Alberta Renewable Energy Alliance

Welcome to
Calgary Renewable Energy Meetup
July 22 ,2023

Net Zero Power in Alberta by 2035 ?

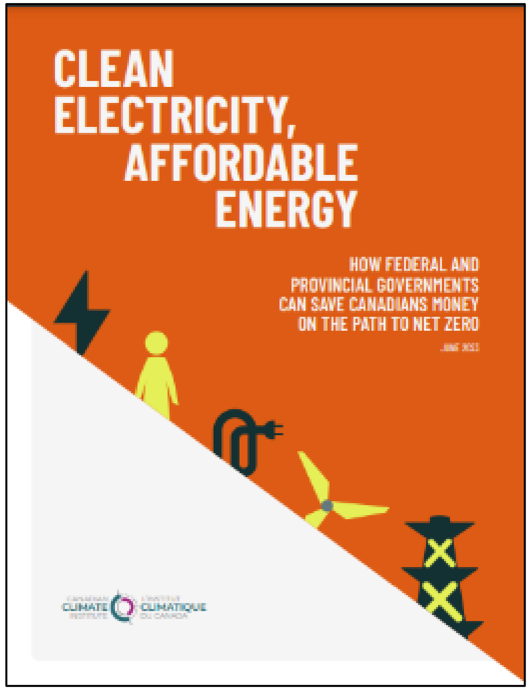
Presentation by Ken Hogg M.Eng., P.Eng.
Founder
Alberta Renewable Energy Alliance

Overview

- Canadian Provincial Total GHG emissions
- Provincial Electricity Generation GHGs
- Positions on 2035 Net Zero Power:
  - Federal
  - UCP
  - Canadian Energy Regulator
  - AESO (Alberta Electric System Operator)

Overview continued

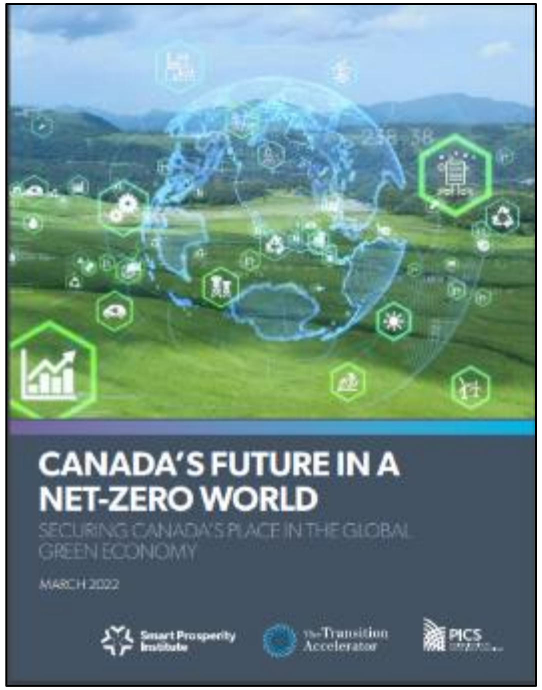
- OTHERS Positions on getting to 2035 Net Zero Power:
  - Pembina
  - Clean Energy Canada
  - AREA (Alberta Renewable Energy Alliance)


CLEAN ELECTRICITY, AFFORDABLE ENERGY
HOW FEDERAL AND PROVINCIAL GOVERNMENTS CAN SAVE CANADIANS MONEY ON THE PATH TO NET ZERO
CANADIAN CLIMATE INSTITUTE L'INSTITUT CLIMATIQUE DU CANADA

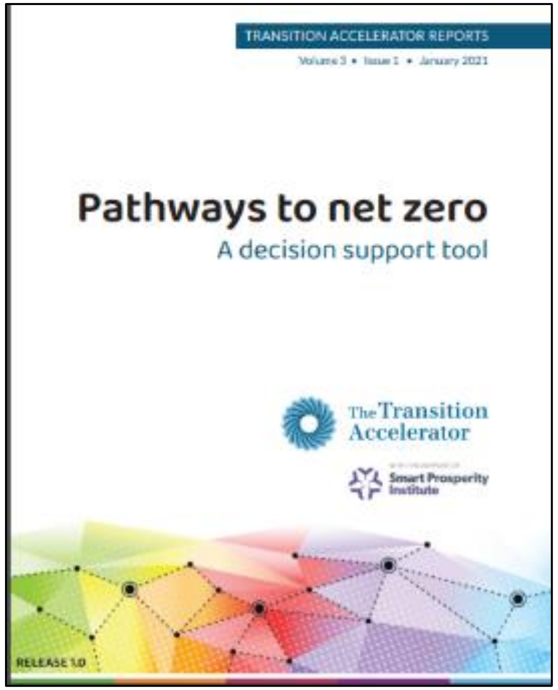

THE BIG SWITCH
POWERING CANADA'S NET ZERO FUTURE
MAY 2022
CANADIAN CLIMATE INSTITUTE L'INSTITUT CLIMATIQUE DU CANADA

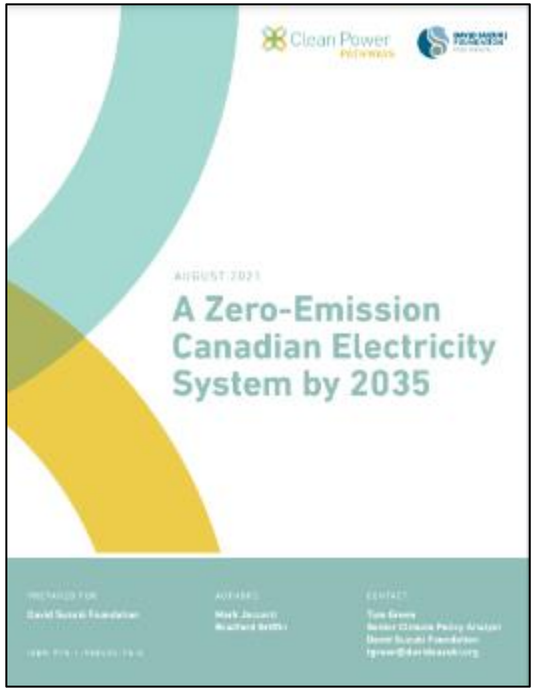

CANADIAN CLIMATE INSTITUTE L'INSTITUT CLIMATIQUE DU CANADA
BIGGER, CLEANER, SMARTER
PATHWAYS FOR ALIGNING CANADIAN ELECTRICITY SYSTEMS WITH NET ZERO
MAY 2022


Creating a Canadian Advantage
Policies to help Canada compete for low-carbon investment
WORKING PAPER
Bentley Allan, PhD
Research Director, Transition Accelerator
Michael Bernstein
Executive Director, Clean Prosperity
Contributing authors
CLEAN PROSPERITY
The Transition Accelerator


CANADA'S FUTURE IN A NET-ZERO WORLD
SECURING CANADA'S PLACE IN THE GLOBAL GREEN ECONOMY
MARCH 2022
Smart Prosperity Institute
The Transition Accelerator
PICS

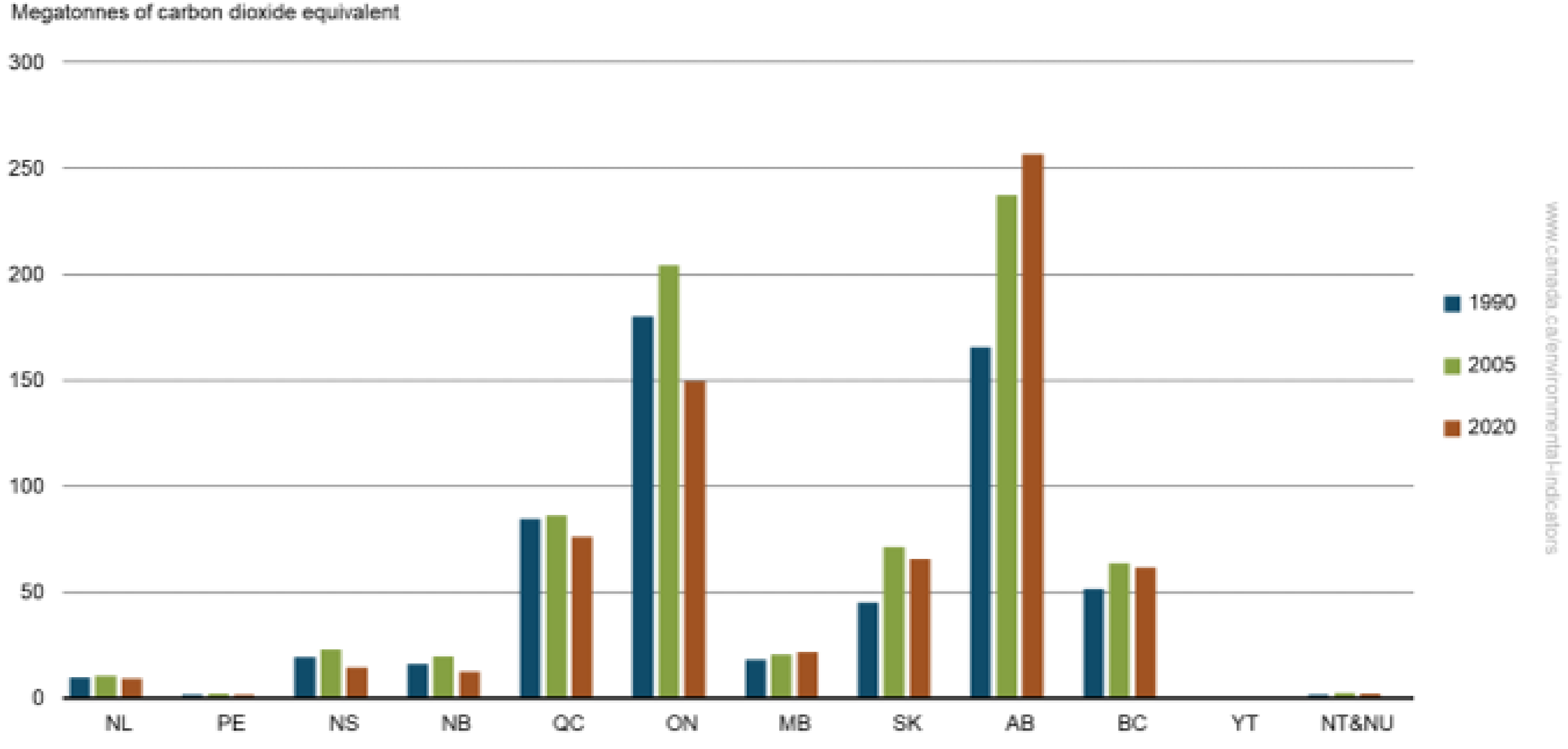

Setting the Pace
The economic case for managing the decline of oil and gas production in Canada
IISD REPORT
IISD
Re-Energizing Canada


TRANSITION ACCELERATOR REPORTS
Volume 3 • Issue 1 • January 2021
Pathways to net zero
A decision support tool
The Transition Accelerator
Smart Prosperity Institute
RELEASE 1.0


Clean Power Pathways
AUGUST 2021
A Zero-Emission Canadian Electricity System by 2035

BACKGROUND ON CANADIAN GHGs

Figure 8. Greenhouse gas emissions by province and territory, Canada, 1990, 2005 and 2020



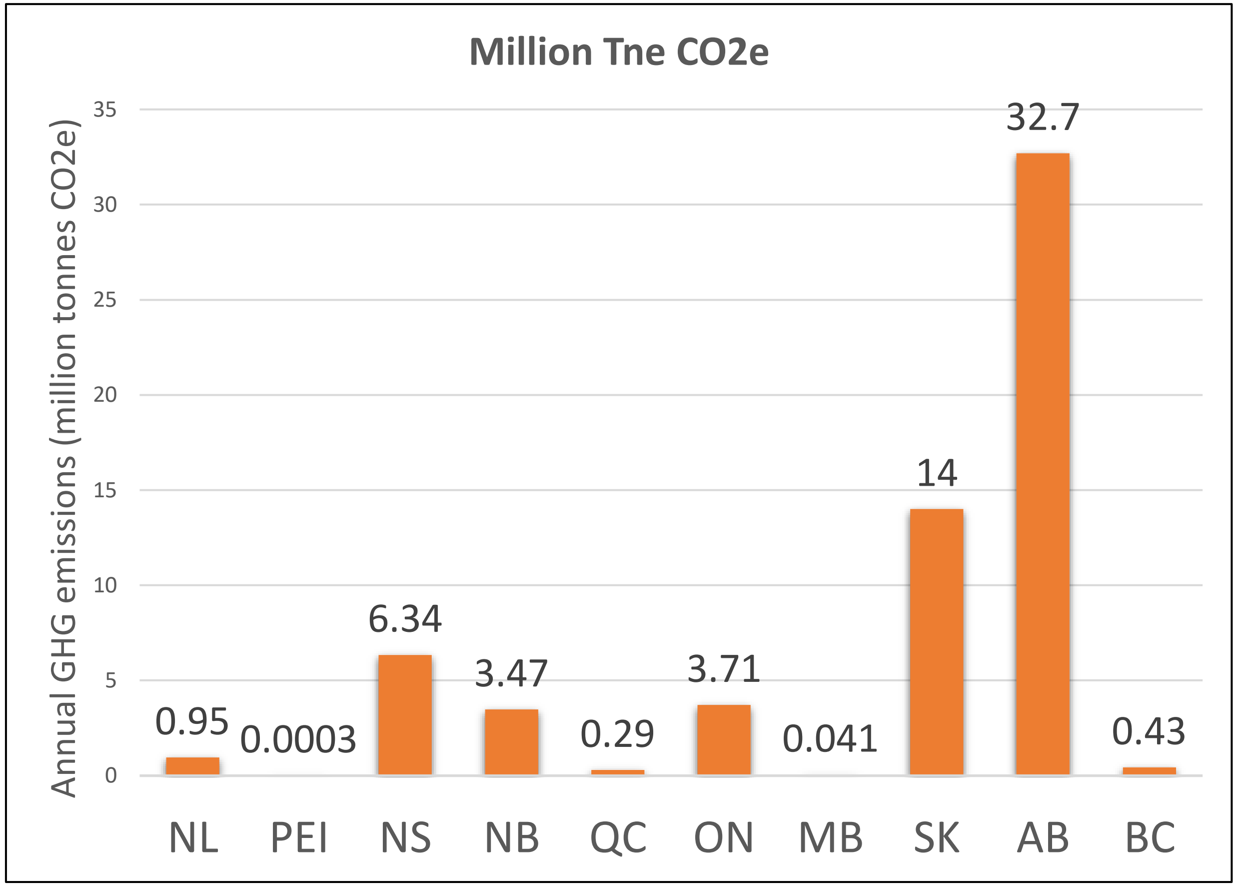
Data for Figure 8

Note: The years selected correspond to the first (1990) and last (2020) years of the dataset and to the base year (2005) for Canada's GHG emission reduction targets.
Source: Environment and Climate Change Canada (2022) National Inventory Report 1990-2020: Greenhouse Gas Sources and Sinks in Canada.

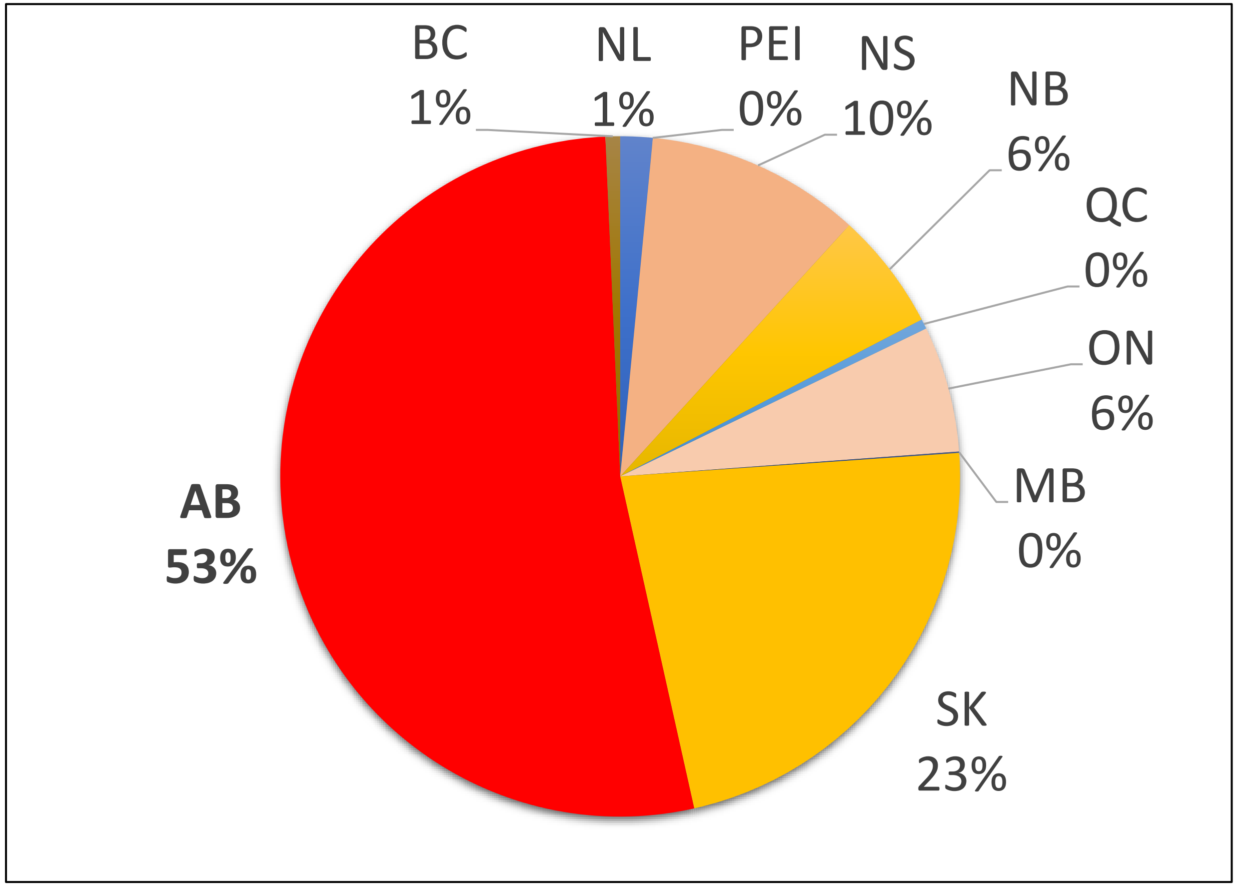
2020 GHG emissions from electricity generation

