Canada's Path to Paris Targets

Forecasting Heavy Industry, Agriculture, Electricity, Land Use, Waste and other GHG Emissions in Canada for Period 2019 to 2030

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December 2022

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Forecasting Heavy Industry GHG Emissions in Canada for Period 2019 to 2030

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Heavy Industry Sector

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Executive Summary Showing Results and Conclusions

Conclusions of Forecast for Emissions from Heavy Industry

- The Environment and Climate Change Canada (ECCC) released the Emissions Reduction Plan (ERP) in late March 2022 setting an emissions target in 2030 for heavy industry of 52 million tons (MT)of greenhouse gas (GHG) emissions

- The model forecasts emissions from the seven categories of heavy industry

	2019	ERP 2030 Target	Model 2030 Forecast
Mining	9	8	9
Smelting and Refining	11	7	8
Pulp and Paper	8	7	6
Iron and Steel	15	7	9
Cement	11	7	8
Lime and Gypsum	2	2	2
Chemicals and Fertilizer.	21	14	20
Total	77	52	62

- The conclusion from the model is that 2030 emissions from buildings will exceed the 2030 target in the ERP by 10 MT

Conclusions of Forecast for Emissions from Heavy Industry

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Reasons why Model Forecasts ERP 2030 Target for GHG Emissions Will Not be Met

- The major tool to lower emissions is to replace hydrocarbon fuels (mostly natural gas) with electricity
  - this has limited applicability to heavy industry

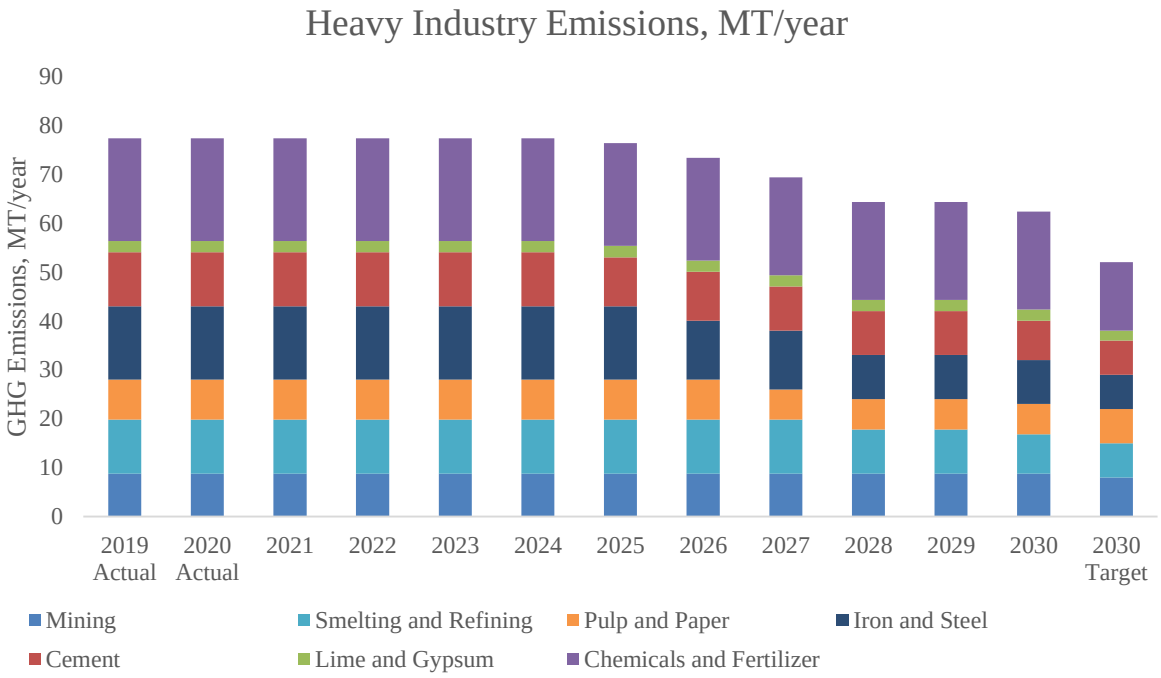
- Steel making is the only subsector that can substitute electric furnaces for gas furnaces

- Cement industry emissions are difficult to reduce since about 50% of emissions come from chemical reaction to produce cement

- Chemicals, pulp and paper, mining and smelting industries have limited methods of reducing emissions

Forecast of Heavy Industry Emissions for Period 2019 to 2030

- Emissions of 77 MT in 2019 are forecast to drop to 62 MT in 2030, or 10 MT above the 52 MT target in the 2030 ECCC ERP.



Methodology of Model

Methodology of Model Used to Forecast Emissions of the Transportation Sector

- This presentation uses a model developed to make a specific forecast of GHG emissions for the building sector
  - it is used to draw the conclusions of a specific number for GHG emissions, and to comment on why this number is the result
  - An Intelligence Memo (IM) published in December 2022 summarizes these conclusions
  - This presentation provides the analytical backup for the IM
  - Both documents are on the C.D. Howe Institute website

Methodology of Model Used to Forecast Emissions of the Heavy Industry Sector

- Model starts with data from three Government of Canada sources
  - Emissions Reduction Plan (ERP) dated March 29 2022 from ECCC
  - National Inventory Report dated April 14 2022
  - Various NRCan websites

- These three documents are used to set the 2019 emissions and the 2030 target for emissions for the seven subsectors that comprise the heavy industry sector

- Model then makes assumptions for the period 2019 to 2030

- Model then calculates GHG emissions for the seven subsectors

Key Variables for Heavy Industry sector

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Key Variables

- List of key heavy industry participants
  - cement
  - steel
  - mining

- Technology breakthroughs in industry
  - cement
  - steel
  - mining

- Energy saving technology

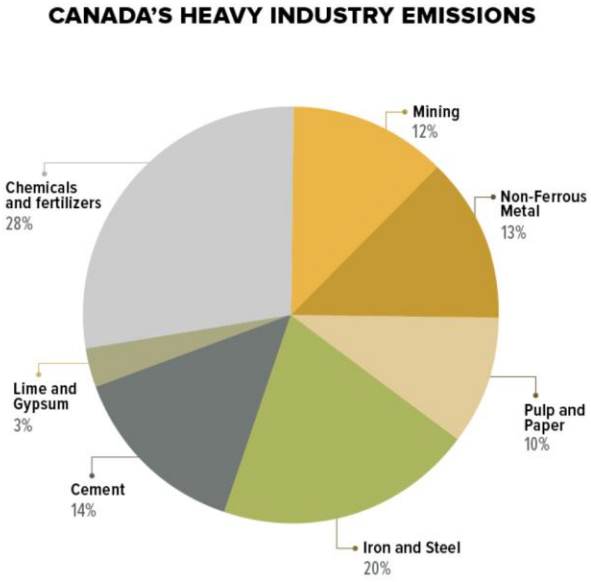
Methodology of Model Used to Forecast Emissions of the Transportation Sector

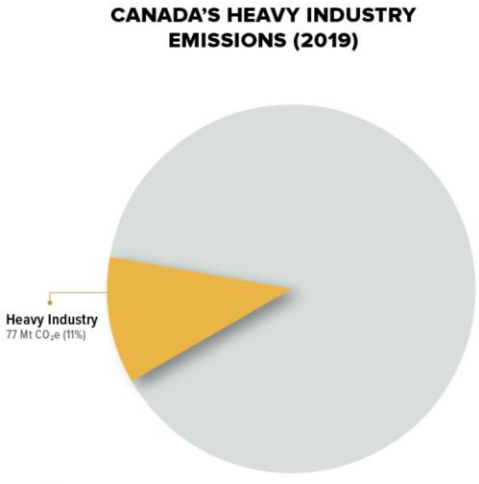
- The final result is a forecast of the total emissions of the entire building sector for each year from 2019 to 2030, broken down by each of the three sub sectors

Summary of 2019 Emissions and 2030 Targets for Heavy Industry in Canada

Emissions from Heavy Industry Sector

- Extract from March 29 2022 ERP shows heavy industry emissions

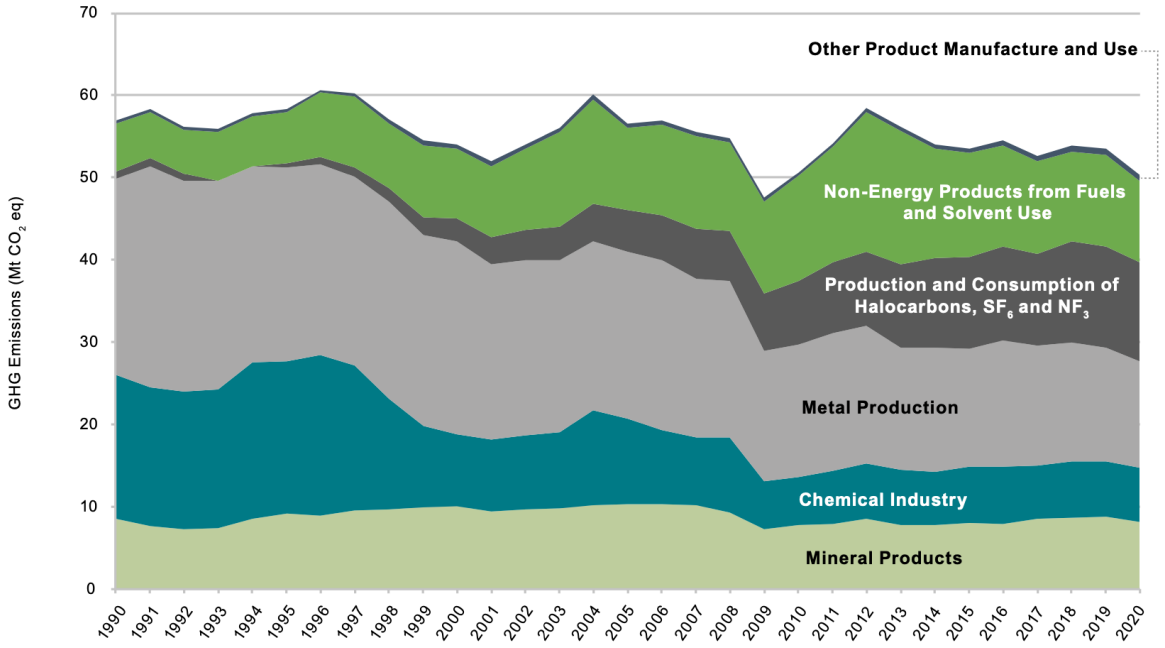




Emissions from Heavy Industry Sector

- Extract from April 14 2022 NIR shows heavy industry emissions

Figure 2–19 **Trends in Canadian GHG Emissions from Industrial Processes and Product Use Sources (1990–2020)**



Emissions from Heavy Industry Sector Arranged by Industry Sector

- Extract from April 14 2022 NIR show heavy industry emissions

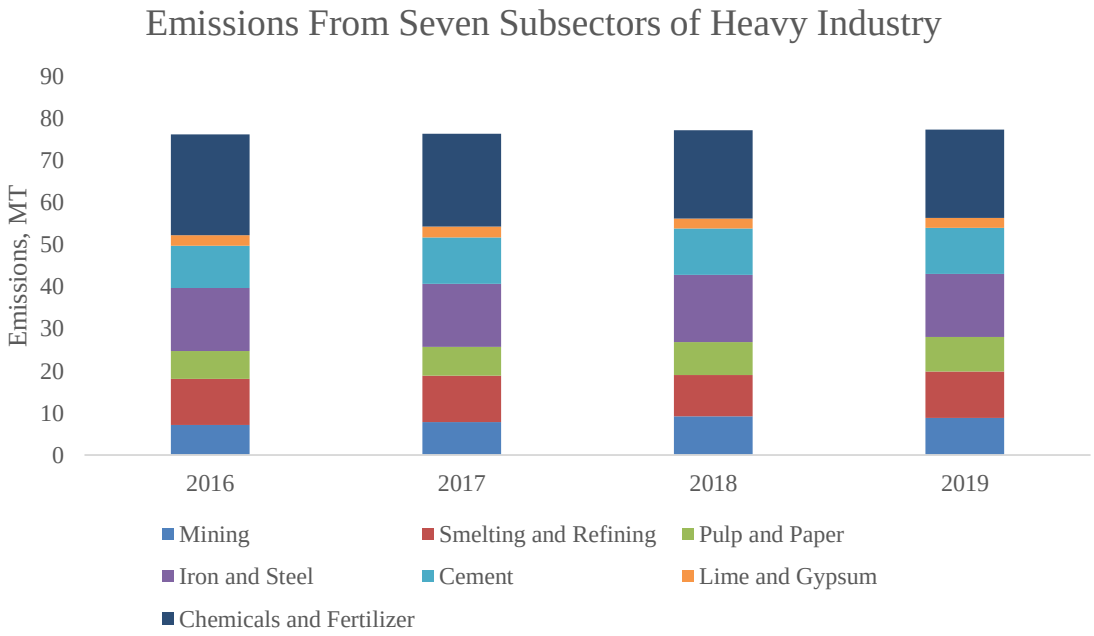
Table 2–12 **Trends in GHG Emissions by Canadian Economic Sector**

