Net Zero by 2035: Potential Paths to a Carbon-Neutral Power Grid in Alberta

Industry CEO Roundtable

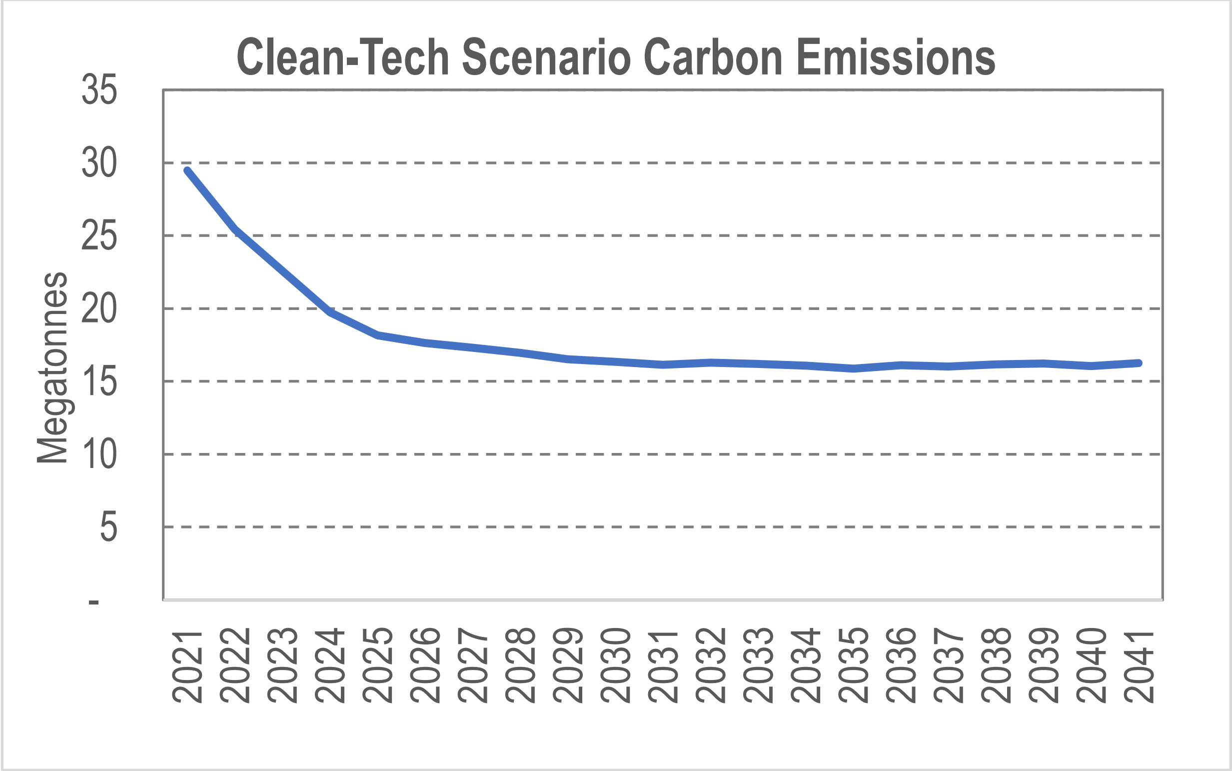
December 3, 2021

Background - “Net-Zero Emissions”

- Within the context of broad, economy wide net-zero by 2050 aspirations, Canadian politicians have announced their intentions to achieve “Net-Zero Emissions” in the electricity sector by 2035
  - Minority Leader Rachel Notley announced that Alberta would build a net-zero electricity grid by 2035, if elected (next election in Spring 2023)
  - The federal Liberal Party platform included reference to Net-Zero emissions from the electricity grid by 2035
    - The plan includes a “Pan-Canadian Grid Council”
    - An interconnected provincial and territorial national power grid
    - Additional investment tax credits for renewable and battery storage technologies
    - Selling more “Clean Canadian Power” to the United States
- Definitions are evolving but “Net-Zero Emissions” generally includes emission reductions via physical removal of carbon, zero-emissions technologies, and via carbon offset mechanisms
  - Alberta has an offset system that has been in place since 2008, with 16 active “Protocols” that can be used to create offset projects
  - Canada is creating a federal offset system and the *Greenhouse Gas Offset Credit System Regulations* were published in *Canada Gazette, Part 1* in March 2021
    - Offsets generated by renewable generation generally not applicable

