Nova Scotia's Carbon Sinks and 2050 Net-Zero Scenarios

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Table of Contents

List of Tables

List of Figures

Executive summary

In 2019, the Nova Scotia legislature passed *An Act to Achieve Environmental Goals and Sustainable Prosperity*, and in 2021 the *Environmental Goals and Climate Change Reduction Act* was introduced, both of which set an emissions target for 2030 (at least 53% below the levels that were emitted in 2005) and stated that the province would reach net-zero emissions by 2050 (by balancing greenhouse gas emissions with greenhouse gas removals and other offsetting measures).

The 2030 target can be achieved if the Atlantic Loop is completed, giving the province access to power from Hydro Québec, as explained in An Analysis of the Greenhouse Gas Emissions Reduction Targets in Nova Scotia's Environmental Goals and Sustainable Prosperity Act of 2019.

Nova Scotia is not alone in its pledge to achieve net-zero by mid-century; an increasing number of other organizations and jurisdictions are doing the same thing. Net-zero requires an entity to balance its actual emissions from all emissions *sources* and any emissions *sinks* it may claim (typically a combination of changes in land use or forestry, or both, technologies for carbon capture and use or carbon capture and storage in geological structures, and emissions credits purchased in emissions trading systems):

$$Total\ Emissions = Emissions\ sources - Emissions\ sinks$$

If the $Total\ emissions$ are zero, the entity has reached net-zero, and if they are less than zero, the entity could sell the emissions as credits; however, if $Total\ emissions$ are greater than zero (i.e., the $Emissions\ sources$ exceed the $Emissions\ sinks$), the entity will need to reduce its emissions in another way, such as purchasing emissions credits.

This report examines Nova Scotia's existing emissions sinks and possible geological stores. It begins with an examination of the different types of emission sinks and the technologies for capturing and storing carbon. Natural sinks (forests, croplands, and wetlands) and carbon capture and storage technologies (direct air capture or DAC and geological structures) are reviewed, first in terms of how the process works, then the process's ability to capture carbon, and finally, the advantages and disadvantages of the process.

This is followed by a detailed analysis of Nova Scotia's natural sinks, the strength of their carbon flux, limitations on their long-term storage ability, the threats facing the sinks (such as drought, fire, or excess moisture), and the vulnerabilities of the sink to these threats. The report has found that in 2019, the province's forests and wetlands absorbed about 11.6 Mt CO_2e, while the croplands emitted about 1.5 Mt CO_2e. This is summarized in Table 1 of the report.

Table 1: Nova Scotia's 2019 carbon sinks baseline summary

Sink	Potential
Forests	9.7 Mt CO_2/y absorbed
Cropland	0.15 Mt CO_2e/y released
Wetlands	1.91 Mt CO_2e/y absorbed

The report also examines the potential for geological sequestration in the province. With the proper carbon capture and storage technology, the potential for carbon storage will be in gigatonnes (Gt) of carbon rather than megatonnes (Mt). This could be financially beneficial to the province and its development needs to be a priority

To get an understanding of the emissions reduction requirements from the province's 2019 levels, we considered three net-zero scenarios for the province in 2050 determined by the CO_2 flux strength: constant strength (the sink strength in 2050 is the same as in 2019), increasing strength (sink strength increases at different, evidence-based rates), and decreasing strength (the sink strengths decrease by 10% of the 2019 capacity per decade).

As Figure 3 from the report shows, in the increasing flux strength scenario, total emissions reduction would be about 13.9 Mt CO_2e from natural sinks (wetlands: -2.1 Mt, croplands: -0.2 Mt, and forests: -11.6 Mt). Since the province's total emissions in 2019 were about 16.2 Mt, the province would need to reduce its emissions by about -2.3 Mt. As we showed in our report on the province's 2020, 2030, and 2050 emissions targets, if the province meets its 2030 target of 10.9 Mt, it will have easily surpassed this, making it a net sink.

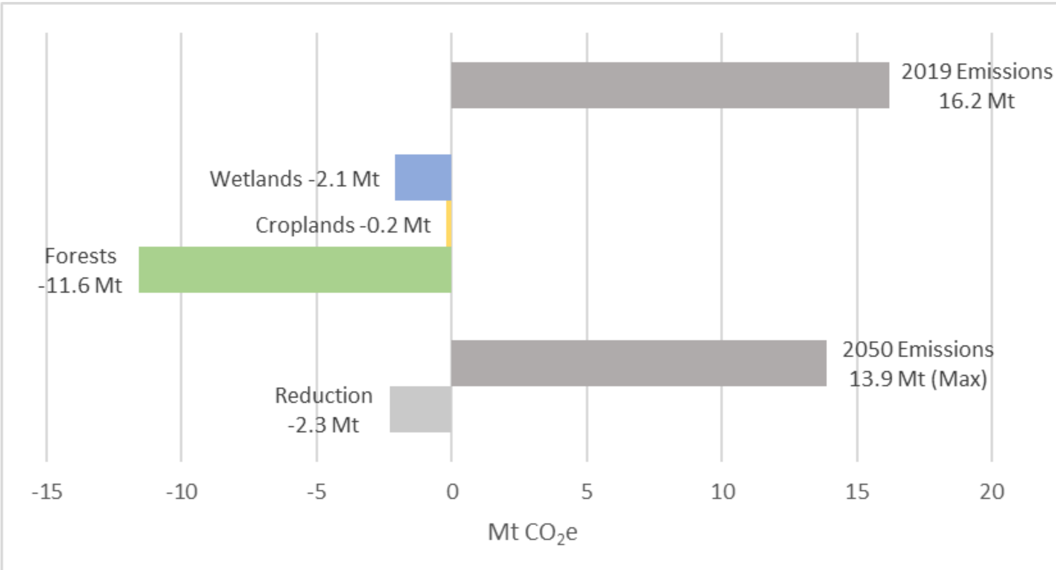

Figure 3: Emissions sinks and sources for the increasing sinks scenario

The three flux-strength scenarios were chosen to give an understanding of the size of the reduction the province would need to attain in 2050, depending on the state of the sinks. In the case of constant and increasing flux strengths, the province would have achieved net-zero by 2030 if the province's 2030 emissions target is met. However, even if the target is met, if the province's sinks weaken by 10% (something possible if extreme climate events become more likely and increase the threats to the sinks), the province will need to halve its 2019 emissions, requiring an additional 3 megatonnes of reduction from 2030 levels).

Table 2: Key results from the net-zero emissions scenarios to 2050

Sink Scenario	Projected total sink flux (Mt CO_2e)	Maximum allowable anthropogenic emissions (Mt CO_2e)	Change in anthropogenic emissions (2019-2050)	
			Mt CO_2e	**Percent**
Constant	-11.5	11.5	-4.8 Mt CO_2e	-29%
Increasing	-14.0	14.0	-2.3 Mt CO_2e	-14%
Decreasing	-7.9	7.9	-8.3 Mt CO_2e	-51%

The report concludes with a summary of the research.

Recommendations

The report makes seven recommendations:

1. *Conduct a complete and accurate biannual assessment of the province's greenhouse gas (GHG) fluxes of the biological sinks (such as forests, croplands, wetlands, and seagrass meadows)*.
2. *Measure, report, and verify the carbon-related impacts of the threats to Nova Scotia's biological sinks and conduct an economic and carbon flux assessment of the potential solutions to reducing the threats and vulnerabilities of the sinks*.
3. *Interim emissions reduction targets should be established*.
4. *Efforts should continually be made to reduce emissions beyond 2050*.
5. *Introduce tax incentives for carbon captured in natural sinks to promote the maintenance of our efforts to increase their carbon capture ability*.
6. *If the purchase of negative emissions is necessary, it must be sustainable*.
7. *Since biological sinks are at risk from extreme climate events, the province must research and if possible, develop its geological storage capacity*.

Final thought

As in our report on our report on the province's 2020, 2030, and 2050 emissions targets, we conclude with the question, if the province is unable to achieve net-zero by 2050, who pays, other than future generations?

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Introduction

In December 2015, world leaders agreed to the Paris Agreement. By November 2016, sufficient countries had ratified the agreement to bring it into non-binding force. Central to the Agreement is Article 2.1(a) which states:

> *Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.*

In 2020, the average global temperature was approximately 1.2°C above pre-industrial levels. According to the Intergovernmental Panel on Climate Change (IPCC) models, in order to limit global warming to 1.5°C or have minimal increase over this temperature, the world must have reduced net anthropogenic CO_2 emissions to roughly 55% of 2010 levels by 2030 and achieved net-zero CO_2 emissions by 2050.

To reach net-zero emissions, a jurisdiction must balance its actual emissions from all emissions *sources* and any emissions *sinks* it may claim (typically a combination of changes in land use or forestry, or both, technologies for carbon capture and use or carbon capture and storage in geological structures, and emissions credits purchased in emissions trading systems):

$$Total\ Emissions = Emissions\ sources - Emissions\ sinks$$

It is important to note that reaching net-zero emissions does not necessarily require that all anthropogenic emissions are eliminated, it just means that the same volume of emissions that are released by a source are absorbed by sinks.

To reach net-zero emissions by 2050, CO_2 emissions must be both reduced (through the use of zero-emissions energy sources and potentially through energy efficiency measures) and removed (using CO_2 sinks).

In late 2020, Canada announced that it plans to achieve a 30% reduction in emissions by 2030 and net-zero by 2050.

Nova Scotia had legislated a 2050 net-zero target in late 2019 when the Legislature passed *An Act to Achieve Environmental Goals and Sustainable Prosperity*. Following on from this in October 2021, Nova Scotia's Minister of the Environment and Climate Change introduced the *Environmental Goals and Climate Change Reduction Act* to the Nova Scotia legislature. Clause 6 of the proposed legislation states:

> *The Government's targets for greenhouse gas emissions reductions are*

> *(a) by 2030, to be at least 53% below the levels that were emitted in 2005; and*
>
> *(b) by 2050, to be net zero, by balancing greenhouse gas emissions with greenhouse gas removals and other offsetting measures.*

Based on the 2030 goal in the Act, 2030 emissions should be at most 10.9 Mt CO_2e.

The Act is non-specific with respect to its 2050 target, allowing regulations to be established as required. However, given the importance of reaching net-zero by 2050 or sooner, the province should develop legislation that addresses how net-zero will be achieved, both through emissions reduction and sink protection, enhancement, and development.

This report takes a first step in addressing how Nova Scotia can achieve net-zero by examining the province's emission sinks.

The report evaluates Nova Scotia's current net emissions and estimates future net emissions. This is done through an analysis of Nova Scotia's existing carbon sinks and examining three different 2050 sink scenarios. The maximum allowable anthropogenic emissions to meet the net-zero target will be determined based on the projections of the sinks, providing clarity for the legislation and what is possible.

The report first reviews carbon sinks, their processes and, in some cases, technologies. Following this, a 2019 Nova Scotian baseline of known carbon sinks and the province's geological sequestration strength is presented along with the threats and vulnerabilites to those sinks and potential solutions to reducing the impacts of the threats. Once the baseline is established, the sinks will be projected under different scenarios to determine the maximum allowable anthropogenic emissions that still meet the province's climate targets. Finally, recommendations that were produced as a result of this research will be provided.

Sections of this report were used in a submission to the Province of Nova Scotia as part of public consultations regarding the Sustainable Development Goals Act.[1]

[1] The report, "An Analysis of the Greenhouse Gas Emissions Reduction Targets in Nova Scotia's Environmental Goals and Sustainable Prosperity Act of 2019", was submitted by Larry Hughes and Mark McCoy on 26 July 2021.

Review of Carbon Sinks

A sink is "any process, activity or mechanism which removes a greenhouse gas from the atmosphere" . Carbon dioxide sinks (also referred to as carbon sinks in this report) are sinks that remove CO_2. There are two kinds of carbon sinks: natural and artificial. Carbon sinks require the sequestration of the CO_2 they capture for an acceptable amount of time if they are to be considered for mitigating climate change. Ideally, the CO_2 would be sequestered permanently or for thousands of years. In this report, a natural sink is a carbon sink that captures CO_2 using processes that occur naturally on Earth.

If a sink is enhanced by humans, but its main process is naturally occurring, this report will consider the sink as natural. In this report, an artificial sink is a carbon sink that captures CO_2 using methods developed by humans. There are three natural sinks that are examined in this report which are relevant to Nova Scotia: forests, croplands, and wetlands. The artificial sink that is examined in this report is direct air capture in combination with carbon sequestration in geological formations. Finally, some other carbon sinks that were not the focus of this report will also be discussed. All monetary figures presented in this section are in 2019 USD.

Forests, Croplands, and Wetlands

The land sink was the largest carbon sink available globally in 2019. This subsection of the report will examine how forests, croplands, and wetlands work as carbon sinks, their ability to capture and sequester carbon, and the advantages and disadvantages to them working as carbon sinks.

How it Works

Various forms of vegetation absorb carbon dioxide from the atmosphere through direct contact. Aquatic plants obtain CO_2 through contact with CO_2 in water, air, or both (if not fully submerged). Plants use photosynthesis to uptake CO_2 and some is released back to the atmosphere through respiration. The retained CO_2 is eventually converted into materials for the structural material of the plant, such as bark or leaves; this is how carbon is stored in plants, and when vegetation dies, it decomposes and begins to release the carbon that it stored. When plant products burn, such as in wildfires or intentional burning. The soil that vegetation is in can also contain a significant amount of the carbon in a vegetated area in the form of soil organic matter (44% of forest carbon is stored in the live vegetation and 45% of forest carbon is stored in the form of soil organic matter).

Three major areas of vegetation for carbon sinks are forests, croplands, and wetlands. There are various proposals on how best to capture carbon by managing these three areas of vegetation, such as coastal blue carbon and terrestrial carbon removal and sequestration (TCRS).

Coastal blue carbon is a carbon capture and sequestration (CCS) method that involves tidal wetlands and seagrasses capturing carbon and storing it in the structural material of the plants as well as burying plant organic carbon in their soils. Tidal wetlands can expand both along the sea floor and vertically (they must expand vertically at the same or greater rate of rising sea levels), potentially increasing the amount of carbon they can capture and sequester. Most of the organic carbon collected in tidal wetlands is a product of the wetlands themselves. While coastal blue carbon is a natural process, with human involvement, its ability to capture and store carbon can be improved through measures such as restoring coastal wetlands; improving the carbon storage of coastal areas by burying high-carbon materials that were not made in the coastal ecosystems in them; managing coastal wetlands in such a way that allows their area to increase with rising sea levels and that increases or maintains the rate at which organic carbon is buried over time; and preventing wetlands from being drained.

TCRS is a CCS method that involves land-based plants capturing CO_2 and storing it in the structural materials of the plants as well as storing carbon in the soil. Increasing the amount of carbon stored in forests requires planting and preserving more carbon-dense trees, or protecting more trees from being lost (through natural death, harvesting, or fire), or both. Increasing the amount of carbon stored in soil requires adding more plant matter to the soil, decreasing the decomposition rate of soil organic matter into CO_2, or both. As with coastal blue carbon, TCRS is a natural process, but humans can improve its ability to capture and store carbon. Various practices of TCRS can be divided into the types of the land that they are used on, such as forests, grasslands, and croplands. Some forestry practices include avoiding deforestation; afforestation and reforestation; management of forests to restore and maintain their health, and increase their growth; increasing the time before harvest of trees to maintain the carbon capture ability of the trees; and preserving more harvested wood and wood products (a developing practice which may improve carbon/CO_2 removal). These practices have the potential to increase carbon capture and reduce CO_2 emissions associated with wood products. In terms of grassland/cropland practices that help remove and reduce CO_2 emissions, they can be divided into two categories: conventional (already established) and frontier (developing). Some conventional grassland/cropland practices are including trees in agricultural land and management techniques such as not tilling the ground as frequently or at all before planting crops (the CCS ability of tilling practices varies based on the climate and soil characteristics). Some frontier grassland/cropland practices include: adding biochar (solid carbon by-product resulting from the biomass-to-fuel process) to soil to store carbon and increase crop productivity; placing high-carbon surface soils deeper underground and low-carbon soils near the surface to allow more carbon to be absorbed and potentially increase the amount of time carbon remains in the soil; and modifying current agricultural plants to increase the amount of carbon sent to the plant roots.

