and market design. The lack of direction to give investors' confidence in the Alberta energy market will result in further delays to the approval and construction of energy storage on a larger scale further resulting in delays to the integration of renewable technologies into the system. There is no clarity or direction in the current legislation indicating how regulatory bodies and agencies will take into account energy storage when creating rules and putting pricing mechanisms in place. Energy Storage Canada expressed the view that the technological progress made in recent years with respect to Distributed Energy Resources (DERs), including energy storage, requires a fundamental shift in mindset and the existing regulatory framework from segmenting the industry into discrete classifications. In Alberta, policy has yet to be adopted that enables storage to function as both a non-wires solution and a product in the Ancillary Services (AS) market. Enfinite submits that enabling this is key to the success of net-zero by 2035. Electricity plays a key role in the path to net-zero and storage is essential to this becoming a reality. Without energy storage there will not be opportunities for growth in the renewable energy space to the degree required to meet net-zero. There is increasing momentum towards investments in renewable technologies in Alberta, but mechanisms need to be put in place to allow energy storage to enable renewables on a larger scale. Energy storage technologies require significant investment and policy direction now to ensure reliability of the grid in a cost effective, net-zero enabling and streamlined way. Energy Storage is changing the way electricity is consumed, as it enables renewables integration to better match supply and demand. Recent

	Questions	Stakeholder Comments
		developments in energy storage technology have achieved significant cost reductions through technology improvements and scaling-up of manufacturing. While providing many significant benefits to the power grid, energy storage projects currently face a variety of challenges and risks in the Alberta market. An opportunity for storage to act as a non-wires transmission solution and "share the load" with transmission is a key enabling reform that policymakers should pursue immediately. This is the most cost effective and efficient net-zero solution for the province as it modernizes its electricity grid. The electricity grid is one of the few large-scale systems that must continually adapt to balance the supply and demand in real time. Integration of storage allows for a smoother and well controlled transition during periods of flux.
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?	Enfinite is concerned that there will be a negative impact to rate payers if the anticipated changes and regulated infrastructure are not distributed over a longer period and that new products that can significantly decrease costs are not utilized effectively. In an inflationary environment, increased energy costs will create a public misconception that the power market is not functioning. Allowing energy storage facilities the flexibility of being utilized as both a reliability service and operating in the market would bring investor confidence into this emerging market, help meet net-zero demands, further strengthen reliability of the grid, alleviate the regulatory burden and substantially decrease electricity costs for rate payers. Further, the AESO needs to factor in these significant changes and their impact on engagements such as the Operating Reserves (OR) Market Review. Until the treatment of these products is defined and established, making changes to the OR Market is premature.

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

Questions	Stakeholder Comments
	Enfinite submits that there is an increasing appetite for renewable technologies such as wind and solar in Alberta. Although we agree that the transition from thermal to net-zero enabling products is necessary to meet the mandate, there needs to be a responsible transition to ensure reliability of the grid in a safe and cost-effective way that benefits rate payers while not imposing punitive targets on existing supply. There needs to be consideration regarding impacts of retirement of existing assets prematurely and their effect on market price and reliability.
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**	Modeling Alberta's hydrocarbon growth is difficult at this time as there are a number of federal and provincial policy changes that have yet to be implemented. It is difficult to determine what the outcome of these policy changes will have on the growth of this industry at this time.

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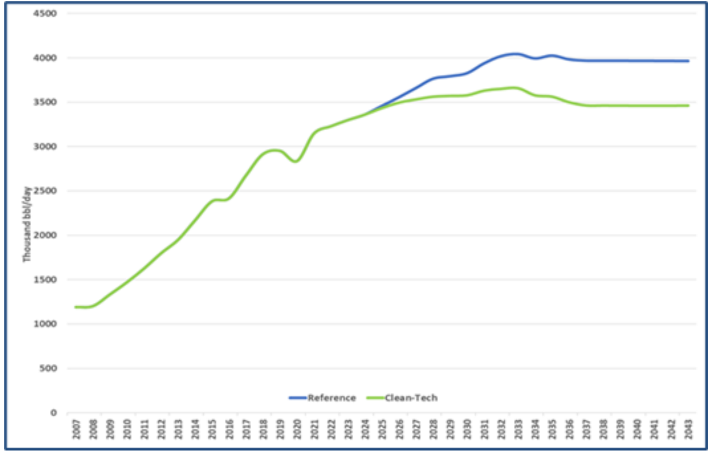
[2] https://ihsmarkit.com/research-analysis/canadian-oil-sands-running-above-prepandemic-highs.html

	Questions	Stakeholder Comments
	 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?	
	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?	Enfinite submits that factors such as increased carbon pricing, inflation, production and procurement concerns, and the cost of carbon abatement technology will increase the cost of gas. These key drivers will have a substantial impact on gas prices moving forward.
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	Enfinite submits that mechanisms like offsets or credits, both inside and outside the electricity sector, are the only way to enable the level of investment in Alberta required to meet the growing demands of electrification of the grid as well as meet the net-zero mandate of 2035. Without an incentive such as credits, the significant investments that Alberta requires to maintain reliability of the grid with the projected increase in demand will be deployed elsewhere, and cost-effective renewable integration systems, such as energy storage, will not attract the investments required to meet these demands.

Questions	Stakeholder Comments
	In order to meet net-zero emissions targets in the electricity sector, energy storage requires different treatment. Some suggested mechanisms for enabling this technology on a larger scale include: • Creating a mechanism for energy storage to be compensated as a dispatchable load (charging) in times of excess generation; • Consideration for existing and in process energy storage assets to provide regulated transmission reliability services; • Energy storage projects should receive emissions reduction credits as they act as Renewable Integration Systems; and • Develop new reliability products to meet the AESO's mandate. There must be clear policy signals to guide investors and enable those responsible for operating and regulating electricity markets to implement these essential pricing mechanisms. Without these clear signals to investors, renewable energy investments will likely not be scalable as they will not be enabled without energy storage. There needs to be a market framework through credit mechanisms to attract investment in this significant and necessary technology if we want to achieve net-zero in the electricity sector by 2035. Alberta is on track to reduce electricity emissions by 40 megatonnes primarily due to the accelerated phase-out of coal fired generation. This is a significant accomplishment but further reductions at the forecasted rate are unlikely to happen without significant investment in storage.
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?	Enfinite expects that carbon prices will continue to increase in line with the federal mandate until 2030 and it is reasonable to expect further increases from 2030-2050 as Canada strives to meet net-zero targets. With escalating carbon pricing, it becomes less feasible and economical for owners to keep carbon emitting assets operational. Options such as retrofitting and opportunities for Carbon Capture, Utilization and Storage, are currently capital intensive and we can expect investment to flow to more efficient clean technologies beyond 2030.

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	Although Enfinite submits that mechanisms such as carbon pricing are fundamental to meet the targets of net-zero electricity by 2035, there needs to be a responsible transition plan in order to ensure assets are retired without negative environmental, societal and economic impacts. Further, the government needs to signal to industry that there is a reliable transition plan in place to ensure that reliability of the grid remains as older facilities are decommissioned, and electricity demands increase. Enfinite reiterates that energy storage is crucial to this reliable and responsible transition and policy needs to be enacted now to ensure commercial viability and investor confidence.
c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	The proposed Electricity Statutes Amendment Act, and its treatment of energy storage, will have a significant impact on investments and the application of these technologies in Alberta. We, as an industry, need to ensure that the government understands how crucial storage is to the success of the net-zero mandate. AESO's current tariff proceeding before the Alberta Utilities Commission will need to be revised to align with these policy directions as upcoming changes will have a material impact on the current and proposed tariff design. Further, as significant changes are made in policy to define and consider the treatment of energy storage in Alberta, there need to be updates to other legislation that will govern this sector. In particular, the Transmission Regulation needs to be reviewed to align with these changes. There are a number of further reviews and engagements that will impact the Alberta electric system. Until we have clarity of the federal government's targets and credits for carbon intensive industries, it is impossible to appreciate the impact of this. Other reviews that need to be considered are a review by the Alberta Government of the Technology Innovation and Emissions Reduction Regulation (TIER).
d) Are there any other related considerations that you would like to provide feedback on?	

	Questions	Stakeholder Comments
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?	As there are more incentives from government in terms of grants and tax breaks to promote energy efficiency, there will be an increase in these technologies being adopted on a wider scale. We can also expect significant regulatory changes that will further accelerate energy efficiency across sectors including: • Net-zero building codes being developed by the federal government for provincial adoption by 2030 • Increasing carbon prices • New high-efficiency standards for heating / cooling equipment and other key drivers of energy use in the commercial building sector
	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.)?	Enfinite submits that Distributed Energy Resources (DERs) support and encourage a low carbon economy. Policies set at all levels of government, together with changes in consumer preferences favouring lower carbon emissions, will increase the demand for electricity and lead to a higher penetration of renewable energy sources. The cost of investments in decarbonization will likely decline when technology improvements in digitalization and decentralization are leveraged. DERS will continue to grow as environmental mandates are the priority of the government and the social license is there. As stated above in detail, these technologies face a number of barriers in the current market but are the key to net-zero by 2035.
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	Municipal, provincial and federal mandates and the move towards net-zero will accelerate the pace of electrification in the transportation sector. Forecasts show a substantial increase in the use of EVs (electric vehicles) which will have a substantial impact on load, particularly if the use of EVs are used in the commercial and industrial fleet. If the use of EVs continue to trend in the current direction, this will have a significant impact on the grid and large-scale infrastructure will need to be put in place. Additional thought must be placed on the change in demand profile for the grid, as a significant portion of EV (Electric Vehicle) charging will take place in the evening hours.

	Questions	Stakeholder Comments
	d) Buildings - What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	As energy efficiency becomes adopted on a larger scale, this will likely become standard practice for new builds. The AESO should take into account the proportionately small percentage of residential load to industrial load when modelling the impact of these changes.
	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)?	The deployment of pre and post CCUS will likely have a sizeable impact on industrial load if it is adopted on a large scale. As industry grows, there is an obvious impact on load that needs to be taken into account. A high parasitic load is required to run CCUS which will result in a loss of net power being delivered to the grid. Current technology has seen losses in the 20-25% range. We can expect load growth as all sectors move to increase electrification to meet net-zero mandates.
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?	Enfinite believes that energy storage paired with renewables is the most economic pathway to decarbonization. Energy storage is the most socially responsible, operationally reliable, and economically sound decarbonization solution that will benefit the grid as well as ratepayers. As storage is adopted on a wider scale, cost is expected to decline significantly, and storage will be the most cost-effective way to ensure grid reliability and enable renewable energy as we move towards net-zero 2035 targets.
	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 Carbon Capture, Utilization, and Storage (ii) Pre-combustion Carbon Capture, Utilization and Storage (hydrogen)	**(i) Post-combustion Carbon Capture, Utilization, and Storage** **Strengths:** ability of the technology to be retrofit to existing facilities may increase its prominence in the future, unique ability to reduce emissions at the source, reduces social and environmental impacts of C02. **Weaknesses**: CCUS can require significant amounts of solvent or sorbent chemicals, drives a large amount of parasitic load at power generation facilities; capital intensive; long-term storage capacity is uncertain.

Questions	Stakeholder Comments
(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	**(ii) Pre-combustion Carbon Capture, Utilization and Storage (hydrogen)** **Strengths:** currently being utilized, relatively safe based on data, relatively little maintenance, profitable as creates carbon offset credits. **Weaknesses:** chemical adsorption process is not environmentally friendly; prohibitive cost; cannot be retrofitted to the older facilities. **(iii) Oxyfueled generation** **Strengths:** coal power plants can be reconfigured to burn oxyfuel without changing the boiler design, nitrogen free, remaining gas can be compressed, dried, and purified much faster and more inexpensively than traditional methods before being moved to storage. **Weaknesses:** turbines require a redesign to operate with oxygenated fuel due to high temperatures. **(iv) Renewable generation including wind, solar, geothermal, and biomass** **Strengths:** less environmental impact, economical, and low carbon. **Weaknesses:** intermittent in nature. Site specific which can create transmission congestion. **(v) Hydroelectric generation** **Strengths:** natural renewable energy source, flexible and able scale up and down quickly to meet changing energy demands, cost competitive. **Weaknesses:** hydroelectric-generation applications are limited by the hydrology and landscape of an area, finding sites with quality hydrology and economically developable resources can be challenging, high upfront capital costs for construction,

Questions	Stakeholder Comments
	higher rate of failure due to natural disasters, high methane emissions, dame to ecosystem. **(vi) Nuclear generation** **Strengths:** highly reliable energy source, smaller environmental impact. **Weaknesses:** waste management and safety concerns coupled with poor economics of the technology, highly regulated, high operating costs. **(vii) Energy Storage** **Strengths:** helps balance supply and demand on the electrical grid, enables variable non-dispatchable renewable energy resources such as wind and solar. frequency regulation, peak shaving, deferral, or substitution of investments in transmission and black-start capability. enables electricity produced at times of low demand, low generation cost or from intermittent energy sources to be used at times of high demand, high generation cost or when no other generation is available. **Weaknesses:** lacks policy direction and pricing mechanisms required to ensure investor confidence in the market. **(viii) Transmission interconnections with other jurisdictions** **Strengths:** reliability. **Weaknesses:** price volatility. Although the above technologies are in different stages of commercialization and market acceptance, it is clear that there is an ongoing push for renewable generation. In 2021, 677 MW of new wind energy and 288 MW of new utility-scale solar energy was commissioned in Canada and Alberta accounted for more than 60% of that growth. More than 3,000 MW are expected to be commissioned in 2022 and a similar number in 2023. Solar and wind are the lowest cost source of electricity generation available in Canada. Energy storage technology will need to

Questions	Stakeholder Comments
	meet the growing demand of these renewable technologies in order to maintain reliability of the Alberta grid. If the AESO looks at the energy storage market in the US, it is clear that the growth in this industry is astronomical and does not show signs of slowing down. Some forecasts anticipate deployment of energy storage systems across utilities grow by over 29% by 2024. Growing investments toward development of efficient, reliable, safe and sustainable electric infrastructure along with supporting policies could strengthen these numbers.
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?	
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.	To reiterate, energy storage is the most beneficial technology listed above because it has the unique ability to function in several ways. It can assist in managing the variability of other renewable energy technologies, improve grid efficiency and reliability by storing excess energy to meet peak demands, relieve congestion, provide reliable backup power solutions and serve as a non-wires solution for the transmission and distribution systems.
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?	

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	-	-
Energy 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

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[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?	Enfinite submits that fixed costs for energy storage are likely to decline following greater adoption by 2035. As represented in the chart above, it is clear that pairing solar and wind with storage is the most efficient, cost-effective and net-zero enabling way of ensuring reliability of the grid while meeting the federal mandate. As these technologies are well into the market acceptance stage, they have a well-developed procurement plan, and it is expected that costs will continue to decrease. Further, the versatility of energy storage makes it an attractive option that can reduce transmission costs, solve the issue of renewable intermittency, provide frequency modulation to the electricity system and ensure reasonably priced baseload power for Albertans.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	Retrofitting thermal generation for smaller generation facilities is cost prohibitive. Further, retrofitting cannot be adopted older generation facilities at this time.
	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.	Alberta is in a strong position to meet net-zero mandates through energy storage, but the government needs to put policy in place to enable this technology. As storage is adopted on a wider scale, the cost is likely to decline significantly and become the most cost-effective way to ensure grid reliability and enable renewable energy to be adopted on a larger scale. As a leader in energy storage, Enfinite is ready to take on the challenge, but immediate action is required from legislators, regulatory bodies and other key decision makers to enable these industries to deliver the results required to meet net-zero by 2035. There also needs to be clear policy signals to guide investors and those responsible for operating and regulating electricity markets. In summary, and as stated above, electricity plays a key role in the path to net-zero and storage is essential to this becoming a reality. Without

	Questions	Stakeholder Comments
		storage there will NOT be opportunities for growth in the renewable energy space. Energy storage technologies need significant investment and energization now to ensure reliability of the grid in a cost effective, net-zero enabling and streamlined way. If we, as a province, want to be a competitive destination for such investment, we need to clearly define and deliver on objectives for the future build-out of new wind, solar and energy storage, and the scale and timing of the path we are taking to get there.

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

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Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Mark McGillivray
Comments from:	ENMAX Corporation	Phone:	
Date:	2022/01/31	Email:	MMcGillivray@enmax.com

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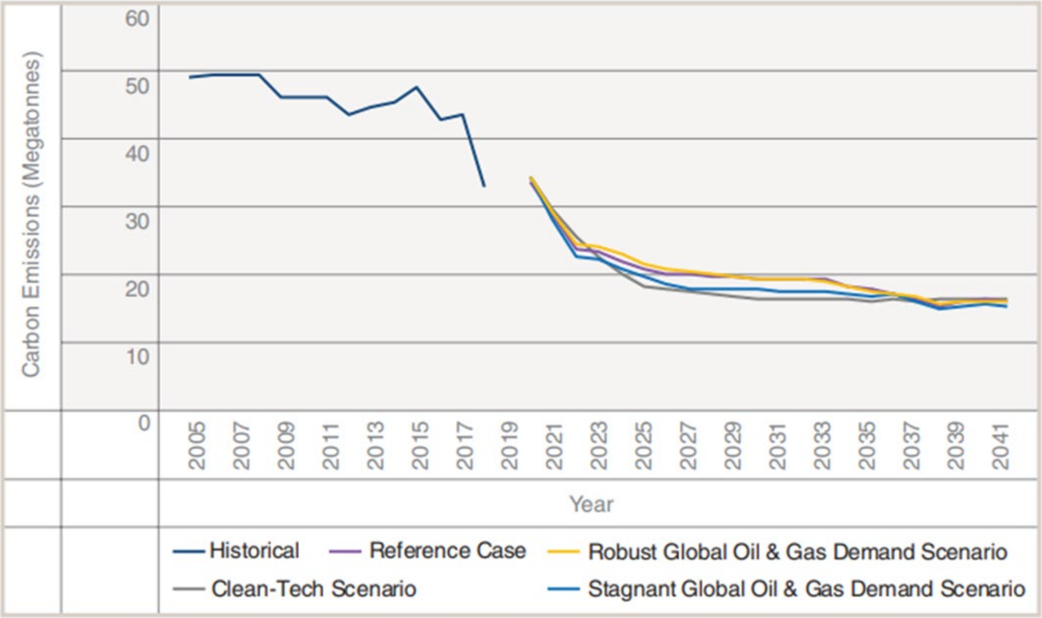
Alberta's electricity generation fleet has undergone significant transformation. Formerly a greenhouse gas intensive, primarily coal-fired generation fleet, Alberta's generation infrastructure has been converted and replaced with cleaner, less emissions intensive natural gas and renewable generation 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.

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?	This scenario planning is to inform the AESO long-term outlook report and should not be considered policy input or advice to any policy makers. It is merely a single scenario based on assumptions. Each assumption can have a large impact on the end result in the analysis. A projection of Transmission and Distribution builds and associated costs is required to understand the total cost impact from the expected increase in renewable builds, along with how different system designs would impact that cost. By only referencing Generation builds, this underestimates the total cost of any generation scenario on Albertans. Net-zero pathways will also need to consider the system as a whole – transmission, distribution, utility scale generation, distributed generation, customer responses to the changing system, new anticipated forms of demand for electricity (such as Electric Vehicles (EVs)), as well as how non-wires solutions and management of Distributed Energy Resources (DER) can reduce costs on the system. The AESO should provide a detailed description of what net-zero means in their analysis. The details of the definition have some potential to

Questions	Stakeholder Comments
	create confusion and it could be different then the terms used in other discussions.
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?	A few of the challenges that ENMAX foresees arising as the transition to net-zero continues are noted below. Ultimately, a balanced approach to maintaining grid stability and reliability, while also supporting the continued growth of renewables is key. In general, it will be important for the AESO to not be overly reactive to the short-term challenges, but rather, focus its efforts on maintaining market confidence along with continuing predictable and consistent business practices. Given that many of the challenges will extend down to the distribution level, Distribution Facility Owners (DFOs) will continue to manage impacts to their respective systems as well as work with the AESO to mitigate impacts on the transmission system. **Electrification in the Transportation Sector** • A rise in electrification efforts within the transportation sector will increase load/demand and result in more dynamic and complex energy flows on the distribution system. While this is mainly an issue for DFO's to manage, this is something for the AESO to keep in mind with the upcoming changes in consumption patterns and customer preferences on how they use electricity. **Variability of Energy Storage Resources** • Given smaller distribution connected energy storage resources have the ability to charge and discharge at any time, these resources will need to be coordinated with each DFO, while considering the distribution system constraints in real time. Given their detailed understanding of distribution systems, DFOs remain in the best position to coordinate these resources in their service territories. **Stranded Assets** • Rapid adoption of new technologies to meet net-zero targets may lead to premature retirement of existing technology. The AUC will need to

	Questions	Stakeholder Comments
		be clear about all associated impacts on ratepayers and investors and the Utility Asset Disposition issue will need to be addressed. **Cost Impacts to Consumers** - Rapid cost increases and a lack of broad support programs will risk the ability and willingness for all Albertans to participate in the transition to net-zero.
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?	Over the long term, but before 2050, a protracted or permanent decline in the oil and gas sector, combined with higher than expected adoption of energy efficiency and carbon reducing technologies, particularly in the industrial sector, could see sustained flat or slight negative demand growth in some areas of the province. Net-zero targets particularly with an emphasis on electrification efforts in transportation could contribute to load growth due to EV charging needs and changes in consumption patterns for some residential customers.
	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**	No comment.

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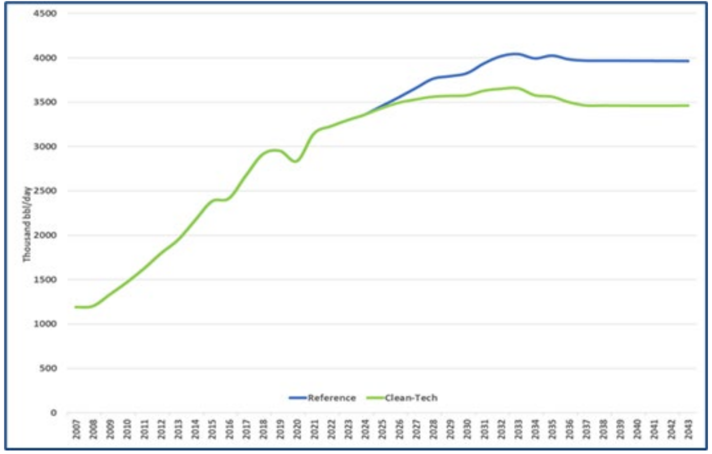
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	In the short term, the forward AECO curve up to 2027 needs to rally a bit to incentivize large scale drilling and production. A key driver will be US and Canadian federal environmental policy and transition plans towards a net-zero economy.
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	We foresee the nature of offsets continuing to evolve over time. Currently, the ability to use different types of offsets generated outside of Alberta in the future is not yet clear. We would expect the market to use all available compliance tools and select the least cost options appropriate for their own needs.

Questions	Stakeholder Comments
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?	ENMAX cannot speculate beyond what has been announced publicly. Based on our understanding of the current situation, the Technology Innovation and Emissions Reduction Regulation (TIER) will be reviewed before 2023 and every five years afterwards. It is reasonable to expect that Alberta would remain in line with federal carbon pricing and equivalent to the federal carbon tax framework.
c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Future policies relating to the integration of DER and EVs have the potential to impact load growth and generation development. With that, it will be important to consider the cost and tariff treatment of new and emerging technologies. Legislation and the regulatory framework must evolve to better consider environmental benefits and not just cost minimization in their decision. Additionally, monitoring will need to continue to ensure that uneconomic by-pass is mitigated, and customers are paying their fair share of the grid. In addition to cost and reliability, we are likely to continue seeing new policies place more emphasis on factors relating to environmental benefits and efficiencies. Of note, the following policy matters relating to the electricity sector remain outstanding and the outcomes on each of these areas will directly impact Alberta's transition to net-zero: • Bill 86 which includes potential changes to facilitate unlimited self-supply and export, participation of energy storage, and the modernization of distribution systems • TIER review expected before 2023 • Federal and provincial targets and announcements relating to net-zero emissions and EVs • Policy and support for hydrogen resource uses • The use and support of carbon capture technologies • The ability for non-wires solutions to be owned or procured as a service by DFOs and Transmission Facility Owners (TFOs)

	Questions	Stakeholder Comments
	d) Are there any other related considerations that you would like to provide feedback on?	It is important to consider the interplay between different policies and objectives being issued at both the provincial and federal level, and any potential misalignment of these policies and related timelines. For example, Alberta residential and building heating to be electric or thermal based (using hydrogen) seems to have conflicting approaches.
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?	The strongest driver to greater energy efficiency across sectors will likely be increasing prices over time. This will be aided if flexible rate options are advanced within Alberta and available to smaller consumers to better incorporate efficiency technology and react to market signals. Given that energy efficiency broadly encompasses all technologies, some out-of-market signals like building codes, appliance/lighting regulation, and government support programs could also help drive this change over the short-term. Utility-led Demand Side Management (DSM) programs (which include demand response and energy efficiency retrofits) could also encourage businesses and homes to better optimize electricity use and be efficient (through things like HVAC improvements, recommissioning, lighting upgrades, etc.), and may prove more economic for customers and ratepayers. In fact, the experience of jurisdictions across North America have proven significant customer benefits of DSM programs and that utilities are well-suited to develop and implement DSM programs. The impacts resulting from energy efficiency will be highly dependent on whether energy efficiency participates in new market mechanisms to achieve new revenue streams (or avoid high enough costs in volatile markets with certainty) to attract investment.
	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.)?	ENMAX would expect that DER growth would be closely tied to economics and new government policies around net-zero. As the drive to net-zero continues, DERs down to the residential level will play a large part in the energy transition. ENMAX continues to work to better understand the opportunities and challenges presented by DERs on its distribution system, and the legislative and regulatory framework required to enable their integration.

Questions	Stakeholder Comments
	As we see more DERs come online, more dynamic agreements will need to be established between DER owners and DFOs prior to connection. Increased coordination between DFOs and DER owners will remain important to manage grid flows and costs to customers, as well as maximize hosting capacity for new customers and further DER installations to optimize the existing infrastructure of the grid.
c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	The pace of transportation electrification will likely be influenced by regulation, incentives and availability of EVs and charging infrastructure. While Alberta does not currently have a significant volume of EVs, ENMAX Power forecasts that EV adoption could reach more than 200,000 vehicles by 2035 in Calgary. Despite federal EV policies that continue to be announced, Alberta will continue to be challenged in this space until clear direction is provided by the Provincial Government or AUC on how DFOs should proceed with electrification efforts, especially as it relates to making the necessary investments to support EVs in our service territories. In general, the magnitude of impacts will be dependent on charging behavior, including location, the time of day, how long they keep it plugged, and what charging technology they use, as well as assumptions around technology advancements, subsidies, tariff approaches and adoption rates.
d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	See response to Question 4a). Currently, there is not any clear provincial policy or goals related to building and transportation electrification in Alberta. Similar to EVs, the pace of electrification in buildings will require the proper incentives and/or price signals. A potential misalignment between provincial and federal policy goals could also be a challenge.
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	Carbon Capture will be a key element in managing a transition towards net-zero for the electricity sector. Its use in other sectors will be essential for their emission reductions but only electricity has a 2035 net-zero goal.

	Questions	Stakeholder Comments
	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)?	The impact of net-zero on other industries (such as those mentioned) remains unclear, but it can be assumed that these industries could include further trends of electrification, use of energy management systems, and DER to help reduce the increased electrical infrastructure required. Continued monitoring will be required through updated load forecasts and economic analysis to understand the direct impact that net-zero targets will have on other industries.
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?	Given Alberta's oil & gas technical expertise and infrastructure, it is likely that some form of Carbon Capture, Utilization and Storage (CCUS) will be used to meet net-zero objectives. While flexible thermal generation will still be required to maintain reliability until technology is able to guarantee reliability at a reasonable cost, further alternative lower carbon intensity fuels (e.g., Renewable Natural Gas, Synthetic Gas, and Hydrogen) could be used to meet net-zero objectives with existing or new thermal generation units. In addition, other pathways could include stand-alone storage or pairing energy storage resources with existing or new generation.
	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 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	**(i) Post Combustion CCUS** - ENMAX understands this technology is capable of reducing emission from generation units in Alberta. The access to storage locations using former natural gas wells is an option for exploration, especially given Alberta's unique and robust oil & gas expertise. - CCUS will be a critical element for the electricity sector to transition and maintain grid reliability while enabling more intermittent resources to deploy. **(ii) Pre-Combustion CCUS (Hydrogen)** - ENMAX's high-level understanding is that pre-combustion CCUS has a higher efficiency than post-combustion CCUS, but with higher capital costs. This would be easier to accommodate in a new greenfield facility.

Questions	Stakeholder Comments
(vii) Energy Storage (viii) Transmission interconnections with other jurisdictions (ix) Offsets or Emissions Performance Credits	**(iii) Oxyfueled Generation** • No comment. **(iv) Renewables** • Renewables can help accelerate path to net-zero and be paired with other technologies to help maximize overall value to the grid. However, the intermittent and non-dispatchable nature of renewables will pose challenges and will need to be managed with added reliability products and services. It also needs to be recognized that these projects can require the addition of more grid infrastructure if they are not located close to existing wires capacity. **(v) Hydroelectric generation** • No comment. **(vi) Nuclear generation** • No comment. **(vii) Energy Storage** • Energy storage is becoming more prevalent in response to an increase in variable renewable generation connecting to the grid as well as a continued decrease in technology costs. • Recognizing that energy storage can be configured to fit several different applications, further definitions in ISO rules for energy storage greater than 5 MW in size are expected. Any AESO developed storage rules should not infringe on the DFO's ability and obligation to continue managing their distribution system in a safe and reliable manner. • To ensure energy storage benefits are fully realized and system impacts are mitigated, coordination of users of this technology (when it is distribution connected) with the DFO will be required. The way in which DFOs operate their systems will also need to evolve in an unencumbered manner to accommodate an increase in two-way power flows.

Questions	Stakeholder Comments
	(viii) Transmission interconnections with other jurisdictions - ENMAX supports using the existing interties and allowing for merchant investments to explore the viability of new interties. Given Alberta's unique electricity market structure, it needs to be well understood that our provincial neighbors may have an ability to distort our market and impact the FEOC market with an unlevel playing field advantage. **(ix) Offsets or Emissions Performance Credits** - See response to question 3.
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?	No comment.
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.	See response to question 5b.
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?	The definition of net-zero is a key requirement in determining what changes and investments are needed in the Alberta electricity sector and with Alberta supply resources. At this time, ENMAX is not certain if net-zero emissions will be required from cogeneration facilities by 2035 and captured under the electricity industry emission targets or under their other industrial use function. This is a policy decision that has not been made. If they are required, the most likely front runner technology for emissions controls would be CCUS or some form of emissions credit system.

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

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[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?	Could be impacted by factors such as economic feasibility, technology advancements and any increase in federal or provincial rebates or subsidies.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	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).	No comment.
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	No comment.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Lisa Lemish
Comments from:	EPCOR Distribution & Transmission Inc.	Phone:	780 969 8210
Date:	2022/01/31	Email:	Llemish@epcor.com

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

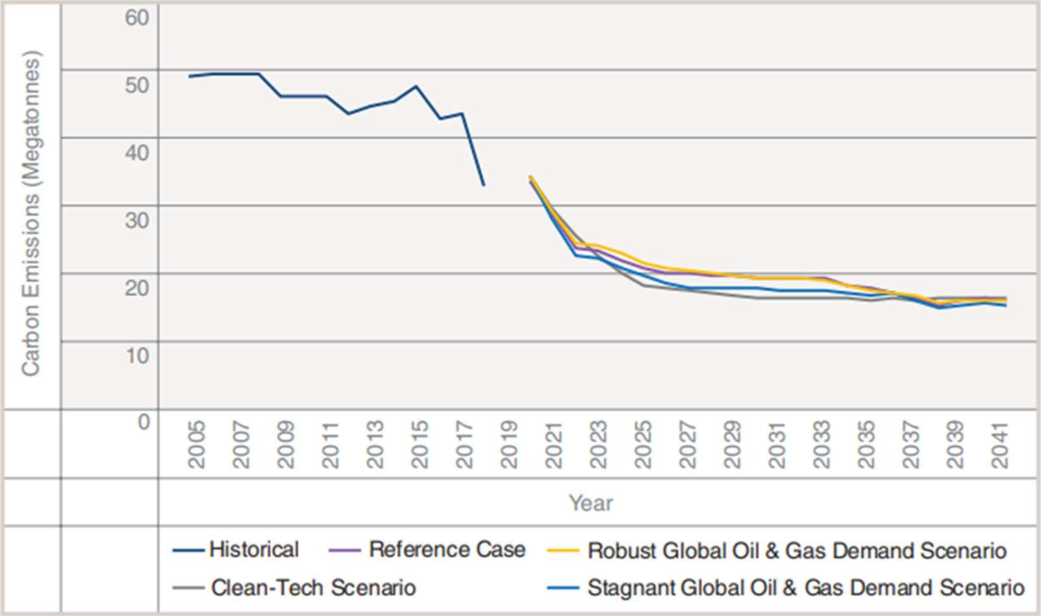
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	EPCOR is supportive of the work the AESO is undertaking to better understanding pathways and challenges associated with achieving net-zero. EPCOR agrees with the intended scenarios and analysis included in the Technology Forward Report.
	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?	As greater electrification is seen as a pathway to net-zero, one of the largest challenges will be ensuring supply adequacy during a period where the pace at which the demand growth for electricity is difficult to predict. Increasingly aggressive federal targets to achieve net-zero emissions will further accelerate the pace of change and will drive increased demand. A further challenge will be minimizing the cost impact on ratepayers during the transition to a net-zero future. EPCOR expects to see impacts soonest on it distribution system. As Alberta moves towards a net-zero future, the way Albertans use the electricity grid will evolve, with electric vehicles, distributed energy generation and energy storage playing increasing roles in the electricity system. These consumer behaviours change the way power flows from

	Questions	Stakeholder Comments
		and into the grid. As the owner of an electric distribution system, EPCOR is working to develop solutions to efficiently and economically accommodate the adoption of Distributed Energy Resources (DERs).
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?	Net-zero targets will drive demand for electricity higher than what has been experienced historically. For example, EV adoption is expected to have the most significant impact to this expected change in electricity use and the pace at which EV adoption take place is likely to increase at a rate higher than economic growth forecasts. Current electric vehicle forecast models for the Edmonton area predict an increase in peak demand of approximately 20% by 2035 as a result of federal targets to have 100% of new passenger vehicle sold to be zero emission vehicles (ZEV) by 2035. Higher electricity costs may negatively impact economic growth in the province. To the extent that higher rates are required to support the deployment of additional infrastructure to meet net zero targets, there would be economic impacts to customers. Assuming that net zero targets apply to the entire electricity system (not just generation), EPCOR anticipates that incremental costs to ratepayers will be incurred for eliminating or offsetting the primary sources of emissions in the distribution and transmission utilities (e.g. vehicle emissions, building energy consumption, and minor emissions from SF6).
	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	EPCOR does not have any comments on this approach.

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

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

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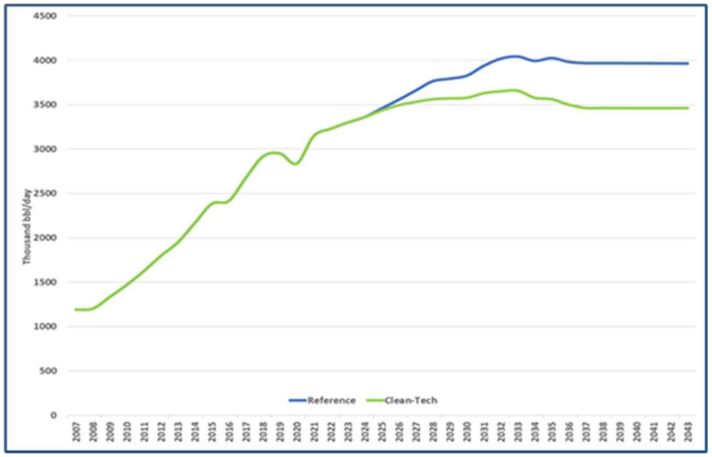
expansions to represent a scenario with no further sectoral growth (see chart below).

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?

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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?

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EPCOR has no comment on future prices of commodities.

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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

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Yes, EPCOR is of the view that a combination of the listed options (i.e., offsets or credits generated outside the electricity section, offsets or credits generated within the electricity sector) and physical emissions reductions) can help achieve compliance of net-zero emissions targets.

Each of the following mechanism will be important to enable compliance of achieving net zero emission targets. For example, as a utility, EPCOR has committed to reduce its companywide greenhouse gas footprint 50% by

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	Questions	Stakeholder Comments
		2025, relative to 2020 emissions. This initial goal will be achieved by using 100% green electricity for all of EPCOR's Edmonton-based operations. Examples of the pathways and actions undertaken by EPCOR to meet its targets include developing an on-site solar resource to power its Edmonton water operations, and a green power initiative that is leading to the development of a new wind power resource in southern Alberta. Together, these are expected to reduce net emissions by more than 95,000 tCO2eq per year. Upcoming strategic initiatives will identify the best ways to achieve the deeper reductions needed to meet EPCOR's 2035 and 2050 targets. The accelerating pace of vehicle electrification, the growing potential for renewable natural gas as a source of energy, and the greening of the electricity grid supply, are each potential enablers of emission reductions. However, reaching net zero will require internal innovation, and close collaboration with regulators and policymakers.
	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?	While EPCOR does not have a specific comment on the forecast of carbon prices in the future, EPCOR is of the view that carbon pricing is one mechanism to potentially reduce GHG emissions and transition to a de-carbonization of the economy. EPCOR expects that as the price of carbon increases, energy efficiency and implementation of new technologies to manage electricity consumption both on a utility and end-user perspective will factor into consumer's decision making processes.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Policies and potential changes that could impact the Alberta electric system include: • Acceleration of electric vehicle adoption targets will increase demand for electricity on distribution and ultimately a transmission systems, where substations and related infrastructure may require replacement or upgrades earlier than forecast. • Increases to carbon pricing has the potential to make the price of electricity more elastic to end-users than it currently is. Large industrial users may look at self-supply options (if possible) to meet their energy needs; and smaller, residential customers may become more aware of

Questions	Stakeholder Comments
	how they use electricity to avoid additional expenses associated with the increase cost of electricity. • Greater ability for large industrial users to self-supply and export to the grid, as described above, will also lead to changes to forecast methodologies. • Changes in policy/regulation that allows DFOs to manage DERs connected to distribution electric systems to monitor reliability by offering services to the grid such as voltage support and frequency regulation. • Changes to how retailers bill end users for energy consumed (i.e. not the delivery and transmission of electricity). For example, time-of-use energy rates depending on rate structure and the ability for end-user to respond to real time price signals will impact how these customers may consume energy. If regulations change to support wide adoption of Time-of-Use pricing for energy only, DFOs will likely see more batteries. At-home batteries may also increase their role in supporting rapid EV charging at home. • Diversity in the different sources for power generation, and policies affecting the use and adoption of alternative generation sources (e.g. hydro, nuclear, hydrogen) could lead to more interconnectivity between provinces as Alberta moves away from electricity generation from fossil fuels. • Regulatory reform that removes barriers for the use of battery storage, demand response and smart grid operators will change how operators manage the grid. For example, incentives for demand-side response of the application of different grid technologies would encourage the innovative solutions to managing grid congestion (e.g., load aggregators, micro-grids). • Changes on how generation is incented to produce energy (e.g. energy only vs capacity market) can impact supply and price of electricity and ultimately demand.

	Questions	Stakeholder Comments
	d) Are there any other related considerations that you would like to provide feedback on?	The Alberta electricity industry, unlike other parts of Canada, is still reliant on fossil fuels for electricity generation. Though Alberta has made investments in alternative forms of energy, the province is well below the national average (83%) of electricity generation coming from non-emitting sources. Developing policy that would allow regulated utilities to access provincial and/or federal grant funding related to grid modernization and to accommodate new generation technologies could minimize the impact of ratepayer increases and also may accelerate changes on the Alberta electric system as the industry moves to a net zero future.
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?	EPCOR at this time has not prepared any detailed studies on the penetration of greater energy efficiency adoption. With the forecast for electricity expected to increase more than what has been experienced historically, energy efficiency and conservation campaigns will play a more significant role in reducing strain on the grid. EPCOR anticipates that greater emphasis will be placed on customer education campaigns to communicate how customer behaviours impact the electricity grid, especially as the adoption of EVs increases (i.e. education on the optimal times to charge EVs). The increasing cost of electricity, including costs associated with the delivery of electricity, could also start to influence customer behavior. Historically, non-industrial consumers, have not responded to price changes in the same way as other customers. Short-lived increases to the price of electricity are generally endured by non-industrial customers without much change in the overall demand for electricity. However, should the price of electricity experience sustained increases due to the impact of carbon pricing, infrastructure upgrades, supply issues, increased demand due to electrification of transportation and heating, it is likely that non-industrial customers could start changing their electricity consumption to minimize the impact of higher electricity prices. Similarly, the overall cost of electricity and how rates are structured will also impact demand for electricity. Although time of use rates are not employed by retailers for residential customers, the ability to respond to real time price signals could reduce electricity use, especially during periods of peak demand. The shift towards time of use rates would require that wide distribution of behind the meter devices that could be used with an AMI meter to provide real time price signals. Advancements in new technologies will assist consumers use

Questions	Stakeholder Comments
	electricity more efficiently and adapt to changing market conditions as consumer reliance on electricity increases.
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.)?	Demand side management technologies are expected to take on an increasing and important role in relieving supply and demand of electricity as Alberta moves away from coal generated electricity. The increased use of distributed connected generation (DCG) will also be dependent on the advances in battery technology that will make storage of electricity more economical on a mass production basis. As adoption of DERs on Alberta's electricity grid becomes more prevalent, utilities must consider their impact when planning and operating their system to relieve congestion on the grid. Coordination between the AESO, utilities, load customers and third-party developers will be required to maximize the benefits of such technologies in achieving net-zero targets. This includes finding ways to monitor and manage the challenges of increased DERs connected to the grid. Specifically, utilities will need to determine how to address: • increased two-way power flow, particularly given that certain types of DCG are intermittent and no DCG is controlled by EPCOR; • protection and coordination requirements to safely and reliably integrate DCG into the distribution system; and • voltage and frequency fluctuations on the distribution system, to maintain customer service connections within permissible voltage limits. The use of distributed energy resources (DERs) has potential to become one of many approaches to achieve net-zero targets. Integration of DERs onto the distribution system to reduce net feeder demand requires that DERs must be able to provide capacity relief during peak load periods. DERs such as solar, could reduce demand as long as peak demand coincides when solar is generating electricity (which is often not the case). DERs can also help regulate active power, reactive power or both, and potentially mitigate many of the voltage issues that arise on a circuit. For example, the response time of an inverter-based generator (a type of DER) can regulate output much more quickly than traditional voltage control devices (such as line regulators or switched capacitor banks). If the DER output is coordinated with existing utility voltage control and provides

Questions	Stakeholder Comments
	voltage support when needed, adverse impacts can be reduced. DERs have the potential to improve reliability, but the technology must be dependable and sited in a location where it can effectively deliver power during system failure events.
c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	In studies commissioned by EPCOR to determine the impact of increased EV growth on its system, peak demand for electricity is likely to increase by 20% by 2035 on EPCOR's distribution system, representing approximately ten times the yearly growth rate compared to historic rates. EPCOR expects that the growth in demand will require additional infrastructure (in excess of normal growth) to support an increase in ZEVs. In addition to incremental infrastructure deployments, the increased load due to EVs will also present opportunities for utilities to advance the development and use of non-wire alternatives and technologies on their electric systems (e.g., demand side management systems and other non-wires alternatives). Ultimately, utilities will need to adapt and find cost effective solutions to manage the increased load to support EV's connecting to the grid. Utilities cannot solely rely on building additional capacity through traditional means (i.e. wires and related infrastructure) as the cost for such a build in such a short timeframe will lead to increases in customer utility bills at levels that have never been experienced before. However, it is important to note that solutions to managing the increase in load using new technologies will require time to research and implement within utility systems.
d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	EPCOR has not specifically studied the impact of electrification of space heating/cooling and/or water heating in detail. Electrification of building heating and cooling systems is an area of study that will be reviewed in the future, however EPCOR expects the penetration and pace will be less than the electrification of transportation. For example, it will be important to understand the rate of change of customers moving from natural gas to electricity for their heating and cooling needs. Today, it is difficult to clearly identify the impact of electrification of heating and cooling has on overall load. The net impact of the electrification in building is not as pronounced as it is as the electrification of transportation and is captured in the overall growth in demand used by EPCOR. The more gradual transition of the

	Questions	Stakeholder Comments
		electrification of space heating/cooling and water heating may be mitigated by solutions to meet the demand from the electrification of transportation. As customers move towards the electrification of space heating/cooling and/or water heating, there will be a lower tolerance for interruptions cause by either disruption of supply from the wholesale market or the distribution system. Policy makers will need to consider how to maintain reliability for users, especially during the colder winter months.
	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)?	EPCOR has not completed detailed analysis on the impact of the industrial sector deploying new production processes.
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?	EPCOR has not completed any detailed analysis on what technologies are the most economic pathway to decarbonization of the electricity supply in Alberta.
	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 Carbon Capture, Utilization, and Storage (ii) Pre-combustion Carbon Capture, Utilization and Storage (hydrogen) (iii) Oxyfueled generation	As solar and wind generation increases, EPCOR anticipates seeing an increase in utility-scale battery storage to account for the intermittent nature that solar and wind technologies offer the grid. As coal is phased out, an increase in natural gas, nuclear, biofuel, or other generation sources, or additional interprovincial ties to other provinces/states may be required to offset the decrease in electricity generation from coal. Examples of the benefits and uses of utility controlled energy storage (ES) systems include the ability to engage in voltage regulation and control, peak shaving, load shifting, renewable energy smoothing or ramp control, frequency regulation, voltage and VAR support, outage management and power quality management.

Questions	Stakeholder Comments
(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	EPCOR is not currently aware of any trending data such as penetration for energy storage in a consumer setting or specific analyses of when energy storage will become economically viable.
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?	EPCOR does not have any additional comments on this topic.
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.	EPCOR does not have a view on most of the technologies listed in the previous questions, however, EPCOR assumes that there will be cost and reliability considerations, especially as it concerns solar or wind generation which may pose operational risks to the electric system in Alberta.
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?	EPCOR does not have a view on this topic.

	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

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[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?	EPCOR has not completed analysis to determine if the data in the table above is representative of costs associated with net-zero generation technologies.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	EPCOR does not have a view on this topic.
	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).	EPCOR does not have any additional comments on net-zero generational technology.
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	Utilities play an important role in supporting community resilience and help customers reduce their own environmental footprint, including activities such as working to modernize the electricity grid, support community-level energy transition, increase the supply of renewable natural gas, promote efficiency, and make it easy for customers to charge electric vehicles and self-supply electricity from renewable sources. It is important that the regulatory framework and provincial policies support the development and implementation of new technologies and reduces market structure barriers to the deployment of distributed generation and energy storage.