	1990	2005	2015	2016	2017	2018	2019	2020
	Mt CO_2 eq							
Heavy Industry	**97**	**87**	**78**	**76**	**76**	**77**	**77**	**72**
Mining	6.7	6.7	7.7	7.1	7.8	9.2	8.8	9.2
Smelting and Refining (Non-Ferrous Metals)	17	14	10	11	11	9.8	11	10
Pulp and Paper	15	9.0	6.4	6.6	6.9	7.8	8.2	7.2
Iron and Steel	16	16	15	15	15	16	15	12
Cement	10	13	10	10	11	11	11	9.9
Lime and Gypsum	2.9	3.5	2.5	2.5	2.6	2.4	2.3	2.1
Chemicals and Fertilizers	29	24	26	24	22	21	22	21

- ERP of March 29 2022 states that emissions from industry are 77 MT/year

Historical Emissions from Seven Subsectors of Heavy Industry Sector

- Emissions have been flat for last four years



Source: April 14 2022 NIR

Emissions Reduction Plans For Seven Subsectors

Emissions reduction Plans for Heavy Industry sector

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Mining (9 MT)

- No plans indicated for period 2021 to 2030

Smelting and Refining (11 MT)

- Rio Tinto and Alcoa have created the ELYSIS partnership to use new technology to reduce emissions (6.5 MT in total if used in all facilities in Canada)
- - assumption of model is that this new technology starts in 2026 and reaches reductions of 3.0 MT per year by 2030

Source:: https://www.riotinto.com/fr-CA/can/news/releases/First-carbon-free-aluminium-smelting
https://www.riotinto.com/news/releases/2021/Carbon-free-aluminium-smelting-a-step-closer-ELYSIS-advances-commercial-demonstration-and-operates-at-industrial-scale

Pulp and Paper (8 MT)

- Assumption is that Resolute Forest Products and West Fraser Timber each continue to reduce emissions, and each reduce emissions by 1.0 MT in the 2021 to 2030 period

Source: https://www.resolutefp.com/Sustainability/Climate_Change_and_Energy/Carbon_Footprint/
https://www.westfraser.com/sites/default/files/sustainability/West%20Fraser%202021%20Sustainability%20Report.pdf

Emissions reduction Plans for Heavy Industry sector

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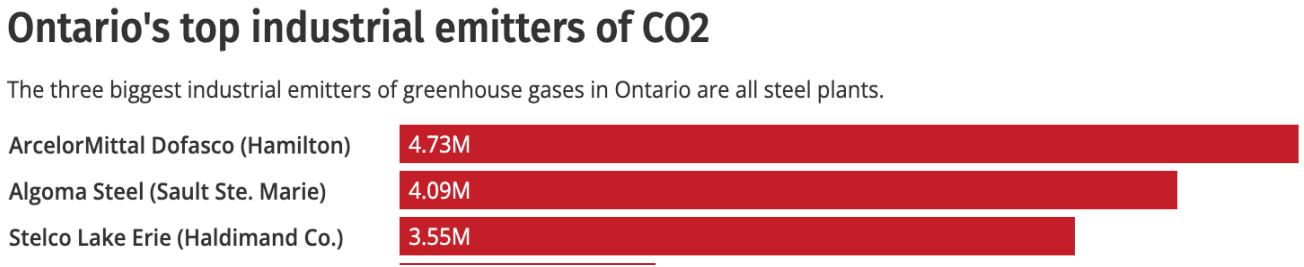
Iron and Steel (15 MT)

- ArcelorMittalDofasco (AMD) is planning to replace coal-fired furnaces with new low emissions electric arc furnaces in its' Hamilton mill
- This investment could reduce annual emissions by 3 MT

Source: ERP March 2022 page 45
https://www.thespec.com/opinion/contributors/2022/10/23/hamiltons-green-steel-revolution.html

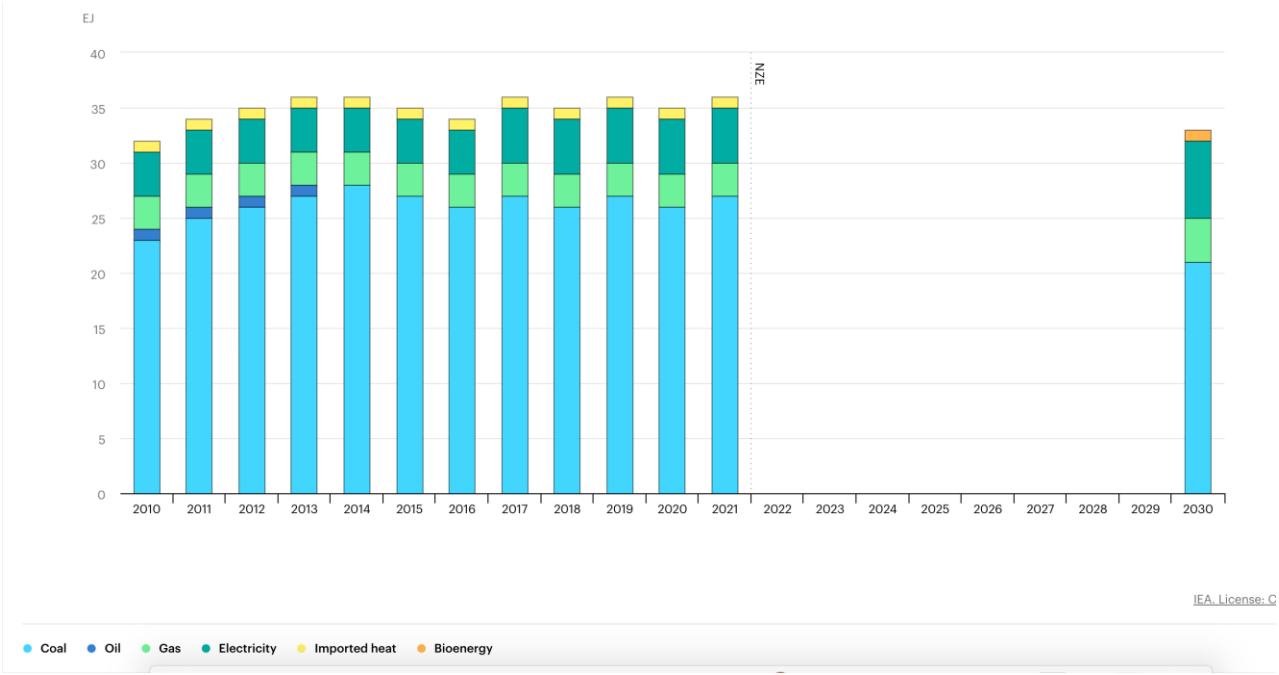
- Ontario and the federal government are also backstopping another coal-to-electricity conversion project at Algoma Steel in Sault Ste. Marie
- The AMD and Algoma projects could reduce the two steel plants' combined annual CO2 emissions by as much as 6 MT



Source: https://www.cbc.ca/news/canada/toronto/ontario-climate-change-steel-co2-greenhouse-gas-emissions-1.6353814#Biggest%20emitters%20chart

Iron and Steel Industry

- Most of energy in steel making comes from coal (light blue in bars)
- Electrification through use of electric arc furnaces needs to accelerate rapidly to substitute for coal from 2020 to 2030



Source: https://www.iea.org/data-and-statistics/charts/energy-demand-for-iron-and-steel-by-fuel-in-the-net-zero-scenario-2010-2030

Emissions reduction Plans for Heavy Industry sector

Cement (11 MT)

- In May 2021, the Government of Canada and Canada's cement sector announced a joint partnership to to provide Canadian cement and concrete industry with the technologies, tools and policy needed to achieve emissions reductions
- Potential emission reductions could be 15 MT cumulatively by 2030, and ongoing reductions of over 4 MT annually
- Model assumes annual reductions of 1 MT starting in 2025 rising to 2 MT in 2030

Source: https://ised-isde.canada.ca/site/ised/en/joint-statement-canadas-cement-industry-and-government-canada-announce-partnership

Lime and Gypsum (2 MT)

- No plans indicated for period 2021 to 2030

Emissions reduction Plans for Heavy Industry sector

Chemicals and Fertilizer (22 MT)

- Dow Chemical Canada Dow has announced the construction of the petrochemical industry's first net-zero ethylene and derivatives complex at its Fort Saskatchewan, Alberta site
- The investment will retrofit the entire complex to reach net-zero emissions by 2030 – a reduction of 1 Mt of GHG emissions.
- Model assumption is that new Dow plant will reduce emissions by 1 MT per year starting in 2027

Source: ERP March 2022 page 44
https://financialpost.com/commodities/energy/oil-gas/staggering-dow-plans-major-petrochemical-expansion-shift-to-net-zero-in-alberta

Final Summary of of Heavy Industry Emissions for Period

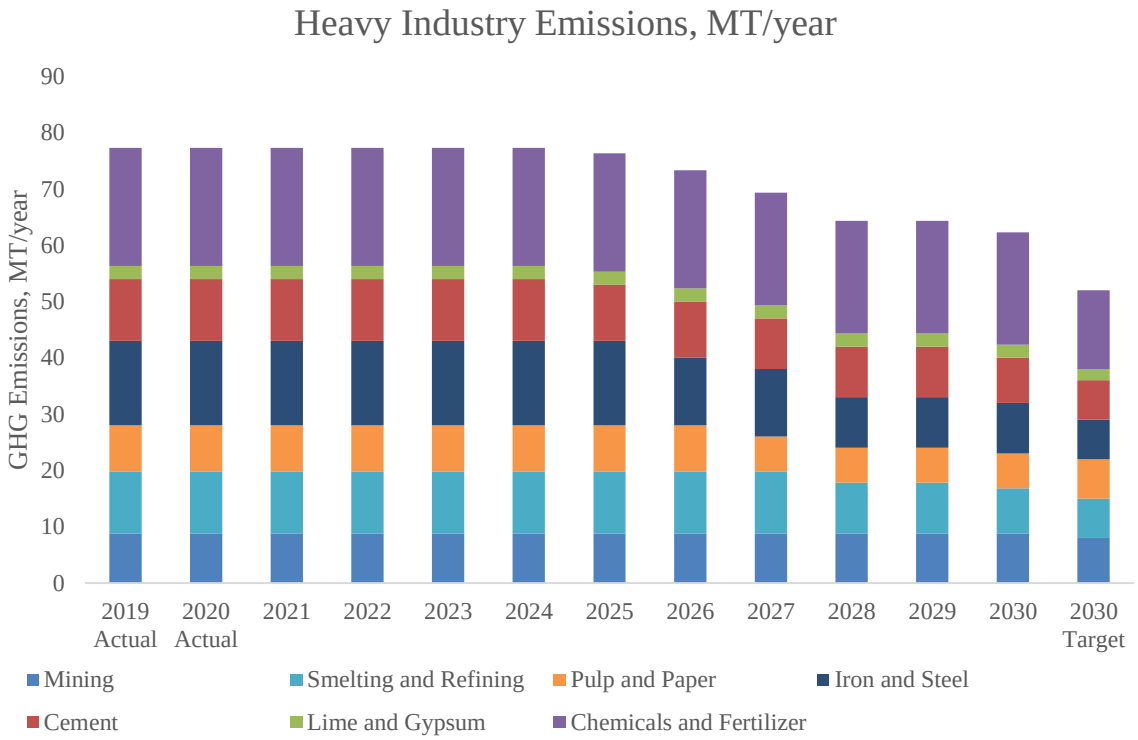
Simple Analysis of Emissions from Heavy Industry 2019 to 2030

- Factor analysis shows that decrease in emissions from 77 MT in 2019 to 62 MT in 2030, versus the 2030 target of 52 MT for 2030

Emissions in 2019	77
Mining	0
Smelting and Refining	-3
Pulp and Paper	-2
Iron and Steel	-6
Cement	-3
Lime and Gypsum	0
Chemicals and Fertilizers	-1
Emissions in 2030	62

Source: Calculations from Model

Forecast of Heavy Industry Emissions for Period 2019 to 2030



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Backup Charts

Emissions from Heavy Industry Sector Arranged Based on IPCC Categories

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- Extract from April 14 2022 NIR show heavy industry emissions

Table 2–8 **GHG Emissions from Industrial Processes and Product Use Categories, Selected Years**

GHG Source Category	GHG Emissions (Mt CO_2 eq)								Change (%)	
	1990	2005	2015	2016	2017	2018	2019	2020	1990–2020	2005–2020
Total – Industrial Processes	**57**	**57**	**54**	**55**	**53**	**54**	**53**	**50**	**-12%**	**-11%**
Mineral Products	**8.5**	**10**	**8.0**	**7.9**	**8.6**	**8.6**	**8.8**	**8.1**	**-4%**	**-21%**
Cement Production	5.8	7.6	6.2	6.1	6.8	6.9	7.1	6.6	14%	-13%
Lime Production	1.8	1.8	1.4	1.4	1.4	1.4	1.3	1.2	-34%	-32%
Mineral Product Use	0.9	0.9	0.4	0.4	0.3	0.3	0.3	0.3	-65%	-67%
Chemical Industry	**18**	**10**	**6.8**	**7.0**	**6.4**	**6.8**	**6.7**	**6.6**	**-62%**	**-37%**
Ammonia Production	2.8	2.7	2.9	2.9	2.6	2.4	2.5	2.5	-10%	-10%
Nitric Acid Production	1.0	1.2	0.2	0.3	0.2	0.3	0.3	0.2	-81%	-84%
Adipic Acid Production	10	2.5	-	-	-	-	-	-	-100%	-100%
Petrochemical Production & Carbon Black Production	3.5	4.0	3.6	3.9	3.5	4.1	3.9	3.9	12%	-1%
Metal Production	**24**	**20**	**14**	**15**	**15**	**15**	**14**	**13**	**-45%**	**-36%**
Iron and Steel Production	10	10	8.5	9.2	8.5	8.9	8.3	7.0	-33%	-32%
Aluminium Production	10	8.7	5.7	6.0	6.0	5.5	5.3	5.9	-43%	-32%
SF_6 Used in Magnesium Smelters and Casters	3.0	1.2	0.2	0.1	0.1	0.1	0.3	0.1	-97%	-92%
Production and Consumption of Halocarbons, SF_6 and NF_3	**1.0**	**5.1**	**11**	**11**	**11**	**12**	**12**	**12**	**1130%**	**135%**
Non-Energy Products from Fuels and Solvent Use	**5.8**	**10**	**13**	**12**	**11**	**11**	**11**	**10**	**70%**	**-1%**
Other Product Manufacture and Use	**0.4**	**0.5**	**0.5**	**0.6**	**0.6**	**0.7**	**0.7**	**0.7**	**94%**	**33%**

Note: Totals may not add up due to rounding.