Carbon Capture Ability

The global land sink captured an estimated 11.50 $GtCO_2$ in 2019, which is approximately 27% of the global CO_2 emissions, while land-use changes were responsible for 6.60 Gt of global CO_2 emissions. The potential annual global CCS ability and CO_2 capacity of coastal blue carbon with the technology and knowledge in 2019 was 0.13-0.80 $GtCO_2$/y and 8-65 $GtCO_2$. The potential annual CCS ability and CO_2 capacity of TCRS practices with the technology and knowledge in 2019 was 5.5-12 $GtCO_2$/y globally and 660-1215 $GtCO_2$ globally, respectively. There are significant variations in the carbon absorbed by the land between years, with variation reaching as high as 4.62 $GtCO_2$/y in the previous decade. This variation is connected to changes in temperatures and stored water in tropical regions, and can result from weather events.

There are multiple factors that affect the carbon capture ability of vegetation and the land sink. The amount of carbon absorbed by vegetation on the land is believed to increase when higher atmospheric CO_2 concentrations increase photosynthesis, causing more plant growth and thus, more carbon to be stored, and when forests reclaim former agricultural land. While increased CO_2 allows for plants to grow more, plants are still limited by other materials that may not be as plentiful to grow. It has been recently found that globally, the effectiveness of 86% of terrestrial ecosystems at capturing CO_2 is decreasing. The vegetation sink can be divided into two categories: vegetation that quickly acts to reach equilibrium with the CO_2 in the atmosphere and the vegetation that is not in equilibrium with the CO_2 in the atmosphere. Types of vegetation that fall into the first category are leaves and small roots, whereas those that fall into the second category are live wood and long-lasting, land-based dead organic matter. Should the CO_2 concentration in the atmosphere decrease over a century, the land is predicted to remain a carbon sink due to the absorption of CO_2 by the vegetation that does not reach equilibrium with the atmosphere, despite the vegetation that releases CO_2 during this time. When more CO_2 is removed from the atmosphere, the effectiveness of vegetation as a carbon sink will decrease. In a business-as-usual scenario, it is predicted that the land carbon sink will become a land carbon source as a result of factors such as plants lacking resources other than CO_2 to grow and the death of forests to high temperatures and drought. The removal of the trees through methods such as harvesting, natural death, or fire affects the carbon capture ability of trees. Also, due to changes in albedo when conducting afforestation/reforestation at high latitudes, the result is an overall increase in temperature even after taking into account the temperature decrease from the emissions reduction from trees.

Advantages/Disadvantages

Some advantages to coastal wetlands are that they help to protect coasts during storms, provide homes for wildlife, and reduce the strength of waves. Coastal blue carbon practices can also reduce the flood risk to humans by reducing the population of regions that are becoming more prone to flooding. Another major disadvantage to coastal blue carbon is that there is risk that the practices used, such as shoreline modification, will ultimately harm the coastal ecosystem. Some advantages to TCRS practices are that the practices can be viewed as repairing damage done to the ecosystem, they may improve ecosystem diversity, and improve soil quality. A significant disadvantage to these practices is that there might be competition for land with other economic needs, such as food production, so what is technically possible for carbon capture may not be necessarily feasible. Another major disadvantage is that the effects of the practices can be reversed by methods such as harvesting, where the carbon that was stored gets released. One final disadvantage to some terrestrial practices is that adoption rates for some of these practices are low, preventing the effects from being realized. The estimated costs to implement the CO_2 removal practices of coastal blue carbon and TCRS span a relatively small range. The cost for coastal blue carbon burial is estimated to be \$10/t CO_2 and the cost for TCRS is estimated to range \$15 to \$100/t CO_2.

Direct Air Capture

As the name suggests, direct air capture (DAC) technology captures CO_2 from the air. While DAC is not a sink by itself, the combination of DAC with carbon sequestration in geological formations is a carbon sink. DAC has the potential to provide significant carbon capture abilities. This subsection examines how DAC works, the ability of DAC to capture carbon, and its advantages and disadvantages.

How it Works

In a DAC system, air is pulled from the atmosphere into an air contactor where CO_2 is removed from the air. DAC systems are carbon capture systems; they do not store CO_2. At present, DAC systems can capture CO_2 using liquid solvents or solid sorbents.

Carbon Engineering's DAC systems use a liquid solvent in the form of a KOH solution and capture 75% of the CO_2 passing through their DAC system. The liquid solvent DAC system uses an aqueous solution of KOH as well and can capture 75% of atmospheric CO_2 passing through the air contactor at an ambient concentration of 400 ppm. In the liquid solvent DAC system, there are five further processes, including causticizing, calcinating, slaking, clarification and filtering, and air separation of O_2, where the KOH is recovered, and high-concentration CO_2 gas is produced. The following are the reactions for the different processes:

$$2KOH_{(aq)} + CO_{2\,(g)} \rightarrow H_2O_{(g)} + K_2CO_{3\,(aq)} \text{ (Air Contactor)}$$

$$K_2CO_{3\,(aq)} + Ca(OH)_{2\,(aq)} \rightarrow 2KOH_{(aq)} + CaCO_{3\,(s)} \text{ (Causticizer)}$$

$$CaCO_{3\,(s)} \rightarrow CaO_{(s)} + CO_{2\,(g)} \text{ (Calciner)}$$

$$CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2\,(aq)} \text{ (Slaker)}$$

Not only is KOH recovered through these processes, but materials for the various processes are recovered throughout the system reactions shown above.

In DAC systems that use solid sorbents, air is brought into contact with a solid, CO_2-adsorbing material which captures the CO_2 on its surface. The material is then heated, or placed in a vacuum, or both which releases the CO_2 from the material at which point it can be processed for sequestration. The CO_2-adsorbing material is then cooled to begin capturing more CO_2.

Once CO_2 is captured through either type of DAC system, it must be stored; for example, in geological formations.

Carbon Capture Ability

The carbon capture ability of DAC is mainly constrained by finances rather than technical constraints. The sequestration of the CO_2 that is captured by DAC systems does have limitations in the form of feasible geological sequestration locations and safe storage capacity. DAC systems can be constructed anywhere, but the infrastructure and resources to operate DAC systems must be in place as well, potentially limiting DAC locations. The energy that is required to run the DAC systems could be obtained from renewable and/or non-renewable sources, the use of renewables increasing the net CO_2 capture ability of the DAC system and the use of non-renewables decreasing that ability. To increase the net CO_2 capture ability of DAC systems, non-emitting energy sources should be employed.

If natural gas was used as a thermal energy source for liquid solvent DAC, the system could absorb the CO_2 produced by the combustion of the natural gas while also absorbing as much atmospheric CO_2 as possible. This reduces the volume of atmospheric CO_2 that can be captured. The employment of power sources at the location of the DAC system has the potential to be limited by land availability. If there are multiple air intake points, it is important to place them such that the air being pulled in by the air intakes at each point has an ambient concentration of CO_2, allowing for optimal carbon capture.

Advantages/Disadvantages

The major advantages of DAC are its potentially large annual CO_2 capture abilities and relatively small land usage to achieve those ends. Also, DAC allows for CO_2 product at various purities to be sold to the market. The most significant disadvantage to DAC is that it is presently an expensive technology for CO_2 removal, with average costs ranging from roughly $90/t to $900/t of net CO_2 captured.

The limited deployment of DAC systems has resulted in a lack of data for analyses to help policymakers understand the costs of negative emissions through DAC systems that are required to meet the climate goals of the Paris Agreement. One advantage is that it does not seem to be a lack of fundamental understanding of the technology that is slowing its uptake.

Some disadvantages of DAC include the significant reduction in local CO_2 concentrations may have a detrimental impact to local ecosystems; potential chemical emissions from solid sorbent DAC systems may harm the environment; more research needs to be conducted into water production and use in DAC; and to reach large scale CO_2 capture via DAC, a significant amount of money needs to go towards research and development. Another significant disadvantage of DAC systems is that they are not carbon sequestration technologies themselves – they need another method to store the carbon they capture to be useful. Looking past 2050, it has been recently found that DAC could decrease the costs of meeting international climate targets, but doing so would require up to 25% of worldwide energy in 2100; this is a significant potential disadvantage.

Carbon Sequestration in Geological Formations

Carbon sequestration in geological formations (CSGF) is an artificial carbon sink support method that works with bioenergy with carbon capture and sequestration (BECCS) and DAC by acting as the storage method. Here we examine how CSGF works as a carbon sink, the ability of CSGF to sequester carbon, and the advantages and disadvantages to CSGF working as a carbon sink.

How it Works

CSGF is a primary CO_2 storage method for both BECCS and DAC systems. This technology is simply a storage method for the CO_2 that other technologies capture. Captured CO_2 must first be compressed into a supercritical fluid before it can be sequestered, allowing for more CO_2 to be stored. The fluid is then pumped into an underground geological formation for long-term storage. The formation must be deep enough that the underground pressure and temperature causes the fluid to stay compressed and supercritical. The geological formations that can be used for CSGF must have porous rock that fluids can pass into and their tops must be sealed by rock that is difficult or impossible for fluids to pass through. Due to the density of supercritical CO_2 in relation to fluids that fill the rock pores, the CO_2 will rise to the top of the rock formation and be stored permanently if there are no leakage pathways; sedimentary rocks can be used for CSGF.[2] Some reservoirs for CO_2 storage include depleted oil/gas deposits and deep saline aquifers – both onshore and offshore locations. One method of CSGF injects CO_2 into oil/gas reserves to increase extraction while also storing CO_2, a process referred to as enhanced oil/gas recovery. To increase the trapping ability of CO_2 in the underground reservoirs, multiple methods can be implemented, such as CO_2 (or carbon) mineralization.

Carbon Storage Ability

By 2019, major saline aquifer CSGF projects sequestered individual amounts between 0.3 and 1.2 Mt CO_2/y. The potential global CO_2 capacity of saline aquifer CSGF given the knowledge and technology in 2019 was 5,000 to 25,000 Gt CO_2. Enhanced oil recovery projects can be carbon sinks provided that substantially more CO_2 is injected into the reservoir per barrel of oil produced.

One factor that affects the ability of CSGF to store CO_2 is the potential for leaks in the CO_2 reservoir. Leaks could be the result of cracks in the low permeable rock. If the sequestration site is not near the capture site, transportation will be required to the sequestration site, potentially resulting in CO_2 emissions (i.e., transportation on a ship burning fossil fuels). Consequently, the net CO_2 captured and sequestered could decrease. Ideally, sequestration sites would be near to the location of carbon capture to avoid transportation costs and potential emissions. It is important to note that there is a maximum sequestration rate for CO_2 in CSGF that is capped where unsafe pressure build-up in a reservoir is not reached. An important factor which limits the CO_2 sequestration capacity of CSGF is that injecting CO_2 into reservoirs can result in a build-up of pressure that may cause seismic activity or break the reservoir seal. Once stored in the reservoir, unless there is leakage, the CO_2 will remain in the reservoir for an indefinite period.

Advantages/Disadvantages

The most significant advantages of CSGF are: it has a large potential CO_2 storage capacity; there is a significant amount of research and experience with CSGF; and storage of CO_2 is permanent provided there are no leaks. Additionally, the cost of CO_2 sequestration is very low at \$7 to \$13/tCO_2. Major disadvantages of CSGF include implementation of CSGF may result in further seismic activity; leakage of the CO_2 reservoir may contaminate groundwater; it requires a significant amount of research to scale up CSGF and

[2] Professor Grant Wach, Dalhousie University, personal communication, 23 June 23, 2021

guarantee its safe and consistent application; and a sequestration site may not necessarily be near high-emissions sources. Given the use of CSGF in enhanced oil recovery, another advantage of CSGF is that the oil industry could play a role in carbon sequestration should it make sense to do so, improving their oil extraction. Another significant disadvantage to CSGF is that, depending on a country's laws, it may not be explicit who is financially liable for CO_2 reservoirs long after a sequestration project has ended; this has been a major contributor to preventing large-scale deployment of CSGF. Another barrier to scaling up CSGF is the potential issue of gaining permission to conduct CSGF under lands that are owned by potentially many people, which expends time and money.

Other Sinks

Other sinks which were not examined in relation to Nova Scotia, but which may have carbon capture potential for the province include bioenergy with carbon capture and sequestration (BECCS) and carbon mineralization. BECCS is a mix between an artificial sink and a natural sink while carbon mineralization is a sink following a natural process. In their respective subsections, how the technologies work will be explained and their global carbon capture potential will be provided.

Bioenergy with Carbon Capture and Sequestration

Generally, BECCS is the process in which CO_2 is captured from the air via growing vegetation, the vegetation is used in bioenergy power plants, CO_2 is captured from the power plants, and CO_2 is then stored in geological formations. As explained above, plants capture CO_2 via respiration and store it in the materials that constitute the vegetation. While some carbon can be stored in the soil at this step, the sequestration of carbon for BECCS is focused on geological formations.

Some other methods of BECCS are: the vegetation is fermented into fuel and CO_2 from the fermentation process is captured and sequestered; and the vegetation is converted to fuel and the biochar product of this conversion is sequestered in soil as in the TCRS practice. Sources that could be used for BECCS include: energy crops grown on marginally productive cropland (of which there is a substantial amount globally); forestry plant residues; crop plant residues; and organic waste from cities. When biomass is collected from the source, it must then be transported to a consumer (including industrial consumers) for conversion into its next product (i.e., fuel, energy, or biochar, or all three). If the product is fuel, that fuel must be transported to the consumer, adding CO_2 emissions to the atmosphere which BECCS can absorb. It is important to note that emissions will vary depending on the mode of transportation as well as the distance travelled. The biomass can be converted to various products (such as heat and fuel) using multiple methods that fall under thermochemical or biological classifications, such as pyrolysis, fermentation, gasification, and simply combustion.

When biomass combustion is used for thermal or electrical power, CO_2 is produced and the methods for capturing this CO_2 are typically no different than the developing methods for CCS in a fossil fuel power plant. Some methods in which power plant CO_2 emissions are removed are where CO_2 is separated either before or after combustion. One technology of CCS used in fossil fuel power plants is CO_2 scrubbers, which remove a net of 80% to 90% of CO_2 emitted by the plant when including the extra energy and emissions for running the scrubbers. Once the CO_2 is captured from these processes, it can be sequestered in geological formations. When biomass is converted to fuel, carbon can be stored in biochar which can be added to soil for sequestration as well as a potential benefit to the productivity of the land.

The potential annual carbon capture ability of BECCS with the technology and knowledge in 2019 was 3.5 to 15 Gt CO_2/y globally. Like DAC, the CO_2 capacity for BECCS methods that store CO_2 in geological formations is constrained by the space in geological formations to store CO_2 safely and feasible geological sequestration locations. The CO_2 capacity for the BECCS method that produces fuel along with biochar seemingly does not have capacity constraints. As discussed previously, the mode of transportation and the transportation distance for biomass can decrease the net CO_2 removal ability of BECCS to varying degrees. Truck transportation has the highest rate of CO_2 emissions per kg of biomass per km travelled, followed by train and then sea freight. A significant factor that affects the carbon capture ability of BECCS is carbon losses: for a bioenergy integrated gasification combined cycle power plant that uses CO_2 capture and sequestration and burns switchgrass, from the point of carbon capture in switchgrass to the point of sequestration of that carbon, over half of the original carbon can be lost. It is important to note that the combustion, degradation, and respiration of living things contribute to CO_2 and CH_4 emissions.