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

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
Comments from:	Energy Storage Canada	Phone:	647 627 1815
Date:	2022/01/31	Email:	jrangooni@energystoragecanada.org

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

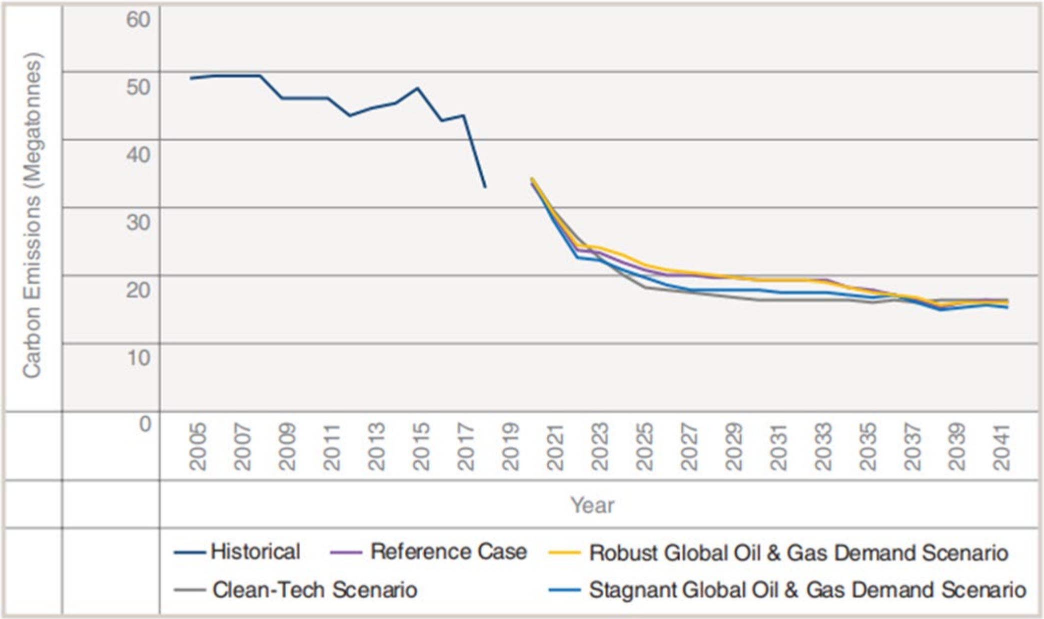
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?

	Questions	Stakeholder Comments
		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?).

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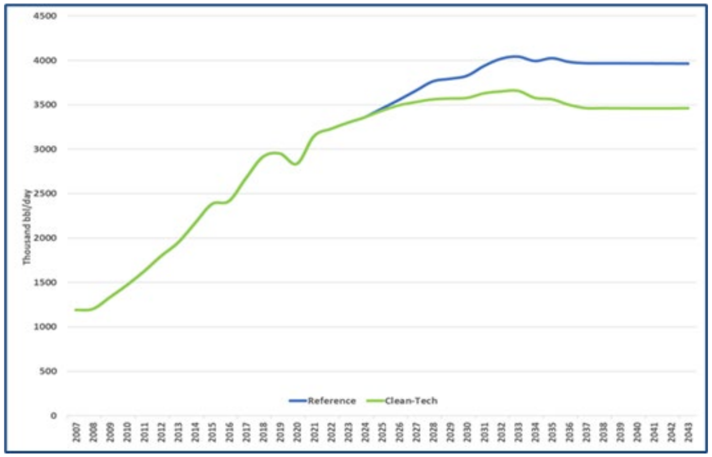
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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.

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[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.

	Questions	Stakeholder Comments
	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.

	Questions	Stakeholder Comments
	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

	Questions	Stakeholder Comments
	(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

Questions	Stakeholder Comments
	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

	Questions	Stakeholder Comments
	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

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[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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Kevin Noble
Comments from:	FortisAlberta	Phone:	403-650-4695
Date:	2022/01/31	Email:	Kevin.Noble@fortisalberta.com

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

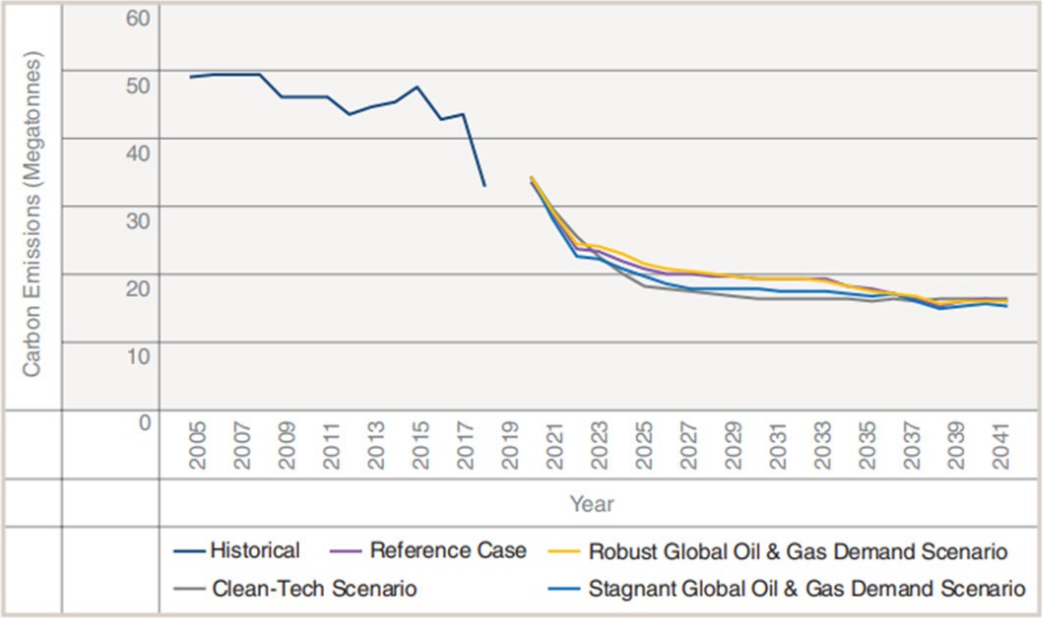
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	N/A
	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?	N/A
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]	N/A

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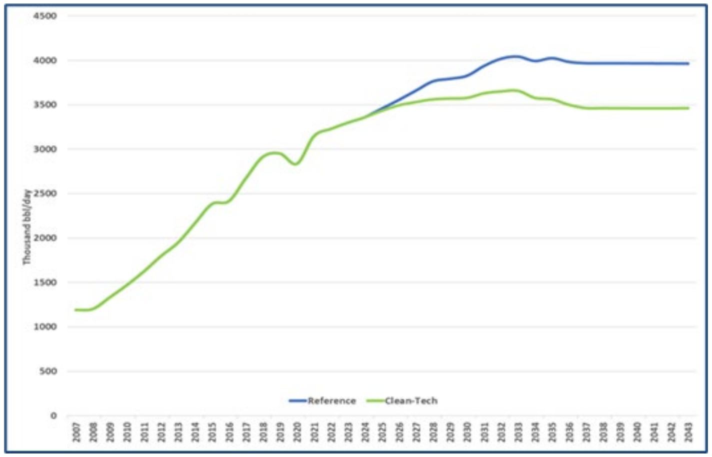
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

Questions	Stakeholder Comments
a) What is your view on the economic impact of expected net-zero targets on this business-as-usual scenario?	
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	N/A

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

	Questions	Stakeholder Comments
	scenario for analyzing the impact of net-zero policies on the oilsands sector and the subsequent impact on load growth?	
	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?	N/A
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	N/A
	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?	N/A
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	There are many federal policies already in place that will impact the Alberta electric system. For example, the federal governments Homes and Buildings initiative seeks to implement energy efficiency standards, including the development of a “net-zero energy ready” model building code, with the goal that provinces and territories adopt it by 2030. Also, the federal government’s electric vehicle mandate “will pursue a combination of investments and regulations to help Canadians and industry transition to achieve the 100% zero-emission vehicle sales by 2035. It will also work with partners to develop interim 2025 and 2030 targets, as well as additional mandatory measures that may be needed beyond Canada’s light-duty vehicle greenhouse gas emissions regulations”. Mandates like these could require different or more flexible investment options for distribution utilities, such as the use of Demand

	Questions	Stakeholder Comments
		Side Management (DSM) programs to mitigate the impact of increased growth on the electricity system. As the provincial government works to release its own climate strategy, provincial policies, such as legislating distribution utilities to administer DSM programs including demand response, energy efficiency and non-wires alternatives will be necessary to allow for greater flexibility and resiliency of the system. Other policies may also need to be updated to reflect the growing need to reduce emissions and ensure equitable participation in the green carbon economy.
	d) Are there any other related considerations that you would like to provide feedback on?	N/A
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?	Demand Side Management (DSM) is the primary way to manage both costs and risks within the electricity system. DSM is a group of actions, activities and programs that influence consumer behaviours to lower energy usage. DSM encompasses energy efficiency (EE) and demand response (DR) programs as well as non-wire alternatives (NWA), such as battery energy storage systems, EV and EV charging infrastructure, distributed generation, and grid software and controls. DSM typically involves supporting customers in making energy efficient choices and participating in demand response programs to reduce both individual and system-wide costs. While DSM programs can be less than one percent of total system costs, they deliver multiple customer benefits, including increased customer satisfaction, reduced disconnection and reconnection costs, lower wholesale energy costs and wires charges, local job creation and carbon emission reductions. DSM initiatives also lead to greater customer understanding and awareness of the different components of their energy bill and provide increased transparency on the effects of reducing energy usage to better control costs. DSM approaches also have the potential to enable greater integration of DER through Distributed Energy Resource Management Systems (DERMS) and other related technologies. One of the biggest opportunities for customers via the energy transition is to enable them to become active participants. The

	Questions	Stakeholder Comments
		electricity grid incorporates more than just generation, transmission, and distribution infrastructure. In fact, it is an ecosystem of asset owners, manufacturers, service providers, government, and regulators working together to strengthen, transform, and improve energy infrastructure to ensure consumer access to reliable and secure sources of energy. The potential for substantive EE penetration can only be achieved through a stable administrative and investment funding model. The predominant model for funding DSM investments is through distribution utilities. In North America, over 90% of DSM programming is funded through the distribution utility given the cost-savings and benefits to the customer and system achieved. Distribution utilities are ideally situated in the energy landscape to provide targeted investment that meets customer needs and expectations while managing the complex and changing nature of the grid caused by additional multi-directional power flows, increased electrification and new technologies. Other mechanisms have been used for energy efficiency investment but most programs outside of distribution utilities rely on government budgets or carbon tax funding that are subject to changing priorities, including funding cuts, that can impact the longevity and overall benefits of energy efficiency. The ideal way to trigger additional and greater investment in energy efficiency, is to enable Alberta utilities through legislated policy, to invest in DSM and unlock the multiple benefits to the system, environment and customers that can be realized through DSM. Furthermore, all customer segments, residential, commercial and industrial can be included in targeted, prescriptive DSM programming that effectively matches their current and future needs. FortisAlberta recently submitted its 2023 Cost of Service Application to the Alberta Utilities Commission. In Appendix G, the Company requested three pilot DSM programs to clearly demonstrate the opportunities, challenges, barriers and benefits that DSM programs can bring. For more information, please see FortisAlberta's 2023 Cost of Service Application, Appendix G, Demand Side Management https://www2.auc.ab.ca/Proceeding26615/ProceedingDocuments/26615_X0039_Appendix%20G%20-

Questions	Stakeholder Comments
	%20Demand%20Side%20Management%20Program%20DSM_000050.pdf#search=appendix%20g%20fortisalberta
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.)?	FortisAlberta is experiencing accelerating interconnection of utility scale renewable DERs, and energy storage. Industry research indicates that the overnight capital cost of photovoltaic panels and battery energy storage is expected to continue to decline until at least 2030. This combined with the rising cost of carbon taxes and government grants will in turn accelerate the adoption of DER technologies by residential and commercial consumers. FortisAlberta expects that increasing electrification trends, especially in the transportation sector, will continue in the near to mid-term future. In response to increasing electrification and proliferation of DERs, it will become necessary to manage grid capacity, and by extension rates, in a more agile manner. FortisAlberta expects that demand-side management will become necessary to manage grid congestions, particularly on the secondary side of residential distribution transformers where most electric vehicles are expected to charge. FortisAlberta expects that load aggregation technologies will become available in Alberta in response to market needs. In the mid to long-term, FortisAlberta expects increasing interest in community and industrial micro-grids to meet resiliency and ESG needs.
c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	Alberta has seen a modest growth in electric vehicles to date, with existing trends indicating a increased rate of growth in the passenger vehicle market. Previous trending reports from AESO are in line with FortisAlberta's forecasts. Light and medium duty vehicles are also seeing an increase in growth, similar to the forecasts of the passenger vehicle market, though these will have different isolated impacts on the distribution system.

Questions	Stakeholder Comments
	Heavy duty vehicles are less clear as there is a rise in competition with fuel cell electric vehicles FCEVs.
d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	Many organizations including BILD Alberta and developers are exploring the technologies and challenges that will assist in the decarbonization of home cooling and heating systems as one aspect of a net zero home. Determining how best to retrofit and pay for existing brownfield infrastructure will be different than finding ways to support integration of lower carbon fuels, renewable energy and other electrification technologies for new developments. For example, a potential study to determine when the increasing cost of carbon (i.e. $170/tonne) would effectively intersect with the higher cost of a combined heat and power unit given the lower carbon footprint and greater efficiency of the technology might be required. How can the building industry, utilities and other stakeholders work together to ensure the right infrastructure is in place to support EV adoption and other carbon-reduction strategies, while maintaining affordability? These are questions that will need to be addressed with a multitude of stakeholders including federal and provincial governments, municipalities, industry associations and the regulator to help determine a path forward.
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)?	N/A
Generation Technologies	N/A

	Questions	Stakeholder Comments
5	a) What net-zero enabling generation technologies do you perceive as being the most economic pathways to decarbonization of the electricity supply in Alberta?	
	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 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	N/A
	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?	N/A
	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.	N/A
	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	N/A

	Questions	Stakeholder Comments
	technologies do you believe can be most economically implemented at cogeneration facilities?	
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*	

Questions	Stakeholder Comments
	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
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[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?	N/A
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	N/A
	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).	N/A
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	N/A

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Jim Hunter
Comments from:	Friends of Science Society	Phone:	18887899597
Date:	2022/01/31	Email:	contact@friendsofscience.org

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

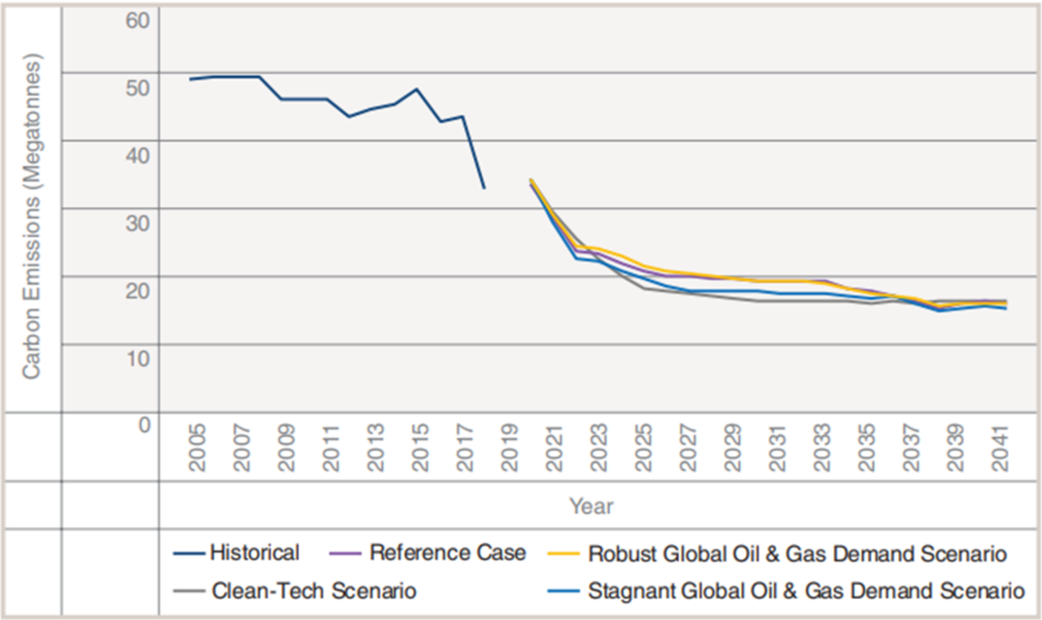
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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.

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td><i>1</i></td><td colspan="2"><i>Net-Zero Analysis Scope</i>
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.</td></tr>
<tr><td></td><td>a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td>Cost matters! People want to be good stewards of the environment, but there is a limit to how much they are willing and able to pay. An October 2021 Associated Press poll found that 59% of Americans said Earth’s warming is very or extremely important to them as an issue; however, only 52% said they would support a $1 a month carbon fee on their energy bill to fight climate change, and the support dwindles as the fee increases. Albertans may be willing to pay more, but there is still a limit. Any CO_2 emissions reductions plan that makes electricity unaffordable for a large number of Albertans will do far more harm than good—even under the dubious assumption that CO_2 is the dominant driver of Earth’s climate.
Net-zero policies are being established in the absence of any real understanding of the cost. The public has never been told the cost by politicians, either because those politicians don’t know themselves or because they fear voter backlash when the true cost becomes known.</td></tr>
</table>

Questions	Stakeholder Comments
	The AESO has a statutory duty under the Electric Utilities Act to provide for the safe, reliable, and economic operation of Alberta's electric system, which we submit imposes on the AESO an obligation to inform ratepayers, taxpayers, and governments of the cost of achieving net zero. Few electricity ratepayers think about or care where their electricity comes from; they simply want a safe, reliable, and affordable supply. If achieving net zero results in unaffordable electricity, they will rebel, and the government's plans for net zero will be abandoned or revised to include only the most efficient parts. Therefore, the AESO should also include in its report the estimated economic efficiency, expressed in $/tonne, of various CO_2 reduction technologies. For the technologies presently being evaluated that have not yet been commercialized, risk-adjusted $/tonne values should be included. The timeline of creating a net-zero electricity grid by 2035 is extremely aggressive and is likely to either: (i) force the premature adoption of technologies that have not yet been fully developed, scaled, tested, regulated, permitted, commercialized, or constructed, thereby producing significant cost and operational risks; or (ii) the adoption of wind and solar generation with battery storage, which at today's costs would result in a highly unreliable grid or out-of-reach electricity prices, both of which are poor outcomes for Albertans (see 5(b)(vii) and 6(a) below). The AESO should make it clear to policymakers that the 2035 deadline introduces substantial risks into what is a mostly futile endeavor anyway (since any reduction in Canadian CO_2 emissions are likely to be quickly swamped by increasing emissions in the developing world). One of the unnecessary risks being driven by the too-short deadline is that the probability that all potential zero-CO_2 technologies can be properly evaluated, and that the best one can be selected by developers, designed, permitted, constructed, and commissioned, is near zero. Some (limited) set of technologies would have to be selected and implemented

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		prematurely. This, in turn, may force government involvement in technology selection and financing, and governments have poor track records in this type of enterprise. A less aggressive timeline would: allow new technologies to be efficiently developed, assessed and implemented; more private sector participation; and a broader range of technology choices being made. The scenarios proposed in Figure 34 are all very similar, so other than cost then the primary considerations must be reliability and safety. In summary, we submit that projections of both the future cost of electricity and the per-tonne cost of CO_2 emissions reductions must be included in the AESO's pathways analysis, even if the error bounds on those numbers are still wide. This is so even though, as we understand it, the scientific and political justifications (or lack thereof) for net zero are beyond the AESO's scope.
	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?	The single biggest challenge will be keeping electricity affordable because, notwithstanding frequent pronouncements from its advocates, renewable energy is NOT cheaper than conventional energy in Alberta once all the costs of turning renewable energy into reliable energy are accounted for. Since electricity is an input cost for almost everything, the potential for serious economic <u>and social</u> harm (and then backlash) from consumers is substantial.
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]	The economic impact of net zero will be devastating for Alberta, in terms of both the direct cost of the programs to get to net zero (as happened in Germany, California and Denmark) and the indirect costs as businesses (not just oil and gas) relocate to other jurisdictions with lower energy costs and less restrictive regulations. This will result in "emissions leakage,"

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

	Questions	Stakeholder Comments
	a) What is your view on the economic impact of expected net-zero targets on this business-as-usual scenario?	since the CO_2 that would have been emitted in Alberta will simply be emitted elsewhere. Regarding current economic forecasts, we believe they are overly optimistic because they seriously underestimate the socioeconomic implications of Canada's overly aggressive CO_2 reduction targets.
	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 MMb/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**	There are competing forces here. On the one hand, the world's demand for oil and gas is not going to decrease any time soon—certainly not before 2030 (EIA - Crude oil production to plateau after 2030). Anything not produced in Canada will simply be produced elsewhere. So, if the governments of Canada and Alberta eschew draconian limits on oilsands production, net zero policies such as the currently proposed taxes and emissions limits will probably not cripple greenfield oilsands expansions. What is more likely to limit the expansions are the delays and uncertainties in project permitting and pipeline expansions, both of which risk being subjected to endless court challenges by environmental groups. The inappropriately named "sustainable financing," whose main objective is to deny financing to oil and gas projects, could also limit development. Net-zero policies such as the proposed carbon taxes and emission limits will not likely cripple oil sands greenfield expansions. The crippling effect will be the delays and uncertainties of getting development permits, new pipeline and marine LNG shipping export capacity and access to capital, all caused by government policies.

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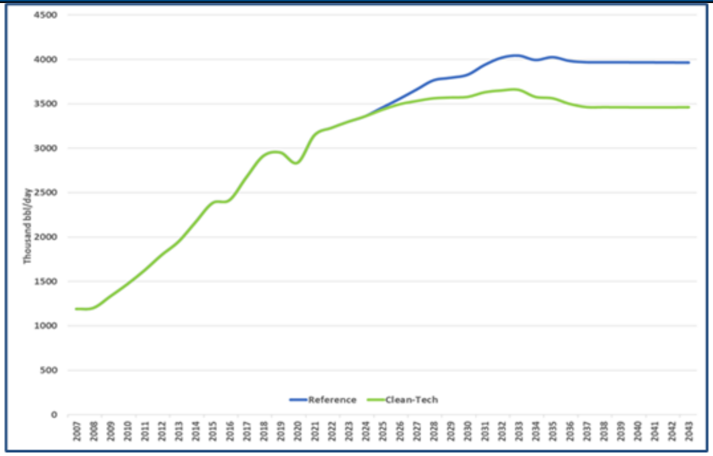
[2] https://ihsmarkit.com/research-analysis/canadian-oil-sands-running-above-prepandemic-highs.html

Questions	Stakeholder Comments
 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?	
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?	Forecasts of future natural gas prices over the next five years (and beyond) are fairly flat at the current price of approximately US$4.00 per MMBtu. The key driver of gas prices in Alberta is government policy. If it is hostile to natural gas development, including export capability, the Alberta price will decouple from US and world pricing and rise. The world price for natural gas should remain relatively stable as other natural gas producing countries will not likely adopt policies that are hostile to their own natural gas production. Countries which rely on the import of natural gas from specific countries (e.g. Western Europe being dependent on imports from Russia) are at the mercy of that country for their natural gas supply and pricing. Prices are subject to geopolitical influences which are presently greatly in flux. As explained by Prof. Emeritus Samuel Furfari, the G-7 have created an energy crisis; it is unclear how this will be resolved. https://blog.friendsofscience.org/2022/01/20/g7-creates-another-energy-

	Questions	Stakeholder Comments
		debacle/ Furfari is Professor Emeritus of Energy Geopolitics, President of the European Society of Engineers and Industrialists, and Former Senior official at DG Energy of the European Commission (for 36 years).
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	We expect that allowable net-zero mechanisms will include offsets or credits both within and outside the electricity sector, as well as physical reductions. However, rules for ensuring the integrity of offsets or credits—either within or outside the electricity sector—are very difficult to enforce (e.g., carbon credits being sold by forest owners who have no intention of cutting down the trees, and claims made by purchasers of credits that they are 100% powered by renewable energy when in reality they depend on the grid for power when the wind is not blowing or the sun is not shining). It is interesting to note that if carbon credits for existing forests are allowed, Canada may already be net zero. Despite the challenge of carbon taxes being applied globally in order to achieve the desired outcome (the benefit of carbon emission reductions outweighing the cost), they are the only government incentives required. In our Net Zero submission to the Net Zero Advisory Board, we proposed that rather than create new measures, simply reclassify any of the many existing GHG taxes/credits. https://blog.friendsofscience.org/2021/12/22/net-zero-a-holy-grail/ A more detailed discussion of carbon taxes was prepared for the NZAB by Ken Gregory, P. Eng. https://blog.friendsofscience.org/2021/12/24/submission-to-the-net-zero-advisory-body-nzab/
	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?	Theoretically, a CO_2 tax is set equal to the estimated cost of the damages caused by each tonne of CO_2 emitted. The term for this value is the social cost of carbon (SCC). There have been many attempts to determine the SCC, and most credible estimates lie between negative US\$10/t (meaning

	Questions	Stakeholder Comments
		there is a net societal benefit from higher CO_2 emissions) and US\$100/t. The estimates depend heavily on the assumptions, including the discount rate and the exclusion (or not) of the well-documented benefits of CO_2, most particularly higher crop yields. The federal government's target of \$170/t was arrived at as a balance between the lower limit of the price required to reduce CO_2 emissions and the upper limit on what voters might find acceptable. Neither of these estimates relate to the theoretical intent of a CO_2 tax. We believe that the public will rebel against the tax long before it gets to \$170/t (long before 2030) as it becomes apparent that other countries are not adopting a similar tax and that it is seriously affecting Canadians' cost of living and the competitiveness of Canadian exports. Another factor in the progression of the Canadian CO_2 tax will be its effectiveness (or lack thereof) in reducing CO_2 emissions. The EIA Analysis of Carbon Fees suggests that a US\$35/t fee that rises at 5% per year in real dollar terms to \$132/t in 2050 will reduce US energy-related CO_2 emissions by 23% from the reference case. This is not a significantly larger emissions reduction than the 19% expected from a US\$25/t fee that rises 5% per year to US\$94/t in 2050. Most of the reductions (82%) are expected to come from the electric power sector, which is the sector that is most responsive to CO_2 fees because coal loses market share to natural gas and renewables. This implies that, at least according to the EIA, CO_2 taxes will not be effective in reducing CO_2 emissions outside the electricity sector.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	There has long existed a belief that Canada could 'go green' with a national hydro-wind grid, and that this could be easily accomplished by 2035. (Danny Harvey 2013) This idea has been popularized by many influential environmental activists and NRCan has also posed it as a possible solution. Many also see an expansion of this concept to that of an 'energy corridor'. Certainly, an east-west grid is not possible by the LEAP Manifesto's dream of 2035 and likely not possible or desirable at all. However, this was central to the LEAP Manifesto and an integral part of the "Act on Climate" document issued by McGill. Clearly influential forces are pushing for the large adoption of wind in Alberta (as per the Harvey

	Questions	Stakeholder Comments
		paper noted above), in the hopes of this being a steppingstone to a national power grid. Kent Zehr, P. Eng. has written this overview discussing some of the complications and costs associated with such a notion. Another power generation engineer in Alberta offered us these insights on Harvey (2013). Another area of influence is the electric vehicle policy (EV). Kent Zehr, P. Eng. did a calculation that to support the existing EV policy of 2019, Canada would have to build an additional 10,000 MW of power generation, and related integration and transmission infrastructure. A full cost-benefit analysis regarding CO2 emissions reduction, reliability, safety and affordability, should be forthcoming from the AESO on the impacts of these federal policies. We believe that many federal and provincial policies will be repealed when taxpayers/ratepayers become aware of the cost of net zero and realize that most of the world outside of the western democracies are favoring economic development and improvements in living standards for their citizens over likely-futile CO_2 reductions.
	d) Are there any other related considerations that you would like to provide feedback on?	It is IMPERATIVE for the future prosperity of Alberta and its citizens that the AESO be very, very clear on the cost and reliability implications of net zero. Any lack of transparency on this point will inevitably lead to bad government policy. The AESO's transparency must act as a counterweight to the "rainbows and unicorns" picture painted by environmental activists.
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?	Once the true costs and benefits of CO_2 reduction, in particular in relation to the SCC, become apparent, taxpayers and ratepayers are likely to demand a roll-back or at least a slowing of the mad rush to CO_2 reduction. Energy efficiency developments will then proceed as economics dictates. If the roll-back does not happen, Alberta's economy is likely to be so devastated that conservation efforts will be moot.

Questions	Stakeholder Comments
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.)?	DERs should be discussed in two groups. The first group contains dispatchable DERs that can be directed to produce power when it is required by consumers or to manage congestion on the transmission and distribution systems. The second group consists of those DERs, like solar and wind, that are not dispatchable. To the extent that net-zero trends (with the accompanying implicit and explicit subsidies to renewable generators) increase the penetration of nondispatchable DERs, costs will increase and reliability will become more difficult to maintain. The penetration of non-dispatchable DERs will be reduced significantly if (as is NOT the case today) they are held financially responsible for the costs of alternate supply resources for when the wind is not blowing and the sun is not shining, the additional costs of real-time balancing, the additional costs of transmission and distribution wires due to low capacity factors and a lack of correlation between renewables output and demand, and the costs imposed on other generators including, but not limited to, additional cycling and greater unit commitment risks. Once the public becomes aware of the true cost of non-dispatchable DERs, they will begin to object to DERs (as has recently happened in California in relation to rooftop solar).
c) Transportation Sector - What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	In the absence of government subsidies or outright internal combustion engine (ICE) bans, the penetration of electric vehicles (EVs) is likely to be small except in niche applications and among virtue-signalers. Canada is characterized by long distances and very cold winters, and as GreenCars reported in 2021, even at a quite mild (for winter) −7 °C, the average EV driving range fell by 12% when the cars' heaters were not used and by 41% when they were. There could be some EV penetration for city-bound fleet vehicles. However, for applications like fire trucks, police cars, and ambulances, long recharging times could present problems. We believe that, if the government were to impose a justifiable CO_2 tax (in concert with the rest of the world), scrap EV subsidies, charge EV owners the same as ICE vehicle owners for highway infrastructure maintenance, and let consumers decide on what's right for themselves, the result would

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	be limited growth in light passenger vehicles and negative growth in other vehicles unless technology improves the economics. Robert Lyman, former federal public servant of 27 years and diplomat for 10 years, who spent much of his career on transportation and GHG-related assessments has provided three reports with some realistic numbers and implications outlined: "You Can't Get There from Here" "Speed Bumps on the Road to Decarbonization" "Hazards Ahead".
d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	Except for very rare niche opportunities, natural gas is far more economic for Alberta's building energy systems than electricity is. Without heavy-handed interference in the market by government, there will be negligible growth in this area. Note that the cost of building electrification in Alberta would place an extreme financial burden on Alberta families, who would have to pay for gas-to-electric conversions in their own homes, in every public building (hospital, school, town/city hall, etc.) through higher taxes, and in every business-related building through higher costs for goods and services. As Robert Lyman notes, in "Look Before You Leap into Building Retrofits" using a UK city as an example: "The City of Cambridge subsequently considered a proposal to retrofit the city's 49,000 homes and 5500 other buildings at a cost of 700,000 to one billion pounds (Canadian $1.2 billion to $1.7 billion) to halve the CO2 emissions. The City declined. If that proposal were to be extended to all 29 million existing homes in the U.K., the cost of retrofitting would be about 4.3 trillion pounds (Canadian $7.5 trillion).

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	If the typical U.K. household energy bill of 2,000 pounds per year (Canadian $3,500) were halved, the saving would be 29 billion pounds (Canadian $51 billion) per year, and the payback time would be 150 years.”
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)?	CCUS and hydrogen are emerging technologies which have not yet proven to be commercially viable or scalable. We are optimistic about CCUS but, like other emerging technologies, it will take 10-20 years for it to commercially proven and adopted by capital markets. Hydrogen may serve some niche markets, such as rail and marine shipping, but its application will be limited due to technical barriers like steel embrittlement and the need for special transportation, storage, and handling procedures which may not be implementable for the general public. Hydrogen is an extremely risky gas to produce and handle with declining energy returns in production and storage, “A Strategy to Nowhere” as discussed by Prof. Emeritus Samuel Furfari. Furfari, a chemist, worked on hydrogen for many years in the hope that it could power society – he calls it now the “Hydrogen Illusion.” It is unlikely that ‘green’ hydrogen could become a reality without significant conventional back-up, and significant safety risks, as outlined by Henrik Domanovsky, explosives materials expert. The cautionary point here is that one should not plan the grid for unlikely or extremely risky outcomes. Regarding other sectors, the driver—as usual—will be economics. If Canada’s climate policies put it on the bleeding edge of the push to net zero and, as a result, the price of energy rises above that in other jurisdictions, the listed businesses will simply move there and take their jobs and CO_2 emissions with them. There is no climate emergency, so Canada has time to take a reasoned and measured approach to energy-systems transformation. A mad rush to net zero by Canada, with or without the other western democracies, will be economically devastating. According to Bjorn Lomborg, if all countries met all their Paris targets by 2030 the total temperature reduction by 2100 would be 0.05° Celsius by 2100.

	Questions	Stakeholder Comments
		As pointed out in Robert Lyman's reports "Speed Bumps on the Road to Decarbonization" and "Hazards Ahead" few of the mentioned heavy industries can be electrified at any reasonable cost or with maintenance of present performance.
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?	We believe nuclear plants and gas-fired plants with CCUS to be the most economic zero-emission resources. CCUS can probably be retrofitted on some of the province's existing power plants and can be included in the design of new ones (subject to our comment above regarding the lack of commercialization experience). Small modular reactor (SMR) technology also appears to be promising. If we are truly concerned about CO_2 emissions, nuclear is really the only scalable, commercially viable technology available today. It also has the best safety record of any power generation technology (including Chernobyl, Three Mile Island, and Fukishima), and new nuclear technology is inherently safe. SMRs are probably more acceptable to the market because of the smaller, more localized scale. However, it will take time for the public and subsequently government to accept nuclear because of it's tarnished image. Since Alberta is so dependent on gas-fired generation, CCUS could prove to be an economic source for safe, reliable electricity from existing and possibly new plants, competing with SMRs. The utilization of carbon from CCUS plants looks promising, but economic viability and scalability are not yet assured. CO_2 utilization may be a limiting factor in CCUS because it affects the amount of CO_2 to be stored. An optimistic time to reach net zero with CCUS and SMR is 15 years, with 25 years more likely.
	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:** This is a promising technology, but it's early in its development process and is a long way from being commercially proven. It would more correctly be termed CCS as the utilization of the CO_2 to make it CCUS is a semi-independent issue depending on the cost and availability of CO_2 storage. We believe the probability of success for this technology to be high with a development period of about 25 years.

Questions	Stakeholder Comments
(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	**(ii) Pre-combustion CCUS:** This is also a promising technology that is early in it's development process. If commercially successful, it could be a game-changing solution to global CO_2 concerns. However, cost, the global storage capability for CO_2, the ability to use the CO_2, and global acceptance are large factors in the technology's commercialization. We believe the technology has a medium probability of success and expect a development period of more than 25 years. **(iii) Oxy-fueled Generation:** The technology is promising but still in its infancy (having not yet been field-tested). We believe the probability of net-zero success with this technology to be low and expect a development period of more than 25 years. **(iv)(a) Renewable Generation—Wind:** Wind generation is a proven technology, but its costs have been grossly mischaracterized. We would not dispute that the plant-gate cost of wind is less than the plant-gate cost of a combined-cycle natural gas plant, but wind's economics are distorted by the failure to account for all the costs it imposes beyond the plant gate. Costs properly attributed to wind generators include those for: (i) the storage and/or generation resources that must be present when the wind is not blowing and that are forced to sit idle when it is blowing; (ii) resources or services needed to maintain supply-demand balance in the presence of large, rapid, and unpredictable changes in wind output; (iii) the additional transmission and/or distribution infrastructure that is made necessary by wind's low capacity factor and its lack of correlation with consumer demand; and (iv) additional operating and maintenance costs imposed on other generators through more off-optimal dispatches, higher cycling-related wear and tear, and higher unit commitment risk. Wind generation also uses a lot of land and creates a large volume of end-of-life waste that, as of today, is not readily recyclable.

	Questions	Stakeholder Comments
		The wise choice for Alberta would appear to be to halt any further wind development. The high variability of wind generation, coupled with its zero marginal cost, means that either energy storage systems or other dispatchable generators are required for supply-demand balancing. In today's market, simple cycle gas turbines can provide that balancing, but CCUS is unlikely to be viable on high-variability generators, so the simple-cycle units could well be casualties of the net-zero rush. We could then be led down the path of having a large amount of wind generation, needing a large amount of rapid-response energy storage to balance supply and demand over short time horizons, needing nuclear or CCUS plants for what has traditionally been called baseload generation, and having so much wind generation that, in periods of high wind output, even the nuclear and CCUS generators get curtailed. The power system would be better off with less wind, less need for real-time balancing, and less curtailment of generators that are best operated at steady output levels. If all the costs imposed by wind generators were properly attributed through market and/or tariff mechanisms, it is likely that wind generation development would become self-limiting. **(iv)(b) Renewable Generation—Solar:** Solar generation exhibits many of the same characteristics as wind generation and it imposes many of the same costs. Solar's end-of-life waste problem is perhaps more acute than that of wind, given the presence of toxic chemicals. Consideration should be given to capping solar generation development for the same reasons as for wind generation. RE: Wind and Solar – please see our reports "The True Cost of Wind and Solar" and "What You Really Need to Know about Renewable Energy (That The Pembina Institute Won't Tell You)."

	Questions	Stakeholder Comments
		(iv)(c) Renewable Generation—Geothermal: The United States is the world's largest producer of geothermal energy, but by 2018 geothermal only supplied 0.4% of its total power generation, despites decades of development and optimal conditions on the San Andreas Fault area. Alberta being part of the continental plate has only a few select areas suitable for geothermal development, and then at significant cost and questionable value (as these are far from population centers). This parallels some situations in Australia where excellent geothermal sites were abandoned simply due to the distance to market. Our report "Geothermal for Alberta – a Case for Caution" explores Alberta's potential and reviews other geothermal activity worldwide. This report was prepared in collaboration with our internal team of Professional Geologists and Professional Geophysicists. While various climate activists have assumed that taking abandoned oil and gas wells and turning them into geothermal operations would be a simple matter, completion engineers have explained that this is an expensive and difficult process. It should also be noted that Alberta has significant hydrogen sulfide gas in the strata. Geothermal heat exchange (using heat pumps) for buildings (i.e., Calgary Airport) may have some useful applications, though Alberta's erratic weather/temperature conditions do not lend themselves to the slow response of geothermal heat pumps and the cost of driving the pumps and load on the system may negate the alleged benefits or carbon dioxide reductions. **(iv)(d) Renewable Generation—Biomass:** Biomass generation associated with forestry operations seem to make sense in Alberta. However, standalone biomass probably does not: the environmental benefits are still being debated and in some cases biomass plants compete with food production for fuel.

	Questions	Stakeholder Comments
		Unless there is a biomass pellet operation, the proposed use of 'slash' (leftovers from clearing trail or forestry) is not consistent enough in quantity or availability to be used as a reliable source of power. **(v) Hydroelectric Generation:** Technically, hydro is a great resource. However, there are few potential storage sites in Alberta, significant opposition to large hydro projects is likely, and small run-of-river hydro plants are susceptible to water shortages in dry years. **(vi) Nuclear Generation:** Nuclear appears to be the best choice, both technically and economically, to reach net zero. However, it will be challenged by public perception and unnecessary permitting and safety costs. **(vii) Energy Storage:** Lithium ion is currently the preferred battery technology to back up wind and solar. Using 2019 Alberta electric system data, we calculated (here) that the seasonality of a wind-and-solar supply mix would lead to a storage requirement of more than 30 days - or about 4TWh under the stated assumptions. The capital cost of these batteries would be approximately $1.9 trillion. The expected life of these batteries is 10 years, therefore the levelized cost of battery storage is far in excess of $200 billion per year (or about 10 times the annual budget of the Alberta Health Care system [~$20 billion]). To put that cost in context, this is equivalent to $45,000 per person per year and is over half of Alberta's GDP which was in $338 billion in 2018. Battery storage as a back-up to wind and solar is simply not affordable! While some short term battery storage would help to manage the short-term variability of wind and solar, seasonal storage based on today's lithium ion battery costs is ludicrously out of the question.

	Questions	Stakeholder Comments
		(viii) Transmission Interconnections with Other Jurisdictions: Interconnections with other jurisdictions provide valuable import and export capacity and can assist with real-time supply/demand balancing, including contingency response. However, the idea of supporting renewable generation with interconnections to other jurisdictions because (for example) "it's always windy somewhere" is just silly. Let's take the simple case of Area A and Area B. The two areas have the same demand profile. If the wind in blowing in A but not in B, then A's renewable generation must supply both A and B (and vice versa). That means A and B must individually contain enough renewable generation to support both regions. Of course, the possibility exists that it will be windy in neither A nor B; do they then rely on Area C? Another problem with interties arises from the possibility of price arbitrage. If Area A has lots of wind and little hydro, while Area B has lots of dispatchable hydro, then B can purchase excess wind energy during periods of surplus, when the price in A will be at or near zero. The wind energy allows B to hold back the water in its dams. When the wind is not blowing in A, B releases the stored water and sells the extra hydro output to A, when the price in A is high because of the wind shortage. This scenario is all to familiar to Ontarians, whose Auditor General noted that the province paid billions for its neighbours to take excess renewable energy during periods of surplus renewable generation. **Offsets or Emissions Performance Credits:** These are susceptible to gaming (see 3(a) above). There are also subsidies paid for by the consumer of the goods produced by the purchaser of the offsets or emissions performance credits in addition to the production of the goods.

	Questions	Stakeholder Comments
		As Interpol has discussed in "A Guide to Carbon Trading Crime" this is an area fraught with potential for fraud.
	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?	
	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.	Yes. Wind and solar are proven technologies but, as described in our responses to (b) and (c), they impose large outside-the-plant-gate costs on consumers and/or other generators and they pose ever-increasing reliability risks as their share of total supply increases. The other enabling technologies suffer from having limited opportunities in Alberta (hydro), having debatable benefits (biomass and interconnections), being immature (pre- and post-combustion CCUS, oxy-fuels), being outrageously expensive (battery storage), having huge cost and regulatory risks (nuclear), or being susceptible to gaming (offsets and credits). Given that CO_2 emissions by much of the developing world are expected to continue to rise for decades, there would appear to be little benefit to Alberta or Canada from all of this, other than virtue-signaling. The potential risks to electricity affordability and reliable far outweigh the benefits. It should be noted that China emits in one month, what all of **Canada** emits in a year and a half. See "Futile Folly: Canada's Climate Policy Goals in the Global Context". Furthermore, the demographics of the world will outdistance Canada and Alberta. North America and Europe make up only 15% of the world's population. All of the emissions growth is occurring in emerging nations. These countries are unconcerned about climate change, but are very interested in gaining geopolitical dominance, which relies entirely on energy. "When Giants Arise" by Robert Lyman shows that the West will be disadvantaged and soundly defeated by their own Net Zero dreams.

	Questions	Stakeholder Comments
		A further risk is that most wind and solar devices are produced in China and if Alberta becomes reliant on wind and solar, then we will also be dependent on China for continuing supply.
	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?	It will be up to the federal and provincial governments to set the rules for cogeneration facilities, at least until the cost-induced taxpayer backlash cause the governments to rethink their approaches. Regardless of what approach(es) the governments may take, it is imperative that the rules be rational and broadly the same across sectors, and that the free market be allowed to function as the mechanism through which compliance is achieved. Governments are notoriously bad at picking winners and losers and should be encouraged to avoid meddling in businesses' approaches to compliance.

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

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[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?	We have no basis on which to agree or disagree with the costs as provided in the table. We will note, however, that the table is misleading. The costs shown for wind and solar are for intermittent, unreliable, and largely unpredictable resources with low capacity factors, and they do not include the beyond-the-plant-gate costs described above. Battery storage costs appear to be reasonable, but that is in part because renewable energy advocates frequently claim that there is a need for no more than a few days' worth of storage to get through a few days of little wind and/or little sun. The reality is that a system powered by wind and solar with battery backup would exhibit seasonality requiring about a month's worth of storage, an amount that is far, far beyond economic reach. The table also fails to deal with price risk. If all the western democracies go all-in on net zero at the same time, the competition for limited resources will cause long delays and drive costs up significantly. There are also strategic and geopolitical risks as Canada becomes increasingly dependent on foreign governments for access to rare earth metals and other commodities that are needed by renewable energy resources. The table does not deal with decommissioning costs, which may become substantial as the magnitude of the disposal problem grows in parallel with the installed capacity of wind and solar. Finally, we will point out that tables like this one can lead (and have led) to the use of perverse logic by some renewable energy advocates. Their reasoning goes something like this: • As we build more wind and solar generation, the capacity factor of other forms of generation goes down (all other things being equal). • As their capacity factors decline, those other generators must raise their prices in order to recover their fixed costs over a declining volume of energy sales.

Questions	Stakeholder Comments
	• As the price from the other generators rises, the consumer benefit of building more zero-marginal-cost wind and solar generation increases. • Ergo, the solution is to build more wind and solar! This perverse logic and the resulting economic distortions are best countered by charging nondispatchable generators for the costs they impose on consumers and/or other generators. We are aware that the market rules must exist within the confines of provincial legislation, but just as we believe the AESO must be very clear about future costs and benefits, it must be very clear about the fairness and efficiency implications of allowing generators to avoid paying costs they create.
b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	We believe the retrofit costs to enable CCUS or hydrogen-fired generation will be site specific. They should come down over time as the design and implementation of the technology improves with experience. This is yet another reason why we believe the 2035 target will result in far more harm than good.
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).	As we noted above, it is the AESO's duty to inform the public and the government of the estimated cost of getting to net-zero electricity and the estimated benefit—as measured by the number of tonnes per year of CO_2 emission reduction—for the various technologies. We strongly support Alberta's competitive market and understand that the AESO is not responsible for the future development of generation technologies in the province. Nevertheless, we believe the AESO should set out a few realistic scenarios and tell ratepayers and the government what it expects the price of electricity to be in 2035. Policymakers must be fully informed of the costs and risks so they don't make poor policy decisions and so that we don't have to reverse course once the true costs of net zero become apparent, as they are becoming in western Europe (especially Germany), California, and Ontario.

	Questions	Stakeholder Comments
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	As also noted above, it is imperative that any cost analysis properly attribute the costs that various technologies impose on consumers or other generators to those technologies. Under the current system, and as reinforced by the table in Question 6, the lack of proper cost attribution leads to economic distortions, unfair subsidies to certain generators from consumers and/or other generators, poor policy decisions, and ultimately economic and social harm to Alberta and the rest of Canada.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Lisa Mueller
Comments from:	FutEra Power	Phone:	
Date:	2022/01/31	Email:	lmueller@futerapower.com

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

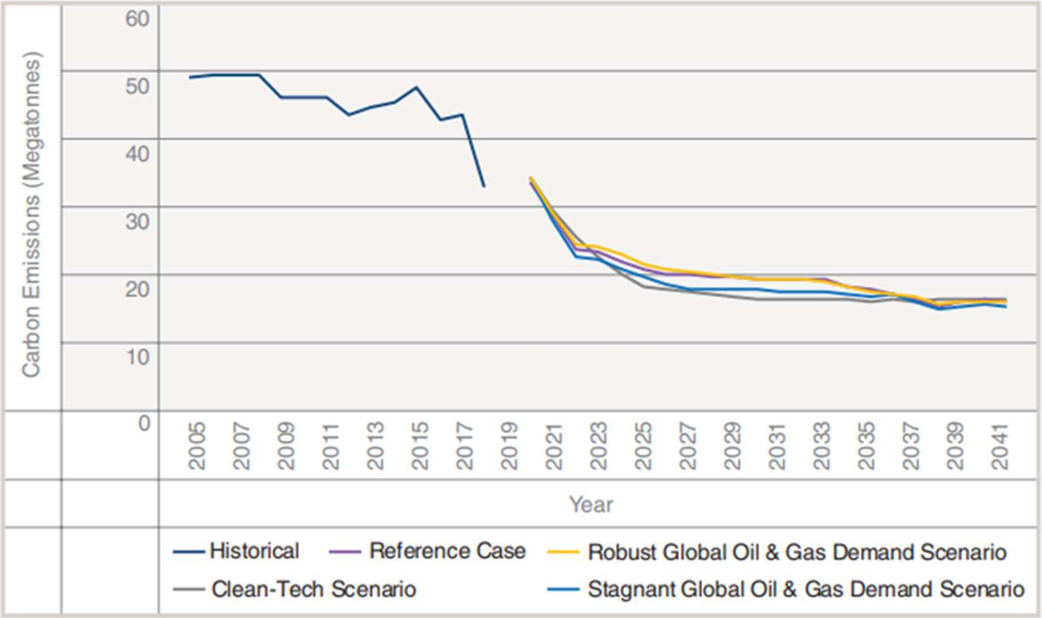
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	FutEra would like to see the AESO embrace the unique aspects of our province when developing the Net0 scenarios. This includes embracing the industrial and O&G producers that make up a large amount of our provincial demand, recognizing the process impacts and cost implications of a Net0 future, and how that will influence their response. FutEra does not believe that a Net0 supply scenario focused on renewables paired with ES is at all viable given Alberta's unique qualities: • Demand from industrials and O&G producers, which often includes thermal energy needs, cannot be met by renewables with ES alone. • There simply is not enough land. Currently, there is no way to obtain a lease for renewables on Crown Land, preventing higher latitude renewables and limiting the renewable footprint to the south. Without changes at the policy level, the province would

	Questions	Stakeholder Comments
		likely run out of room to site the amount of renewables required for this supply scenario to be viable. In FutEra's view, the only viable supply pathway is one that embraces the uniqueness of our market, including the vast network of infrastructure already in place, enabling pathways that achieve Net0 without requiring entirely new, and costly infrastructure. When considering a range of potential Net0 supply sources and technologies, we recommend the AESO focus on what is technically and commercially viable today, and avoid focusing on technologies that cannot be deployed in any meaningful capacity by 2035 (i.e. nuclear). Already, we have seen industry leading the charge, in areas like geothermal, CCUS, and H2 production. The AESO's analysis would be best served by following this lead from industry, versus trying to move away from a pathway many are already headed down. FutEra would be happy to share with the AESO our experiences developing what will be Alberta's first utility-scale, co-produced geothermal power plant.
	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?	Customers, who ultimately pay, will be one of the main areas impacted by a Net0 future, as well as present some of the largest challenges. Already the DCE is high, and customers are responding, in part by taking all or a portion of their electricity demand off-grid. Any future where the DCE continues to increase, will continue to send a signal to customers that self-supply, even potentially higher cost Net0 self-supply, remains technically viable and an economic alternative to traditional grid supplies.
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]	See response to 1(b) above.