source: 2020 Canadian National Inventory Report

Provincial Electricity Emissions



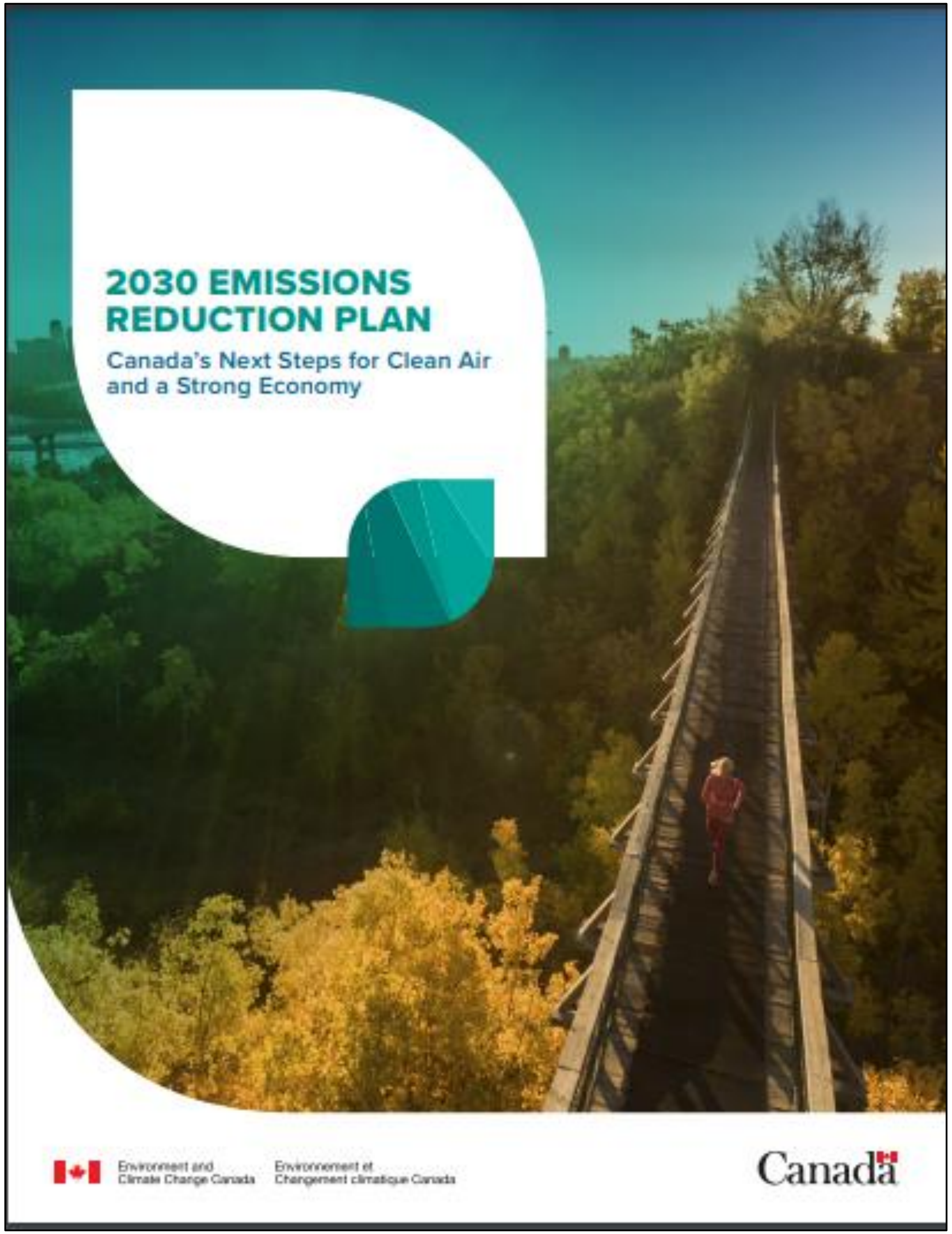
Provincial % from Electricity Emissions



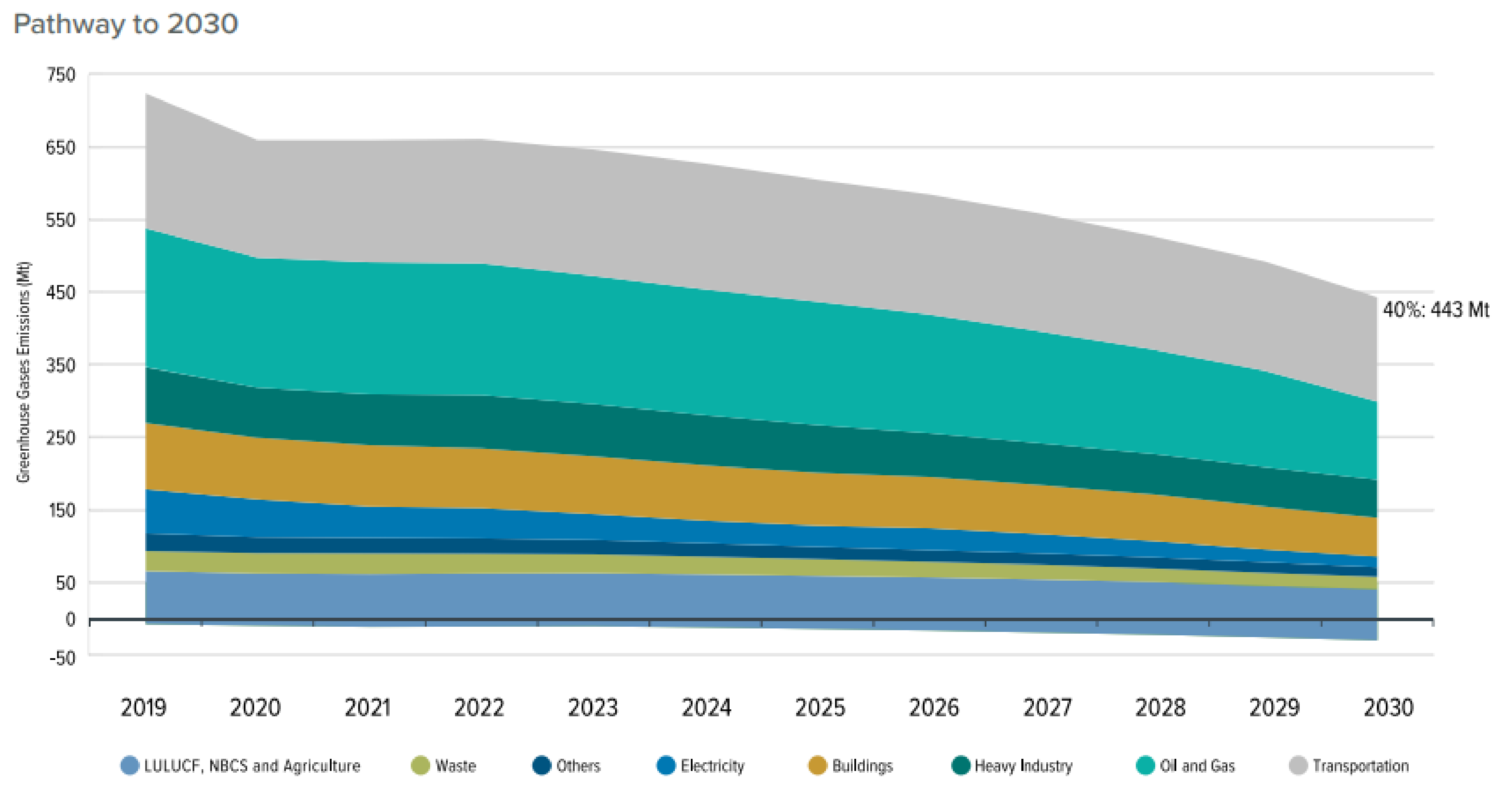
Canada's 2030 Emissions Reduction Plan

Issued June 2022

https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/erp/Canada-2030-Emissions-Reduction-Plan-eng.pdf



2030 Emission Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy



CANADA'S EMISSIONS REDUCTION PLAN FOR 2030 AND PATHWAY TO 2050

Buildings

Transitioning Canada's building stock to net-zero over the long term creates new opportunities to promote a low-carbon supply chain, adopt net-zero ready building codes, transform space and water heating, improve affordability through energy efficiency, and accelerate private financing and workforce development to support the transition.

Electricity

Working towards net-zero electricity by 2035 will expand non-emitting energy across Canada, connect regions to clean power, and foster more clean, reliable, and affordable electricity supply. It will also help reduce emissions from other sectors, such as industry, buildings, and transportation.

Heavy Industry

Emissions reductions will come from efforts to decarbonize large emitters, and strengthening Canada's mining sector. Enhancing clean growth in the sector will create new job opportunities, enhance Canada's industrial low-carbon advantage in global markets, and create investment opportunities in Canadian clean technology.

Require net-zero electricity by 2035 through a Clean Electricity Standard

Developing a Clean Electricity Standard (CES) to support a net-zero electricity grid by 2035 will provide a clear path forward and certainty for industry. To achieve this goal, the Government has released a discussion paper and launched a collaborative process with provinces, territories, and Indigenous partners to inform the design and scope of the standard. This process will help ensure that the design of the CES provides a clear and workable basis for provinces and territories to be able to plan and operate their grids in a way that will continue to deliver clean, reliable and affordable electricity to Canadians. Establishing a net-zero-emitting electricity sector will require substantial effort from provinces and territories, and a CES will provide the regulatory signal to support decision-making at all levels of government to achieve this goal.

Environnement et Changement climatique Canada
Environment and Climate Change Canada

A Clean Electricity Standard in support of a net-zero electricity sector

Discussion paper

4) The proposed CES regulations

While carbon pricing is a foundational measure in Canada's overall approach to reducing GHG emissions, it is designed to incent the lowest cost reductions across the economy and does not guarantee emission reductions in specific and targeted sectors. Given the long lifespan of electricity generation assets, decisions made over the next few years will impact Canada's GHG emissions for decades. Therefore, carbon pricing alone is not sufficient to ensure that the electricity sector achieves net-zero emissions by 2035, or likely even by 2050. A Canada-wide CES will complement carbon pricing by requiring the phase-out of all conventional fossil fuel electricity generation. In tandem, carbon pricing will incent fuel switching in other sectors to drive increased demand for clean electricity.

Regulations to limit fossil fuel generation must be decisive and swift enough to prevent locking in new fossil fuel infrastructure that will persist beyond 2035. These policies must also be flexible enough to account for regional differences, such as resource availability and interconnection (interties) with neighbouring jurisdictions. In the end, all actions taken together will ensure that electricity is clean, reliable and affordable for all Canadians.

The Government of Canada is planning new regulations under CEPA for all sources of emitting electricity generation that sell to the electricity system (grid). A CES regulation would set emissions performance standards for emitting electricity generators to ensure that the electricity sector transitions to NZ2035.

UCP on Net Zero Electricity by 2035

- Financial Post June 20, 2023

Premier Danielle Smith on Net Zero

“Smith said Ottawa’s plan for an emissions-free electricity grid by 2035 and a cap on oil and gas sector emissions that could be announced before the end of June aren’t realistic for her province without a massive cost to the economy and jobs. She said she was drawing a line in the sand that Ottawa can either get on board Alberta’s plan for getting to net-zero emissions by 2050, or it can get out of the way.”

UCP on Net Zero Electricity by 2035

- Media Enquiries July 19, 2023

Minister of Affordability and Utilities Nathan Neudorf

“Accelerating toward net-zero by 2035 would cause massive immediate increases to the power bills of individual consumer.”

“I am focused on ensuring we can provide affordable and reliable electricity for generations to come.”

Note: No recognition of how CLEAN the electricity should be

UCP on Net Zero Electricity by 2035

- Calgary Herald August 3, 2023
- Alberta’s United Conservative government is pausing all approvals in the province’s booming renewable energy industry

Minister of Affordability and Utilities Nathan Neudorf

“There is a little bit of inconvenience now for the next few months,” said Nathan Neudorf, minister of affordability and utilities. “But if we can set that right for the next 20 years, I think that’s trade-off most people are willing to make.”

Neudorf said he didn’t meet with industry before the announcement because of scheduling problems.

Albertans need 'immediate relief': NDP critic

Nagwan Al-Guneid, Opposition NDP energy and climate critic for electricity, utilities and renewables, said in a statement the cost of electricity is out of control and Albertans pay the most for car insurance anywhere in Canada.

"This government needs to create a short-term relief plan for Albertans, as well as a long-term plan to advance a more diversified electricity grid that is reliable, affordable, and low-emission," she said.

On March 31, 2017 Lieutenant Governor Lois Mitchell signed Order in Council O.C. 120 / 2017 which recognized under SCHEDULE Clause G "***the Government of Alberta's objectives of providing clean, affordable and reliable energy to Albertans.***"

Canada Energy Regulator

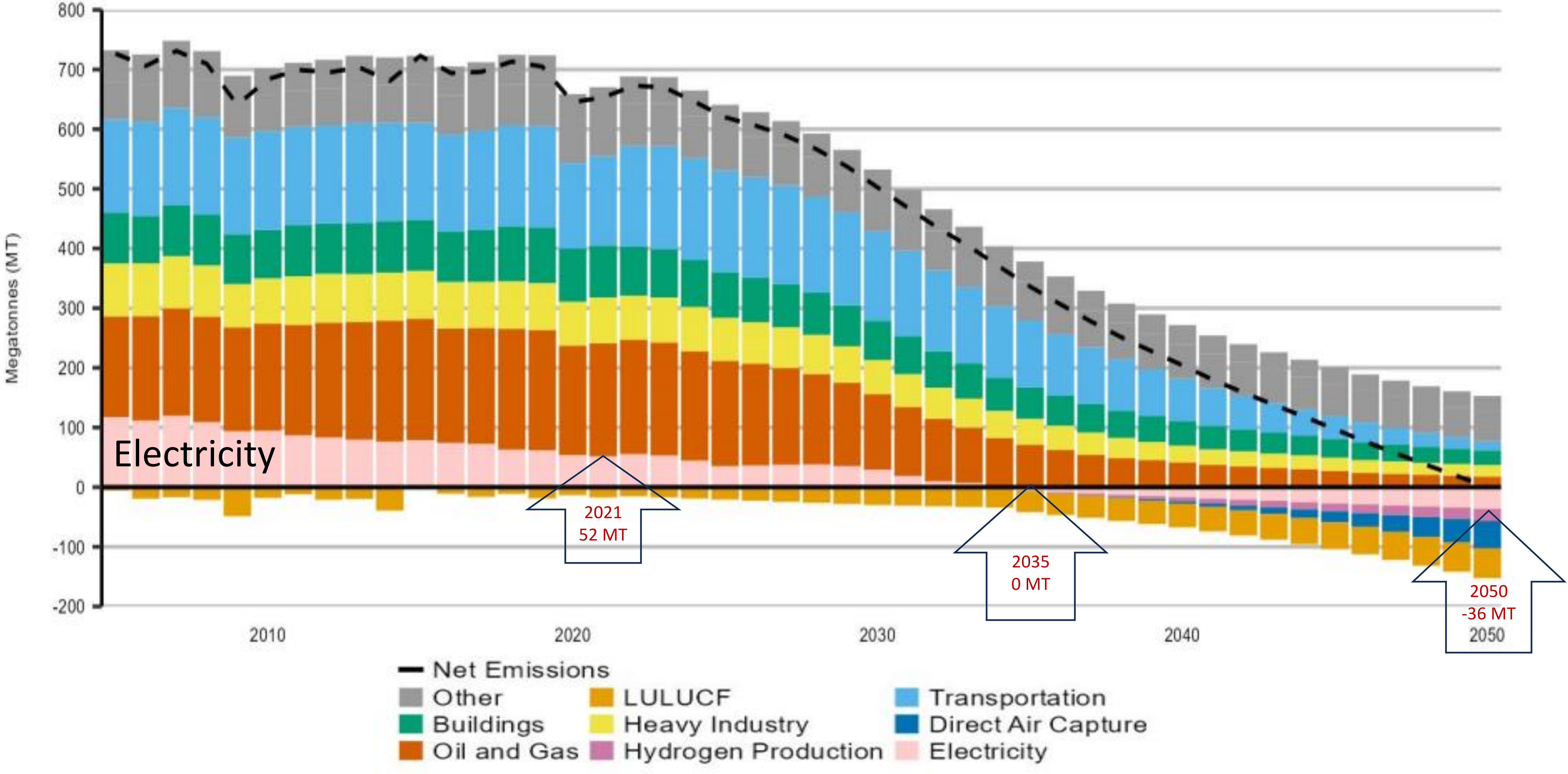
Canada's Energy Future 2023 Report

Issued June 2023

https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2023/canada-energy-futures-2023.pdf

Figure ES.10:

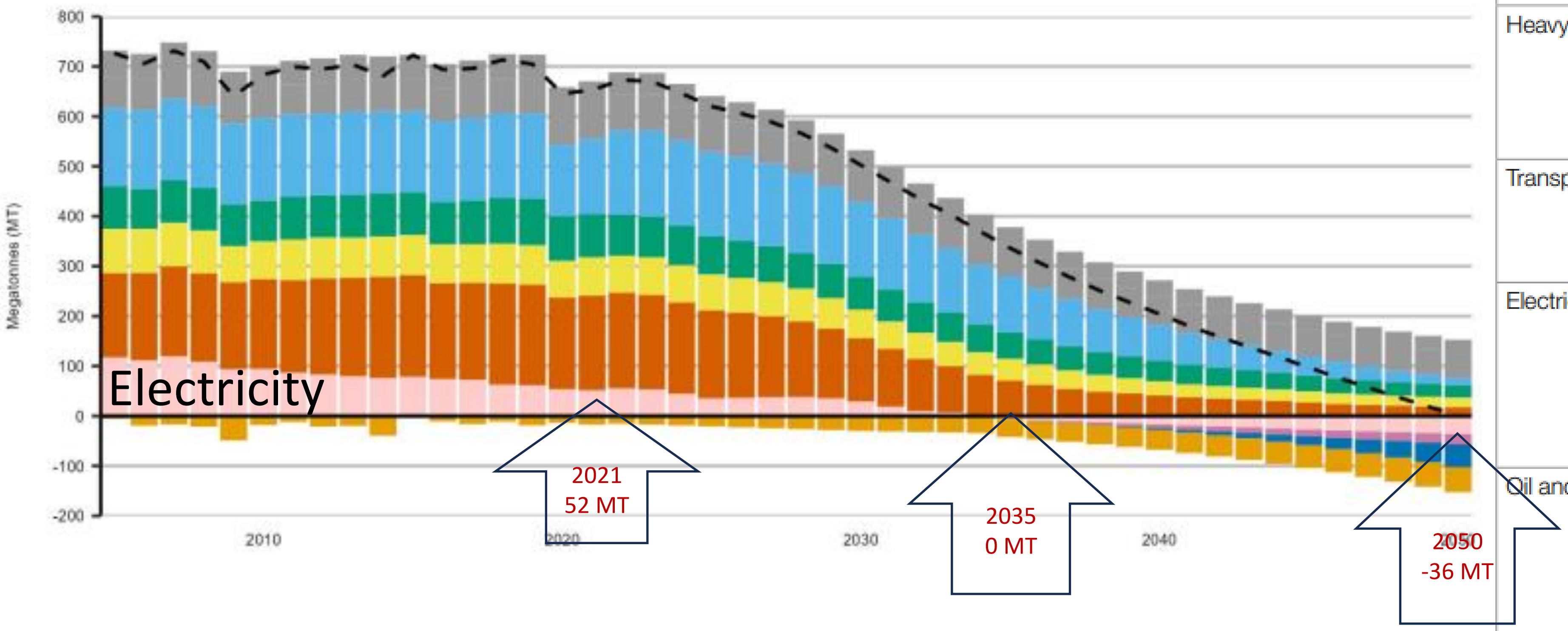
GHG emissions by economic sector, Global Net-zero Scenario



Canada's Electricity GHG Emissions are assumed to decrease from 52 MT in 2021 to zero MT by 2035 and to -36 MT by 2050

Figure ES.10:

GHG emissions by economic sector, Global Net-zero Scenario



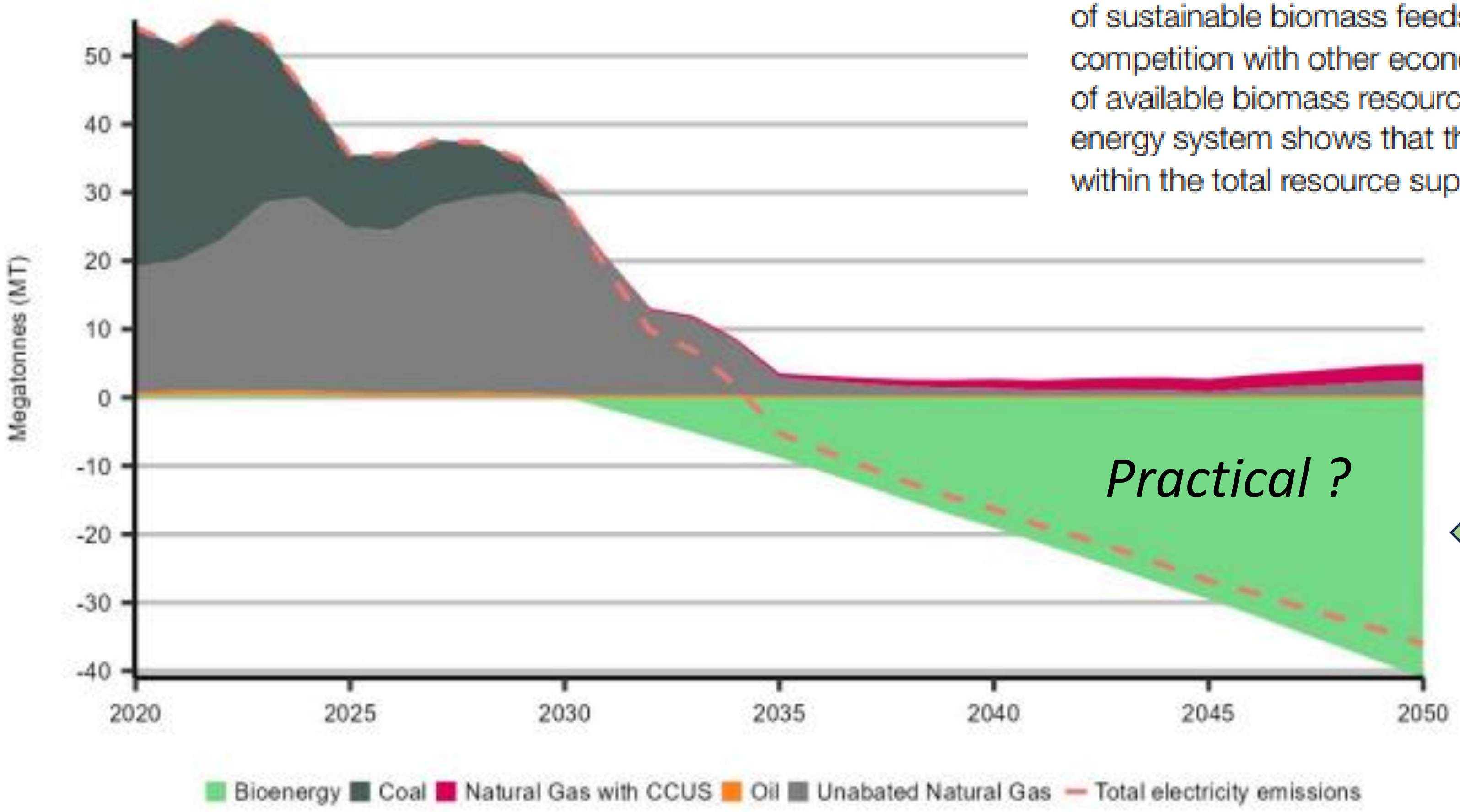
Sector	2021	2050	
		Global Net-zero	**Canada Net-zero**
Total	653 MT	0 MT	0 MT
Buildings	87 MT	25 MT	25 MT
Heavy industry	77 MT	19 MT	19 MT
Transport	150 MT	15 MT	14 MT
Electricity	52 MT	-36 MT	-35 MT
Oil and gas	189 MT	17 MT	32 MT

Table R.1:
Change in emissions from 2021 to 2050 by economic sector, and key outcomes, Global and Canada Net-zero scenarios

Sector	2021	2050		Key outcomes – Net-zero scenarios
		Global Net-zero	Canada Net-zero	
Total	653 MT	0 MT	0 MT	• Domestic and global climate policy assumptions drive most of the emission reductions in both net-zero scenarios, which grow in strength over the projection period.
Buildings	87 MT	25 MT	25 MT	• Heat pumps steadily replace natural gas and heating oil furnaces. • Improved efficiency of buildings, reducing overall space heating needs.
Heavy industry	77 MT	19 MT	19 MT	• Innovative industry-specific technologies to reduce energy and process GHG emissions. • Application of carbon capture, utilization, and storage (CCUS) in industries like chemicals and fertilizers, cement, and iron and steel. • Some switching to low- or non-emitting fuels like electricity, hydrogen, and biofuels.
Transport	150 MT	15 MT	14 MT	• Electric vehicles become the primary mode of on-road passenger transportation. • Freight shipping by truck, train, and ship is increasingly fueled by electricity, hydrogen, or biofuels. • Aviation emissions are reduced using a mix of bioenergy and hydrogen-based aviation fuel.
Electricity	52 MT	-36 MT	-35 MT	• Electricity use doubles over the projection period in both net-zero scenarios. • Rapid growth in low- and non-emitting generation sources, led by wind, natural gas with CCUS, bioenergy with CCUS, and nuclear, accompanied by steady growth in solar and hydro. • The electricity system decarbonizes and becomes net-negative by 2035 with the deployment of bioenergy with CCUS generation facilities.
Oil and gas	189 MT	17 MT	32 MT	• Declines in crude oil and natural gas production in the Global Net-zero Scenario, mostly driven by falling international demand and prices. Production declines more slowly in the Canada Net-zero Scenario. • Adoption of CCUS, especially in the oil sands. • Rapid uptake of processes and technologies to significantly reduce methane emissions from conventional oil and natural gas production and processing activities.