- ERP of March 29 2022 states that emissions from industry are 93 MT/year

Forecasting Agriculture GHG Emissions in Canada for Period 2019 to 2030

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Agriculture Sector

Executive Summary Showing Results and Conclusions

Conclusions of Forecast for Emissions from Agriculture

- The model forecasts emissions from the three categories of agriculture, namely animals, land (fertilizer and manure) and farm equipment (tractors and propane drying)

- The Environment and Climate Change Canada (ECCC) released the Emissions Reduction Plan (ERP) in late March 2022
  - the ERP stated an emissions target in 2030 for agriculture of 73 million tons (MT) of greenhouse gas (GHG) emissions

- The model forecasts emissions from buildings in 2030 as follows

	2019	ERP 2030 Target	Model 2030 Forecast
Animals	35	35	35
Land	20	20	19
Farm Equipment	18	16	18
Total	73	71	72

- The conclusion from the model is that 2030 emissions from agriculture will exceed the 2030 target in the Emissions Reduction Plan by 1 MT

Conclusions of Forecast for Emissions from Agriculture

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Reasons why Model Forecasts ERP 2030 Target for GHG Emissions will Not be Met

- Most of the emissions from agriculture are not carbon dioxide from combustion, but rather methane from animals (35 MT) and nitrous oxide from fertilizer (20 MT)

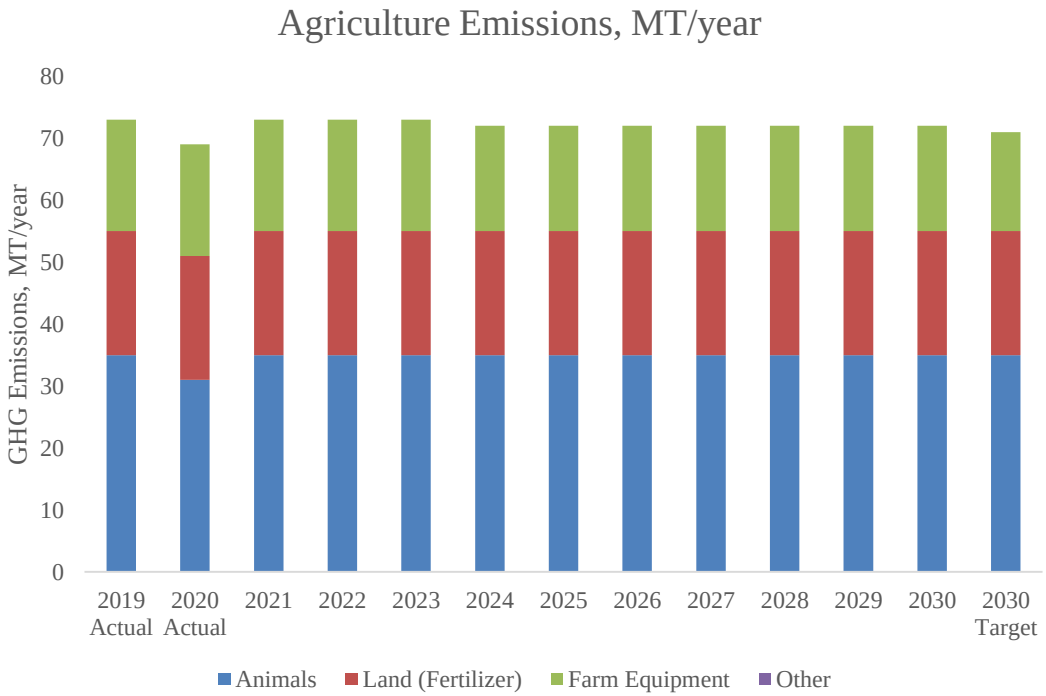
- The remaining 18 MT comes from the combustion of fuel for farm equipment such as tractors and propane to dry crops

- There is no current method of reducing animal and land emissions
  - Canada has set a national fertilizer emission reduction target of 30% below 2020 levels by 2030, but there has been much pushback from the farming community

- Some reductions in farm equipment can occur through electrification of tractors and heating equipment
  - the assumption in the model is that emissions can be reduced by 1 MT

Source: https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=AN&sector=aaa&juris=00&rn=6&page=0 , NIR Report page 66, ERP page 65

Forecast of Agriculture Emissions for Period 2019 to 2030



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Methodology of Model

Methodology of Model Used to Forecast Emissions of the Agriculture Sector

- Model starts with data from three Government of Canada sources
  - Emissions Reduction Plan (ERP) dated March 29 2022 from ECCC
  - National Inventory Report dated April 14 2022
  - Various NRCan websites

- These three documents are used to set the 2019 emissions and the 2030 target for emissions for the three subsectors that comprise the agriculture sector
  - Animals
  - Land (Fertilizer)
  - Farm Equipment

- Model then makes assumptions for the period 2019 to 2030

- Model then calculates GHG emissions for the three subsectors

Key Variables for Agriculture sector

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Key Variables

- Emissions from fertilizer usage

- Makeup of farm transportation (diesel versus electric)

Methodology of Model Used to Forecast Emissions of the Agriculture Sector

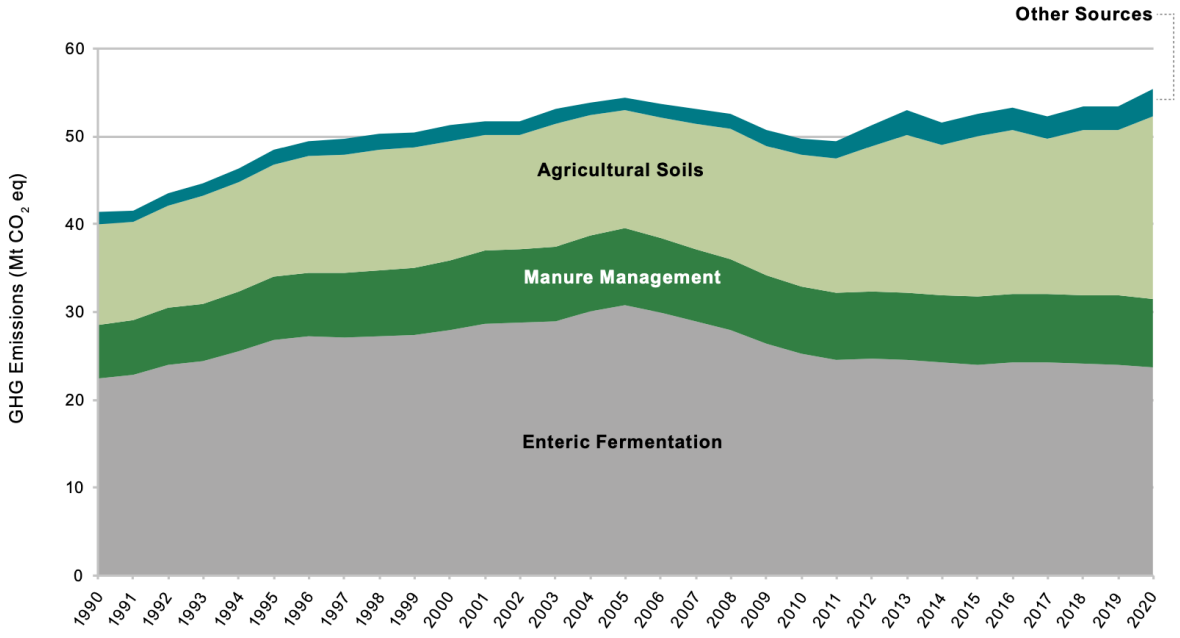
- The final result is a forecast of the total emissions of the entire agriculture sector for each year from 2019 to 2030, broken down by each of the three sub sectors

Summary of 2019 Emissions and 2030 Targets for Agriculture in Canada

Emissions from Agriculture Sector

- Extract from April 14 2022 NIR shows agriculture emissions

Figure 2–20 **Trends in Canadian GHG Emissions from Agriculture Sources (1990–2020)**



Emissions from Agriculture Sector Based on IPCC Categories

- Extract from April 14 2022 NIR shows agriculture emission page 66

Table 2–12 **Trends in GHG Emissions by Canadian Economic Sector**

	1990	2005	2015	2016	2017	2018	2019	2020
	Mt CO_2 eq							
Agriculture	**52**	**66**	**65**	**65**	**64**	**66**	**67**	**69**
On-Farm Fuel Use	11	12	12	12	12	13	13	13
Crop Production	10	12	18	18	17	18	19	21
Animal Production	31	42	34	35	35	35	35	34

Emissions from Agriculture Sector Based on IPCC Categories

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- Extract from April 14 2022 NIR shows agriculture emissions

Table 2–9 **GHG Emissions from Agriculture, Selected Years**

GHG Source Category	GHG Emissions (Mt CO_2 eq)								Change (%)	
	1990	2005	2015	2016	2017	2018	2019	2020	1990–2020	2005–2020
Agriculture	**41**	**54**	**52**	**53**	**52**	**53**	**53**	**55**	**34%**	**2%**
Enteric Fermentation	22	31	24	24	24	24	24	24	6%	-23%
Manure Management	6.1	8.7	7.7	7.8	7.9	7.8	7.8	7.8	28%	-11%
Agricultural Soils	11	13	18	18	17	19	19	21	82%	56%
Field Burning of Agricultural Residues	0.22	0.04	0.06	0.05	0.05	0.05	0.05	0.05	-76%	25%
Liming, Urea Application and Other Carbon-Containing Fertilizers	1.2	1.4	2.6	2.5	2.4	2.6	2.7	3.0	155%	114%

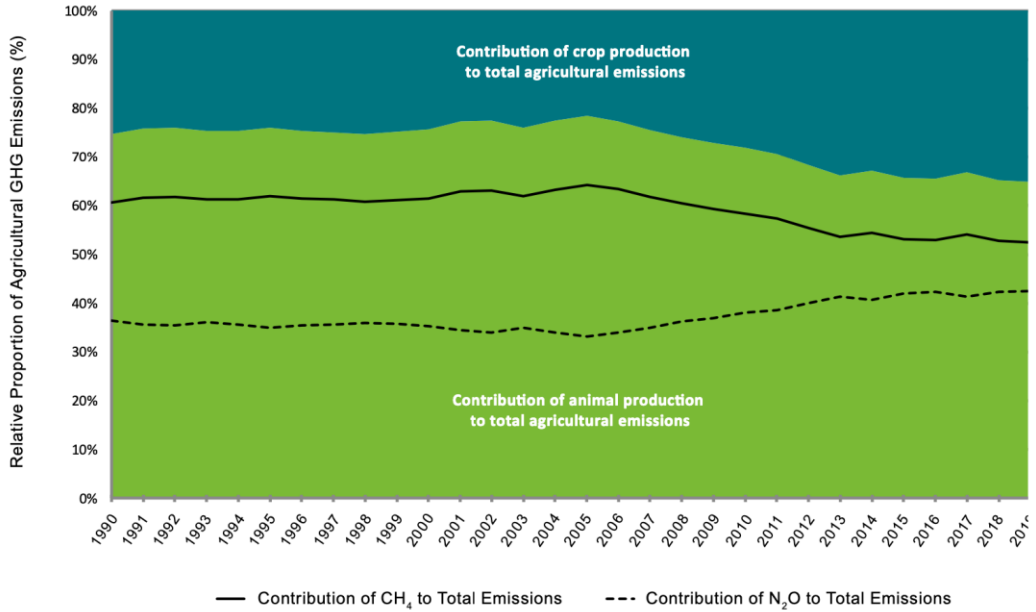
Note: Totals may not add up due to rounding.