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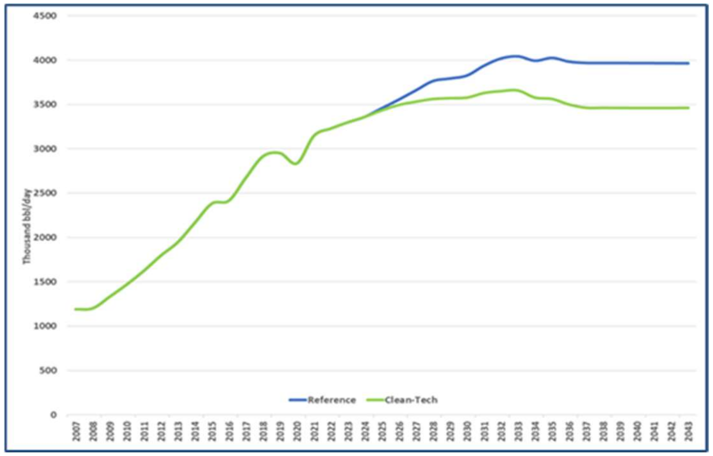
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

Questions	Stakeholder Comments
a) What is your view on the economic impact of expected net-zero targets on this business-as-usual scenario?	
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	A Net0 future does not mean a future without O&G production, as hydrocarbons remain an essential feedstock for a wide range of products beyond fuels (i.e. chemical, H2, plastics, etc). FutEra notes that O&G producers are already embracing Net0 targets, leading the charge, and will remain an important element of Alberta's economy, one which will continue to contribute to provincial electric demand.

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

	Questions	Stakeholder Comments
	scenario for analyzing the impact of net-zero policies on the oilsands sector and the subsequent impact on load growth?	
	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?	
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	The lack of policy clarity, from both the federal and provincial governments, is complicating Net0 planning, initiatives, and investment. Without clarity, and alignment between these two levels of government, any comment on future policy changes is simply speculative at this point. This analysis would be best served by remaining open and flexible to accommodate policy changes as they are announced and evolve.
	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?	FutEra has not seen anything that would suggest carbon pricing would not follow the federally announced pathway to $170/t by 2030. Beyond 2030, commenting on pricing is simply speculative, without further direction from the government.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Alberta will need to address the roadblocks preventing leases for renewables on Crown Land.
	d) Are there any other related considerations that you would like to provide feedback on?	
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,	See response to 1(b) above.

Questions		Stakeholder Comments
	commercial, and/or industrial)? What would trigger more energy efficiency or conservation efforts?	
	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.)?	FutEra anticipates Net0 targets will support continued expansion of DCG / DERs, as customers look for greater control over the supply, and cost, of their energy.
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	FutEra anticipates the penetration and pace of electrification of the transportation sector will have significant impacts on the Dx system, which will require better alignment across the entire integrated electric system (i.e. policy, rates, etc.), supported by improved integrated system planning.
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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)?	See response to 1(b) above.
	Generation Technologies	See response to 1(a) above.

	Questions	Stakeholder Comments
5	a) What net-zero enabling generation technologies do you perceive as being the most economic pathways to decarbonization of the electricity supply in Alberta?	
	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 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	One weakness associated with each of these Net0 enabling technologies is the length of time it takes to get connected to the grid. While the AESO has made enhancements to the Connection Process over the years, continued improvement is required such that obtaining a grid connection does not delay development timelines.
	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?	
	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.	
	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	

	Questions	Stakeholder Comments
	technologies do you believe can be most economically implemented at cogeneration facilities?	

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, 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 %
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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

	a) Do you believe that these are representative of the costs associated with potential future Alberta net-zero generation	No. The above entirely ignores DCG, with each Net0 generation type listed being TCG (potentially with the exception of fuel cells).

	Questions	Stakeholder Comments
	technologies? How do you expect the cost of these technologies to change by 2035?	Generation connected to the Dx system is, and will continue to be, a substantial source of supply. There is currently more DCG operating in the province (908 MW) than hydro (894 MW), recording a year-over-year growth rate of 20% (source: AESO DER Progress Update, Dec-21). FutEra anticipates Net0 targets will support continued expansion of DCG / DERs, as customers look for greater control over the supply, and cost, of their energy. The AESO would benefit, across the value chain, from an increased understanding of the motivations and economics behind investment in DCG / DERs.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Scott Perry
Comments from:	Greengate Power Corporation	Phone:	403.519.6194
Date:	2022/01/28	Email:	scott@greengatepower.com

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.**
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Introduction

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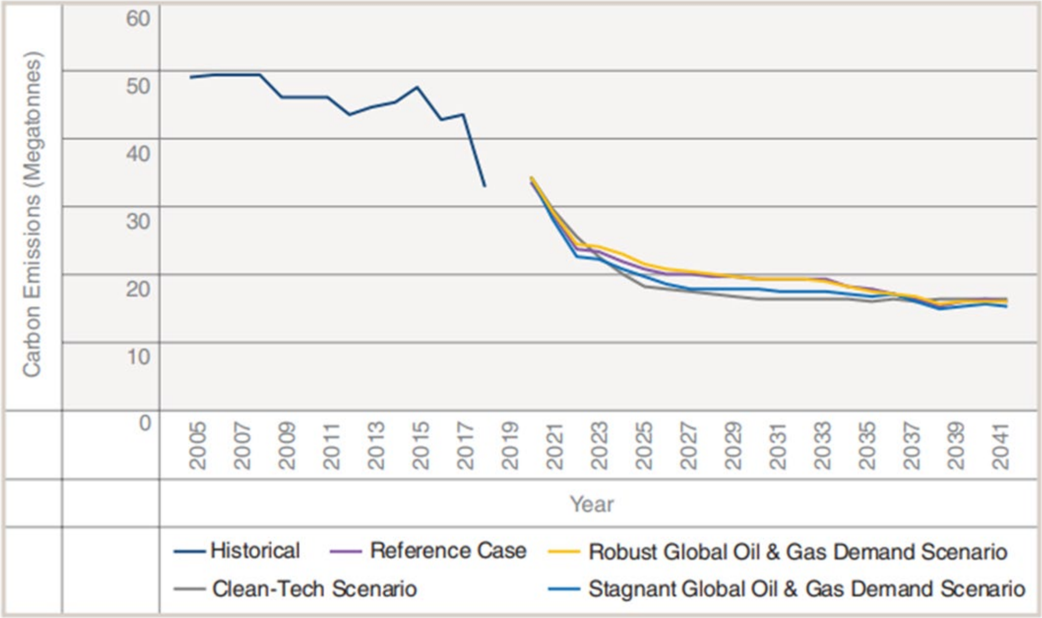
In 2022, the AESO will examine potential pathways to achieve a net-zero greenhouse gas emissions electricity sector in Alberta and the market, operational and cost implications of these pathways. The AESO intends to review and understand the most prominent zero and low-carbon emissions technologies, 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.

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.

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td><i>1</i></td><td colspan="2"><i>Net-Zero Analysis Scope</i>
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.</td></tr>
<tr><td></td><td>a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td>The AESO’s planned scenarios and analysis appear to be reasonable approaches to examining net-zero pathways. Greengate agrees that a “renewable paired with energy storage” scenario is especially important given that the competitive Alberta generation market is already attracting a very large amount of renewable generation and plans for storage from incumbent and growing market participants.
In such a short period from today to 2035, there are still multiple ways that net-zero can be achieved. The second scenario should focus on the diversity on alternatives to reach net zero based on technology adoption possibilities and plausibility of each technology, from today’s standpoint, over that time period.
Greengate recommends that the AESO’s analysis must include a pool price forecast from each scenario and a review of the required transmission infrastructure resulting from each scenario. While we understand the scope of this Net-zero Analysis does not include operational impacts and mitigation measures, we feel that this is a critical</td></tr>
</table>

	Questions	Stakeholder Comments
		component of the analysis and that the AESO should also comment on the ability of the market to achieve net zero from a reliability perspective.
	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?	The addition of renewable energy and storage technologies should be made a priority given their ongoing and growing success in Alberta's market. These technologies are competitive and produce good outcomes for rate payers in the energy market. However, given the large queue of projects facing the AESO, renewable generation could face challenges with getting the transmission capacity required to enable this generation to contribute to a net zero future. The AESO should examine and analyze how these infrastructure needs can be met from a cost perspective as well as schedule. Decarbonization is a topic at the forefront of minds at Greengate and is certainly a topic of great importance to many stakeholders in the electricity sector. A 2035 net zero timeline will present many challenges and need for flexibility, but recent successes in renewables as well as the elimination and replacement of coal generation in the province as of next year. These industry and policy accomplishments were not always expected to happen and it was not long ago that they were seen as unlikely or impossible outcomes. This should be kept in mind as the AESO considers what is possible in achieving a net zero grid by 2035.
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?	Over the course of the AESO's analysis and following it, more details will likely become available on the federal government's net-zero policy plans or intentions. Greengate recommends that the AESO regularly update and engage with stakeholders when these impactful policies are apparent and be open to adjusting its analysis of net-zero policy impacts and to update its analysis regularly following its first release. Depending on the policies chosen to support the net zero goal, energy and transmission costs may increase and this may have a negative impact on load customers. The AESO must assess the path to net zero based with consideration on the impact of higher prices on loads.

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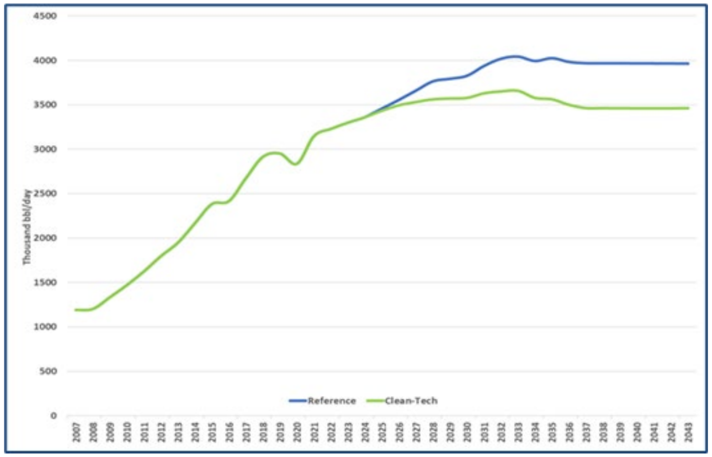
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

	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?	As in Greengate's response above, it is recommended to engage with stakeholders and adjust assumptions when impactful government policies become known, and to update the analysis when future policies and market information that impacts the net zero scenarios are better understood. Furthermore, using the Clean-Tech scenario at this time appears reasonable, but it may not be illustrative of all large impacts on load in the province depending on the scale and speed of electrification across industries.

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[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?	
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	To achieve reductions in emissions within the electricity sector, Greengate expects that physical emissions reductions are the primary goal of a net zero grid, given that the sector can enable decarbonization in other sectors through electrification. However, Greengate supports the use of offsets to meet a net-zero grid goal. Government policies at the provincial and federal levels will be important for determining the answer to the AESO's question, considering that the provincial government governs the sector, and both levels of government will likely have impactful funding, taxes, and credits policies within the 2035 timeframe. If possible, each of these definitions of offsets should be used in the AESO's analysis and the impact of their definition on the outcomes of the AESO's analysis should be clearly communicated to stakeholders.
	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?	Greengate expects that the federal carbon price will reach $170 CAD by 2030. It would seem plausible that this price increases to provide an incentive for hard to decarbonize segments of the economy. Although it is currently unknown what will happen beyond 2030. It does not appear unreasonable to assume that the carbon price will increase at the same pace of $15 per year or greater following 2030. However, it is possible that policies with carbon price equivalents, particularly in certain sectors, will also be introduced by 2030 and in the years beyond.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Greengate anticipates that the Federal Government will continue to offer support to the Provinces in regard to tax and emission policies to reach net zero. Greengate supports policies that enable the market to function effectively to achieve net zero including building transmission on a just in time basis and market policies that will enable the market to attract the required new generation.

	Questions	Stakeholder Comments
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	
	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.)?	
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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?	

	Questions	Stakeholder Comments
	• 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)?	
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?	Greengate believes that what works today will be the most viable pathway to achieving a net-zero 2035 target. Wind and solar generation will provide the most efficient pathway to enable a net-zero grid by 2035 and beyond. Storage including lithium-ion batteries and competing storage technologies will enable flexibility and growth in the assets and could make the grid more efficient at adopting them.
	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 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	It is likely that all listed technologies will have to be adopted in some capacities to meet a 2035 net-zero grid goal. The impact of pricing policies, tax-breaks, and subsidies, should not choose pathways, but rather invest in areas where the most carbon reduction per dollar can be achieved. Private capital is an ongoing and growing investment in efficient solar and wind technologies, as well as storage. The AESO's analysis should consider this reality and the need for more solar, wind, and storage penetration in the market given the market interest. In the medium to long run, increased transmission infrastructure, other technologies and interconnections with other jurisdictions will become more important.
	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	The AESO would be best positioned to consider the impact of storage technologies to enable renewable generation to the greatest extent possible and to use the grid in the most efficient way possible in order to reduce the remaining carbon burden of the electricity sector.

	Questions	Stakeholder Comments
	emissions, and enable a pathway to net-zero emissions in Alberta?	
	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.	
	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?	While it is currently unclear how the ‘good as best gas’ policy aligns with a net zero emissions target by 2035, Greengate expects that the accounting for net zero emissions has to include emissions from all generating facilities. Base loaded generation such as cogens are difficult to replace due to their nature as the backbone of the generating fleet, and no one technology can economically replace cogens. A portfolio approach is required, starting with a robust solar, wind and energy storage suite of zero emissions generations. The remaining footprint must then be addressed via direct air capture, long duration storage, CCUS or other technology that is not fully developed.

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

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[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?	
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Kurtis Glasier
Comments from:	Heartland Generation Ltd.	Phone:	(587) 228-9617
Date:	[2022/01/31]	Email:	Kurtis.Glasier@heartlandgeneration.com

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

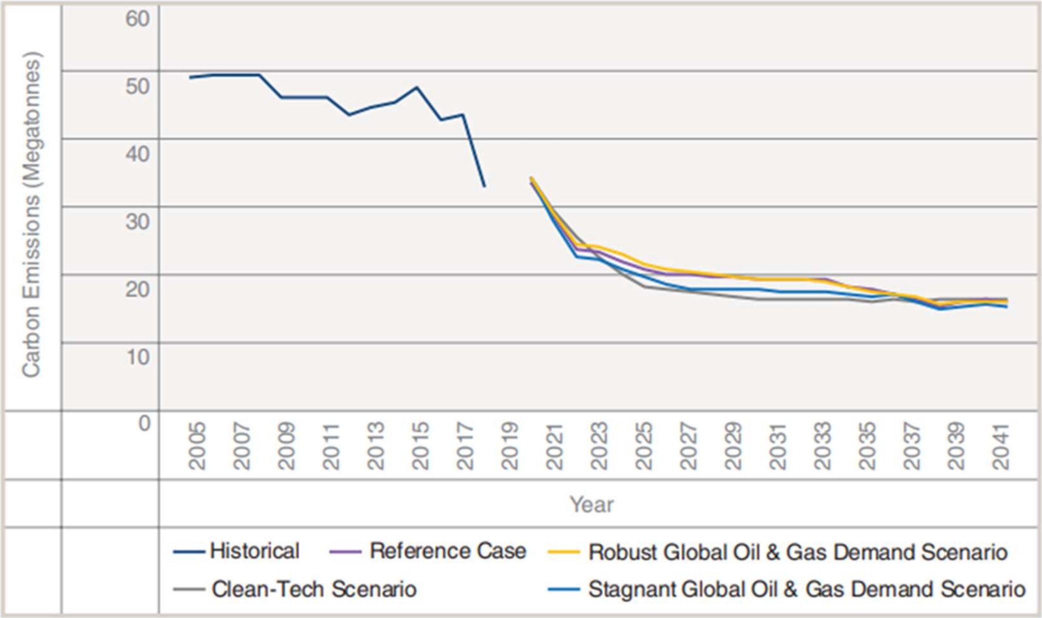
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	Heartland Generation is interested in how the AESO will account for the future role of interties in the net-zero supply scenarios. Net-zero by 2035 is a federal objective, and as such will likely involve larger grid implications than are currently contained in the AESO's analysis. If the AESO intends this forecasting to be solely within Alberta's borders, this may underestimate the influence of other jurisdictions on the Alberta electricity grid over the net-zero transition. Further, the AESO should provide analysis regarding the impact to resource adequacy, customer cost impacts/affordability, and market implications for the net-zero scenarios provided. These are key investment drivers that will be important in evaluating the impacts from a net-zero pathway.

	Questions	Stakeholder Comments
	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?	One of the potential largest areas impacted by the pathway to net-zero is likely to be customer costs and affordability. The AESO has indicated that it does not intend to report on the "specific impact to consumers", however, this reporting should be prioritized. Simply put, the proposed scenarios should be evaluated not only on the economically driven decisions of generators, but on the cost implications to customers from the range of ways to meet net-zero carbon emissions. There are multiple jurisdictions with net-zero policies that may impact the others. Developing a harmonious and comprehensive net-zero pathway will be difficult to achieve across all levels of policymakers (federal, provincial, regulated utilities and specialized regulators).
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?	Heartland Generation does not have specific comments on the economic outlook provided by the Conference Board of Canada at this time.

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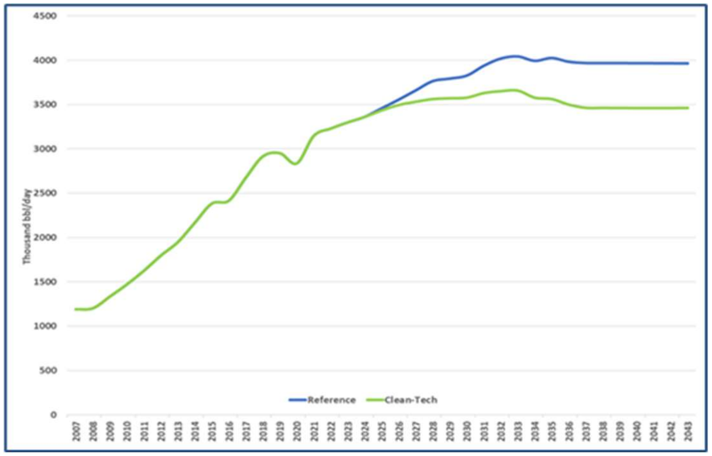
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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?	Heartland Generation is concerned that this approach undervalues the potential for load growth and expansion in the oilsands sector given compliance options (e.g., offsets). It seems unlikely that demand for oilsands production will disappear during this time period. The AESO should engage a third party to analyze the impact of net-zero policies on Alberta oil production, rather than proposing modifications to a forecast that was created for a different purpose. This would be a more direct approach and would remove the compounding of assumptions.

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[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?	Heartland Generation suggests that the AESO hire a third party to conduct a market survey. This could create a more rigorous and unbiased view to inform the study.
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	Offsets are an effective way to achieve aggressive greenhouse gas (GHG) reduction targets by providing an opportunity to reduce the cost of compliance and to promote voluntary reductions, not covered by carbon pricing and potentially not occur otherwise. It is important that offset systems are credible, consistent with international standards and only recognize activities that represent real, quantified, verified, and unique GHG reductions that are additional to what would have occurred in the absence of the project. Alberta currently has an offset system with components to be reviewed in 2022 and the federal Offset Regulations are expected to be final in 2022, which could potentially expand compliance options for Alberta TIER participants. Further, the AESO needs to evaluate the impacts of offsets or credits on the fair, efficient, and openly competitive (FEOC) operation of the wholesale electricity market. Subsidized resources and out-of-market payments will undermine the competitive energy-only market, ultimately to the detriment of customer interests, investment, and reliability, unless the market design is adjusted to account for the impact of such payments. The AESO should examine the potential impacts and how the market will internalize these potential distortions to the FEOC market. As seen in the Market Surveillance Administrator's Quarterly Report for Q1 2021, the value of offset credits can undermine the price signals of the energy-only market.
	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?	The Government of Canada updated the benchmark in 2021 for carbon pricing setting annual minimum national pricing for 2023-2030. By December 31, 2022, Alberta must complete legislative or regulatory changes to implement 2023-2030 price increases or publish a commitment to the price increases and details on how regulatory changes will take effect.

	Questions	Stakeholder Comments
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	There are multiple upcoming reviews at the provincial and federal levels starting in 2022 with respect to climate change and energy transition which could potentially impact Alberta's electric system. Examples are potential changes to the provincial carbon framework (TIER review and pricing schedule) and the federal climate initiatives (TIER equivalency review, net-zero electricity grid by 2035 and *Clean Electricity Standard*).
	d) Are there any other related considerations that you would like to provide feedback on?	It may also be worthwhile to explore how changes to the distribution systems and tariffs will impact the Alberta electric system (e.g., Performance Based Rates review, Bulk and Regional Rate Designs, and distributed energy resources integration).
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?	One key predictor of energy efficiency adoption is the affordability of energy consumption. Retail electricity rates should inform assumptions on the potential penetration and pace of energy efficiency; retail rates and elasticities vary across industrial, commercial, and residential sectors, so the impact on energy efficiency will vary to a similar degree.
	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.)?	Distributed energy resources (DER), including both renewable and thermal, can support electrification. Provincial policy and regulatory interpretation should permit DER when it can add electrification projects through more efficient use of self-supply or co-located sources of generation. DERs can become an enabling technology for the efficient use of existing infrastructure, while adapting to the increased demand for electrification.
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	Heartland Generation does not have specific comments about the electrification of transportation at this time.

	Questions	Stakeholder Comments
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	The AESO should explore the potential issues with electrification of space heating, e.g., the non-linear functionality of electric space heating experienced in ERCOT.
	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)?	Heartland Generation does not yet have enough detail on potential projects and regulatory clarity to offer an informed view on how changes to the industrial sector might impact load.
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?	It is difficult to validate the “most economic pathways” for net-zero generation technologies given the potential impact of provincial and federal policies and/or incentives that are currently under development It is Heartland Generation's view that carbon policy will be the driving factor in investments in specific technologies. Overall, the Alberta market design should create a level playing field in order to maintain the FEOC operation of the market. The AESO should not seek to incent specific technologies but should assign appropriate reliability value when modelling resource adequacy. This ensures that carbon pricing assigns value to environmental attributes and the market design correctly evaluates cost efficient and reliable technologies. In tandem, this ensures that Alberta’s electricity system is decarbonized efficiently in response to policy and customer demands.

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 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	The AESO should limit the net-zero scenarios to those technologies that can realistically be employed within the allotted timeframe. Heartland Generation believes that a public report comparing the most likely technologies will be the most useful to market participants. For example, it is unlikely that a large hydroelectric or nuclear generation facility will be constructed and operational within Alberta under these timelines. The enabling legislation and policies would need to be in place first, which would then allow the AESO to adjust this assumption; absent these regulatory changes it is safe to assume that new facilities of these technologies will not be constructed. Below are Heartland's comments for each of the technologies referenced: **(i) Post-combustion Carbon Capture, Utilization, and Storage (CCUS)** Some of the benefits of this technology include the relative commercial readiness and the opportunity for Alberta to decarbonize its existing thermal fleet by upgrading existing sites, utilizing existing bulk system infrastructure and workforces. **(ii) Pre-combustion Carbon Capture, Utilization and Storage (hydrogen)** This approach to CCUS may offer greater economic value than post-combustion CCUS, given that this process results in the creation of a new commodity (clean hydrogen), which is expected to support the decarbonization of other industrial and commercial sectors. This results in an effect through the greening of the grid. **(iii) Oxyfueled generation** Oxyfueled generation is still under technological development. It is likely not ready for commercial operation and could be justifiably excluded from the AESO's analysis. **(iv) Renewable generation including wind, solar, geothermal, and biomass:** These technologies are all commercially viable and deployed in Alberta and many other jurisdictions around the world. However, unless paired with robust dispatchable generation, their low capacity factors could exacerbate

low transmission and distribution utilization, increase the delivered cost of energy, and pose a reliability risk to the grid.

(v) Hydroelectric generation

Large hydroelectric generation will have difficulty participating in the competitive electricity market given the regulatory approval process for these types of projects. Any analysis involving hydroelectric generation needs to be realistic, and this may warrant a limited involvement in this analysis.

(vi) Nuclear generation

Like hydroelectric generation, large nuclear generation seems unrealistic under the timelines, given the associated extensive regulatory approval processes. It is for that reason that Heartland Generation expresses caution over including large nuclear in the analysis but could potentially see a role to play for small modular reactors (SMRs).

(vii) Energy Storage

Energy storage, including batteries, could be an enabling technology for the participation of more intermittent technologies, increased stability in the reliable operation of the electrical grid, and will likely contribute to the broader provincial economy.

(viii) Transmission interconnections with other jurisdictions

The lack of governance or market integration between Alberta and neighboring jurisdictions results in significant limitations for relying on additional intertie imports as a solution for significant decarbonization of Alberta's electricity grid. The lack of a framework pertaining to competitive exchange of electricity between provinces is a meaningful market issue. Further, the lack of a "must offer" obligation is a significant barrier to integrating the reliability or resource adequacy between provinces.

The AESO could evaluate productive efficiency benefits for consumers if Alberta significantly added transmission interconnections in order to support decarbonization objectives. However, this analysis must consider the full impact to Alberta's internal resource adequacy, the additional cost of managing an expanded intertie as the most severe single contingency (MSSC), the impact to the FEOC operation of the market, and governance requirements of accommodating additional energy exchange between

Questions	Stakeholder Comments
	provinces with very different regulatory frameworks regarding electricity generation. **(ix) Offsets or Emissions Performance Credits (EPCs)** Heartland Generation does not view this as a separate technology but rather as a carbon policy compliance mechanism similar to a TIER fund payment. The AESO should take into account how offsets impact the FEOC operation of the market. Specific to offsets or EPCs, it is imperative that the AESO considers how the demand for these attributes, created by electric generation facilities in Alberta could outpace demand for electrical outputs from the same facilities. In such instances, electrical supply and demand would be disconnected with significant implications for Alberta's market design and overall electricity system. In particular, the AESO should model the transmission and distribution requirements necessary to accommodate net-zero scenarios that primarily rely on offsets produced from electric generation. The AESO should also consider the impact this outcome would have price formation and market design.
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?	Heartland Generation, at this time, does not have specific suggestions of generation technologies outside those listed by the AESO.
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.	See comments above in 5(b), whereby nuclear and new large hydroelectric facilities are unlikely to be constructed in Alberta.
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?	The Government of Canada has announced intentions to initiate discussions in 2022 on a net-zero electricity grid by 2035 and a Clean Electricity Standard. These discussions could potentially limit generation technology choices in Canada and may also set boundaries for what is considered as the electricity grid.

	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

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[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?	As a current and prospective developer of generation technology, Heartland Generation has concerns disclosing potentially commercially sensitive information; as such this information will not be shared in the public forum.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	See above response to 6(a).
	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).	See above response to 6(a).
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	There will be several developments this year that may impact a net-zero analysis, therefore it may be prudent for the AESO to defer a specific net-zero pathways scenario until after these policies are better known. The Alberta government has indicated it will be consulting on the TIER Regulation this Spring, followed by potential changes and an updated price schedule due by End-of-Year 2022. This will allow for a federal review of TIER in order to meet the equivalency standard with the federal framework. Further, the federal government intends to initiate discussions on a Clean Electricity Standard in the coming months. The AESO should ensure that its forecasting and publications are fully aligned with the larger initiatives and policies anticipated at multiple levels of government. As stated above the AESO should continually assess the FEOC operation of the market in light of regulatory policies as they are announced.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Vittoria Bellissimo
Comments from:	Industrial Power Consumers Association of Alberta (IPCAA)	Phone:	403 966 2700
Date:	2022/01/31	Email:	Vittoria.Bellissimo@IPCAA.ca

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

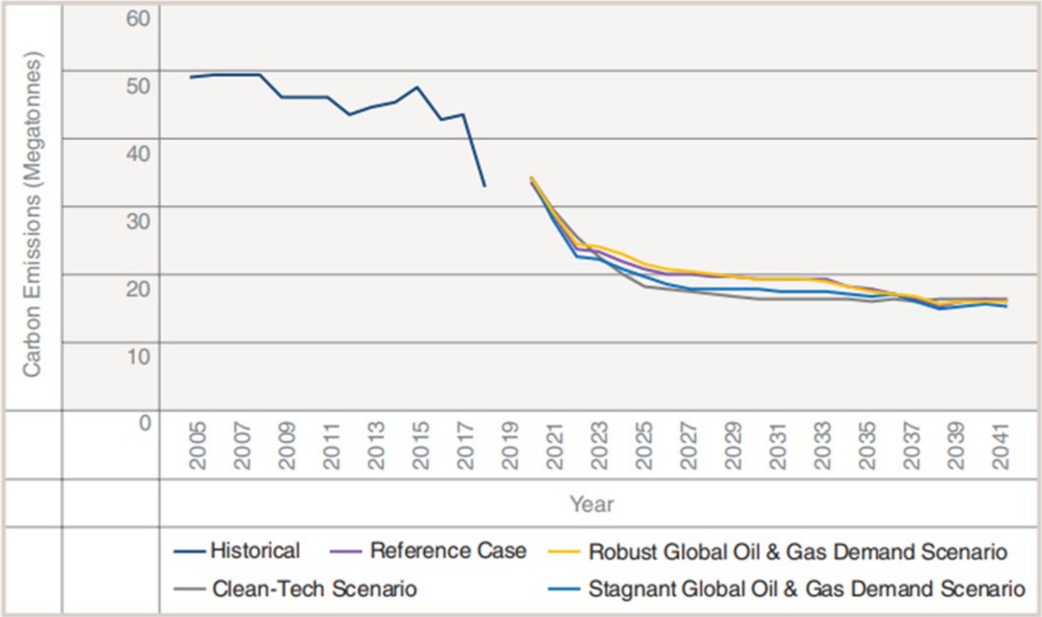
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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.

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td>1</td><td colspan="2">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.</td></tr>
<tr><td></td><td>a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td>The AESO's market is already a critical player in promoting cleaner energy by incorporating the carbon price into the market that both consumers and generators respond to. The price signal becomes the largest going-forward signal to get to a net-zero grid. Incorporating the carbon price into the market price makes the current Alberta electricity market design one of the most enlightened of all organized electricity markets in North America when dealing with carbon.
The scenarios the AESO has proposed to examine are appropriate at this time. IPCAA assumes the Pathways Report will be a living document with recurring updates, and as such, the scenarios will be updated as required.</td></tr>
<tr><td></td><td>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?</td><td>The AESO, in its discussion, is proposing to assess net-zero pathways to achieve emissions policy objectives while minimizing disruptions to the existing market framework. IPCAA interprets this as the AESO will not be examining changes in the current market framework to incent potential</td></tr>
</table>

	Questions	Stakeholder Comments
		pathways to a net-zero grid future. Instead, possible pathways will have to account for the existing market framework. Please confirm if this is correct. Depending on the refund/wealth transfer mechanism that is used to allocate carbon revenue, the largest challenges will include: • High costs to consumers and how to decarbonize without making Alberta uncompetitive for its electricity customers; • Appropriate border carbon adjustment implementation to ensure carbon accounting in electricity is tracked properly; • How to address the advantages of our interconnections with other jurisdictions without harming the sustainability of our market; and • How to manage the regulated side of the electricity market to ensure that wires costs are not compounding the cost problem.
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?	Alberta continues to see an increase in behind-the-fence electricity consumption, but the actual DTS energy is not reflecting the same growth. The 2021 DTS energy of 58,999 GWh, while higher than 2020, is down from its historic annual peak of 61,058 GWh in 2018 by 2,059 GWh (3.4%). IPCAA continues to be concerned that the AESO is focusing on the total electricity consumption rather than the primary demand which is the energy actually flowing across the grid and the energy that will be displaced by renewables connecting to the grid.
	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	While the AESO focusses on total electricity consumption in Alberta, including BTF, it needs to be undertaking an analysis of the actual MWs flowing on the grid, the DTS load. The DTS load is paying the transmission

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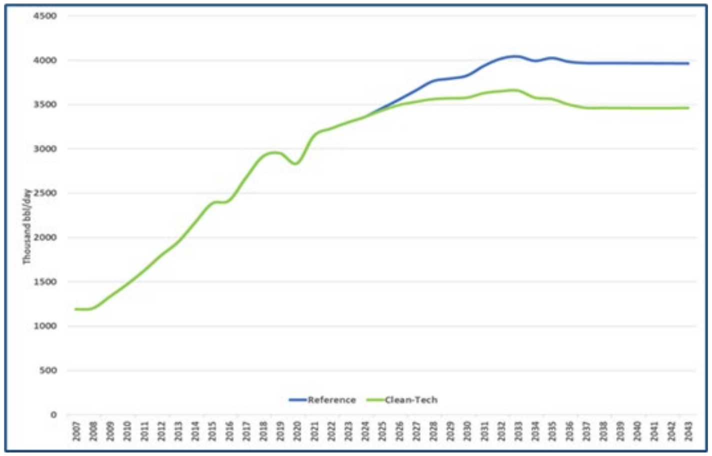
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	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?	costs and determines the need for new generation and transmission required.
	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?	As the coal fleet retires by 2023 there will be an increased reliance on natural gas as the "backing fuel" that will be required in summer and winter in particular. The $3/GJ range reflects the current forward curve.
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)	While off-sets and credits are important aspects of the carbon market, at some point they have to translate into physical emissions reductions either in Alberta or in receiving jurisdictions.

	Questions	Stakeholder Comments
	- Offsets or credits (generated within the electricity sector) - Physical emissions reductions only	
	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?	IPCAA expects that the price of carbon will rise to $170/T by 2030 as per the federal announcement. No specific views on pricing beyond 2030 at this point, although overall carbon will likely increase.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	At some point, as offsets get traded in the marketplace, there will need to be comprehensive accounting of the carbon. If Alberta is selling carbon offsets "off-shore" elsewhere in Canada, the carbon offset in another jurisdiction will need to be added to the Alberta carbon footprint to avoid double accounting.
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	Energy efficiency is an important driver of carbon reductions as carbon is priced into the Alberta market price. Please see the Energy Efficiency Alberta Potential Study for a (dated) view of potential. In addition, in the IEA Net Zero by 2050 Roadmap for the Global Energy Sector (Oct 2021), the IEA states: "In the net-zero emissions pathway presented in this report, the world economy in 2030 is some 40% larger than today but uses 7% less energy. A major worldwide push to increase energy efficiency is an essential part of these efforts, resulting in the annual rate of energy intensity improvements averaging 4% to 2030 – about three times the average over the past two decades." In order to facilitate energy efficiency in Alberta we need interval metering and a price signal that appropriately rewards consumer behaviour.
	b) Distributed Energy Resources (DER)	The AESO needs to recognize that there are market initiatives that need to be put into play. IPCAA has advocated that all load should receive the same

	Questions	Stakeholder Comments
	- 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.)?	price signal, not different signals as the transmission tariff is translated through distribution tariffs. Uptake of DERs will depend on appropriate price signals. The AESO needs to institute interval pricing and the AUC needs to institute smart metering so that all consumers have the right price signals. If these changes are made appropriately, IPCAA expects increased levels of demand response via new types of retail contracts and load-aggregation.
	c) Transportation Sector - What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
	d) Buildings - What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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)?	
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?	

	Questions	Stakeholder Comments
	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 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	IPCAA recommends that the AESO reach out to other entities in the Alberta, Canada and international innovation eco-system. Much of this work has been completed and discussed at length in other areas.
	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?	
	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.	
	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?	

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 %
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	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?	
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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.	It would be useful to understand the AESO's plans for this information, beyond producing a report in June 2022 and providing input into the LTO and LTP processes. Who is the audience for the June 2022 report – Government? Stakeholders? With the shutdown of thermal stations and load levels that are significantly lower than the AESO's historical forecasts, ratepayers are dealing with a grid that is over-built in some areas of the province. The AESO should explore opportunities to site wind, solar or energy storage projects where there is excess transmission capacity already available. This should be considered as part of the net-zero analysis. Thank you for the opportunity to comment.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Evan Bahry
Comments from:	IPPSA	Phone:	403-669-8664
Date:	2022/01/31]	Email:	Evan.Bahry@IPPSA.com

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.
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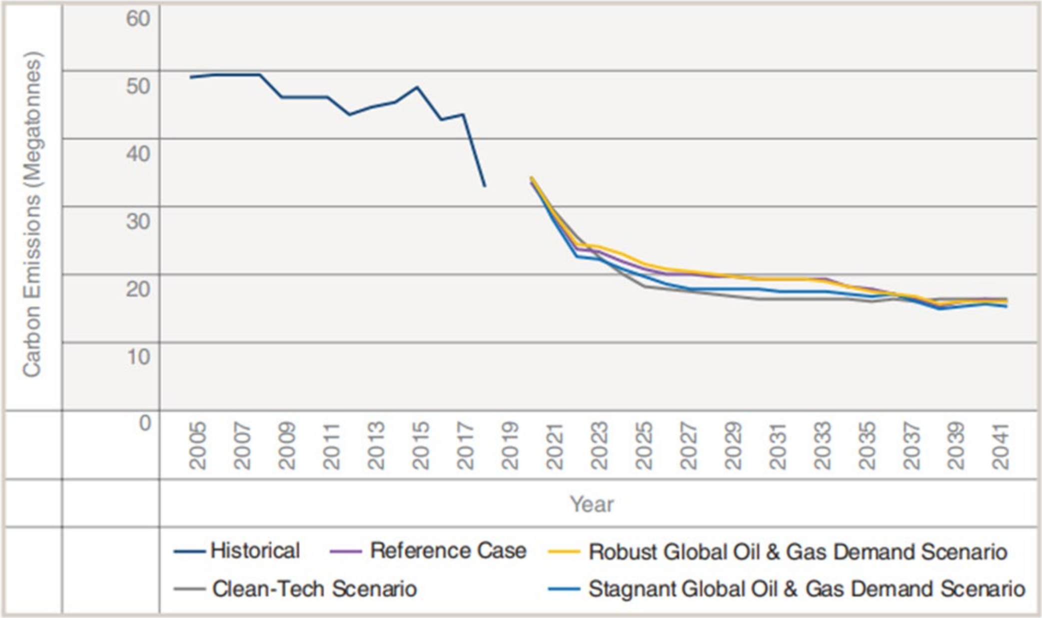
Electrification of high-emitting sectors and energy efficiency will also be key drivers along a pathway to net-zero outcomes. Mandates have been proposed for zero-emission vehicles, mentioned in the most recent federal election campaign and subsequent throne speech pledge, requiring at least half of 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.

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td>*1*</td><td colspan="2">***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.
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• 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.</td></tr>
<tr><td></td><td>a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td>▪ IPPSA supports the AESO in undertaking this analysis given that decarbonization is the largest issue facing the industry in the near future.
▪ We would recommend that the AESO conclude its assessment by highlighting the implications of various technologies on: 1) reliability, 2) affordability and 3) what, if any, improvements to the market are required.
▪ To this end, IPPSA recommends that the problem statements for the study should be: “What are the most realistic commercially available technologies – in tandem with offsets – that can reduce remaining emissions to Net 0 by 2035, while maintaining reliability? And what improvements to the current market - if any - are required to incorporate federal and provincial carbon policies and to enable the recovery of the costs of that needed technology?”
▪ Answering these problem statements would be make the study more meaningful to the market and would inform potential future</td></tr>
</table>

Questions	Stakeholder Comments
	market changes (price floor/price cap, ancillary services, etc.) that may be needed in short order to achieve the Net 0 by 2035 target. ▪ Of the scenarios described for the study, we do not believe that a system comprised of just renewables (wind and solar) paired with energy storage is reasonable by 2035; given the need to ensure system reliability. Furthermore, we do not believe that many of the other technologies proposed are feasible or available on the scale required for Alberta by 2035, including advanced nuclear fission reactor, hydro-electric and 100% H2-fired combined cycle. ▪ As such, we recommend an abbreviated list of generation technologies for inclusion in this study - namely NGCC + CCUS, wind, solar, battery storage, SMR. We also recommend a re-evaluation of the modelling parameters when the federal plans (electricity and hydrocarbon), and Alberta's response, are released, which are expected over the course of the AESO study.
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?	1) Rapidity of Net 0 by 2035 ▪ Wind and solar generation are commercially viable, with profound investor momentum behind them (See AESO's Nov LTA report). However, 2035 greatly reduces the options - and reduces the window for cost-cycle improvements - of Net 0 technologies available for baseload/dispatchable supply in Alberta. Solutions such as 100% H2 CC or geothermal will likely not be available on the scale required by 2035. 2) Understanding What 'Net 0' Means? ▪ 'Net 0' implies the ability for emitters to employ emissions credits and offsets to achieve compliance. This supports optionality, is market consistent and may greatly reduce the cost of achieving Net 0. However, there is no policy clarity on the definition 'Net 0' yet. 3) Implementation via Market Means or via Central Planning? ▪ Should policy-makers continue to rely on Alberta's open market to drive new investment, then Alberta's many generators, energy service providers and loads would be

	Questions	Stakeholder Comments
		expected to continue to explore ever more efficient and emissions reducing technologies. ▪ Alternatively, if policy-makers adopt a central planning approach to implementation – e.g. CFDs, discrete subsidies to companies, discrete subsidies for a given fuel type, financial support for East/West transmission – then all market-based approaches may be deterred. ▪ IPPSA continues to favour market-based solutions. But also supports investments in cross-cutting or enabling technologies such as CCUS at the storage end or H2 pipelines and production. These investments should be based on level playing field principles and not benefit one competitor over another. 4) Unknown Federal Policy Goals for Alberta's Resource Industries ▪ At this time, the future of Alberta's primary industry - oil and gas - remains unknown. This obviously has implications on Alberta's demand, the future of cogeneration supply, and the prospect of energy and power aiding in the economies of scale for CCUS and H2 production. That's why we recommend this study adapt in response to the release of the federal electricity and hydrocarbon plans and Alberta's response. ▪ Other industries where Net 0 aspirations/implementation remain unknown include agriculture, forestry, petrochemical and tourism. Targets for these sectors will also have implications on electricity demand. Despite the challenge of the near-term targets, IPPSA remains optimistic once the power grid is through the transition. A Net-0 barrel and Net-0 MWh would provide Alberta with a competitive advantage and would position Alberta very well for the future.
2	***Macroeconomic Context***	▪ The clear intent of Net 0 by 2035 is to deter unabated thermal supply and encourage non-emitting supply. Even without direct policy support, we see wind and solar continuing to be added to

	Questions	Stakeholder Comments
	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?	Alberta's grid via the FEOC market and contributing to the transition. However, given that Alberta's thermal fleet is essential to ensure baseload and dispatchable supply, and that few options are open to enable that transition before 2035, it should be assumed that dramatically rising carbon taxes on the thermal fleet will have implications on Alberta's power consumers and the economy. (e.g. "*Europe's biggest aluminum smelter cuts output on power price surge*", Bloomberg News, 21 December 2021). ▪ There are secondary costs that consumers and the economy will need to bear such as more transmission and ancillary services. ▪ There will also be direct costs to ratepayers associated with electrification as distribution grids are re-built to enable PHEV, rooftop solar, bi-directional power flow. Electrification will also spur new demand, with the commensurate pool price required to incent it. ▪ There could also be secondary costs to ratepayers associated with electrification in the form of commensurately lessened utilizations of undepreciated transmission assets. This may be offset by increased demand associated with electrification. Either way the AESO should incorporate the implications of Net 0 by 2035 on distribution costs and transmission costs. ▪ These costs may be alleviated by public support (financial or tax treatment) of CCUS or storage to lessen the impact of carbon prices on generators. Costs and impacts may also be alleviated depending on the design of any federal carbon rebate and any job creation, investment associated with CCUS, renewables and storage.

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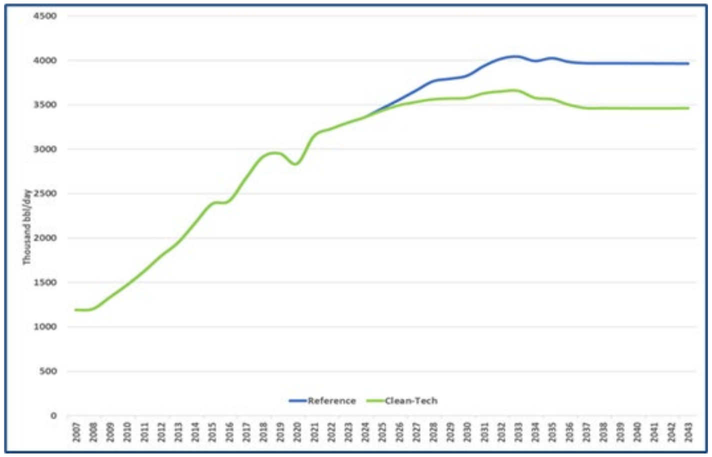
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

	Questions	Stakeholder Comments
		▪ Commitment to market-based solutions should ensure the adoption of the most efficient, least cost solutions to enable the transition.
	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	▪ We appreciate the difficulty the AESO faces in modelling Alberta's hydrocarbon production growth. The fact remains that many Alberta realities hinge on the federal government's plans. There are both headwinds to Alberta's growth (unknown emissions/production cap facing hydrocarbon production, unknown CCUS support or tax treatment) and, on the other hand, opportunities for growth (should Alberta achieve a Net 0 barrel and Net 0 GJ, Canada may have a global competitive energy advantage. Should policy recognize the value for domestic gas producers in displacing international coal-fired generation, Alberta may have a competitive advantage.) ▪ Greater clarity on the federal government's plans will likely materialize during the course of the AESO's assessment. (Q2 2022). This is why we recommend that that the AESO's study adapt to those policy announcements – and stakeholder reaction – once they are announced.