Figure R.26:

GHG emissions from electricity generation, by fuel, Global Net-zero Scenario



Negative emissions from BECCS plays an important role in both net-zero scenarios

In the Global Net-zero Scenario, BECCS generation begins in 2035 and grows to reach 51 TWh in 2050, or 4% of total generation. The negative emissions resulting from BECCS are 9 MT in 2035, and 41 MT by 2050 in both net-zero scenarios. We discuss total GHG emissions from the electricity sector later in this section.

In both net-zero scenarios, bioenergy plays an increasingly important role, in electricity as well as in the entire energy system. However, the annual availability of sustainable biomass feedstocks is limited by biological constraints and competition with other economic sectors like forestry and agriculture. An analysis of available biomass resources and our projections of its usage within Canada's energy system shows that the bioenergy used for electricity generation is well within the total resource supply.

BECCS
Bio Energy with
Carbon Capture
and Storage

Policy	Description	Global Net-zero and Canada Net-zero Scenarios	Current Measures Scenario
Net-zero accelerator initiative and strategic innovation fund	A federal investment of $3 billion over five years for the development and adoption of low-carbon technologies in all industrial sectors. Budget 2021 provided an additional $5 billion over seven years for the Net Zero Accelerator.	Development and adoption of low-carbon technologies in the industrial sector. Examples include fuel switching to low-carbon heat sources, adoption of inert anodes, CCUS, replacing fossil fuel feedstocks, hydrogen-based steel making, and DAC.	Examples include fuel switching to low-carbon heat sources, adoption of inert anodes, and CCUS.
Clean Electricity Regulations	The Clean Electricity Regulations would establish an emissions performance standard having an intensity form (i.e., t/GWh). It would be set at a stringent, near-zero value in line with direct emissions from well-performing, low-emitting generation such as, geothermal or combined cycle natural gas with CCS.	Net-zero electricity generation by 2035 through to 2050. Small generating units and those that produce electricity for remote communities are excluded from the regulation. The full regulatory details of the Clean Electricity Regulations are still under development. We follow the details in the Proposed Frame for the Clean Electricity Regulations.	Not included. Electricity generation facilities are covered under the OBPS.
Phase out of coal-fired generation of electricity	A carbon intensity performance standard for coal-fired power plants.	Limits emissions intensity of existing coal-fired electricity generation to 420 t/CO_2e per gigawatt hour (GWh) by 2030.	
National energy code for buildings	Sets out technical requirements for the energy-efficient design and construction of new buildings.	New buildings are "net-zero energy ready" by 2030 and net-zero by 2050. These codes are still under development, so we follow modeling in the Emission Reduction Plan that result in substantial increases in the efficiency of building shells.	Assumes that the 2017 building code applies throughout the projection period, with marginal efficiency improvements to building shells and space conditioning.
Energy Efficiency Regulations	Minimum energy efficiency standards for energy-using technologies in the residential, commercial, and industrial sectors (e.g. space conditioning equipment, water heaters, household appliances, lighting).	Marginal efficiency gains occur from 2030-2050.	Includes Amendment 17 to the Energy Efficiency Regulations. Energy efficiency gains end in 2030 and are carried through to 2050.
Hydrofluorocarbon (HFC) regulation	A phase down of HFC consumption from a baseline.	An 85% reduction in consumption of HFCs by 2050 from 2019 levels.	

Table A.2:
Overview of technology assumptions[a]

Technology	Global Net-zero	Canada Net-zero	Current Measures
CCUS	Capture costs are different by industry and range from \$45-200/tCO_2 by 2030 and \$30-160/tCO_2 from 2030-2050.	Capture costs are different by industry and range from \$45-200/tCO_2 by 2030 and \$ 30-160/tCO_2 from 2030-2050.	Capture costs are different by industry and range from \$45-200/tCO_2 through the projection period.
Battery-electric passenger vehicles	Cost declines 30% by 2030 and 38% by 2050.	Cost declines 28% by 2030 and 36% by 2050.	Cost declines 26% by 2030 and 33% by 2050.
Medium and heavy-duty freight vehicles	Battery-electric and fuel cell truck costs fall steadily, approaching parity with diesel vehicles in 2035-2050 period.	Battery-electric and fuel cell truck costs fall steadily, approaching parity with diesel vehicles in 2035-2050 period.	Battery-electric and fuel cell truck costs remain near current levels.
Heat pumps	Cost declines 15% by 2030 and 40% by 2050.	Cost declines 13% by 2030 and 34% by 2050.	Cost declines 7% by 2030 and 20% by 2050.
Wind electricity	Capital cost declines 13% by 2030 and 17% by 2050.	Capital cost declines 10% by 2030 and 16% by 2050.	Capital cost declines 9% by 2030 and 15% by 2050.
Solar electricity	Capital cost declines 44% by 2030 and 60% by 2050.	Capital cost declines 44% by 2030 and 60% by 2050.	Capital cost declines 40% by 2030 and 57% by 2050.
Direct Air Capture (DAC)	Capture cost declines to \$330/tCO_2 by 2035 and \$230/tCO_2 by 2050.	Capture cost declines to \$350/tCO_2 by 2035 and \$250/tCO_2 by 2050.	Capture cost remains at \$400-450/tCO_2 over projection period.
Hydrogen electrolyzer	Capital cost declines 80% by 2030 and 84% by 2050.	Capital cost declines 74% by 2030 and 82% by 2050.	Capital cost declines 62% by 2030 and 70% by 2050.

[a] Cost reductions are relative to 2021, and dollar figures are adjusted for inflation.

Appendix 2: Technology Assumptions

This appendix outlines key technology assumptions included in the Current Measures, Global Net-zero, and Canada Net-zero Scenarios. The percent changes in the assumptions are relative to 2021 unless otherwise noted. All costs are in $2022 CAD unless otherwise noted.

Table A2.1

Key Technology Assumptions

	Global Net-zero	Canada Net-zero	Current Measures
Electricity Generation			
Wind electricity[k]	Capital cost declines from $1,900/kW in 2020 to $1,752/kW by 2030 and $1,630/kW by 2050 (14% below 2020).	Capital cost declines from $1,900/kW in 2020 to $1,763/kW by 2030 and $1,668/kW by 2050 (12% below 2020).	Capital cost declines from $1,900/kW in 2020 to $1,791/kW by 2030 and $1,736/kW by 2050 (9% below 2020).
Solar electricity[l]	Capital cost declines from $1,400/kW in 2020 to $790/kW by 2030 and $535/kW by 2050 (62% below 2020).	Capital cost declines from $1,400/kW in 2020 to $840/kW by 2030 and $585/kW by 2050 (58% below 2020).	Capital cost declines from $1,400/kW in 2020 to $905/kW by 2030 and $675/kW by 2050 (52% below 2020).
Battery storage (4 hr) [m]	Capital cost declines from $2,198/kW in 2020 to $952/kW by 2030 and $549/kW by 2050 (75% below 2020).	Capital cost declines from $2,198/kW in 2020 to $1,261/kW by 2030 and $925/kW by 2050 (58% below 2020).	Capital cost declines from $2,198/kW in 2020 to $1,563/kW by 2030 and $1,506/kW by 2050 (32% below 2020).
Natural gas combined cycle with CCS[n]	Capital cost declines from $3,705/kW in 2020 to $2,625/kW by 2030 and $2,075/kW by 2050 (44% below 2020).	Capital cost declines from $3,705/kW in 2020 to $3,005/kW by 2030 and $2,530/kW by 2050 (32% below 2020).	Capital cost declines from $3,705/kW in 2020 to $3,385/kW by 2030 and $2,990/kW by 2050 (19% below 2020).
Nuclear small modular reactors[o]	Capital cost declines from $9,262/kW in 2020 to $8,348/kW by 2030 and $6,519/kW by 2050 (30% below 2020).	Capital cost declines from $9,262/kW in 2020 to $8,348/kW by 2030 and $6,519/kW by 2050 (30% below 2020).	Capital cost declines from $9,262/kW in 2020 to $8,595/kW by 2030 and $7,400/kW by 2050 (20% below 2020).

Sources and notes:

a. IEA World Energy Outlook 2022, NREL Electrification Futures Study.

b. Various sources including: Global CCS Institute, Leeson et al 2017, International CCS Knowledge Centre, IEA Levelized cost of CO_2 capture.

c. For an example of coal to EAF see Algoma Steel.

d. For an example of coal to direct reduced iron EAF see ArcelorMittal Dofasco.

e. IEA Clean Energy Technology Guide.

f. For an example of intert anodes see Elysis Carbon-Free Aluminum Facility.

g. IEA World Energy Outlook 2022, EIA Annual Energy Outlook 2022.

h. EPRI US-REGEN Documentation Version 2021 LCRI, On-Road Fleet Vehicles.

i. EPRI US-REGEN Documentation Version 2021 LCRI, On-Road Fleet Vehicles.

j. IEA World Energy Outlook 2022, Canada's Aviation Climate Action Plan.

k. NREL Annual Technology Baseline, IEA World Energy Outlook 2022.

l. NREL Annual Technology Baseline, IEA World Energy Outlook 2022.

m. NREL Annual Technology Baseline, IEA World Energy Outlook 2022.

n. NREL Annual Technology Baseline, IEA World Energy Outlook 2022.

o. NRCan 2020, NREL Annual Technology Baseline.

p. Various sources including: Global CCS Institute, Leeson et al 2017, International CCS Knowledge Centre, IEA Levelized cost of CO_2 capture, Quest Carbon Capture and Storage Project: Annual Report, Ordorica-Garcia, et al 2011.

q. IEA World Energy Outlook 2022.

r. EPRI US-REGEN Documentation Version 2021 LCRI, IEA Direct Air Capture 2022.

s. Canada's 8th National Communication and 5th Biennial Report 2022, Canada's LTS submission to the UNFCCC 2022, CCA NBCS 2022, Drever et al. 2021, Smith 2020.

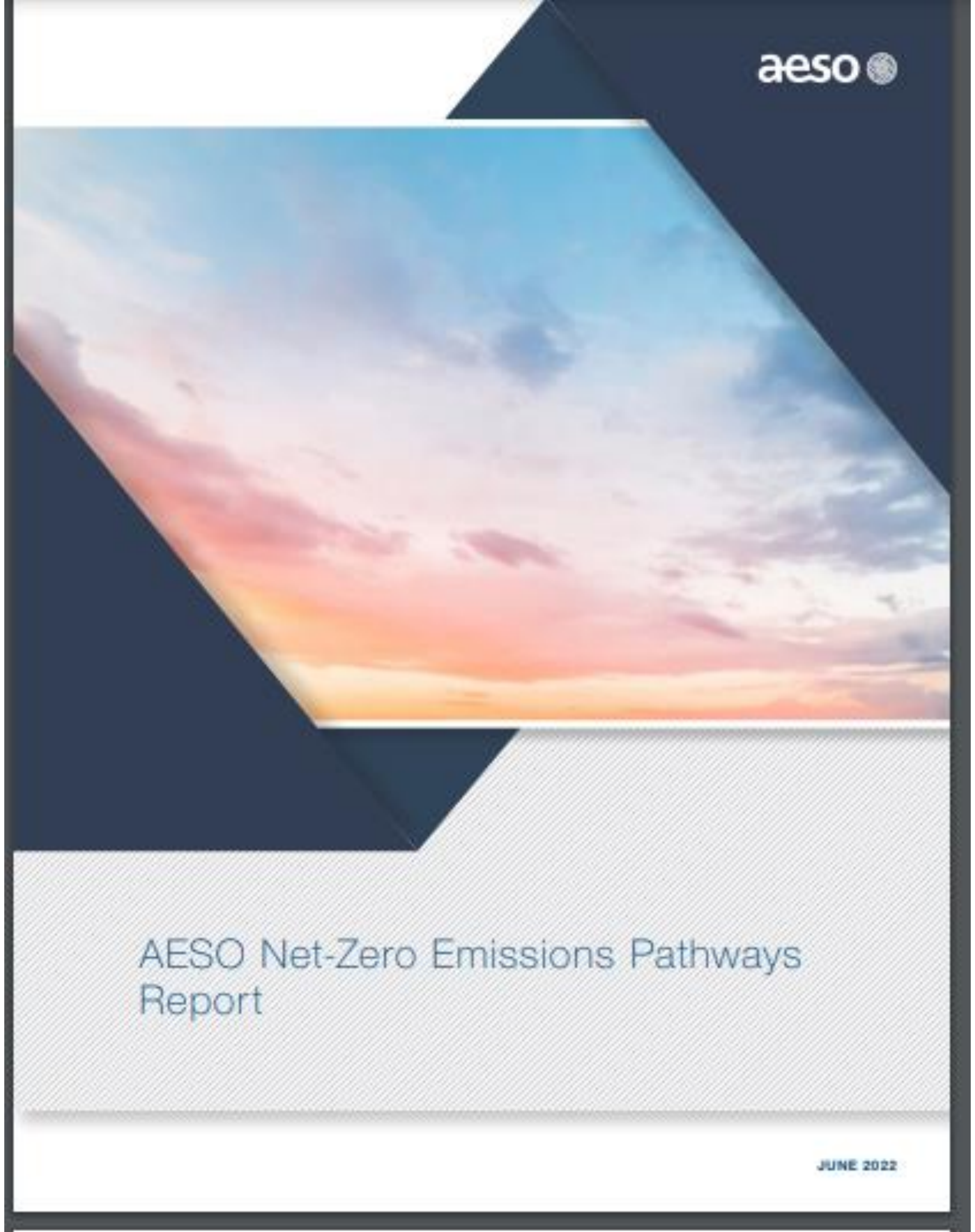
t. Canada's 8th National Communication and 5th Biennial Report 2022, Canada's 2030 emissions reduction plan, Chapter 3 2022.

u. McKinsey, Agriculture and climate change 2020, RBC, The Next Green Revolution 2022, SPI, NZ: Implications for Canadian Agriculture 2021, Trottier, Canadian Energy Outlook 2021.

AESO (Alberta Electric System Operator)

June 2022

https://www.aeso.ca/assets/AESO-Net-Zero-Emissions-Pathways-Report-July7.pdf



Three Capacity Scenarios to 2035

Dispatchable Dominant

First Mover Advantage

Renewables and Storage Rush

TABLE 5: Comparison of Net-Zero Emissions Pathways Scenarios and 2021 LTO

Description	Dispatchable Dominant 2035	First-Mover Advantage 2035	Renewables and Storage Rush 2035	2021 LTO Clean-Tech 2035	2021 LTO Ref Case 2035
	Equal and Greater than 5 MW Generation (MW Installed Capacity)				
Wind	3,922	6,922	9,422	4,997	4,747
Solar	1,872	2,572	3,724	2,539	1,189
Storage - Battery	330	330	3,060	1,020	85
Storage - Compressed Air	-	-	496	-	-
Storage - Pumped Hydro	-	-	600	75	-
Hydrogen Simple Cycle	2,049	1,599	1,494	-	-
Combined-Cycle with CCS	2,262	1,508	-	-	-
Natural Gas Combined-Cycle	1,768	1,548	1,548	4,822	2,648
Natural Gas Simple-Cycle	751	1,278	1,205	1,544	1,397
Coal-to-Gas - Steam Boiler	929	929	-	935	2,535
Cogeneration	6,712	6,712	6,712	6,669	6,669
Hydroelectric	894	894	894	894	894
Other	443	443	443	483	423
Total	**21,932**	**24,735**	**29,598**	**23,978**	**20,587**

Generation Capacity Compared to Previous Forecasts

aeso

	2023 LTO Reference Case				Net Zero First Mover Advantage	Net Zero Renewable and Storage Rush	2021 Clean-Tech Scenario	2021 LTO Reference Case
Capacity (MW)	2023	2028	2035	2043	2035	2035	2035	2035
Coal	820	-	-	-	-	-	-	-
Coal to gas	3,075	1,724	1,724	-	929	-	935	2,535
Cogeneration	5,235	6,266	6,491	6,491	6,712	6,712	6,669	6,669
Cogeneration - Hydrogen Fired	-	233	512	558	-	-	-	-
Simple Cycle	1,240	1,304	1,244	962	1,278	1,205	1,520	1,397
New Simple Cycle - Hydrogen Fired	-	-	-	698	1,599	863	-	-
New Combined Cycle - Hydrogen Fired	-	-	-	837	-	-	-	-
Combined Cycle	1,810	1,861	411	122	1,548	1,548	4,822	2,648
Retrofitted Combined Cycle (CCS)	-	745	2,804	2,804	-	-	-	-
New Combined Cycle (CCS)	-	-	-	1,508	1,508	-	-	-
Hydro	894	894	894	894	894	894	894	894
Other	444	444	444	444	443	443	473	423
Solar	1,179	4,302	5,702	5,887	2,572	3,444	2,114	1,104
Wind	3,618	6,439	7,211	6,369	6,922	8,722	4,797	4,717
Storage	80	347	367	350	310	3,656	1,005	85
Hybrid Storage	10	150	150	150	-	-	195	35