- Enteric Fermentation occurs in cattle and results in methane emissions, mostly from burping cows

Emissions from Agriculture Sector

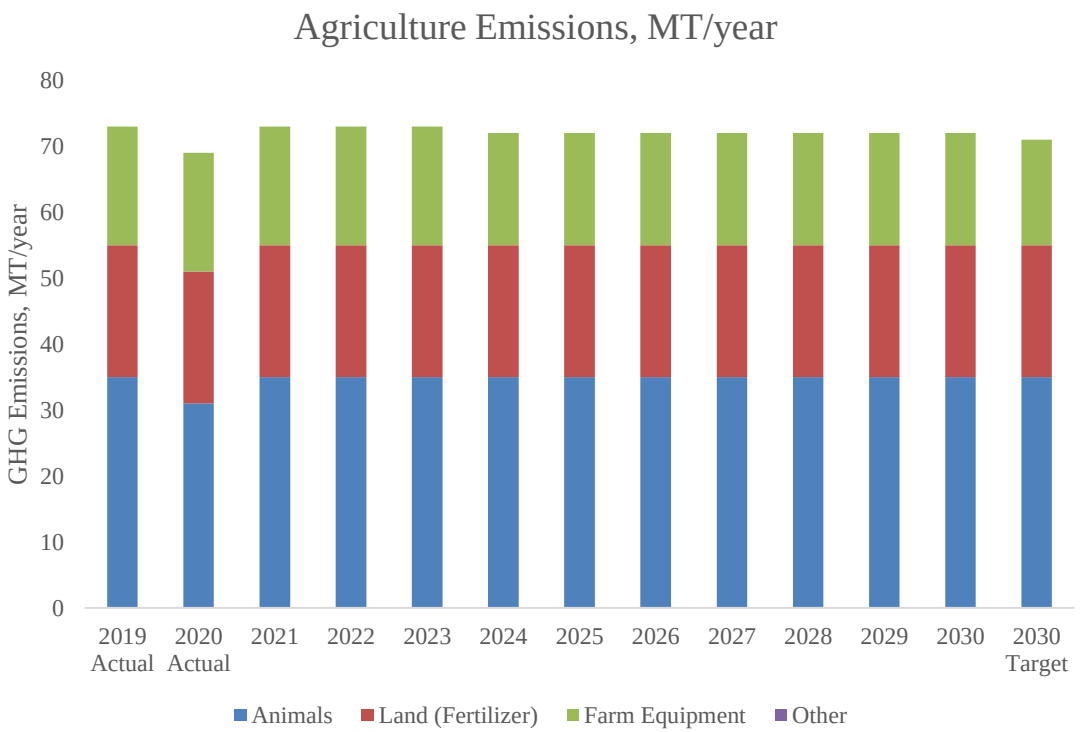
- Extract from April 14 2022 NIR shows agriculture emissions

Figure 2–21 **Proportions of Canadian Agricultural GHG Emissions Emitted as CH_4 and N_2O, or attributed to Livestock and Crop Production (1990–2020)**



Forecast of Agriculture Emissions for Period 2019 to 2030

Forecast of Agriculture Emissions for Period 2019 to 2030



Forecasting Electricity GHG Emissions in Canada for Period 2019 to 2030

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Electricity Sector

Executive Summary Showing Results and Conclusions

Conclusions of Forecast for Emissions from Electricity

- The model forecasts emissions from the three sources of electricity generation, namely coal, natural gas and other (petroleum and diesel)
- The Environment and Climate Change Canada (ECCC) released the Emissions Reduction Plan (ERP) in late March 2022
  - the ERP stated an emissions target in 2030 for electricity of 14 million tons (MT) of greenhouse gas (GHG) emissions

- The model forecasts emissions from buildings in 2030 as follows

	2019	ERP 2030 Target	Model 2030 Forecast
Coal	40	4	5
Natural Gas	20	10	13
Other	1	0	0
Total	61	14	18

- The conclusion from the model is that 2030 emissions from electricity will exceed the 2030 target in the Emissions Reduction Plan by 4 MT

Conclusions of Forecast for Emissions from Electricity

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Reasons why Model Forecasts ERP 2030 Target for GHG Emissions will Not be Met

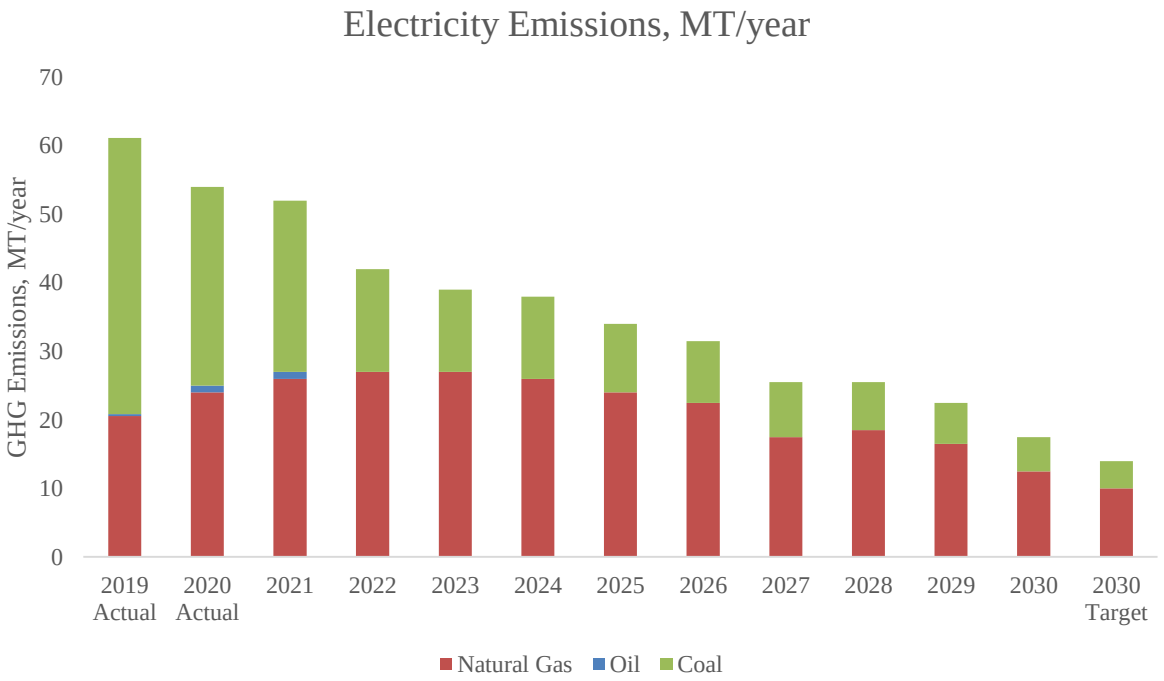
- Most of the reduction in emissions comes from the elimination of coal in Alberta and the reduction of coal in Saskatchewan and Nova Scotia

- This reduction is offset by the increase in natural gas generation
  - some natural gas combined cycle plan to use CCUS

- Ontario has stated it will increase capacity in natural gas to offset the decommissioning of the Pickering nuclear plant

Source: https://www.theglobeandmail.com/business/article-ontario-natural-gas-energy/#:~:text=Opinion-,Ontario%20to%20increase%20use%20of%20gas%2Dfired%20plants%20for%20energy,further%20questions%20about%20climate%20commitments&text=Ontario%20will%20procure%20additional%20electricity,emissions%20from%20the%20electricity%20sector.

Forecast of Electricity Emissions for Period 2019 to 2030



- Coal is phased out in Alberta, still some in Saskatchewan and Nova Scotia
- Some natural gas plants install CCUS

Methodology of Model

Methodology of Model Used to Forecast Emissions of the Electricity Sector

- Model starts with data from three Government of Canada sources
  - Emissions Reduction Plan (ERP) dated March 29 2022 from ECCC
  - National Inventory Report dated April 14 2022
  - Various NRCan websites

- These three documents are used to set the 2019 emissions and the 2030 target for emissions for the three sources of electricity
  - Coal
  - Natural Gas
  - Other

- Model then makes assumptions for the period 2019 to 2030

- Model then calculates GHG emissions for the three subsectors

Key Variables for Electricity sector

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Key Variables

- Focus on key provinces that currently have GHG emissions

- Amount of electricity currently generated by
  - combined cycle natural gas
  - simple cycle natural gas
  - natural gas cogeneration
  - coal

- Rate of carbon capture for natural gas facilities

- Rate of installation of solar and wind generation capacity

- Rate of battery storage installation

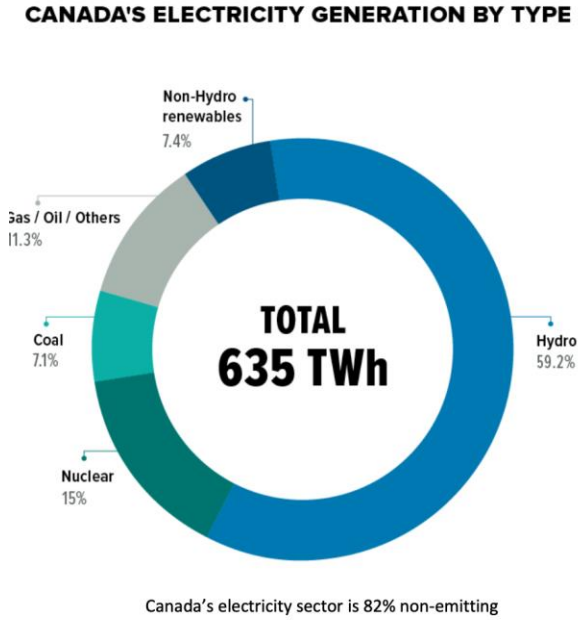
Methodology of Model Used to Forecast Emissions of the Electricity Sector

- The final result is a forecast of the total emissions of the entire electricity sector for each year from 2019 to 2030, broken down by each of the three sub sectors

Electricity Sector Electricity Generated and Emissions Data

Sources of Electricity in Canada

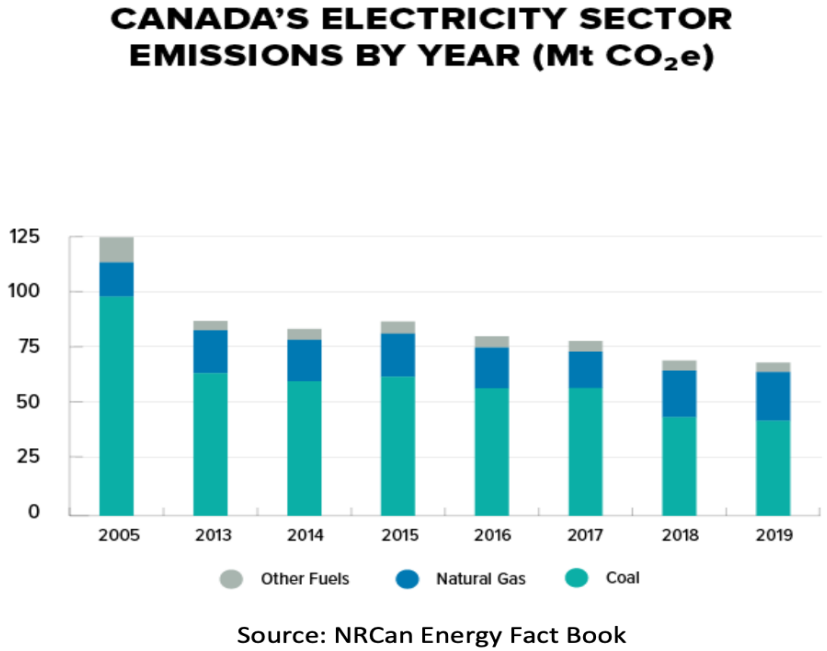
- Emissions come from coal, natural gas and oil supplying 18% of electricity generated in Canada



Source. Canada 2030 Emissions Reduction Plan page 38

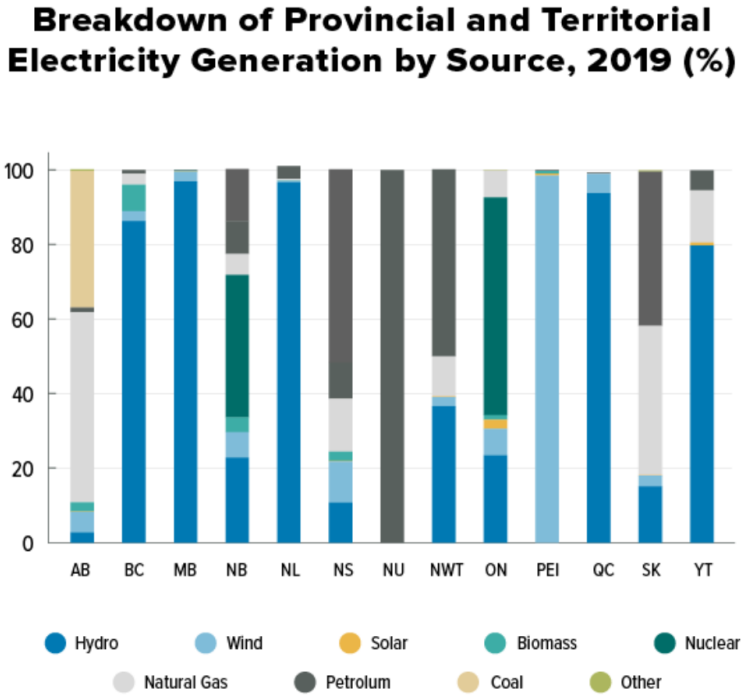
Historical Emissions of Electricity Sector

- Emissions in 2019 were 61 MT, about 40 MT from coal, 20 MT from gas and 1 MT from other (mostly oil and diesel)



Source. Canada 2030 Emissions Reduction Plan page 38

Sources of Electricity by Province



Source. Canada 2030 Emissions Reduction Plan page 38

- Quebec, British Columbia, Manitoba and Newfoundland get most of their electricity from hydro, very little from natural gas
- Alberta, Saskatchewan, Ontario, New Brunswick and Nova Scotia currently rely on coal, natural gas and heating oil for significant amount of electricity
- Emissions reductions will come from these five provinces

Sources of Electricity in Alberta is from 2016 to 2022

- About 90% of Alberta's electricity comes from natural gas and coal
  - about half comes from gas tied in to industry with cogeneration
- Coal will be phased out before 2030
- Capacity in wind and solar increasing significantly, but utilization factor limits generation

Source: https://public.tableau.com/app/profile/market.analytics/viz/AnnualStatistics_16161854228350/Introduction

Emissions Intensity of Electricity Sector on a Unit Basis

- Converting to metric units, unit emissions are

Natural gas	0.5 T per Mwh
Coal	1.0 T per Mwh

U.S. electricity net generation and resulting CO_2 emissions by fuel in 2021

	Electricity generation	CO_2 emissions		
	million kWh	million metric tons	million short tons	pounds per kWh
Coal	897,885	919	1,013	2.26
Natural gas	1,579,361	696	767	0.97
Petroleum	19,176	21	23	2.44

Data source: U.S. Energy Information Administration, State Electricity Profiles, U.S. Profile.
Note: Data are for utility-scale electric power plants, including combined heat and power plants.