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

	Questions	Stakeholder Comments
	scenario for analyzing the impact of net-zero policies on the oilsands sector and the subsequent impact on load growth?	
	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?	▪ We recommend that the AESO examine price forecasts from various established sources.
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	▪ IPPSA supports the use of offsets as a tool to achieve Net 0 emission by 2035. We expect greater clarity from the federal government on its plans within Q1-Q2 2022. We'd encourage the AESO to keep this question open and allow participants to provide their comments when more is known from policy-makers.
	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?	▪ We expect greater clarity from the federal government on its plans within Q1-Q2 2022. We'd encourage the AESO to keep this question open and allow participants to provide their comments when more is known from policy-makers
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	There remain a number of unknown policy matters that will impact the electricity sector's implementation of Net 0 by 2035: ▪ The federal government's targets and supports for the electricity and hydrocarbon industries. ▪ The content of Alberta's response. ▪ The review of the Technology Innovation and Emissions Reduction Regulation (TIER) in 2022. ▪ The review of the Transmission Regulation, slated to commence at the end of 2022. ▪ The implications of the AESO's Revenue Sufficiency Calculation and Flexibility Studies in 2022. The former may precipitate

	Questions	Stakeholder Comments
		discussions on Alberta's price cap and price floor, supply surplus, etc. The latter may precipitate discussion on the ancillary services products required to integrate more renewables. ▪ Alberta Environment and Parks' intended development of a Carbon Sequestration Tenure framework at the end of Q1 2022. ▪ Federal targets and support for electric vehicles may impact Alberta's power demand, timeline and costs of electrification and ultimately investor confidence in hydrocarbon production.
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	▪ When it comes to pace, it depends if energy efficiency is driven by central planning (direct subsidies) or via market means (the price signal.) A market-based approach is expected to enable more rapid adoption, which is exactly what Alberta's open market has enabled for wind, solar, storage and cogeneration. ▪ A central planning approach could be assumed to be slow to design and may roll-out technologies on a piecemeal basis. A central planning approach may deter competitive market offerings. ▪ Furthermore, those with time-of-use meters – commercial and industrial customers – are best able to incorporate energy efficiency technologies. The residential market's participation will likely hinge on electrification. ▪ Changes to building codes would likely spur the adoption of energy efficiency, but only on a prospective basis. The AESO should take into account the proportionately small percentage of residential load to industrial load when modelling the impact of these changes.
	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	▪ It depends if these are driven by central planning (direct subsidies) or via market means (the price signal.) ▪ A central planning approach could be assumed to be slow to design and may roll out technologies on a piecemeal basis. The

	Questions	Stakeholder Comments
	storage systems, demand-side management technologies, load aggregator technologies, micro-grids, etc.)?	presence of a central planning approach may deter competitive market providers.
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	▪ Electrification of transportation will require planning, regulatory approval and investment, along with policy clarity on the financial supports available to it via both provincial and federal governments. More is expected to be known in Q1-Q2 2022 from the federal government.
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	▪ Changes to building codes would likely spur the adoption of energy efficiency, but only on a prospective basis. The AESO should take into account the proportionately small percentage of residential load to industrial load when modelling the impact of these changes.
	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)?	▪ We'd encourage the AESO to reach out to the proponents of the Quest project, Alberta Carbon Trunk Line, and Air Products to understand their practical experiences on the energy requirement to sequester CO2 and their views on its 'economy of scale' going forward. ▪ (IPPSA held a webinar for members featuring the Shell Quest project in 2021. Cost to sequester = $80/T. Quest could be done 25%-30% cheaper today, or ~$60/T.)
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?	▪ For a Net 0 by 2035 target, the most likely technologies include: wind, solar, lithium ion storage, carbon capture on existing supply and new NGCC + CCUS and potentially SMR. These are commercial, scalable and more readily available than 100% H2 CC, geothermal or large hydro.

Questions	Stakeholder Comments
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 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	▪ In Alberta's open market, investors will consider what technologies are best suited for them to invest in based on a host of factors. ▪ Recent history with the dramatic improvements to the cost of wind and solar and the rapid commercialization of storage suggest that it is best not to second-guess the market. ▪ When it comes to interties, IPPSA recognizes their role in helping the market to clear. While expanding interties can be part of this study a realistic volume should be considered and IPPSA also believes level playing field issues need to be addressed as a pre-condition to any expansion. ▪ Without ensuring a level playing field, expanded interties risk impacting investor confidence in needed, intra-Alberta renewable supply and in the investments needed to ensure intra-Alberta baseload and dispatchable supply.
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?	
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.	▪ Price polarity, flexibility, system inertia, supply surplus are all challenges associated with balancing a renewable (wind and solar) and thermal fleet. IPPSA believes that a portfolio approach is required to reduce emission and ensure reliability for the near term. We encourage the AESO to model operational risks as part of this study.
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	

	Questions	Stakeholder Comments
	technologies do you believe can be most economically implemented at cogeneration facilities?	
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*	

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

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[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?	
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Company Representative
Comments from:	Company Name	Phone:	Contact Phone Number
Date:	[yyyy/mm/dd]	Email:	

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

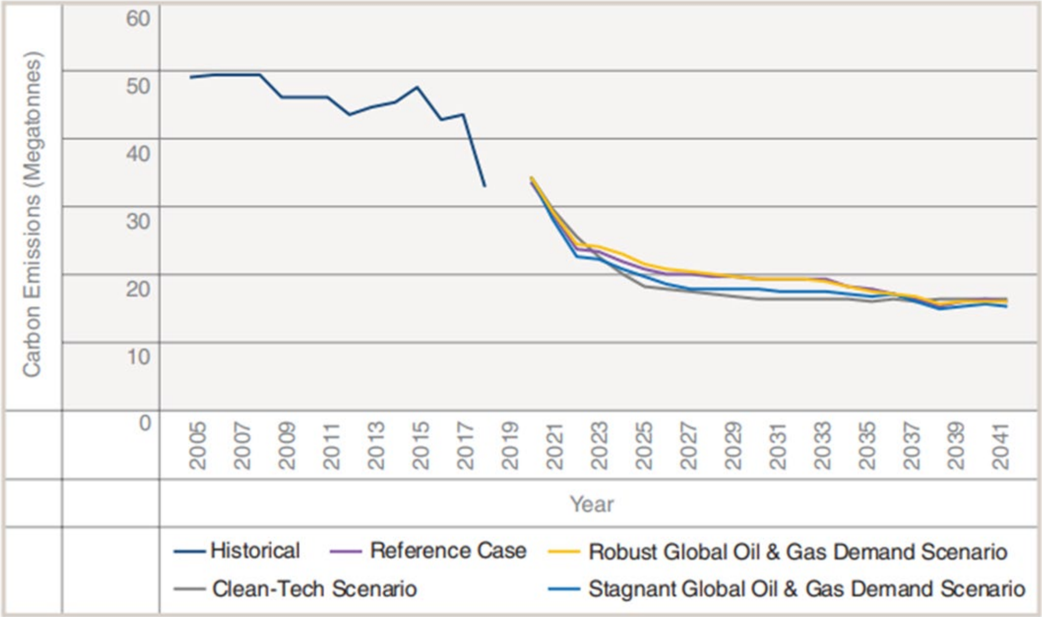
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	None of this work is helpful if it does not include a cost / benefit analysis. Renewables (wind, solar) paired with energy storage is a pathway guaranteed to lead to grid instability.
	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?	Challenges: 1) Consumer costs will become unbearable 2) Net zero implies all the natural gas generating assets will be abandoned. The owners of those assets will demand compensation. Who will pay ? 3) The baseload in Alberta, in a net zero world, can only be achieved by building many nuclear generating facilities. Going from ZERO nuclear to at least 50% of baseload by 2035 is a dream that can not be achived
	Macroeconomic Context	

	Questions	Stakeholder Comments
2	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?	
	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**	Can not comment – just do not know

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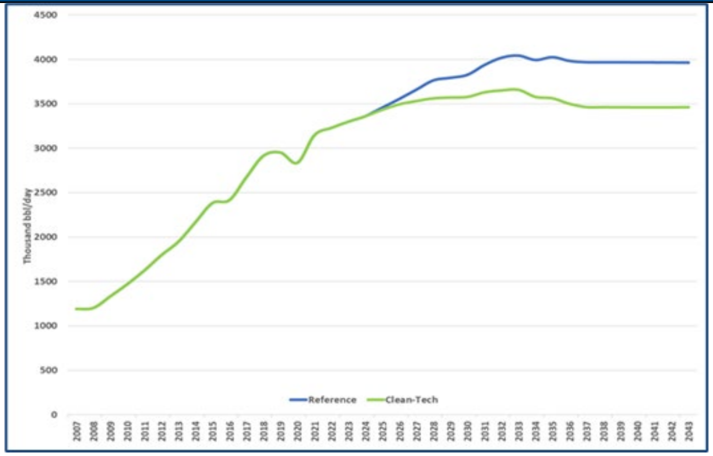
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	Gas prices will increase beyond inflationary rates The Key driver of natural gas prices will be the push by the federal government to drive investment in the oil and gas industry OUT of Canada. Decreasing investment capital will lead to steep declines in gas production – and consequent price increases.
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	I do not understand what you are asking me !!

	Questions	Stakeholder Comments
	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?	Caron price policy will fall apart when the public "wakes up"
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Who can possible guess what the politicians will do !!
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	No idea as about 95% of the public does not care and just wants to lives their lives as they have for the last several decades
	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.)?	No impact expected
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	Next to zero penetration
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	Very very very slow. Who wants to pay for that???

	Questions	Stakeholder Comments
	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)?	Don't worry about hydrogen – it is an uneconomic dream of technically illiterate politicians This question assumes these industries will accept net-zero targets. I sure hope they do not.
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?	Nuclear is the only viable hope
	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 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	It would take days to answer these questions

	Questions	Stakeholder Comments
	(ix) Offsets or Emissions Performance Credits	
	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?	No. This assumes the current fascination will the greenhouse gases theory continues.
	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.	I fully expect significant grid instability in the AESO allows the net zero ideas to get put into operation.
	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?	I have no idea on this one.

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

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[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?	I have no ability or background to comment
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	I have no ability or background to 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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Kate Moore
Comments from:	Kineticor Resource Corp.	Phone:	403-703-8772
Date:	2022/01/31	Email:	kate.moore@kineticor.ca

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

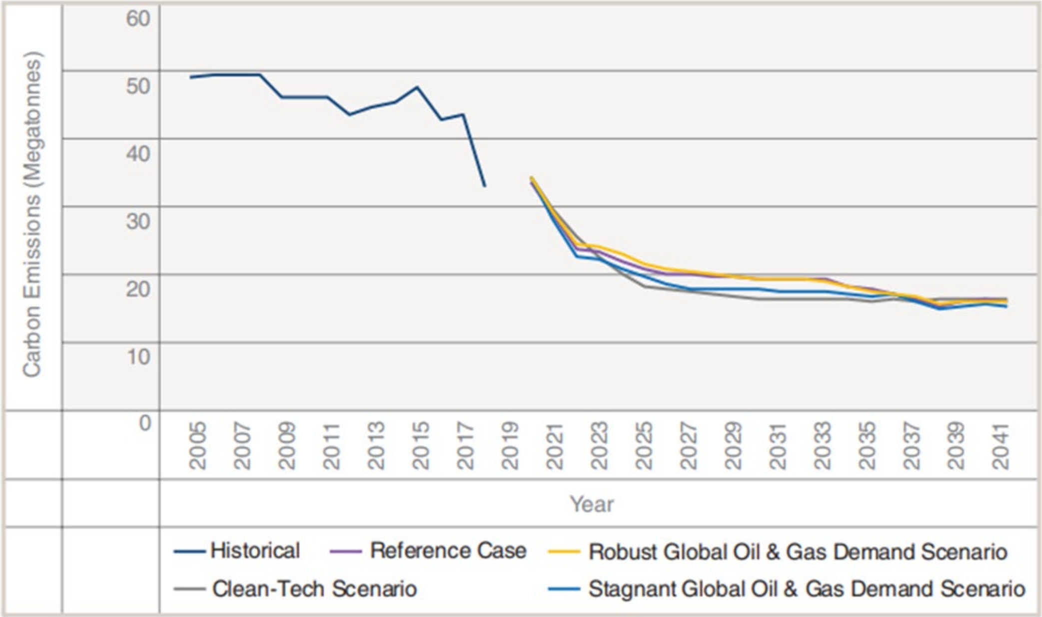
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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.

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.

Questions	Stakeholder Comments
a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?	- We agree with considering a range of potential zero-emission sources, notably options that will continue to provide baseload, reliable generation. - While it is stated above that specific impact to consumers is not included in this analysis, we would recommend that the scope include impact to consumers and/or tax payers regarding increases to power price.
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?	- Pace of transition to Net-Zero for the sector - Ability to secure financing for new and emerging technologies - Government Policy and Support Undeclared ▪ The technology path chosen to reduce emissions, specifically for thermal generators, will depend heavily on the final structure for government support (i.e. tax credits for CCUS, incentives for hydrogen). As this is yet to be declared, it is difficult to make

	Questions	Stakeholder Comments
		investment decisions at this time and therefore, the timeline for the transition will be further reduced until clarity is provided. ▪ Uncertainty around the carbon policy benchmarks in Alberta also introduced further uncertainty that needs to be clarified before decisions and investments are made.
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?	- The impact on the BAU scenario will depend on the approach taken by the federal and provincial government to achieve net-zero targets, including adjustments to the decline rate for the electricity benchmark and support/incentives provided for emission reduction technologies and pathways. - We expect power prices to increase in Alberta as our thermal fleet is essential to ensure baseload and dispatchable supply and option that enable a transition before 2035 are limited. - We expect the growth rate to rely on overall costs to generators, and the resulting increase to power prices in Alberta as well as other government policy decisions, such as the cap to hydrocarbon production. These decisions can potentially reduce expected growth in the province due to high power costs and reduced industrial activity or alternatively, increase the BAU growth scenario by encouraging new, emission reduction investments and accelerated electrification in the province.
	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-	- The expected government clarity on what net-zero means is needed for this question.

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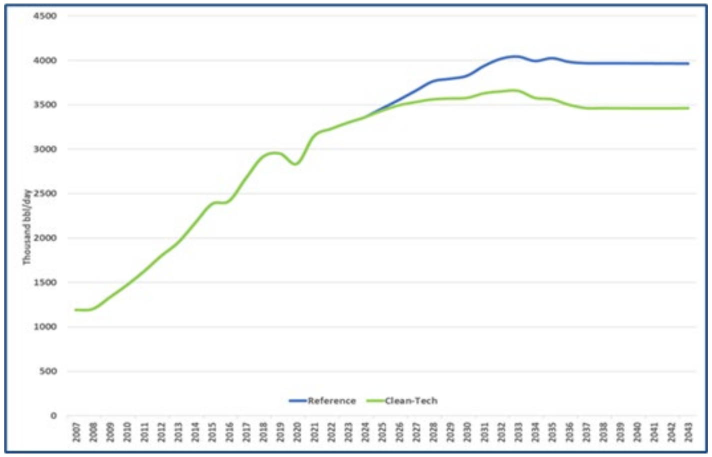
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	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?	
	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?	
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)	- We hope that offsets or credits are included as a compliance mechanism to account for the speed of the net-zero transition. - We expect the federal government to clarify this soon and suggest aligning the AESO's analysis with the information provided.

	Questions	Stakeholder Comments
	- Offsets or credits (generated within the electricity sector) - Physical emissions reductions only	
	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?	
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	- Implementation of energy efficiency measures is expected to be driven by the power price vs construction costs (and future expectations of increases to the average power price) and policy support.
	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.)?	
	c) Transportation Sector - What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	- We expect penetration to depend on policy put in place federally.
	d) Buildings	

	Questions	Stakeholder Comments
	• What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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)?	- We encourage the AESO to reach out to companies in the CCUS and hydrogen sectors as well as technology providers. The current auxiliary load of CCUS is significant, however, we expect advancements in the future to reduce the load required. - Load growth and impacts of Net-Zero targets will heavily rely on government policy and strategy to achieve these targets.
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?	- We expect renewables and storage to play a part as well as technologies to reduce emissions from baseload thermal generation. - The actual technologies applied for thermal generation will depend on government policies and support as well as technology advancements in the short to medium term.
	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 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	- An important strength of post and pre-combustion CCUS is that it would allow continued reliability in Alberta's market. Costs, parasitic loads and the pace of technology advancements are the main weaknesses we see. - Weakness - CCUS on gas-fired generation hasn't been widely deployed around the world. This could have financing issues for early adopters. - The main weakness for all options is the current policy uncertainty. - A weakness that should be considered for all options when considering government policy decisions is the priority of maintaining a level playing field among generators in Alberta. We believe this is crucial to encourage investment and innovation that will be required to meet Net-Zero targets and reduce price increases for consumers.

Questions	Stakeholder Comments
(vi) Nuclear generation (vii) Energy Storage (viii) Transmission interconnections with other jurisdictions (ix) Offsets or Emissions Performance Credits	
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?	
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.	
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?	- We believe cogeneration facilities should be included to keep an even playing field within the electricity sector. We believe all generation in the province should be included in the same policy

	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

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[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?	- More studies and the development of actual projects are needed to understand the associated costs of these technologies in Alberta. We encourage all government funding to require sharing of cost information and information on lessons learned to increase knowledge across the sector.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	- More studies and the development of actual projects are needed to understand the associated costs of these technologies in Alberta. We encourage all government funding to require sharing of cost information and information on lessons learned to increase knowledge across the sector.
	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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Robert Bell
Comments from:	Montem Resources	Phone:	604-763-4180
Date:	2022-01-31	Email:	rbell@montem-resources.com

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.**
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Introduction

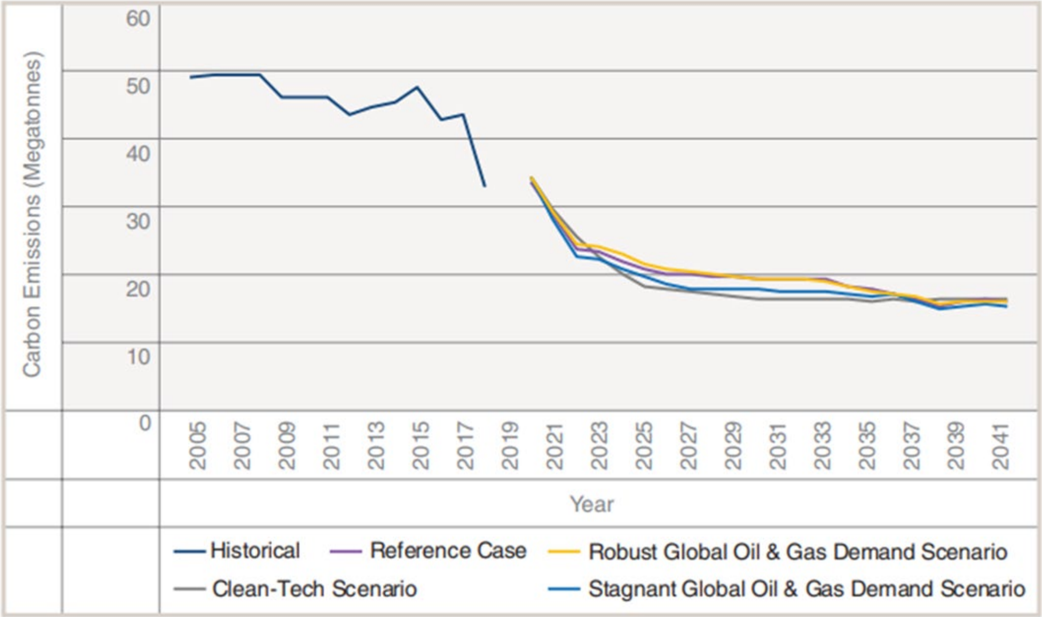
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	
	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?	1) Grid Inertia: Over the past two years, the AIES has experienced under frequency load shed when forced outages occur on the synchronous interties. Legacy ancillary services products have proven to be insufficient to prevent rapid decline in grid frequency. As the AIES becomes increasingly reliant on asynchronous generation such as wind and solar, this issue will become increasingly problematic. 2) Supply Surplus: When growing non-dispatchable renewable capacity is combined with baseload generating facilities such as CCGT+CCUS or SMR, supply surplus will become much more frequent. Exports may not be a viable solution if neighboring jurisdictions are also experiencing supply surplus. Long duration energy storage within Alberta will be required.

	Questions	Stakeholder Comments
		3) Transmission expansion: Significant transmission build will be required to interconnect new generation, increase import/export capability, and facilitate power flow from wind/solar regions to load centers. Long duration energy storage may mitigate some of this transmission need by time-shifting a portion of renewable output, smoothing local load peaks, and providing local/regional reliability services to support the transmission network. It is our view that in order to reach net zero, markets and tariffs must properly compensate facilities for inertia, flexibility, and transmission deferral.
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?	Net zero aspirations are likely to boost economic growth in Alberta. The most obvious source of growth is development of carbon-free generation such as wind, solar, energy storage, CCGT+CCUS, and nuclear. However, low-cost carbon free electricity also has the potential to attract entirely new industries. Amazon's plan to open a cloud computing hub near Calgary is an example of new industry drawn by low carbon electricity supply.
	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	The 2021 LTO approach is reasonable. While we appreciate that oil sands have historically been the primary driver of load growth in Alberta, we expect this industry's impact to be diminished going forward. We expect that load growth will be driven by electrification of transportation; electrification of heating; hydrogen production; and technology/computing (data centers, cryptocurrency, etc).

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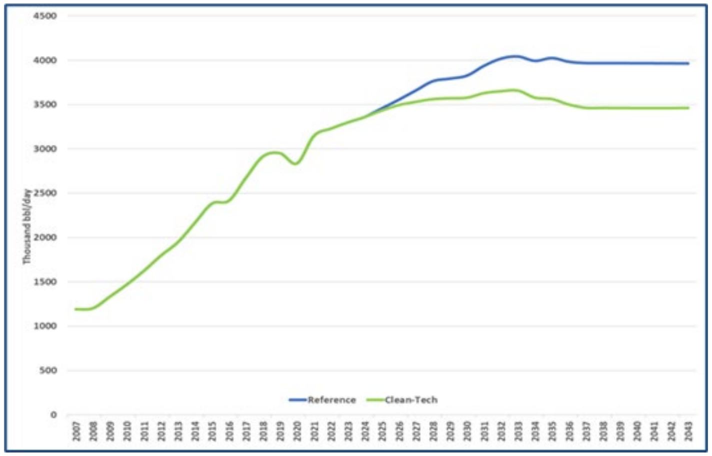
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	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?	
	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?	We expect natural gas prices to climb in real terms. This will be driven by increased demand in the short/medium term from electricity generation and LNG exports. Also, supply growth may be hampered by declining production of legacy gas fields, more stringent environmental regulations, and rising interest rates.
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)	It is our view that net zero cannot be achieved from offsets and credits, and that physical emissions reductions will be required. A system based on offsetting and crediting will likely always be dependent on fossil-based generation during periods of low renewable output. To achieve net-zero, companies must commit to physical emissions reductions. The 24x7

	Questions	Stakeholder Comments
	• Offsets or credits (generated within the electricity sector) • Physical emissions reductions only	Carbon Free Energy (CFE) commitment is an example of an initiative that will promote physical emissions reductions.
	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?	We are expecting approximately $150/t by 2030 and inflationary growth thereafter. While we expect carbon prices to grow steadily throughout the decade, we acknowledge that the rate of growth may be tempered by changes in government and/or rising energy costs. In addition to carbon pricing, policy that requires physical reduction or capture of carbon emissions may be required to achieve net zero.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	The evolution of the TIER output-based benchmark will play a key role in the energy transition. In order to achieve net-zero, the benchmark will need to be reduced to 0 t/MWh. The electricity grid displacement factor (the rate at which renewable energy generates emissions offsets) is another key policy element.
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	
	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.)?	
	c) Transportation Sector	

	Questions	Stakeholder Comments
	- What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
	d) Buildings - What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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)?	
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?	Long duration energy storage combined with wind/solar is expected to be the most economic pathway to net zero. However, given the magnitude of the challenge, it is likely that all technologies will play a role in the path to net zero, including CCUS, hydrogen, and nuclear.
	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 Carbon Capture, Utilization, and Storage: Lack of flexibility (ramp down); technology/cost risk; 2030 (ii) Pre-combustion Carbon Capture, Utilization and Storage (hydrogen): High fuel cost; Complex fuel distribution network; 2035 (iii) Oxyfueled generation

Questions	Stakeholder Comments
	(iv) Renewable generation including wind, solar, geothermal, and biomass: Non dispatchable, no inertia; 2022 (v) Hydroelectric generation; 2028 (vi) Nuclear generation: lack of flexibility, public opposition, regulatory uncertainty; technology risk, 2040 (vii) Energy Storage; Lack of duration for BESS; Pumped hydro strength: long duration; 2025 (viii) Transmission interconnections with other jurisdictions: Provincial self sufficiency, capital cost, regulatory burden; 2030 (ix) Offsets or Emissions Performance Credits: Will not achieve net-zero; 2022
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?	Assuming that pumped hydro is included in the energy storage category, then we have nothing to add. However, it may make sense to separate BESS and PHES into separate categories, as these technologies have very different characteristics.
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.	As mentioned earlier, many of these technologies do not provide inertia, which will continue to present challenges relating to frequency stability. Additional sources of inertia will be required. Baseload technologies combined with non-dispatchable renewables will result in increased supply surplus. Long duration energy storage will be required to prevent material curtailment of renewables.
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?	Yes, cogeneration facilities should be counted in the context of net-zero. CCUS is the technology that is most likely to de-carbonize cogeneration facilities. However, it is likely not feasible for all cogen facilities to install CCUS by 2035.

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

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[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?	
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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).	We believe that Pumped Hydroelectric Energy Storage (PHES) will play a crucial role in the energy transition. Capital operating costs vary significantly depending on design and operating profile. Projects that make use of existing reservoirs and have large vertical displacement tend to offer the most compelling economics.
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	We believe it is important to consider whether existing market and tariff structures provide the correct economic signals to incent investment in technologies required to achieve net zero. Currently, long duration energy storage is challenged by lack of revenue certainty, high tariff costs, and lower market volatility relative to some other markets. Reconsidering the energy price floor and ceiling is an example of a policy change that would incent energy storage investment. Storage-friendly demand tariffs and ancillary services are also key elements. Adoption of 24/7 carbon-free energy will be crucial in achieving net zero by 2035. The AESO should endeavor to ensure that the market can facilitate the real-time tracking of electricity supply/demand. In particular, interval metering should be mandated province wide, including at the residential level.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Mark Zanewick
Comments from:	Market Surveillance Administrator (MSA)	Phone:	403-705-8504
Date:	2022/01/31	Email:	mark.zanewick@albertamsa.ca

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

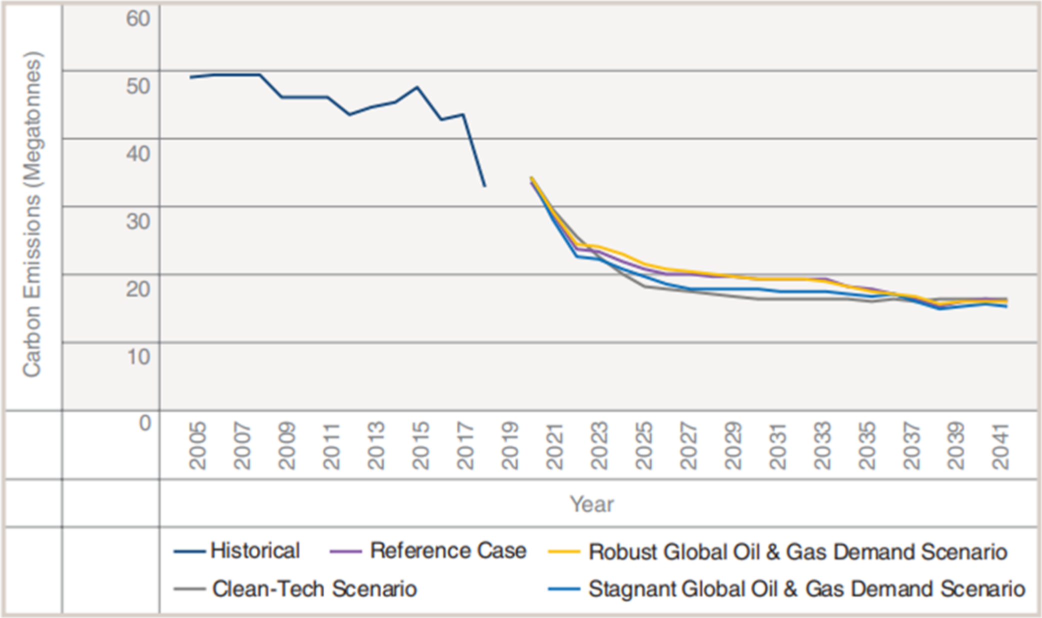
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	No comment at this time.
	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?	No comment at this time.
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]	No comment at this time.

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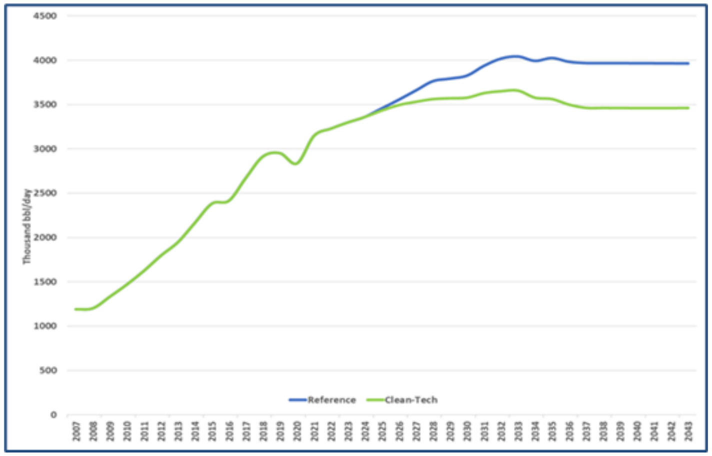
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

Questions	Stakeholder Comments
a) What is your view on the economic impact of expected net-zero targets on this business-as-usual scenario?	
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	No comment at this time.

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

	Questions	Stakeholder Comments
	scenario for analyzing the impact of net-zero policies on the oilsands sector and the subsequent impact on load growth?	
	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?	No comment at this time.
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	No comment at this time.
	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?	No comment at this time.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	No comment at this time.
	d) Are there any other related considerations that you would like to provide feedback on?	No comment at this time.
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?	No comment at this time.

	Questions	Stakeholder Comments
	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.)?	No comment at this time.
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	No comment at this time.
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	No comment at this time.
	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)?	No comment at this time.
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?	No comment at this time.

Questions	Stakeholder Comments
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 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	No comment at this time.
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?	No comment at this time.
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.	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?	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.

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[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 comment at this time.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	No comment at this time.
	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).	No comment at this time.
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	The MSA offers no specific comments at this time as it relates to the scope and input assumptions of the AESO's proposed net-zero emissions pathways analysis. The MSA's mandate includes protecting and promoting the fair, efficient, and openly competitive operation of Alberta's electricity market. The MSA expects that the AESO's net-zero emissions pathway engagement and analysis will provide insights into a range of potential future performance and structural implications for Alberta's electricity market. Accordingly, the MSA intends to remain apprised of the discussions and developments throughout the planned engagement process. While the MSA offers no initial comments on either scope or input assumptions, the MSA may elect to provide comments as appropriate at future points of the AESO's planned process, including the March Q1 target timeline of stakeholder feedback regarding the preliminary modelling results.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Binnu Jeyakumar
Comments from:	Pembina Institute	Phone:	587-436-3667
Date:	2022/01/31	Email:	binnuj@pembina.org

Instructions

a) Please fill out the section above as indicated.

b) 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.

c) **Please submit one completed comment matrix per organization.**

d) **Stakeholder comment matrices will be published on aeso.ca, in their original state.**

e) Email your completed comment matrix to forecast@aeso.ca **by Jan. 31, 2022.**

Introduction

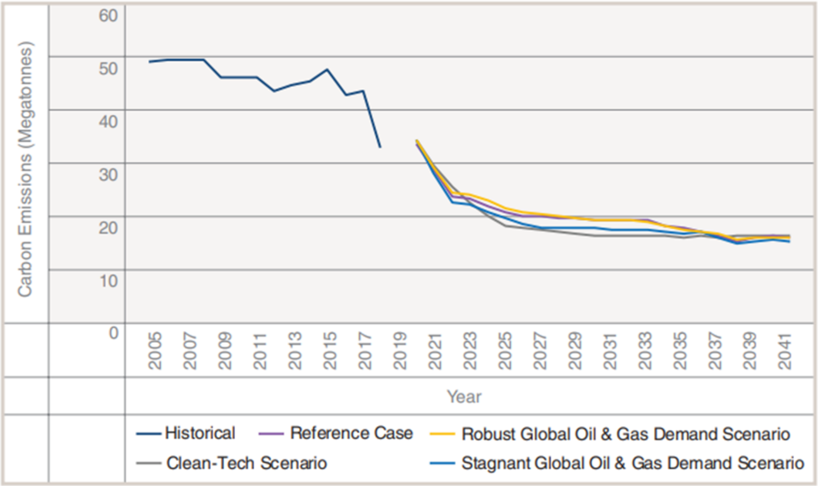
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	• Both scenarios should be modelled to 2035 in line with International Energy Agency recommendations and Canada's target to have a net-zero electricity grid by 2035. • As renewable energy with storage is a limited and impractical scenario, this model would yield limited insights. There would be more value for system planning in testing the system impacts and the model's sensitivity to some key policy unknowns, using scenarios that test the model's response to variables that are uncertain in the present and in the future (e.g., rate of fuel-switching, demand reduction due to retrofits). • Scenarios should include updated cost projections for energy storage and other maturing technologies, and should be tested for sensitivity to the projected cost reductions in these technologies. • Modelling of variable energy should also take in to account the benefits of combining it with other clean energy sources such as battery and energy efficiency. The Pembina Institute's research has shown that a portfolio of wind, solar, storage, demand

Questions	Stakeholder Comments
	flexibility, and energy efficiency can generate electricity in Alberta at a lower cost to consumers than gas plants while providing the same energy services.[1] - Scenarios should consider different levels of electrification, as well as demand-side management (DSM) and energy efficiency. - Scenarios should model the optimized use and benefits of – in addition to costs - from these services (e.g., flexibility, peak load shifting, avoided costs from deferred or unnecessary infrastructure upgrades), particularly when they are deployed with Advanced Metering Infrastructure, regulatory updates and grid modernization that can leverage their benefits.[2] - The assumed carbon price in the cost comparison should be at least $170/t on a full emissions pricing basis. The model should also account for carbon prices increasing beyond $170/t after 2030. - Scenarios should consider transmission interties to non-emitting electricity generation supply in neighbouring jurisdictions, as they will make decisions around new supply based partly on the potential to access the Alberta market. An assessment of the availability of non-emitting supply in nearby jurisdictions should not assume the same long-term planning as is currently undertaken in the context of limited access to the Alberta market. - Scenarios should consider the cost implications of climate change and extreme weather events on system reliability with respect to differing generation types and system designs.

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[1] https://www.pembina.org/reports/reliable-affordable.pdf

[2] https://rmi.org/wp-content/uploads/2018/12/rmi-non-wires-solutions-playbook-report-2018.pdf

	Questions	Stakeholder Comments
	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?	• Recent and forthcoming capital investments in emitting technologies that are not net-zero-ready with retrofits can lead to stranded assets, including both private generating capital and the supportive infrastructure that is recovered from rate base. • Regulatory and legislative structure updates are required to enable the grid to fully take advantage of net-zero energy services. Rate design changes and performance-based regulation can mitigate the impacts of service upgrade costs being passed on to consumers. Integrating on-site renewables can defer or eliminate the need for infrastructure upgrades. • The cogeneration facilities that primarily provide heat for oilsands operation, while behind-the-fence, nonetheless need an equivalent non-emitting technology or combination of technologies.
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.[3] • What is your view on the economic impact of expected net-zero targets on this business-as-usual scenario?	• To sustain that rate of growth, Alberta must meet global investment community expectations around net-zero economy as well as net-zero electricity and take full account of the long-range economic impacts of carbon liability risk, given increasing global financial sector attention to Scope 2 emissions. • With a net-zero grid, Alberta can attract more corporations (e.g., Amazon, Telus[4]) with ESG (environmental, social, and governance) targets. This increase in corporate investment can enable market access for Alberta products and foster ongoing capital investment within the province. • Renewable energy, retrofits, and the clean energy supply chain are big job creators that can bring talent to the province. Alberta's decarbonizing economy has the potential to add 67,200 jobs in

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Commented [GB2R1]: I'm unclear, as well. @Binnu Jeyakumar, can you add some detail to this?

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

[4] https://businessrenewables.ca/deal-tracker

	Questions	Stakeholder Comments
		the province through 2030.[5] Across Canada, the energy efficiency sector employed 436,000 workers in 2018, accounting for 2.3% of all jobs in Canada. From 2017-2018, energy efficiency employment (2.8%) outpaced overall job growth (1.0%).[6]

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[5] https://www.pembina.org/reports/albertas-emerging-economy.pdf

[6] https://www.pembina.org/reports/canadas-renovation-wave.pdf

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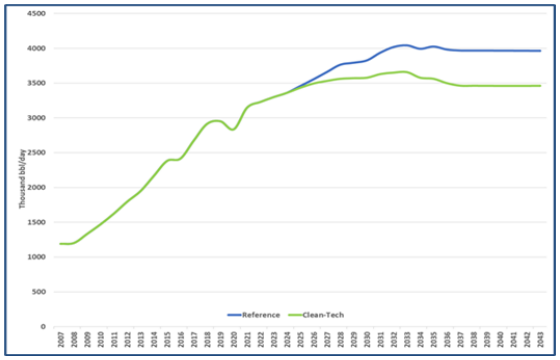
The current IHS Markit outlook notes that Alberta oil sands production has surpassed pre-pandemic levels and forecasts incremental growth out to 2030 to more than 3.6 MMMb/d.[7] Oilsands production is a key driver of Alberta's load growth. In the 2021 LTO, the AESO adopted an earlier version of the IHS 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



- 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?

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It is vital that AESO adopt an oil production scenario that aligns with net-zero given that the majority of the world's GDP is now under governments that have net-zero commitments and the oilsands companies themselves have formed an alliance and committed to achieving net-zero by 2050. This is unlikely to result in increased production.

Oil companies like BP and Equinor, as well as consultancy McKinsey, all predict oil demand peaking within the next few decades, even without more ambitious climate action. Each year, the projections of peak oil demand edge closer and closer. More importantly, a number of scenarios suggest oil demand may have already reached its peak and could experience a steep drop in coming years, in no small part due to coordinated action to limit global warming to 1.5ºC and prevent irreversible damage to ecosystems and communities. If this restructuring happens at the faster pace needed to achieve net-zero GHG emissions, as the International Energy Agency's 2020 World Energy Outlook shows (see Figure 1, below), demand for oil will drop over time. Either way, the oil and gas sector is unlikely to experience the rapid growth of decades past. With pressure from investors requiring better ESG performance from all businesses, it is reasonable to expect a higher number of oil-industry-led corporate power purchase agreements (PPAs) supporting more renewable electricity projects.

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	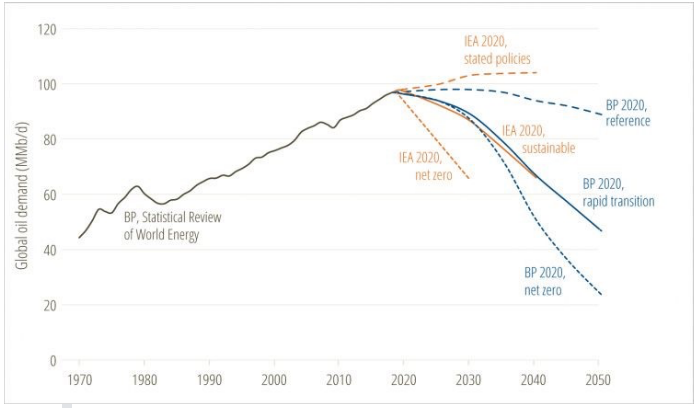 Figure 1. Global oil demand outlooks from the IEA and BP[8]

	Questions	Stakeholder Comments
	• 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?	The analysis of different scenarios with different proportions of gas-fired generation will be sensitive to the natural gas price, which has proven to be both volatile and difficult to predict. It will be important for the analysis to recognize this sensitivity and acknowledge the wide range of uncertainty around cost outputs relating to forecast fuel cost inputs. It is also important to incorporate the risk of full carbon pricing at $170/t (and above $170/t after 2030), including on upstream fugitive methane emissions, into the forecast for natural gas prices.
3	***Policy and Electricity Value Chain Impact*** • Do you interpret net-zero emissions targets as enabling compliance via the following mechanisms? a. Offsets or credits (generated outside the electricity sector) b. Offsets or credits (generated within the electricity sector) c. Physical emissions reductions only	We anticipate that some flexibility mechanisms may be permitted to give credence to the “net” in “net-zero”. However, given that there are several economic and reliable alternatives to GHG-emitting technologies within the electricity sectors – while some other sectors are still lagging behind in terms of commercially available and economic alternatives - it would be prudent to aim for the electricity sector to be as near zero emissions as possible.
	• 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?	With federally announced carbon prices rising at $15/t per year through 2030, we anticipate carbon prices will continue to rise at a minimum of $15/t per year beyond 2030.
	• What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	• Federal Clean Electricity Standard • Federal mandates and support for electrification • Federal support for grid innovation and for deployment of net-zero grid enabling technologies such as storage. • Increased interprovincial transmission • US zero-carbon grid 2035 target • Need for increased grid resilience for climate mitigation
	• Are there any other related considerations that you would like to provide feedback on?	• Assets that are susceptible to climate impacts may be subject to increased insurance costs as the insurance industry addresses an

	Questions	Stakeholder Comments
		expected increase in severe weather damage and other climate change-related claims.[9] Grid resilience assessments should include the economic and social costs of blackouts and brownouts, as these will become more common as the fire season lengthens.[10] - More frequent and severe heat waves are changing seasonal load profiles. Thermal generation derates due to poor hot weather performance will continue to exacerbate this issue.[11] - Regulatory reforms, including rate design changes, energy efficiency policies, and introduction of performance-based regulations, must keep pace with implementation of net-zero technologies to realize the full potential of flexible, electrified buildings.[12]
4	***Electrification and Electricity Demand Drivers in Alberta*** **(i) Energy efficiency** 1. 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?	- The Pembina Institute has used top-down estimates for energy efficiency potential calculated from Energy Efficiency Alberta's 2018 study[13], based on economic potential for energy efficiency. However, we recognize that there is a lack of data and the true potential could be much higher. - Regulatory and rate structure are necessary to ensure price signals properly incent appropriate energy efficiency and demand response technologies.

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[9] https://www.insuranceinstitute.ca/en/resources/insights-research/Climate-risks-report

[10] https://www.psehealthyenergy.org/news/blog/preventing-wildfires-with-power-outages-2/#ref

[11] https://www.energy.gov/sites/prod/files/2019/09/f67/Oak%20Ridge%20National%20Laboratory%20EIS%20Response.pdf

[12] https://www.raponline.org/wp-content/uploads/2021/01/rap-shipley-hopkins-takahashi-farnsworth-renovating-regulation-electrify-buildings-2021-january.pdf

[13] Energy Efficiency Alberta, 2019-2038 Energy Efficiency and Small-Scale Renewables Potential Study (2018), prepared by Navigant Consulting

Questions	Stakeholder Comments
	- Rate structure reform is needed to accelerate electrification of building space, water heating systems, and on-site generation, especially to protect residents of multi-unit residential buildings against high demand charges. - The AESO should assume that the policies and frameworks are in place to make full use of energy efficiency and DER technologies in carrying out this analysis and that the technology cost declines in these sectors will match those in other recent sectors. The analysis should not be limited by current market or social barriers to adoption of new technologies or behaviours and instead should assume that appropriate system and policy measures are implemented which enable the full economic use of these technologies. - A provincial energy efficiency target and program would trigger more energy efficiency and conservation efforts. To compare the costs and benefits of energy efficiency across the grid, cost-benefit testing must consider all relevant material, energy, and non-energy impacts, including energy savings, peak demand savings, and reduced ramp rates.[14]
(ii) Distributed Energy Resources (DER) 2. 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.)?	- We expect net-zero trends will result in DER growth due to increasing consumer demand and growing interest from municipalities. Energy efficiency and demand-side management (DSM) technologies will reduce overall and peak electricity demand while increasing flexibility to add DERs. - DERs can also help provide Non Wires Alternatives to additional transmission infrastructure and can be a greater part of a cost-optimized electricity system.

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[14] https://www.nationalenergyscreeningproject.org/national-standard-practice-manual/

Questions	Stakeholder Comments
	• Assuming the most economical DERs will be added to the generation mix first, a portfolio of demand response, energy efficiency, battery energy storage, wind, and solar will be prioritized.[15]
(iii) Transportation Sector 3. What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	• Over half of Albertans (54%) say the next car they purchase in the next one to five years will be an electric vehicle.[16] The Government of Canada's target for 100% of new light-duty car and truck sales to be net-zero by 2035 will further accelerate the pace of passenger vehicle transportation electrification.[17] • Commercial electric vehicle adoption is expected to accelerate quickly.[18] BNEF recently estimated that electric buses and trucks will require only 1.3% of all charging ports but will account for ~25% of the total electricity used for electric transportation.[19] As electrified fleet vehicles can charge more predictably and flexibly than passenger vehicles, modelling should be optimized to include smart charging patterns and load distribution, rather than assuming vehicle charging that occurs predominantly at peak hours. Rate structures can be designed to further encourage this behaviour. Vehicle-to-grid integration should also be modelled to assess the potential for deploying fleet vehicles as an energy storage asset.
(iv) Buildings	• From a carbon perspective, our modelling shows that if Alberta retires all coal and builds up to 30% renewable energy, electrification of building space and water heating makes sense.