AESO Cost Scenarios 2022 and 2026

- Capital Costs
- Fixed Operation and Maintenance
- Variable O & M

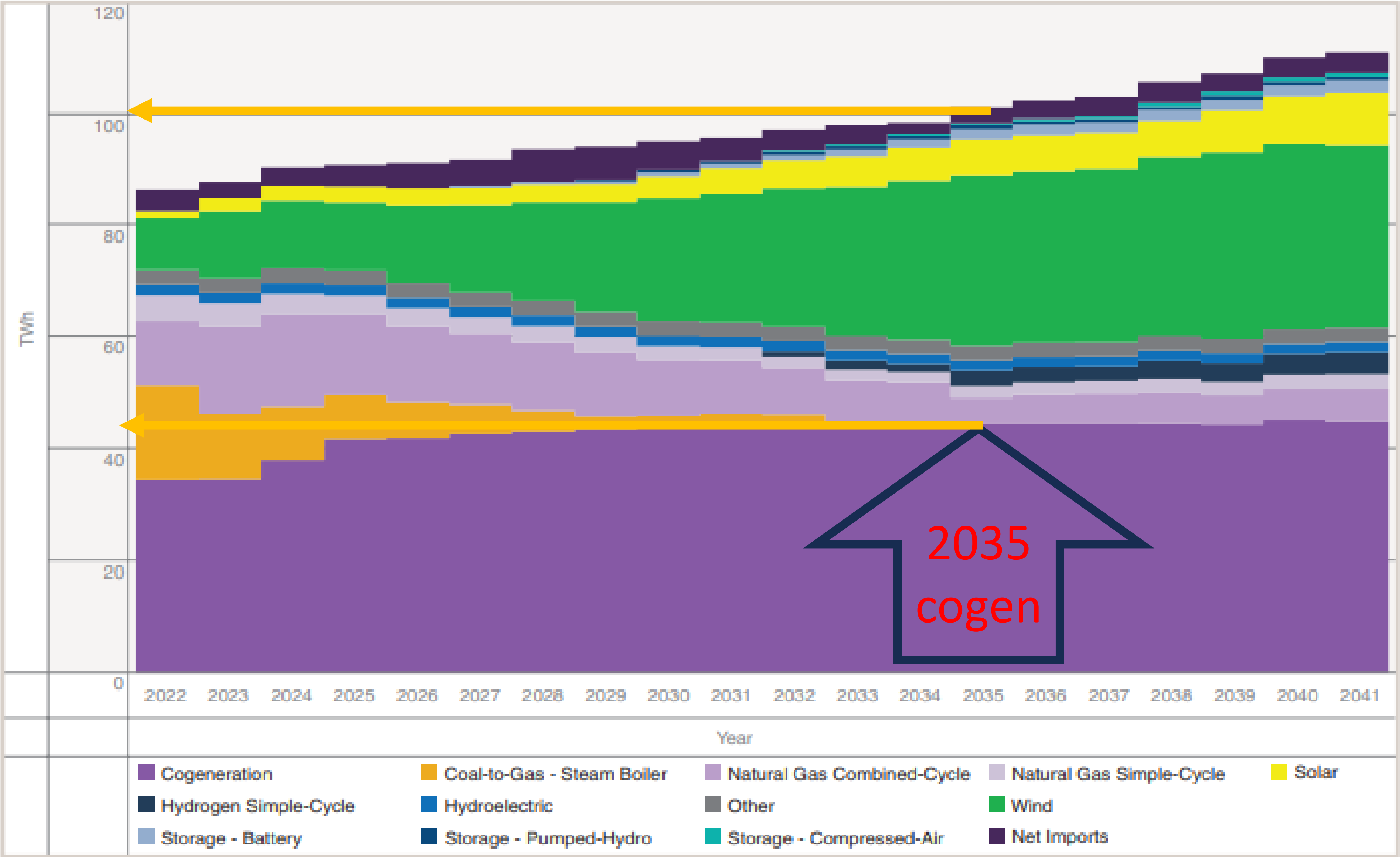
Note: Carbon Costs are ***excluded*** *from this table*

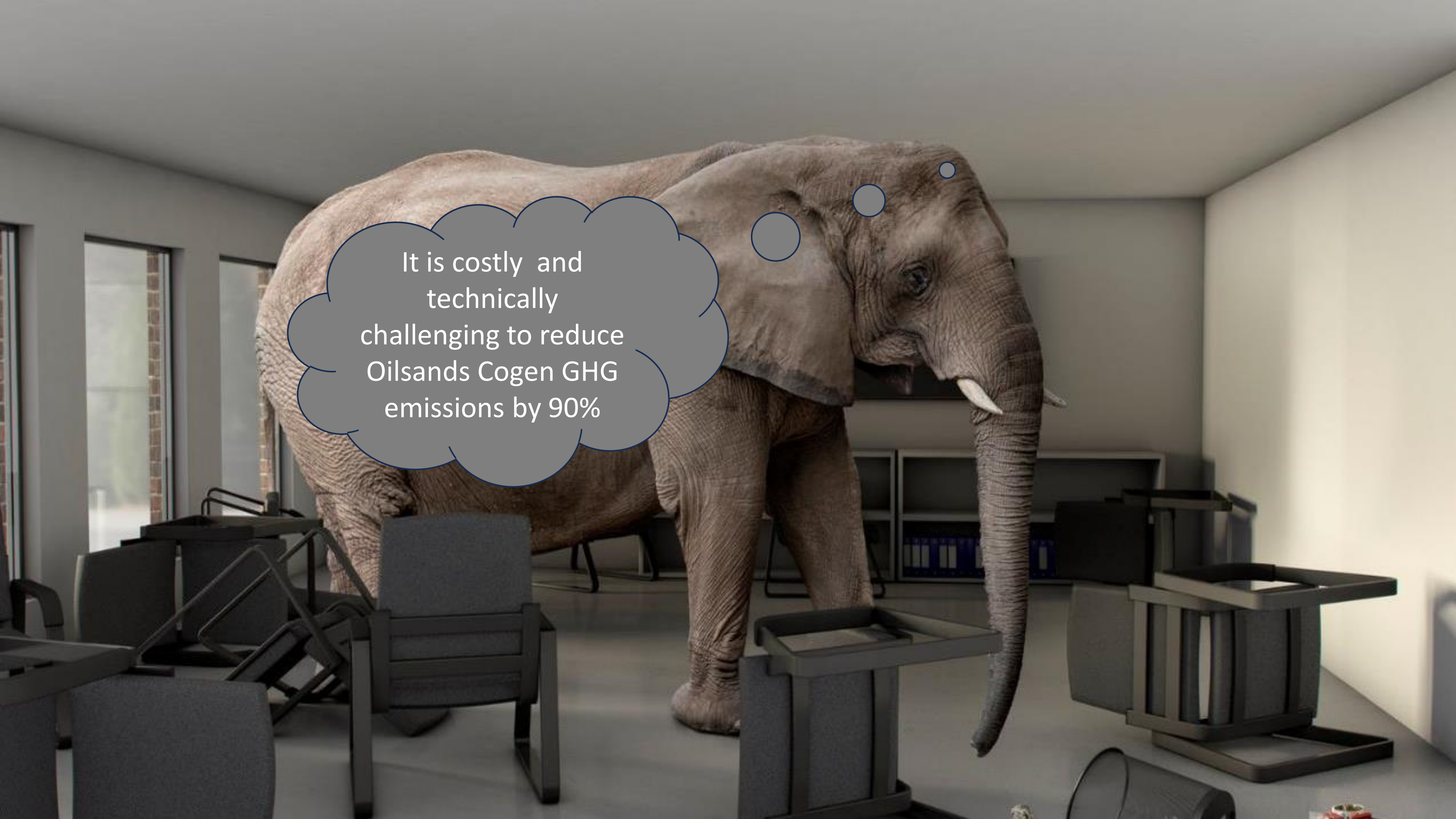
TABLE 1: Characteristics of Low-Carbon Electricity Technologies Modelled in the AESO's Net-Zero Pathways Analysis

Technology	Capacity, MW	Capital Cost, $2022/kW		Efficiency or Heat-Rate, % or GJ/MWh	Fixed O&M, $2022/kW-yr		Variable O&M, $2022/MWh
		2022	2026				
Solar PV – 2022; 2026	50	1,702	1,425	-	35		-
Wind – 2022, 2026	50	1,682	1,159	-	35	32	-
Nuclear Fission	2,156	8206		-	165		3.22
Nuclear Fission SMR	600	8410		-	129		4.08
Hydroelectric	100	14,545		-	41		-
Combined-Cycle CCS	377	3,370		7.52 GJ/MWh	37		7.93
Hydrogen-Fired Combined-Cycle	418	1841		6.79 GJ/MWh	55		2.75
Hydrogen-Fired Simple-Cycle – Frame	233	992		10.45 GJ/MWh	30		0.82
Hydrogen-Fired Simple-Cycle – Aeroderivative	105	1,280		9.68 GJ/MWh	58		4.69
Battery Energy Storage	10 (4 hour)	2244	1603	86% to 88%	5		0.68
Compressed-Air Energy Storage	100 (60 hour)	1585	1577	52%	21		0.68
Pumped-Hydro Energy Storage	150 (19 hour)	3493		80%	40		0.68

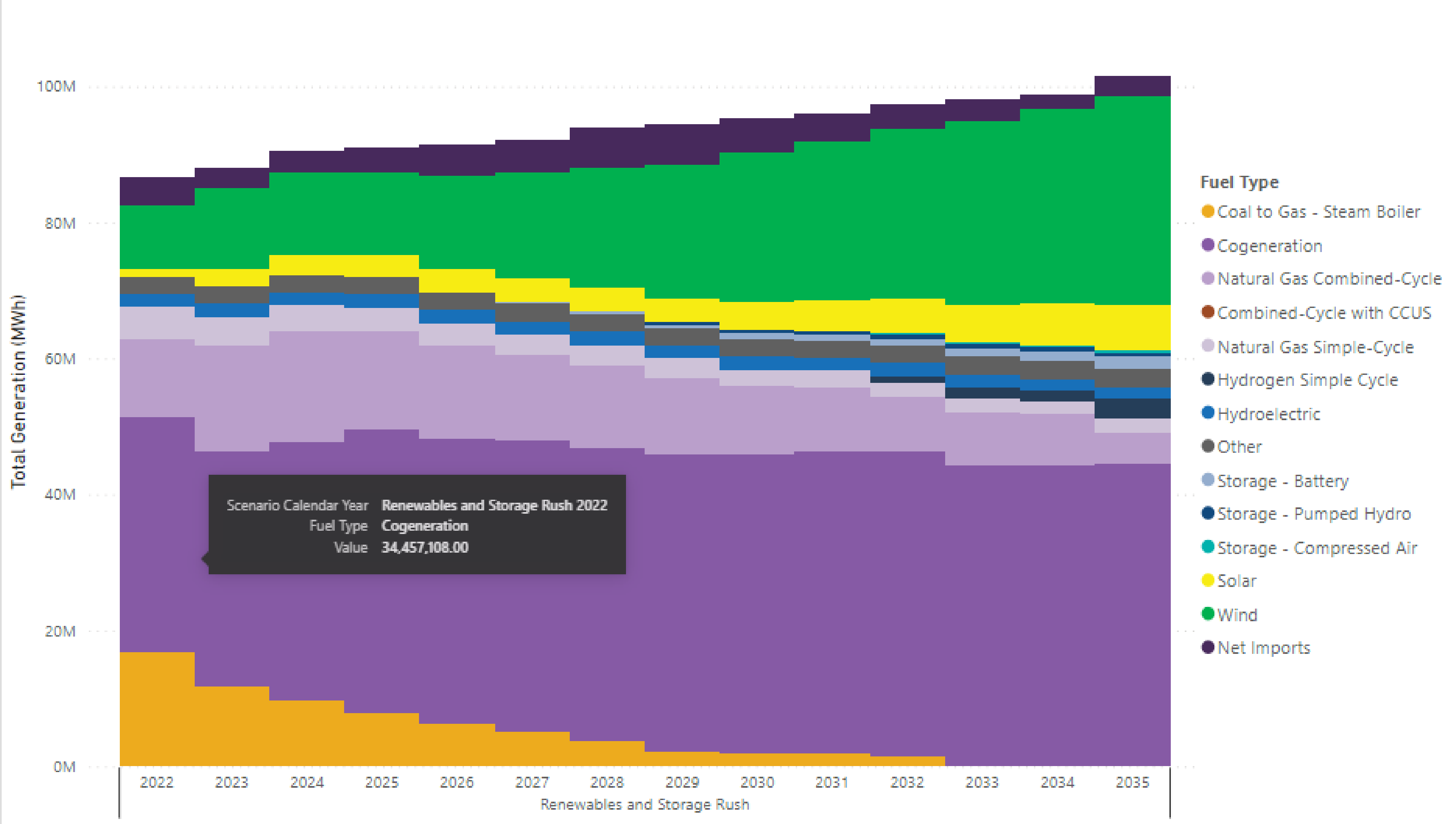
Total Generation

FIGURE 26: Renewables and Storage Rush Scenario - Total Generation




It is costly and technically challenging to reduce Oilsands Cogen GHG emissions by 90%

Total Generation

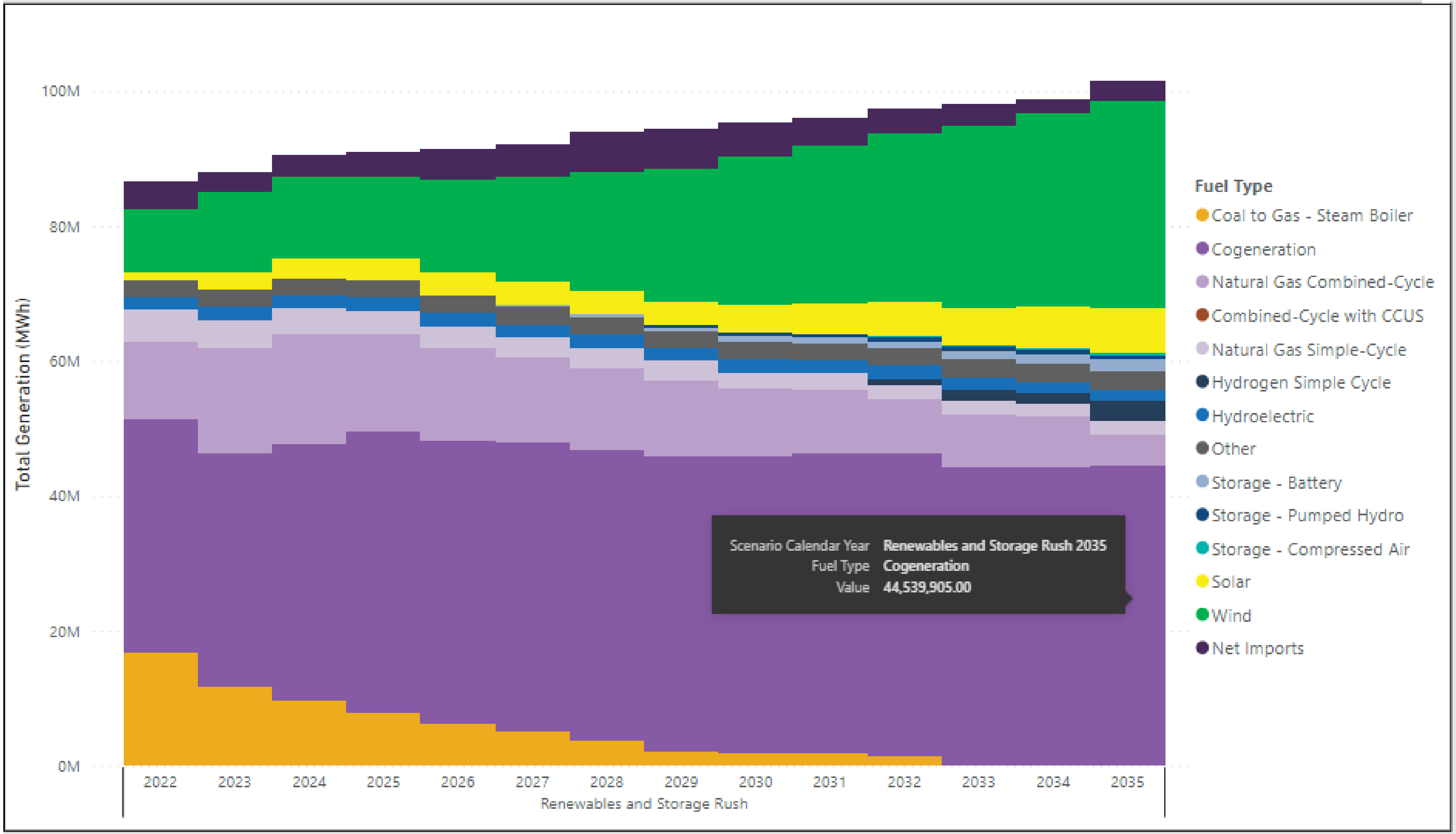


Scenario
- Select all
- Dispatchable D...
- First Mover Ad...
- Renewables an...

Year
- 2031
- 2032
- 2033
- 2034
- 2035
- 2036
- 2037
- 2038
- 2039
- 2040
- 2041

Note: For storage assets, energy refers to discharged energy outputted by the asset (net of losses). Net imports refers to annual teract with the report

Total Generation



Scenario

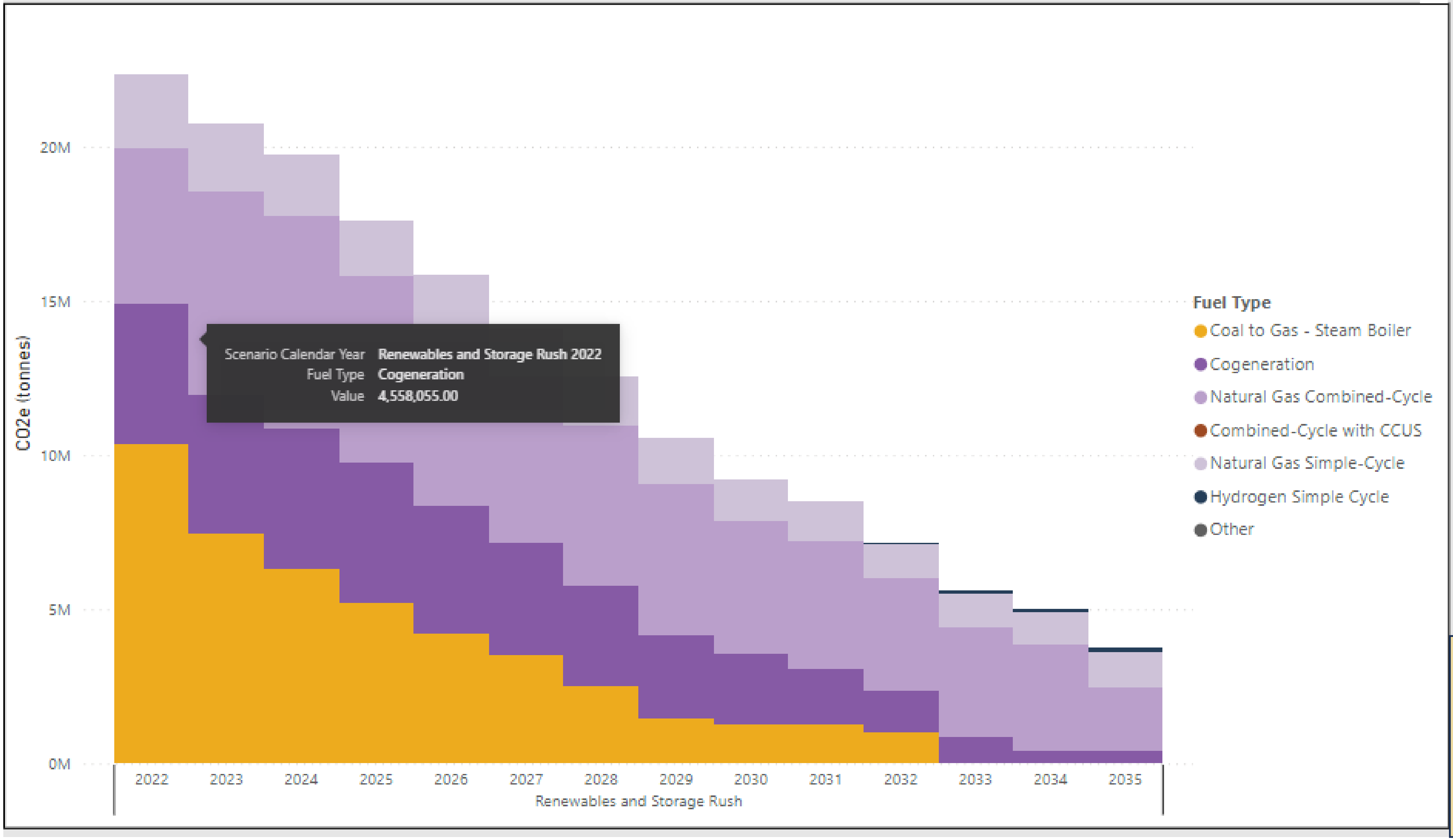
- Select all
- Dispatchable D...
- First Mover Ad...
- Renewables an...