Carbon Mineralization

Carbon mineralization is a natural process that occurs when various kinds of silicates and rocks high in calcium or magnesium content are weathered. Natural carbon mineralization can capture 30 Gt CO_2 over a century. CO_2 can be stored as carbonates by reacting with the previously described materials. Some preferred types of minerals for carbon mineralization are mantle peridotite and basaltic lavas. Some of the mineralization reactions are shown below:

$$\mathrm{CaSiO_3 + CO_2 \rightarrow CaCO_3}$$

$$\mathrm{Mg_2SiO_4 + 2CO_2 \rightarrow 2MgCO_3 + SiO_2}$$

$$\mathrm{Mg(OH)_2 + CO_2 \rightarrow MgCO_3 + H_2O}$$

Humans can get involved with carbon mineralization to achieve two outcomes: sequestering CO_2 in carbonate materials or both capturing and sequestering CO_2 in carbonate materials – each outcome has methods that can be taken to achieve them.

For storing CO_2, three methods can be used: ex situ, in situ, and surficial carbon mineralization. For ex situ carbon mineralization, material used in the CO_2 to carbonate reaction is brought to locations of CO_2 capture where it is reacted with CO_2 in its temporary storage substance. For in situ carbon mineralization, CO_2 that is temporarily stored in fluids are passed through viable underground rock formations to react and store CO_2 in carbonate materials. For surficial carbon mineralization, CO_2 that is temporarily stored in fluids are passed over a high surface area of certain industrial waste products (such as mining tailings) or a high surface area of reactive rocks where CO_2 can react with the material. The method for both carbon capture and storage could use in situ or surficial mineralization along with surface water as the temporary storage substance for CO_2. CO_2 from the atmosphere will dissolve in surface water naturally, so the surface water for this carbon mineralization process acts as the carbon capture component.

There is a wide range and some unknown quantities for the carbon capture ability of the various methods of carbon mineralization, given the technology and knowledge of 2019. The known values for individual sequestration-only carbon mineralization methods could be as high as 32 Gt CO_2/y for annual CO_2 removal and as high as roughly one million Gt CO_2 for global capacity. Two potential limiters of the carbon capture ability of in situ carbon mineralization are that the pores of rocks could be clogged by carbonates, preventing further carbon storage, and that the reactions that produce the carbonate materials could form a layer that protects the reactants from further reacting, potentially slowing or stopping further carbon storage. Certain kinds of rocks have higher rates of carbonation, so their abundance (or lack thereof) is important to consider when choosing a rock for carbon mineralization. For surficial carbon mineralization, some industrial waste products do not contain much calcium or magnesium, thus reducing the carbon storage capability of this method.

Nova Scotia's Carbon Sinks Baseline

To develop emissions scenarios that extend decades into the future, it is necessary to establish a baseline of the province's current carbon sinks. This section examines Nova Scotia's forests, croplands, and wetlands as carbon sinks and Nova Scotia's geological sequestration potential. The baseline year is 2019 as it is the most recent year for which key data involved in this report is available, such as the annual GHG emissions for Nova Scotia.

Nova Scotia's Forests

According to the provincial Ecological Landscape Analysis (ELA) reports for Nova Scotia's eco-districts, which use data from 2015 and 2017, the total area of Nova Scotia's forests is approximately 4.3 Mha (found by summing the forest areas provided in the ELA report for each eco-district). Assuming that this area is the area of the province's forests in 2019 and using the ELA data it was determined that forests constituted approximately 78.3% of the land area of Nova Scotia in 2019; this makes the forests Nova Scotia's largest carbon sinks by land area. This subsection will discuss the ability of forests to absorb carbon as well as the threats to the forest and vulnerabilities to events that will impact this ability.

Forest Sink Ability

The average CO_2 flux (i.e., change in CO_2 emissions) of Nova Scotia's forests was approximately -9.38 Mt CO_2/y between 2013 and 2017 and approximately -9.06 Mt CO_2/y between 2008 and 2012. This report assumes that the change in these values is linear to get the CO_2 flux for the next five-year period (2018-2022), resulting in a CO_2 flux of approximately -9.70 Mt CO_2/y for the baseline year. The data used to determine this value were collected from permanent forest sample plots (PSPs) in the province. The PSP-based estimations show only change in carbon stocks between measurement periods. Therefore, if a given plot is harvested, it is assumed that all emissions associated with the harvested wood products are emitted entirely at harvest, which will lead to an overestimation of emissions from harvested wood products that store carbon for a longer period as they decompose.[3]

Additionally, forests and PSPs were stratified by ecoregion and it is therefore assumed that the sample plots share the same carbon capture characteristics of a given ecoregion. Moreover, emissions from dead organic matter only include coarse woody debris and standing dead trees (i.e., snags) and not litter, fine woody debris, dead tree roots, or soils, which will lead to an underestimation of emissions from forests due to the decomposition of these dead organic matter pools. The total net removal of carbon from forests and harvested wood products is likely overestimated by the PSP-based data.[4]

Given that the carbon capture value for Nova Scotia's forests is likely overestimated,[5] it is important to compare it to the carbon capture value of the forests of a jurisdiction that is geographically close to Nova Scotia. Maine is one such jurisdiction, with a forested area of 17.30 million acres (approximately 7 million ha) and Maine's forests captured an estimated average net of about 15.1 Mt CO_2e/y between 2006 and 2016 (value obtained by subtracting wood product emissions from net forest uptake and converting from carbon to CO_2e). From this data, the per hectare carbon capture of Maine's forests can be estimated to be approximately 2.16 t CO_2e/ha/y. Comparing the results from Maine's forests to Nova Scotia's over a similar period (2013 to 2017) which have an estimated net per hectare carbon capture of 2.17 t CO_2e/ha/y

[3] Dr. James Steenberg, Nova Scotia Department of Lands and Forestry, personal communication, 26 July 2021)

[4] Ibid.

[5] Ibid.

(from the 2013 to 2017 flux data for the province's forests and Nova Scotia's forested area from the 2019 ELA reports), suggests the estimate for Nova Scotia is reasonable.

Threats and Vulnerabilities

There are multiple threats to Nova Scotia's forests that could reduce their ability to capture and store carbon, such as drought, fires, pests, and strong weather events.

Some potential solutions to reducing the threat of droughts to Nova Scotia's forests are to thin or intentionally burn the forest to decrease the forest density and to promote trees that can resist the effects of droughts. The likelihood of droughts happening in Nova Scotia's future is likely given that there has been a drought of any intensity during six years of the last decade and that temperatures increase with global warming.

Reducing the threat of drought consequently reduces the threat of fires to the province's forests. The risk of potentially high-damaging fires can be reduced through management practices such as prescribed burning. The likelihood of forest fires happening in Nova Scotia's future is almost certain given that there have been wildfires reported every year for the past five years and that in the rapid emissions reduction climate scenario, the province's fire season is expected to get longer.

Pests, including new pests introduced from southern climates, are considered by the province to be the highest threat to Nova Scotia's forests; to reduce the threat of these pest, the province should prepare and research forest management practices to reduce the impact of the most likely pests on Nova Scotia's forests. To reduce the threat of pests that currently inhabit the province's forests, practices to reduce their impact which already exist (such as those meant to deal with the spruce beetle) should be used (if not currently practised) and research should be conducted to improve their effectiveness or to find more effective practices. A vulnerability of Nova Scotia's forests is the vulnerability of all spruce trees to the spruce beetle during spruce beetle outbreaks. The likelihood of new pests is almost certain since it is already occurring (i.e., the hemlock woolly adelgid was reported in Nova Scotia in 2017). The likelihood of spruce budworm infestations is likely to decrease in the future should temperatures at their southern limit rise; currently, certain spruce budworm infestations cause low amounts to significant amounts of damage to large quantities of spruce-fir forests in 30- to 40-year intervals. To reduce the vulnerability of Nova Scotia's forests to pest infestations, various forest management practices can be conducted, such as decreasing the number of a pest's host trees in a forest through thinning and predicting when and where pest infestations will occur so that action can be taken to prevent further infestation. An example of a practice that is currently implemented to reduce the potential of spruce beetle infestations is removing blown down trees from an area of forest.

Some other vulnerabilities of Nova Scotia's forests are the vulnerability of tall stands of mostly spruce or balsam fir to wind damage, and the vulnerability of shallow rooted trees to wind damage. In Nova Scotia, between 2008 and 2012, two softwood tree species that were among the highest in commercial populations were red spruce and balsam fir, and a hardwood tree species that was among the highest in commercial population was red maple. The trees listed all have shallow roots which means that the province's commercial trees with some of the highest populations in their respective category were vulnerable to wind damage and likely still are. A potential solution to reducing the vulnerability of the province's forests to wind damage would be to assess areas that are high-risk and ensure that the trees do not grow too tall (since some tall trees are more vulnerable to wind damage). The likelihood of strong weather events is almost certain since hurricanes hit Nova Scotia every seven years on average, while the likelihood of extra-tropical cyclones that have winds that could result in significant damage is almost certain since cyclones of this strength hit Nova Scotia roughly once every two years.

Other threats to the province's forests are: anthropogenic actions which help the forest sink can be undone deliberately (i.e., forest clearing) or through natural disturbances (i.e., fires or windstorms), thus reversing progress; and the potential to increase the amount of harvested wood to decrease emissions by replacing higher-emissions materials like steel and concrete with harvested wood products. To reduce the threat of actions that improve the forest sink being intentionally undone, a potential solution would be to produce legislation that "locks in" the action unless the scientific community decides, in the future, that the action is ultimately harmful to the forest sink. The increase in emissions resulting from an increase in the production of harvested wood products would have to be offset by increasing the net carbon uptake of the forest through various methods such as improved forestry management practices as well as afforestation/reforestation. A serious impact from climate change is potential changes in growing season length: while potentially longer growing seasons could increase plant growth, warmer temperatures could increase carbon loss from plant respiration enough to offset some of or exceed the carbon capture from the longer growing season, presenting a significant challenge.

Nova Scotia's Croplands

In 2011, the area of cropland in Nova Scotia was 280,889 acres, and the area decreased by 4.8% to approximately 267,406 acres (or 108,218 ha) in 2016. For the baseline year of this report, the cropland area will be assumed to be the same as the area in 2016. When comparing this value to the total area of Nova Scotia calculated from the data in the ELA reports, cropland constituted approximately 1.96% of Nova Scotia's land area in 2016. This subsection will discuss the ability of cropland to absorb carbon as well as the threats to cropland and vulnerabilities to events that will impact this ability.

Cropland Sink Ability

Due to insufficient data available about the ability of Nova Scotia's croplands to absorb or emit carbon, a coarse estimate was made. The most specific data provided regarding the carbon capture ability for cropland is the Land-Use, Land-Use Change, and Forestry (LULUCF) data for the Atlantic Maritime Ecozone (AME), which is that the cropland for this region released approximately 541 kt CO_2e in 2019. This value was scaled down linearly from the cropland data of the AME to the cropland data of Nova Scotia by using the ratio of the area of Nova Scotia to the area of the AME.[6] The result of this calculation is that Nova Scotia's croplands are a source of approximately 145 kt CO_2e/y rather than a sink in 2019. Due to the coarseness of this estimate, it does not provide an accurate depiction of Nova Scotia's cropland sink. Since it is relatively small in comparison to other sinks and sources, this inaccuracy does not have a significant impact on Nova Scotia's carbon sink baseline. Currently, there is no incentive for cropland owners to focus on carbon sequestration on their cropland.[7]

Threats and Vulnerabilities

Like the forests, there are multiple threats to Nova Scotia's croplands that could make them emit more carbon via degradation of the ecosystem's ability to capture carbon. Climate change could result in an increased quantity and strength of droughts that reduce the productivity of the cropland; this means that the plants on the cropland would not be absorbing as much carbon. To reduce the effect of droughts on crops, cropland, livestock, and forestry systems can be combined in various ways on one farm. A cropland management practice that can reduce the effects of floods and droughts on croplands is planting cover

[6] The area information reproduced in the calculations is a copy of an official work that is published by the Government of Canada and the reproduction has not been produced in affiliation with or with the endorsement of the Government of Canada.

[7] Professor Derek Lynch, Dalhousie University, personal communication, 30 June 2021

crops. Another effect of climate change is that it could increase pest infestations which may require the use of pesticides – the use of which could increase energy usage for their production and distribution and potentially GHG emissions depending on the energy source used. Efforts should be made to avoid the potential emissions connected to the production and distribution of pesticides or to capture them at source points. Another threat to the productivity and survivability of cropland plants is the potential introduction of salt water to cropland. To reduce the impact of salt water intrusion, various adaptation actions can be taken, such as adding gypsum to the soil and planting cover crops; however, these are only short-term solutions.

Nova Scotia's croplands have some vulnerabilities, such as having low-lying coastal cropland (e.g., parts of the Annapolis valley) being prone to saltwater intrusion as sea levels rise. To prevent the intrusion, sufficiently high dykes should be constructed or maintained, or both, in areas that are at risk of saltwater intrusion. Other vulnerabilities are that: Nova Scotia uses unirrigated farming, making the cropland susceptible to drought; the province's soils are coarse and sloped, making them vulnerable to erosion; and the soils are low in soil organic matter, reducing their water holding capacity and structure related to water infiltration capacity.[8] This reduction in soil health related to water infiltration and retention has multiple detrimental effects: it leaves the land vulnerable to both flooding and drought.[9] The adoption of cropland management practices that increase soil organic matter would decrease the risk of both flooding and drought.[10] Some potential examples of management practices to increase soil carbon would be to include trees on cropland and the planting of cover crops and diverse crop rotations to allow inclusion of some perennial crops.[11] Increasing the amount of soil organic matter in cropland soils would increase soil structure and thus, decrease erosion.[12]

The likelihood of droughts occurring in the province's future is already discussed in the Nova Scotia's Forests subsection of this report. If sea barriers are not constructed to prevent the sea from reaching inland, the likelihood of salt water intrusion is likely given the expected sea level rise and that Nova Scotia is slowly losing land. The likelihood of flooding occurring in Nova Scotia in the future is likely given that the annual precipitation is predicted to increase in the future and that more intense rainfalls are predicted.

Nova Scotia's Wetlands

According to the most recent provincial ELA reports for Nova Scotia's eco-districts, which use data from 2015 and 2017, the total area of Nova Scotia's wetlands is approximately 383 kha (found by summing the wetland areas provided in the ELA report for each eco-district. Assuming that this area is the area of the province's wetlands in 2019 and using the ELA data, it was determined that wetlands constituted approximately 6.9% of the land area of Nova Scotia in 2019; this makes the wetlands Nova Scotia's second largest carbon sink by land area. This subsection will discuss the ability of wetlands to absorb carbon as well as the threats to the wetlands and vulnerabilities to events that will impact this ability.

Wetland Sink Ability

A study of Nova Scotian wetlands examined 55 wetlands consisting of five kinds of wetland across the province during summer of 2017. One portion of the study was to determine the GHG flux from Nova

[8] Ibid. 15 August 2021
[9] Ibid. 15 August 2021
[10] Ibid. 30 June 2021
[11] Ibid. 15 August 2021
[12] Ibid. 15 August 2021

Scotian wetlands and it was determined that the wetlands emit an average of 1.46 t CO_2e/ha/y in the form of methane and capture 6.45 tCO_2e/ha/y in the form of CO_2e, resulting in an average net capture of 4.99 t CO_2e/ha/y. For this report, the net capture rate is assumed to be the same as the baseline year. With this assumption, the net capture rate along with the area of wetlands were used to calculate the net carbon capture ability of Nova Scotia's wetlands. The province's wetlands were calculated to be a sink of approximately 1.91 Mt CO_2e/y for the baseline year.