Carbon Emissions: The Challenge

- AESO's 2021 LTO Clean-Tech Scenario results in 15.9 Mt of carbon dioxide emissions in 2035
  - All emissions in 2035 result from natural gas combustion at simple-cycle, combined-cycle, coal-to-gas, and certain cogeneration facilities[1]



[1] Cogeneration facilities aren't generally included in electricity sector emissions calculations but rather in the sectors that they service

"Net-Zero Emissions" in electricity by 2035

- It is anticipated that "Net-Zero" compliance can be met via a combination of techniques:
  - **Physical Reductions of CO_2e:** Replacement of high emissions electricity sources with low-carbon or zero-carbon electricity sources*
  - **Carbon Offsets:** Federally or Provincially certified carbon "Offsets" can be created from a variety of protocols that actively reduce carbon dioxide emissions
  - **Emissions Performance Credits (EPCs):** Performance credits, measured in tonnes of CO_2e, that can be generated under the *TIER Regulation* by facilities that have emissions intensities lower than the "high performance benchmark"

*At present, physical reductions of CO_2e can be used to produce tradable carbon offsets or emissions performance credits, which links all of these compliance mechanisms

- It is also possible that Carbon Offsets and EPCs will not be deemed acceptable compliance mechanisms by regulators, leaving only physical reduction options
  - Federal and Provincial governments have expressed support for various physical reduction techniques, such as small nuclear, carbon capture and underground storage, and hydrogen-fired generation
- Certain technologies may advance and mature, as government investments champion their growth, leading to cost reductions and improved economic

Timeline to Net-Zero

- Options to implement a net-zero electricity sector in Alberta face different timelines, many of which may be challenged to achieve 2035:
  - **Offsets/EPCs** can be developed annually by various existing and new projects, but aggregation of 16 Mt annually will require large incremental sources that could take several years to develop
  - **Renewable plus Battery** options can likely be built incrementally in 2-5 year projects but scale may challenge regulatory, supply chain, tx capacity, etc.
  - **Pre-combustion (hydrogen)** and **post-combustion CCUS** options can likely be implemented in 3-6 years at existing or new sites
  - **Large scale hydro** and **nuclear** would likely take 10-15 years or more before the first generation is delivered to customers and face large regulatory hurdles
  - **Large scale transmission** interconnections will also likely take 5-15 years, depending on the distance and the routes considered, particularly considering new and modified federal legislation including the *Canadian Energy Regulator Act*, the *Impact Assessment Act,* and the *Navigation Protection Act*
    - Transmission interconnections alone will not address reliable decarbonized supply; clean / renewable generation will be required
- Timelines may be optimistic, and may not account for delays associated with complex projects

Cost Uncertainty

- Many of the technologies to achieve net-zero are in their infancy. Capital and operating characteristics could be subject to material deviations
  - CCUS is expected to be successful at removing and storing carbon without leakage
  - Hydrogen production costs are expected to decline
  - Battery and renewable costs are expected to decline, as technology advances
  - Recent nuclear and hydroelectric costs have been subject to massive cost over-runs compared to initial budgets
- Costs associated with stranded capital at existing thermal power stations are a consideration

Cost Impacts

Cost impacts include:

- Generation & emissions control capital costs
- Transmission capital costs
- Increased or decreased fuel costs, variable operating & maintenance costs, and fixed operating & maintenance costs

Scenario	Generation Capital Cost Assumptions	Transmission Capital Cost Assumptions	Generation Operating Cost Assumptions
Pre-combustion sequestration	-Most existing gas plants will not be able to economically convert to hydrogen fuel (new facilities will be required) -Approximately 4,000 MW of new generation will be required to burn hydrogen by 2035	-No incremental transmission will be required	-Fuel costs will increase as hydrogen production will require more expense than natural-gas fired generation -Power plant operating & maintenance costs are assumed to be the same as natural gas fired generation
Post-combustion sequestration	-Significant capital investment will be required to retrofit CCS at existing power stations (~$1,400/kW of capacity) -No new generation capacity will be needed but dependent on size of parasitic load	-No incremental transmission will be required	-Parasitic load increases 14% (results in higher heat-rate at plants) -Variable O&M increases by ~70% -Fixed O&M increases by ~ 50%
Hydro or Nuclear	-5,000 MW of hydro or 3,000 MW of nuclear capacity will be required to replace existing natural gas generation	-Significant new transmission will be required to integrate hydro (~**$6B)** -Significant new transmission will be required to integrate nuclear (~**$3.5B)**	-Generation fleet fuel costs will be eliminated -Variable O&M costs similar for hydro, but increased in the case of nuclear -Fixed O&M costs reduced for hydro, increased for nuclear
Wind, Solar, & Battery	-In addition to Clean Tech volumes, another 5,300 MW of wind & 4,300 MW of solar capacity required -14,750 MW of battery capacity required (1 week of peak demand)	-Significant new transmission will be required to integrate renewables (~**$3.5B)**	-Generation fleet fuel costs will be eliminated -Variable and fixed O&M costs reduced
Offsets	-New renewable generation will produce offsets: 3,700 MW of wind, 3,500MW of solar, 300 MW of biomass -incremental costs for non-electricity offsets	-Modest new transmission may be required to integrate renewables (**$<3.0 billion**)	-Generation fleet fuel costs will be eliminated -slight increase in fleet variable O&M costs -Fixed O&M costs reduced
Transmission Interconnections	-Generation investment in Alberta may be stifled by generation in interconnected crown corporation or regulated jurisdictions	-Significant transmission capital will be required to create multiple interconnections	-Alberta generation may be underbid by jurisdictions with cost recovery