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[15] https://www.pembina.org/reports/reliable-affordable.pdf

[16] https://www.newswire.ca/news-releases/the-next-new-vehicle-purchase-for-nearly-70-per-cent-of-canadians-will-be-an-electric-model-kpmg-in-canada-survey-889637501.html

[17] https://www.canada.ca/en/transport-canada/news/2021/06/building-a-green-economy-government-of-canada-to-require-100-of-car-and-passenger-truck-sales-be-zero-emission-by-2035-in-canada.html

[18] https://www.nationalgridus.com/media/pdfs/microsites/ev-fleet-program/understandinggridimpactsofelectricfleets.pdf

[19] https://about.bnef.com/electric-vehicle-outlook/

	Questions	Stakeholder Comments
	4. What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	The breakeven point is estimated at 0.33 tCO2e/MWh. According to 2020 CER CEF Generation, Alberta's grid intensity is on track to drop below that threshold by 2030. That result is assuming a current average coefficient of performance (COP) of 2.9 (from NRCan) and does not take into account expected improvements in performance – for example, heat pumps with higher COPs are already available outside Canada. As long as the policy landscape continues to encourage electrification with cold climate heat pumps paired with envelope insulation and air tightness upgrades, Albertans can decarbonize their buildings through electrification. • From a cost perspective, rate structures and carbon price are needed to encourage fuel-switching and demand reduction. In parts of Canada that also have high cooling demand (which are expected to rise in future climate scenarios), the business case for heat pumps improves, as they replace both heating and cooling systems.
	(v) Industrial Sectors 5. 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? 6. 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)?	We estimate that if 8 Mt of CO_2 are captured, as the oilsands net-zero pathways alliance estimates they can capture by 2030, it would lead to an additional 5 PJ of electricity demand (1.5 TWh).
5	***Generation Technologies*** • What net-zero enabling generation technologies do you perceive as being the most economic pathways to decarbonization of the electricity supply in Alberta?	• A portfolio of technologies that includes energy efficiency, DSM, storage, wind, and solar provides the most cost-effective solution

Questions	Stakeholder Comments
	for meeting electricity needs in Alberta, as shown in the Pembina Institute's 2019 study.[20] • Energy efficiency is one of the cheapest solutions for grid decarbonization.[21] • The cost of battery storage continues to decline dramatically.[22] • With increasing electrification of energy end uses and increased use of advanced metering infrastructure, the potential for DSM continues to grow.
• 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? a) Post-combustion Carbon Capture, Utilization, and Storage b) Pre-combustion Carbon Capture, Utilization and Storage (hydrogen) c) Oxyfueled generation d) Renewable generation including wind, solar, geothermal, and biomass e) Hydroelectric generation f) Nuclear generation g) Energy Storage h) Transmission interconnections with other jurisdictions	In evaluating the strengths and weaknesses of the technologies, we recommend the following be taken into consideration: • Costs – current and projected • Lifecycle GHG emissions, including upstream emissions • The services they provide to the grid, especially in terms of flexible operations (i.e., responsiveness to increasing electrification of energy end uses) and ancillary services • Additional environmental risks Below are a few comments on the various technologies, however these are not comprehensive. The Pembina Institute is currently undertaking studies that will provide further information, and would appreciate the opportunity to share its findings when available. (a) Post-combustion CCUS: • Strengths: mitigate risk of stranded gas assets, Alberta has a carbon trunk line to transport CO_2

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[20] https://www.pembina.org/reports/reliable-affordable.pdf

[21] https://www.pembina.org/blog/carbon-capture-cant-beat-energy-efficiency

[22] https://www.pembina.org/reports/towards-a-clean-atlantic-grid.pdf

Questions	Stakeholder Comments
i) Offsets or Emissions Performance Credits	- Weaknesses: expensive, large capital-intensive projects with long timelines, potential to achieve high carbon capture rates not clear, need to evaluate cost effectiveness for peaker plants with low capacity factors. (b) Pre-combustion CCUS (hydrogen): - Strengths: potential to achieve high capture rates - Weaknesses: energy intensive, upstream emissions, low efficiency due to splitting of methane molecule (d) Renewable generation, specifically wind and solar: - Strengths: low cost, commercially deployed widely, lowest lifecycle GHG emissions, economically attractive to ESG corporate interests - Weaknesses: variability, most effective when paired with storage (e) Hydroelectric generation - Strengths: potential to provide storage, commercially deployed widely, some flexibility, lower environmental impact for run-of-river hydro - Weaknesses: capital-intensive and long timelines to develop, limited flexibility for existing run-of-river hydro (g) Energy storage - Strengths: low cost and costs continue to decline rapidly, commercially deployed widely, highly responsible and flexible - Weaknesses: battery storage is short-term (four hours), need pumped hydro or other technologies for longer-term storage (h) Transmission interconnections with other jurisdictions - Strengths: reduces overall system costs, increases reliability, provides flexibility - Weaknesses: capital-intensive, requires coordination between jurisdictions, long development time

Questions	Stakeholder Comments
	(i) Offsets or EPCs: - Strengths: provides a flexible option for meeting net-zero targets - Weaknesses: may not provide truly additional carbon benefits, system may be susceptible to manipulation
- 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?	- Energy efficiency, DSM, and fuel-switching provide significant GHG reductions as well as cost savings.[23] - Non-technological solutions such as congestion charges can incentivize load distribution and reduce usage of peaking power plants.
- 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.	Scalable and relatively quickly deployed technologies are well-suited for navigating uncertainty and responding economically and efficiently to changed circumstances. However, this parameter is often overlooked in grid modelling. Forecasting models typically take a particular parameter (e.g., peak demand) as an assumed outcome or use a small number of scenarios (low growth, mid, and high demand growth) and build supply mixes to meet these assumed precepts. In reality, however, Alberta's demand growth and certain important inputs like natural gas fuel costs are notoriously difficult to forecast accurately beyond a year or two. Technologies or applications that can respond to changing circumstances during development through scalability and modularity offer particular attributes for serving system needs economically and efficiently. For example, it may or may not be more costly today to add solar and storage to meet 800 MW of firm baseload in 2025 than to add 800 MW of NGCC, but due to their modularity, the solar and storage approach will more ably and economically respond to a drop in demand growth that ends up only requiring 200 MW of new supply. They can also be added on shorter timeframes when there is unexpected growth in demand, which is relevant

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[23] https://envizi.com/demand-side-energy-management/

Questions	Stakeholder Comments
	for both system planners that direct new infrastructure investments and for market participants looking to finance capital-intensive projects. A tendency toward inaccurate growth and price forecasts will only be aggravated by the unprecedented energy transition that is underway that will challenge models built for the existing system and verified against historical hindcasting. It is also important to acknowledge the multiple attributes that can be provided by technologies like energy storage, DSM, and energy efficiency to different components of the electricity system, including energy, distribution, transmission, reliability, and resiliency. Because these components are handled through different markets and non-market approaches, it is common for models to fail to acknowledge the value provided across different system components. The economic value of all these different system benefits should be acknowledged for all technologies, either in the reduction of overall system costs or as an alternative revenue source for these technologies that reduces their LCOE.
• 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?	As cogeneration facilities export energy into the grid, net-zero emissions should be required for the proportion of the emissions that are contributed to the grid. The Pembina Institute has not yet examined alternatives to cogeneration, but will share findings when its studies are complete.

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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*[24], 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

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

Questions	Stakeholder Comments
- 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?	- There has been a history of over-estimating technology costs when those technologies are in a phase of rapid cost declines. Growth of the wind and solar energy industries has also been consistently underestimated in previous LTOs, suggesting that the AESO did not recognize the economic viability of these technologies. In particular, battery storage is a technology that is maturing and undergoing rapid expansion globally (cutting across other sectors like transportation and personal computing), which brings down technology, manufacturing, and supply chain costs. The rapid decline of solar PV costs, which decreased by 88% over nine years, provides a good precedent for battery storage cost declines.[25] - Wind and solar costs can continue to decline in certain circumstances, especially through capitalizing on emerging opportunities such as repowering brownfield sites.[26] - The analysis should incorporate price signals for siting wind, solar, and storage in a way that reduces overall system costs. It should not be assumed that these technologies will be sited according to historical patterns. Existing policy frameworks should be updated to account for and incent siting efficiencies that better reflect the net-zero system and its technology mix.
- What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	There is a risk of overestimating or overstating the true cost of retrofits and transitions. Such overestimations were notable in the policy conversations around coal phase-out that began in 2014 and continued through the Alberta Climate Leadership Plan consultations in 2015, and continued into

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[25] https://www.pembina.org/reports/reliable-affordable.pdf

[26] https://fcm.ca/en/funding/gmf/capital-project-renewable-energy-production-brownfield

	Questions	Stakeholder Comments
		the implementation of coal phase-out in 2016. Despite a rapid deployment of coal-to-gas retrofits underway in the United States at the time, generators in Alberta expressed strong pessimism around this opportunity. In the end, even just the carbon price rising to $30/t was sufficient to prompt a rapid transition from coal to gas generation, including several conversions, many years ahead of regulatory schedules. This experience demonstrates the tendency to overstate the costs of regulations, transitions, and new technologies during the policy consultation and advocacy phase. Once a clear policy trajectory is set and transitionary investments and operational decisions are forced, technology costs turn out to be much lower than originally stated. There is a very good chance that the same dynamic will be at play in the process of transitioning to a net-zero electricity grid.
	• 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.	Vibrant Clean Energy in the US, has extensive experience in modelling grid optimization[27] scenarios with zero emitting technologies. We recommend examining his methodology and results. The David Suzuki Foundation is conducting an extensive study, Clean Power Pathways, modelling net zero scenarios for Canada, projected to be released in the spring of 2022, which may be informative for the AESO analysis.

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

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[27] https://vibrantcleanenergy.com/wp-content/uploads/2020/06/VCE-FPMF-06022020_LR.pdf

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Connor Curson
Comments from:	Powerex Corp.	Phone:	604-891-6028
Date:	2022/01/31	Email:	connor.curson@powerex.com

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

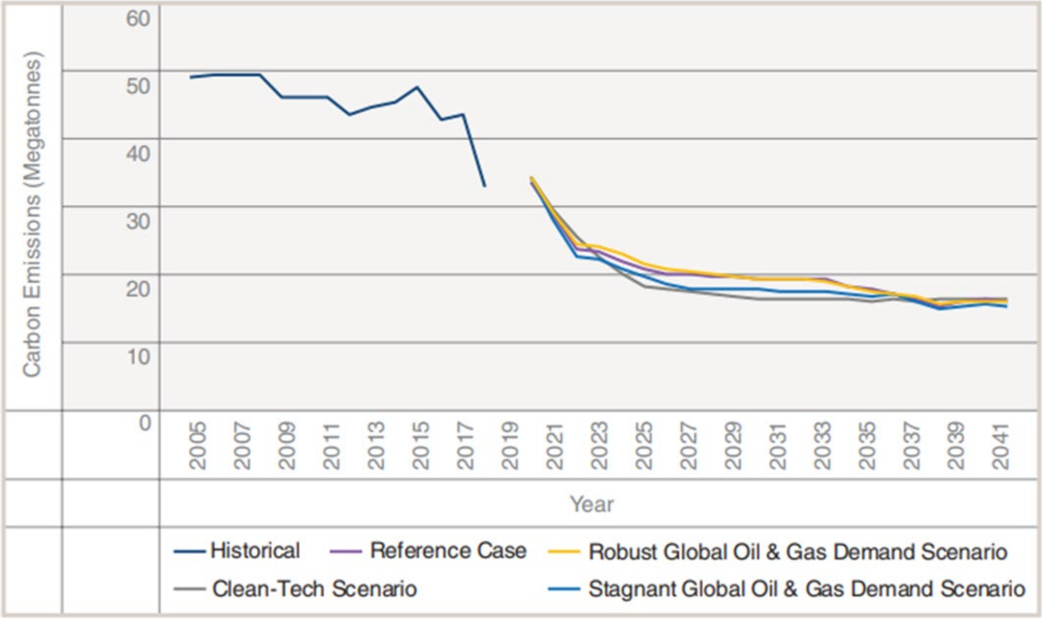
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	
	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?	
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]	

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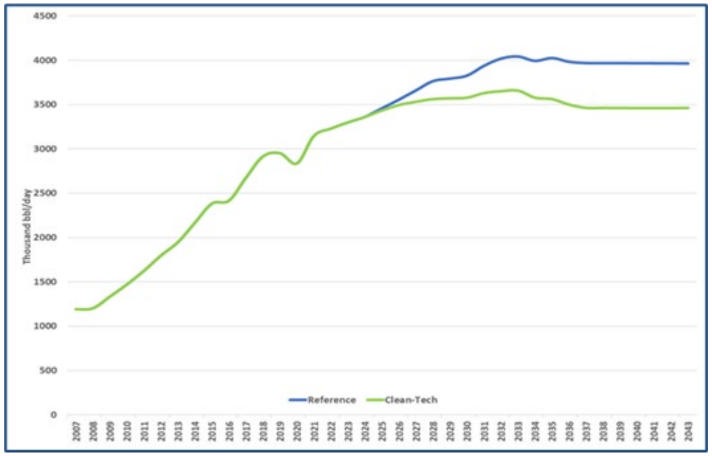
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

Questions	Stakeholder Comments
a) What is your view on the economic impact of expected net-zero targets on this business-as-usual scenario?	
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	

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

	Questions	Stakeholder Comments
	scenario for analyzing the impact of net-zero policies on the oilsands sector and the subsequent impact on load growth?	
	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?	
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	
	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?	
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	

	Questions	Stakeholder Comments
	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.)?	
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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)?	
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?	

	Questions	Stakeholder Comments
	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 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	With respect to "**(viii) Transmission interconnections with other jurisdictions**": Other jurisdictions in the WECC have adopted or are adopting 100% Clean Energy Standards. Within their respective programs, these jurisdictions acknowledge potential benefits arising from trade, particularly where it allows benefits of diversity in load and generation to be achieved. Efforts such as SPP's Markets+ and CAISO's EDAM initiative are both mechanisms which can play a role in unlocking these benefits. However, the various jurisdictional standards incorporate explicit contracting and accounting to avoid issues of leakage and double counting of reductions. Consequently, these programs consider both the import and export of clean and emitting electricity from the relevant jurisdiction. Given the foregoing, the interties can provide a present day option for clean electricity that could assist in Alberta's net zero transition. However, the AESO would need to consider its treatment of clean and emitting electricity for both imports and exports within its net zero framework. Powerex also notes that using the interties to exchange clean *energy* with other jurisdictions needs to be evaluated against other potential uses of the intertie capability (for example, *flexible capacity*). When the AESO evaluates uses of the interties, it should acknowledge that the ability to achieve the identified benefits or uses may require the cooperation of other jurisdictions, which may depend on the ability for mutual benefits to be achievable whether economically, reliability and/or environmentally derived.

	Questions	Stakeholder Comments
	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?	
	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.	Please see response to 5(b) above.
	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?	

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

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[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?	
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Tonja Leach
Comments from:	QUEST Canada	Phone:	613-797-8998
Date:	[2022/01/31]	Email:	tleach@questcanada.org

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

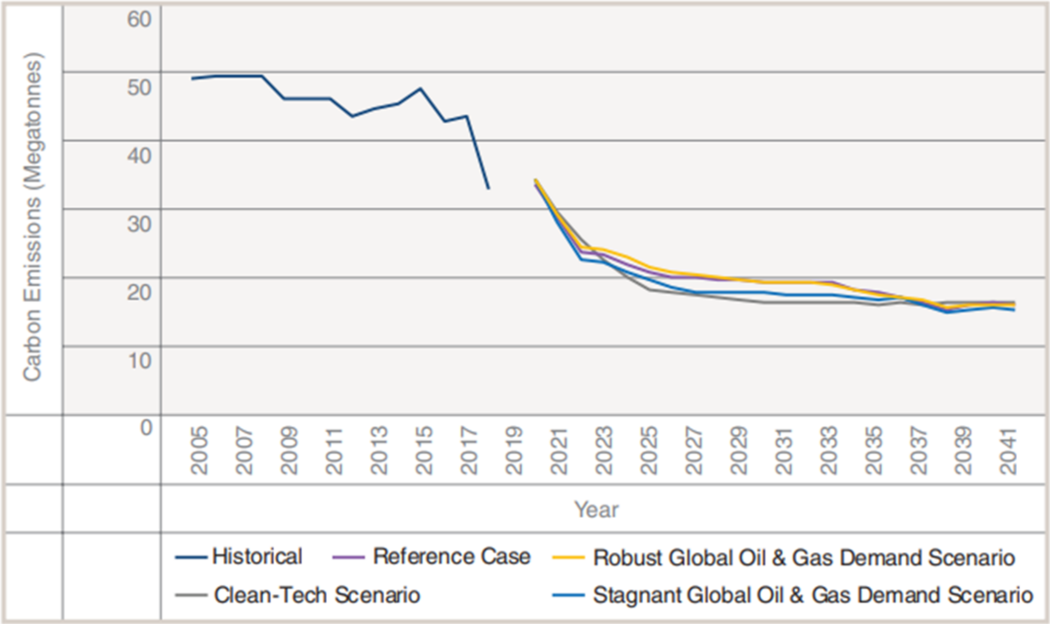
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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.

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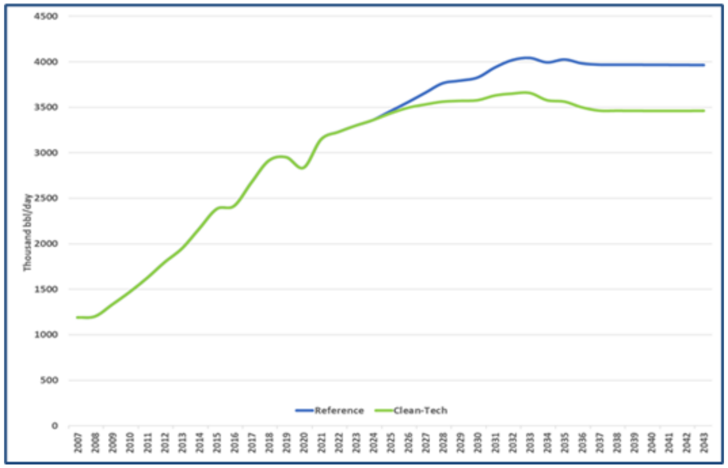
The AESO intends to produce the first AESO Net-Zero Emissions Electricity System Pathways report, to be published in June 2022. The AESO's Pathways report will describe potential decarbonization pathways that can lead to a net-zero emissions electricity sector in Alberta by 2035. The report will include 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.</td></tr>
<tr><td></td><td>a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td>QUEST encourages the AESO to consider in its scenarios the intentions of Alberta municipalities with respect to their emission and energy objectives. Through Community Energy Plans and/or Community Energy and Emissions Plans, communities are setting targets and expectations with respect to their energy future - what types of energy they are willing to have serve them that align with their values, what economic and job opportunities renewables and low carbon thermal solutions offer, how they can keep more of their energy dollars local, and more.
With a lens on the interests of Alberta communities, communities can not only be a very attractive partner for the AESO in meeting future energy demand but a necessary one in keeping peak loads in check through local energy system integration and low-carbon thermal solution policy that</td></tr>
</table>

		encourages implementation, enabling renewable supply and fostering a supply/demand balance. Energy system integration needs to play a more significant role in the scenarios and analysis. As we are seeing in Quebec, hybrid solutions are being sought as a mechanism to shave peak load, while reducing emissions at the lowest possible cost. Ontario and Alberta benefit from Combined Heat and Power as it offers firm capacity for the electricity system and gets the most useful energy out of each molecule of natural gas. Other low-carbon thermal systems such as heat pumps, biomass, renewable natural gas, hydrogen and advanced energy management are also available solutions that should be considered in the scenarios and analysis beyond typical demand-side management and energy efficiency incentives to support the electrification of transportation, buildings and industrial activities.
	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?	Some of the greater challenges that we see from our work across Canada relating to the path to net-zero is less about the supply mix and technology choices that need to be made. It is more so about the institutional, governance, regulatory, legislative and policy changes that need to be made. A lack of multi-sectoral and frank discussions on emissions reductions, energy reliability/affordability, prosperity/competitiveness, community engagement/support, equity/ diversity/inclusion, and trade-offs. Lastly, collaboration among governments (f/p/t), municipal and Indigenous communities is needed to increase the public trust in decision-makers which is critical to achieving net-zero. While there will certainly be many impacts within the Alberta electricity system on the path to net-zero, without the aforementioned engagement, direct discussions and acknowledgment of what trade-offs are acceptable or not and which can be mitigated and how, there is a guarantee that those most impacted will be low-income and marginalized Albertans. Additionally, this will also have an impact on the trust Albertans and Albertan communities have in their energy decision-makers.
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?	
	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	

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

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

	scenario for analyzing the impact of net-zero policies on the oilsands sector and the subsequent impact on load growth?	
	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?	
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	
	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?	
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	A Regulatory Innovation Sandbox approach could be used to introduce and support innovations into Alberta's electric system. A sandbox is a policy tool that uses collaboration to create conditions for innovation to be integrated into the energy system, allowing for the examination of real (and often perceived) barriers as well as testing solutions in a real-world environment. This could provide the opportunity to change how processes, procedures, policies, rules, or regulations are applied in a controlled manner, with the ultimate goal of creating durable and lasting systemic change to enable innovations that benefit the electric system, consumers, and society.
	d) Are there any other related considerations that you would like to provide feedback on?	QUEST is encouraged by the Government of Alberta's recent announcements that the intention is to amend the Electricity Act to allow for unlimited self-supply and export - something that QUEST and our

		members have been advocating for over the last two years. However, we are concerned that the proposed amendments introduce the potential for additional transmission tariffs that will create additional barriers to investments in customer-owned, low carbon electricity generation capacity. Alberta needs more investment in low carbon generation, especially firm capacity that technologies like CHP can provide as the transition away from coal takes place. As the natural gas fuelling these CHP plants eventually gets cleaner, through investments in renewable natural gas and hydrogen, these CHP facilities will be able to keep Alberta companies competitive, further reduce GHGs, enhance community resilience to extreme weather events, and also provide valuable grid services.
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?	We are not in a position to comment on industrial efficiency but there is room for growth across the residential and commercial sectors with regard to energy efficiency, as well as with other large energy users such as greenhouses and agricultural operations. These end-users are major contributors to communities' overall energy use and emissions profile, and with the rising costs of electricity, there will be growing interest in increasing energy efficiency. A major trigger would be the availability of stable and long-term incentive programs targeted towards these sectors, in addition to maintaining and growing the existing programs targeting municipalities and industry.
	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.)?	As the trend towards net-zero continues, Alberta communities will continue to build up their community energy and emission planning capacity. This will involve increased DER opportunities being recognized and being considered for development. These opportunities entail both building-level microgeneration, as well as utility-scale energy projects. Communities see local DER opportunities as a means of economic development and community resilience, in addition to it being a viable pathway to meet energy and emission goals.
	c) Transportation Sector ● What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger	Non-ICE options will see growth throughout communities as both the municipalities and local residents and businesses seek to lower their transportation emissions. Municipalities are having increased interest in electrifying their fleet as well as their service vehicles and equipment.

	vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	They will also be looking to build up local public EV charging infrastructure, based on the demand of their residents and local businesses
	d) Buildings ● What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	A shift towards net-zero may result in a shift in the mindset of traditional space and water heating practices away from natural gas and towards electrification or other more innovative options. The precedents that are being set in other jurisdictions around no new fossil fuel-based heating in new builds may also cause communities and their residents to demand other heating options to be more readily available. Recognizing the demands that electrification of space heating and cooling and water heating will place on the electricity system in Alberta, there is a compelling argument for enabling policy that increases the penetration of low-carbon thermal solutions (heat pumps - geoexchange, air source, wastewater, building integrated systems, hybrid fuel systems, RNG/hydrogen, advanced energy management) in addition to demand-response and energy efficiency as a means to reduce the impact of energy switching on the grid while still meeting emission reduction targets and keeping costs in check.
	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)?	
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?	
	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 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	
	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?	QUEST strongly encourages the AESO to also explore opportunities for combined heat and power (CHP) with CCUS and hydrogen - these plants can generate electricity as well as provide valuable thermal energy for a variety of heating loads, including industrial, agricultural, commercial and residential.
	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.	
	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	

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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.

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a) Do you believe that these are representative of the costs associated with potential future Alberta net-zero generation

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

	technologies? How do you expect the cost of these technologies to change by 2035?	
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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).	
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Thank you for your input. Please email your completed matrix to: forecast@aeso.ca

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Robert Stewart
Comments from:	RMP Energy Storage	Phone:	587-920-4833
Date:	2022/01/31	Email:	Robert.stewart@rockymountainpower.ca

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.
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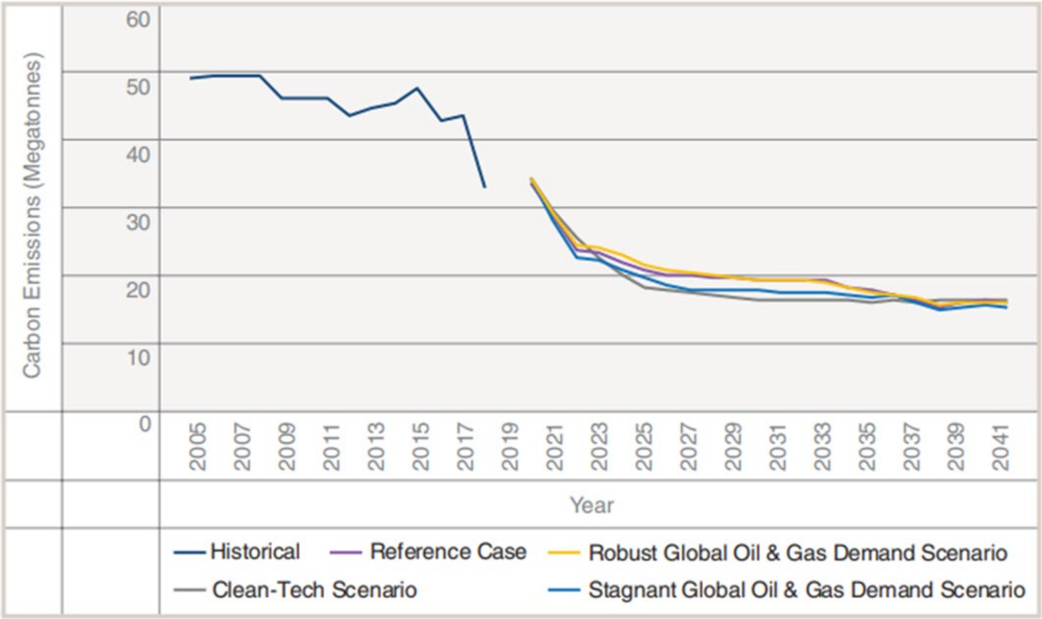
FIGURE 34: Alberta Electricity Sector Emissions by Scenario



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• Renewables paired with energy storage; and
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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.</td></tr>
<tr><td></td><td>a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td>When looking at energy storage paired with renewables it is critical that different forms of energy storage and various integration models be considered.
Energy storage is a broad range of technologies that operate in very different ways and have different strengths and weaknesses (cost, duration, construction time, scalability, locationality, etc.). In this study it is critical to note that Alberta and Saskatchewan have the best geology globally to deploy Compressed Air Energy Storage. There is easily enough suitable geology to allow for a 100% wind + CAES powered electrical system in Alberta and Saskatchewan. Additionally, CAES is a proven technology that leverages the vast experience available from the oil and gas industry.
Consideration should be given to the integration model for energy storage such as collocated, aggregated or stand-alone assets. It is important to consider the market signals in the tariff and interconnection process that may unintentionally favor one design.</td></tr>
</table>

	Questions	Stakeholder Comments
	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?	To enable the renewable paired with energy storage option to develop within the current market framework the tariff structure needs to be changed to reflect that energy storage generates all of its revenue in competition with dispatchable generation and that there is value that energy storage provides to the system when operating as a dispatchable sink. This is not how energy storage is treated currently or under the proposed updated DOS.
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?	
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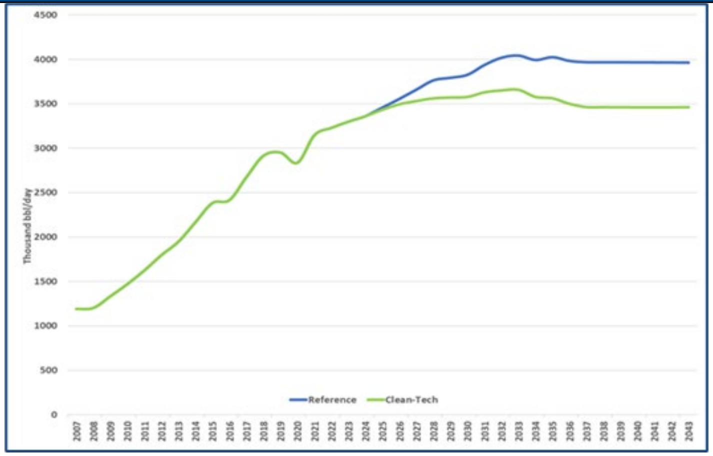
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td></td><td>


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?</td><td></td></tr>
<tr><td></td><td>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?</td><td>Significant price uncertainty should be applied to forward gas prices to ensure the range of potential outcomes is correctly captured.</td></tr>
<tr><td>***3***</td><td>***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</td><td>This is unclear and this study should send a clear message to GoA and GoC as to what are possible outcomes. All three should be considered with associated costs, jobs and land use changes.</td></tr>
</table>

	Questions	Stakeholder Comments
	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?	$170/t by 2030 is directly aligned with federal government net-zero policy targets. If this policy does not achieve the emissions reduction desired by 2030 then the price will be increased, or additional mandates will be put in place.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Interprovincial transmission has the potential to significantly impact the Alberta electrical system. Provincial and Federal policy related to TIER particularly for cogeneration treatment and how Net-Zero is defined have large implications to the Alberta electrical system.
	d) Are there any other related considerations that you would like to provide feedback on?	No comment
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?	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.)?	
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	Pace of EV adoption in the clean tech model ok but the usage pattern requires refinement.
	d) Buildings	No comment

	Questions	Stakeholder Comments
	• What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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)?	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?	Compressed Air Energy Storage (CAES) and wind are the most economic pathway to achieve net-zero in Alberta. If external offsets or credits are permitted then this may change whether adiabatic (fuel free) or diabatic (fuel) CAES systems are considered.
	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 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	viii) Energy storage is a broad range of technologies that have different strengths and weaknesses. Current tariff treatment and uncertainty is a significant weakness compared to the generation technologies listed.

Questions		Stakeholder Comments
	(vi) Nuclear generation (vii) Energy Storage (viii) Transmission interconnections with other jurisdictions (ix) Offsets or Emissions Performance Credits	
	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?	No comment
	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.	Energy storage enables significant benefits in addition to the generation sources as it can manage load variability and reduce curtailment.
	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?	A net-zero electricity system by definition must include cogeneration facilities. This means that the emissions generated will be allocated towards steam generation and the operating corporations will need to determine if they buy/generate emissions offsets or capture the emissions. It is noted that many cogeneration assets online today may be nearing end of design life by 2035.

	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

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[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?	- Technologies that are accelerating in deployment and benefit from global supply chain competition (Solar PV, Wind, hydrogen fuel cells, Li-Ion batteries, other ES technology) will or will continue to see significant reductions in cost. - The modeling completed should consider Li-Ion batteries with various durations to ensure the ideal duration for the market is considered. -Cost uncertainty on yet to be proven at scale in Alberta should be included in the analysis (CCUS, SMR, Advanced Nuclear).
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	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).	Diabatic Compressed Air Energy Storage Plant Capacity: 320 MW, 19,200 MWh (or more) Capital Cost: $2,350/kW Fixed O&M: $30/kW/yr Variable O&M: $5/MWh Heat Rate: 3.8 GJ/MWh Electricity ratio (MWhout/MWhin): 1.45 or 145% Please contact Robert Stewart for further information or questions about modeling this asset.
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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Blake Shaffer, University of Calgary
Comments from:	Dr. Blake Shaffer and Dr. Sara Hastings-Simon	Phone:	403.701.8983
Date:	2022/01/24	Email:	Blake.shaffer@ucalgary.ca

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

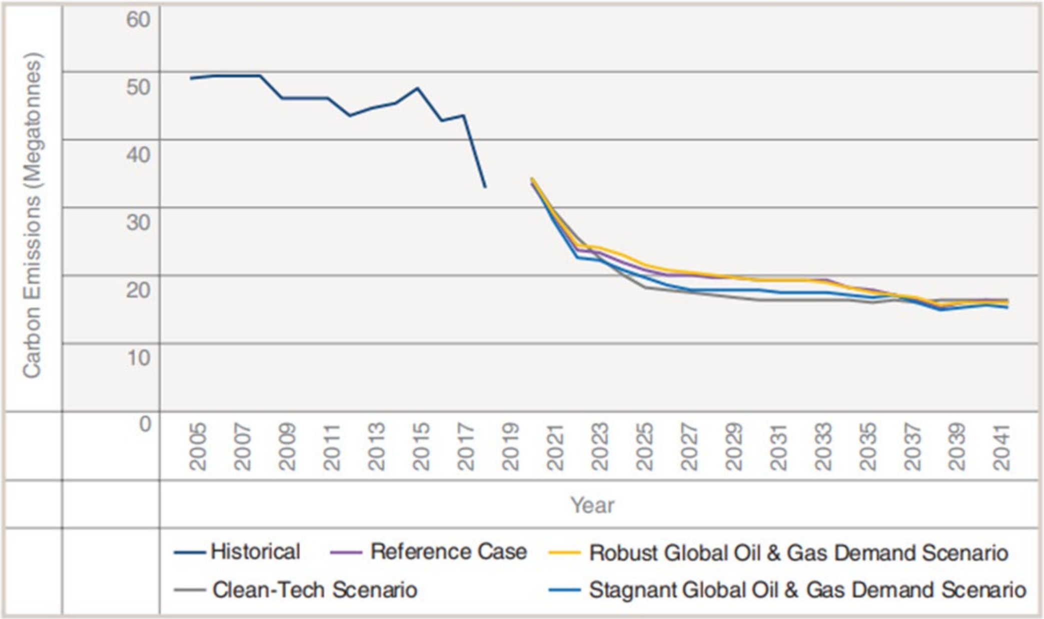
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	1) The description of the 2nd scenario as "economically driven" implies the 1st scenario is not economic. This is odd framing. 2) The dichotomous framing is problematic in its limitations. In reality, a portfolio approach is most likely. Limiting the scenarios as exclusive prevents a potentially optimal mix. We would prefer to see different technological solutions all on the table, with the opportunity to be part of varying mixes, with sensitivity analyses based on their future costs. 3) There is no mention of expanded transmission interties as part of the solution mix. This is a gaping hole given the high value role expanded transmission plays in modelling results in both Canada and the US net-zero scenarios. We would recommend inclusion of scenarios with expanded interties layered on top of the other assumptions to show the impact they can have. Demand scenarios, especially additional EVs, should be sufficiently flexible to include scenarios with load profiles that differ from historical patterns. Extrapolating current EV profiles into a future scenario of

	Questions	Stakeholder Comments
		large EV penetration would be extreme in its lack of behavioural response from both EV chargers and retail providers to encourage EV charge load-shifting.
	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?	The low cost and abundance of renewables makes clean energy less of a challenge. Clean *capacity* will be more challenging and should be the focus of the challenge for Alberta. Storage, demand-shifting, clean supply (e.g. hydrogen, CCS, nuclear), and transmission should all be assessed as potential pathways to incorporate abundant and low cost variable energy into clean firm power. Inertia and frequency response will be increasingly important with less rotational thermal mass and more intermittency in Alberta's system. Consideration of shared resources, such as low storage capacity/high power capacity battery banks should be considered. There may be benefits to central procurement of these resources versus private competition due to the thinness of the market and the potential for under-investment as a result. Synthetic inertia (from renewable resources and batteries with power control) should be studied further
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?	The electricity price impact of net zero targets will be a function of whether all options (e.g. expanded interties) are on the table, and the degree of coordination on potential shared resources (e.g. frequency response assets). It will also be a function of future technology costs. Done well, we see no reason for significant cost pressures impacting Alberta's growth. Any policy-driven costs through carbon pricing include revenue which can be used to mitigate cost impacts while incentivizing a shift in the generation mix. Moreover, we assume that if Alberta pursues a net-zero target, it will be in the context of a global push for net-zero.
	The current IHS Markit outlook notes that Alberta oil sands production has surpassed pre-pandemic levels and forecasts	The largest historical growth in Alberta was tied to expansion of the oil sands. This is less likely in a world with slowing or falling oil demand. The

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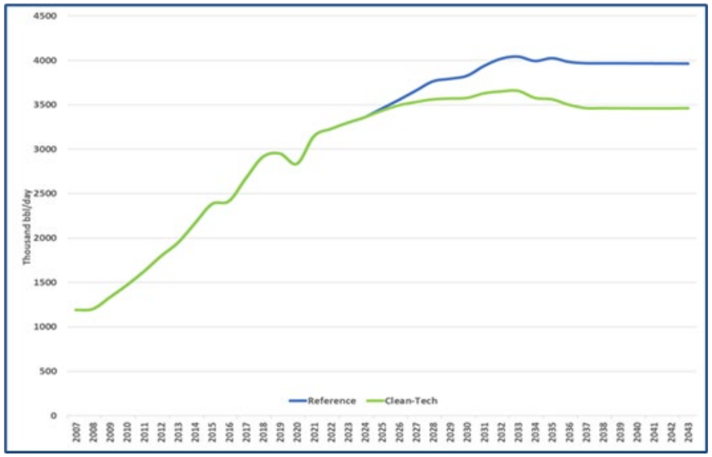
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

Questions	Stakeholder Comments
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?	AESO should reconsider historical electricity demand/GDP relationships given the lessening role of this energy-intensive expansion. We agree with removing any greenfield oilsands growth from the forecast as the central assumption.

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[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?	Key drivers: speed of electrification of heating and industry; hydrogen through methane reformation demand; electrolyzer costs (as substitute for the former); LNG demand and terminal expansion.
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	We acknowledge the need for "escape valves" in getting to zero for electricity. A physical zero could impose unnecessarily high costs. There should be latitude to run some natural gas, sparingly, in peak periods. Even allowing for 1% of hours to be met in this way can have a material impact on avoiding cost increases. This flexibility could be consistent with net-zero in allowing for offsets or credits across the economy (not only within the electricity sector). By allowing credits to be traded across the economy, this sends a stronger carbon price signal to other sectors, as the net-zero target would be acting implicitly as a higher shadow price of carbon if binding.
	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?	We see the carbon price rising following the stated path to $170 and rising beyond 2030.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	If the federal government implements technology-specific tax credits, such as the proposed CCUS tax credits, in addition to avoided carbon price incentives, this will shift investment towards these subsidized resources. With an increasing carbon price, and the durability of CCIR/TIER, we question the future role of the offset program for renewables in electricity. All zero emission generation could instead receive EPCs under TIER. This would equate all zero emission generation, rather than specifically targeting certain renewable generation. It is also possible that the Federal OBPS backstop and equivalency requirements eliminate the 370g/kWh benchmark. This would not change relative policy costs of generators, but would raise average costs and in turn market prices. This would also increase the amount of collected

	Questions	Stakeholder Comments
		revenue, which could be returned to all consumers in the province proportional to consumption. We note that Alberta currently has a 30% renewable energy generation target in law and any BAU/other scenarios that the net zero scenario compares to should include compliance with that target.
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	Approaching energy efficiency as a resource is the most effective way to increase penetration. One of the most significant triggers would be the implementation of a provincial/utility target and program for energy efficiency. Similar programs in other regions that target only cost effective energy efficiency measures have been successful at achieving annual electricity demand reductions of 2% per year and more. Given the limit of energy efficiency programs to date in Alberta it is reasonable to expect there could be similar savings available. Energy efficiency is important for decarbonization of the electricity sector as it can moderate an increase in demand that will arise from electrification, but the combination of carbon pricing structure that shields the electricity price as well as a move towards net zero electricity systems means that carbon price mechanisms will be insufficient to drive the desired behaviour alone. Simple price-based mechanisms focused on total consumption are similarly problematic as electrification will unavoidably increase consumption, instead more targeted measures are required. Performance-based regulation should encourage efforts at energy efficiency. Rate-cap structures encourage distribution sector efficiency but also encourage greater sales, therefore discouraging consumer efficiency. Regulations should align with the goal of greater energy efficiency.
	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	We see demand-side management playing a larger role as EV penetration increases. EV charging presents as a large residential load with significant

	Questions	Stakeholder Comments
	storage systems, demand-side management technologies, load aggregator technologies, micro-grids, etc.)?	flexibility and ease of scheduling. Incentives (i.e. tariff innovation) will be required to encourage behaviour. The proliferation of other DERs will be largely driven by the tariff structure in Alberta, e.g. the presence or lack thereof of distributed generation credits, cost allocation for transmission charges, and other fixed fees. As such fees increase, and as energy storage becomes cheaper, grid defection will increase.
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	We expect EV penetration to rise exponentially in the province based on observed trends elsewhere and a shift in manufacturer focus. This will add load to the system and, currently, increase evening peaks and potential distribution overloads. A push to introduce load-shift incentives and managed charging is imperative to avoid high costs of increased EV penetration. If charging load is shifted and smoothed, the impact can be negligible due to the low cost of raw energy.
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	We believe there is significant uncertainty in the pace of electrification, depending primarily on the commercial availability of high efficiency low temperature heat pumps, and the policies or programs to incentivize their deployment.
	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)?	
5	***Generation Technologies***	Given the low cost of renewables, coupled with the falling cost of energy storage, we see the least cost pathway consisting of larger shares of wind and solar, increased energy storage, increased energy efficiency and

<table>
<tr><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td>a) What net-zero enabling generation technologies do you perceive as being the most economic pathways to decarbonization of the electricity supply in Alberta?</td><td>demand response, and, critically, expanded interties. NG+CCS and H2-capable turbines are also likely to play a role given the low cost of Alberta’s NG resource. Nuclear is possible, but challenging in the timeline given (2035).</td></tr>
<tr><td>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 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</td><td>
<table>
<tr><td></td><td>Strength</td><td>Weakness</td></tr>
<tr><td>(i)</td><td>Abundant low cost NG resource</td><td>Technical readiness and cost uncertainty</td></tr>
<tr><td>(ii)</td><td>Abundant low cost NG resource
Likely improved technical readiness over post-combustion CCS</td><td>Current high cost</td></tr>
<tr><td>(iv)</td><td>Abundant wind and solar resource; geothermal potential
Mature technology
Low costs (wind, increasingly solar)</td><td>Wind and solar: variability, geographic concentration, correlation with load
Geothermal: scale</td></tr>
<tr><td>(v)</td><td>Clean firm source
Flexible</td><td>Limited sites
Slave River poor location
Additional resources at existing sites limited</td></tr>
<tr><td>(vi)</td><td>Clean firm source
Scalable</td><td>Technical readiness (SMR) and cost uncertainty
Long regulatory lead time
High cost (traditional nuclear)</td></tr>
</table>
</td></tr>
</table>

Questions	Stakeholder Comments		
	(vii)	Rapidly declining battery costs Easily deployable Can assist in energy markets but also A/S markets and support single contingency limit relaxations Pumped hydro potential on existing disturbed sites Compressed air potential at sites in province	To date there has been limited demand for longer duration solutions, but that will change as non-gas solutions are needed. Long duration costs are currently higher with technology developing.
	(viii)	Increases efficiency by enabling more trade between complementary systems Would enable more low cost variable renewable penetration in AB Provides source of peaking power and flexibility Can point to many US studies regarding benefits of broader transmission connectivity in terms of lowering the cost of decarbonization. Will be modelling these scenarios in Canada in the future.	Single contingency risk (could be dealt with by separate DC connection, rather than adding to WECC AC cutplane or additional battery systems with high power, low storage, as A/S service)
	(ix)		Not a technical solution Increasingly unavailable in net zero economy.

Questions	Stakeholder Comments
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?	
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.	All generation technologies with have risks and challenges. All large generators can have sudden forced outages, as can interties, as can transmission lines within the province. All with solutions that can include: more distributed resources, more demand-side flexibility, and energy storage solutions purpose-built to manage these contingencies to allow them to bring their large benefits to the grid.
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?	Given the current structure of the TIER system, yes. Alternatively, if the emissions are not reduced, they would need to be fully assigned to the sector in which they are generated. Careful attention needs to be paid to avoid distortions, such as cogenerators, or other generation structures, establishing small behind-the-fence heat needs solely for the purpose of policy arbitrage.

	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
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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
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[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?	This deserves closer scrutiny from a broad range of technical experts, and more sources than a single EIA source. There is a long, well-established, history of overly conservative estimates of cost declines in developing technologies with evidence that costs will continue to decline significantly as deployment increases see e.g., https://www.inet.ox.ac.uk/files/energy_transition_paper-INET-working-paper.pdf. It looks as though the estimates for wind and solar, technologies with clear cost discovery now, are too high. The 2020 EIA report referenced is based on a consultant's report from 2019, which itself relies on capital cost reports from 2018. Just eyeballing this table and already it looks like wind and solar costs are overly conservative (too high). The included capital cost estimates reflect costs in 2017 in Canada, not 2022, let alone 2035 (https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2018/market-snapshot-cost-install-wind-solar-power-in-canada-is-projected-significantly-fall-over-long-term.html). Whereas estimates for SMRs and CCUS, though difficult to assess on an expected basis, come with significantly more uncertainty due to lack of technical readiness. In short, it looks like the known lower price of wind right now is being compared to a very much unknown price of other clean firm technologies. Overall, rather than quibbling over specific numbers, the best would be to attach sensitivity analysis to these critical assumptions. Include scenario analysis with +/- X% on each technology. Reflect the much greater risk of higher costs in technologies without proven install records.
b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	Hydrogen-capable turbines have likely less technical uncertainty as compared to post-combustion NG CCUS.

	Questions	Stakeholder Comments
	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).	Expanded interties are not shown. Demand response and energy efficiency isn't included (maybe considered elsewhere) but has a potentially large role. Geothermal is missing. Other energy storage options are missing, including pumped hydro and compressed air. Hydrogen CT not listed, only CCGT. Hydrogen as peaker may be more economic than broad energy provider (see, e.g. https://www.policyschool.ca/wp-content/uploads/2021/11/EFL49A_AB-Electricity_Neff-et-al.pdf)
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	We applaud the AESO's initiative in starting this net-zero pathways analysis. Ultimately, robust modelling will be at the core of the report. We implore the AESO to question historically conservative cost assumptions in their analysis, and to include sensitivity analysis around costs. The University of Calgary and the nascent Energy Modelling Institute stand ready to support this endeavour.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Heather MacKenzie
Comments from:	Solar Alberta	Phone:	780-443-7788 (ext. 100)
Date:	2022/01/31	Email:	executive.director@solaralberta.ca

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

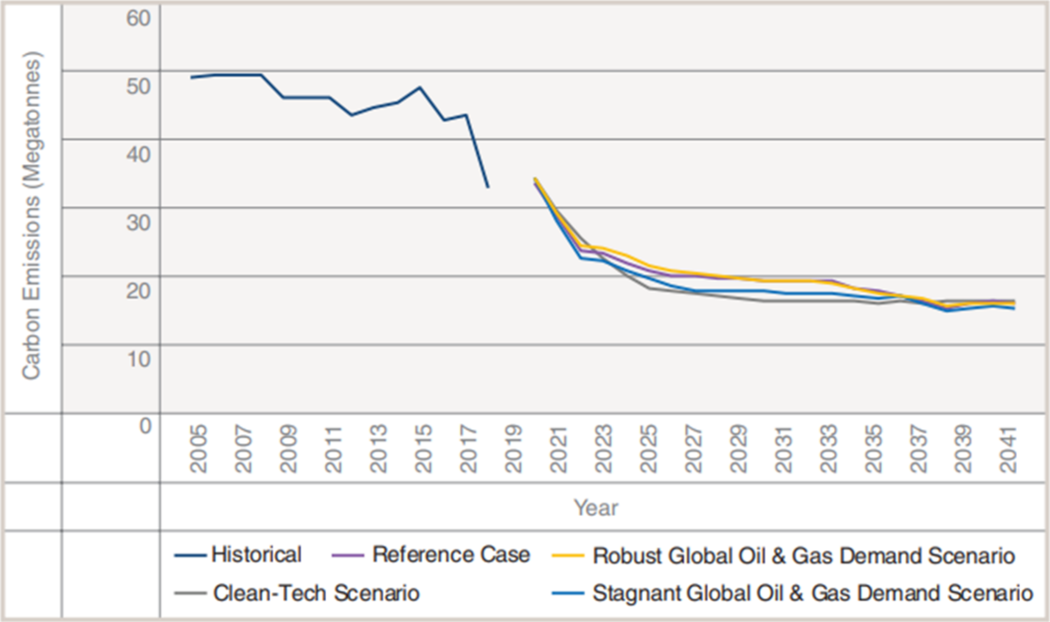
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	It is important to consider the integration of solar and solar-related technologies such as storage in this process, because solar has been proven to be one of the cheapest forms of new energy generation around the world. Given that the price of solar PV has dropped by 90% in the last 10 years, it can produce electricity very affordably both at the utility scale and in the microgeneration sense. The decentralized nature of solar, coupled with the expansion of energy storage, can also help increase the reliability of our system.
	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?	- Enabelling microgenerators to maximize their solar generating and storage potential could have incredible results, but will require changes to the microgeneration regulation to enable production beyond consumption. - Enabling community generation to take off in Alberta through establishing virtual net metering processes, as seen in many other

		jurisdictions, would also have a significant impact and speed up the path to net-zero.
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?	As we work towards achieving our net-zero targets, we anticipate significant new job creation in the solar sector. Our 170 business members are already having trouble keeping up with the demand and are hiring new staff regularly. We anticipate this trend will continue and accelerate even further. We also believe that these solar-related jobs will be quite stable and that they will attract a diverse array of people from around Canada and beyond. The renewable energy sector is known to employ more women than other energy sectors (while still not achieving gender parity), and as such, we anticipate better economic outcomes for women and children associated with the transition to net-zero.
	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**	No comment

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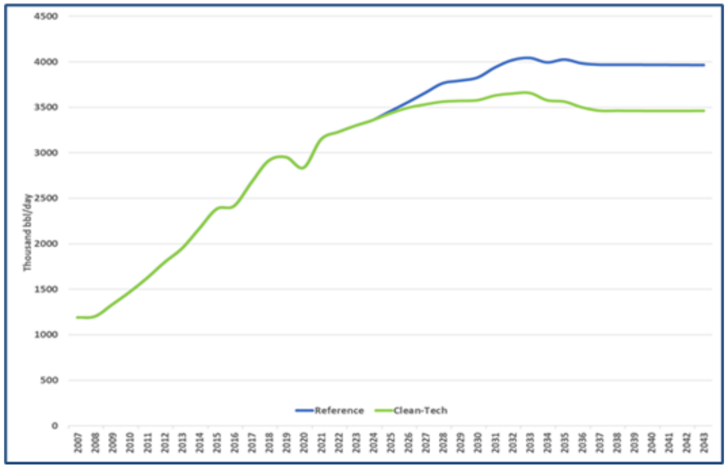
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	 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?	
	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?	No comment
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	No comment.