Threats and Vulnerabilities

From Australian research which has shown how climate change will affect the CO_2 and CH_4 fluxes in wetlands in certain climate change scenarios, we believe the most significant threat to the ability of the province's wetlands to absorb carbon is climate change. According to the Australian Department of Sustainability, Environment, Water, Population, and Communities and the Wetlands and Waterbirds Taskforce, these are potential changes to the GHG fluxes in wetlands:

- Warmer climates will accelerate the rate of production of carbon dioxide and methane from wetland soils, but may also increase primary production.
- Wetter climates will increase wetland surface areas and promote carbon sequestration and increased primary production, but may increase methane emissions.
- Drier climates will increase the oxidation of carbon stores but reduce methane emissions.

Dry and wet environments could be created by droughts and floods, respectively, potentially resulting in changes to the GHG flux of Nova Scotian wetlands. Before any solution is chosen to counter the effects of increased wetness or dryness, an assessment of the GHG fluxes from a wetland in its original state should be made along with an estimate of the GHG fluxes with the solutions applied. If a solution will have lower net emissions or be a greater net sink than the original state, then the solution should be applied. An example of a solution to counter the effects of wetland soil drainage (which may result from excessive dryness) would be to rewet the soil of the wetland. A potential solution to counter the effects of wet environments on wetlands would be to drain the excess water, though the ecological effects of such an action requires further research. Some threats to coastal wetlands are coastal erosion and "sea-level rise, where inundation will threaten the survival of the largely intertidal wetland plants". To control the erosion of coastal wetlands, sediments can be added to a region; for example,

> *If continued input of suspended sediment from rivers is sufficient for sediment accretion to keep pace with a steadily rising sea-level, then carbon dioxide emissions could decrease as the tidally-flooded coastal areas increase in area and plant population size and existing inundated carbon pools are buried even deeper – provided that such landward movement of intertidal areas is not prevented by coastal squeeze such as the presence of hard sea-defences and other infrastructure.*

Management practices should be developed and adopted to allow coastal wetlands to move inland with rising sea levels and to maintain the sink. A potential technological solution to impacts of rising sea levels is to use control gates to maintain the current tides into the future; however, this should be considered a last resort.

We believe that the greatest vulnerability of the wetlands carbon sink is that its GHG fluxes are influenced by its climate. This means that unless climate change is reversed, there are a couple measures that could be taken to reduce the impacts on the sink, notably to estimate the GHG fluxes under the new climate and attempt to modify the environment where necessary and possible (as described in the previous paragraph). The vulnerability of coastal wetlands is their location – they are susceptible to both coastal erosion and flooding from rising sea levels. The potential solutions for both issues are discussed in the previous paragraph.

The likelihood of droughts which may cause wetlands to dry was already discussed in the Nova Scotia's Forests subsection of this report. As noted in the Nova Scotia's Croplands subsection of this report, there is more annual precipitation expected in Nova Scotia's future which means that the province's wetlands could experience the GHG flux changes associated with a wet environment. The likelihood of sea level rise is considered by the IPCC to be virtually certain. The likelihood of coastal erosion continuing in the future is certain since it is considered an inevitable process.

Nova Scotia's Geological Sequestration Sites

While geological sequestration sites do not capture carbon on their own and as such, are not technically sinks, it is important to discuss them as they make up Nova Scotia's "natural" carbon storage capacity for artificially captured carbon. Nova Scotia has the potential to be an important location for CO_2 sequestration given the number of offshore sedimentary basins in the region, which have excellent potential for carbon sequestration.[13]

While work is being done to determine an estimate for the CO_2 sequestration potential in and around Nova Scotia, an estimate can be made for some potential sites that are known, namely the depleted offshore oil and gas fields.[14] For example, the volumes of oil or gas that were extracted from the Sable Offshore Energy Project, the Deep Panuke Offshore Gas Development Project, and the Cohasset-Panuke Project are 60 billion m^3, approximately 4.2 billion m^3, and 7.1 million m^3, respectively. Assuming that the volume that can be injected into the depleted reservoirs is equivalent to the volume that was extracted, that the density of supercritical CO_2 being injected into the reservoirs is 600 kg/m^3, and that the reservoirs can retain supercritical CO_2, the potential CO_2 storage capacity of Nova Scotia's depleted offshore oil/gas fields is approximately 38.5 $GtCO_2$. Given that Canada's total anthropogenic GHG emissions were 730 Mt CO_2e in 2019, this is a significant storage potential, equivalent to about 53 years' worth of Canada's 2019 anthropogenic GHG emissions.

Summary of Nova Scotia's Carbon Sinks

Nova Scotia has both carbon sinks and geological storage for potential CO_2 capture and storage. While other sinks do exist, such as carbon mineralization and seagrasses, they were not the focus of this report. Research to quantify these other sinks could be used to enhance the accuracy of the scenarios that will be provided in this. Of the three sinks examined, Nova Scotia's forests were found to be the largest sink by far, followed by the province's wetlands. Nova Scotia's croplands were estimated at present to be a source rather than a sink, though not a significant one in comparison to other emissions sources. Table 1 provides a summary of the 2019 baseline for Nova Scotia's carbon sinks.

Table 1: Nova Scotia's 2019 carbon sinks baseline summary

Sink	Potential
Forests	9.701 Mt CO_2/y absorbed
Cropland	0.145 Mt CO_2e/y released
Wetlands	1.911 Mt CO_2e/y absorbed

[13] Professor Grant Wach, Dalhousie University, personal communication, 23 June 23, 2021
[14] Ibid. 5 July 2021

The vulnerabilities, threats, and likelihoods of those threats must be taken into consideration when examining the net-zero scenarios. Policymakers need to understand the risks associated with the sinks when developing policy. It is essential that the quantities shown in Table 1 are kept up-to-date and accurate so that the state of the sinks can be measured and the net-zero goals can be adjusted accordingly.

2050 Net-zero scenarios

A jurisdiction's total emissions are the sum of its actual emissions from all emissions *sources* and any emissions *sinks* it may claim (typically a combination of changes in land use or forestry, or both, technologies for carbon capture and use or carbon capture and storage in geological structures, and emissions credits purchased in emissions trading systems):

$$Total\ Emissions = Emissions\ sources - Emissions\ sinks$$

When a jurisdiction reaches its net-zero target date, it will be in one of three states, determined by its total emissions:

$Total\ emissions\ = 0$: In this state, the jurisdiction's emissions sources are offset by its emissions sinks and the jurisdiction has achieved net-zero emissions.

$Total\ emissions\ < 0$: The jurisdiction is a net sink; after removing its own emissions, it still has "sink space" to remove additional emissions. The jurisdiction could, for example, use the space to attract industries from emissions intensive jurisdictions or sell the space as emissions credits to jurisdictions that are net emitters (see below). (As with the Covid-19 vaccines, there would always be the danger of jurisdictions hoarding emissions credits to force up the market price.)

$Total\ emissions > 0$: The jurisdiction's emissions sources exceed its sinks, making it a net source. If a jurisdiction in this state is required to achieve net zero, it should aim to maximize its decoupling and decarbonizing efforts before the net-zero target date. Since the total emissions exceed zero, it will be necessary to obtain emissions credits from jurisdictions that are net sinks. Such purchases will need to be made until the jurisdiction finds other, lower-cost sinks.

Achieving zero-emissions this way could be a costly exercise if there is a significant global demand for the carbon-removal process, as there may well be, given the number of organizations, regions, and countries pledging to attain net-zero by 2050.

In Nova Scotia's case, the province is committed to achieving net-zero emissions by 2050 .

This section considers three net-zero scenarios for the province in 2050 determined by the CO_2 flux strength: constant strength (the sink strength in 2050 is the same as in 2019), increasing strength (sink strength increases at different, evidence-based rates), and decreasing strength (the sink strengths decrease by 10% of the 2019 capacity per decade). (Emissions from Land-Use, Land-Use Change, and Forestry (LULUCF) are included in the greenhouse gas flux estimate for the province's croplands.)

Each scenario is described in terms of the total emissions sink strength (the sum of the forest, wetland, and cropland strength for 2050), the maximum permissible emissions in 2050 (the total sink strength), and the emissions reductions the province must make between 2019 and 2050 to reach the maximum permissible emissions.

Nova Scotia's 2019 emissions were 16.2 Mt CO_2e and are summarized by sector in Figure 1.

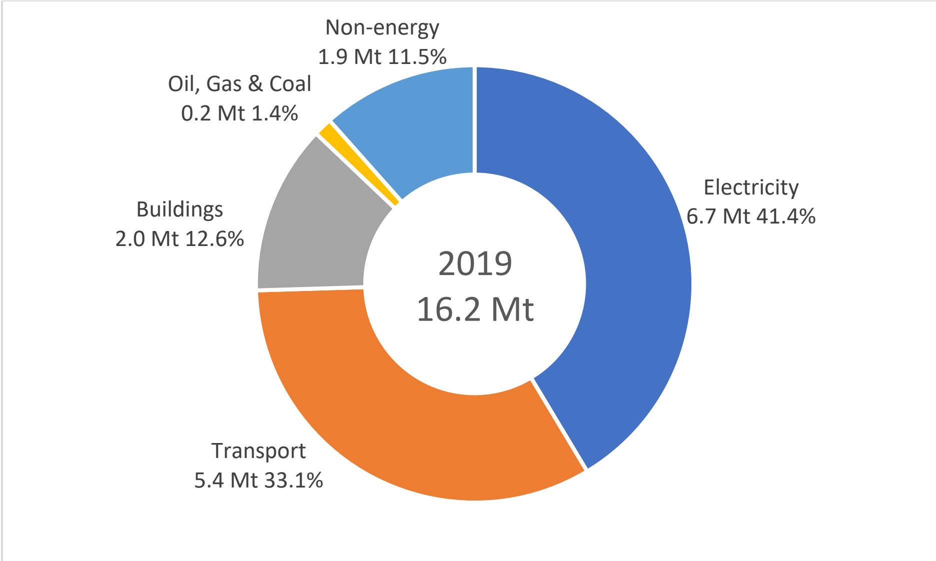

Figure 1: Nova Scotia 2019 GHG emissions by sector

Scenario 1: Constant Flux Strength

In the constant flux strength scenario between 2019 and 2050, the sink strength of Nova Scotia's forests and wetlands remains constant while croplands continue to act as a source. In this scenario (see Figure 2), the total sink strength in 2050 is 11.5 Mt CO_2e (sum of wetlands, croplands, and forest fluxes), to achieve net-zero, the province's emissions could not exceed 11.5 Mt CO_2e. The total anthropogenic emissions reduction from 2019 is 4.7 Mt CO_2e or approximately 29% below 2019 levels. This is higher than the province's 2030 emissions target of at least 53% below 2005 levels, or about 10.9 Mt CO_2e, suggesting the target would be easily achievable if the 2030 target was met.

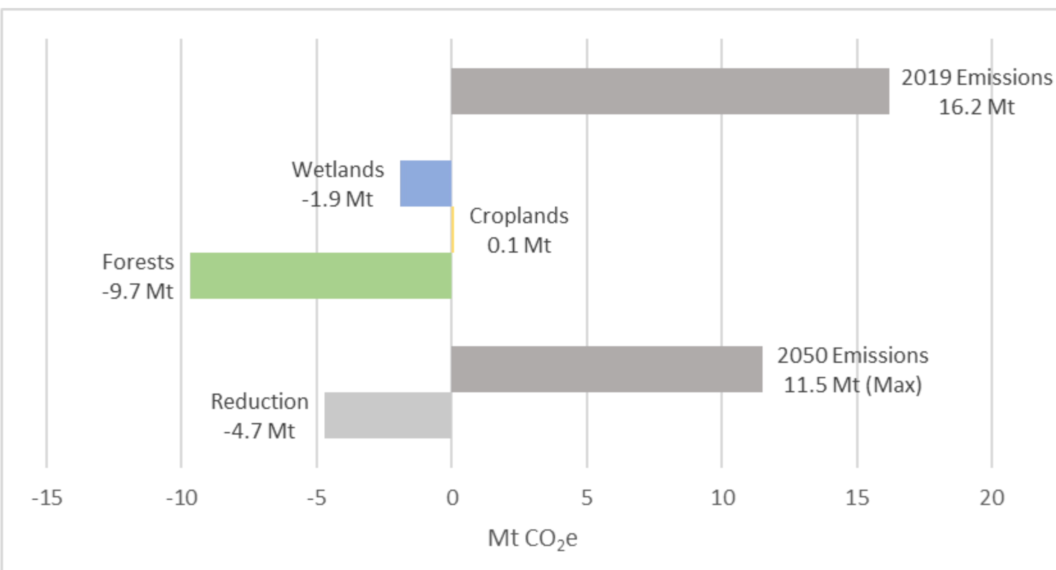

Figure 2: Emissions sinks and sources for the constant strength scenario

This scenario would probably be difficult to maintain, given the threats to and vulnerabilities of the sinks from climate change and anthropogenic activities.

Scenario 2: Increasing Flux Strength

In this scenario, sink flux strengths increase between 2019 and 2050, based on the following assumptions:

Forests: The forest sink CO_2 flux increases by 0.319 Mt CO_2 every five years (estimates based on data from Steenberg).[15]

Croplands: Improved cropland practices are fully implemented by 2050. The resulting changes in Nova Scotia's soil organic carbon are assumed to be the same as in the United States (0.36 t C/ha/y for cover crops, 0.14-0.18 t C/ha/y for improved crop rotations, and 0.33 t C/ha/y for no tilling). The increase in soil organic carbon is converted to CO_2 sequestered when calculating the CO_2 flux.

Wetlands: Net carbon sequestration rates remain constant and wetlands are restored so the sink increases by 4% of the baseline value every decade.

The increasing sinks scenario would be the most difficult scenario to achieve because the impact of the threats to and vulnerabilities of the biological sinks would have to be reduced while also increasing their carbon capacity.

By 2050, few emissions reductions would have to take place to meet the 2050 goal of net-zero emissions (see Figure 3). The maximum anthropogenic emissions permitted in 2050 is 13.9 Mt CO_2e, a reduction of about 14% from 2019. This value is significantly higher than what emissions should be reduced to in the 2030 target without sinks. An emissions reduction of about 2.3 Mt CO_2e is highly likely. The main issue with achieving this scenario is ensuring that the sinks' strengths increase while their threats and vulnerabilities decrease.