Year

- 2031
- 2032
- 2033
- 2034
- 2035
- 2036
- 2037
- 2038
- 2039
- 2040
- 2041

Note: For storage assets, energy refers to discharged energy outputted by the asset (net of losses). Net imports refers to annual

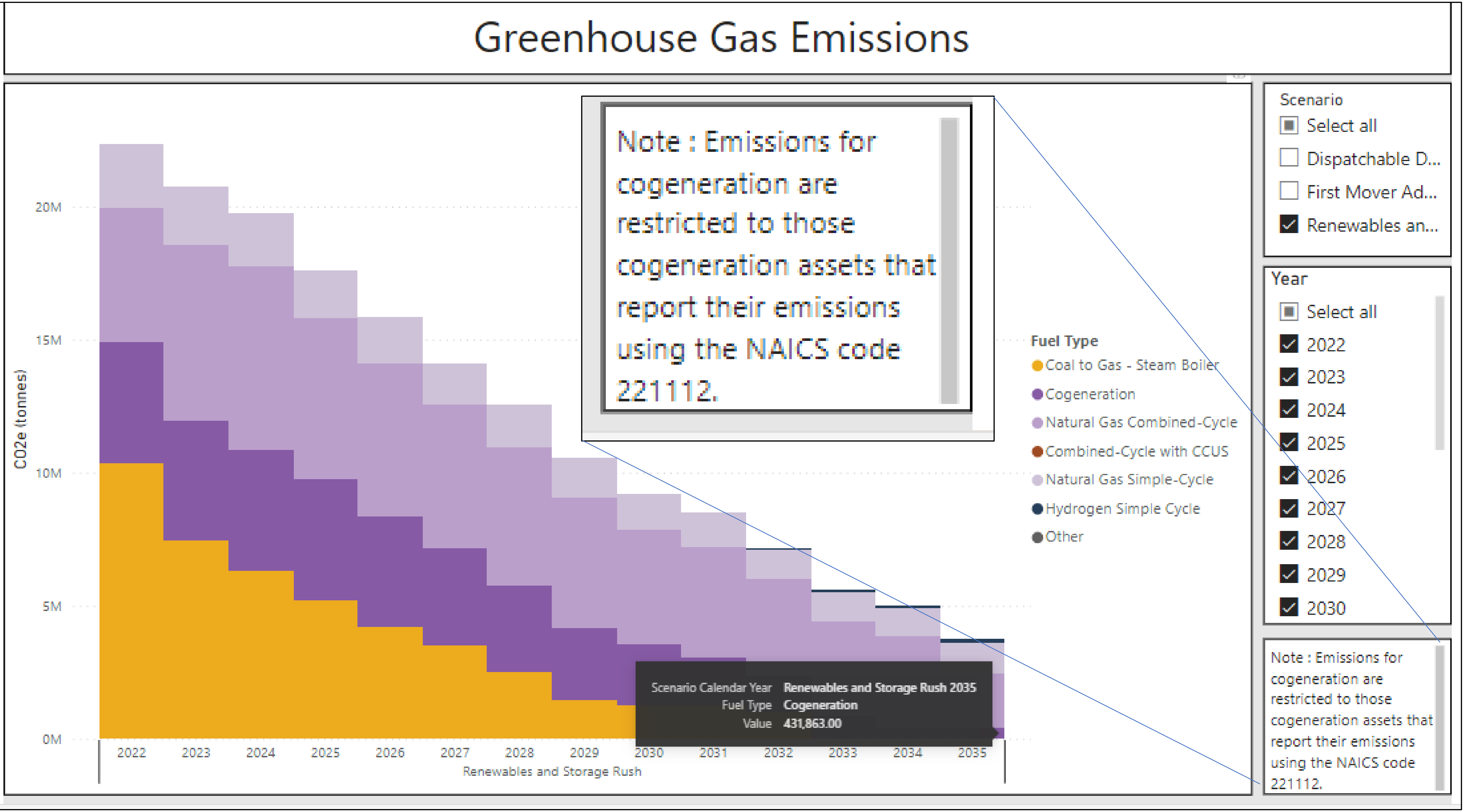
Greenhouse Gas Emissions



Scenario
- Select all
- Dispatchable D...
- First Mover Ad...
- Renewables an...

Year
- 2032
- 2033
- 2034
- 2035
- 2036
- 2037
- 2038
- 2039
- 2040
- 2041

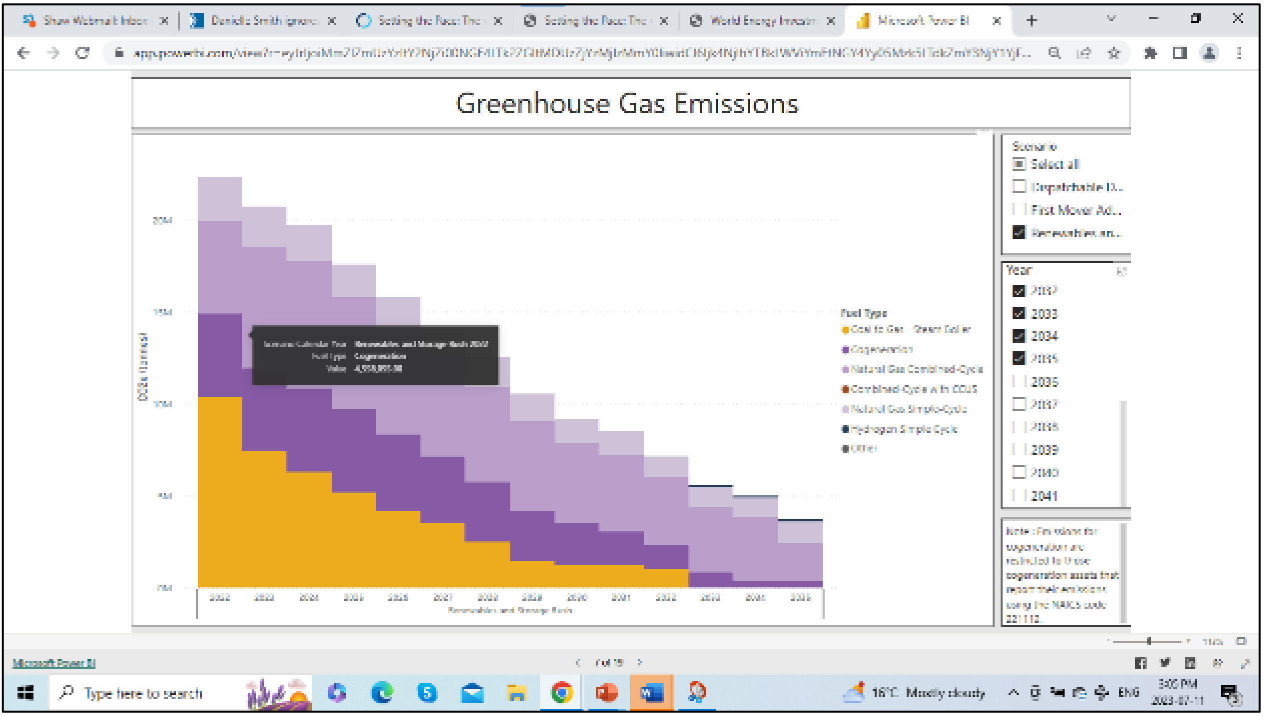
Note : Emissions for cogeneration are restricted to those cogeneration assets that report their emissions using the NAICS code 221112.

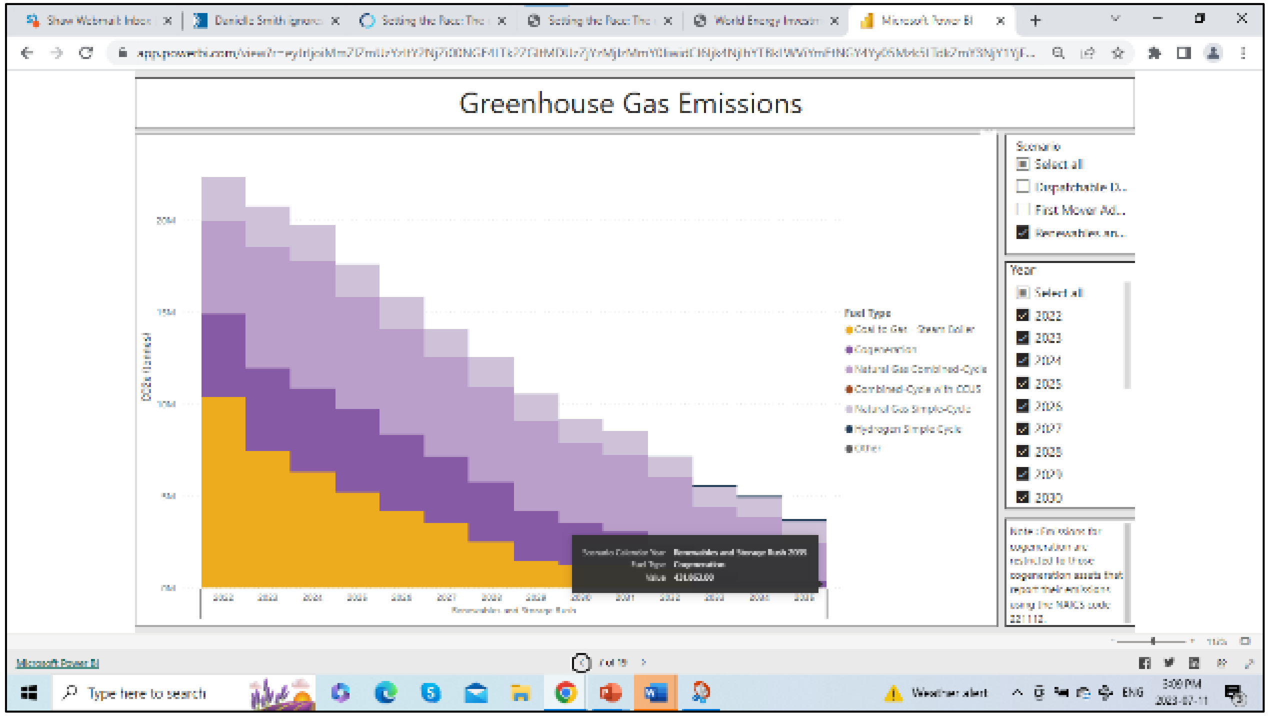

Greenhouse Gas Emissions
Note : Emissions for cogeneration are restricted to those cogeneration assets that report their emissions using the NAICS code 221112.
20M
15M
10M
5M
0M
CO2e (tonnes)
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
Renewables and Storage Rush
Scenario Calendar Year Renewables and Storage Rush 2035
Fuel Type Cogeneration
Value 431,863.00
Fuel Type
Coal to Gas - Steam Boiler
Cogeneration
Natural Gas Combined-Cycle
Combined-Cycle with CCUS
Natural Gas Simple-Cycle
Hydrogen Simple Cycle
Other
Scenario
Select all
Dispatchable D...
First Mover Ad...
Renewables an...
Year
Select all
2022
2023
2024
2025
2026
2027
2028
2029
2030
Note : Emissions for cogeneration are restricted to those cogeneration assets that report their emissions using the NAICS code 221112.

AESO assumed Cogen GHG emissions 2022 and 2035

2022 **4,558,055 tnes CO2e**

2035 **431,863 tnes CO2e**





In the Renewables and Storage Rush Scenario AESO assumes 97% Cogen emission intensity ‘improvement’. Is this even feasible and at what cost?

2022

- 34,457,108 MWh
- 4,558,055 tnes CO2e
- Emission Intensity
  - 0.132 tne CO2e/MWh

2035

- 44,539,905 MWh
- 431,863 tnes CO2e
- Emission Intensity
  - 0.0097 tne CO2e/MWh

Read the fine print !

Emissions Reduction Outcomes

EMISSIONS CALCULATION METHODOLOGY

The AESO's Net-Zero Pathways Analysis focuses on emissions outcomes from potential electricity grid future energy supply mixes. The diverse nature of the Alberta electricity system's generation supply introduces complexity in the calculation of emissions. Many facilities in Alberta generate electricity on site as part of their manufacturing production, refining, and resource extraction activities. The integrated nature of these facilities may lead to the export of excess electricity to the AIES and may also introduce multiple sources of greenhouse gas emissions from a single facility.

Greenhouse gas records collected by the Government of Canada in the Greenhouse Gas Reporting Program (GHGRP) – Facility Greenhouse Gas (GHG) Data[56] provide detailed insights into sectoral emissions, categorized by North American Industry Classification System codes (NAICS codes).

Based on available data, accurately differentiating between emissions attributed to electricity production and those attributed to other industrial activities becomes difficult. Cogeneration—the simultaneous production of electricity and other useful products—further complicates the calculation of emissions from integrated facilities: A single cogeneration unit may produce useful process heat and electricity, as well as greenhouse gas by-products which are single-source emissions related to the creation of multiple products.

The AESO's calculation of emissions follows the methodology of greenhouse gas emissions reported to the Government of Canada's GHGRP in Alberta, associated with the following NAICS codes:

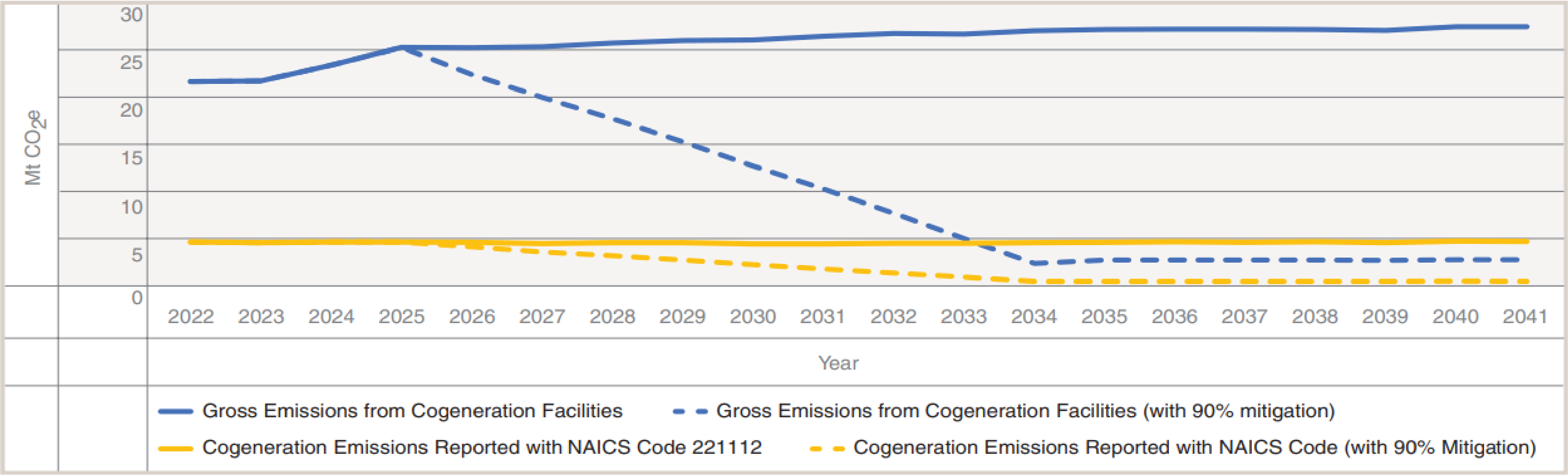
- 221112 - Fossil-fuel electric power generation
- 221111 - Hydro-electric power generation
- 221119 - Other electric power generation

There are approximately 1,000 MW of cogeneration facilities, out of 5,197 MW of existing capacity, that report their greenhouse gas emissions using the NAICS codes 221112. Such facilities are included in the emissions calculations performed by the AESO. This methodology enables accurate comparison of greenhouse gas emissions forecasts with historical data collected by the Government of Canada.

Gaslighting:

Manipulation using counterfactual assumptions

FIGURE 27: Cogeneration Emissions



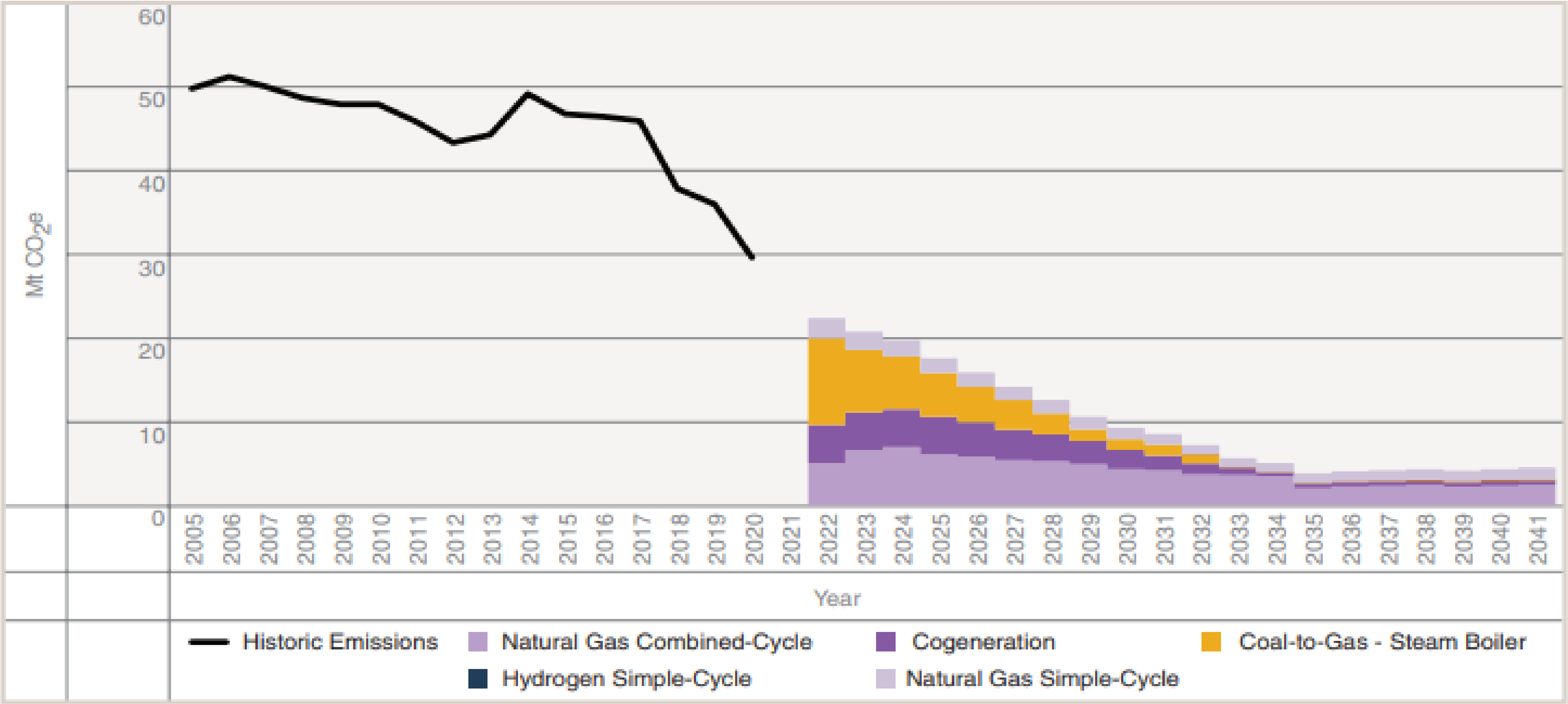
Assumptions regarding cogen

Cogeneration facilities in Alberta service the oil and gas sector, chemical production sector, pulp and paper industry and various other economic sectors. These facilities typically report greenhouse gas emissions in their primary product categories. The AESO anticipates that governments will take an economy-wide approach to emissions reductions, and that similar greenhouse gas targets will be implemented in sectors other than electric power generation to achieve reduction objectives. It is therefore plausible that pre-combustion and post-combustion carbon sequestration methods will be able to reduce carbon dioxide emissions from cogeneration facilities by 90 per cent.

To the extent that the AESO's scenario emissions forecasts contain physical emissions, the AESO has assumed that remaining emissions may need to use carbon offsets, emissions performance credits, or other regulatory mechanisms that enable net-zero emissions outcomes. However, the AESO also expects that owners of the remaining emitting facilities will explore alternatives to mitigate compliance costs, including CCS retrofits, hydrogen firing or co-firing, and efficiency upgrades. The AESO has not included the estimation of these retrofit alternatives in its cost or emissions forecast due to the complex and unique nature of individual facility constraints and opportunities. Instead, the AESO has estimated the cost of offsets or emissions performance credits, assuming a 15 per cent discount to the price of carbon.

Renewables and Storage Rush Scenario Emissions Results

FIGURE 30: Renewables and Storage Rush Scenario – Total Electricity Sector Greenhouse Gas Emissions



The Renewables and Storage Rush Scenario results in 3.8 megatonnes of greenhouse gas emissions by 2035. The majority of these emissions come from combined-cycle and simple-cycle natural gas units, with a modest amount of emissions from cogeneration sources. Fuel switching, low-carbon fuel blending, and post-combustion carbon-capture could provide physical mitigation opportunities, and incremental offsets can provide a net-zero emissions outcome.