Benefits and Drawbacks of Net-Zero Options

Scenario	Benefits	Drawbacks
Pre-combustion sequestration	-Most effective CCUS option: easiest to capture carbon from SMR or ATR technology -Technology to burn hydrogen is being refined by all major equipment manufacturers -May be able to utilize significant amount of existing capital (gas turbines)	-Likely to rely on fossil-fuels for feedstocks -Hydrogen as a fuel is expensive and inefficient from an energy balance perspective -Fewer fugitive emissions than post-combustion sequestration
Post-combustion sequestration	-Utilizes significant amounts of existing capital (fewer stranded assets than alternative scenarios) - Dispatchable and baseload supply	-Relatively large amount of fugitive emissions due to the less carbon-rich flue gas from which carbon is extracted -Significant parasitic load reduces overall energy efficiency
Hydro or Nuclear	-Low variable costs -Large amounts of power available -Baseload supply -Flexible supply in the case of hydro -Tangible carbon emissions reductions	-Very high capital costs (generation and transmission) -Long development timelines -Potential for significant environmental impacts outside of carbon emissions -Detrimental to existing Alberta electricity market structure -Likely to require governmental support -Significant volume of stranded generation assets
Wind, Solar, & Battery	-Very low emissions -Diversified supply -Tangible carbon emissions reductions	-Battery requirements would lead to high cost at current prices and reliability expectations -Significant volume of stranded generation assets
Offsets	-Likely lowest cost “net-zero” emissions strategy -Diversified offset/EPC supply -Low stranded generation asset risk but dependent on source of offsets	-May not meet all definitions of “net-zero” -Significant volumes of annual offsets and EPCs will be needed to decarbonize the electricity industry -Less tangible as a “net-zero” option, since emissions reductions are not in the electricity sector
Transmission Interconnections	-Significant access to other markets for electricity -Potential to be a low-cost solution if more economic generation is available in connected markets - Diversification of supply and balancing of variable generation	-Detrimental to existing Alberta electricity market structure -Significant volume of stranded generation assets -Requires significant generation capacity in other markets -Strong reliance on neighboring jurisdictions

Benefits & Drawbacks of Net-Zero Options

- The diverse nature of "Net-Zero" options lends each alternative to various benefits and drawbacks based on the technologies that are implemented
- Implications in each category are highly dependent upon details of implementation

Scenario	Pre-combustion Sequestration (Hydrogen)	Post-combustion Sequestration	Hydro or Nuclear	Wind, Solar, & Battery	Offsets	Transmission Interconnections
Total Generation Costs	🟠	🟠	🔴	🔴	🟢	🟠
Transmission Rate Impacts	🟢	🟢	🔴	🟠	🟡	🔴
Capacity utilization	🟢	🟢	🟢	🟠	🟡	🟠
Electricity Market Impact	🟢	🟢	🔴	🟠	🟡	🔴
Stranded Asset Considerations	🟠	🟢	🔴	🔴	🟡	🔴

Conclusions

- Switch from coal to gas incented by existing carbon pricing policies has already achieved significant emissions reductions
- Many “net-zero” options are conceivable by 2035 for Alberta’s electricity sector
- Several decarbonization options have significant cost uncertainty due to lack of construction and operational history of the technologies
- A blend of the options is likely and may produce the lowest cost decarbonization option for Alberta

Thank you