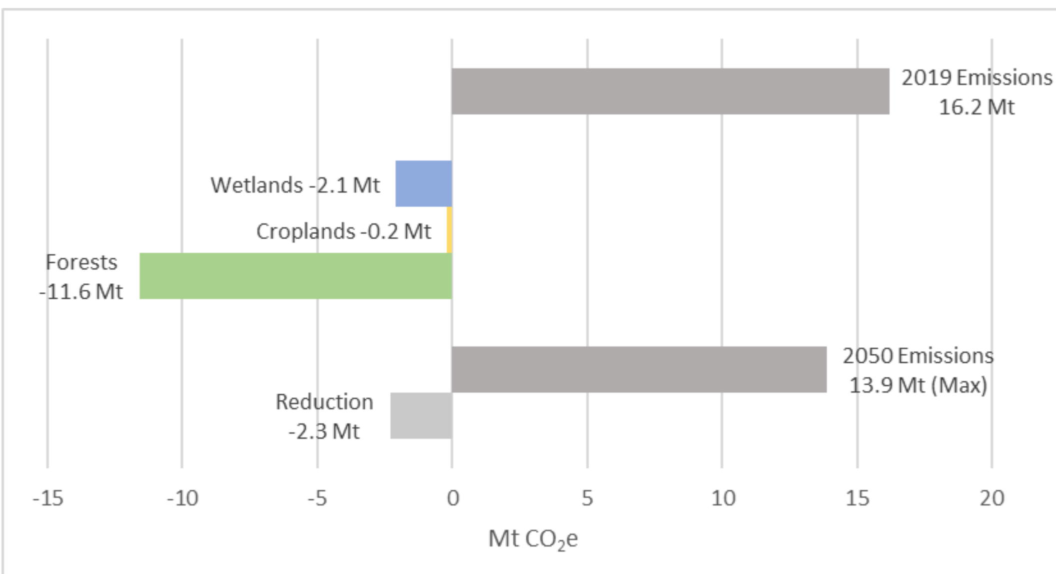

Figure 3: Emissions sinks and sources for the increasing strength scenario

Scenario 3: Decreasing Flux Strength

In this scenario, the flux strength of the sinks decreases. With the growing threat of climate-related events, this scenario may be considered more plausible than either of the two previous scenarios. Should the sink

[15] Dr. James Steenberg, Nova Scotia Department of Lands and Forestry, personal communication, July 2021

strengths decrease, the degree to which they decrease may be hard to predict; however, we assume the forest and wetland sink strengths decrease by 10% of the baseline value each decade, and for croplands, emissions increase by 10% of the baseline value each decade. As Figure 4 shows, the sinks remove a total of 7.9 Mt CO_2e; to achieve net-zero, Nova Scotians would need to reduce their emissions by 8.3 Mt CO_2e or 51% from 2019 levels.

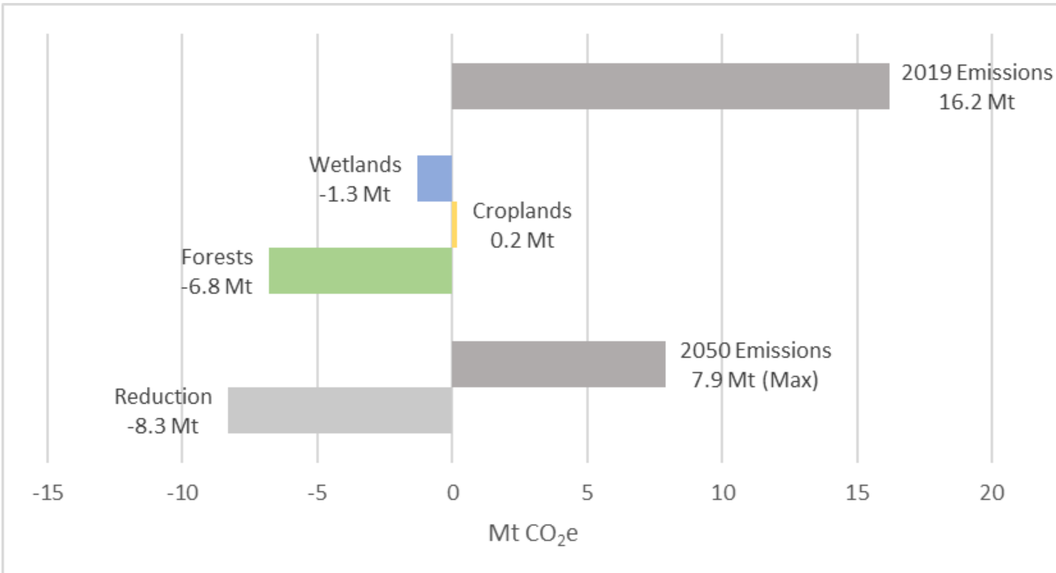

Figure 4: Emissions sinks and sources for the decreasing strength scenario

Summary

All the scenarios presented require some level of anthropogenic emissions reduction to achieve the 2050 net-zero emissions target. Table 2 details key information from the three net-zero emissions scenarios.

Table 2: Key results from the net-zero emissions scenarios to 2050

Sink Scenario	Projected total sink flux ($Mt CO_2e$)	Maximum allowable anthropogenic emissions ($Mt CO_2e$)	Change in anthropogenic emissions (2019-2050)	
			Mt CO_2e	**Percent**
Constant	-11.5	11.5	-4.8 Mt CO_2e	-29%
Increasing	-14.0	14.0	-2.3 Mt CO_2e	-14%
Decreasing	-7.9	7.9	-8.3 Mt CO_2e	-51%

The anthropogenic emissions reductions from 2019 levels range from 14% to 51%, and the projected total GHG flux of all sinks in 2050 range from approximately -7.9 Mt CO_2e to -14.0 Mt CO_2e. The projected total GHG flux of all carbon sinks in 2050 is always equal to the maximum anthropogenic emissions in 2050 for net-zero to be achieved.

Both maintaining and increasing sinks could be a major problem given all the vulnerabilities of sinks and the threats they face, such as the threats of fires and pests to the forests. Preventing sinks from decreasing in strength any further than the assumptions made for the decreasing sinks scenario could also be difficult depending on the impacts of the threats to and vulnerabilities of the sinks. It is important to note that, for the decreasing sinks scenario, the maximum anthropogenic emissions will continue to decline past 2050 if the sink strengths decline as well. This means that efforts to reduce emissions should not be given up once 2050 is reached.

If Nova Scotia is unable to achieve the emissions reduction necessary to meet the 2050 emissions target, it will have to either purchase negative emissions from another jurisdiction or construct direct air capture facilities. The cost of direct air capture ranges from 2019 values of roughly $90 to $900 USD per net tonne of CO_2 captured. For this report, it is assumed that these prices are both the cost of negative emissions (through purchasing or direct air capture) and the sale price of negative emissions.

If the province needs to remove one Mt CO_2e of emissions to reduce its emissions to net-zero, the cost would be between C$120 million and C$1.2 billion. Alternatively, if the province sold one Mt CO_2e of negative emissions, its revenue would be approximately $120 million to $1.2 billion in 2019 CAD. At the maximum cost of roughly $900 2019 USD per net tonne of CO_2 captured, the cost or revenue could be significant, especially if there is more than one Mt CO_2e that needs to be removed or can be sold. Work should be done to maintain and increase the biological sinks while also reducing anthropogenic emissions so that negative emissions can be sold, providing another revenue stream to the province.

Conclusion and Recommendations

By 2050, Nova Scotia intends to reach net-zero emissions "by balancing greenhouse gas emissions with greenhouse gas removals and other offsetting measures". Since the province has yet to develop a plan to achieve either removals or offsetting measures, this report provides an estimated baseline of Nova Scotia's natural carbon sinks and its geological sequestration capacity and shows that Nova Scotia has significant carbon sinks and geological capacity in relation to its annual greenhouse gas (GHG) emissions.

The report explains the carbon capture potential of the province's sinks (forests, croplands, and wetlands) and the province's carbon storage capacity. It also examines possible threats to, and vulnerabilities of, the natural sinks, and considers potential ways of reducing the impact of the threats and vulnerabilities. Natural sinks, direct air capture, and carbon sequestration in geological formations are also described to give a better understanding of their concepts and carbon capture and sequestration potential.

Three different sink scenarios have been considered, developed on the assumption that between now and 2050, changes to the climate could affect the sinks. Using the province's 2019 emissions and estimated sinks as a baseline, three different sink scenarios (steady, increasing, and decreasing) were developed to determine the maximum allowable anthropogenic emissions to meet the 2050 net-zero target.

The minimum reduction from 2019 emissions levels to achieve net-zero depends on the changes to the province's sinks. If emissions levels remain steady at 11.5 Mt CO_2e, the province would need to reduce its emissions by about 4.8 Mt CO_2e or 29% from 2019 levels, slightly less than the province's 2030 emissions target requires. However, if the sinks are enhanced by various means each decade, by 2050 the sinks would remove about 14 Mt CO_2e and the Nova Scotians would only need to reduce their emissions by 2.3 Mt CO_2e or 14% from 2019 levels. In the case in which sinks flux strength is weakened by 10% a decade, Nova Scotians would need to reduce their emissions by 8.3 Mt CO_2e or 51% from 2019 levels. We should assume this last case is becoming increasingly likely.

If Nova Scotians are unable to achieve net-zero using emissions reduction programs or the sinks have insufficient capacity, the province would need to purchase negative emissions using direct air capture or emissions credits. The magnitude of the cost per Mt CO_2 was found to be about $120 million to $1.2 billion in 2019 CAD; however, if the province became a net-sink, it could sell the negative emissions.

Quite simply, the importance of the province's emissions sinks cannot be overstated if we are to achieve net-zero. The province must ensure that sinks remain protected or enhanced and geological sequestration be pursued. Net-zero must be maintained annually and in perpetuity.

To this end, we urge the province to adopt the following recommendations:

1. *Conduct a complete and accurate biannual assessment of the province's greenhouse gas (GHG) fluxes of the biological sinks (such as forests, croplands, wetlands, and seagrass meadows)*:
    - The assessment should be released as a publicly accessible state-of-the-sinks inventory report. Changes to the fluxes must be identified.
    - Each sink should be mapped and its GHG flux made available in a publicly available map. The associated data tables should be released with the map.
    - At a minimum, the following information should be supplied for each sink: location, area, annual GHG flux, and maximum annual GHG flux. This will provide better estimates of the maximum anthropogenic emissions for the 2030, 2050, and any interim targets. The data must be verifiable.

- Trends in the strength of the biological sinks should be monitored and appropriate action should be taken if the strengths decrease.

2. *Measure, report, and verify the carbon-related impacts of the threats to Nova Scotia's biological sinks and conduct an economic and carbon flux assessment of the potential solutions to reducing the threats and vulnerabilities of the sinks*:
   - Quantify the impacts on the carbon flux of any of the provincial biological sinks using known measurement, reporting, and verification techniques (MRV).
   - Conduct research into the potential solutions (including those presented in this report) to the threats and vulnerabilities faced by the sinks.
   - Evaluate the economic feasibility and changes to the carbon flux of potential methods to reduce the impact of the threats and vulnerabilities to biological sinks.
3. *Interim emissions reduction targets should be established*:
   - In addition to the legislated 2030 and 2050 targets, three interim emissions targets 2035, 2040, and 2045 will allow for changes to regulations to reduce the likelihood of overshooting net-zero.
   - These targets will provide emissions reduction reference points.
4. *Efforts should continually be made to reduce emissions beyond 2050*:
   - Net-negative global anthropogenic CO_2 emissions will need to be maintained annually and in perpetuity to prevent further increases in global temperature.
   - Reducing emissions so that net-negative emissions are achieved means environmental security if the sinks decrease in strength.
   - Maintaining net-negative emissions creates a potential revenue stream to the province and helps other jurisdictions reach their climate targets.
5. *Introduce tax incentives for carbon captured in natural sinks to promote the maintenance of our efforts to increase their carbon capture ability*:
   - Nova Scotia or the Government of Canada should provide tax incentives to managers of forests, croplands, wetlands, and seagrasses based on a per verified tonne of carbon captured. This incentive should be less than the annual cost-per-tonne for DAC; otherwise, it might be more financially reasonable to spend the government funds on DAC.
   - This will motivate land managers to manage their lands in a way to maintain or increase their carbon capture capacity.
6. *If the purchase of negative emissions is necessary, it must be sustainable*:
   - Achieving and maintaining negative emissions will require the province to budget for the purchase of emissions credits annually and in perpetuity.
7. *Since biological sinks are at risk from extreme climate events, the province must research and if possible, develop its geological storage capacity*:
   - The removal and long-term storage of existing atmospheric carbon using Direct Air Capture (DAC) is essential if global temperatures are to be maintained or, ideally, reduced by removing new and existing carbon from the atmosphere.
   - If properly managed, this could be a potential revenue stream for the province.

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Canada

An Analysis of the Greenhouse Gas Emissions Reduction Targets in Nova Scotia's Environmental Goals and Sustainable Prosperity Act of 2019

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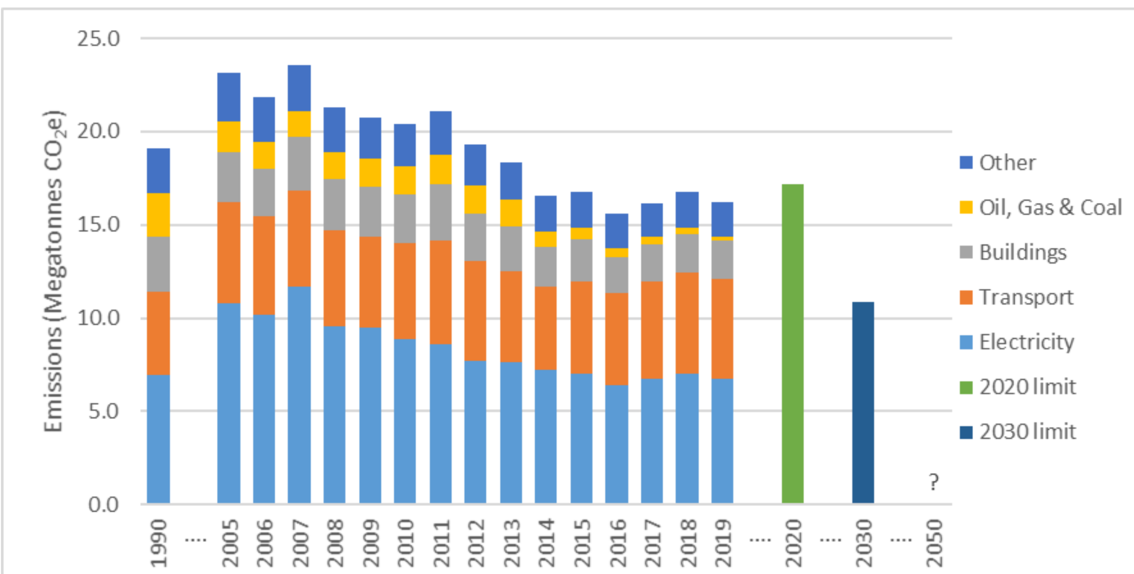
Contents

Overview

Nova Scotia, like all other Canadian provinces and territories, has emissions reduction targets for 2030 (as part of Canada's commitment at the Paris COP-21 meeting in 2015, Canada has pledged to achieve a 30% reduction by 2030) and a mid-century target of net-zero (in keeping with the growing body of evidence that to stop global average temperatures exceeding 1.5°C this century, the total of emissions sources and sinks must be zero by mid-century.)

Legislation in the early 2000s and subsequent amendments meant that the province's major emitter, Nova Scotia Power, was required to reduce its emissions from about 10 megatonnes (Mt) in 2010 to 4.5 Mt in 2030, while at the same time increasing its use of renewables from about 10% in 2010 to 40% in 2020. This, coupled with a weak economy, resulted in Nova Scotia achieving its Paris emissions reduction target of 30% below 2005 levels in the mid-2010s (subsequent revisions of the emissions data from Environment and Climate Change Canada show that Nova Scotia never reached the 30% mark).

In November 2019, Nova Scotia passed *An Act to Achieve Environmental Goals and Sustainable Prosperity* which, amongst other things, specified greenhouse gas reduction goals for 2020 (10% below 1990 emissions levels), 2030 (53% below 2005 emissions levels), and 2050 (net zero), as the following graphic from the report shows:



This report is an analysis of the Act, using existing data to consider the likelihood of the province having met its 2020 target, the challenges facing the province if it is to reduce its emissions by 53% by 2030, and the availability of emissions sinks in the province to offset the province's emissions in 2050.