	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?	No comment
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	- Federal policies and programs supporting more EV infrastructure and interprovincial interconnection will likely support the electrification of Alberta's grid and enhance our grid reliability. - Provincial policies and programs further supporting the adoption of solar and solar-related technologies by businesses will likely take shape due to the successful inclusion of solar PV into ERA's Energy Savings in Business program. There is clearly significant demand by businesses for government supports to adopt solar. This includes the desire by farmers and others to be able to maximize their solar generating and storage potential rather than being restricted to production based on their own consumption. Albertans are hoping to diversify household and business income alike through the adoption of renewables and our policy framework will likely be amended to reflect this demand.
	d) Are there any other related considerations that you would like to provide feedback on?	With respect to community generation, uptake would also be significantly supported by ensuring greater consistency in studies required and a simplified application process to connect to the various distribution systems. These changes would reduce the administrative burden and up front costs for community generation.
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?	More energy efficient building design and retrofits will need to be encouraged through regulation. Incentives alone will not result in the level of energy efficiency needed to accomplish our net-zero goals.
	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.)?	Solar pv will continue to expand and make up a larger and larger segment of our electricity supply in the province as we head to net-zero. We will also see a lot of wind generation as it is an excellent compliment to solar, and Alberta has incredible wind *and* solar resources. Additionally, as the price of energy storage, EVs, air-source heat pumps and other solar-related technologies drop, we will see even more interest in solar

		generation. Solar is the most ‘grassroots’ of the various energy sources and can be readily embraced by more and more Albertans on a home or business level, therefore, it will be central to our cultural/identity shift as well. Albertans love that solar can help them achieve greater energy independence.
	c) Transportation Sector ● What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	Now that trucks and other more common vehicles are being made available as EVs, the adoption will rise significantly in Alberta. Albertans have higher disposable income than most other jurisdictions in Canada, and this will also result in significant EV uptake. The limitations will primarily be in relation to the expansion of charging infrastructure. That said, with charging infrastructure now established in most major centers around the province, and the MCCAC leading new programming to expand EV adoption in municipalities, this shift won’t take long.
	d) Buildings ● What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	We are already seeing significantly more interest in air-source heat pumps than just last year. Albertans seem very keen to offset *both* their appliance and heating costs through installing solar systems. Air-source heat pumps and other electric heating mechanisms make this possible. The interest in the electrification of heating/cooling systems is not only taking shape in the new housing market, but we are also seeing significant interest in deep energy retrofits that include these elements coupled with the adoption of solar.
	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)?	- The increase in industrial load caused by these shifts could be addressed by ensuring the development of renewable energy keeps pace with demand. This will require some changes such as removing the consumption cap on microgenerators, enabling virtual net metering for community generation, renewing incentives for businesses and individual Albertans to adopt solar pv, and streamlining the application processes for community generators. - As other industries are supported in their energy transition, we anticipate that they will see significant benefits including reduced utility bills and increased competitiveness as they will be increasingly seen as leaders in their industries. The key will be to get out ahead of the others in this green transition. Early adopters will be rewarded by increasingly thoughtful consumers and shareholders.

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?	Solar pv and wind combined
	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 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	Solar pv and wind, combined with energy storage (including storage through EVs) will be the strongest enabling technologies for achieving Alberta's transition. Solar pv and wind are already proven and complementary technologies that are extremely cost effective. Additionally, we have incredible solar and wind generating potential in our province - the envy of many jurisdictions around the world!
	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?	No comment
	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.	Solar energy will be very beneficial to the electric system in Alberta in that it is accessible to a large number of generators at a wide variety of scales. This distributed generation will enhance grid reliability and ensure that more Albertans are thoughtfully and meaningfully engaged in the processes of electricity generation, distribution, and consumption.

	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?	No comment

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

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 comment

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

	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	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).	No comment
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	No comment

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Neil Cumming
Comments from:	Solas Energy Consulting Inc.	Phone:	403.200.0049
Date:	2022/01/28	Email:	ncumming@solasenergyconsulting.com

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.**
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Introduction

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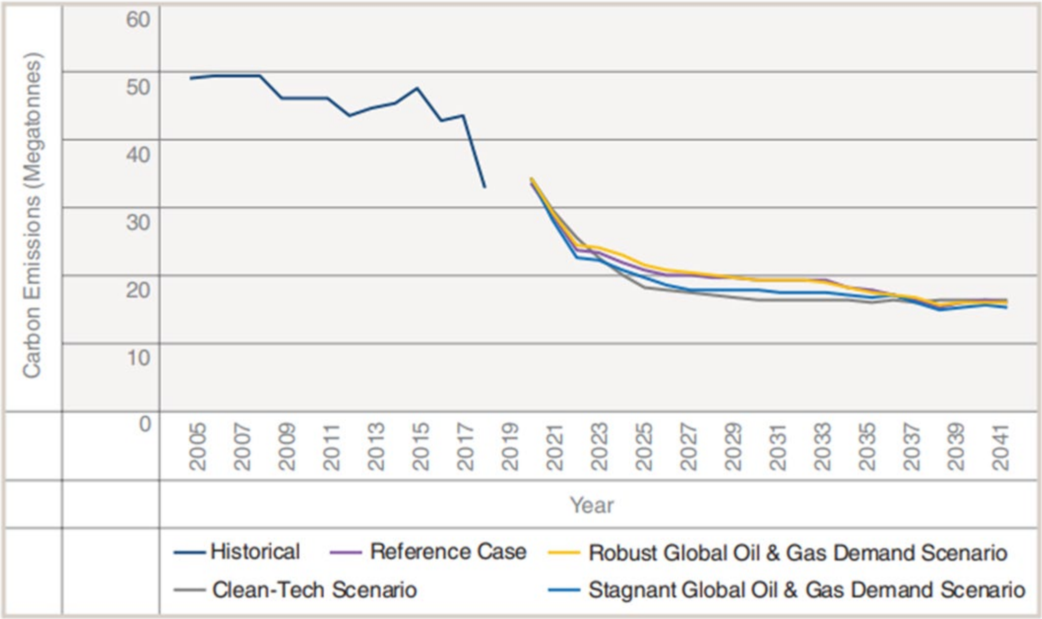
In 2022, the AESO will examine potential pathways to achieve a net-zero greenhouse gas emissions electricity sector in Alberta and the market, operational and cost implications of these pathways. The AESO intends to review and understand the most prominent zero and low-carbon emissions technologies, 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.

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?	Solas Energy applauds the AESO for undertaking these steps to identify what a transition to net-zero emission electricity system will mean for Alberta, to engage stakeholders early and often, and to build a collective foundation of knowledge to help understand the policy, regulatory, market and system change required to meet these targets. Solas Energy appreciates the opportunity to share our views on a net-zero emissions grid. We believe our experience with technology, utility and system operation, tariffs, markets, policy and regulatory process offers a comprehensive view of the challenges and opportunities ahead of us.
	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?	The largest challenge is the **pace of change** required to meet 2035 and 2050 targets. These targets will require years of aggressive industry change. Prior to that change, industry will need clarity on the foundational policy and regulatory framework that will accommodate this transition. As we saw during deregulation, much work is required to negotiate with incumbents, to ensure invested capital can be fairly utilized in the net-zero grid of the future, or they are fairly compensated for early retirements.

	Questions	Stakeholder Comments
		The area requiring a major operational shift will be AESO, TFOs, DFOs getting comfortable with more **reliance on demand-side measures** and ancillary service markets. Reliability and security of the electricity system will only grow in importance, however without more trust in customers to support the function of the grid (both generation & load) there will be an overdevelopment of resources burdening ratepayers with unnecessary costs.
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?	Steady business-as-usual economic growth can be expected. The pace and impact of this growth will be gradual. The larger impact to Alberta's electricity system will be the **electrification of existing industries**, as evidenced by early trends in the transportation sector and likely followed by other industries as they make investments to move away from emitting technologies. This has the potential for transformational demand growth on the electricity system.
	The current HIS 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 HIS 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**	Solas Energy agrees with the procedure of using best-available forecast data to create a base-case and applying **sensitivity analysis** to determine the impacts of various future scenarios and their effect on the future electricity system. This is especially important when the system change is transformational as the shift to a net-zero grid will be.

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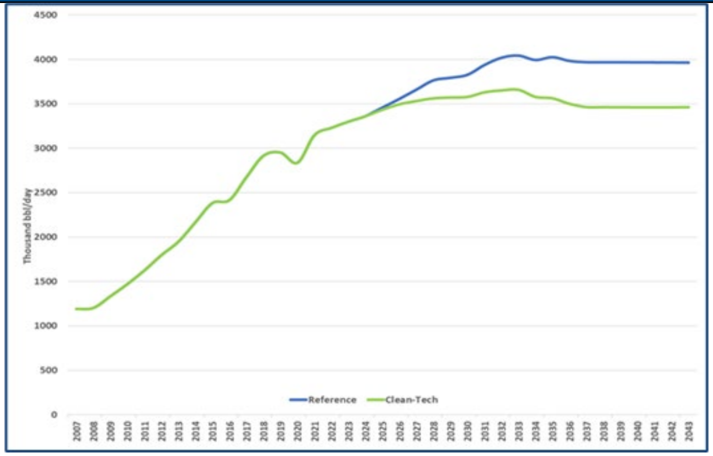
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	Gas price forecasts generally show a **long-term trend upwards** due to carbon pricing. Gas prices may become more volatile as global demand is impacted by climate change (ie more extreme weather events). In a net-zero electricity system less reliant on fossil fuel generation, electricity rates for energy will become increasingly **less closely linked** to 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	Solas Energy believes carbon emission offsets must occur both outside and inside the electricity system to meet net-zero targets. Policy outside the electricity system by way of carbon offsets or credits will affect customer behaviour to manage their costs with a growing carbon price. This will attract more industries to electrification, especially as the grid becomes an ever-greener source of energy, but will not be sufficient to shift the electricity industry all the way to net-zero.

Questions	Stakeholder Comments
	Incenting renewables by way of credits, tax incentives or other will undermine the competitiveness of the energy-only market. Net-zero mandates will require a change in market design such that the risk of future investments is reasonable to incent the required development of new generation and supporting technologies. The electricity system being an industry with centralized planning and regulated investment will be looked upon by governments to lead the transition to a net-zero economy. It is however a complex industry with many stakeholders. It is also an extremely important industry which impacts the overall economy, so electricity industry experts will be looked upon to help guide and implement transformational system change to net-zero emissions in the most efficient and lowest-cost methods possible.
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?	No comment.
c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Alberta must always keep in mind the cost of delivered energy as it moves to a net-zero grid. **Alberta must remain cost-competitive** with other provinces or will risk losing industries to other jurisdictions with lower-cost of energy. Grid defection will occur at a more rapid pace as the cost of grid-supplied energy becomes comparable to the dropping price of self-supplied renewable energy and storage technologies. The **Clean Fuel Regulation** will require gasoline and diesel producers and importers to reduce the carbon intensity of their liquid fuels used in Canada. Options for regulated parties to create credits are through on-site renewable electricity and investment in advanced vehicle technologies such as electric and hydrogen fuel cell vehicles. This Regulation is expected to be implemented in Spring 2022 and may impact the Alberta electric system.

	Questions	Stakeholder Comments
	d) Are there any other related considerations that you would like to provide feedback on?	No comment.
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?	This is **the largest relatively untapped resource** to support the evolving electricity system in Alberta. Energy efficiency including demand-side management programs across all sectors are the lowest-cost resource to help meet net-zero targets, offset future demand growth due to electrification, and participate in the safe, reliable operation of the electricity system. Industrial and large commercial operations are already deploying demand-side management applications to reduce their energy cost. The forestry industry is a prime example, where industrial processes are non-integrated which allow flexibility in their operations to react to electricity market signals and reduce consumption or even export generation back onto the grid. For energy efficiency and conservation efforts to be adopted at the residential level, there needs to be programs and financial mechanisms to support energy audits and energy improvements. Large energy efficiency upgrades can require significant capital investment which homeowners may not be able to meet. Changes to the residential electricity rates structure such as time of use or dynamic pricing will allow for demand side management and provide another incentive for homeowner to make energy efficiency changes.
	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.)?	Net-zero demands significant buildout of renewable energy resources. DER interconnections will **continue to accelerate** due to falling technology prices and the smaller cost and time to interconnect compared to a transmission interconnection. Solas Energy sees rising electricity bills will continue to spur motivation for grid cost avoidance via DER as technology **prices continue to fall**. Solar PV will become standard on new homes and buildings in the shift toward net-zero home building. Smart home technologies will continue to be adopted, and as seen in demonstration projects throughout North America can be integrated with autonomous system controls to support the grid.

Questions	Stakeholder Comments
	There will be a greater need for energy resiliency through micro-grids, providing backup power to remote communities and customers sensitive to system outages. DER penetration will aggregately have an increasingly larger effect on the transmission system and should be viewed as a valuable resource to support grid operations.
c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	Demand growth from the transportation sector will be significant and has the potential to overburden some parts of the system such as distribution transformers. With correct policy and price signals in place, the **intelligent adoption** of electric vehicles onto the system through managed charging will allow for **more efficient use of existing grid assets** without the need for major additional infrastructure investment.[3] This is especially true for passenger vehicles and light-duty trucks who can primarily be charged at-home overnight during off-peak hours. Larger, centralized load growth from charging of commercial fleets heavy duty trucks will require expansion of the grid. Solas Energy expects this will be a modest long-term growth trend, boosting business-as-usual load growth by a **noticeable but not unmanageable level.**[4]
d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	Solas Energy believes the **transition to electric space and water heating will be slow** in Alberta. Long cold winters, and existing preference for gas heating lend to a continued reliance on gas as the main energy source, with a shift toward renewable natural gas. A transition to electric heating, if adopted will start with new homes and buildings. Retrofits are expensive and will be a slower, more complex transition. Oil and gas heating bans are starting to be announced in provinces with

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[3] https://www.forbes.com/sites/jamesmorris/2021/11/13/electricity-grids-can-handle-electric-vehicles-easily--they-just-need-proper-management/?sh=18ce8b3a7862

[4] https://www.energy.gov/sites/prod/files/2019/12/f69/GITT%20ISATT%20EVs%20at%20Scale%20Grid%20Summary%20Report%20FINAL%20Nov2019.pdf

Questions	Stakeholder Comments
	significant hydro resources.[5] [6] As the Alberta grid becomes closer to net-zero, this type of policy may start to gain attention. Electricity demand from cooling will continue at a modest and manageable growth rate and will be more of a factor to consider in system planning.
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)?	Solas Energy believes Alberta can become a global leader in both CCUS and green hydrogen production. However, CCUS and hydrogen are costly. **CCUS** will help extend the operating life of existing emitting industries in the province while meeting net-zero emissions targets. This will be a bridge technology until other non-emitting technologies are more prevalent and the cost of retrofits decreases, **Green hydrogen** via electrolysis is a process which requires a significant amount of energy. Using grid-supplied electricity for this process drives costs higher. More realistically, electrolysis will be self-powered through low-cost renewable energy production with energy storage. [7] All industries will need to add intelligence to their operations, and have more control over their energy footprint and resultant costs. Self-supply, storage, peak shaving, and ancillary markets are all measures industries will need to explore to remain competitive. **Forestry** - have some non-integration in their process which has allowed proliferation of **demand-side management schemes**. Customers are already seeing significant cost savings through managing when they draw from the grid. Customers are also using waste product as a biomass source for generation.

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[5] https://www.cbc.ca/news/science/bans-fossil-fuel-heating-homes-1.6327113

[6] https://climatechoices.ca/reports/canadas-net-zero-future/

[7] https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis

	Questions	Stakeholder Comments
		Hydrogen - Solas Energy sees **hydrogen** in Alberta in the near term will primarily be **adopted for industrial applications**. Hydrogen will become more cost competitive as carbon prices increase. Alberta is already the largest producer of hydrogen in Canada, and will continue to increase production as global demand increases. Hydrogen in the transportation sector may come later, but has challenges relating to safety, logistics of fueling, and will require more investment and marketing efforts from auto-manufacturers.[8] **Crypto** – **grid-supplied energy costs are already too high** for most cryptocurrency mining applications. Green cryptocurrency will have higher prices than traditional mining, and will most often be self-powered through off-grid low-cost renewable energy and storage systems. **Data centres** – data centres will have continued reliance on grid as well as robust UPS systems due to their need for resiliency.
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?	Taking into consideration Alberta's natural resource mix, historical generation fleet, and business environment, Solas Energy anticipates the following technologies will be most economic on the transition to net-zero. 1) **Demand-side management**. As mentioned in 4a) this is the least expensive opportunity to reduce demand and as a result the available generation supply, and will also drive the more efficient use of grid assets. Demand-side management needs to be incorporated at the residential level for this opportunity to be fully realized. 2) **Solar PV and wind energy paired with energy storage**. Alberta's abundance of both solar and wind resources, and falling technology costs make these attractive, low-cost emissions free

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[8] https://www.alberta.ca/hydrogen-roadmap.aspx

Questions	Stakeholder Comments
	generation sources. Energy storage in many cases is already a necessary pairing to manage intermittency. 3) **Interties** to other provinces, especially British Columbia. The continued reliance on low- or no-emission electricity from our neighbours will be an attractive option. 4) **Carbon Capture**, especially as a bridge technology as renewables are developed. This is an expensive technology itself, but will allow existing investments in emitting generation to continue without expensive early retirement measures.
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 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	i) CCUS is applicable to Alberta, especially as a bridge measure to extend the operating life of existing emitting assets. CCUS will help meet short-term emissions targets and will utilize existing infrastructure investments without expensive early retirement. Alberta already has pipeline capacity, skilled expertise to capture, ship, and sequester carbon. Post-combustion capture is an expensive process and further development is still required. It reduces the efficiency and capacity at power plants and is likely not as attractive for greenfield applications as other non-emitting energy technologies reduce in cost. Storage is well understood in Alberta and a current practice. Carbon Utilization is still in the development phases with minimal technologies and processes currently at commercial scale. Carbon use within the cement sector is the further along. Carbon Utilization technologies can have a significant energy demand. ii) Pre-combustion capture is expected to be applied to steam methane reforming processes within Alberta to produce clean hydrogen. This process is efficient but is still expensive and can be difficult to apply to existing facilities. There is significant opportunity for hydrogen in Alberta, especially as a producer to meet forecasted growing global demand. Storage

Questions		Stakeholder Comments
		and Utilization opportunities and changes are the same as identified above. iii) Oxyfuel combustion is still in the development stages. There are still key challenges to overcome such as the capital cost, energy consumption, and operational challenges of oxygen separation. iv) There is significant renewable generation opportunity in Alberta. Solar and wind technologies will lead the way due to their low cost and Alberta's excellent resource. These are the largest renewable resources within Alberta, and are proven low-cost sources of energy. Geothermal and biomass may have niche opportunities within Alberta. v) Small opportunity in Alberta due to the lack of large-scale hydro-capable resources. Run of river technologies are still too expensive to be competitive in Alberta. vi) The future of nuclear generation in Alberta is unclear. Technology-wise, nuclear is an expensive but excellent non-emitting baseload technology which would make a lot of sense in Alberta. Political and social comfort around the safety of this technology will still be a barrier in the long term. Small module reactors have potential to proliferate throughout the province, both for grid-connected and off-grid applications. Small module reactor technologies are still under development with pilot projects being deployed in Ontario. vii) Energy storage investments will be necessary for high penetrations of variable renewable generation. Battery energy storage technologies are currently commercial and being deployed at large scale in Alberta. Other types of energy storage technologies such as flow batteries, compressed air energy storage, mechanical storage technologies, etc. are still in the development stages. Different technology types will be required to meet the various grid services in a net-zero scenario.

Questions	Stakeholder Comments
	viii) There is major advantage for leveraging interties with other provinces to boost reliability and import non-emitting generation sources. This is especially true in BC due to their hydro resources. Increasing interties will require political support and market changes to accommodate the different electricity structures between Alberta and BC. ix) Offsets and performance credits will be a big component of new investments decisions. These will make non-emitting sources more attractive in the market, and will drive significant change in the existing generation resources in Alberta. These will not be enough to transition all the way to a fully net-zero electricity system. Additional mechanisms beyond the energy market plus performance credit revenues are necessary to reach a 100% non-emitting grid.
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?	No comment.
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.	No comment.
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?	No comment.

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*[9], 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

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[9] 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 comment.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	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).	No comment.
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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Derek Davies
Comments from:	Suncor Energy Inc.	Phone:	(403) 808-9760
Date:	2022/02/03	Email:	dedavies@suncor.com

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

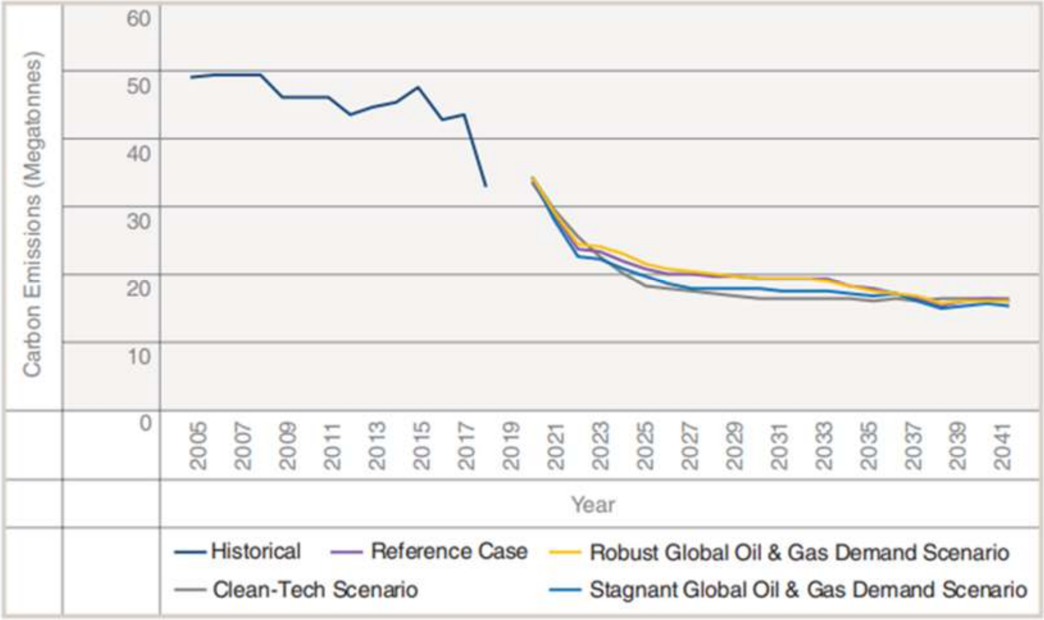
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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.

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.

Questions	Stakeholder Comments
a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?	Suncor has a strategic objective to be a net zero company by 2050. In that context, Suncor sees value in the Net-Zero Emission Electricity System Pathways evaluation to further understand a potential range of solutions and challenges in reaching net-zero. The evaluation should be pragmatic, specifically regarding the time to reach the net-zero objective. Suncor believes that maintaining a safe, reliable and efficient system with the substantial changes that would need to be undertaken to meet 2035 are exceedingly challenging. Ensuring a safe, reliable and efficient system needs to be the key objectives of the electricity system. Suncor believes renewables and storage play a large part in transitioning to net-zero due to their low levelized cost of capital. However, it is unlikely that renewables and storage could be built out to such an extent that it could reliably supply power for all of Alberta's load by 2035. Additionally, the need for steam in industrial processes will likely require cogeneration to exist in some form. Partnerships with governments to deploy at-scale carbon capture, use, and sequestration (CCUS) on these facilities will be critical to achieve the proposed objectives. Modeling the outcomes of the anticipated Investment Tax Credit for CCUS would be useful. Suncor

Questions	Stakeholder Comments
	suggests that the renewable and storage market penetration scenario would be more valuable if a high percentage penetration was determined versus full market penetration. An important aspect of the net-zero transition is that sectors are not looked at in isolation, and that the integration of transportation, heating, industry etc., are all considered. The questions in this survey touch on these interactions and to the extent possible, scenarios should be undertaken to understand the implications of varying levels of synergy with other net-zero initiatives.
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?	Suncor believes the largest challenges on a pathway to a net-zero grid are: • Increased tariff costs due to transmission buildout, as well as increased pool price due to early generation retirement and generation decarbonization projects that will likely result in consumer concerns. These concerns would hold back electrification and put pressure on the government to slow the transition. • Significant capital and operating costs associated with CCUS projects, which will be required to achieve the stated objectives. • The combination of uncertain policy and the rate of change required to meet 2035 will challenge investment certainty. Without investment certainty, delivering on the rate of change will be a substantial hurdle. • Regulatory efficiency and predictability will have to continue to improve to support the implementation of a significant number of new generation projects, new generation technologies and likely new transmission projects. • The development/implementation of demand management systems for residential to industrial users will be important. The increased variability in generation with the high penetration of renewables and changes to load profiles with electrification will make load smoothing an essential component of an efficient power system.

	Questions	Stakeholder Comments
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?	
	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**	

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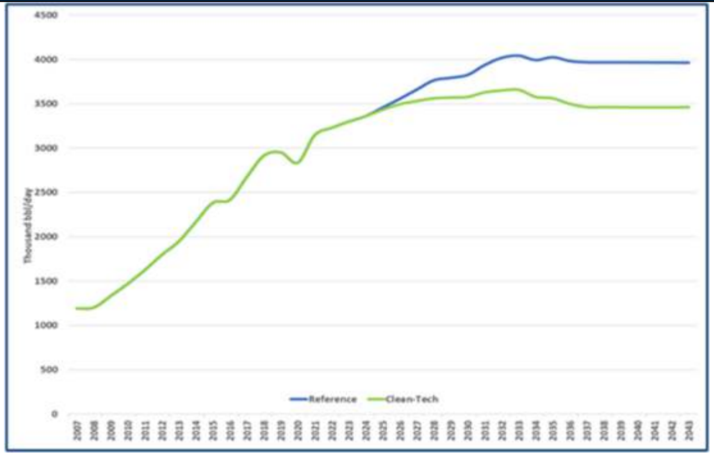
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	
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	Credit trading across industries promotes cost-efficient carbon reduction and Suncor sees that as promoting efficient capital deployment through the transition. We also see value in policy that supports efficient carbon reduction across industries to keep Alberta competitive with other jurisdictions. All three of the proposed mechanisms will be needed to achieve the objectives.

Questions	Stakeholder Comments
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?	Suncor is expecting carbon prices to follow the trajectory announced by the federal government out to 2030. Beyond 2030, it is not clear how carbon prices will change, and how the price changes will be influenced by successes or challenges in reaching the government's milestones on the path to net zero GHG emissions by 2050.
c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Suncor believes there is a need for changes/clarity in the following areas: 1. An Investment Tax Credit of 75% to support deployment of CCUS technology for large point sources including those from the combustion of natural gas within the power sector. 2. To what extent inter-provincial transmission will be part of the solution, *i.e.* who is building how much and by what time. 3. Considering potential increased interties and with a continued proliferation of intermittent resources, the Alberta market design needs to be reviewed and potentially adjusted to ensure long term reliability. 4. Policy changes in a timely fashion with a clear, stable policy environment afterwards. Certainty is required for private companies to make their investment decisions. 5. A more streamlined and efficient regulatory approval process. The amount of investment required to reach a net-zero grid by 2035 is staggering. There needs to be certainty that individual projects can complete the regulatory approval process at a pace that meets the goal date, including time for design, construction and commissioning. 6. An aligned and consistent pan-Canadian carbon market to provide a larger market to buy/sell credits and facilitate efficient decarbonization across the country. The system must integrate into the North American and eventually global markets. 7. Alignment between the various levels of government on realistic targets and programs to support achieving those targets.

	Questions	Stakeholder Comments
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	Demand side management has an important role to play that should not be overlooked. Attention should not be placed exclusively on the supply side of the equation. Improvements in energy efficiency will reduce the amount of new supply needed. Policy makers can influence this change by updating construction codes and implementing incentives for retrofits.
	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.)?	Increasingly, end consumers are changing their participation in the energy market. This change is being enabled through technologies such as rooftop solar, home battery storage, vehicle-to-grid, smart meters, programmable appliances and connected appliances, as well as regulatory changes such as time-of-use billing and feed-in tariffs. An accelerated effort to reach a net-zero (or truly zero-emitting) power grid should be able to take full advantage of any of these opportunities. In particular, regulators should encourage the ability for companies to partner with customers to enable aggregation and coordination of these opportunities. In such an arrangement, a company providing the aggregated service (through scale and continuity afforded by aggregation) would share the financial benefits with the customers. Alberta's current grid management approach and regulatory structure does not allow for some of these innovative solutions to be applied.
	c) Transportation Sector - What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	It may be reasonable to assume that light duty vehicles will be electrified before the heavy-duty sector. The overall pace of penetration will likely be highly dependent on purchase incentives and infrastructure availability to encourage widespread use. Suncor has built out an extensive EV charging network at our Petro-Canada stations across Canada. Through this experience we have learned that access to the grid and a level playing field are crucial to the

	Questions	Stakeholder Comments
		success of having private companies fairly compete with crown energy corporations. There are challenges to electrifying heavy duty transportation and renewable fuels or hydrogen may be more feasible for these sources.
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
	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)?	Any forecast of a net-zero grid should account for CCUS technology power requirements. The deployment and impact of CCUS likely requires a focused effort to understand the potential for these technologies across Alberta's portfolio of generation assets.
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?	It is too early to determine which technology will be the most economic at this point in time. All pathways should be considered as advances are occurring in each technology. Any wind and solar pathway should be considered with an appropriate amount of long duration storage to ensure grid stability.
	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 Carbon Capture, Utilization, and Storage	Each technology has different strengths and weaknesses, and combinations of technologies and tools (such as offsets) will be needed. The regulatory pathways, efficiency and certainty should also be considered, as this may dominate the development timeline.

Questions	Stakeholder Comments
(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	
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?	By examining the overall theoretical generation capacity and the overall power demand over a certain period of time (i.e. one day, one week, or more), it may become evident that the issue of bringing online non-emitting power, especially variable renewables, could be achieved more easily if we can satisfy the overall demand and worry less about the peak demand. Demand-side management is a powerful mechanism to optimize the use of the non-emitting generation. Early investment in demand side technologies and regulations could make the transition of power generation to fully non-emitting much more achievable.
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.	
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?	Co-generation facilities will very likely be operating in 2035 and beyond. If the grid is to achieve net zero, then all natural gas power generation facilities will need to be net zero. CCUS is one of the few technologies that creates a significant reduction in emissions from combustion of fossil fuels in power plants. Suncor believes a strong partnership with government is required to deploy CCUS technologies at scale, to achieve the objective of having a net-zero grid by 2035, and to lower other emissions sources across Alberta.

	Questions	Stakeholder Comments
6	***Net-Zero Generation Technology Costs***	

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

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[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?	The assumptions for each generation type should be clearly identified to ensure that costs can be fairly compared with each other. Long duration storage is not identified and should be considered with the appropriate cost structure.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	Retrofits will be challenging due to the larger capital and operational costs compared to greenfield construction and the need to de-rate the facility to support the new electricity and heat requirements. Alignment with government on programs and partnerships will be required to make these projects feasible (per above comments).
	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).	There is potential for hydrogen peakers to play a role in the energy transition. It may be valuable to include these in in the study.
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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Mark Thompson
Comments from:	TC Energy ("TCE")	Phone:	403-589-7193
Date:	2022/01/31	Email:	markj_thompson@tcenergy.com

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

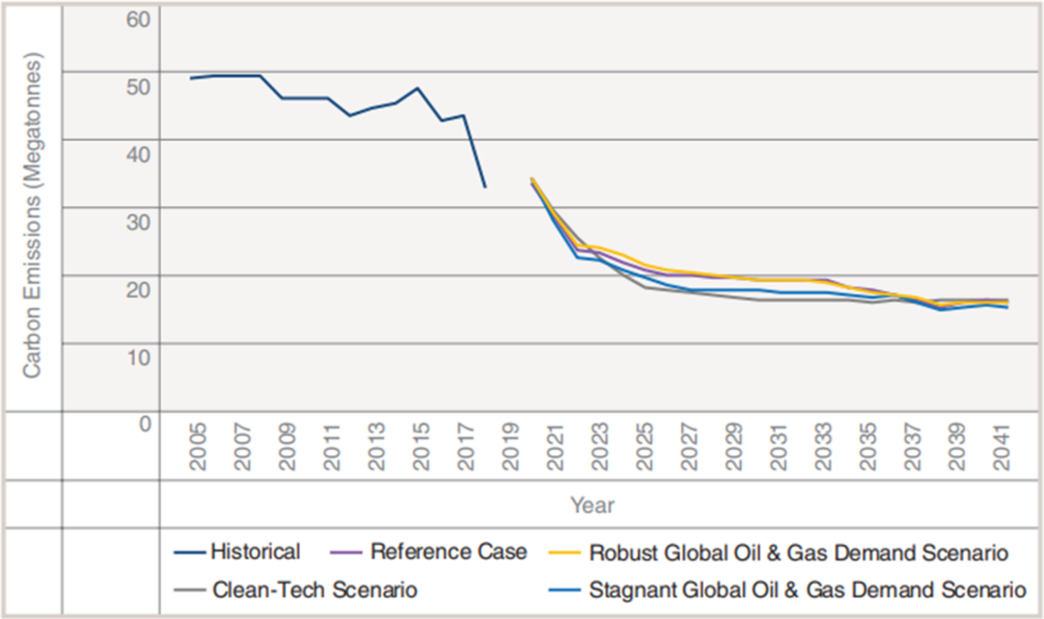
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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.

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td>1</td><td colspan="2">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.</td></tr>
<tr><td></td><td>a) Is there any feedback that you would like to provide to the AESO with respect to the intended scenarios and analysis?</td><td>TCE supports the AESO’s initiative to produce an initial Net-Zero Emissions Electricity Systems Pathway report. In light of the increasing calls from different levels of government and consumers, and recent commitments from industry, for net-zero initiatives, it is important that the AESO and Alberta’s market participants understand the impacts that such initiatives may have on the electricity sector.
TCE understands that the AESO’s initial report is not intended to be a fulsome report that studies all potential pathways to net-zero nor all of the potential impacts. However, it is important to note that that this report, or a report similar to this, could and should be used as a resource for governments when developing net-zero legislation. As such, the most likely pathways be studied so that the resulting impacts to costs, resource adequacy, and market structure are well understood.
Key to this is a clear and precise definition of what a “net-zero emissions electricity sector in Alberta” means, which the AESO will use as a baseline scenario. There will be a range of potential net-zero definitions, each with differing impacts to Alberta’s electricity sector. For example, the options</td></tr>
</table>

Questions	Stakeholder Comments
	presented in Question 3(a) below will drive very different results. TCE recommends that the AESO consult with stakeholders to determine the most reasonable definition as a starting point, and include one or two different options in its scenario analysis. It will be critical to understand the sensitivity that this definition will have on reliability and market outcomes. The two scenarios identified by the AESO, plus the sub-scenarios to capture the definition of net-zero as described in the prior paragraph, are reasonable starting points for the initial report. While TCE does have some concerns from a reliability and diversity of supply perspective of achieving net-zero from renewables and storage alone, studying such a scenario will be informative. Regarding the second scenario, TCE recommends that more than a single scenario be considered to reflect the uncertainty with which the various generation technologies will develop.
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?	From a long-term planning perspective, 2035 is not far away. Achieving net-zero emissions in the electricity sector within that timeframe will be a challenge in itself. Significant investment in new capacity and new technologies will be required. Siting and permitting take time especially for the new/unproven technologies. Achieving net-zero in a reliable and cost-effective manner without stranding assets and impacting Alberta's economy will be an even greater challenge. Diversity of supply is an important component to maintaining a reliable electricity system. Yet, the cheapest pathway to net-zero may not allow for the diversity required to maintain the current level of reliability as some of the technologies listed in Section 6 below are still in early development and their costs are uncertain. Thermal generation currently accounts for over 70% of Alberta's installed capacity. The cheapest pathway to net-zero may risk stranding these generation resources depending on the definition of net-zero and the speed at which CCUS and hydrogen generation are developed. Stranding assets may put a chill on new investment when it will be needed most. A balance will be required to maintain reliability, a diverse supply mix, and a healthy investment climate in a cost-effective manner.

	Questions	Stakeholder Comments
		Another challenge will be to achieve all of this with the energy-only market. Alberta has proven that competition drives the lowest cost outcomes. A competitive market structure should be maintained. Yet, certain technologies, such as nuclear, hydro and transmission infrastructure, are capital intensive and long-life assets that will be challenging to build in an energy-only market. These challenges will be significant and will be exacerbated as other sectors of the economy strive to achieve net-zero through electrification. This will be both a great challenge and opportunity.
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?	The push to net-zero will both increase demand through electrification and cause a shift in supply to more expensive technologies. As such, a sector-wide net-zero initiative may increase the delivered cost of electricity to consumers. Over the long-term as these newer technologies develop and benefit from economies of scale or scope, we can expect the costs to stabilize or fall.
	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**	The Oil Sands Pathways to Net-Zero initiative, an alliance between Canada's five largest oil sands producers, has announced a detailed plan to achieve the goal of net-zero greenhouse gas emissions from oil sands operations. Thus, there is a possible scenario where oil sands production increases while their emissions decline.

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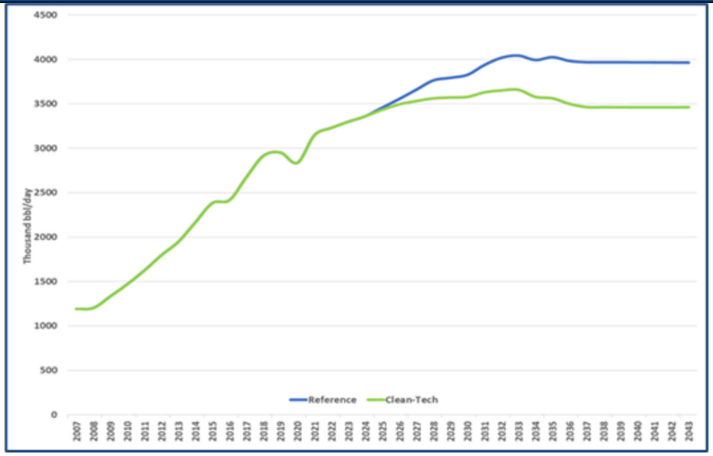
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	Gas prices can be volatile making them difficult to forecast. Assuming forward gas prices in the $3/GJ range is a reasonable assumption.
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	It is important that each of the identified mechanisms be included as part of the solution to reach net-zero by 2035. Eliminating any of these mechanisms will result in an inefficient outcome as cost-effective pathways to net-zero would be overlooked resulting in higher costs than necessary. Limiting the compliance mechanisms to physical emissions reductions only may impact reliability during tight market conditions and may strand assets needlessly. In addition, the electricity market will experience demand growth as it enables electrification in the economy as a whole. The economy-wide

	Questions	Stakeholder Comments
		emissions reductions from electrification should be allowed to offset electricity grid emissions. As stated above, it is important the that AESO defines what is meant by net-zero.
	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?	It is reasonable to assume that carbon prices will rise in accordance with the federally-announced carbon prices and reach $170/t by 2030, and then to continue to grow with inflation.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	The following policies, or potential policies, may impact the Alberta electric system with respect to net-zero compliance: • Clean Electricity Standard • A federal Canada-wide “net-zero by 2050” target • Changes to the federal carbon price • Changes to the TIER regulation • A cap on oil sands emissions • A performance standard for new natural gas generation • Changes to ambient air quality (NOx) emissions standards • Changes to the federal Impact Assessment Act
	d) Are there any other related considerations that you would like to provide feedback on?	
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?	The pace and penetration of energy efficiency will be primarily driven by government policy including changes to standards and regulations. These policies can be expected to influence behaviour across all sectors of the economy. Subsidized investment in efficiency and or conservation will enhance the pace.
	b) Distributed Energy Resources (DER)	In general, net-zero trends can be expected to impact DERs in a similar manner to the rest of the electricity sector and will be driven by

	Questions	Stakeholder Comments
	• 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.)?	government policy. The pace of DER development will likely increase as a result of a net-zero policy, particularly if influenced by government subsidies.
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	A net-zero scenario should increase the adoption rate of EVs and more electrification than under the clean tech scenario.
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	A Canada-wide net-zero standard would increase the pace of electrification for the heating and cooling of buildings. Associated government standards will directly influence the pace of electrification.
	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)?	The development of CCUS and hydrogen production could allow for increases to industrial load that may not have otherwise been permitted under environmental legislations. The impact of net-zero targets on the load growth for other sectors will depend primarily upon: (i) the timing and definition of net-zero policies; (ii) the response by industries to achieve net-zero; and (iii) the timing and cost of new technologies. As referenced above in the response to Question 2(b), the Oil Sands Pathways to Net-Zero initiative may allow for continued growth.
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?	As mentioned above, a diverse supply mix will be necessary to achieve net-zero emissions in a reliable and cost-effective manner. The data derived from the US Energy Information Administration's *Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies* is a good starting point to determine the relative cost of the technologies in the short- to medium-term.

	Questions	Stakeholder Comments
	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 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	The primary benefit of CCUS technologies is that they will allow for the continued use of existing thermal assets. This will help to maintain reliability (due to their dispatchability), will focus development on brownfield sites, and will significantly reduce the risk of stranded capital. The challenge with these resources is the cost and timeline to cost-effective deployment. However, TC Energy and others are actively working to develop these technologies. Renewable generation such as wind and solar generation is currently economic and will likely continue to be so for the foreseeable future. The challenge with these technologies is the variable energy production. Wide-scale development would impact system reliability and may not be possible under the current market structure. This issue can be addressed by various storage technologies, but the extent by which it can be addressed has not been fully determined. Energy storage technologies are improving and are just becoming a viable technology as their cost curves improve. The flexibility of storage technologies will assist with increased variability caused by the penetration of renewable generation. The tariff rates, rules, and regulations for energy storage have not been fully developed and will impact the rate of deployment in the province. It is yet unknown whether wide-scale deployment of energy storage will be possible by 2035. One challenge for energy storage is that they are a net-load. Hydroelectric generation is highly flexible and has low emissions. Large-scale hydro, however, would be difficult to locate and permit. This technology would also require long timelines and is capital intensive that may be inconsistent with the current market structure as subsidies would likely be required. Pumped hydro technologies are, however, currently viable in Alberta and have the same benefits. Large-scale nuclear generation could produce significant amounts of baseload generation. Its challenges are the long timelines and large capital costs that may require subsidies and stress the energy-only market design. Small modular reactors could be a nuclear solution that works for Alberta, but remain several years away from deployment.

	Questions	Stakeholder Comments
		Transmission interconnections with other jurisdictions could facilitate the transfer of net-zero electricity from other jurisdictions. The timelines to locate, permit, and build transmission lines are long and capital intensive. Many of Alberta's interconnected neighbours operate in a fully-integrated utility model run by crown corporations. Maintaining a level playing field that facilitates competition is, and will continue to be, a challenge. The future supply of net-zero electricity from other jurisdictions is unknown. As other jurisdictions are similarly required to achieve net-zero targets in their industrial, commercial, and residential sectors, the availability of net-zero electricity for export to Alberta is a question that will need to be addressed.
	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?	
	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.	
	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?	Cogeneration facilities are critical to Alberta's economy. The baseload generation provided by Cogens are a significant portion of Alberta's current supply mix. Attributing the emissions from cogens to the electricity rather than the associated industrial process would impact grid reliability and Alberta's economy. A net-zero emissions policy that limits reductions to physical reductions would not be economic for small cogeneration facilities. A TIER-type program that permits offsets to achieve compliance is required.

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	-	-
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Hydrogen-Fired Combined Cycle	450	1,667	52.84	2.65	6.79

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[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?	In general, the costs presented appear reasonable. The cost of the nascent technologies would be expected to decrease by 2035 as the technologies mature. In particular, the fuel cell and SMR costs would be expected to fall over time as projects are developed worldwide allowing these technologies to move up the learning curve.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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

SOME THOUGHTS ON NET-ZERO PATHWAYS FOR ALBERTA

BY COSMOS VOUTSINOS 2022/01/11

Here are a few thoughts to possibly be shared with the AESO in response to their recent request for input on Net Zero emissions pathways for Alberta electricity generation.

- Let us examine first, whether the AESO will decide to proceed with nuclear power, what kind of Canadian sourced reactor will be chosen and how much will it cost?

- Let us also consider that:
  - No Gen 4 SMReactor has been built yet, so AESO will be a "guinea pig" especially if it goes with a prototype Canadian Design. Alternatively, it could go with the traditional 60 year old, GEN 1 CANDU reactor.
  - The old CANDU has proven to be a reliable work horse with a lot of electricity production under its belt, and manageable operating problems. Its two major drawbacks are the production of long lived radioactive spent fuel and the high original capital costs.
  - The SMRs promise to eliminat or reduce both these problems:
    - <u>The spent fuel problem</u>: by selecting a high temperature SMR that can also be a "breeder reactor" (make more fuel than it burns) or a "converter reactor" (make as much fuel as it needs to burn) so that we don't have the volume of very long living radioactive remnants.

  - <u>The high original cost</u>: by selecting a reactor than can be built by assembling moduli, will reduce the construction time from 10 years to 2-4 years.
  - When a Utility decides to build a power plant it pays out advanced money until the plant is built, commissioned, and connected to the grid ready to produce electricity. The interest on these payments is called “interest carry over” and it keeps compounding during the design and construction periods. I experienced, during the construction of the Point Lepreau reactor, where the “interest carry over” doubled all the “out of pocket’ payments for the project. In fact, towards the end of the construction period it was adding $2.5 million per day to the cost. In Industrial projects that require construction periods of close to a decade, the most expensive commodity becomes TIME. Yet, consulting engineering firms, on “cost plus” contracts spend weeks preparing and issuing tenders to save few thousands of dollars from the cost of equipment purchased.

- The deciding issue for AESO then becomes the establishment of an efficient “on time” supply line for the precisely manufactured moduli. This in turn will define the real cost of their SMR reactor. One would prefer to have a Gen 4 modern SMR reactor which has corrected the old problems, than a Gen 1 reactor designed 60 years ago.

- Having established the type of reactor needed, we now need to look at the most suitable deployment for it. A 300 MW SMR with an established supply line for the moduli cannot be expected before 2030 – 2035; consequently, large reactors (300 MWe) cannot meet the Net Zero deadline. Smaller SMR's will be prototyping as early as 2025 and be commercially available by 2030. These smaller reactors will validate the design and ensure timely supply lines for the various moduli.

- The problem is that these 1MW to 10MW SMRs are not suitable for providing electricity to a large grid system. They are suitable for providing power for industrial loads, electricity to remote communities and micro-grids. The micro-SMRs, under 5Mwe, are delivered pre-assembled and contain their fuel for 20 years of full power operation.

- If we look at the oil sands we see that they consume energy at a rate of 1,000 cu. ft of natural gas per barrel of oil produced. This natural gas is removed at the wellhead and is called "utility gas".

- If we have a working and proven process by 2030, Canada will be better positioned to meeting its Net Zero Commitments by reducing the much larger industrial emissions than by reducing electricity emissions which add up to only 17% in Alberta.

The following steps are recommended

- It is therefore recommended that: the first step should be to build small SMR's of various sizes to be used to replace the natural gas energy used at the oilsands to produce oil & gas. This alone would be significant enough to meet Canada's net zero reductions. At the same time, it will save billions of cubic feet of clean natural gas which can be exported. In addition, our oil production will be the cleanest in the world and can be used for "input energy" for mining materials and manufacturing systems for Alberta's "Energy Transition" to decarbonization.

- Secondly while we produce and use the small SMRs, the AESO should start the stochastic process of sourcing the larger moduli to follow the evolution of the smaller SMRs. When they are reasonably convinced that a project for a 300 MW SMR will be successful commit to a prototype.
- The third step will be when the 300 MW prototype construction phase is completed as expected (2 to 4 years to construct), to then commit to additional units, depending on AESO's grid needs.
- Evaluation of a grid line between Alberta and Manitoba and Alberta and BC should be considered at this time.