Source: https://www.eia.gov/tools/faqs/faq.php?id=74&t=11

Total Emissions of Electricity Sector by Province and Source in 2019

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Emissions by Province and Source, MT

Province	Coal	Natural Gas	Other	Total
Alberta	24	12	0	36
Saskatchewan	11	4	0	15
Nova Scotia	5	1	1	7
Ontario	0	3	0	3
Other	0	0	0	0
Total	40	20	1	61

- As a check, ERP states that emissions from Electricity sector in 2019 were 61 MT
- The largest potential emission reductions would be in Alberta and Saskatchewan

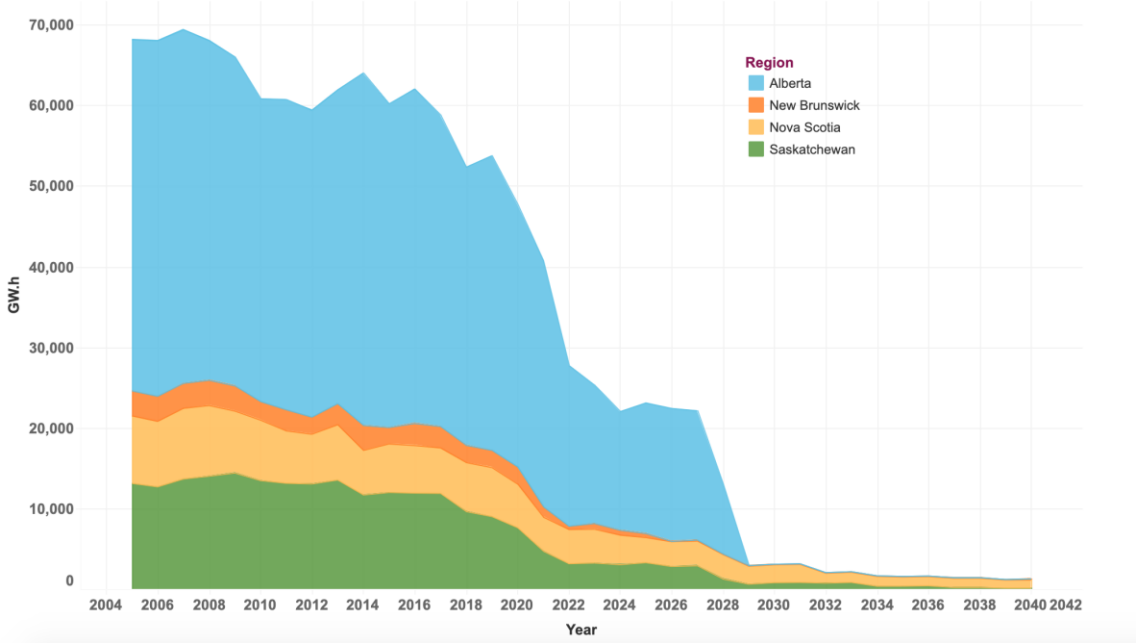
Source: Various sources cited in previous slides

Emissions Reduction Plans for Electricity sector for 2019 to 2030

Phase Out of Coal Fired Plants

- Federal regulations require phase out of coal by 2030

Figure 1. Canadian coal electricity generation by region to 2040



Source: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2020/market-snapshot-canadas-retiring-coal-fired-power-plants-will-be-replaced-renewable-low-carbon-energy-sources.html

Emissions Reduction Plans for Alberta for 2019 to 2030

Electricity Sources for Alberta Grid in 2019

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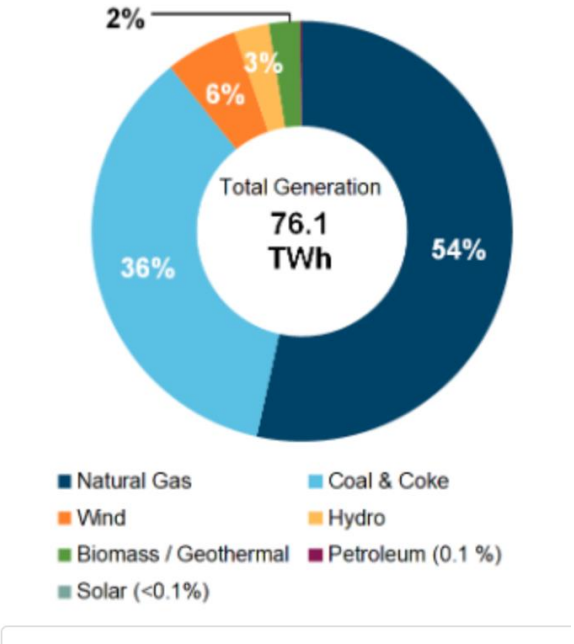
Figure 2: Electricity Production (2019)



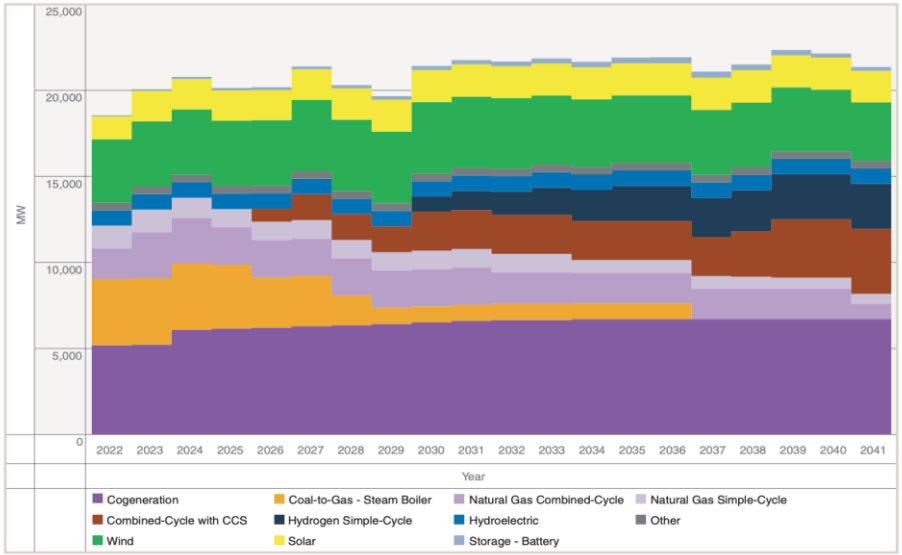
Source: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-alberta.html

Change in Generating capacity for Alberta Grid from 2022 to 2041

- Cogen grows slowly, coal to gas is retired, existing combined cycle and simple cycle continue, combined cycle with CCUS introduced, no hydrogen until 2030, wind and solar stay constant, overall capacity stays around 20,000 MW

Total Capacity

FIGURE 17: Dispatchable Dominant Scenario - Total Capacity



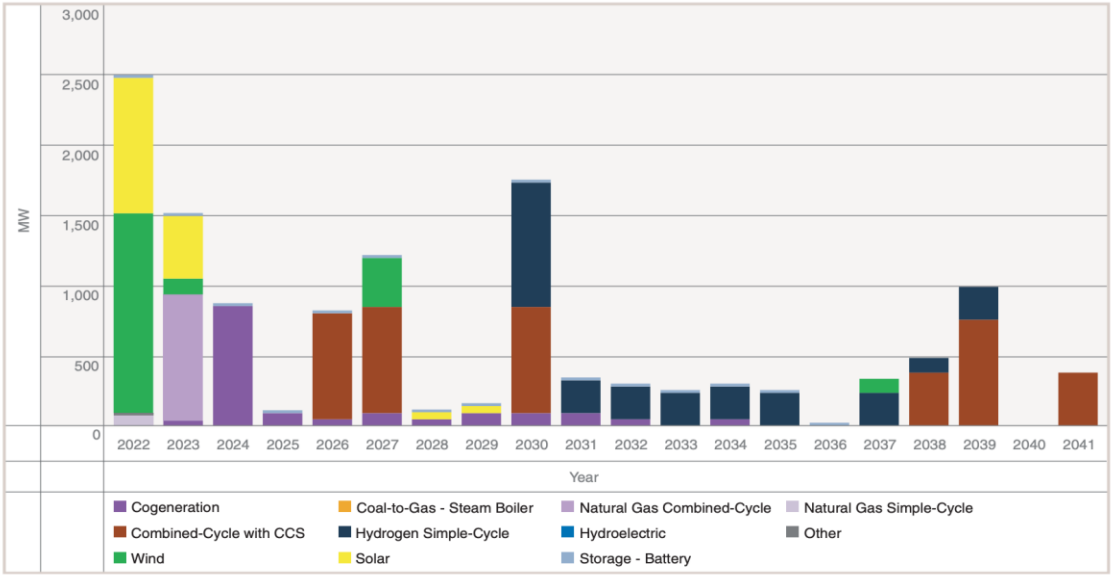
Source: https://www.aeso.ca/assets/Uploads/net-zero/AESO-Net-Zero-Emissions-Pathways-Report.pdf

Additions of Gas Capacity in Alberta Grid from 2022 to 2041

- Alberta plans to add combined cycle gas (some with carbon capture CCUS and some without), wind and solar in 2022 to 2030 period

Capacity Additions and Retirements

FIGURE 15: Dispatchable Dominant Scenario - Capacity Additions

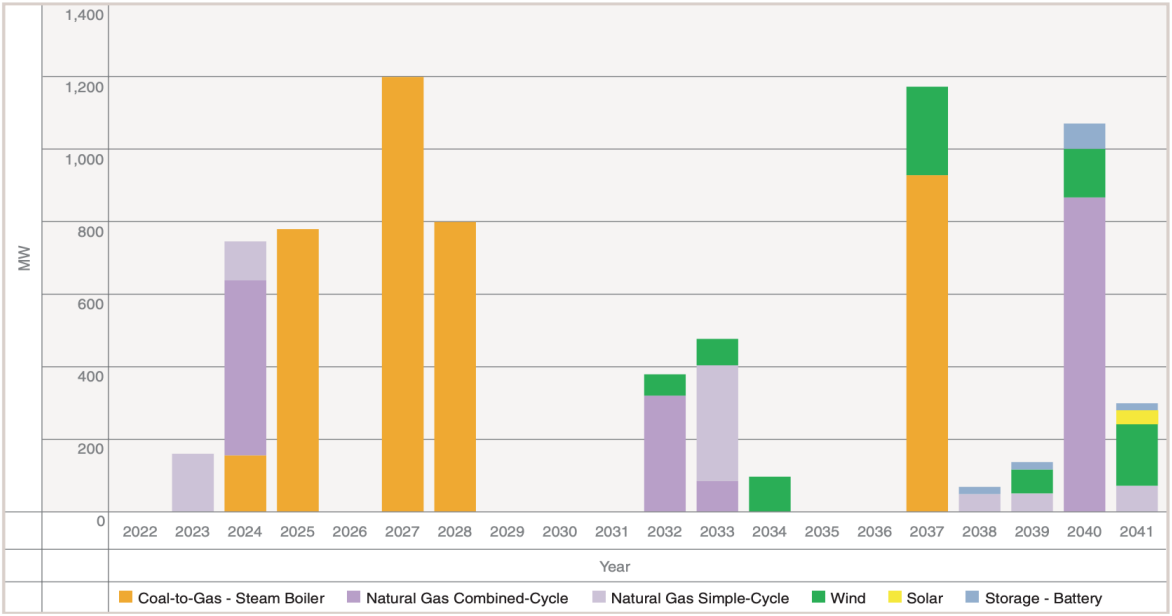


Source: https://www.aeso.ca/assets/Uploads/net-zero/AESO-Net-Zero-Emissions-Pathways-Report.pdf

Retirements of Gas Capacity in Alberta Grid from 2022 to 2041

- Alberta plans to retire coal to gas and simple cycle gas in 2022 to 2030 period

FIGURE 16: Dispatchable Dominant Scenario - Capacity Retirements



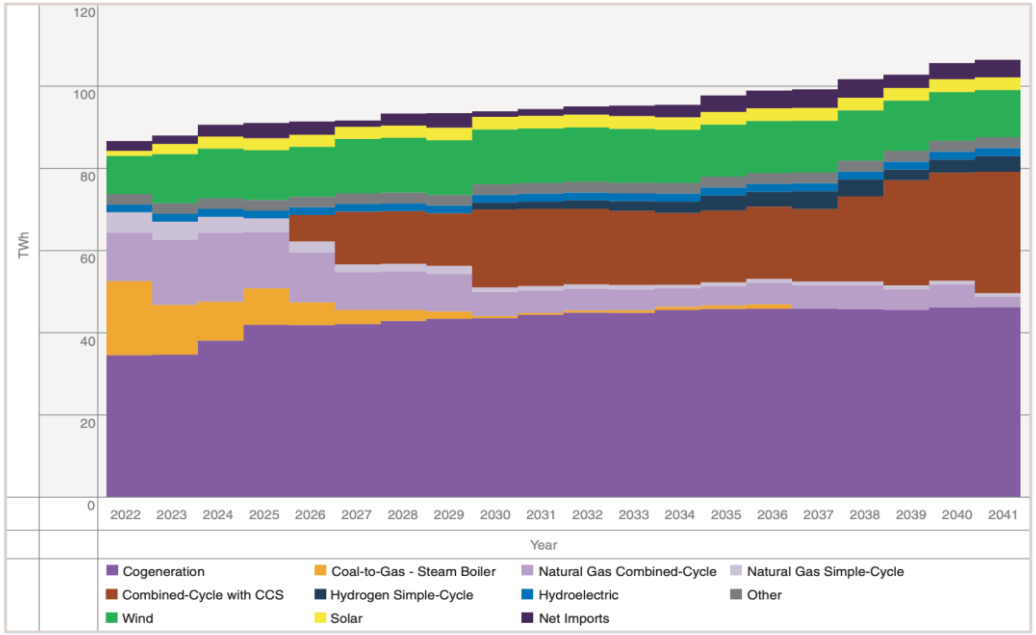
Source: https://www.aeso.ca/assets/Uploads/net-zero/AESO-Net-Zero-Emissions-Pathways-Report.pdf