2020

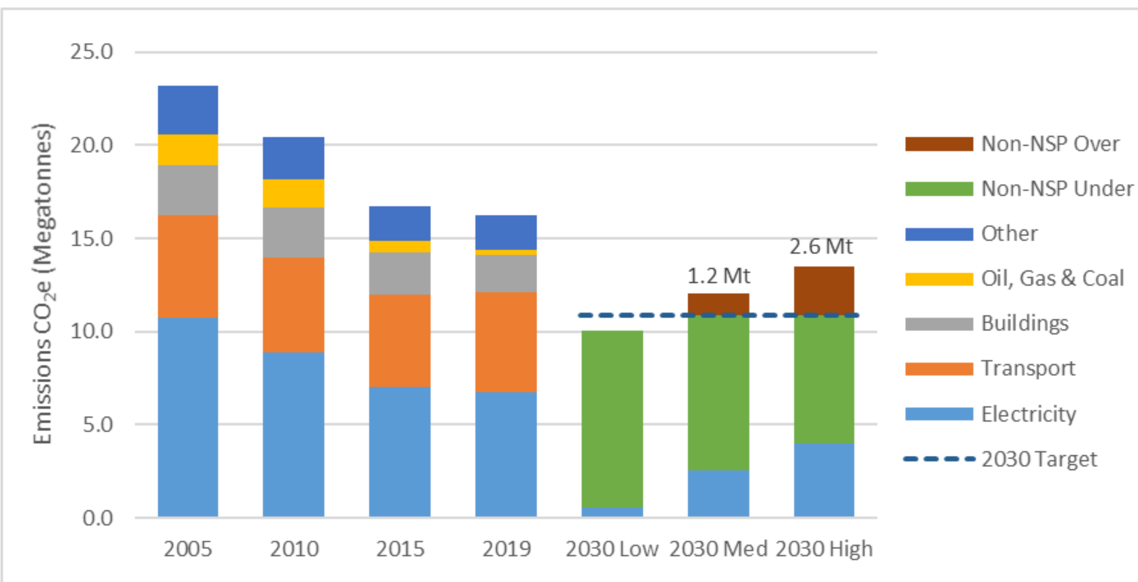
While we will not know Nova Scotia's actual emissions for 2020 until Environmental and Climate Change Canada National Inventory Report (NIR) in early 2022, the province has probably met its 2020 goal because of revisions to the province's NIR data for years leading up to and including 2017, pandemic-induced reductions in transportation, and reductions in Nova Scotia Power's emissions.

2030

Almost 90% of the province's emissions come from energy use, meaning that any reduction must focus on the three major emissions sources in the province: Electricity (6.7 Mt in 2019), Transportation (5.4 Mt in 2019), and Buildings (2 Mt in 2019).

The success of the 2030 goal hinges on the completion of the Atlantic Loop, an interconnection between the Maritime Provinces and Hydro Quebec. We use Nova Scotia Power's Integrated Resource Plan (IRP) to show that if the Atlantic Loop is completed by 2030, Nova Scotia Power will be able to phase out coal use and reduce its emissions to the point where none of the other emitting sources will need to reduce their emissions (in 2030).

However, if the Atlantic Loop is not completed by 2030, other sectors (notably Transportation and Buildings) will need to make reductions, the amount of which depends on the depths of Nova Scotia Power's reductions. In the worst case, Nova Scotia Power will reduce its emissions by 4 Mt (and still meet its 2030 emissions cap), but this will require the other sectors to reduce their emissions by about 1.2 Mt (in the Median case) and 2.6 Mt (in the High case), as the following figure from the report shows:



Since the province has focussed on Nova Scotia Power's emissions and to a lesser extent, Building emissions, it will probably be hard pressed to get sufficient electric trucks and electric vehicles on the road by 2030 to make up the difference. Reductions in Oil, Gas & Coal and Other (such as Agriculture, Forestry, Heavy Industry, and Waste) will undoubtedly help, but the focus will need to be on Transportation and Buildings.

It is absurd that the province's goal of a 53% reduction in emissions in less than 10 years is based on a policy of hope that the Atlantic Loop will come to fruition.

2050

Net-zero emissions means that the sum of a jurisdiction's emissions sources is equal to its emissions sinks. If there are more sinks than sources, the jurisdiction can, potentially, sell its excess sinks to other emitters. However, if the jurisdiction's sources exceed its sinks, the jurisdiction will need to find sinks.

The section examining the province's 2050 goal of net-zero does not consider the emissions sources in 2050, but rather the sinks. By knowing the sinks, we can develop policies to protect and enhance the sinks, as well as policies to target specific sectors to reduce their emissions to meet the sinks.

We show that the province has biological sinks (notably forests and wetlands) as well as geological capacity for storing carbon. The biological sinks capture carbon naturally, whereas the geological sinks require technologies such as Direct Air Capture (DAC) to remove the carbon from the air and store it in the geological format.

Without interim targets for the sources (to reduce emissions) and known emissions sinks (to know the upper limit on the sources), achieving the 2050 goal could prove costly for the province.

Recommendations

The report makes seven recommendations:

1. *Conduct a biannual inventory of the province's quantifiable and verifiable biological carbon sinks and continue to search for potential geological carbon storage sites that are quantifiable and verifiable.*
2. *Monitor the progress of the Atlantic Loop (for the 2030 goal).*
3. *Focus on electric vehicle infrastructure rather than subsidizing electric vehicles.*
4. *Introduce emissions targets for 2035, 2040, 2045, and 2050 (for the 2050 goal).*
5. *Adopt the recently modified federal carbon-pricing system or develop a provincial carbon-pricing system based on the federal backstop for emitters under 50,000 tonnes per year.*
6. *Apply an Output-Based Pricing System to industries emitting over 50,000 tonnes of CO2e per year.*
7. *Unallocated revenues collected from the carbon levy (emitters < 50,000 t) and the OBPS (emitters > 50,000 t) should fund programs to maintain and enhance the province's carbon sinks.*

Final thought

The *Environmental Goals and Sustainable Prosperity Act*, describes two goals, one for 2030 (emissions are to be at least 53% below the levels that were emitted in 2005) and the other for 2050 (emissions will be at net zero, by balancing greenhouse gas emissions with greenhouse gas removals and other offsetting measures).

If these goals are not met, who is responsible?

An Analysis of the Greenhouse Gas Emissions Reduction Targets in Nova Scotia's Environmental Goals and Sustainable Prosperity Act of 2019

Larry Hughes, PhD Mark McCoy

26 July 2021

1 Introduction

In the first decade of the 2000s, most Canadian provinces and territories implemented emissions reduction legislation and regulations designed to meet or exceed Canada's Kyoto protocol commitments. Nova Scotia was no exception, in 2007, the provincial government enacted the *Environmental Goals and Sustainable Prosperity Act* with the objective of achieving "sustainable prosperity". This and subsequent Acts have focussed on capping greenhouse gas emissions from the province's electricity supplier, encouraging energy efficiency programs in buildings, and introducing a carbon pricing system.

In late 2019, the Government of Nova Scotia passed *An Act to Achieve Environmental Goals and Sustainable Prosperity*. The principal objective of the Act is to reduce the province's greenhouse gas emissions. To this end, subsection 7 of the Act states:

> *The Government's goals in relation to greenhouse gas emissions reductions are that greenhouse gas emissions in the Province are*
>
> *(a) by 2020, at least 10% below the levels that were emitted in 1990;*
>
> *(b) by 2030, at least 53% below the levels that were emitted in 2005; and*
>
> *(c) by 2050, at net zero, by balancing greenhouse gas emissions with greenhouse gas removals and other offsetting measures.*

Figure 1 shows Nova Scotia's emissions stack by sector for 1990, 2005 through 2019, and the 2020 and 2030 reduction targets of 17.6 megatonnes (Mt) and 10.9 Mt, respectively (how these values were determined is shown in Table 1).[1, 2] The 2050 target, although net-zero, is shown as a '?' because we are interested in Nova Scotia's emissions sinks in 2050 as they can determine the limit on the province's emissions sources.

[1] 2020 emissions data for Canada's provinces and territories will not be available until early 2022.

[2] The economic sectors examined in this report fall into five groups, four of which are considered energy-related by the UNFCCC: electricity; transport; buildings (residential, and commercial and institutional); and energy-related extraction and production industries (oil and natural gas, refining, and coal mining), collectively referred to as Oil, Gas & Coal. The fifth group (referred to as Other) consists of economic sectors or activities that are responsible for non-energy related emissions, notably waste and industrial processes Light Manufacturing, Construction and Forest Resources; Agriculture; and Heavy Industry.

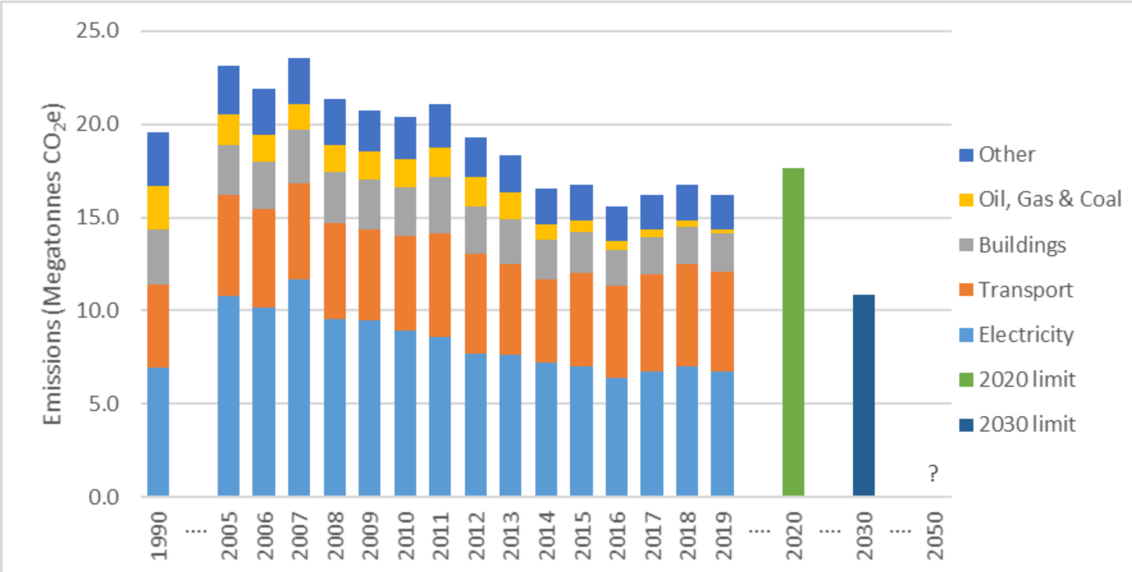


Figure 1: Sectoral emissions stacks for 1990, 2005-2019, and reduction targets for years 2020, 2030, and 2050 (data from ECCC)

Table 1: Base and target emissions for 2020 and 2030 (Emissions in megatonnes)[3]

Base		**Target**		
Year	**Emissions**	**Year**	**Requirement**	**Emissions**
1990	19.6	2020	10% below 1990 levels	17.6
2005	23.2	2030	53% below 2005 levels	10.9

The remainder of the report is organized as follows.

In the next section, an introduction to energy systems, emissions reduction, and emissions policies is presented. This section also examines the changes in Nova Scotia's emissions between 2005 and 2019 in terms of how the provincial economy decoupled from the province's energy system and how the energy system decarbonized during this period.

The third section briefly discusses the province's 2020 emissions target and explains how the decline in emissions that started in 2018 and the province's response to the Covid-19 pandemic in 2020 likely meant the target was met.[4]

In the fourth section, we examine how the 2030 target can be met. Since Nova Scotia Power is the province's largest emitter, we use three of the 27 scenarios presented in its Integrated Resource Plan (IRP) for the years 2021 to 2045, for its projected low, median, and high emissions scenarios for 2030. With this, we determine the total emissions reduction required by the remaining emitters (Transport; Buildings; Oil, Gas & Coal; and Other). For each of these sectors, we suggest ways in which they can reduce their emissions by 5%, 10%, and 15% from

[3] How the 53% was obtained is discussed in Section 4.1.

[4] Nova Scotia's actual emissions for 2020 will be released in Environmental and Climate Change Canada's National Inventory Report (NIR) in early 2022.

2019 levels. The section concludes with a detailed discussion of the likelihood of reaching these targets and what this could mean for the province's 2030 emissions target.

The fifth section starts with an introduction to net-zero and emissions sinks, explaining how sinks can determine a jurisdiction's maximum emissions sources and how exceeding net zero could well prove costly. This is followed by an examination of Nova Scotia's biological sinks and geological storage capacity for carbon, and the importance of understanding them.

The report concludes with a review of the analysis and a series of recommendations.

2 Background

In 2019, about 87.1% of the province's emissions were to meet energy demand and came from three sectors: Electricity, Transportation, and Buildings. To make any significant reduction in the province's emissions it will be necessary to target the province's energy system and its relationship to these sectors.

2.1 Energy systems

Nova Scotia, like all other jurisdictions, has an energy system responsible for meeting the activity requirements of its end-users. For most jurisdictions, such as Nova Scotia, a simplified version of its energy system can be discussed in terms of energy providers and energy services (see Figure 2):

- Energy providers are responsible for converting primary energy sources into secondary energy and then distributing the secondary energy to energy services used by end-users. The energy provider is to meet the energy demands of the energy services within limits specified by the government or corporate regulations. Depending on the primary energy source and the energy provider's conversion and distribution processes, the provider may be associated with emissions. Examples of energy providers include refineries converting crude oil into refined products such as gasoline, diesel, and heating fuel for distribution through a variety of networks; and electricity providers, which covert a variety of primary energy sources including coal, natural gas, uranium, and various renewable sources into electricity that is transmitted and distributed through electrical grids.
- Energy services use the secondary energy from the energy providers to meet the energy requirements of the end-user's activities. Some of the more common services are transportation, heating and cooling for industry and buildings, and services requiring electricity. Most services have some form of regulation to meet safety standards. As with energy providers, the use of some services results in emissions, for example, driving an automobile powered by an internal combustion engine, whereas others, such as electrical appliances, do not.

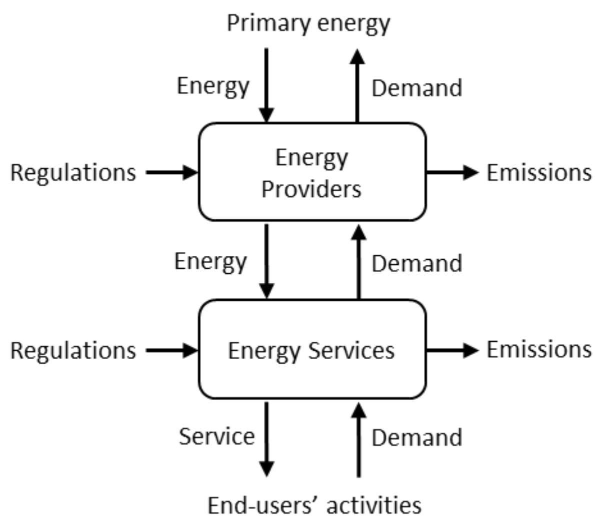


Figure 2: [A simplified energy system]

Since some emissions reduction measures are applicable to both energy providers and energy services, we refer to them as Processes and distinguish between them when necessary (see Figure 3). A Process takes $Energy_{IN}$ (e.g., primary or secondary energy) and converts it to meet the requirements of $Demand_{IN}$, either as $Energy_{OUT}$ (e.g., secondary energy) or a service (such as transportation). Depending on the Process there can be emissions ($Environment_{OUT}$), for example, from a natural gas plant generating electricity or an automobile powered by an internal combustion engine.