I believe that this approach involves low risks and high returns for Alberta. Note that Ontario Hydro selected the BWRX-300 likely because they did not want to expose themselves to the risk involved in the 15 year construction for an unproven, new, and evolving design that has the potential to result is worse cost over-runs than those experienced with their Darlington reactors

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Akira Yamamoto
Comments from:	TransAlta Corporation	Phone:	403-267-7304
Date:	2022/01/31	Email:	akira_yamamoto@transalta.com

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

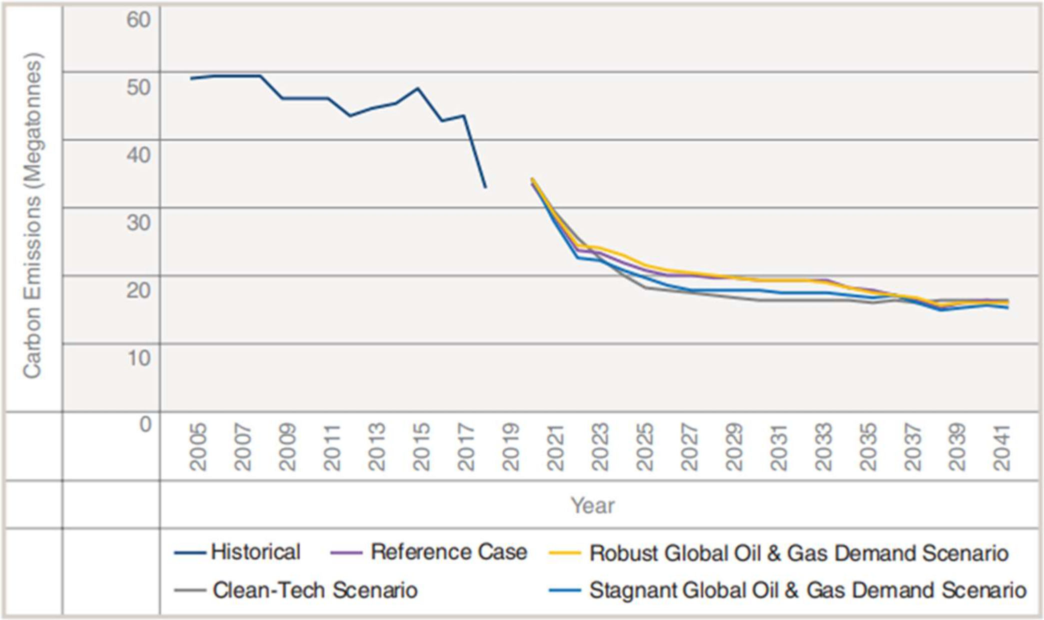
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	***TransAlta strongly supports the development of an Alberta net-zero scenario given stated federal policy goals. In our view, some generating technologies will be substantially restricted or eliminated if governments implement carbon pricing and regulation to achieve a net zero goal.*** TransAlta expects that carbon emissions policy and regulation will significantly change to achieve a goal of net-zero emissions from Alberta's electricity sector by 2035. • No new thermal generation will be permitted without carbon capture or storage, other carbon emissions control technology, and/or the requirement to generate using lower carbon fuels such as hydrogen. • Stringency and carbon obligations for new thermal generation will be based upon a zero/near-zero standard. • Existing coal to gas generation and gas generation will retain current performance standards to 2035 at which point they will face the same performance standard as new thermal facilities (this may be regulated

Questions	Stakeholder Comments
	physical standard or a performance standard under a carbon pricing regime or both). • Carbon pricing systems will evolve to only recognize Carbon Dioxide Removal (CDR) offsets that achieve negative emissions. Technologies achieving emissions avoidance (renewables, Carbon Capture, Utilization, and Storage (CCUS) that is not direct air capture) will no longer receive crediting. We expect that Alberta will continue to operate its own carbon pricing framework with some flexibility to adopt standards different from the federal Output-Based Pricing System (OBPS), but the federal government will introduce new regulations to ensure emissions performance of thermal generating facilities aligns with a net zero goal, similar to the approach taken to achieve the off-coal transition. ***The starting point of the analysis of net-zero generation supply scenarios should not presume two scenarios*** Given that we expect achieving net zero will likely require a mix of renewables, energy storage, and zero or near-zero emitting thermal generation, TransAlta believes that the AESO should perform its review of net-zero scenarios without the presupposition that there are two distinct pathways: one with only renewables paired with energy storage and an economically driven generation resource addition scenario. For the AESO to perform its modeling and present its findings in the most helpful manner to government, policy makers and market participants, it should recognize that there are a range of economic options to achieve net zero for Alberta's electricity system that are likely to be informed by future reliability needs, changing supply and demand fundamentals, and technological breakthroughs that could drive reductions in the cost of generation and storage technologies. Under Alberta's merchant market construct, all future generation investment will be driven by economics, including renewables paired with energy storage. In this context, TransAlta recommends creating scenarios based on:

<table>
<tr><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td></td><td>

- The relative cost of competing technologies: The scenarios should consider various scenarios of future changes in the cost of competing generation technologies; and
- The absolute emissions from the system in 2035: The financial and reliability costs of achieving a fully zero-emissions grid are likely much higher than a grid with near-zero emissions that utilizes negative emissions offsets. The AESO should consider the relative cost of each approach.

TransAlta recommends that the AESO model the following:

<table>
<tr><th>Scenarios</th><th>Sensitivities</th></tr>
<tr><td>Technology Scenarios</td><td>(1) No change to cost – use TransAlta’s estimates of current technology costs and assume no changes over time.
(2) High-cost reductions in CCUS – utilize TransAlta’s high cost reduction scenario for combined cycle with CCUS and hydrogen-fired combined cycle.
(3) High-cost reductions in Renewables & Energy Storage – utilize TransAlta’s high-cost reduction scenarios for wind, solar and battery technologies.
(4) High-cost reductions for all key technologies: utilize TransAlta’s high-cost reduction scenarios for all technologies.</td></tr>
<tr><td>Net Zero Targets</td><td>(1) Canada-only offset system – 5 MT CO^2e/year target physical emissions from Alberta’s electricity sector.
(2) Alberta-only offset system – 2 MT CO^2e/year target physical emissions from Alberta’s electricity sector.</td></tr>
<tr><td>Natural Gas Pricing</td><td>(1) Stable gas pricing – gas pricing remains in the $3/GJ on a real basis over the study horizon.
(2) Increasing gas pricing – gas prices increase to $6/GJ on a real basis by 2030 and stay at that level to 2042.</td></tr>
<tr><td>Load Forecast</td><td>(1) Moderate Energy Efficiency & Moderate Electric Vehicles – utilize TransAlta’s moderate energy efficiency estimates of electricity consumption reductions and moderate adoption of electric vehicles.
(2) High Energy Efficiency & Moderate Electric Vehicles – utilize TransAlta’s high energy efficiency estimates of electricity consumption reductions and moderate adoption of electric vehicles.</td></tr>
</table>

</td></tr>
</table>

Questions	Stakeholder Comments
	(3) **High Energy Efficiency & High Electric Vehicles** – utilize TransAlta's high energy efficiency estimates of electricity consumption reductions and high adoption of electric vehicles.
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?	***Maintaining a reliable electric system through this transition and evolving the market to provide the investment signals and procure the needs of a changing system*** The most significant challenge to Alberta's electricity system will be maintaining system reliability as we see the supply mix change from conventional thermal generation to renewable and other forms of lower emitting resources. We are already aware of the challenges with maintaining sufficient system inertia with high levels of renewable intermittent resources comprising the overall supply mix. To address these emerging reliability needs, TransAlta recommends that the AESO start the work to identify those system needs and requirements and create procurement mechanisms that will provide appropriate investment signals to ensure those future needs can be addressed. We also expect that Alberta will need to continue to rely on firm and reliable natural gas generation to meet electricity demands as we transition to a net zero grid. Fortunately, Alberta has the benefit of a large fleet of existing thermal generation that can bridge the gap between what the lowest cost net zero technologies can provide today and provide the time for other net-zero technologies to advance, prove their technical feasibility at a commercial scale, and come down in cost to become competitive and economical. However, the real-time, energy-only market design will need to evolve so that existing thermal generation assets are provided the right price signals to ensure that they are available and generate when needed. More specifically, these resources need to be compensated to maintain a

Questions	Stakeholder Comments
	high level of availability despite potentially running less[1] and need to be dispatched in a manner that recognizes their long lead time constraints. ***Managing electric system development to enable electrification while keeping the cost of delivered electricity affordable*** A second significant challenge will be the development of distribution and transmission systems to enable electrification. Alberta is in a challenging position given the already high cost of the transmission and distribution systems. Driving more capital investment into those systems risks creating electricity affordability issues for consumers. Electrification in transportation is a key opportunity for deeper emissions reduction in the economy and an important way that the electricity system will contribute to a reduction in fossil fuel use. The challenge is that these investments must be made to enable adoption of lower emitting technologies, such as electric vehicles, but not so early that the system is overbuilt for a long period ahead of their need. The transition to electrification must be as efficient as possible. This means enabling the lowest cost pathway that keeps electricity costs in Alberta competitive with other jurisdictions and affordable for users, matching the scale and timing of future need, and minimizing the risk of stranded assets (a utility/ratepayer cost). The federal government has set out its targets for zero emissions vehicle purchases in 2030 and 2035.[2] We recommend that the AESO modeling adopt these targets as a starting point to assess demand for electric vehicles in Alberta.

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[1] The low variable cost renewable resources will displace higher variable cost thermal resources in the energy market as renewables increase their share in the supply mix resulting in thermal resource operating at lower capacity factors over time.

[2] https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/healthy-environment-healthy-economy.html

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td>2</td><td><i>Macroeconomic Context</i>
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.[3]
a) What is your view on the economic impact of expected net-zero targets on this business-as-usual scenario?</td><td><i>Real GDP growth of nearly 5% in 2022 and 4% in 2023 and 1.9% long-term is more reasonable; a low scenario under net-zero should be developed (reflecting a 1-1.5% growth rate long term)</i>
TransAlta generally agrees that in the near term (2022-2023) Alberta Gross Domestic Product (GDP) will reflect robust growth. Alberta Treasury Board and Finance forecasts 5.1%, 2.9% and 2.7% real GDP growth in 2022, 2023, and 2024, respectively.
The following table provides a summary of various banking institutions forecasts:
Real GDP YOY% Change
<table>
<tr><th>Financial Institution</th><th>2022</th><th>2023</th></tr>
<tr><td>TD[4]</td><td>5.0</td><td>4.0</td></tr>
<tr><td>ATB[5]</td><td>4.0</td><td>2.5</td></tr>
<tr><td>RBC[6]</td><td>4.7</td><td>5.9</td></tr>
<tr><td>CIBC[7]</td><td>4.9</td><td>3.3</td></tr>
<tr><td>BMO[8]</td><td>4.6</td><td>4.7</td></tr>
<tr><td>Average</td><td>4.6</td><td>4.1</td></tr>
</table>
Based on this information, we agree that economic growth in 2022 will grow at just below 5%. In 2023, we suggest that will start to decline to 4% as it begins to reflect the longer-term growth rate. We do not expect that the near-term economic growth rate will change substantially under business-</td></tr>
</table>

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

[4] https://economics.td.com/domains/economics.td.com/documents/reports/pef2021/ProvincialEconomicForecast_dec2021.pdf

[5] https://www.atb.com/siteassets/pdf/company/insights/outlook/alberta-economic-outlook-november-2021.pdf

[6] https://royal-bank-of-canada-2124.docs.contently.com/v/provinces-enter-advanced-stages-of-recovery-in-2022-pdf

[7] Provincial Outlook: When the growing gets tough(er), CIBC, December 1, 2021

[8] https://economics.bmo.com/media/filer_public/a6/fd/a6fd81f1-71a6-4ecd-9fe7-5e315121a778/outlookprovincial.pdf

Questions	Stakeholder Comments
	as-usual (reference case) or net-zero scenarios given that the high growth rate is reflecting the recovery from the pandemic. In the long-term, we anticipate real GDP to grow at 1.9% under a business-as-usual (reference case), which is consistent with the historical average. Under a net-zero scenario, we expect that real GDP could be lower to the extent that the scenarios impact the oil and gas industry and results in lower global oil prices, thereby reducing the profitability of Alberta production relative to other global producers, and ultimately resulting in lower Alberta production and capital investment. We suggest that Alberta's real GDP be modeled at between 1.0% and 1.5% real GDP to reflect this potential outcome, but we also note that this is highly contingent on whether the global trend toward net-zero gains further momentum such that prices fall in response to supply and demand fundamentals (reduced global demand and/or higher conventional oil production). We recommend the AESO consider the recent Bank of Canada climate scenario work to inform GDP assumptions.
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.[9] 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**	***The Net-Zero scenario should include a sensitivity that reflects a decline in oilsands production and capital investment*** TransAlta recommends the AESO consider the Evolving Policies Scenario presented in the Canada Energy Regulator's (CER) *Canada's Energy Future 2021 Report*[10] as the most generous estimate for future oil production. We believe these represent the upper boundary of future oil production because they do not model a full net zero scenario. Under a more aggressive policy scenario, production levels may be lower. The forecast scenarios are helpful and relevant because they are modeled based upon the federal carbon pricing scheme.

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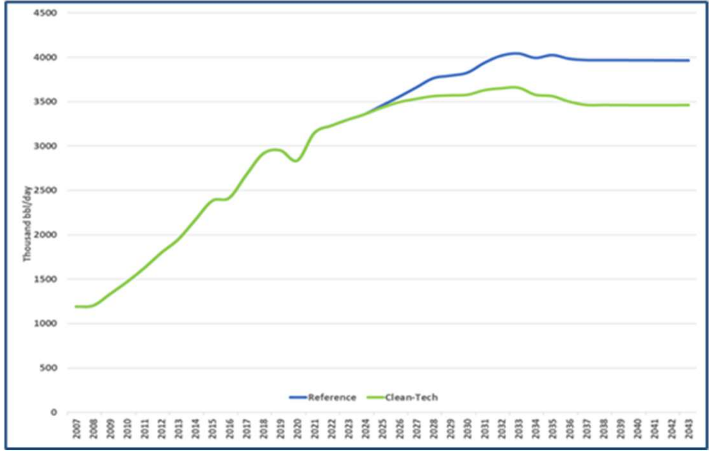
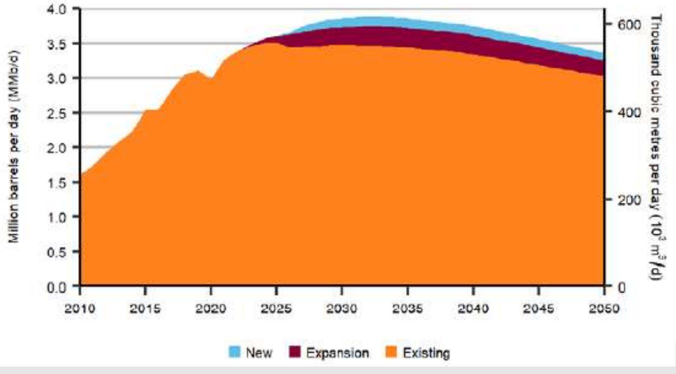
[9] https://ihsmarkit.com/research-analysis/canadian-oil-sands-running-above-prepandemic-highs.html

[10] https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2021/canada-energy-futures-2021.pdf

Questions	Stakeholder Comments
 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?	Consistent with its 2020 report, the CER projects Canadian crude oil production to peak at 5.8 million barrels per day (MMMb/d) in 2032 and decline to 4.8 MMMb/d in 2040. More specific to Alberta's oil sands production, the "Evolving Policies" scenario shows the following: Figure ES.9: **Oil sands Production from Currently Producing Facilities, Expanded, and New Facilities, Evolving Policies Scenario**  Source: Page 12, Canada's Energy Future 2021 Report, CER. This scenario appears to be in line with the AESO's previous Clean-Tech scenario but may not reflect a net-zero scenario. A net-zero scenario may include impacts greater than just "derating the outlook for greenfield expansions to represent a scenario with no further sectoral growth". For example, an acceleration of US adoption of electric vehicles could have global consequences on oil demand. As noted in the CER report, global net-zero scenarios show a rapid decline of global demand for oil demand for transportation which could significantly lower Canadian production levels. A potential helpful point of reference to develop a net-zero scenario could be to reference the decline in Alberta oil sands production levels experienced during the pandemic as the anchor point as the estimated production reduction (and the industrial electricity

Questions	Stakeholder Comments
	demand from oil sands). We would further recommend that advancing the timing of Canadian/Alberta peak oil production to 2027 and reflecting a straight-line reduction to the anchor point would provide a more meaningful representation of a net-zero scenario compared to the previous approach, which only assumed a plateauing in production.
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?	***Demand and supply drivers are more likely to place upward pressure on gas prices in Alberta*** We expect that demand for natural gas globally will increase as the transition to cleaner power generation hastens for developed countries and as developing countries (e.g., China, India) reduce their reliance on coal powered electricity generation. This is likely to increase demand for Liquified Natural Gas (LNG) in export markets and increase demand (and export competition) for domestically produced natural gas. We also see the production of hydrogen using natural gas as a feedstock as another potential driver of demand in the long-term. In terms of Alberta gas prices, we foresee upward price drivers from the supply-side. These include potential stakeholder and regulatory challenges[11] with expanding BC and Alberta gas production as well as potential requirements to increase more expensive renewable natural gas/biogas content in natural gas. Overall, we do not expect gas prices to decrease on a real basis five years in the future. TransAlta recommends that the AESO develop two scenarios of future gas prices five years into the future: (1) Stable gas prices: Gas prices remaining stable ($3/GJ) on a real basis (increasing on a nominal/inflationary basis).

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[11] These include securing agreements with First nations communities on land that eligible for future natural gas production.

	Questions	Stakeholder Comments
		(2) Increasing gas prices: Gas prices rising to $6/GJ on a real basis by 2030. The $6/GJ price level has been historically observed in Alberta and would be a reasonable range estimate under an increased demand/limited production expansion scenario.
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	***The AESO's analysis should consider various scenarios of offset/emissions performance credit compliance mechanisms and stringency*** The AESO must be clear about whether it is modeling "net zero" or "carbon neutrality". The federal government's definition under the *Canadian Net-Zero Emission Accountability Act* is that "net zero emissions means that anthropogenic emissions of greenhouse gases into the atmosphere are balanced by anthropogenic removals of greenhouse gases from the atmosphere over a specified period". This means that net zero only recognizes CDRs. TransAlta recommends the AESO adopt the *Canadian Net Zero Emissions Accountability Act* definition for the purposes of this analysis. Adoption of this definition will make the analysis relevant to the policy work of the broadest number of government stakeholders. It is very important that the AESO explain the assumptions that it applies in its analysis so that stakeholders can understand and interpret the modeling results accordingly. More specifically, TransAlta asks the AESO to explicitly identify what it has assumed in the following key areas: 1. Does the AESO's "net zero" target allow for only compliance-grade instruments that are currently eligible under TIER? 2. What is the usage limit that is applied to these instruments (i.e., is the current 60% limit applied or is that usage limit increased or decreased in the future)? 3. Are there vintage restrictions on the use of various compliance instruments? How has compliance instrument banking been factored into the analysis?

	Questions	Stakeholder Comments
		4. Are international carbon offsets eligible to be used to achieve the net-zero target? 5. How are offsets from avoided emissions and CDR treated? Are they both eligible to achieve net-zero? Are they treated or accounted for differently? ***Compliance mechanisms are likely to become more stringent over time*** TransAlta expects that those enabling compliance mechanisms will become more stringent over time as more industries and a greater proportion of the overall economy is captured by greenhouse gas reduction requirements. The availability of offsets from other countries may play a role in Canada and Alberta as countries adopt more consistent greenhouse gas emission frameworks; however, stringency for international carbon offsets will likely also experience tightening over time. The current framework in Alberta imposes a significant limitation on the use of international offsets and with compliance instruments that only recognize emissions reductions in Alberta. We expect that Alberta and Canada will continue to limit compliance instruments to avoided emissions in the province and country; however, this may change in the long-term as the frameworks for greenhouse gas emissions between countries becomes more consistent and prevents carbon leakage and regulatory system arbitrage. The global goal is to keep global temperatures below a 1.5°C increase is a key driver for stringency. Notably, the Intergovernmental Panel on Climate Change (IPCC) notes[12] that global temperatures could rise to this temperature level in the near term (2021-2040), exceed the threshold in the mid-term 2041-2060), and that CDR or negative emissions will be required to achieve the temperature goal by 2100. As identified in the IPCC reports,

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[12] *Global warming of 1.5℃*, IPCC Special Report, 2018 and *Climate Change 2021*, IPCC, August 2021.

Questions	Stakeholder Comments
	an overshoot (exceedance) of the 1.5°C increase in global temperatures will require increased future deployment of CDR, which is currently challenged in terms of cost and scale. TransAlta recommends that the AESO model the following scenarios including the eligibility of reduction offsets, performance credits, and avoidance effects: • Canada-Only "Net Zero" compliance eligibility: ▪ Permits Alberta and Canada performance credits and offsets for CDR only. ▪ Maintains the existing usage limit of 60%. ▪ Under this scenario, electricity emissions from Alberta's electricity sector may be constrained to 5 million tCO_2e by 2035 based on projected availability of CDRs. • Alberta-Only "Net Zero" compliance eligibility: ▪ Permits only Alberta offsets and tightens over time to exclude avoided emissions and only CDR to qualify. ▪ Limited banking. ▪ Maintains the existing usage limit of 60% to offsets but increases to 100% when stringency only recognize CDR.[13] ▪ Under this scenario, electricity emissions from Alberta's electricity sector may be constrained to 2 million tCO_2e by 2035 based on projected availability of CDRs.
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?	***Carbon pricing post-2030 should reflect the increase required to achieve a national 2050 net zero goal.*** It is our understanding that the federal government received briefings indicating the carbon price would have to rise to between \$200-300/t by

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[13] While we acknowledge that an even more lenient scenario would be that the usage limit permits full compliance using only compliance instruments that include out of province and international offsets. However, we believe that the provincial government will require reported physical emissions to show a decline.

Questions	Stakeholder Comments
	2050 to hit a national net zero target.[14] Further, we note that the Parliamentary Budget Officer estimated that carbon prices would need to reach up to $239/t to reach the federal 2030 target depending on the stringency of Canada's performance standards for trade exposed sectors. While neither of these figures represents a directly applicable estimate, we view them as indicative of the need for escalating carbon prices post 2030. Given this assumption, we would recommend adopting the currently announced escalation rate to $170/t in 2030 and a linear increase to a carbon price of $300/t in 2050 thereafter.
c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	***Implementation of a Clean Energy Standard (CES) for electricity, regulation of fuels (liquid fuels under Clean Fuel Regulation), and a cap and future reductions on oil and gas sector emissions will impact net-zero scenarios*** The Government of Canada has not outlined the elements of the proposed CES; however, we understand it will be designed as a complement to existing carbon pricing frameworks and act as a backstop to ensure Canada achieves a net zero grid by 2035. Given this understanding, we expect that CES will require all new thermal generation to meet stringent performance requirements and face full exposure to federal carbon pricing on any physical carbon emissions that are not captured or sequestered. TransAlta recommends that the net-zero scenarios reflect the capital cost associated with carbon capture, as well as a reasonable estimate of the carbon capture rate, and carbon costs charged at OBPS carbon prices associated with net carbon emissions after accounting for captured and sequestered emissions. Clean Fuel Regulation (CFR) only applies to liquid fuels and permits the development and carbon emissions reductions associated with on-site cogeneration to qualify as an eligible compliance instrument. As explained in our response to 3(a) above, we expect that net-zero carbon compliance qualification will increase the stringency for qualifying compliance

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[14] https://nationalpost.com/news/politics/secret-briefing-says-up-to-300-per-tonne-federal-carbon-tax-by-2050-required-to-meet-climate-targets

	Questions	Stakeholder Comments
		instruments and disqualify on-site cogeneration given that the federal definition of net-zero only recognizes CDRs and should not assign value to carbon reductions associated with avoided emissions. We expect that new cogeneration will be treated in a similar and consistent manner to new natural gas-fired generation with stringency requirements that charge cogeneration for any carbon emissions at federal carbon pricing levels. Given our views regarding future carbon regulation under a net-zero scenario, we anticipate that growth in cogeneration development will be limited due to regulatory uncertainty about carbon compliance quantification and benefit for cogeneration, the high cost of emission control and abatement for cogeneration (e.g., hydrogen and CCUS), and technological and operational uncertainty over capture rates. *<u>Oil and Gas Regulation</u>* Federal policies and regulation on the oil and gas sector could have impacts on economic growth and oil and gas investment in Alberta, production and electricity use. These actions include the federal government's announcements to impose an absolute carbon emissions cap on the oil and gas sector and its "global methane pledge", which seeks to enforce a 75% reduction of methane emissions from 2012 levels from the oil and gas sector by 2030. We view these movements as restrictive on future expansion of Alberta oil and gas investment and a limitation to upward increases in future oil production.
	d) Are there any other related considerations that you would like to provide feedback on?	Please refer to TransAlta's response in section 1(a).
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?	***Government subsidy programs, the cost of energy efficiency improvements, technology and installation, the cost of avoided gas or delivered electricity are key factors in energy efficiency uptake*** We expect that the pace of energy efficiency under a net-zero scenario could increase as governments strive to incentivize greater conservation with subsidy programs. We anticipate that this may occur faster and with

	Questions	Stakeholder Comments
		greater impact from the commercial and industrial segments as these customer classes are unlikely to be shielded from the energy cost impacts of carbon regulation.[15] The scale of response from these customers is likely proportionate to the share that energy cost comprises of their overall operating costs and the perception of risk related to future cost increases. Additionally, the availability of cost-effective alternatives to enable energy saving and conservation will be a key factor in evaluating how effective a government subsidy program may be in encouraging greater energy efficiency uptake. The relative cost of natural gas and delivered cost of electricity will also be an important consideration of how energy efficiency or conservation may unfold. For example, a trend of high natural gas prices and stable or lower delivered cost of electricity could trigger substitution of natural gas with electricity (e.g., electric heaters/boilers and pumps) or vice versa. Carbon emissions reporting and responsibility could also factor into industrial decisions with respect to how on-site energy needs are served – if a company accounts for the carbon emissions from natural gas consumption in their reporting, but does not do so for electricity, a customer may have a preference for electrification. We specifically refer to the delivered cost of electricity because industrial customers have demonstrated a strong sensitivity and response to transmission costs and the historical trend of high annual increases in making self-supply (cogeneration investment) decisions. This includes the tariff and rate design and how that allocates costs across customer class/groups and drives consumption behaviour. Given the high level of current transmission (and distribution) system costs and the declining cost of smaller scale generation, we expect that customers may adopt even marginally efficient (or slightly less efficient) solutions in order to avoid delivery costs. We note that the impacts of grid avoidance may be

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[15] Residential customers will likely be shielded with mechanisms such as the carbon tax rebate.

Questions	Stakeholder Comments
	indistinguishable for energy efficiency or conservation efforts from an AESO Alberta system load forecasting perspective. TransAlta recommends that the AESO model two net-zero sensitivities:[16] (1) Moderate energy efficiency – a 1.5% per year reduction from business-as-usual electricity usage and a 1.0% per year reduction in business-as-usual peak electricity demand by 2035. (2) High energy efficiency - a 3.0% per year reduction from business-as-usual electricity usage and a 2.0% per year reduction in business-as-usual peak electricity demand by 2035.
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.)?	***DERs development under a net-zero scenario will increase particularly for renewables and batteries*** Yes, we expect that net-zero trends will drive customer interest in DER investment, more specifically, investment in renewable generation (predominantly solar, but also potentially wind, biogas/landfill gas and biomass) and small-scale energy storage. We see the drivers for these trends including: • Municipal and provincial government policies and programs to increase renewable investment and environmentally-conscious electricity procurement. We have already seen governments (e.g. City of Calgary, City of Edmonton, Alberta Government) develop their own energy projects and engage in procurements for their own electricity

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[16] Studies from the Office of Energy Efficiency & Renewable Energy in the US show that the majority of studies published since 2010 estimate the annual energy efficiency potential savings rate in the range of 1 to 1.5% electricity savings per year over a period of 10-20 years. The *Energy Efficiency Alberta 2019-2038 Energy Efficiency and Small Scale Renewables Potential Study* authored by Navigant and dated October 17, 2018 provides the point of reference for the theoretical potential in electricity consumption The high energy efficiency scenario roughly approximates the Achievable Potential at 9.9% by 2038. We believe that the estimates of Achievable Potential are highly optimistic, but the details contained in that report may be informative of the areas that customers could seek to improve their energy usage.

Questions	Stakeholder Comments
	requirements, specifically targeting renewable generation. In addition to decisions about their own electricity requirements, municipalities like the City of Edmonton, provide Solar Rebate Programs to residential consumers. • Competitive Retailers programs such as the retail rates programs for small micro-generation that support micro-DERs by contracting higher rates than prevailing market prices.[17] • DER development to avoid the high delivered cost of electricity. As captured in the section above commercial and industrial customers currently served by the distribution system could seek self-supply solutions to avoid high and increasing delivered cost of electricity. These could include gas-fired generation, particularly for those operations that have inflexible operational and reliability requirements; however, it is important to note that gas-fired DERs are likely to be subject to comparable greenhouse gas regulation requirements and the emissions will need to be abated. We expect that these requirements will challenge small-scale gas-fired development for which emissions control may be difficult to deploy and be less economic compared with larger scale projects that may be able to reduce costs through economies of scale. Furthermore, some of the incentive for these types of DER projects may lessen as the Distribution Connected Generator credit programs offered by the distribution utilities (ATCO, ENMAX and FortisAlberta) are unwound. • Demand Side Management (DSM) technologies are likely to increase as technology Original Equipment Manufacturers (OEMs) invest in new and better smart technologies to meet the demands of early adopter, energy-savvy customers, followed by more mainstream user adoption. We expect that the deployment and use of DSM technologies will

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[17] The Market Surveillance Administrator's Q1 2021 Report specifically identifies the current and ongoing retail rates practice (pages 54-55).

Questions	Stakeholder Comments
	increase in pace with consumer trends such as the Internet of Things (IOT), smart appliances, and increasing energy costs. TransAlta recommends that the AESO consider modeling DERs achieving the 2021 Long-Term Outlook Clean-Tech Scenario estimates for Solar and Wind in 2041 by 2035:

Installed Capacity (MW)

DER Resource Type	2035	2042
Solar	2,051	2,880
Wind	58	70
Gas	120	120
Battery	150	214
Other	51	60
TOTAL	**2,430**	**3,344**

Load Consumption and Energy Demand Profiles should be modeled assuming the introduction of Rate Design and DSM

The AESO should estimate and reflect the benefits of shaping system load profiles through rate design and deployment of DSM. These may be driven by the adoption of time-of-use programs if smart metering technology is available but could also be implemented through a time differentiated rates for only commercial and industrial customers that may be interval metered today. Rate designs that encourage customers to shift their consumption to reduce peak demand have high potential as a lower cost alternative to building delivery infrastructure and power plants to address high system peaks.

Additionally, we anticipate that providing appropriate rate designs, DSM and deploying DERs will be even more applicable in high electrification net-zero scenarios. It should be assumed that electrification demands will be enabled with mechanisms that incentivize efficient energy usage including charging when wholesale power prices are low and least costly from a delivery infrastructure perspective (when there is surplus distribution/transmission capacity).

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c) Transportation Sector

- What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?

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Electrification in the transportation sector should be quicker and larger in magnitude that the previous Clean-Tech scenario

TransAlta expects that the pace of electric vehicle adoption/penetration will be higher under net-zero scenarios. We anticipate that the policy drive towards electrification of the transportation sector is likely to increase in pace once the electricity system in Alberta achieves. However, there are many practical challenges to advancing electrification of transportation including: the availability of electric charging infrastructure (e.g., the capacity of the distribution systems to enable residential customer adoption of electric vehicles), the speed of capital stock turnover for existing vehicles, and the availability and cost of vehicles (the advancement of electric vehicles has been focused on passenger vehicles whereas Albertans have a high proportion of light-duty trucks).

TransAlta recommends the AESO model the following net-zero scenarios for electric vehicle adoption:

Number of Electric Vehicles

<table>
<tr><th>Scenario</th><th>2030</th><th>2035</th><th>2042</th></tr>
<tr><td>2021 LTO Reference: Clean Tech</td><td>253,596</td><td>725,206</td><td>N/A
(2041: 1,957,734)</td></tr>
<tr><td>Moderate Pace</td><td>340,000</td><td>800,000</td><td>2,250,000</td></tr>
<tr><td>High Pace</td><td>500,000</td><td>1,000,000</td><td>2,450,000</td></tr>
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d) Buildings

- What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?

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The pace of electrification in space heating/cooling and water heating is likely to be slower than the pace of electrification in transportation; this is likely to a greater focus post 2035

We do not see similar drivers in the area of building space heating/cooling and water heating as we see for electrification in transport. More specifically, vehicle makers have made significant commitments to shift away from manufacturing internal combustion engines by 2035, including significant investment in technology and shifting their supply chains and manufacturing to focus on electric/fuel cells vehicles, customer demand and

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Questions	Stakeholder Comments
	sales of electric vehicles, and governments that are focused on increasing adoption through vehicle subsidy programs. Unlike transportation, heating and cooling is largely met through the use of natural gas, which is an already low emissions fuel type. Therefore, an early shift toward electrification does not carry the same carbon emission benefit, particularly if the supply of electricity for electrification is still significantly sourced from natural gas-fired generation. Furthermore, we expect that the supply and demand economics of pushing too much demand toward electricity will have the negative consequence of pricing out electrification solutions (e.g., even bigger electricity infrastructure delivery investment, more significant reliability impacts, and more generation investment). The demands on the end-use consumer to pay for new electric heating and cooling equipment, which are also the consumers of electric vehicles, are likely too high to expect a significant transition prior to 2035. Beyond 2035, and under the assumption that Alberta achieves a net-zero electric system by 2035, the government focus is likely to shift to this space in order to achieve the net-zero goal for the Canadian economy. A lot will hinge on the relative prices of natural gas and electricity and the overall cost of electric heating and cooling versus natural gas heating and cooling (both in terms of upfront and ongoing costs). To assess the true potential, an assessment of the economics to the end-user of switching should be conducted based upon the forecasted natural gas and electricity prices as well as the cost reduction curves on heating and cooling equipment. As a simplifying assumption, TransAlta recommends that the AESO models limited electric heating and cooling electrification up to 2035 and modest adoption to 2042.
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	***Alberta is more likely be a producer of blue hydrogen versus green hydrogen*** We expect that significant development of new hydrogen production capacity will be focused on hydrogen production from natural gas. Furthermore, we expect that hydrogen-fuel cogeneration will likely be

Questions	Stakeholder Comments
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)?	pursued on the sites of new hydrogen production facilities to maximize the carbon reduction benefit and lower on-site emissions from production. This type of cogeneration development obviates the need for fuel transportation to site and carries all of the benefits of self-supplied generation under an Industrial System Designation, including operational control and flexibility, line loss savings, and avoided electricity delivery costs. We do not expect that hydrogen production from water (green hydrogen) will be significant enough to model as an increase in overall industrial load in Alberta. Green hydrogen is already known and expected to be a high-cost hydrogen source compared to blue hydrogen. The cost of green hydrogen is unlikely to be competitive with blue hydrogen unless the source of the electricity for its process is very low. Alberta has historically (and currently) been a province with a higher delivered cost of electricity compared to other jurisdictions. Furthermore, Alberta does have comparative advantages in producing blue hydrogen, such as ample access to low-cost natural gas, existing carbon pipeline infrastructure, unique access to geological formation with significant carbon emission storage capacity, and a regulatory framework that enables carbon sequestration and storage. We expect these advantages position Alberta to be a stronger market producer of blue versus green hydrogen. ***Load growth could be impacted by limited provincial economic growth, reductions in high electricity demand industries, and energy efficiency and conservation*** As mentioned in our comments on GDP growth and oil and gas investment, we expect that there may be net-zero scenarios that will disproportionately impact Alberta's industries. We anticipate that these impacts could include a decline in oil and gas investment and reducing our long-term GDP growth to between 1-1.5%. We expect that industries with high electricity needs and strong price sensitivity (inability to pass high costs onto their consumers because they operate in international markets), such as pulp and paper, cryptocurrency mining, and data centers, to reduce load (self-supply, reduce production) or otherwise relocate under net-zero scenarios that result in Alberta's

	Questions	Stakeholder Comments
		delivered cost of electricity in the long run being significantly higher on a comparative basis to other jurisdictions. We anticipate that Alberta's economy could respond with greater diversification into technology services, which would mitigate the overall impact to provincial economic growth; however, if our traditional industries decline and are replaced with service economy industries, we expect that load growth would reflect a decline but for the countervailing impact of new demand from electrification in transportation and potentially heating and cooling uses post 2035.
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?	***Renewables are the most economic form of generation currently and are likely to maintain strong cost competitiveness; battery storage is expected to experience exponential cost declines and become cost competitive this decade*** Wind and solar generating technologies have demonstrated strong cost declines and are now competitive against conventional thermal generation in Alberta. The AESO's interconnection queue[18] currently lists 5,939 MW of active wind developments and 6,347 MW of active solar developments. These cost trends are likely to maintain a downward declining slope; however, for wind we expect that the historical cost decline pattern may slow, but solar should continue to see a steeper decline in cost. These declining costs relative to other generating technologies will maintain these technologies as highly cost competitive and the least cost compared to the other "net-zero" generation technologies that have been identified by the AESO. In addition to being lowest cost and true net-zero technologies, wind and solar generation are likely to be supported by policy support that will continue to encourage their expanded use (e.g., procurement specifically

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[18] https://www.aeso.ca/assets/Uploads/project-reporting/January-2022-Project-List.xlsx

	Questions	Stakeholder Comments
		targeting their deployment, project funding and access to subsidies), favourable access to capital, and consumer/corporate interest in securing electricity generated from these technologies. The availability of commercial contracts for renewables mitigates or otherwise reduces a developer's exposure to merchant market risk. As noted in TransAlta's July 6, 2020 submission to the 2021 Long-Term Outlook,[19] the corporate Power Purchase Agreement (PPA) market is around 250-500 MW per year and could expand out to 1,000 MW per year. This interest is driven by corporate Environmental, Social and Governance (ESG) considerations as much as it is for operational electricity need. We expect that this interest will primarily focus on renewable PPAs for new projects. Furthermore, we believe that the support for renewable development will continue to encourage their development in the short and long-term because they are driven by policy and ESG considerations and not solely by economic opportunity. Additionally, potential future increases in energy storage could be viewed as mitigation to weaker realized real-time prices for renewables. For these reasons, we expect that the growth in renewables could continue in spite of their downward pressure on real-time electricity prices that would otherwise suggest a plateau or diminishing need in the future. Battery storage technology is the next technology that is likely to become economic in the near future. More specifically, lithium-ion battery storage continues to show accelerating cost reductions that are making the technology almost at parity with other peaking sources of generation. Lithium-ion is most likely to be economic and widely deployed within the decade. We also expect that other types of battery storage technology, including long duration energy storage, will show strong cost reduction but may not reach cost competitiveness until the 2030s. These other battery

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[19] https://www.aeso.ca/assets/Uploads/LTO-questionnaire-matrix-TransAlta-Redacted.pdf

<table>
<tr><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td></td><td>storage technologies have unique strengths and weaknesses relative to lithium-ion and may outperform other technologies in specific use cases (i.e., multi-hour storage, high cycling capability, safety performance, and use of less scarce chemicals).</td></tr>
<tr><td>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 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</td><td>
<table>
<tr><th>Technology/ Development Timelines</th><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>Post-Combustion CCUS
Development time: 5-7 years</td><td>• Dispatchable generation profile
• Provides inertial support
• Utilizes commercially available power plant equipment
• Utilizes natural gas as a feedstock fuel (taps into Alberta's existing and extensive natural gas pipeline system and takes advantage of Alberta/BC gas production)
• Unique access to suitable geological formations for carbon storage
• Potential to achieve economies of scale for carbon capture infrastructure</td><td>• Not a true net-zero technology. Current real-world data suggests that CCUS capture rates are lower than projected.
• High capital cost of carbon capture equipment
• High operating costs (high parasitic load, solvent cost for capture)
• Operating limitations for high capture scenarios (restricts plant turndown and ability to ramp)
• Limited carbon capture infrastructure currently
• Difficult to forecast return of/on investment in an energy only market</td></tr>
<tr><td>Pre-Combustion CCUS (hydrogen)
Development time: 5-7 years</td><td>• Dispatchable generation profile (potentially fast ramping capability if it is a simple cycle configuration)
• Provides inertial support
• No carbon capture equipment required on the power plant site
• Existing gas-fired generation fleet may have some capability to use natural gas/hydrogen blended fuel
• Brownfield development opportunities for existing gas-fired generation sites that</td><td>• Current technology relies on CCUS which does not capture all emissions. Also creates additional lifecycle emissions from production and transportation.
• High hydrogen costs relative to natural gas (cost to build hydrogen plant with CCUS)
• Potential for higher maintenance for existing generation that use blended fuel</td></tr>
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Questions	Stakeholder Comments		
		could be connected to a hydrogen gas pipeline system • Potential to co-locate power plants near hydrogen plants or otherwise develop on-site cogeneration	• Requires new turbines that are capable of burning high hydrogen content fuel • Blended hydrogen/natural gas options will still be carbon emitting • Need for new hydrogen transportation/pipeline system (challenges include hydrogen embrittlement, control of hydrogen leakage and permeation, cost of compression)
	Oxyfueled Generation Development time: 5-7 years	• Dispatchable generation profile • Provides inertial support • No carbon capture equipment or infrastructure needed	• Requires customized turbine designs (not off-the-shelf technology) • Requires the development of an oxygen plant • High capital cost due to need to develop both an oxygen plant and a power plant
	Renewable Generation Solar Development time: 1-3 years Wind Development time: 2-3 years Geothermal Development time: 4-7 years Biogas/biomass Development Time: 2-4 years	• True net-zero technologies (assured carbon emission performance) • Some or full dispatchability for geothermal and biomass • Wind and solar are cost competitive today • High wind and solar potential in terms of resource quality and availability of development sites • Low operating and maintenance costs – no fuel cost for solar and wind • Ease of installation, low complexity (maturity of solar and wind technology), and quick deployment • Ease of contracting under commercial PPA	• Intermittency of wind and solar resources • Limited capability to provide inertial support (wind and solar) • Cost of interconnecting resources • Biogas/biomass is highly contingent on availability and cost competitiveness of fuel including the cost of transport and processing • Geothermal is a location specific opportunity and could face regulatory challenges

Questions	Stakeholder Comments		
	Hydroelectric Small scale Development time: 3-5 years Large Scale Development time: 7-14 years	• True net-zero technology (assured carbon emission performance) • Dispatchable generation profile (large scale with reservoir storage) • Provides inertial support • Low operating and maintenance costs – no fuel cost • Opportunities to develop power generation on hydroelectric dams needed for flood protection • Long lived assets (80-100 year+)	• Intermittency with small-scale run-of-river hydro • High capital cost • Large development footprint for large scale hydro • Long lead time and high potential for cost overruns on large scale hydro • Exposure to long term climate change and changing hydrological conditions
	Nuclear Development time: 7-14 years	• True net-zero technology (assured carbon emission performance) • Dispatchable generation profile • Provides inertial support • Technology advancement in the areas of safety	• Nuclear waste storage and disposal requirements • High capital cost • High insurance costs • In early stage development for small modular reactors (e.g., technology risk, risk in achieving commercial scale) • Long lead time • Public attitudes towards nuclear waste and safety
	Energy Storage Lithium Battery Development time: 1-2 years Pumped Storage Development time: 10-14 years	• Dispatchable profile • Various technologies that can be suited to different grid applications • Battery storage is a modular, scalable and potentially movable technology • Battery storage has very fast response times and low roundtrip efficiency loss • Battery storage is showing exponential cost declines • Complimentary operating characteristic that show a good fit with renewable	• Not a true generation source (needs to be paired with generation or otherwise charge from the grid) • Battery storage is short duration limited and cycle constrained • Pumped hydro storage is locational constrained

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<tr><td></td><td>technologies (significant development of hybrid asset configurations)
• Potential to be supplied by bi-directional utilization of electric vehicle batteries in future
• Pumped hydro storage is proven and low-cost longer duration storage technology</td><td></td></tr>
<tr><td>Interties
Development time: 5-7 years</td><td>• Increased access to neighboring electricity systems that can be used for increasing reliability (frequency event response, balancing)
• Increased geographic diversity in generation resources</td><td>• Increased exposure to reliability issues that may be experienced in neighboring connected markets
• Reliance on resources that may be committed in other markets (no certainty on resource availability)
• Intertie seams issues related to differences in market structures, designs and regulation that could unlevel the playing field with intra-Alberta supply and other competition issues
• Local landowner issues/concerns with linear infrastructure development (e.g., visual impact, land value impact, perceived risk of exposure to electromagnetic fields)</td></tr>
<tr><td>Offsets or EPCs
Direct air capture development time: 5-10 years</td><td colspan="2">To meet the federal definition of “Net Zero” we expect limited use of compliance mechanisms but for CDRs.
Please refer to TransAlta’s response to 3(a) above.</td></tr>
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</td></tr>
<tr><td>c) Are there generation or emissions control technologies other than those listed in (b), which you believe can</td><td><i>The cost of hydrogen and the technologies that could drive future production should be considered in the AESO’s modeling</i></td></tr>
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Questions	Stakeholder Comments
contribute to meaningful reductions in greenhouse gas emissions, and enable a pathway to net-zero emissions in Alberta?	The AESO should consider expanding its list of emission control technologies to consider those technologies that could be used to reduce the greenhouse gas emissions in fuel, including hydrogen production. This may yield a more meaningful comparison between the pre-combustion and post-combustion technologies identified by the AESO. Alternatively, the AESO could model different scenarios of forecast hydrogen costs that reflect the impacts of deploying various hydrogen technologies to produce competitively priced hydrogen fuel. TransAlta suggests that the AESO investigate and monitor the technological evolution and costs of the following hydrogen technologies: • High- and low-temperature electrolysis (e.g., alkaline and polymer electrolyte membrane electrolyzers), and • Methane pyrolysis for blue hydrogen production. ***Other forms of energy storage beyond lithium-ion batteries should be considered*** The AESO's analysis focuses on the cost of lithium-ion batteries, but does not include other forms of energy storage. As explained in our comments in section 6 below, we generally agree that lithium-ion technology is most likely to be cost competitive in the near-term; however, these technologies also have limitations in terms of cycling and duration that could make them less flexible in meeting future grid reliability needs. Other energy storage technologies may have superior characteristics in terms of cycling, degradation, and duration that could prove more valuable for integrating renewables and meeting evolving system needs. TransAlta recommends that the AESO track the costs and cost reduction potential for the following energy storage technologies: • Pumped storage hydro; • Compressed air; • Flywheel energy storage; and • Flow batteries.