Electricity Generated in Alberta Grid from 2022 to 2041

- Electricity generated rises from 85 Twh in 2022 to 90 Twh in 2030

Total Generation

FIGURE 18: Dispatchable Dominant Scenario - Total Generation



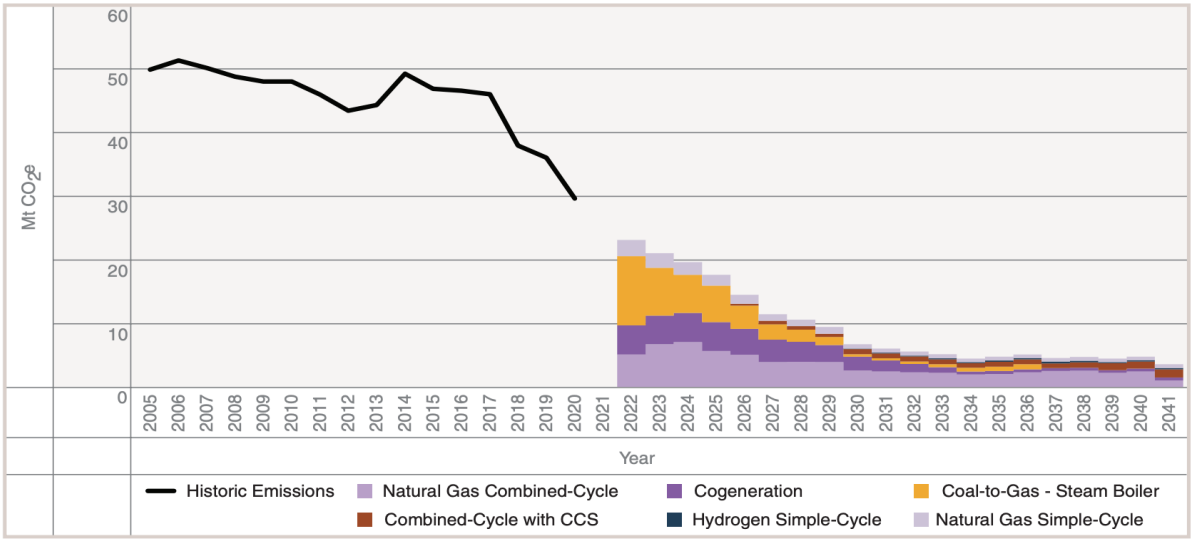
Source: https://www.aeso.ca/assets/Uploads/net-zero/AESO-Net-Zero-Emissions-Pathways-Report.pdf

Emissions From Alberta Grid from 2022 to 2041

- Emissions drop from 36 MT in 2019 to 7 MT in 2030

Dispatchable Dominant Scenario Emissions Results

FIGURE 28: Dispatchable Dominant Scenario - Total Electricity Sector Greenhouse Gas Emissions



Source: https://www.aeso.ca/assets/Uploads/net-zero/AESO-Net-Zero-Emissions-Pathways-Report.pdf

Emissions Reduction Plans for Saskatchewan for 2019 to 2030

Electricity Sources for Saskatchewan Grid in 2019

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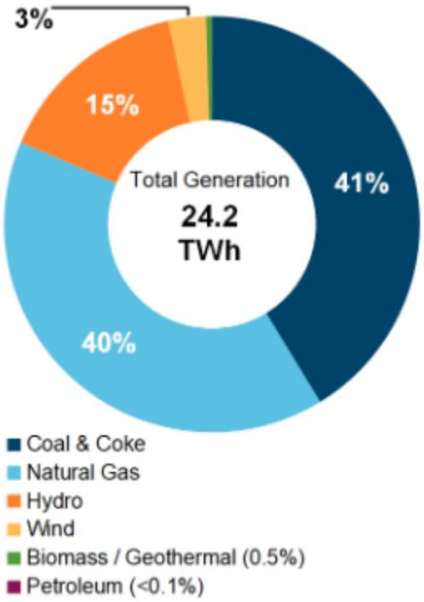
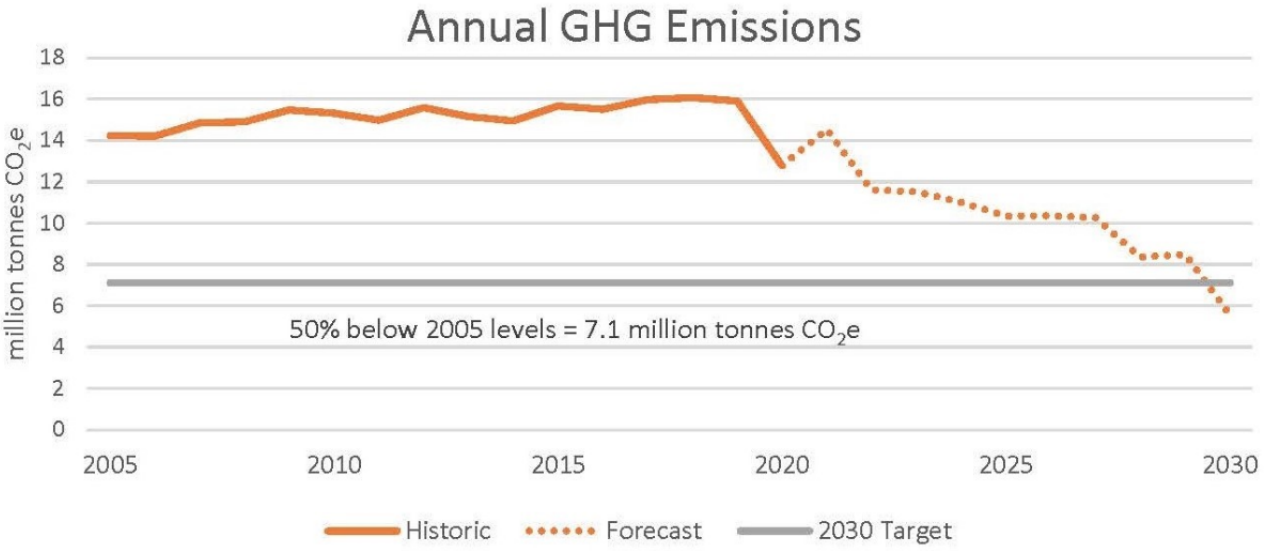
Figure 2: Electricity Generation by Fuel Type (2019)



Source: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-saskatchewan.html

Emissions From Saskatchewan Grid from 2020 to 2030

- Assumption is that most if not all of Saskatchewan emissions come from Saskpower
- Emissions drop from 15 MT in 2019 to 6 MT in 2030



Source: https://www.saskpower.com/Our-Power-Future/Powering-2030/Emissions

Reasons for Drop in Emissions From Saskatchewan Grid from 2022 to 2041

- The first full year of operation of new and efficient Chinook Power Station
- Increased capture of carbon at Carbon Capture and Storage facility compared to 2019
- Maximized hydroelectric generation during high water runoff in the Saskatchewan and Churchill Rivers

Source: https://www.saskpower.com/Our-Power-Future/Powering-2030/Emissions

Emissions Reduction Plans for Nova Scotia for 2019 to 2030

Electricity Sources for Nova Scotia Grid in 2019

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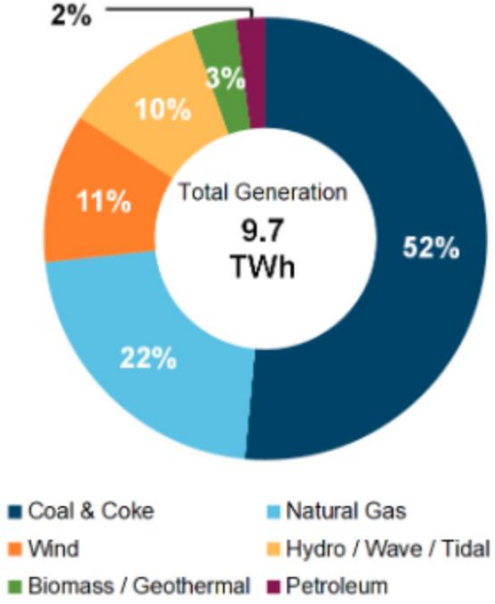
Figure 2: Electricity Generation by Fuel Type (2019)

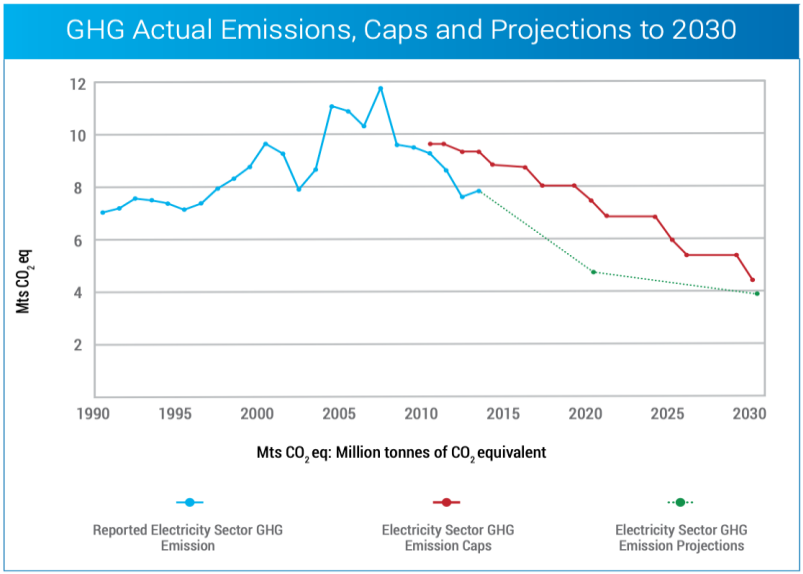


Source: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-nova-scotia.html

Emissions From Nova Scotia Grid from 2020 to 2030

- Projection from Nova Scotia Power show emissions drop from 7 MT in 2019 to 4 MT in 2030

Figure 7: Nova Scotia electricity sector GHG emissions



Sources: 1. 2020 target: Canada-Nova Scotia Agreement in Principle on Efforts to Address Climate Change, January 25, 2010 (The Equivalency Agreement) 2. 2020 & 2030 projections: 2014 Integrated Resource Plan, Nova Scotia Power, October 15, 2014 ; 3.Emissions data: Nova Scotia Environment ; 2020 Projections based on Nova Scotia Power's 2014 Integrated Resource Plan are dependent on electricity load (positive or negative growth), the amount of market energy purchased from Maritime Link and the volume of demand side management (DSM) occurring.