Emissions Reductions

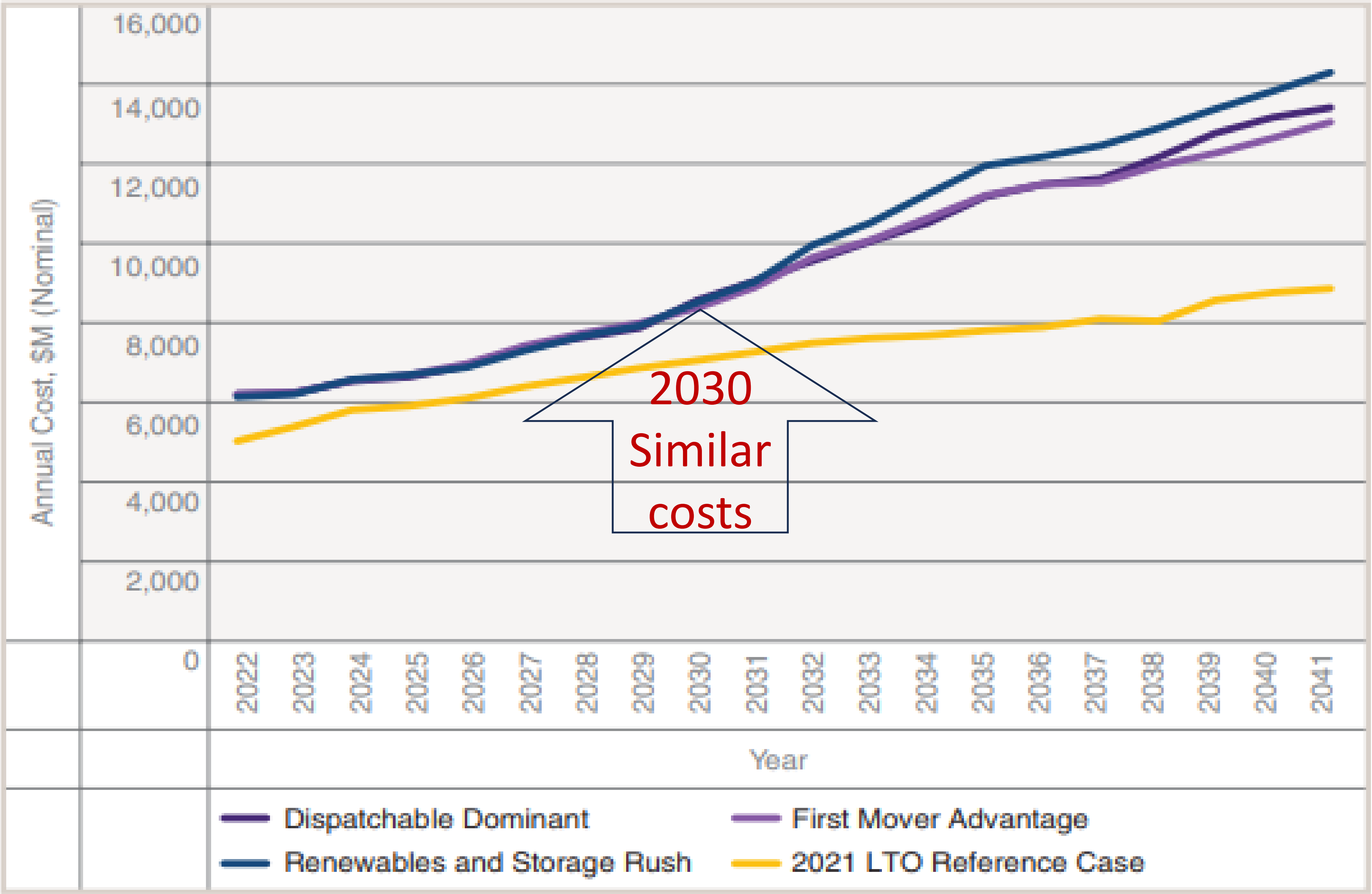
Under all three scenarios, by 2035 the Alberta electricity system could approach zero emissions; however, it is anticipated that a small volume of emissions would remain due to the continued operation of some unabated assets as well as residual emissions, since carbon-capture technologies do not capture 100 per cent of emissions. Two approaches can be taken to close this remaining gap and achieve net-zero: the use of emissions offsets or credits or physical abatement via retrofits or replacement of unabated assets. Either approach could result in a net-zero emissions electricity sector by 2035, and the AESO expects that ultimately the lowest cost alternatives will be adopted by large emitters in the electricity sector. However, full physical abatement across all assets is likely to be operationally unrealistic (for example due to residual emissions under CCS technologies) and consequently marginal physical abatement costs are likely to escalate rapidly as sector emissions trend toward zero. As such, the AESO does not anticipate that zero physical emissions will be achieved by 2035, pointing to a role for offsets in achieving net-zero.

Costs

The high-level cost estimates provided in the AESO's Net-Zero Report demonstrate that the diverse technological pathways that can be followed to reduce electricity sector emissions have the potential to increase system costs materially. Relative to the non-net-zero 2021 LTO Reference Case, incremental costs of $44 to $52 billion (nominal, undiscounted) for generation capital including return, generation operating costs and transmission revenue requirements are required. This represents a 30 to 36 per cent increase relative to the LTO baseline. Comparatively, the Dispatchable Dominant, First-Mover Advantage, and Renewables and Storage Rush scenarios demonstrate a similar cost trajectory despite the different emissions reduction strategies employed in each scenario. Cumulative costs from 2022-2041 are within 5 per cent between all three scenarios.

Given the relatively immature nature of certain generation technologies assessed in the AESO's Net-Zero Report Analysis, a degree of caution should be taken in interpreting cost results. Technological costs and operational performance of emerging technologies could deviate materially from the estimates used in the report. The AESO has also not been able to estimate costs in all electric system categories, with distribution system costs being the most notable.

FIGURE 39: Estimated Electricity Cost



2023 LTO Generation Forecast – Key Messages

- Development of supply technologies in the 2023 LTO is heavily influenced by federal investment tax credit (ITC) subsidies, increasing carbon tax rates, tightening high-performance benchmarks, and *Clean Electricity Regulations* (CER)
- The 2023 LTO Reference Case forecast anticipates significant renewable development in the 2020's and early 2030's driven by corporate PPA interest, 30% reduced capital costs from the federal investment tax credits, and forecast technological capital cost declines
  - The pace of renewable development is expected to accelerate compared to previous AESO forecasts
- Carbon capture retrofits of existing combined-cycle assets are viewed as cost-effective thermal technology in the 2020's due to the reduced carbon price exposure, while receiving 50% subsidization of carbon capture technology costs via refundable federal investment tax credits
- Least efficient gas assets are forecast to retire in the near term due to increased competition from new combined-cycle and cogeneration assets
- Energy storage experiences growth in niche ancillary service applications, but is not expected to be cost effective for energy arbitrage given forecast costs

Key Generation Assumptions

- Generation forecast is predicated on the existing market framework
  - New build forecast follows economic build, based on a 10.5% pre-tax Weighted Average Cost of Capital (WACC)
  - Model assumes a congestion free transmission system
- Wind, solar, and battery energy storage capital costs are expected to decline towards 2030
- Combined-cycle natural gas with carbon capture, utilization, and storage (CCUS) and hydrogen-fired technologies represent key decarbonization technologies in the 2023 LTO
- Nuclear technologies, hydro-electric technologies, and storage technologies have been included as future decarbonization opportunities

PEMBINA Institute

https://www.pembina.org/reports/alberta-roadmap-to-the-new-energy-economy.pdf

Alberta has not made effective progress on reducing total emissions

As noted above, Alberta remains the largest single provincial contributor to Canadian emissions. This is in part due to its large oil and gas industry (which emits 132.8 megatonnes (Mt) per year), a relatively carbon intensive electricity system (29.3 Mt), as well as a lack of specific policies and incentives to reduce emissions in sectors such as transportation (28.1 Mt), buildings (20.7 Mt), and agriculture (19.4 Mt) (Figure 3).

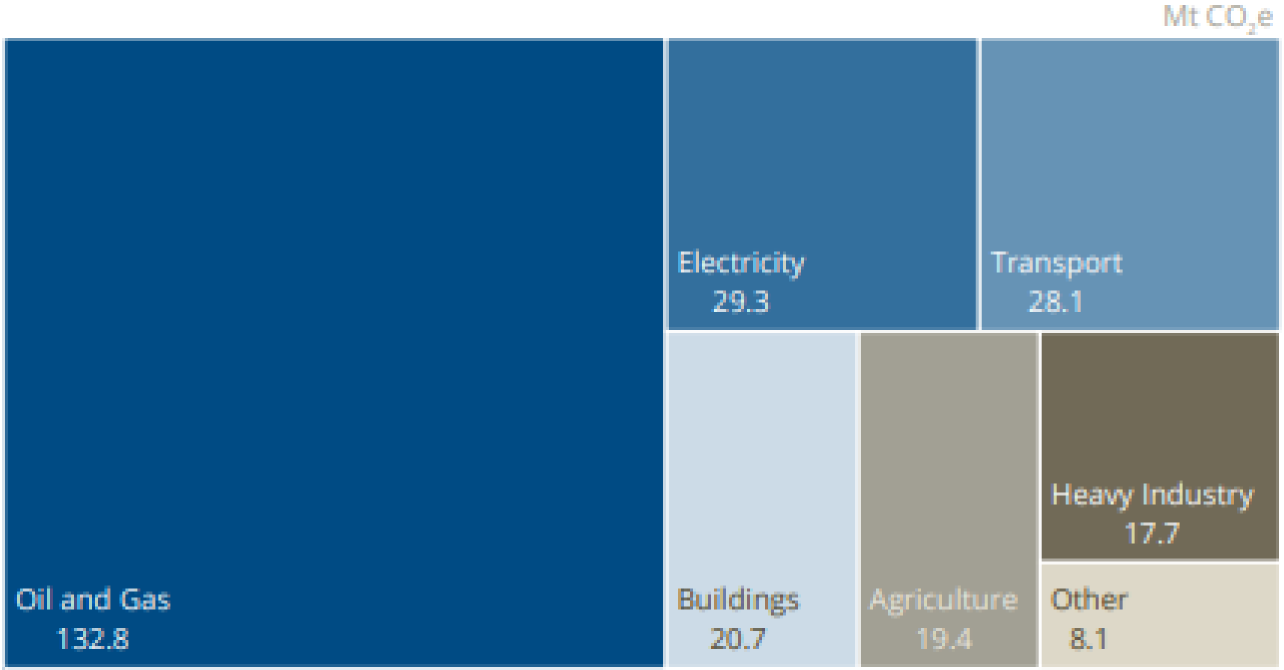


Figure 3. Sectoral contribution to emissions in Alberta, 2020

Data source: Environment and Climate Change Canada[10]

METHANE

GWP of 84 over a 20 year time frame

Address methane emissions

Methane abatement is amongst the cheapest, most easily implemented options for emissions reductions in the oil and gas sector. Our research, based in Alberta, demonstrates that strong regulations can result in drastically lowered emissions, without negatively impacting levels of oil and gas production.[23] We therefore recommend that Alberta set a provincial target to reduce methane emissions by at least 75% by 2030, and concurrently strengthen regulations to achieve that. In doing so, Alberta can build on its leadership on methane, which has created a whole ecosystem of methane technology companies and world-leading specialists in the province. According to the Methane Emission Leadership Alliance, a grouping of Canada's leading methane-reduction practitioners, there are more than 170 Canadian companies providing methane-emissions management solutions right now — 80% of which say they expect jobs to grow as a result of methane regulations.

Modernize, decarbonize, and upgrade Alberta's electricity grid

Creating a clean electricity grid will provide environmental, social and economic benefits for Alberta and Albertans. It is also an opportunity to modernize the system, which will improve the resilience of Alberta's electricity supply. Diversifying the generation mix, investing in energy efficiency, and enabling demand-side management will result in electricity being provided where and when it is needed, at an affordable cost to Albertans — given the low and still falling cost of clean energy solutions (Figure 11).

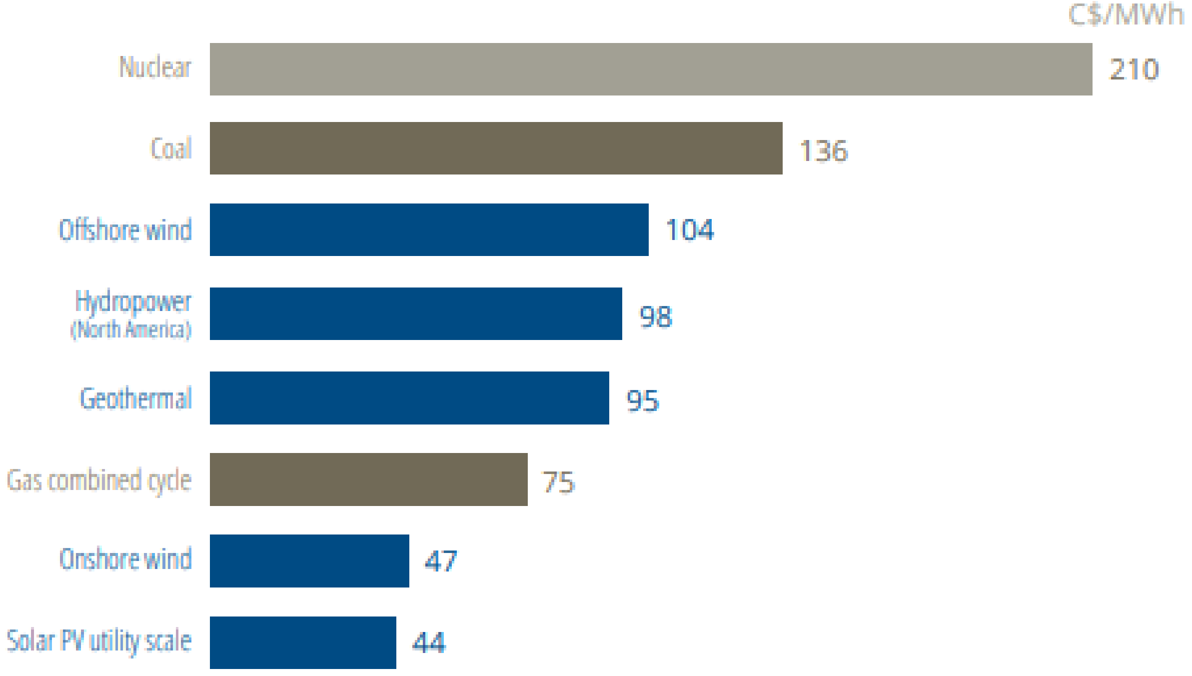


Figure 11. Global levelized cost of energy for various generation options

Data sources: Lazard, IRENA[25]

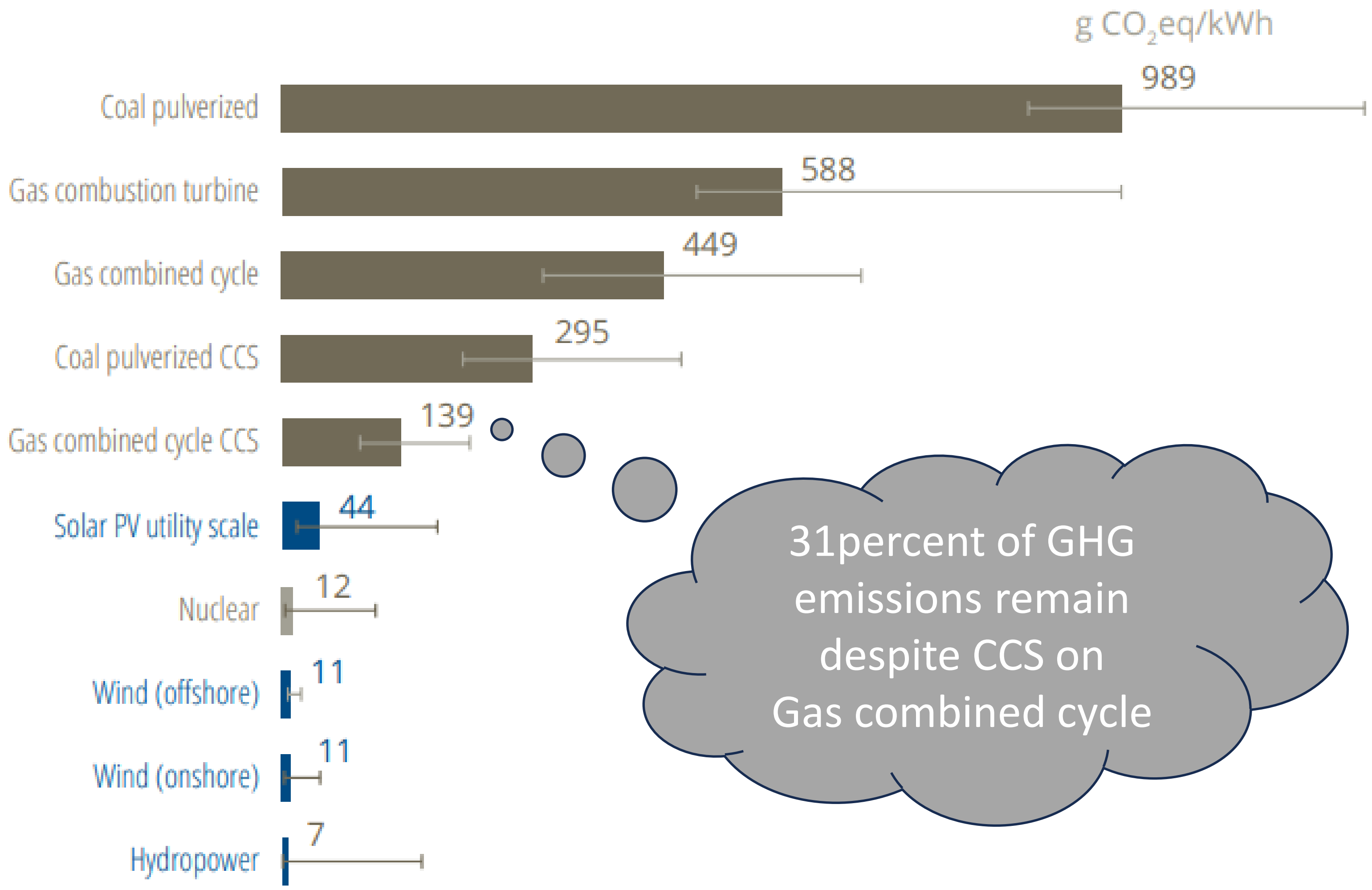


Figure 12. Global average life-cycle GHG emissions by generation type

Data source: UNECE[26]

Electricity

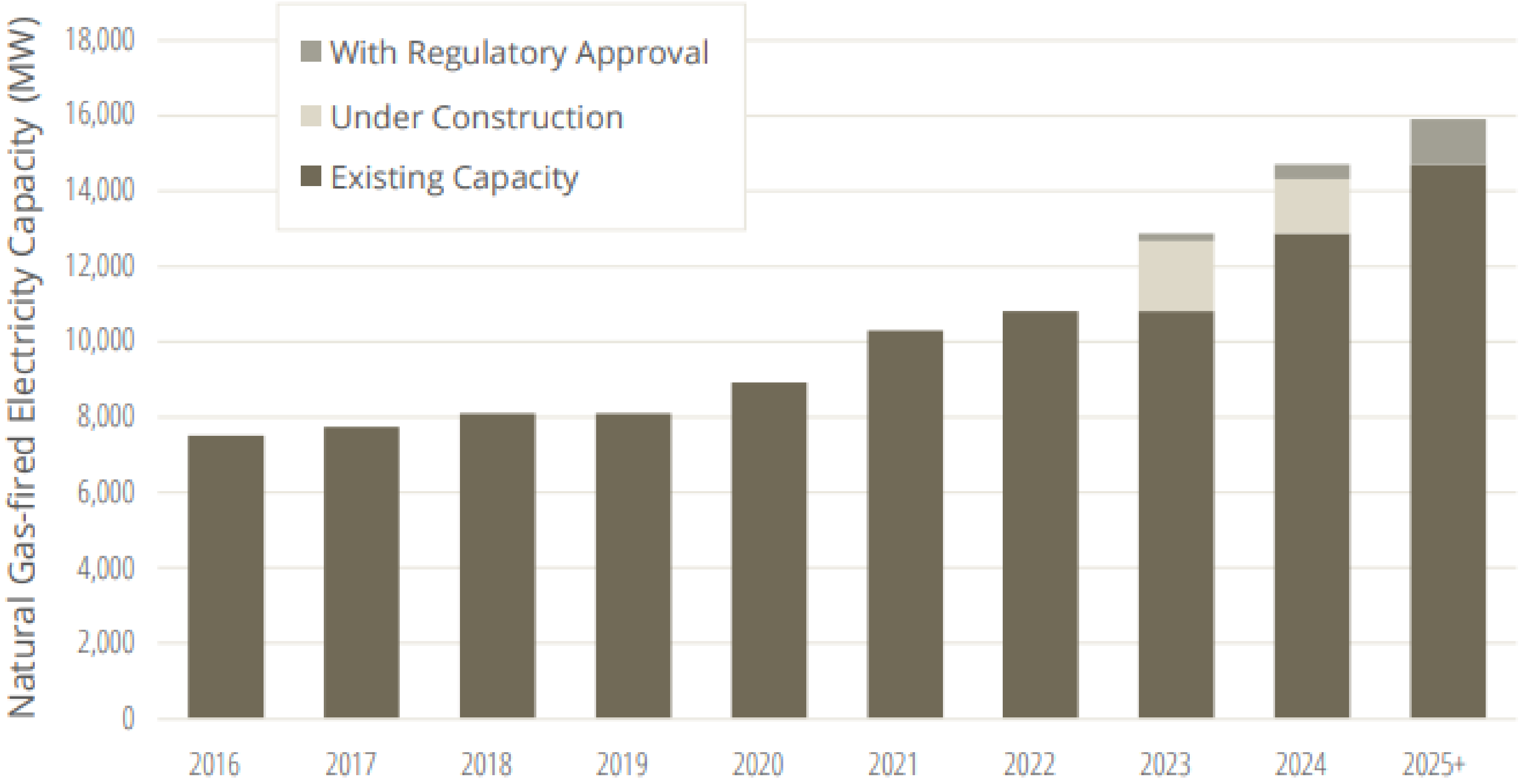


Figure 13. Total installed and planned capacity of natural gas-fired electricity generation in Alberta

Data sources: CER, AESO[27]

Caution regarding Gas power generation

On this, Alberta is off to a good start. As mentioned earlier, it has led Canada in installations of wind and solar over the last few years, driven by private sector investment in Alberta's deregulated market. Additionally, the province is on track to fully retire coal as a source of electricity in 2023, some forty years ahead of the schedule that was in place at in 2012.