Questions	Stakeholder Comments
	Hydrogen-fired simple cycle may be a lower capital cost and suitable source of reliable and dispatchable generation to serve reliability needs The AESO's analysis focuses combined cycle technology costs but simple cycle technology has lower capital cost and fast ramp characteristics that could be well-suited to provide a backstop to reliability needs in the future. While we acknowledge that simple cycle generation may not be a net-zero generation technology, these technologies are designed for lower capacity factor operations and have operational characteristics that may be more flexible than a baseload combined cycle power plant.
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.	***Highly cost competitive renewable technologies will be the most significant net-zero generation technology and the focus in the energy transition to 2035 needs to manage the risks and reliability challenges needed to accommodate their greater role*** All of the generation technologies described above have various technology specific benefits and operational limitations and constraints that could impact operations and result in risk for the Alberta electric system. In this regard, a key mitigation to electric system risk is diversity in the Alberta supply mix because it protects against an overexposure to a difficult to address risk and provides the benefit of creating synergies from the complementary and coordinated operation of a fleet of assets (that would not otherwise be available when the supply mix has a homogenous composition). The intermittency of renewables is a key challenge that could limit its development despite its low-cost. More specifically, the lack of dispatchability and control over generation presents challenges in achieving real-time balancing of supply and demand. Another issue with inverter-based renewable generation is the reduction in resources that contribute to system inertia. This results in more severe rate of change of frequency, drives a need for fast response to arrest system frequency decay, and requires a complimentary response from other operating reserves to restore system frequency to normal operating ranges. We expect that this will

Questions	Stakeholder Comments
	dictate a need for specific response characteristics and a more sophisticated response in terms of greater adaptability to changing system conditions. These operational risks and challenges are likely to increase in frequency and magnitude as renewable penetration increases and as thermal resources are on-line less. Beyond real-time balancing and system frequency management challenges, another key challenge will be maintaining reliability with respect to resource adequacy and backstopping renewables. The existing energy-only market design is a real-time market design and may not provide the right price signal in a time frame that would allow existing gas generation to respond and be online to be dispatched when the intermittency of renewable generation is experienced. Furthermore, gas-fired generation is likely to show declining capacity factors with more baseload requirements being served by renewable generation, which could impose further challenges to the economic viability of retaining these integral dispatchable reliability resources in a real-time only market. The AESO's net-zero report could provide important information in identifying these reliability needs to help inform how we adapt the competitive energy-only market design to achieve net-zero, reliability, and at an affordable cost to Albertans.
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?	***Net-zero emissions standards will likely apply to natural gas-fired cogeneration*** Yes, TransAlta expects that new cogeneration facilities will be subject to net-zero emission requirements and the same stringency requirements that apply to natural gas-fired power plants in the electricity sector. We expect that this will be a requirement in near future – well before 2035. Additionally, we expect that existing natural gas-fired cogeneration will likely be subject to transition mechanisms that will tighten emissions requirements over time. Emissions control technologies will likely include the use of hydrogen or natural gas blended with hydrogen, CCUS, or the development of small modular nuclear reactors to serve thermal and electricity industrial process requirements. Additionally, we expect that industrial facilities will increasingly consider the use of electric boilers to reduce their on-site

	Questions	Stakeholder Comments
		carbon emissions given the cost of implementing emissions controls on thermal cogeneration. Those electric boilers could be served by self-supply renewable generation, batteries, and/or grid supplied electricity.
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*	

Questions	Stakeholder Comments
	Characteristic Estimates for Utility Scale Electric Power Generating Technologies[20], 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

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[20] 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?	The US EIA report cited by the AESO presents the estimated cost in 2019 US dollars. While the AESO has converted the estimate to Canadian dollars, it has not adjusted the cost by an escalation factor to translate those costs to an indicative 2021 estimate. TransAlta provides the following comments with respect to the estimated costs presented in the AESO's "Net Zero Generation Technology Cost" table. • **Combined Cycle with CCUS:** The US EIA report assumes a carbon capture rate of 90% for the combined cycle with CCUS. Real-world evidence suggests that CCUS facilities have yet to achieve capture rates that approach (90% or) what would be required to be considered a net-zero technology. Further, CCUS facilities may also face risks associated with the cost of upstream natural gas emissions mitigation. In this respect, this is not a zero-emissions generating technology and the AESO will have to estimate (based on real-world data and design specifications) and account for the carbon emissions from any combined cycle with CCUS facilities it forecasts may be operating in its net zero scenarios. CCUS examples in Western Canada, such as Quest and Boundary Dam (recognizing these are different applications), capture rates have been significantly below 90%.[21] The referenced source of the costs is presented based upon US experience. We note that the construction costs in Alberta have typically been higher than US estimates particularly for combined cycle technology. TransAlta recommends that the AESO assume a 20% higher capital cost for combined cycle with CCUS yielding an estimate of $3,750/kW.

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[21] SaskPower's Boundary Dam carbon capture targeted a capture rate of 90% or 3,200 metric tons of CO_2 per day but have only achieved capture rates of 1,167-2,165 metric tons of CO_2 per day. SaskPower's target is now 65% carbon capture. Shell's Quest project reported an average capture ratio of 78.8% in 2019 (https://open.alberta.ca/dataset/f74375f3-3c73-4b9c-af2b-ef44e59b7890/resource/c36cf890-3b27-4e7e-b95b-3370cd0d9f7d/download/energy-quest-co2-capture-ratio-performance-2019.pdf), which is lower than the project's target capture ratio of 80%.

Questions	Stakeholder Comments

TransAlta recommends that the AESO consider the following moderate and high-cost reduction scenarios for its combined cycle with CCUS cost projections:

Combined Cycle with CCUS Capital Cost ($/kW)

Scenario	**2021**	**2025**	**2030**	**2035**	**2042**
Moderate	$3,750	$3,750	$3,500	$3,250	$3,000
High		$3,500	$3,250	$3,000	$2,750

- **Hydrogen-Fired Combined Cycle:** TransAlta recommends that the AESO apply an adjustment of 10-20% to account (i.e., $1,800-$2,000/kW) for the potential additional costs of a fully hydrogen-fueled power plant versus a natural gas fired power plant.

  TransAlta recommends that the AESO consider the following moderate and high-cost reduction scenarios for its hydrogen-fired combined cycle cost projections:

Hydrogen Combined Cycle Capital Cost ($/kW)

Scenario	**2021**	**2025**	**2030**	**2035**	**2042**
Moderate	$2,000	$1,750	$1,500	$1,300	$1,200
High		$1,650	$1,400	$1,250	$1,100

- **Wind:** The capital cost estimate of $1,596/kW is consistent with the low range of Lazard's *Levelized Cost of Energy Analysis*[22] estimate. Lazard's estimates the capital cost for wind to be between US$1,028-$1,350/kW. Adjusting Lazard's estimate by an assumed 20% higher capital cost and converting to Canadian dollar yields an estimate of CAD$1,554-$2,041/kW, which is slightly under the AESO's reference cost.

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[22] https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf

Questions	Stakeholder Comments
	The International Renewable Energy Agency (IRENA) reported that the total installed cost of newly commissioned wind farms fell to US $1,355/kW (CDN $1,707/kW) in 2020.[23] The report also cites increases in the average capacity factors to 36% in 2020 for new projects due to improvements in "hub heights, larger turbines and swept blade areas".[24] IRENA forecasted installed costs of US $1,370/kW by 2025 (CAD $1,726/kW), but that forecasted decline in cost is already likely to have been exceeded in Alberta. TransAlta recommends that the AESO consider the following moderate and high-cost reduction scenarios for its wind cost projections:

Wind Capital Cost ($/kW)

Scenario	2021	2025	2030	2035	2042
Moderate	$1,594	$1,400	$1,250	$1,050	$950
High		$1,300	$1,100	$900	$800

- **Solar PV:** The capital cost estimate of $1,624/kW appears high compared to other studies. This may be partly explained because the study assumes that the solar PV is built with solar tracking. Lazard's *Levelized Cost of Energy Analysis*[25] estimates the capital cost for utility scale crystalline and thin film PV at US$800-$950/kW. Adjusting Lazard's estimate by an assumed 20% higher capital cost and converting to Canadian dollar yields an estimate of CAD$1,152-$1,348/kW. We recommend that the AESO utilize an average of those costs or $1,250/kW.

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[23] IRENA Report, *Renewable Power Generation Costs in 2020*, June 2021 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jun/IRENA_Power_Generation_Costs_2020.pdf

[24] Page 26, *Idem*.

[25] https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf

Questions	Stakeholder Comments

IRENA reported the total installed cost of newly commissioned utility-scale solar of US $883/kW in 2020 (CAD $1,112/kW).[26] IRENA's previous forecast[27] notes module costs will contribute to 68% of their expected total cost reduction, and Balance of System (BoS) costs to decline between 55-74%. IRENA forecasted installed costs of US $800/kW by 2025 (CAD $1,008/kW). TransAlta recommends that the AESO consider the following moderate and high-cost reduction scenarios for its solar cost projections:

Solar PV Capital Cost ($/kW)

Scenario	**2021**	**2025**	**2030**	**2035**	**2042**
Moderate	$1,267	$1,100	$1,000	$900	$800
High		$1,000	$800	$700	$600

- **Small Modular Nuclear (SMR) and Advanced Nuclear Fission Reactors:** Lazard's *Levelized Cost of Energy Analysis*[28] estimates the capital cost for nuclear to be between US $7,800-$12,800/kW. Adjusting Lazard's estimate to Canadian dollar yields an estimate of CAD$9,828- $16,128/kW. The Economic and Financing Working Group *SMR Roadmap*[29] provides potential assumed capital cost estimates for on-grid nuclear of $7,098-$10,120/kW. Even under the lowest capital cost scenarios in the SMR Roadmap report, the capital cost for nuclear only reduces to $2,510/kW to be marginally competitive

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[26] IRENA Report, *Renewable Power Generation Costs in 2020*, June 2021, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jun/IRENA_Power_Generation_Costs_2020.pdf

[27] IRENA Report, *The Power to Change: Solar and Wind Cost Reduction Potential to 2025*, June 2016, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Power_to_Change_2016.pdf

[28] https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf

[29] Economic and Finance Workshop, *SMR Roadmap*, https://smrroadmap.ca/wp-content/uploads/2018/12/Economics-Finance-WG.pdf

Questions	Stakeholder Comments
	with natural gas combined cycle generation with CCUS. Beyond just cost considerations, permitting a nuclear development would be new in Alberta and will likely face challenges and delays. Nuclear development is unlikely to play a significant role in the 2035 or 2042 timeframes. Even under the most optimistic scenarios, development would likely be only 1-2 projects (<400 MW). • **Battery Energy Storage:** The AESO should strongly consider increasing its consideration of energy storage technologies and expand coverage to long duration storage (pumped hydro, compressed air, flow batteries, and hydrogen). The AESO has identified the energy technology, shorter duration (4-hour battery storage), that is most likely to become economic in the near-term. However, long duration (>4 hour) energy storage including mechanical and different battery chemistries beyond and including lithium-based may experience steep declines in capital costs. Many of the companies developing these technologies have been active and successful in raising capital and advancing investment and development. The National Renewable Energy Laboratory's (NREL) report, *Cost Projections for Utility-Scale Energy Storage: 2021 Update*,[30] estimates the reported median of published values of round-trip efficiency is 85% and the capital cost of a 4-hour battery to be US \$1,380/kW (CAD \$1,738/kW).[31] NREL provides low, medium and high cost estimates that range from US \$572-\$992/kW (CAD \$720-\$1,250/kW) in 2030 and \$348-\$992/kW (CAD \$438-\$1,250/kW) in 2050. TransAlta recommends that the AESO consider the following moderate and high-cost reduction scenarios for its solar cost projections:

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[30] NREL, *Cost Projections for Utility-Scale Energy Storage: 2021 Update*, June 2021. https://www.nrel.gov/docs/fy21osti/79236.pdf

[31] Page 11, reference 2020 starting point is \$345/kWh. The author states on page 8 that: "The \$/kWh costs we report can be converted to \$/kW costs simply by multiplying by the duration (e.g., a \$300/kWh, 4-hour battery would have a power capacity cost of \$1200/kW)." 345/kWh x 4 hours = \$1,380/kW

<table>
<tr><th></th><th>Questions</th><th>Stakeholder Comments</th></tr>
<tr><td></td><td></td><td>Battery Capital Cost ($/kW)
<table>
<tr><th>Scenario</th><th>2021</th><th>2025</th><th>2030</th><th>2035</th><th>2042</th></tr>
<tr><td>Moderate</td><td rowspan="2">$1,750</td><td>$1,500</td><td>$1,250</td><td>$1,000</td><td>$900</td></tr>
<tr><td>High</td><td>$1,250</td><td>$1,000</td><td>$750</td><td>$800</td></tr>
</table></td></tr>
<tr><td></td><td>b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?</td><td><i>Brownfield retrofits can provide construction advantages and significant potential cost savings benefits</i>
We expect that the brownfield development including retrofits on existing generation could represent between a 20-40% capital cost savings compared to greenfield power generation. The estimated cost savings is highly contingent on the degree of reuse of existing infrastructure (e.g., water and cooling infrastructure, substation, and electrical interconnection). Moreover, a key benefit, even with limited reusable equipment or infrastructure, is building on already developed site which reduces local landowner opposition and factors into regulatory permitting decisions.
The location of a brownfield site may also provide cost saving benefits compared to a greenfield site if it is located close to a sequestration site or provides closer proximity access to carbon or hydrogen pipeline infrastructure.</td></tr>
<tr><td></td><td>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).</td><td rowspan="2">TransAlta has performed internal modeling on net-zero scenarios and welcomes the AESO to request information that it may find useful in developing its modelling. Our modeling approach uses our own proprietary modelling program that is enabled to specifically target an emission profile for Alberta. We understand that this approach is different than the modeling approach used by the AESO, but we are willing to share the details of our modeling approach, methodology, inputs, and results as assistance to the AESO.</td></tr>
<tr><td><i>7</i></td><td><i>Other</i>
Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.</td></tr>
</table>

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Nola Ruzycki
Comments from:	The Office of the Utilities Consumer Advocate	Phone:	403 462 4299
Date:	2022/01/28	Email:	nola.ruzycki@gov.ab.ca

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

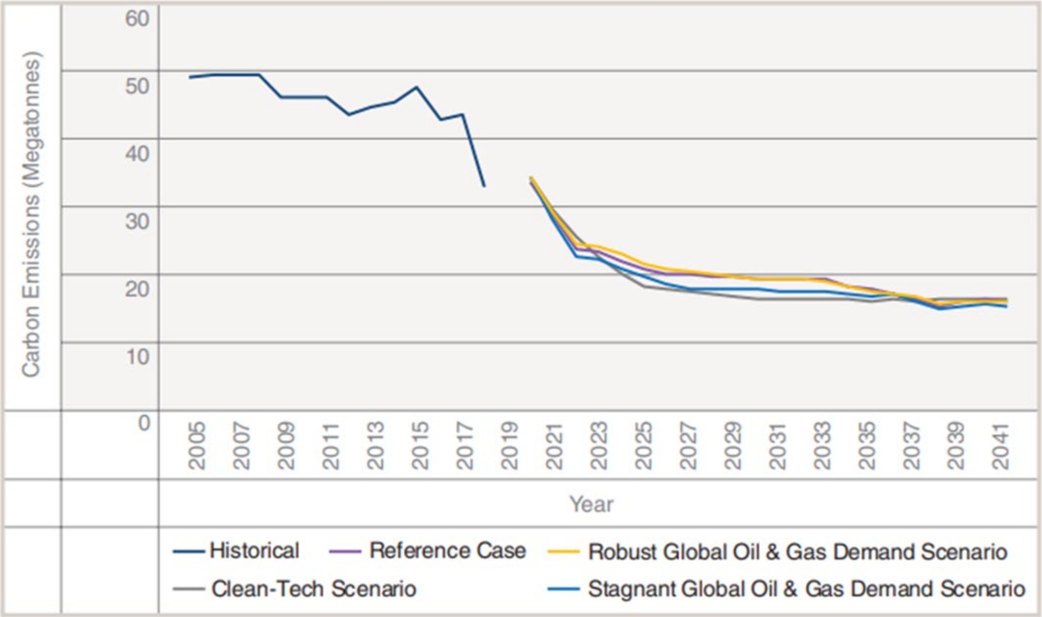
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	Least cost alternatives should be examined in the Net Zeros pathways scenarios. Non wire alternatives are paramount to cost management, including, various load management programs, (e.g., smart charging, time of use rates, vehicle to grid technologies, dynamic pricing), that have the potential to alter consumption behavior and subsequently defer or eliminate the need for new infrastructure and optimally manage grid electrification caused by Electric Vehicle (EV) loads, grid modernization and decarbonization. Renewables paired with energy storage will play an important role in the net- zero emissions generation supply scenario. The AESO should remain open to adding new types of technologies in Section 6 below, given these technologies are in varying states of maturity, as technologies evolve and new technologies emerge in the future.

Questions	Stakeholder Comments
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?	One of the largest challenges that the Alberta Electric system will face is determining how much, if any, investment in increased load capacity brought on by electrification of transportation, decarbonization and grid modernization is necessary. Cost minimization to rate payers and also achieving decarbonization goals could be working against each other. Grid bypass is also a key challenge, as grid costs go up, consumers will want to get off the grid, leaving a large revenue requirement gap to be filled by remaining customers. Once the capacity requirements are determined it will require a significant balancing act to ensure that the essential amount of capacity is available to optimally manage the electric system using as many of the load/demand management tools, energy efficient technologies and storage as necessary, to eliminate or defer the need for costly new infrastructure builds. With the introduction of Zero-Emission Vehicle (ZEV) sales mandates by the Government of Canada and consumer adoption expected to grow exponentially by 2030, ensuring that sufficient ZEV charging infrastructure is in place not only in homes and condos but at businesses and commercial charging locations throughout Alberta is available to meet the changing load patterns will be a challenge. Neighbourhoods with electric vehicle (EV) clustering are at higher risk of potential distribution system overload than those where adoption is geographically dispersed. The uncertainty around the speed of EV adoption and timing will pose a challenge to the Alberta electric system. Should higher EV adoption rates than expected be experienced the system may not be prepared, while consumer hesitancy to invest in EVS could result in excess capacity. Large scale consumer acceptance of EVs will have massive implications and challenges on how electricity is consumed, stored and how Albertan's will utilize the electric grid. The charging profile for EVs will be an area to closely monitor. There will be a need to engage with the DFO's with respect to EVs and the network impacts arising from coincident charging.

Questions	Stakeholder Comments
	Modifications will be needed to the cost/rates structure to provide more efficient and accurate price signals to consumers. Advanced demand-side response (DR) technologies such as wireless telecommunications and internet-based solutions can provide consumption data to consumers and utilize the flexibility of customer-owned technologies to meet the balancing challenges of the changing supply mix while being a cost-effective solution for the system's reliability. According to a study by The Brattle Group regarding the U.S. potential for load flexibility, technologies such as adjustable smart thermostats for air conditioning and heating, grid integrated water heating, and managed EV charging will be gateways to a DR market that adds residential Distributed Energy Resources (DERs) to traditional commercial/industrial customers' DR. The need to significantly increase the amount of clean power in a short period of time will be necessitate the need for the AESO to continually monitor and assess the impacts on the power grid and take actions to ensure that the Alberta electric system remains reliable. The intermittency of some renewable energy sources (e.g., solar and wind) will not be as pronounced with the introduction of energy storage technologies. As the amounts and types of energy storage evolves it will be essential to integrate storage into the supply mix. Energy storage resources can provide many other benefits including frequency regulation, lower ramp rates, deferral or substitution of investments in transmission and voltage support and should be strongly relied on. DERs can improve grid reliability and resilience and help utilities meet emissions reduction mandates but may pose a challenge owing to the highly variable pattern of flow. DERs growth will require the ability for two-way flow vs. the traditional single directional flow between the consumer and the electric grid which may result in more unpredictable flow patterns. Given the above, capital additions to grid strengthening should be one of the last considerations. Smart grids and non-wire alternative should be rigorously investigated and considered prior to new capital additions, which will result in increased costs to consumers.

	Questions	Stakeholder Comments
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?	Net-zero targets will challenge the business-as-usual scenario. Rapid technology advancements which are in various stages of maturity will need to be fully evaluated to determine which technologies are most appropriate and cost effective to achieve the required capacity load. The amount and pace of development will be affected by technology costs and government policy. The AESO must utilize a variety of low-carbon technologies, energy efficiency and load management options to enhance the electric grid and ensure uninterrupted operations of the system.
	The current IHS Market 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**	As the U.S. economy started to recover from its pandemic restrictions, the oil and gas industry had a solid start in 2021, following with lower-than-expected growth in the second quarter due to refinery outages along the U.S. Gulf Coast. In Alberta, as the expanded Line 3 pipeline went into service at the start of October last year and U.S. oil demand will remain robust, it is anticipated that Alberta's oil exports are set for strong growth in the 2022 year. While the price for Western Canadian Select oil is forecasted to remain firmly above US$50 a barrel over the next year, drilling activity has started to tick up. Based on the Conference Board of Canada, oil and gas producers in the province have largely improved their financial positions last year. Even so, they will continue to prioritize their balance sheets and focus their spending on maintenance work and existing projects. The AESO submitted in the LTO 2021 that "the clean-tech scenario assumes a future driven by decarburization efforts will lower longer-term energy demand and reduce oil sands production compared to the Reference Case by approximately 13 percent by 2040". With these assumptions, the UCA agrees that the AESO adopted a similar approach

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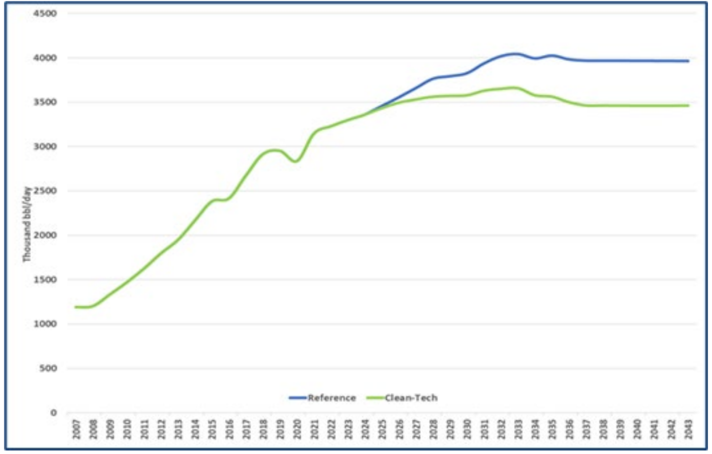
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	used to develop the 2021 LTO for analyzing the impact of net-zero policies.
	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?	Natural gas prices five-years into the future will depend on supply and demand, the availability of renewable energy, storage, weather, government policy and the strength of the economy. Based on information from the NGX website, the 5-year forecast anticipates that the average AECO, Henry Hub and Union Dawn prices to be: CA3.04/GJ, $3.39/GJ and $3.31/GJ, respectively.
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)	The Government of Canada announced that it is committed to achieving net-zero emissions by 2050 and will establish the country's 2030 Emissions Reduction Plan by the end of March 2022. The Canadian Net-Zero Emissions Accountability Act is vague on whether offsets or credits can be enabled to fulfill compliance.

Questions	Stakeholder Comments
• Offsets or credits (generated within the electricity sector) • Physical emissions reductions only	
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?	Carbon prices should be reduced significantly or be eliminated on energy with the implementation of net-zero emission. Under a zero-carbon scenario, the prices on carbon should decrease from the current level. Should carbon prices remain any funds collected from consumers for carbon pricing, should be used to pay for continuing infrastructure improvements.
c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	Supplemental or enhanced sales mandates or quicker or greater sales targets for ZEVs could impact the Alberta electric system. Financial and non-monetary rebates and incentives for purchasing electric vehicle and charging infrastructure will impact the speed of proliferation of electric vehicles and the timing. Building code changes necessitating electric appliances over natural gas appliances would have an impact on Alberta's electric system. Any new green initiatives that require the move away from natural gas to electricity will impact the electric system.
d) Are there any other related considerations that you would like to provide feedback on?	The AESO must delicately balance the utilization of a variety of low-carbon technologies and options to enhance the electric grid with the utilization of load/demand side management (DSM) tools, energy efficient technologies and storage as necessary, to eliminate or defer the need for costly new infrastructure builds. All generation should be required to pay for grid connection and associated system costs. This will require a change to the transmission policy. However, this is really the only way to ensure that capital additions do not create a negative feedback loop where increasing grid charges are forcing new consumers to bypass the grid. The AESO needs to fully

	Questions	Stakeholder Comments
		assess viable cost management options to ensure sustainable grid strengthening. This aligns with the AESOs public interest mandate. Non wire alternatives are paramount to cost management given the magnitude of the investments will be extremely high which will add to the current utilities rate base and increase the costs to consumers.
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?	Modifications will be needed to the cost/rates structure to provide more efficient and accurate price signals, encouraging greater energy efficiency and consequently bill savings for consumers. Demand-side technology such as wireless telecommunications and internet-based solutions provide real or close to real time consumption data to consumers and that combined with effective, clear and accurate price signals will result in changing consumer behavior that will trigger more energy efficiency and conservation efforts. Without these efforts the pace of energy efficiency across sectors will be slower. The AESO needs to develop and implement a DSM program for customers, and this effort needs to be aligned to that of the DFOs. Smart charging, time of use rates, dynamic pricing, smart grid technologies, and demand response are all active load management programs that have the potential to alter consumption behavior and subsequently defer the need for new infrastructure and optimally manage EV loads.
	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.)?	Net-zero trends will have a significant impact on the proliferation and penetration levels of DERs. Consumers will seek to have more control over their energy footprint and energy demand. The ability to generate some or all of their own energy needs and be able to monitor their generation and consumption data will entice more consumers to this type of technology.
	c) Transportation Sector - What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	EV adoption in Alberta has been slow to date but is starting to gain speed. Due to Government of Canada imposed (ZEV) sales mandates and increasing consumer acceptance and adoption EVs are expected to grow exponentially up until the phase out of internal combustion engine vehicles in year 2035. The speed of growth of electrification in the transportation sector will be determined based on incentives and rebates available, the

Questions	Stakeholder Comments
	type and cost of vehicles being offered by manufactures, battery life, charging infrastructure, at home and away, and the extent of consumer education available. The uncertainty around the speed of EV adoption and timing may test physical limits and impact system operations which will pose a challenge to the Alberta electric system. Should higher EV adoption rates than expected be experienced, the system may not be prepared, while consumer hesitancy to invest in EVs could result in excess capacity. Large scale consumer acceptance of EVs will have massive implications and challenges on how electricity is consumed, stored and how Albertan's will utilize the electric grid. The charging profile for EVs will be an area to closely monitor. Commercial fleets, rail, buses and heavy-duty trucks may see a quicker adoption rates than consumers as corporations look to meet emissions standards.
d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	The pace of electrification of space heating/cooling and/or water heating will vary owing to the amount upfront capital costs required, availability of incentives and the preference for better energy management controls. DSM program should be available for institutions, and coordinated electrification of heating/cooling capital investments.
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	In November 2021 the Government of Alberta (GoA) announced seven successful recipients of the Industrial Energy Efficiency, Carbon Capture Utilization and Storage grant programs. The GoA is also committing $1.24 billion through 2025 to two commercial-scale carbon capture and storage projects and its Hydrogen Road map aims to secure over $30 billion in capital investments. There are many other government and corporate initiatives underway that will focus on advancing next-generation innovation solutions to meet emissions target and support market growth. These initiatives will likely result in an increase in industrial load.

	Questions	Stakeholder Comments
	(e.g., cryptocurrency mining, data centers, petrochemical facilities, cement, steel, others)?	CCUS will likely have BTF load impacts from energy penalty losses, and not necessarily a draw from the grid. Cryptocurrency mining, data centers to support two-way real-time communications, petrochemical facilities, cement, steel and other processes are energy intensive and have the potential to result in an increase in load.
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?	The enabling of net-zero generation technologies will result in a multi-faceted approach to decarbonization which will include the substitution of lower- or no-emission power growth, increased energy efficiency, grid flexibility, consumer behavioural changes, storage, the use of carbon capture, utilization and storage and other technologies. The most economic pathways will be to utilize demand side and load management tools wherever possible alongside other non-wire alternatives which will be paramount to cost management.
	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 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	No comment.

Questions	Stakeholder Comments
(viii) Transmission interconnections with other jurisdictions (ix) Offsets or Emissions Performance Credits	
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?	No comment.
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.	No comment.
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?	No comment.

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

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[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 Comment.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	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).	N/A
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	The AESO should utilize a variety of low-carbon technologies and options to enhance the electric grid at a steady rate of implementation. The development and deployment of a range of net-zero energy technologies, combined with energy efficiency and load management, can enable sustainable energy transitions. Net zero energy systems need to be reliable, safe, sustainable, affordable and resilient. Ensuring that the electric grid is preserved through the transition to net-zero emissions is critical. This will necessitate the need for a diverse and sustainable clean energy supply and technology mix while best managing the existing infrastructure to ensure the uninterrupted flow of energy. The Office of the Utilities Consumer Advocate appreciates the opportunity to comment on this critical initiative and looks forward to participating in future engagements.

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

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Nicole Irwin-Viet
Comments from:	Voltus Energy Canada, Ltd.	Phone:	(857) 321-0314
Date:	[2022/01/31]	Email:	nirwin@voltus.co

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

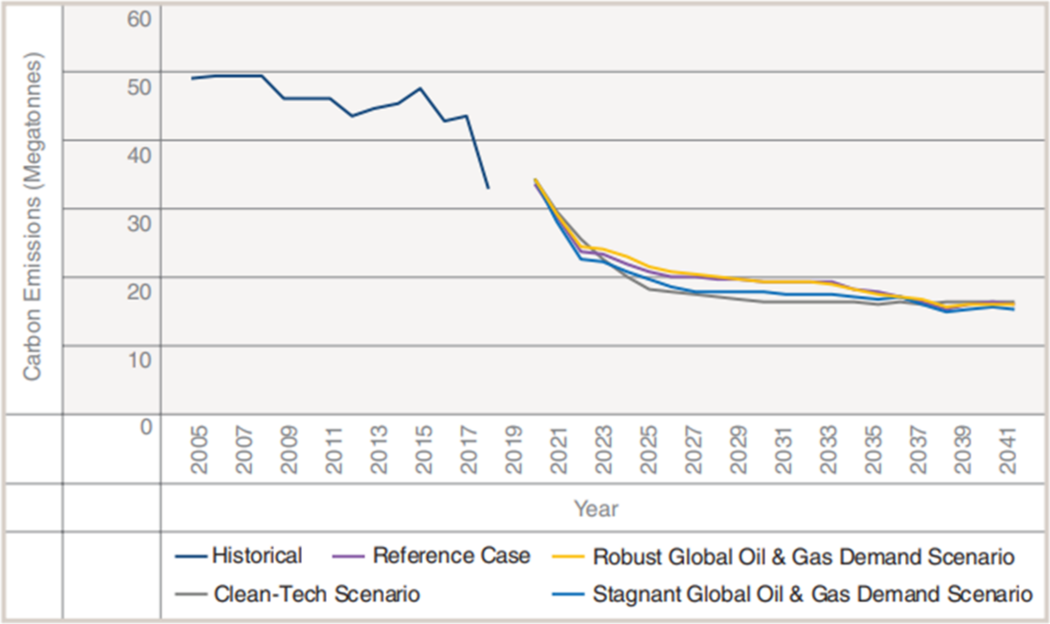
Given the strong interest by stakeholders in potential pathways to a net-zero electricity grid by 2035, the AESO will be building upon the Clean-Tech Scenario of the *2021 Long-term Outlook* (LTO) in an effort to provide further insights to our stakeholders. A driver for such analysis is that the potential 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.

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?	Flexible load, including Demand Response (DR), is a key resource that AESO should consider and encourage on the path to net-zero electricity sector emissions. Not only can DR help manage peak conditions, it can also provide reserve products that help alleviate short-term imbalances on the grid. In both contexts, DR is a low-cost resource that avoids emissions from fossil fuel generation. Voltus would like AESO to elaborate on what "potential impact[s] of demand-side management and energy efficiency initiatives" are being included in its scenario analysis.
	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?	The Alberta electric system will be increasingly faced with the challenges posed by intermittent sources of generation (renewables). This problem has already been observed in the United States, where increasing penetration of wind and solar resources has contributed to more frequent

	Questions	Stakeholder Comments
		and severe grid emergencies. For example, in California the Final Root Cause Analysis of the August 2020 outages noted that the transition to renewables made balancing supply and demand more challenging (see *CAISO*, *Final Root Cause Analysis: Mid-August 2020 Extreme Heat Wave*, Jan. 2021). Increasing penetration of renewable resources contributes to wholesale price volatility as well as operational challenges. Voltus notes that a clear relationship already exists between wind generation volumes and Pool Price, namely that the Pool Price tends to spike when wind generation is low. See Attachment A, Figure 7 from the Market Surveillance Administrator's Quarterly Report for Q2 2021). Flexible load assets, for example as fast-response operating reserves, will serve to mitigate the trend of high and volatile pricing, as well as stabilize the grid on the path to net-zero.
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?	
	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).	AESO's 2021 LTO Clean Tech scenario includes "greater Distributed Energy Resources (DER) technologies". However, Demand Response is not part of the AESO's current definition of DER technologies. Voltus requests that AESO add Demand Response to its definition of DER technologies and that Demand Response be included in any kind of Clean Tech scenario for the purposes of the net-zero analysis. This would align the AESO definition of DERs with the US definition.

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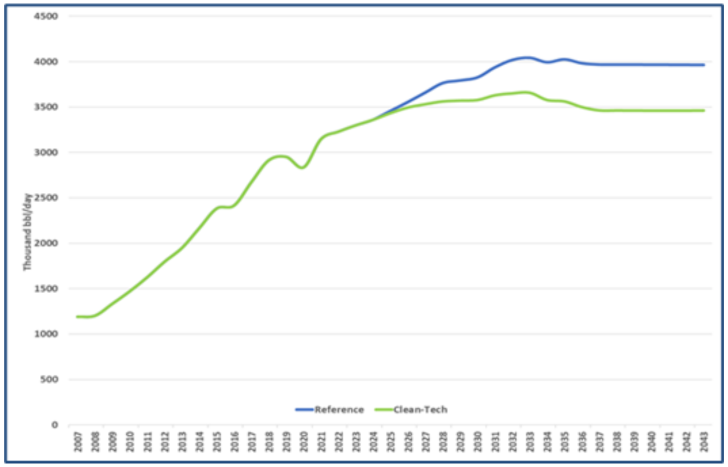
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	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?	
	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?	
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)	

	Questions	Stakeholder Comments
	- Physical emissions reductions only	
	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?	
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	
	d) Are there any other related considerations that you would like to provide feedback on?	In light of AESO's consideration of cost impacts of potential policy instruments to achieve net-zero, Voltus notes that the long-standing cost savings of DR are well-documented. By reducing demand in high cost hours and shifting demand from high to low cost hours, demand response provides flexibility for maintaining system reliability, mitigates supplier market power, reduces price volatility, lowers capacity costs, and avoids investment requirements. See Attachment B below for references.
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?	
	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.)?	DERS, including DR, will become an increasingly important component of Alberta's electricity sector as it transitions to net-zero. They will be called upon more frequently, and dispatchable DERs that can respond upon short notice will provide increasing value to the system. The North American Electric Reliability Corporation ("NERC") has stated that DR provides transmission system operators with additional system-balancing tools to maintain bulk-power system reliability. NERC has also stated that, as the resource mix changes, flexible resources that can be called upon on short notice, including demand response, are needed to

Questions	Stakeholder Comments
	ensure resource adequacy and meet ramping needs. See *NERC, Essential Reliability Services Task Force Measures Framework Report, Nov. 2015 and NERC, State of Reliability*, Jul 2020. In particular, load aggregator technologies provide an essential link between end-use customers and the wholesale market, allowing even very small loads to provide value to the grid and receive compensation. Flowing payments back to customers for grid services will also help mitigate potential economic impacts of electricity sector reform.
c) Transportation Sector ● What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	
d) Buildings ● What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	
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)?	As industrial load increases, flexibility provided by these resources will become increasingly important. Loads can and want to contribute to achieving net zero in Alberta cost effectively.
Generation Technologies	

	Questions	Stakeholder Comments
5	a) What net-zero enabling generation technologies do you perceive as being the most economic pathways to decarbonization of the electricity supply in Alberta?	
	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 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	
	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?	
	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.	
	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	

	Questions	Stakeholder Comments
	technologies do you believe can be most economically implemented at cogeneration facilities?	

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 %
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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

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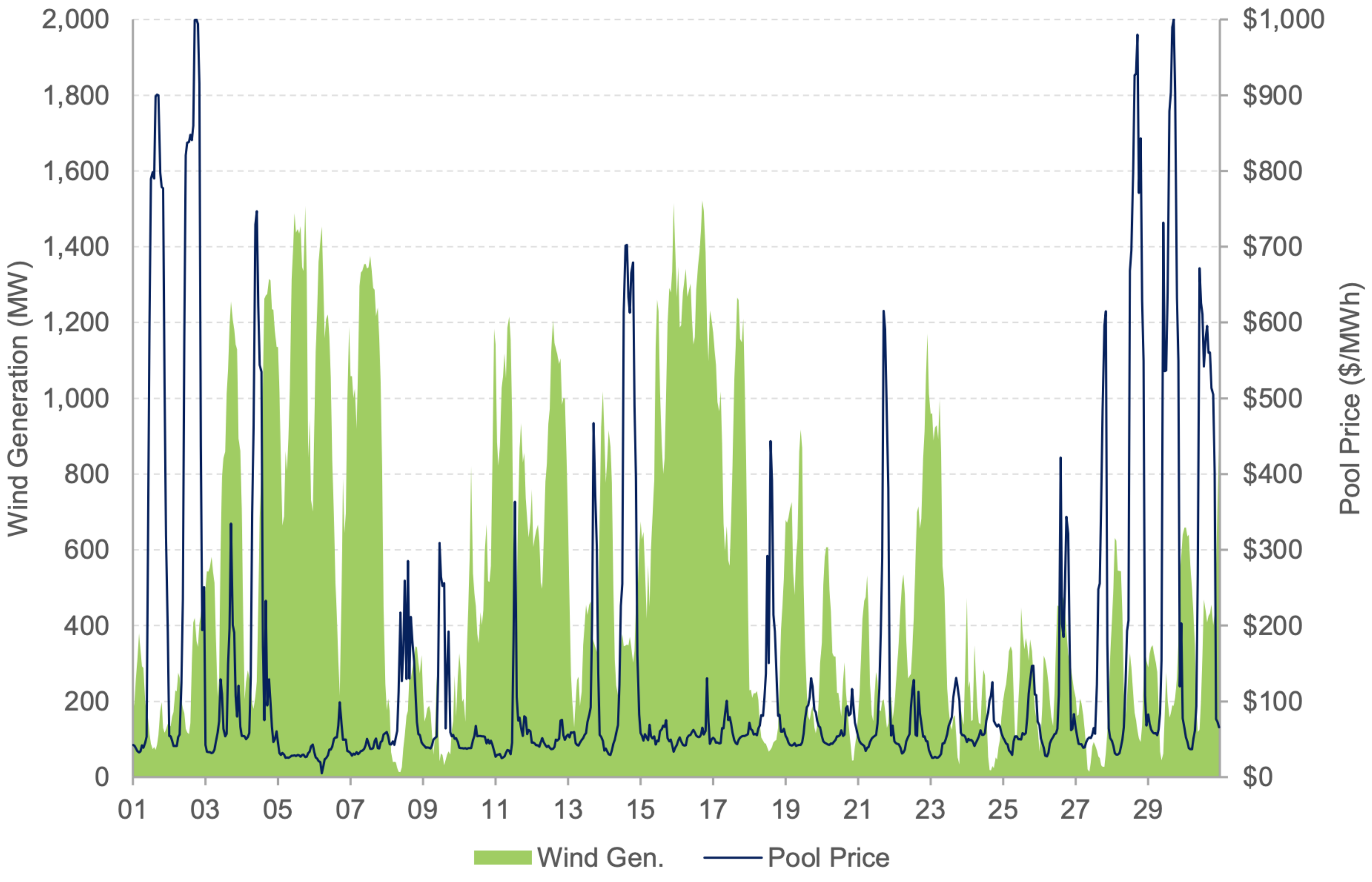
[3] https://www.eia.gov/analysis/studies/powerplants/capitalcost/

	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?	
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	
	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).	Demand Response is missing from the above table of DERs.
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

Attachment A - Relationship Between Pool Price and Wind Generation

Figure 7: Hourly pool price and wind generation (June 2021)



Source: MSA Quarterly Report for Q2 2021.

Attachment B - References on Cost Savings Attributable to Demand Response

- A study by PJM demonstrated that "a modest three percent load reduction in the 100 highest peak hours corresponds to a price decline of six to 12 percent." See Order 745 at P 10, n.15 (citing ISO-RTO Council Report, Harnessing the Power of Demand How RTOs and ISOs Are Integrating Demand Response into Wholesale Elec. Mkts. (Oct. 16, 2007), https://www.naesb.org//pdf3/irc_dr_report_101607.pdf).
- Ahmad Faruqui et al., The Power of 5 Percent, 20 The Elec. J. 68, 68–77 (Oct. 2007) (conservatively estimating that a five percent reduction in peak demand through demand response programs could lead to $35 billion in savings over a 20 year period), https://www.sciencedirect.com/science/article/abs/pii/S1040619007000991?via%3Dihub.
- FERC, A National Assessment of Demand Response, (June 2019) (potential to reduce peak demand by ten to twenty percent through demand response, effectively eliminating the equivalent of between 1,000 and 2,500 peaking units), https://www.ferc.gov/sites/default/files/2020-05/06-09-demand-response_1.pdf.
- Brady Stoll et al., The Value of Demand Response in Florida, 30 The Elec. J 57, 57–64 (Nov. 2017) (studying value of demand response under high renewable penetration scenarios and finding $76 million to $259 million in cost savings due to increased deployment of demand response).
- Stephen J. Rassenti et al., Controlling Mkt. Power and Price Spikes in Elec. Networks: Demand-Side Bidding, 100 PNAS 2999 (2001) (demonstrating the ability of demand response to prevent the exercise of supplier market power).
- Fei Wang et al., The value of market-based demand response on improving system reliability under extreme conditions, 193 Applied Energy 220, 220–231 (2017) (Describing the benefits and role of demand response in improving reliability during the 2014 Polar Vortex in PJM).
- Herman K. Trabish, Demand response failed California 20 years ago; the state's recent outages may have redeemed it, Utility Dive (Sept. 28, 2020) (documenting the contribution of demand flexibility to reducing California 2020 power outages), https://www.utilitydive.com/news/demandresponse-failed-california-20-years-ago-the-states-recent-outages/584878/.
- Potomac Economics, 2019 State of the Market Report, at 107 (June 2020) (citing "[r]eductions in price volatility and other market costs"), https://www.potomaceconomics.com/wp-content/uploads/2020/06/2019-MISO-SOM_Report_Final_6-16- 20r1.pdf.
- Ryan Hledik & Ahmad Faruqui, Valuing Demand Response: International Best Practices, Case Studies, and Applications, The Brattle Group (Jan. 2015).

Stakeholder Comment Matrix – Dec. 16, 2021

Net-Zero Emissions Pathways | Analysis Scope and Inputs

Comment period:	**Dec. 16, 2021 to Jan. 31, 2022**	Contact:	Patrick Bateman
Comments from:	WaterPower Canada	Phone:	(613) 290-9818
Date:	2022/01/31	Email:	patrick@waterpowercanada.ca

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.**
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Introduction

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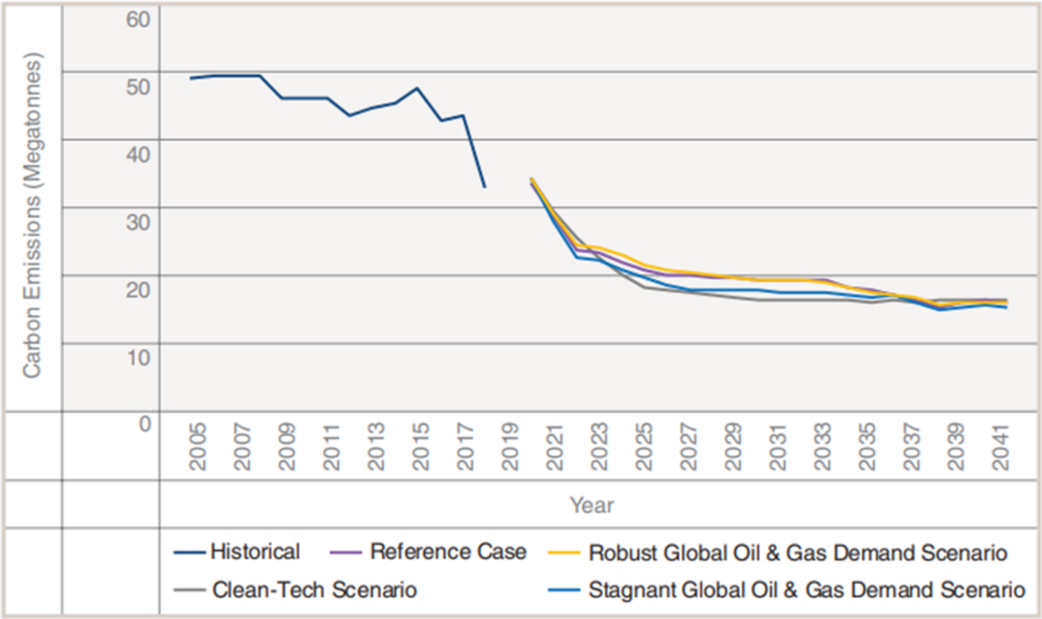
Alberta's electricity generation fleet has undergone significant transformation. Formerly a greenhouse gas intensive, primarily coal-fired generation fleet, Alberta's generation infrastructure has been converted and replaced with cleaner, less emissions intensive natural gas and renewable generation 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.

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



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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?	Scenario development and analysis should prioritize solutions that are proven to contribute to resource adequacy in winter months, and that are available in the 2035 time-frame, including: i) existing hydropower; ii) long duration energy storage from pumped storage hydro; and iii) Where consistent with the design of the Alberta market and the goal of increasing reliability, additional interconnection transmission capacity to British Columbia and Saskatchewan. The production of hydrogen from electrolysis should also be considered both as a potential fuel for generation, and as a means to reduce curtailment and transmission congestion for wind and solar.
	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?	Resource adequacy in winter months.

	Questions	Stakeholder Comments
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?	No comment at this time
	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**	No comment at this time

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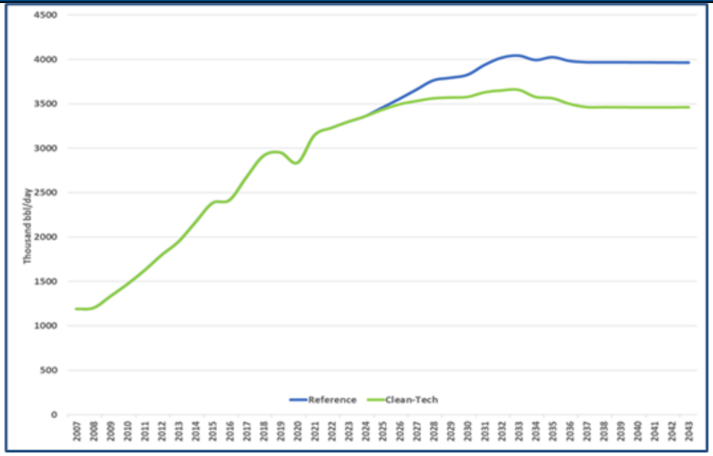
[1] https://www.conferenceboard.ca/temp/dece8ebd-ff72-4d8d-9813-c85a9dd47c61/11357_ip_provincial-outlook_nov2021.pdf

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

	Questions	Stakeholder Comments
	 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?	
	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?	No comment at this time
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	No comment at this time

	Questions	Stakeholder Comments
	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?	In addition to the carbon price increasing from $50/t to $170/t by 2030, it can be expected the Output Based Standards in the federal carbon pricing backstop for natural gas-fired electricity generation will become more stringent.
	c) What additional provincial or federal policies, policy scenarios or potential changes do you see impacting the Alberta electric system?	The proposed Clean Electricity Standard, and the Clean Fuel Regulation.
	d) Are there any other related considerations that you would like to provide feedback on?	No comment at this time
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?	No comment at this time
	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.)?	No comment at this time
	c) Transportation Sector • What is your view on the potential penetration and pace of electrification of the transportation sector (e.g., passenger vehicles and light-duty trucks, commercial fleets, heavy-duty trucks, rail, other)?	No comment at this time
	d) Buildings • What is your view on the potential penetration and pace of electrification of space heating/cooling and/or water heating?	No comment at this time

	Questions	Stakeholder Comments
	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)?	No comment at this time
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?	Existing hydropower (and refurbishments and redevelopments thereof); long duration energy storage from pumped storage hydro; where consistent with the design of the Alberta market and the goal of increasing reliability, additional interconnection transmission capacity to British Columbia and Saskatchewan; and the production of hydrogen from electrolysis both as a potential fuel for generation, and as a means to reduce curtailment and transmission congestion for wind and solar.
	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 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	Strengths of existing hydropower and pumped storage hydro, and transmission interconnections with other jurisdictions, include their ability to contribute to resource adequacy in winter. In addition, pumped storage hydro can provide the flexible energy and reserves, dependable capacity, long duration energy storage and other ancillary services required to integrate high penetrations of wind and solar.

	Questions	Stakeholder Comments
	(vii) Energy Storage (viii) Transmission interconnections with other jurisdictions (ix) Offsets or Emissions Performance Credits	
	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?	No comment at this time
	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.	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?	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

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[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?	Given the small number of Pumped Storage Hydro projects (e.g. including Brazeau, and Canyon Creek), AESO should engage with the Proponents of these projects directly with relation to project attributes such as cost.
	b) What is your expectation of the retrofit costs to existing thermal generators to enable CCUS or hydrogen-fired generation?	No comment at this time
	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).	No comment at this time
7	***Other*** Please provide any additional information that you would like to share, which may contribute to the net-zero analysis development.	No comment at this time

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