Source: https://energy.novascotia.ca/sites/default/files/Our-Electricity-Future.pdf

Emissions Reduction Plans for Ontario for 2019 to 2030

Electricity Sources for Ontario Grid in 2019

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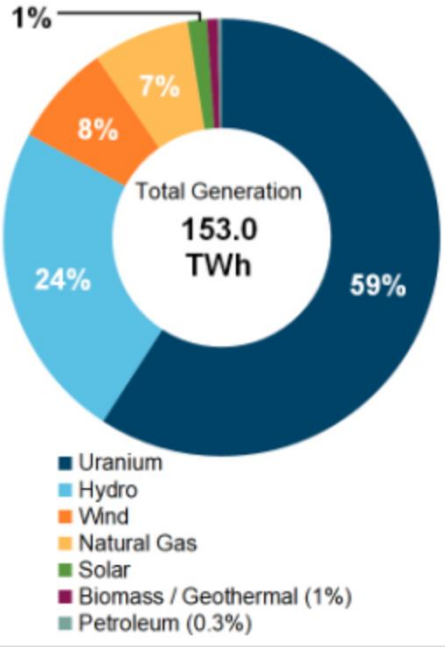
Figure 2: Electricity Generation by Fuel Type (2019)



Source. https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-ontario.html

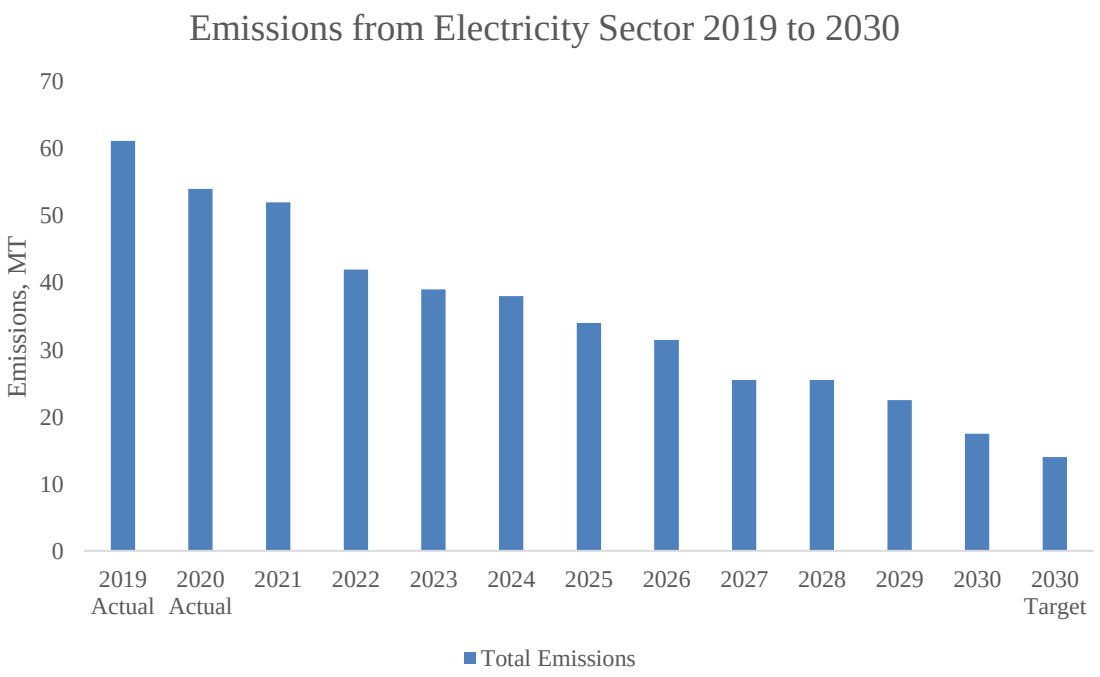
Reasons for Drop in Emissions From Ontario Grid from 2022 to 2041

- Pickering A nuclear plant scheduled to be decommissioned in 2026
- Ontario Power Generation may install natural gas capacity to replace this lost capacity

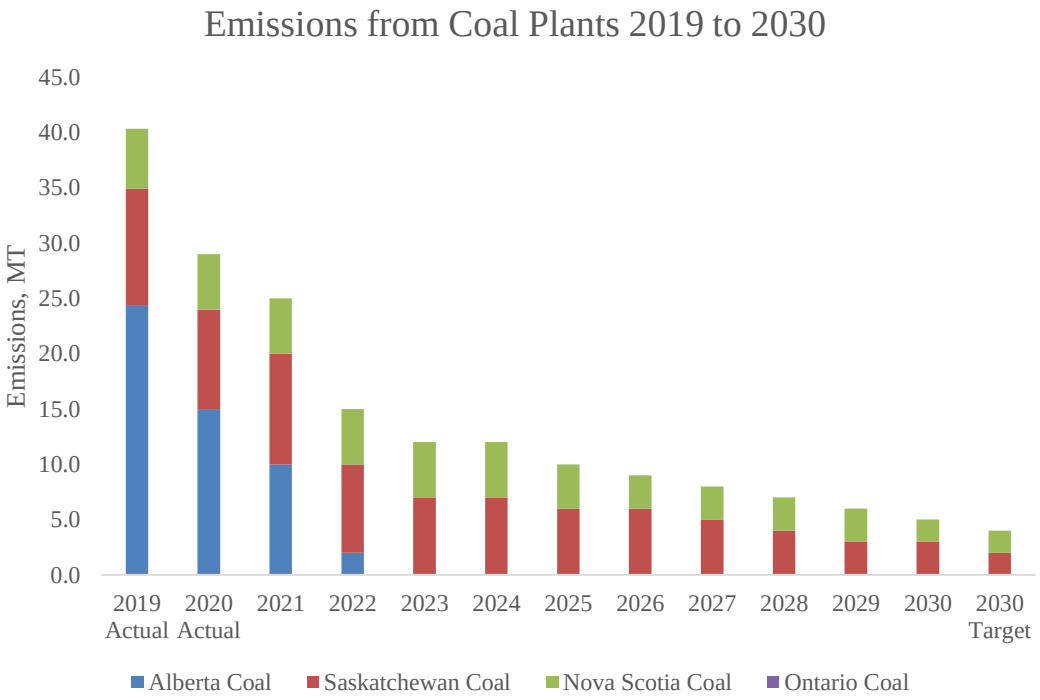
Source: https://www.theglobeandmail.com/business/article-ontario-natural-gas-energy/#:~:text=Opinion-,Ontario%20to%20increase%20use%20of%20gas%2Dfired%20plants%20for%20energy,further%20questions%20about%20climate%20commitments&text=Ontario%20will%20procure%20additional%20electricity,emissions%20from%20the%20electricity%20sector.

Total Emissions from Electricity in 2019 to 2030 Period

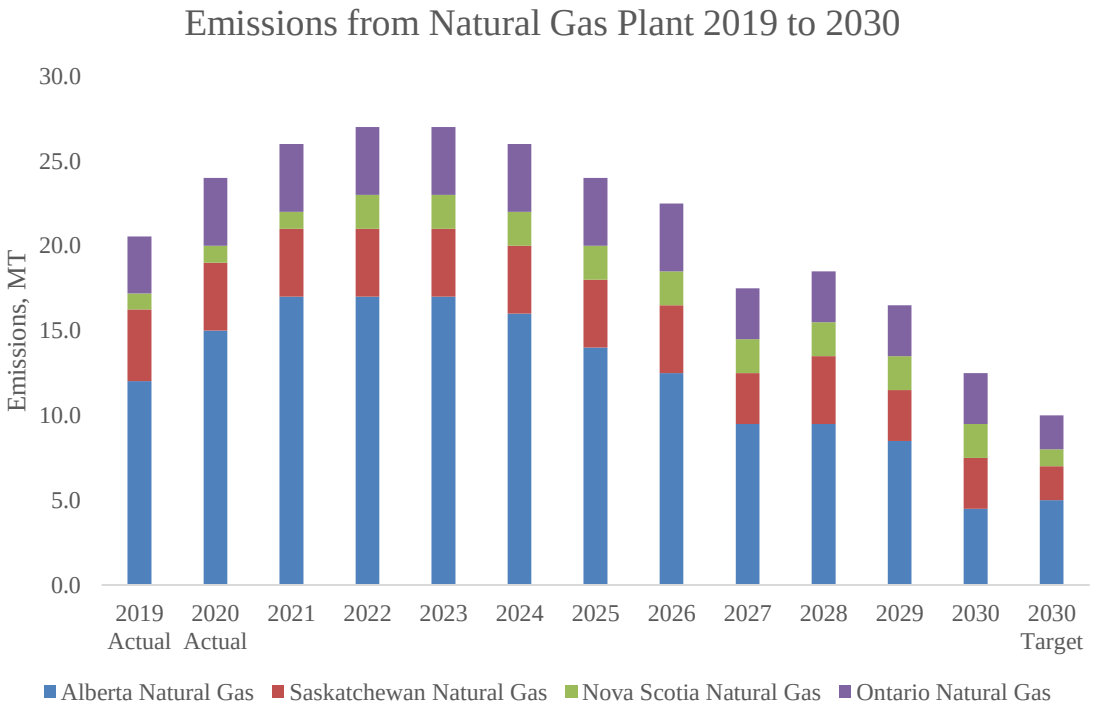
Total Emissions from Electricity Sector



Total Emissions from Coal Plants in Electricity Sector



Total Emissions from Natural Gas Plants in Electricity Sector



Backup Charts - Emissions Reduction Plans for 2019 to 2030

Phase Out of Coal Fired Plants

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Plans by Different Provinces to Phase Out Coal

- In Alberta, most coal units are projected to be converted to run on natural gas. The conversion starts as early as 2021, with the last unit expected to be converted by 2029.

- The Dispatchable Dominant Scenario demonstrates a significant shift away from natural gas generation (combined-cycle, simple-cycle, and coal-to-gas conversion units) to combined-cycle with CCS and hydrogen-fired generation. Wind, solar, and hydroelectric generation provide sustained contributions to the clean-energy grid throughout the forecast term. As with other scenarios, cogeneration continues to provide significant contributions to the total energy consumed in Alberta. Fossil-fuel-based combined-cycle and simple-cycle generation diminished significantly throughout the forecast horizon. By 2030, 23 per cent of the energy generated in Alberta is forecast to come from renewable resources in the Dispatchable Dominant Scenario.

Source: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2020/market-snapshot-canadas-retiring-coal-fired-power-plants-will-be-replaced-renewable-low-carbon-energy-sources.html

Phase Out of Coal Fired Plants

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Plans by Different Provinces to Phase Out Coal

- Saskatchewan currently has one coal-fired generation station that is equipped with carbon capture and storage technology.[Footnote3] In the projection period, Saskatchewan's retiring coal is replaced by a growing share of renewables. By 2030, renewables supply over 40% of the province's electricity demand. Saskatchewan also plans to purchase over 300 MW of hydroelectric power from Manitoba starting in 2022.

- New Brunswick and Nova Scotia plan to add wind, expand hydro units, and purchase hydroelectricity from Newfoundland and Labrador, who is now connected to their electricity markets by the Maritime Link transmission line.

Source: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2020/market-snapshot-canadas-retiring-coal-fired-power-plants-will-be-replaced-renewable-low-carbon-energy-sources.html

Phase Out of Coal Fired Plants

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Plans by Different Provinces to Phase Out Coal

- In Ontario The Independent Electricity System Operator (IESO) recommended in a report released the same day that Ontario add up to 1,500 megawatts by 2027, largely through expansions of existing natural-gas plants.
- Source. https://www.theglobeandmail.com/business/article-ontario-natural-gas-energy/#:~:text=Opinion-,Ontario%20to%20increase%20use%20of%20gas%2Dfired%20plants%20for%20energy,further%20questions%20about%20climate%20commitments&text=Ontario%20will%20procure%20additional%20electricity,emissions%20from%20the%20electricity%20sector.

Source: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2020/market-snapshot-canadas-retiring-coal-fired-power-plants-will-be-replaced-renewable-low-carbon-energy-sources.html

Forecasting Land Use GHG Emissions in Canada for Period 2019 to 2030

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Land Use (Tree Planting) Sector

Executive Summary Showing Results and Conclusions

Conclusions of Forecast for Emissions from Land Use

- The model forecasts emissions from the four categories of land use, namely wetlands, forestry, agricultural and settlements
- The Environment and Climate Change Canada (ECCC) released the Emissions Reduction Plan (ERP) in late March 2022
  - the ERP stated an emissions target in 2030 for land use of -30 million tons (MT) of greenhouse gas (GHG) emissions

- The model forecasts emissions from land use in 2030 as follows

	2019	ERP 2030 Target	Model 2030 Forecast
Wetlands	3	3	3
Forestry	9	-25	-15
Agricultural	-4	-10	-5
Settlements	2	2	2
Total	10	-30	-15

- The conclusion from the model is that 2030 emissions from land use will exceed the 2030 target in the Emissions Reduction Plan by 15 MT

Conclusions of Forecast for Emissions from Land Use

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Reasons why Model Forecasts ERP 2030 Target for GHG Emissions Will Not be Met

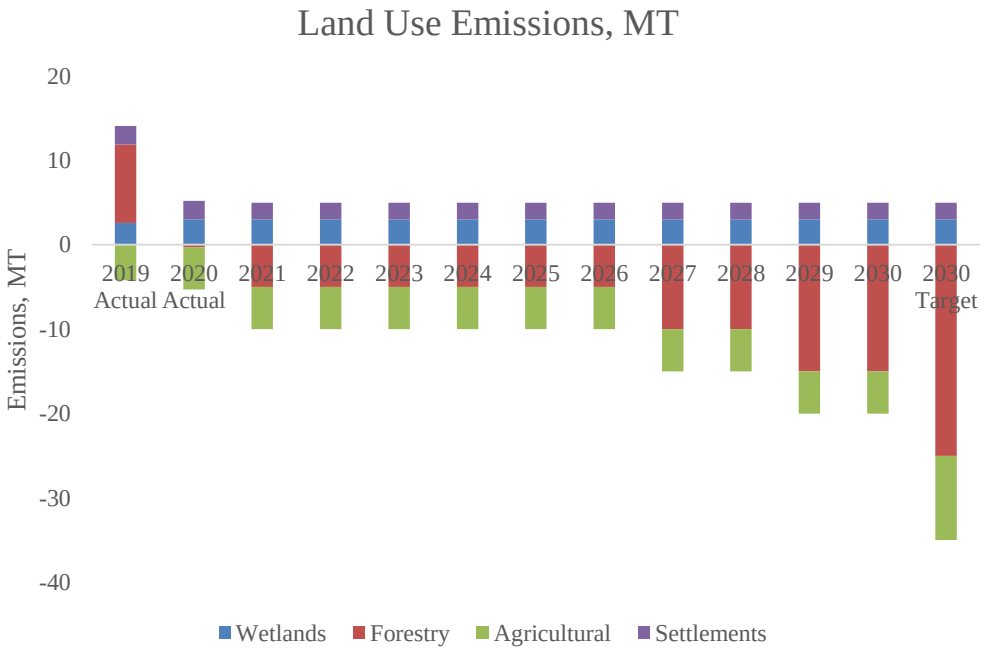
- The major tool to lower emissions for land use is to grow plants and trees that will act as a carbon sink to absorb GHG emissions

- The 2030 target in the ERP to absorb 30 MT is above the 2019 number of 10 MT of releasing emissions, and above most recent historical numbers
  - the -30 MT target likely depends on increasing forest area by planting 2 billion trees