However, Figure 13 demonstrates that while installed coal capacity in Alberta is declining rapidly, emitting natural gas generation is growing dramatically — undermining the achievements of the coal phase-out.

In the next two years, an additional 3886 MW of new gas capacity is set to be added to the Alberta grid. If this happens, Alberta will continue to have one of the most emissions-intensive grids in the country.

These gas power stations would also be at risk of becoming stranded assets, either due to lack of cost-competitiveness, or because they will not be compatible with forthcoming federal regulations aimed at achieving a nationwide net-zero electricity grid by 2035. A grid dominated by gas also exposes Albertans further to volatile gas prices.

Fast, decisive action is required to mitigate against this risk of gas lock-in in Alberta, and instead spur large-scale investment in clean grid technologies. In the context of the above, there should be particularly careful consideration paid to new investments and approvals of unabated gas-fired power stations in Alberta.

Electricity

RECOMMENDATIONS

Commit to a net-zero grid by 2035

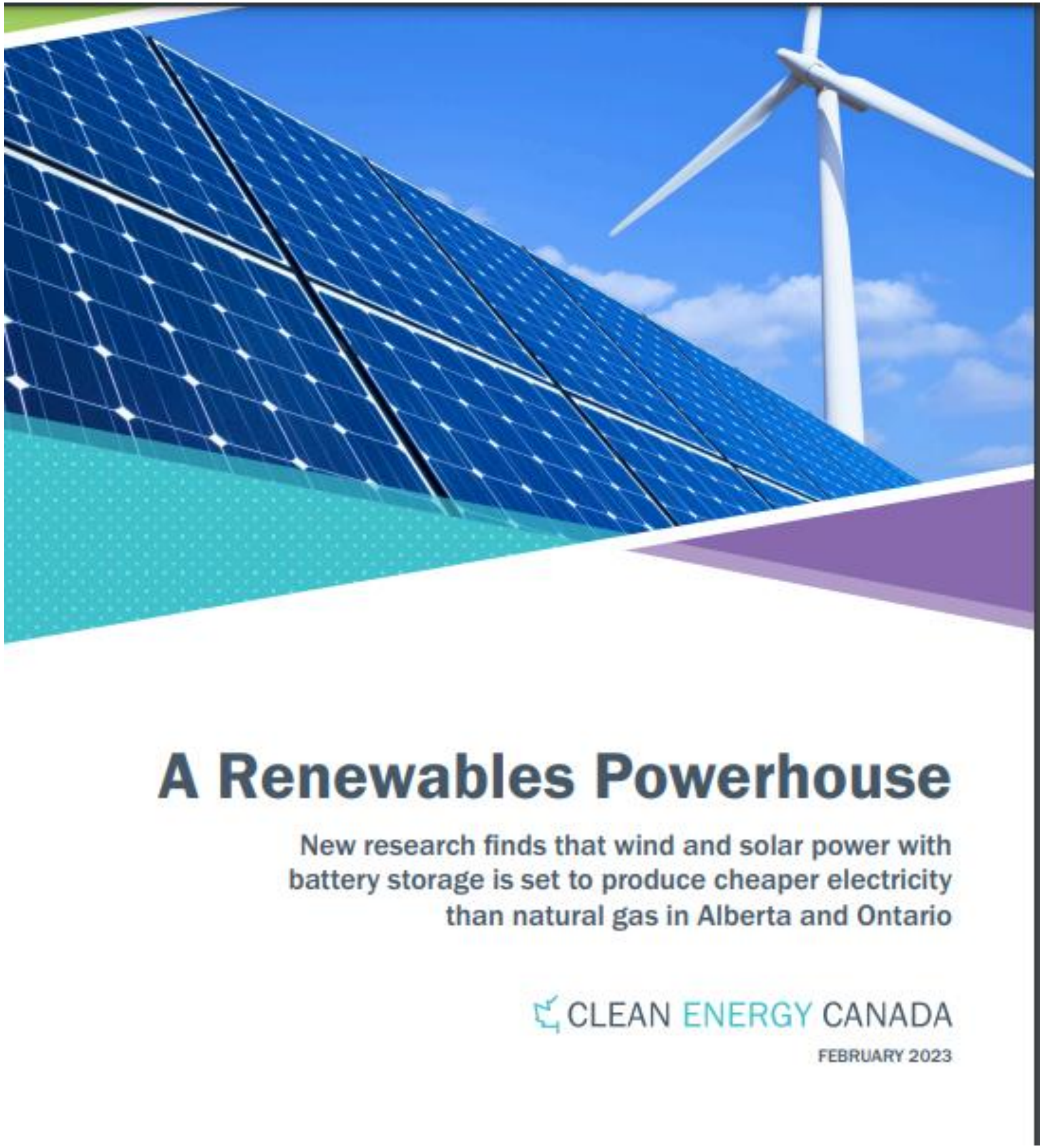
This would bring Alberta in line with Canada's nationwide commitment to the same — which itself is aligned with clean grid commitments from peer economies such as the U.S. and U.K. Setting a clear target will not only make Alberta more attractive to companies with sustainability goals, but will also send an important early signal to generators and utilities in the province about investments today that will affect the grid of 2035 and beyond.[28] It will also provide an opportunity for the province to create a made-in-Alberta plan that addresses the unique features and challenges of our electricity grid.

In addition, using transmission infrastructure to connect Alberta to neighbouring grids will allow it to bring in low-cost energy from other provinces when available, and export the electricity it generates when there is excess. Such balancing of the grid across borders helps the development of cheap renewables, while reducing costs to ratepayers.[29]

Similarly, as the costs of energy storage decline rapidly, the province must encourage the development and integration of significant amounts of storage in the grid. This will also help reduce electricity costs, while increasing grid reliability.[30] There are opportunities to leverage funding from the federal government for such investments.

CLEAN ENERGY CANADA

https://cleanenergycanada.org/report/a-renewables-powerhouse/



A Powerful example from Australia

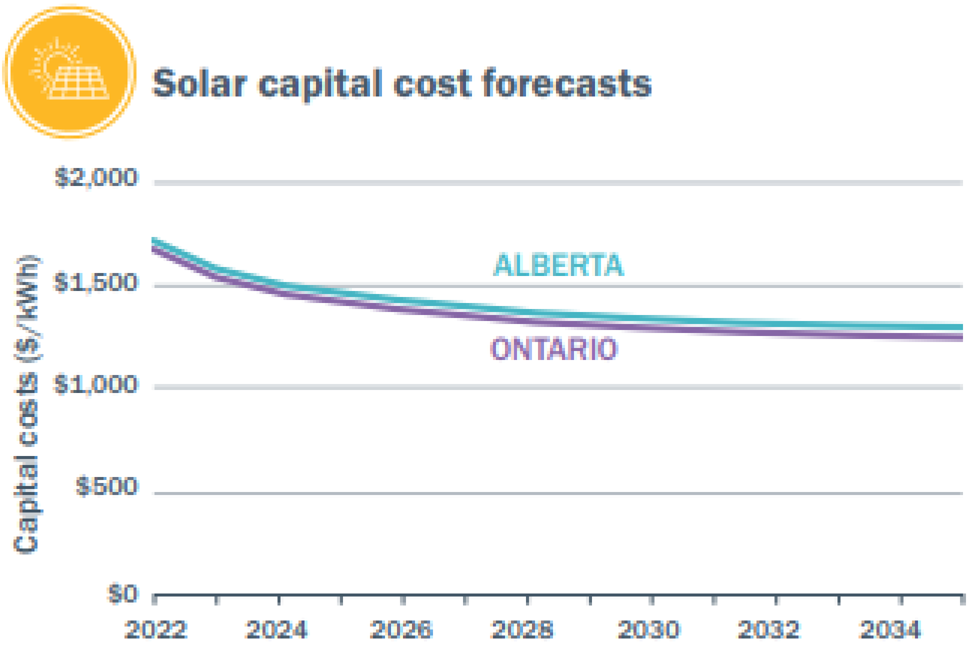
SOUTH AUSTRALIA

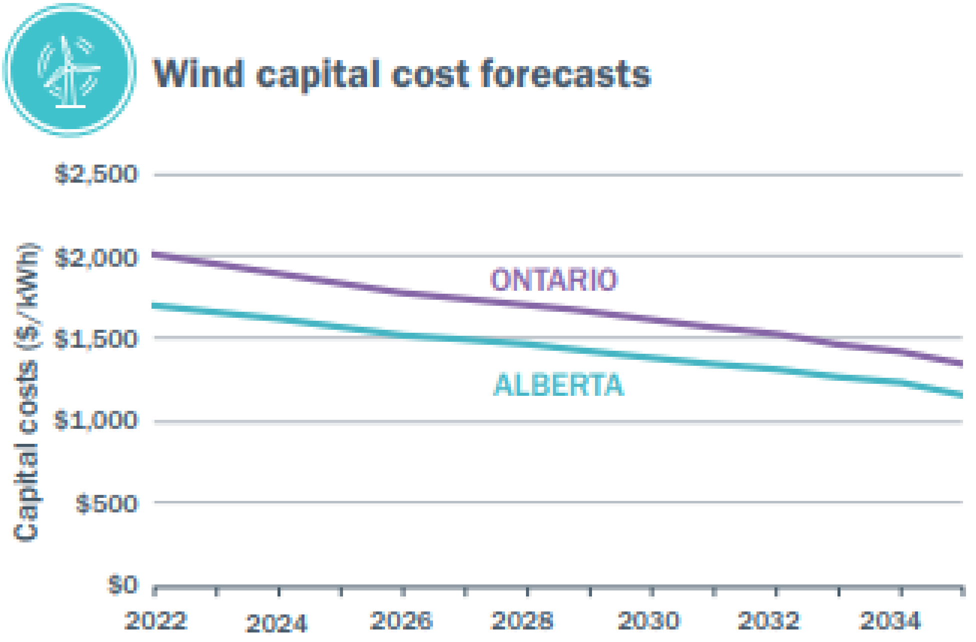
The rise of renewables is especially impressive in South Australia. In 2006, the region was wholly reliant on fossil fuels for electricity generation, before completely transforming its grid through good planning and policy.[47] By 2021, wind and solar (both utility-scale and rooftop) supplied 63% of electricity demand in the state, second in the world only to Denmark.[48,49] The Australian Energy Market Operator forecasts this could rise to approximately 85% by 2025, and the state is now aiming to supply 100% of its electricity from renewables by 2030.[48] The early adoption of grid-scale batteries was key to its success.

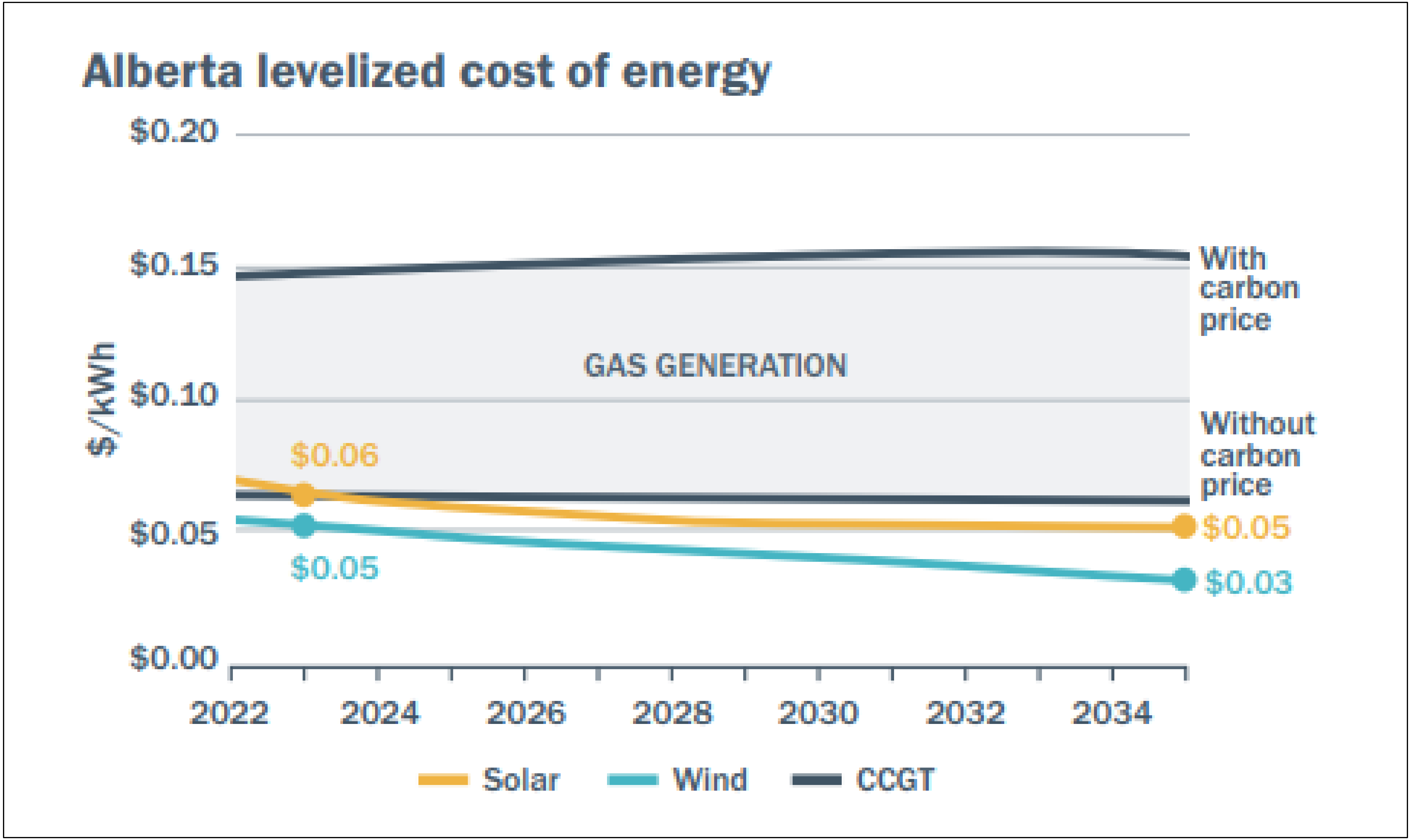
In 2017, South Australia built what was the the world's largest battery at the time and has built three more since.[49]

CLEAN ELECTRICITY IS **CANADA'S ECONOMIC ADVANTAGE**

A clean electricity grid is an economic advantage for Canada, as our largest trade partners increasingly look to forge trade relationships that favour low-carbon exports and imports. Europe has plans for carbon tariffs, for example, while it has been reported that the U.K. will propose a carbon border tax on imported steel to level the playing field against competitors with lower environmental standards.[34,35] By powering our industries with clean power and putting a price on carbon, Canada can deliver the premium low-carbon goods more and more countries and companies are looking to buy.





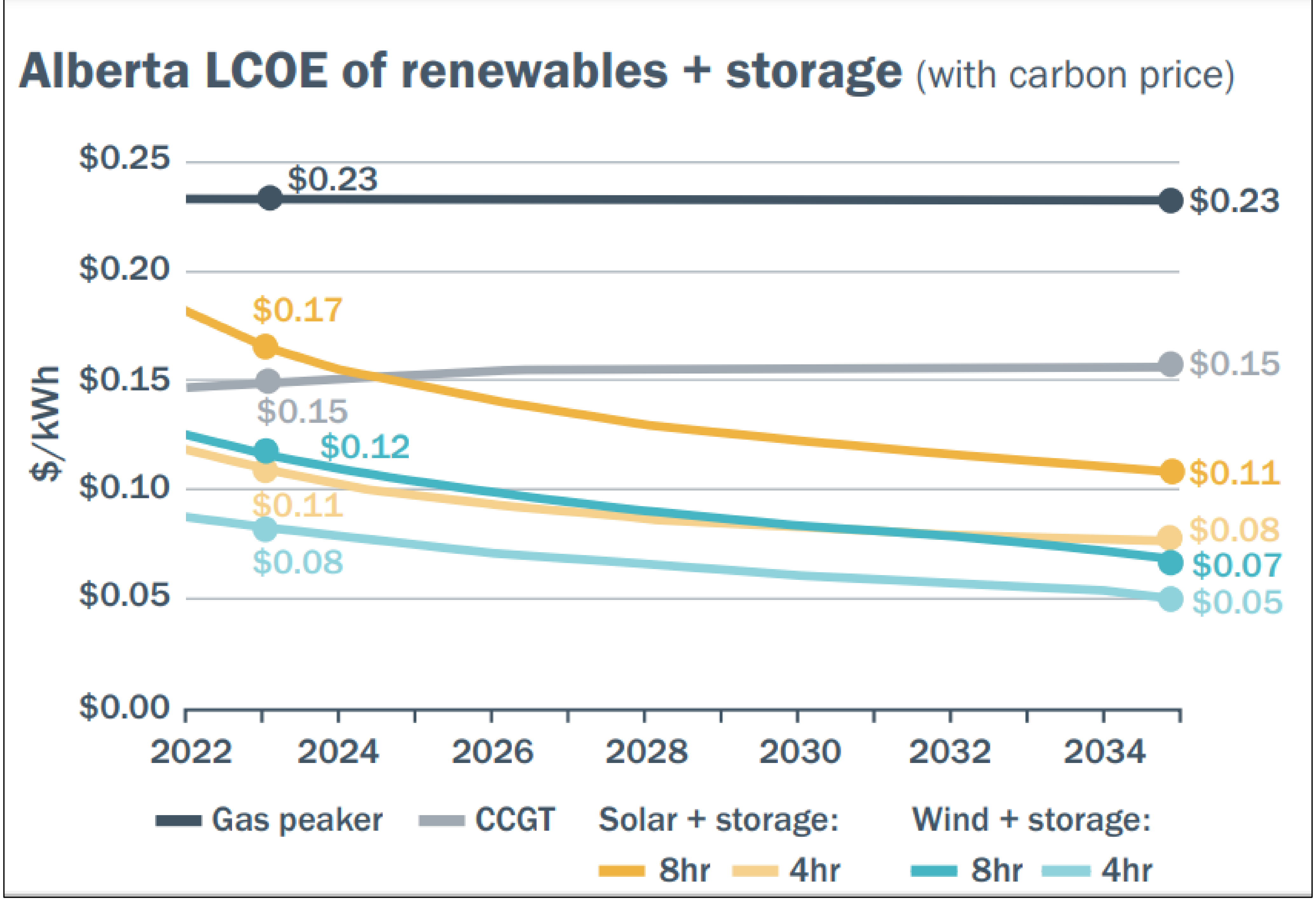

Alberta levelized cost of energy
$0.20
$0.15
$0.10
$0.05
$0.00
$/kWh
GAS GENERATION
With carbon price
Without carbon price
$0.06
$0.05
$0.05
$0.03
2022
2024
2026
2028
2030
2032
2034
Solar
Wind
CCGT

1 Electricity from wind and solar is already cost-competitive with natural gas generation in Ontario and Alberta.

When the current carbon price is also included, both wind and solar are significantly cheaper than natural gas. What's more, costs are expected to decline by a further 40% by 2035, compared to relatively flat costs for new gas deployments. That said, it's important to note that lower costs alone are only part of the consideration.[24] Wind and solar are variable resources, meaning they provide most power to the grid when the sun shines or the wind blows, which may reduce their value relative to other electricity sources. However, as costs continue to fall, there are a number of ways to complement wind and solar, one of which is energy storage.[25]

2 When paired with energy storage, wind and solar can offer dispatchable grid power at more competitive costs than gas peakers.

With energy storage added, variable renewables have more flexibility to target output during high-cost periods in the electricity market, irrespective of whether the sun is shining or the wind is blowing. By deploying batteries on their own or alongside wind and solar, surplus power can be stored and redeployed during periods of higher demand. Including four- or eight-hour storage means wind and solar power can be used to supply hour-to-hour and day-to-day energy peaks, making the electricity more valuable to utilities. While additional storage solutions will be needed to manage seasonal capacity gaps, four- or eight-hour storage is a very cost-competitive way to address daily load management needs and contribute to the reliability of the system overall. Battery technologies stand to see significant declines in cost, as innovation in battery chemistries increases their effectiveness and we reach economies of scale.[26]



Alberta LCOE of renewables + storage (with carbon price)
$/kWh
$0.25
$0.20
$0.15
$0.10
$0.05
$0.00
2022
2024
2026
2028
2030
2032
2034
$0.23
$0.23
$0.17
$0.15
$0.15
$0.12
$0.11
$0.11
$0.08
$0.08
$0.07
$0.05
Gas peaker
CCGT
Solar + storage:
8hr
4hr
Wind + storage:
8hr
4hr

Recommendation 1: Establish a Clean Electricity Standard (CES) that:

- Sets out interim carbon intensity performance standards for new and existing electricity generators, and;
- Establishes a stringency of 0g CO_2/kWh by 2035 for all electricity generation in Canada.

Recommendation 2: Ensure the CES comes into force by 2023, including the establishment of an interim standard in 2023 that applies to new facilities, and an interim standard in 2030 that applies to existing facilities.

Recommendation 3: Establish an interim standard for 2023, which sets a carbon intensity performance standard for all new electricity generation facilities that is sufficiently stringent to exclude non-abated natural gas facilities from complying.