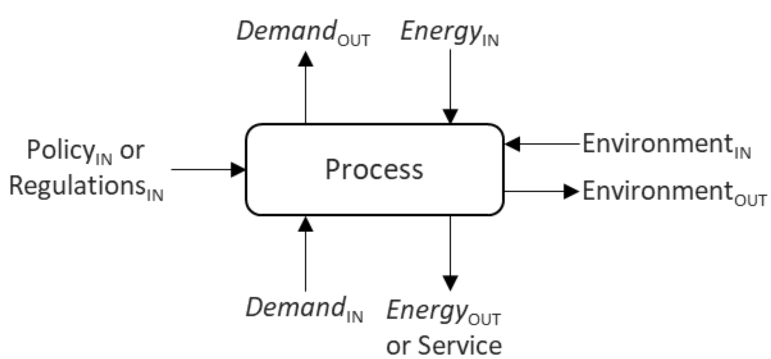


Figure 3: [A process and its flows]

2.2 Emissions reduction

Many jurisdictions have an emissions reduction target, typically a percentage below the emissions in a starting year to be achieved by a certain future date. Progress is measured by comparing the annual change in emissions relative to the starting year.

[Changes in energy emissions] are a function of:

- The volume of energy consumed to meet the energy requirements of an activity in the jurisdiction. If the activity and energy demand are greater than their starting year levels, the jurisdiction is in the *coupling state*; however, if the activity is greater than its starting year level and demand is less than its starting year level, the jurisdiction is in the *decoupling state*. Jurisdictions often have policies intended to decouple the activity from its energy demand by increasing the activity and lowering its energy demand.

- The emissions associated with the energy consumed. The jurisdiction is said to be in the *carbonizing state* if both the emissions and energy consumed are increasing relative to their starting year values. If emissions are below the starting year value and the rate of emissions is declining while the energy consumption rate is increasing, then the jurisdiction is in the *decarbonizing state*. This state also applies in the case that energy consumption is declining, but emissions are declining at a faster rate. Many jurisdictions have decarbonizing policies targeting emissions-intensive processes so the same activity can be achieved by a low- or zero-emission process, such as replacing liquid-fueled internal combustion engines with electric-powered motors in the transportation sector.

2.2.1 Emissions reduction policies

Emissions reduction policies can target an energy service or energy provider, or both. They can be described in terms of one of the following three categories of energy policy.

Reduction policies

Reduction policies refer to measures that reduce energy demand without changing the Process or the energy it consumes ($Energy_{IN}$). These policies normally target end-users so that $Demand_{IN}$ declines and can include financial incentives to reduce energy demand (such as building retrofits), and pricing mechanisms to discourage energy use (such as carbon-pricing).

The Process can also be targeted in an energy reduction policy, typically to return it as closely as possible to its original efficiency to reduce its $Demand_{OUT}$ and possibly emissions; for example, tuning an automobile or heating furnace.

Pricing mechanisms can encourage a decline in $Demand_{IN}$ on the part of the end-user (e.g., driving less, switching off unused lights, or raising the setpoint on an air conditioner); however, such mechanisms can be detrimental to low-income or disadvantaged groups, or inconsequential to high-income earners.

Reduction policies can weaken coupling by reducing $Demand_{OUT}$; however, a reduction policy need not lead to a reduction in emissions. For example, if the $Energy_{IN}$ used by an energy service comes from an energy provider using zero-emissions sources, any reduction in $Demand_{IN}$ might lead to a decoupling, but it will not reduce emissions.

Replacement policies

Replacement policies are measures that either:

- Change the energy supply ($Energy_{IN}$) but not the Process meeting the demand (i.e., the energy provider or energy service).

  Examples include replacing the coal in a thermal generating station with a mixture of coal and biomass, and replacing petroleum products used for transportation with a petroleumethanol mix. Such measures are usually intended to weaken the carbonizing state; however, there is often disagreement as to the degree of this reduction [ref].

- Use the same energy supply ($Energy_{IN}$) but change the Process that consumes it. These replacements typically refer to an end-use energy service rather than an energy provider.

  Examples include replacing an internal combustion vehicle (ICE) with a hybrid electric vehicle (HEV), replacing baseboard heating with a heat-pump, or replacing an incandescent bulb with a light-emitting diode (LED). These measures are intended to lead to a reduction in energy demand (i.e., weakening the coupling state) and depending on the energy used, weakening the carbonizing state.

Restructuring policies

Restructuring policies fall into one of two categories:

- In the first, existing demand is met by replacing *both* the Process and $Energy_{IN}$. Examples include the shuttering of coal plants in favour of natural gas and renewables, a consumer purchasing a plug-in electric vehicle to replace an existing conventional petroleum vehicle, and replacing an oil furnace with a heat pump.
- The second involves adding a new Process and a new $Energy_{IN}$ to the system to meet new demand that cannot be met by the existing energy system. For example, an electricity supplier adding new natural gas combined cycle turbines to meet new demand or someone opting to purchase an electric vehicle rather than a conventional (ICE) vehicle.

Restructuring can change the decarbonizing state, potentially leading to a decarbonization of an energy provider. For example, replacing a fleet of coal-fired thermal stations with a combination of hydroelectric, nuclear, and new renewables [ref]. However, restructuring can also put the jurisdiction in the carbonization state if, for example, coal-fired thermal stations are brought online to meet rising demand for electricity (Li, Gallagher and Mauzerall 2020).

Unless the restructuring results in changes to the end users' activities, such as an increase in the cost of using the service, there is little incentive for the end user to reduce energy demand. If the restructuring is intended to meet new demand, demand could increase, strengthening the coupling state.

2.3 Nova Scotia's emissions from 2005 to 2019

Nova Scotia's emissions have remained below 23.2 Mt since 2005. Much of this can be attributed to the decoupling of various sectors of the economy from the province's energy system; for example, declines in energy demand in the industrial and transportation sectors. In addition, there was success in decarbonizing parts of Nova Scotia Power's generation.

Although Nova Scotia's emissions declined by 6.9 Mt between 2005 and 2019 (see emissions stacks in Figure 4), the energy related grouping (Electricity, Transport, Buildings, and Oil, Gas & Coal) was responsible for 88.5% of the province's emissions, while Other emitters remained at slightly over 11%. The largest declines over this period were in Electricity (-4.1 Mt), because of legislation targeting Nova Scotia Power and the decline in electricity demand by major industrial users; and Oil, Gas & Coal (-1.4 Mt), the result of shuttering the only refinery in the province and the permanent production shutdown of the province's two offshore natural gas projects (Sable and Deep Panuke).

Legislation creating a provincial organization to decouple and decarbonize Buildings resulted in emissions declining by 0.66 Mt, while Other also experienced a decline of 0.73 Mt, largely due to declines in non-energy activities (notably agriculture and manufacturing). Transport emissions were essentially unchanged.

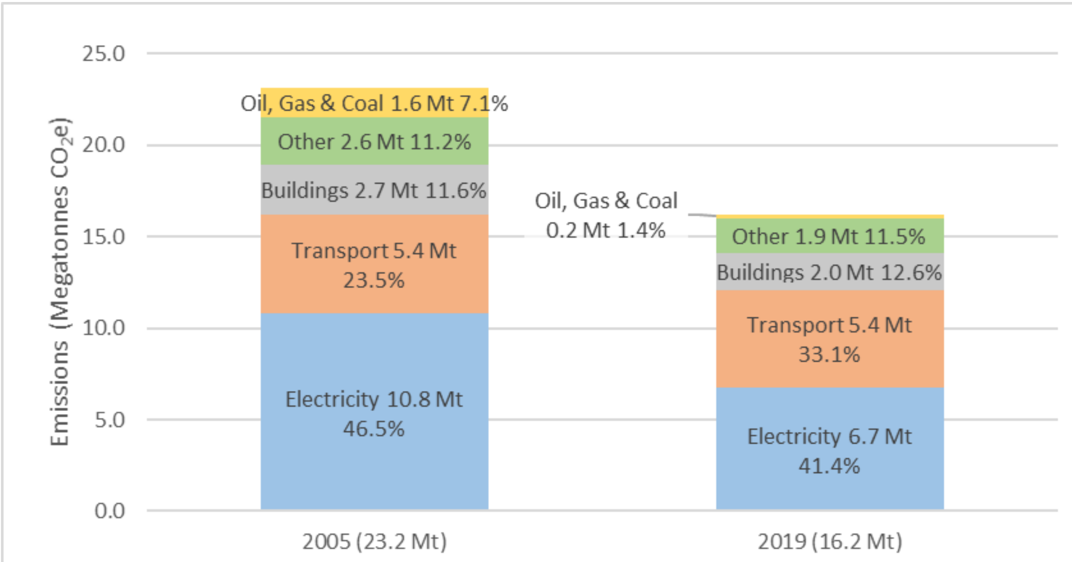


Figure 4: Nova Scotia's emitters by economic sector in 2005 and 2019

Figure 5 shows the evolution of the province's emissions states between 2005 to 2019; by 2019:

- GDP had grown by 16.9% (ΔGDP) and its trend (GDP') was positive.
- Energy demand was about 20% lower than it was in 2005 (ΔEUD) and the trend (PES') was negative.
- The province's total emissions fell by 29.9% (ΔCO_2), and the trend (CO_2') was negative.

The province's economic growth, represented by its GDP, was the third lowest in the country, after Newfoundland and Labrador and New Brunswick. The province's weak economic growth and a corresponding decline in energy demand, resulted in strong decoupling.

Emissions declined at a slightly greater rate than decline in energy demand, in part because of the restructuring of Nova Scotia Power in response to legislation imposing an emissions cap and a requirement to increase its use of renewables. Consequentially, the province was in the moderate decarbonizing state.

The increase in emissions between 2016 and 2018, and the subsequent decline in 2019 reflects changes in transportation energy demand.

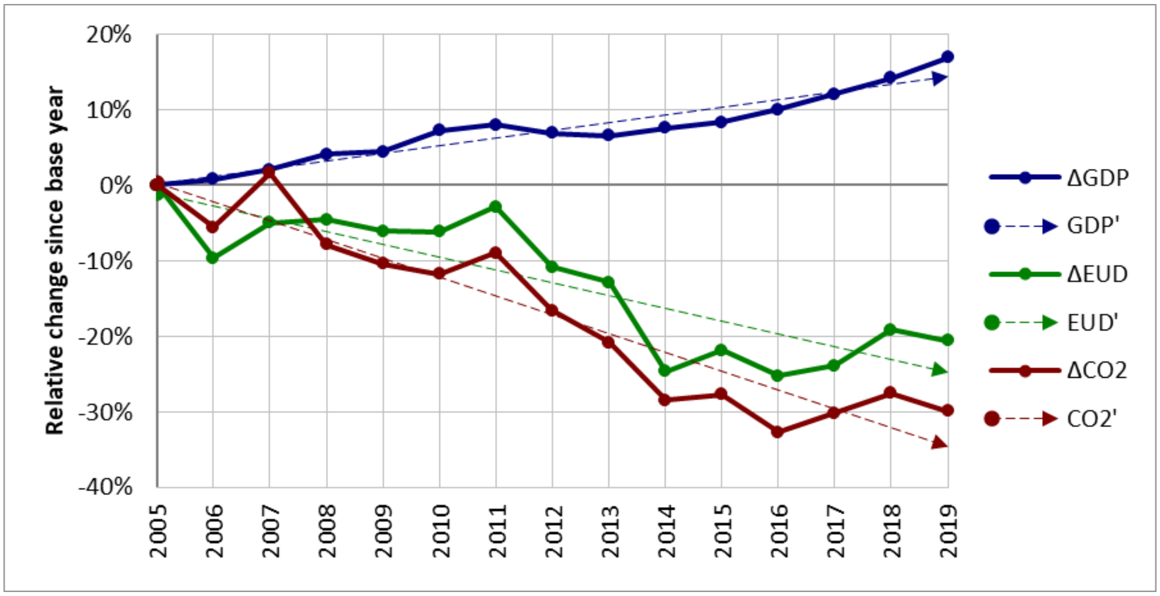


Figure 5: Nova Scotia (Strong decoupling and moderate decarbonizing)

3 2020: 10% under 1990 emissions levels

In 2007, the Government of Nova Scotia passed legislation to reduce its emissions by 10% from 1990 levels by 2020, from 19.6 Mt to 17.6 Mt. This was reaffirmed in province's 2019 Environmental Goals and Sustainable Prosperity Act.

The province's emissions have consistently remained below 17.6 Mt since 2014. In 2019, the province's emissions were 16.2 Mt or 17.2% below 1990 levels, tied with 2017 for the second lowest since 2005 (the lowest being 2016). For the province's emissions to exceed the 10% target, they would need to rise by 1.4 Mt over 2019 levels in 2020.

This is unlikely for several reasons:

- The province's Renewable Electricity Regulations require Nova Scotia Power to achieve a ratio of total renewables production to total sales (demand) of 25% for calendar years 2015 through 2019. Starting in calendar year 2020, this was to increase to 40%; however, because of Covid-19 related delays to the Muskrat Falls project, this target cannot be met. In response, the provincial government has relaxed the regulations and now requires Nova Scotia Power to have an average ratio of 40% between 2020 and 2022.[5]

  As Table 2 shows, between 2019 and 2020, Nova Scotia Power's sales of electricity declined by 0.44 TWh from 2019 levels, a result of the impact of the Covid-19 pandemic on the province's economy. This, plus the need to reduce emissions to meet the province's 2020-2022 ratio, resulted in the company reducing its reliance on coal and purchased power, and increasing its use of natural gas, oil, and petroleum coke. Despite the loss of 0.26 TWh of production from renewables, Nova Scotia Power's emissions fell by an estimated 0.29 Mt.

Table 2: Nova Scotia Power's emissions for 2020[6]

Fuel	2019			2020	
	Production TWh	**Emissions Mt**	**Intensity Mt/TWh**	**Production TWh**	**Emissions Mt *est.***
Coal	4.95	4.75	0.960	4.34	4.17*e*
Natural gas	1.44	0.78	0.539	1.87	1.01e
Oil and petcoke	0.91	1.02	1.124	0.97	1.09e
Purchased power	0.79	0.03	0.040	0.66	0.03e
Renewables	3.18	0.0		2.92	0.0
Totals	11.26	6.58		10.76	6.29e
Sales (Demand)	*10.47*			*10.03*	

[5] This should be achievable by, for example, Nova Scotia Power increasing the number of "blocks" of electricity it purchases from the Muskrat Falls project when finally commissioned.

[6] Nova Scotia Power was approached in late June with a request to update its Air Emission webpage, which as of 25 July 2021 had not been done, hence the use of estimates rather than actual values.

- The Canada Energy Regulator estimated the energy content of liquid fuels sold in Nova Scotia during 2020 declined from 2019, as Table 3 shows (the actual sales of liquid fuels will not be available from Statistics Canada until 2022). The pandemic is assumed to have affected the major energy consuming sectors differently: Commercial, Industrial, and Transportation sectors experienced a decline in emissions; whereas Residential increased. From these estimates we can assume that emissions from liquid fuels declined.

Table 3: Estimated energy content (petajoules) of liquid fuels sold in Nova Scotia

Sector	2019	2020
Commercial	4.49	3.90
Industrial	10.57	9.88
Residential	16.74	17.45
Transportation	79.25	70.69
Total	111.31	102.15

The available data would suggest that Nova Scotia met its 2020 emissions target of 10% below 1990 levels. However, had the province not achieved this target, there were no penalties associated with missing it.