- A more realistic 2030 target is -15 MT

Forecast of Land Use Emissions for Period 2020 to 2030

- Emissions of 10 MT in 2019 are forecast to drop to -15 MT in 2030, or 15 MT above the -30 MT target in the 2030 ECCC ERP

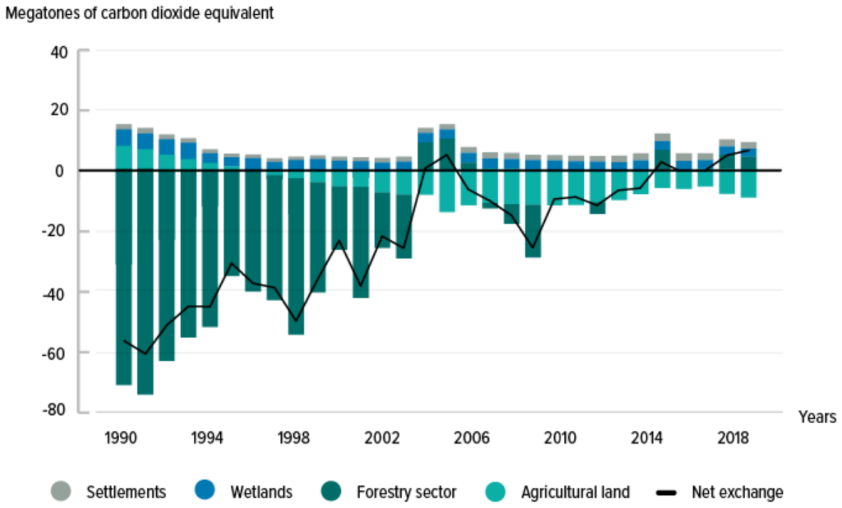


Methodology of Model

Historical Emissions for Land Use sector

- Black line shows that net emissions from land use has averaged a negative (absorbed emissions) of about -10 MT for the period from 2002 until 2019, and was a positive (released emissions) of 9.9 MT for 2019

Land-based greenhouse gas emissions and removals from human activities by activity sector, Canada, 1990 to 2019



- In 2019, lands under the influence of human activity emitted 9.9 Mt into the atmosphere. Forestry, wetlands and settlements emitted 9.3, 2.6 and 2.2 Mt CO2e, respectively, while agricultural lands removed 4.2 Mt CO2e.

Source: March 2022 ERP page 70 and 71

Emissions from Land Use Sector

- Extract from April 14 2022 NIR shows land use emissions
- Note that the number of -16 MT for 2019 is different from the +9.9 MT number in the ERP
- Data from this chart not used

Table 2–10 **GHG Emissions and Removals from LULUCF, Selected Years**

Sectoral Category		Net GHG Flux (Mt CO_2 eq)[a]								Change (Mt CO_2 eq)	
		1990	2005	2015	2016	2017	2018	2019	2020	1990–2020	2005–2020
Land Use, Land-Use Change and Forestry TOTAL		**-64**	**-4.2**	**-0.1**	**-11**	**-17**	**-8.5**	**-16**	**-6.8**	**57**	**-2.5**
a.	Forest Land	-200	-130	-130	-140	-140	-130	-140	-130	72	4.7
b.	Cropland	0.4	-22	-10	-17	-23	-19	-14	-9.6	-10	12
c.	Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
d.	Wetlands	5.4	3.1	3.0	3.1	3.1	2.8	2.9	2.9	-2.5	-0.2
e.	Settlements	1.9	1.7	2.5	2.5	2.4	2.2	2.2	2.2	0.3	0.5
g.	Harvested Wood Products	130	150	140	140	140	140	130	130	-2.7	-20

Notes:

Totals may not add up due to rounding.

a. Negative sign indicates net removals of CO_2 from the atmosphere.

Forecasting Waste and Other GHG Emissions in Canada for Period 2019 to 2030

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Waste and Other Sector

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Executive Summary Showing Results and Conclusions

Conclusions of Forecast for Emissions from Waste and Other

- The model forecasts emissions from the three categories of Waste and Other, namely solid waste disposal, other waste disposal and emissions from light manufacturing (coal, light manufacturing, construction and forest resources)

- The Environment and Climate Change Canada (ECCC) released the Emissions Reduction Plan (ERP) in late March 2022
  - the ERP stated an emissions target in 2030 for waste and other of 29 million tons (MT) of greenhouse gas (GHG) emissions

- The model forecasts emissions from waste and other in 2030 as follows

	2019	ERP 2030 Target	Model 2030 Forecast
Solid waste	23	15	22
Other waste	5	2	3
Light manufacturing	23	12	14
Total	51	29	39

- The conclusion from the model is that 2030 emissions from waste and other will exceed the 2030 target in the Emissions Reduction Plan by 10 MT

Conclusions of Forecast for Emissions from Waste and Other

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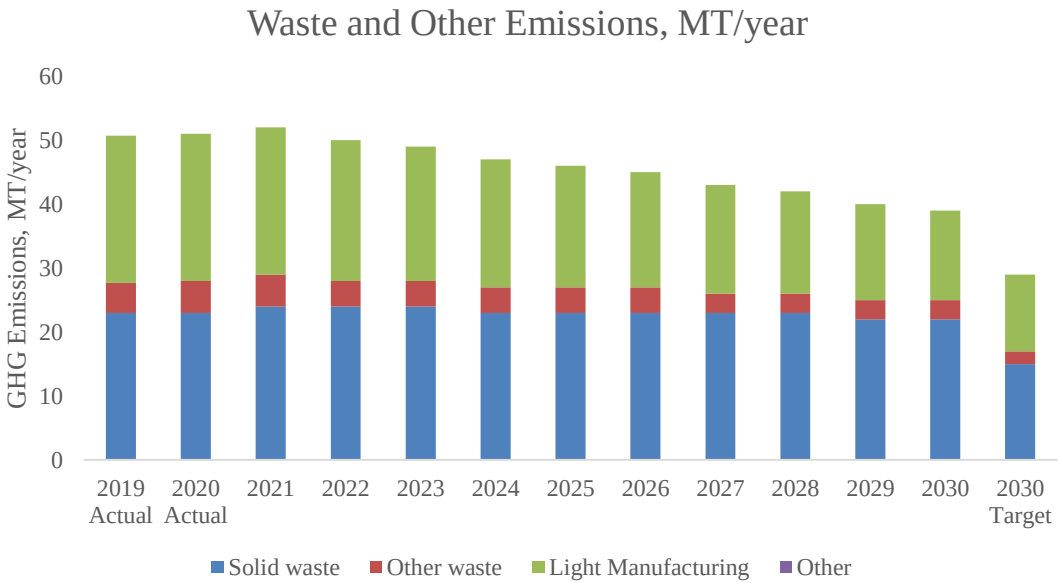
Reasons why Model Forecasts ERP 2030 Target for GHG Emissions will Not be Met

- Most of the emissions from waste (28 MT) are not carbon dioxide from combustion, but rather methane from decomposing waste in landfills and other processes
- Reducing these methane emissions will be a technology challenge and limited to 3 MT reduction
- The remaining 23 MT comes from the combustion of fuel for various light manufacturing and other activities
- Some reductions in these emissions from other can occur through electrification
  - the assumption in the model is that emissions can be reduced by 9 MT

Source: https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=AN&sector=aaa&juris=00&rn=6&page=0 , NIR Report page 66, ERP page 65

Forecast of Waste and Other Emissions for Period 2020 to 2030

- Emissions of 51 MT in 2019 are forecast to drop to 39 MT in 2030, or 10 MT above the 29 MT target in the 2030 ECCC ERP



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Methodology of Model

Methodology of Model Used to Forecast Emissions of the Waste and Other Sector

- Model starts with data from three Government of Canada sources
  - Emissions Reduction Plan (ERP) dated March 29 2022 from ECCC
  - National Inventory Report dated April 14 2022
  - Various NRCan websites

- These three documents are used to set the 2019 emissions and the 2030 target for emissions for the three subsectors that comprise the waste and other sector
  - solid waste disposal
  - other waste disposal
  - light manufacturing

- Model then makes assumptions for the period 2019 to 2030
  - Any reductions from solid and other waste,
  - Reductions due to electrification of light manufacturing

- Model then calculates GHG emissions for the three subsectors

Key Variables for Waste and Other sector

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Key Variables

- Development of technology to capture methane from waste sites and processes
- Ability to electrify equipment used in light manufacturing

Methodology of Model Used to Forecast Emissions of the Waste and Other Sector

- The final result is a forecast of the total emissions of the entire waste and other sector for each year from 2019 to 2030, broken down by each of the three sub sectors

Summary of 2019 Emissions and 2030 Targets for Waste and Other in Canada

Emissions from Waste and Other Sector Canadian Economy Sectors

- Extract from April 14 2021 NIR show waste and other emissions page 56

Table 2–12 **Trends in GHG Emissions by Canadian Economic Sector**

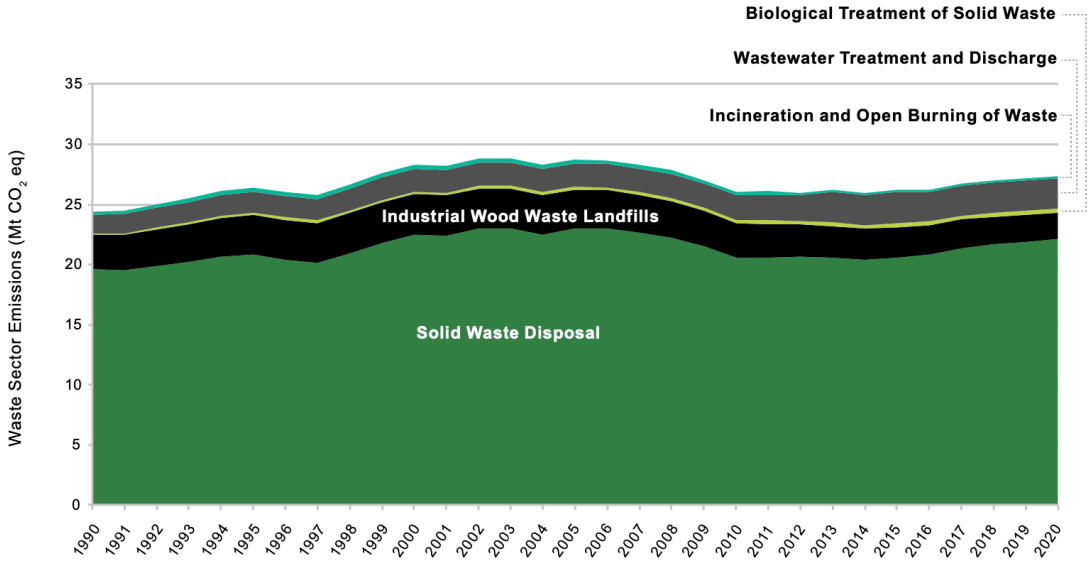
	1990	2005	2014	2015	2016	2017	2018	2019
	Mt CO_2 eq							
Waste and Others	**58**	**57**	**50**	**50**	**50**	**50**	**51**	**51**
Waste	26	31	27	27	27	27	27	28
Coal Production	4.0	2.3	2.4	2.3	2.4	2.2	2.5	2.6
Light Manufacturing, Construction and Forest Resources	28	24	21	21	21	21	22	21

- ERP of March 2022 states that emissions from waste and other are 51MT/year
  - 23 MT from solid waste
  - 5 MT from other waste
  - 23 MT from light manufacturing

Emissions from Waste and Other Sector

- Extract from April 14 2022 NIR page 59 shows waste emissions

Figure 2–24 **Trends in Canadian GHG Emissions from Waste (1990–2020)**



Emissions Forecast for 2019 to 2030 Period

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Solid and Other Waste

- Emissions from waste have not decreased for over a decade
- Methane is the primary GHG emitted from the sector, representing about 27% of Canada's methane emissions
- To further decarbonize this sector, landfills across Canada need to capture more of the methane they generate

Source: ERP page 67

- Given these challenges, assumption is that emissions will only drop by 3 MT

Light Manufacturing

- Light manufacturing can use electrification to replace emitting sources of energy

- A reasonable assumption is a reduction of emissions from 23 MT to 14 MT

Backup Charts

Emissions from Waste and Other Sector Based on IPCC Categories

- Extract from April 14 2022 NIR page 60 show waste emissions

Table 2–11 **GHG Emissions from Waste, Selected Years**

GHG Source Category	GHG Emissions (Mt CO_2 eq)								Change (%)	
	1990	2005	2015	2016	2017	2018	2019	2020	1990–2020	2005–2020
Waste Sector	**24**	**29**	**26**	**26**	**27**	**27**	**27**	**27**	**12%**	**-5%**
Biological Treatment of Solid Waste	0.07	0.24	0.31	0.32	0.33	0.36	0.36	0.36	389%	47%
Incineration and Open Burning of Waste	0.27	0.35	0.20	0.20	0.19	0.18	0.18	0.16	-40%	-52%
Industrial Wood Waste Landfills	2.9	3.3	2.5	2.4	2.4	2.3	2.2	2.2	-24%	-33%
Solid Waste Disposal	20	23	21	21	21	22	22	22	13%	-4%
Wastewater Treatment and Discharge	1.6	1.9	2.6	2.4	2.5	2.5	2.5	2.5	56%	32%

Note: Totals may not add up due to rounding.

- ERP of March 29 2022 states that emissions from waste and other are 51MT/year