Recommendation 4: Establish an interim standard for 2030 that applies to all existing electricity generation facilities, which sets a carbon intensity performance standard that is sufficiently stringent to exclude non-abated natural gas facilities from complying.

Recommendation 5: Establish the CES as a federal backstop policy that can be superseded by an equivalent provincial policy, including approaches that regulate the grid as a whole instead of individual generators. The Government of Canada should actively encourage provinces to implement equivalent, comprehensive policies, but must establish clear guidelines on what constitutes equivalency.

Recommendation 6: Remove the electricity sector from the federal output-based pricing system and apply the full federal carbon price to emissions associated with electricity generation.

Recommendation 7: Ensure revenue generated by the application of the full carbon price on the electricity sector is used to help mitigate impacts of decarbonizing the electricity system on consumer rates and ensure affordability.

Recommendation 8: In addition to carbon pricing and electricity regulation, the federal government must play a leadership role in decarbonizing Canada's electricity grid by:

- Convening relevant stakeholders to provide advice and oversight;
- Supporting the planning efforts of provinces, utilities, and Indigenous Nations, and helping drive the deployment of net-zero energy plans; and
- Accelerating the deployment of clean electricity infrastructure and technologies, including investments in new clean electricity generation capacity, grid modernization, and transmission infrastructure.

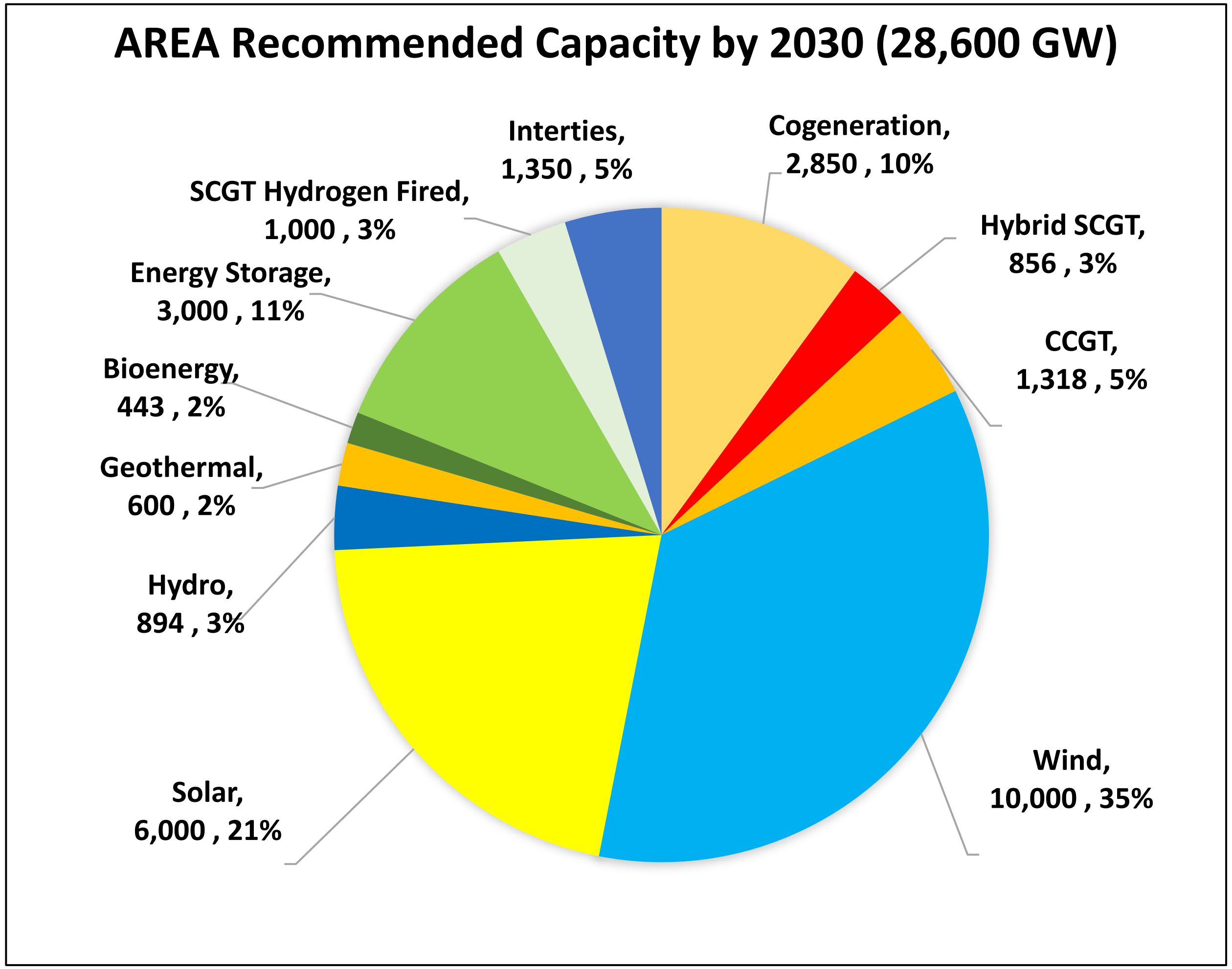
AREA
(Alberta Renewable Energy Alliance)

https://www.abrenewableenergy.ca

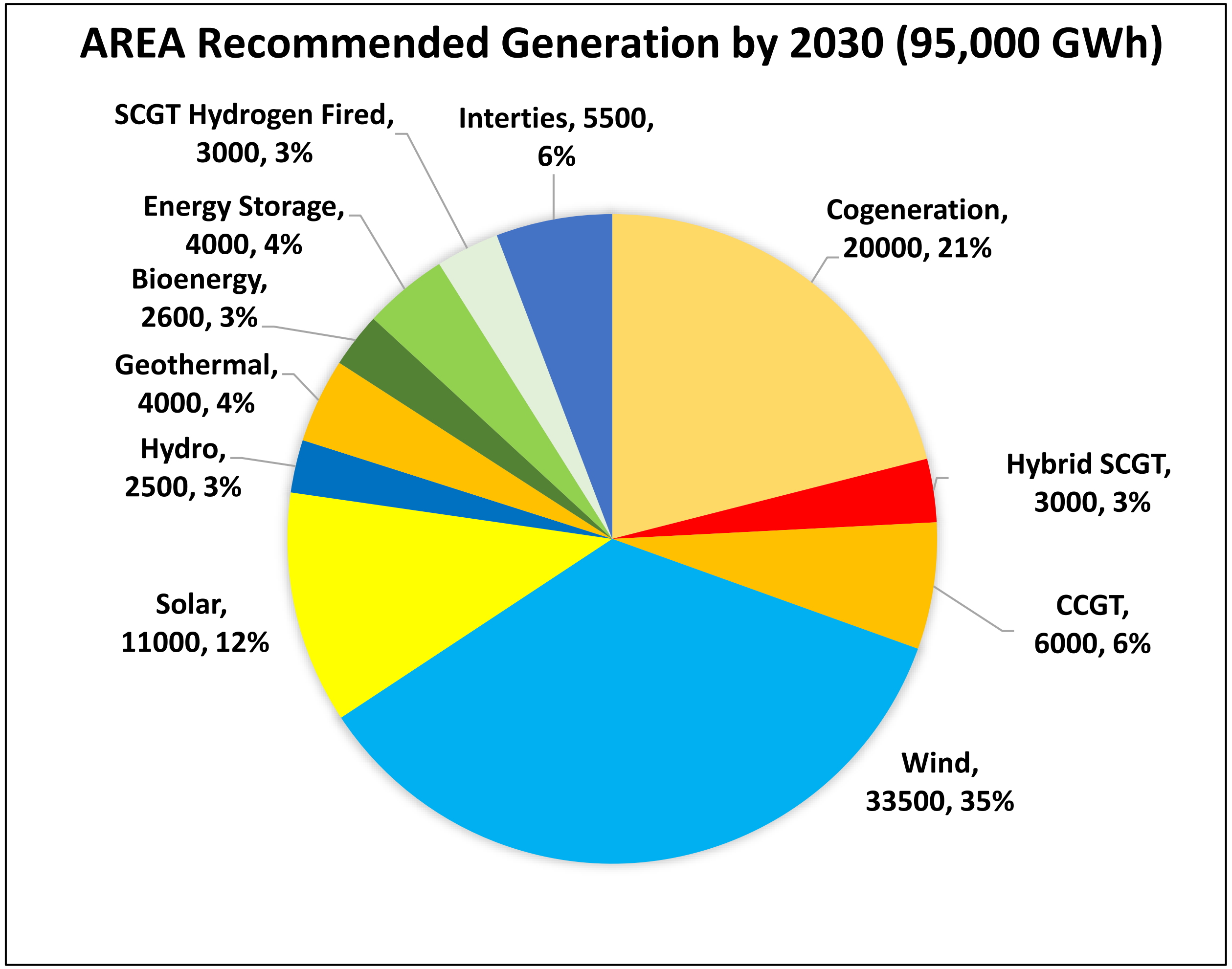
AREA Recommended Capacities by 2030 to Achieve 70% generation from Renewable Energy, Energy Storage and Hydro Interties

Total Capacity = 28,600 GW   Annual Generation in 2030 = 95,000 GWh

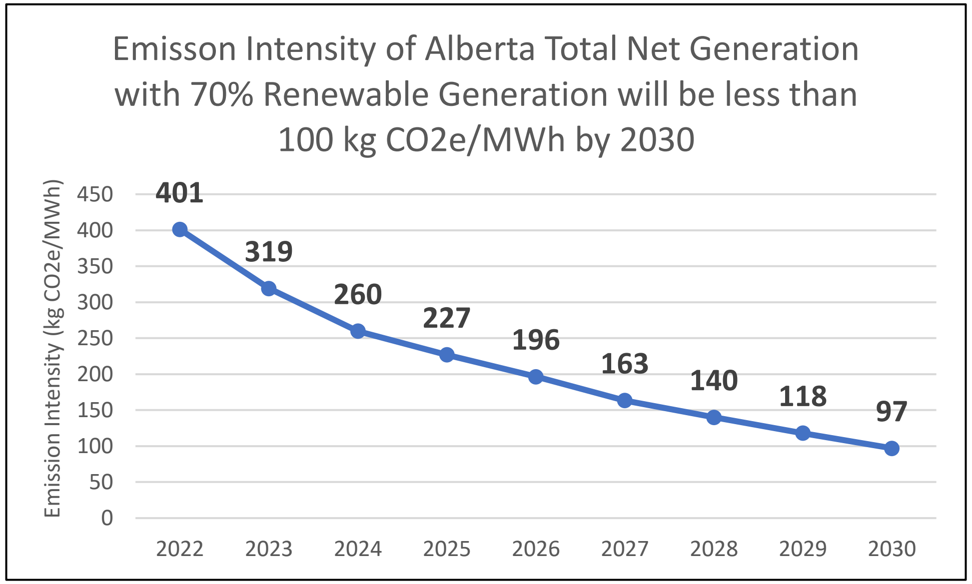
2030 Capacity (GW)

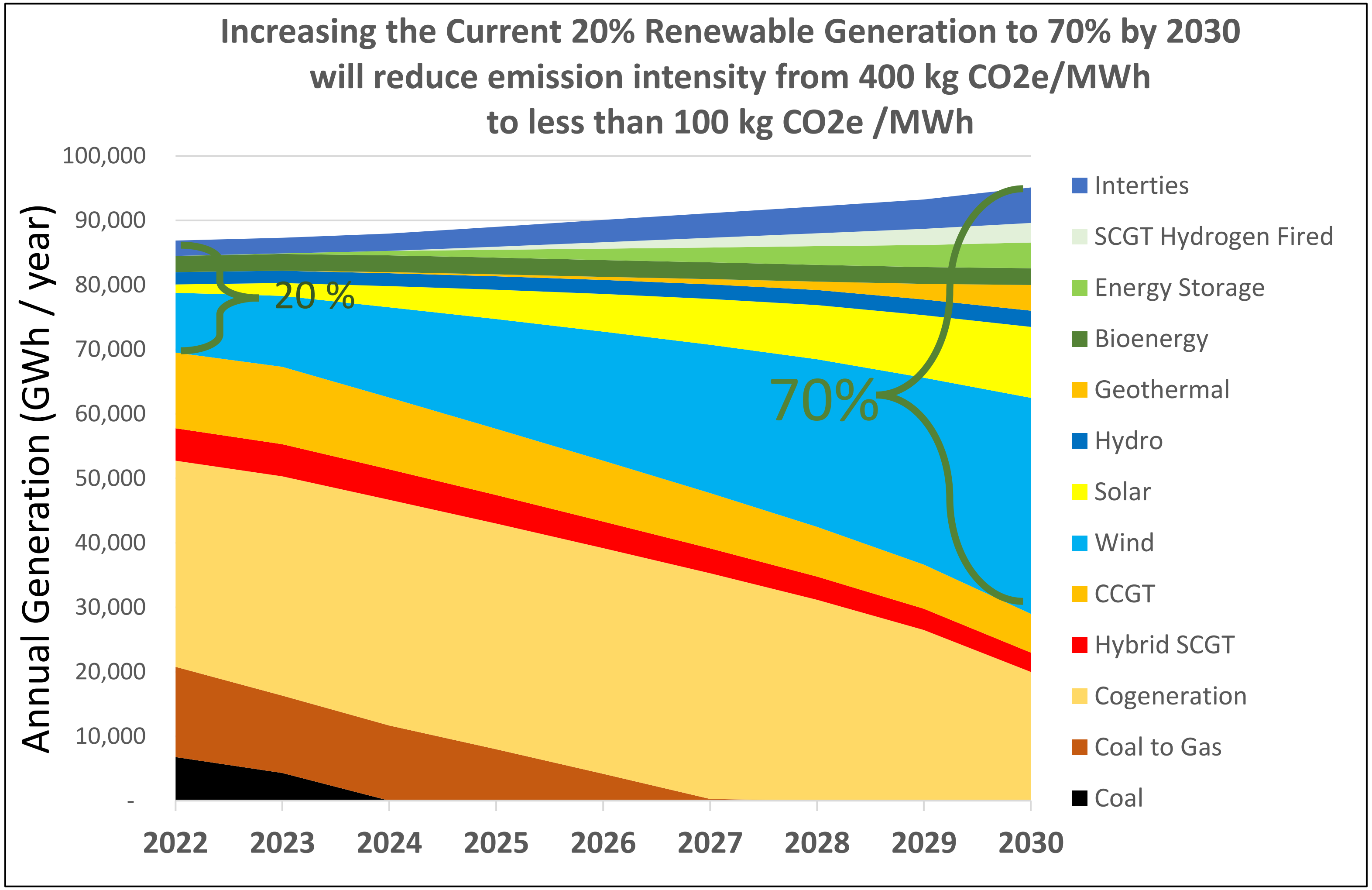


2030 Generation (GWh/year)



70% Renewable Generation and Storage by 2030 will reduce the current emission intensity of 400 kg CO2e/MWh to less than 100 kg CO2e/MWh



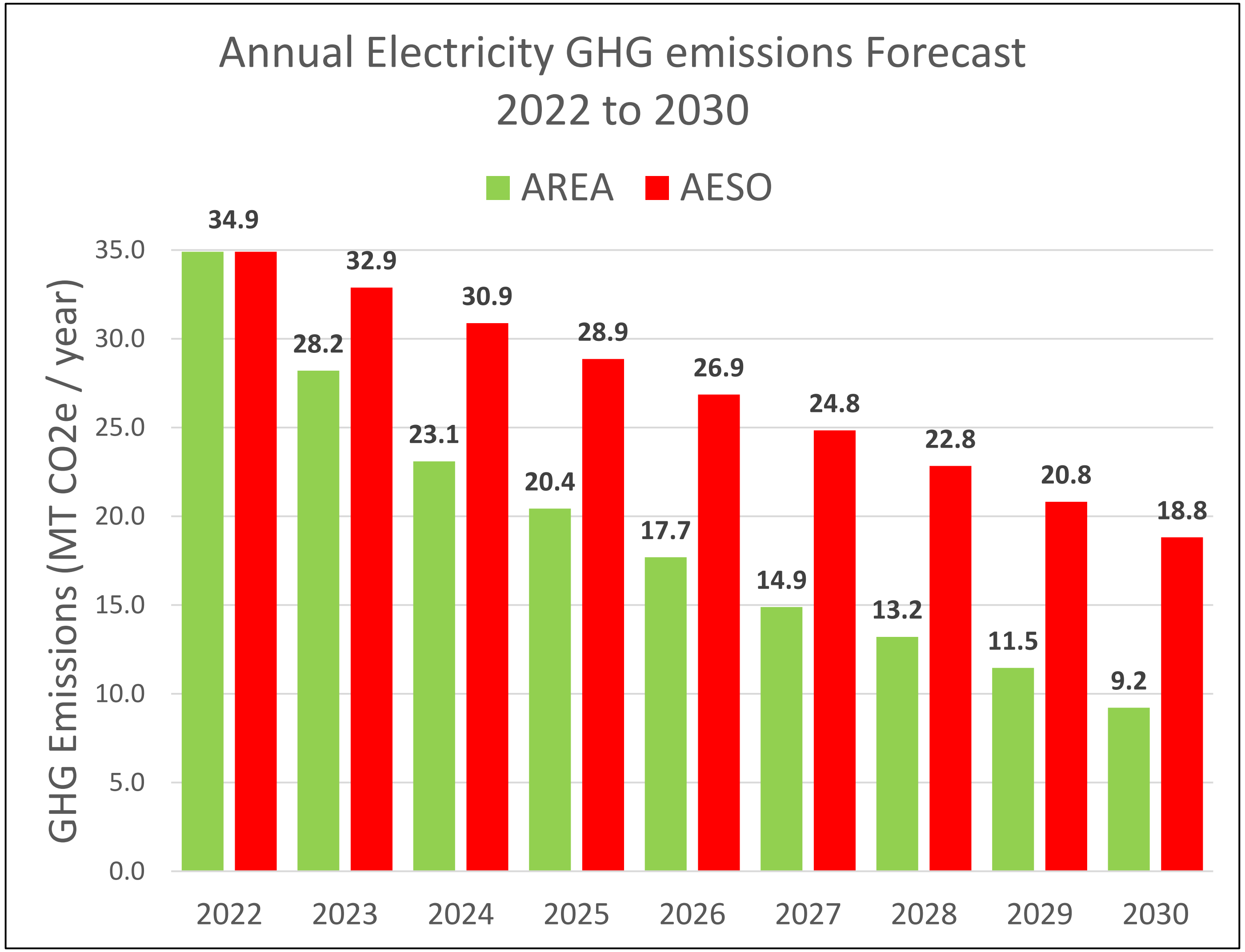


70 Percent Renewable Generation and Storage by 2030 will reduce Cumulative CO2e emissions by 29%
(from 242 MT to 173 MT)

2022 GHG emissions from Generating units in Alberta were 34.9 million tonnes CO2e.

AESOs ***Dispatchable Dominant*** Scenario will result in GHG emissions of 18.8 million tonnes CO2e in 2030.

AREAs Recommended 70% Renewable Generation will result in GHG emissions of 9.2 million tonnes CO2e in 2030.



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AREA Estimated Investment & Job Opportunities

Renewable Technology Added By 2030	Added Capacity (MW)	Unit Cost ($/kW)	Investment Opportunity ($)	Jobs per $Million Invested (IRENA & NREL)	Forecast New Jobs (direct & indirect)
Wind	6,269	$1,400	$8,776,600,000	2.23	19,572
Solar	4,135	$1,600	$6,616,000,000	12.5	82,700
Geothermal	600	$2,500	$1,500,000,000	5.7	8,550
Energy Storage	3,000	$2,000	$6,000,000,000	10.0	60,000
SCGT Fired on Hydrogen	1,000	$1,200	$1,200,000,000	3.0	3,600
Hybrid SCGT	856	$500	$428,000,000	1.0	428
Interties Upgrades	1,350	$444	$600,000,000	1.6	960
TOTAL	**17,210**		**$25,120,600,000**		**175,810**

Toward Net Zero by 2035

*Set a 2030 INTERIM Target of **100** kg CO2e/MWh*

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https://www.abrenewableenergy.ca/

To achieve the Low Carbon target by 2030, the following actions should be taken:
Coal power generation should be eliminated by 2023
Renewable energy and energy storage should supply at least 67% of total electricity generation by 2030
Priority should be given to Renewable Generation of Wind, Solar Photovoltaic, Geothermal Power and Interties Upgrades
Short term (four hours) and Long duration (seasonal) Energy Storage should be integrated with renewable generation to mitigate the intermittent nature of wind and solar power
17 GW of additional zero-carbon renewable capacity and energy storage by 2030 should foster more than 150,000 direct and indirect jobs and offer an investment opportunity of $25 billion
Natural gas turbine generation should be required to achieve 100% reduction in GHG emissions by 2035
The Low Carbon target should be reduced annually such that in the year 2030 the target shall be less than 100 kg CO2e per MWh
An annual report should be posted publicly on Alberta Environment and Parks website by each fiscal year ending March 31 to document the cumulative GHG emission reductions measured and to indicate the rate of progress toward the 2030 Low Carbon Target.

HOPE