4 2030: 53% under 2005 emissions levels

Nova Scotia's Environmental Goals and Sustainable Prosperity Act of 2019 was enacted before Covid-19 affected the province in 2020. The 2030 emissions target specified by the Act requires the province's emissions to decline by 53% of its 2005 emissions levels, from 23.2 megatonnes to 10.9 megatonnes or 12.3 megatonnes. However, reaching the target from its 2019 level of 16.2 megatonnes (the most recent data from ECCC) will require the province's emissions to decline by 5.3 megatonnes.

4.1 Why 53%?

Nova Scotia's 2030 target of "at least 53%" below its 2005 level of emissions exceeds Canada's Paris pledge of 30%. The choice of 53% was based on the province's desire to meet the emissions targets specified by the IPCC to limit global temperature increases to no more than 1.5°C this century. To achieve this, the IPCC recommended that global anthropogenic emissions decline about 45% from 2010 emissions levels by 2030 and reach net-zero by 2050.

The steps used to obtain Nova Scotia's 2030 target are summarized in Table 4 (column Unrounded): a) the province's emissions for 2010 were about 20.4 Mt; b) 45% of the 2010 emissions is 9.2 Mt; c) the 45% reduction is subtracted from the 2010 emissions level to give the 2030 target of 11.2 Mt; d) the province's emissions in 2005 were about 23.2 Mt; e) the required reduction (2005 to 2030) is 11.9 Mt; and f) in percentage terms, the province needs to reduce its emissions by 51.5%.

However, a series of assumptions were made by the Department of the Environment, the first being to round the target down from 11.2 Mt to 11 Mt (step c in column Rounded), giving a reduction of 12.1 Mt or 52.5%. The 52.5% was then rounded up to 53%, making the target "at least 53%" below the 2005 emissions level.

By rounding the 2030 target down from 11.2 Mt to 11 Mt and the percentage up from 52.5% to 53%, the 2030 target is 53% below the 2005 level (23.2 Mt) or 10.9 Mt.

Table 4: Determining the 2030 target

	Unrounded	Rounded
a) Emissions in 2010	20.4	
b) 45% reduction of (a)	9.2	
c) 2030 target (a)-(b)	11.2	11
d) Emissions in 2005	23.2	23.2
e) Required reduction from 2005 to 2030 (d)-(c)	11.9	12.1
f) Fraction: (e)/(d)	51.5%	52.5%

While the choice and reasoning for the choice is laudable, there appears to have been little thought given to whether or how this target could be achieved. The remainder of this section describes different changes to the provincial energy system needed to meet the 2030 target.

4.2 Nova Scotia Power's 2030 emissions scenarios

Legislation requires that by 2030, Nova Scotia Power's emission must not exceed 4.5 megatonnes and 40% of the electricity it sells in the province comes from renewables sources.

In late summer 2020, Nova Scotia Power released its Integrated Resource Plan for 2021 to 2045. The IRP lists 27 scenarios of possible generation sources, capacity, generation, production, and emissions. The emissions associated with each of the 2030 scenarios are shown in Figure 6, ranked from the lowest emissions (left) to the highest (right).

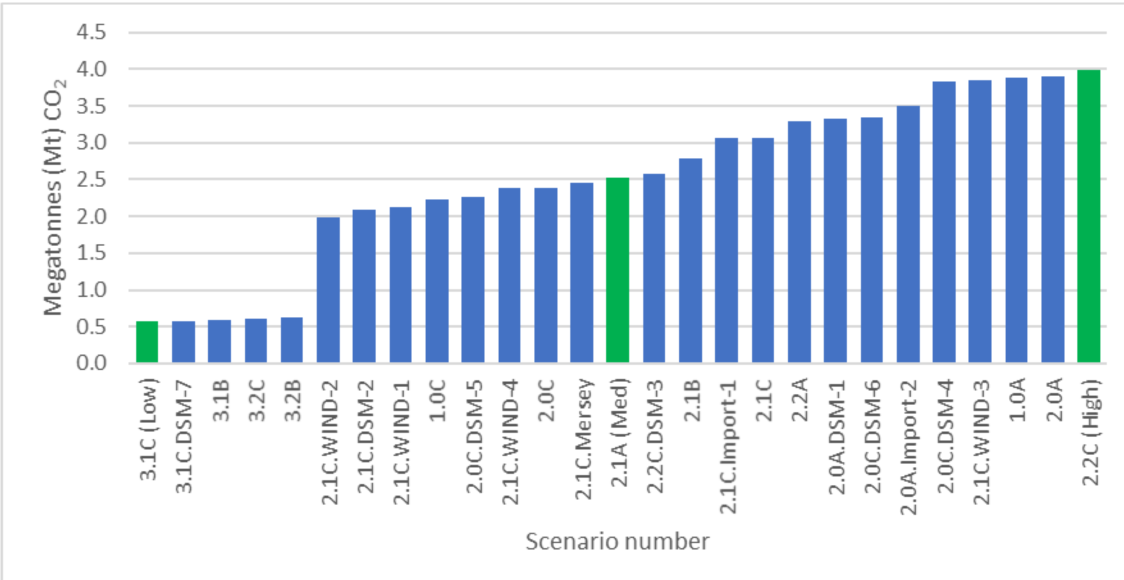


Figure 6: Nova Scotia Power's scenario emissions for 2030 (data from Nova Scotia Power)

For the purposes of this report, we consider three of Nova Scotia Power's scenarios for 2030:

3.1C (Lowest emissions): In this scenario, referred to as Accelerated Net Zero 2045, Nova Scotia Power's emissions decline from 6.7 Mt in 2019 to 0.57 Mt in 2030, removing about 6.1 Mt of emissions. By 2030, about 50% of the province's electricity will be supplied from renewable sources within the province (36% from wind) and coal will be phased out entirely. Complete regional integration between Quebec, New Brunswick, and Newfoundland and Labrador (using the existing Maritime Link) is required since 42% of the electricity is imported. Although not explicitly mentioned, the underlying assumption in this scenario is that the Atlantic Loop will be completed by 2030, giving Quebec access to the Maritime Provinces and, more importantly for Hydro Quebec, New England.

Electricity demand in 2030 is 11.5 TWh.

2.1A (Median emissions): This scenario sees Nova Scotia Power's emissions fall to 2.5 Mt, a decline of about 4.2 Mt from 2019 levels. As with 3.1C, in 2030 almost half of the electricity available in the province comes from provincial renewable sources (34% from wind), with the remainder evenly split between carbon-intensive sources (coal contributes 17%) and imports.

Electricity demand in 2030 is 11.4 TWh.

2.2C (Highest emissions): In the high-emissions scenario, Nova Scotia Power reduces its emissions by 2.7 Mt, from 6.7 Mt to 4.0 Mt of CO_2e in 2030 (this is 0.5 Mt below the federal-provincial emissions cap for Nova Scotia Power). A total of 40% of the production comes from emissions-intensive sources (25% still comes from coal); of the remainder, 31% comes from in-province sources (with wind contributing about 20%). 29% is imported.

Despite assuming maximum Demand Side Management (DSM) adoption, total demand is 11.8 TWh.

4.3 The impact of Nova Scotia Power on the 2030 target

In 2019, Nova Scotia Power was the province's single largest emissions source. Before considering the province's remaining emissions sources, it is necessary to understand the impact Nova Scotia Power will have on the province's 53% reduction target.

In 2019, Nova Scotia Power's emissions totalled 6.7 Mt and emissions from sources other than Nova Scotia Power totalled 9.5 Mt, for a total of 16.2 Mt. If the province is to meet its 2030 target of 10.9 Mt, emissions need to decline by 5.3 Mt from 2019 to 2030.

Figure 7 shows the province's emissions by sector for selected years between 2005 and 2019. The dashed line is the 2030 target level of 10.9 Mt.

The rightmost three bars show Nova Scotia Power's emissions for its Low, Median, and High emissions in 2030 (blue, at the bottom of the stack) and the 2019 total emissions from sources other than Nova Scotia Power (i.e., Transport, Buildings, Oil & Gas, and Other).

The non-Nova Scotia Power emissions are stacked on top of Nova Scotia Power's emissions (shown in green and red, indicating the total volume below and above the 2030 target, respectively). The red bands are the volume of reductions required by sources other than Nova Scotia Power in 2030:

2030 Low: Emissions from Nova Scotia Power (0.57 Mt) and non-Nova Scotia Power sources (9.51 Mt) total about 10.1 Mt, meaning in this scenario, emissions from sources other than Nova Scotia Power could *increase* their emissions by almost 0.8 Mt and the province would still achieve its 2030 target.

2030 Median: In this scenario, the province's total emissions in 2030 would be about 12 Mt (2.53 Mt from Nova-Scotia Power and 9.51 Mt from sources other than Nova Scotia Power). In this case, emissions from sources other than Nova Scotia Power would need to decrease their emissions by about 1.2 Mt to meet the 10.9 Mt target.

2030 High: In the third scenario, Nova Scotia Power's emissions are 4 Mt, which would put the province's emissions at 13.5 Mt, requiring a reduction of 2.6 Mt from sources other than Nova Scotia Power to meet the 2030 target.[7]

[7] If Nova Scotia Power achieves its 2030 High scenario target of 4 Mt, it will have met the 4.5 Mt CO2e emissions cap required by the province.

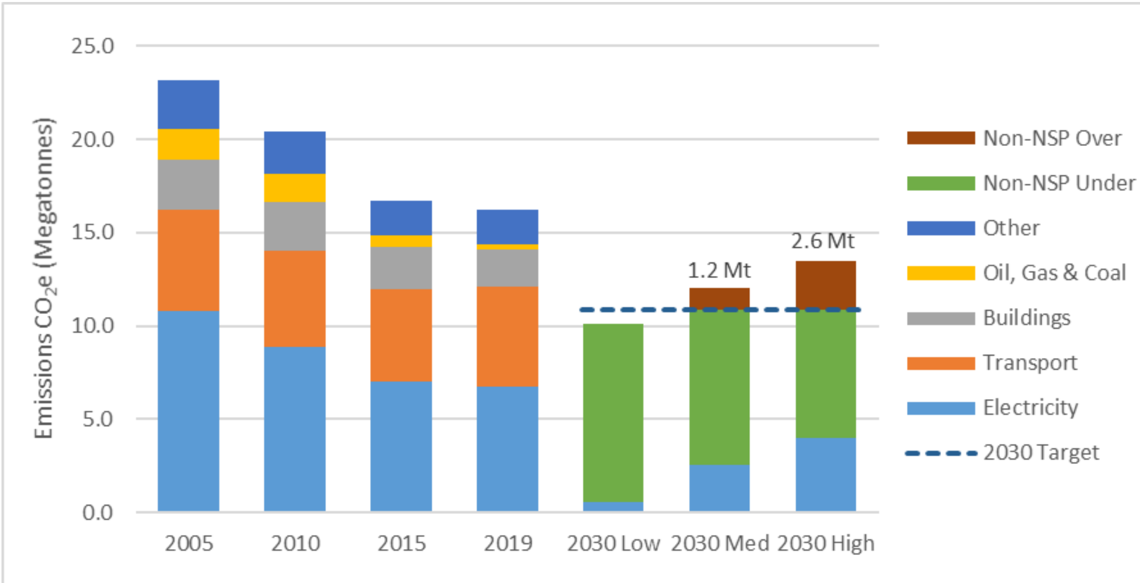


Figure 7: Nova Scotia's emissions for major emitters for selected years and Nova Scotia Power's importance to the 2030 target

4.4 Emissions from sources other than Nova Scotia Power

In this section we examine emissions from sources other than Nova Scotia Power: Transport; Buildings; Oil, Gas & Coal; and Other. In each case, we consider the effect of no reduction (Business as Usual), and three reduction scenarios: 5, 10, and 15 percent.

We do not consider the impact on Nova Scotia Power's emissions of any decoupling or decarbonizing action that takes place by one of these sources, regardless of whether it changes the volume of electricity produced.

4.4.1 Transportation

After electricity, transportation is the second largest source of emissions in the province. Transportation refers to all possible transportation modes used in the province: road, marine, rail, air, and off-road.[8] Within each mode there are several subcategories; for example, road includes light-duty gasoline trucks (passenger and freight) and vehicles (cars), off-road vehicles, and motorcycles. The UNFCCC reporting requirements state that transportation emissions are the result of the combustion of different fuels (including gasoline, diesel, aviation fuels, and liquefied petroleum gases (LPG)).

Analysis

Between 2005 and 2019, Nova Scotia's total transportation emissions declined from a high of 5.74 megatonnes in 2005 to a low of 4.53 megatonnes in 2014 then climbed to 5.70 megatonnes in 2018, and dropped to 5.58 megatonnes in 2019. The rebound from 2014 is due

[8] According to the UNFCCC's Common Reporting Format for emissions, "… emissions from international aviation and marine bunkers … should not be included in the national total emissions from the energy sector".

almost entirely to the growth in the use of light duty gasoline trucks. The change in emissions by type of transportation (vehicle category or mode) are shown in Figure 8.[9]

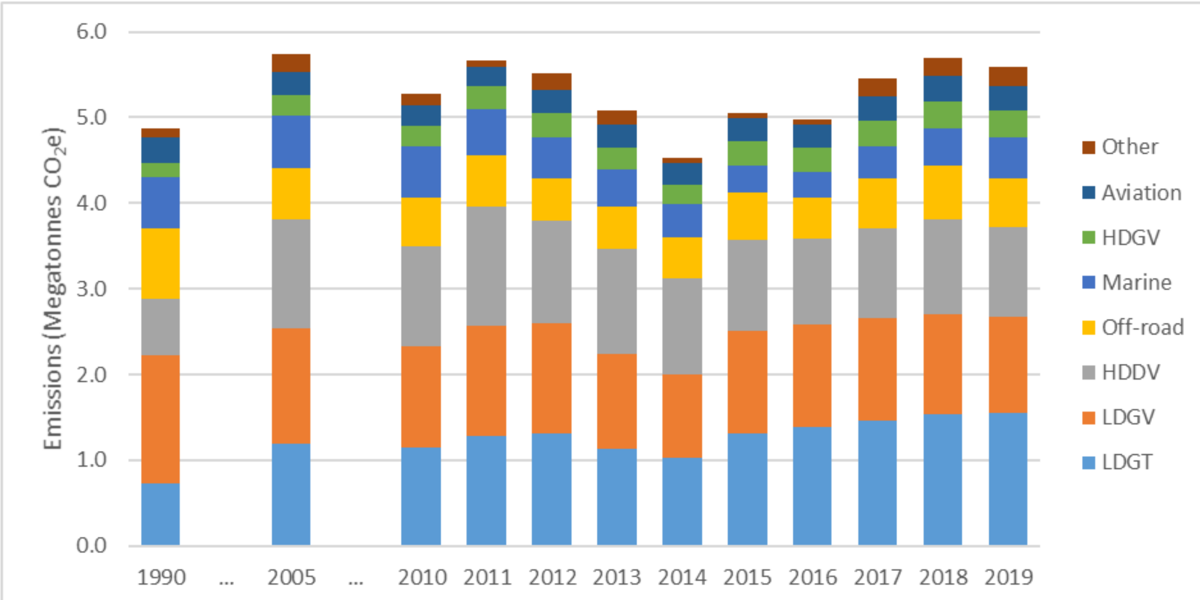


Figure 8: Transportation emissions by vehicle/mode for selected years (Other includes railways, LDDV, LDDT, motorcycles, pipelines, and PNG vehicles)

During this period, the contribution of road emissions increased marginally as a percentage of overall transportation emissions, from 71.5% of emissions in 2005 to 73.3% in 2019. The causes of the changes in road transport emissions are summarized in Table 5.

Table 5: Change in road transport emissions between 2005 and 2019

Vehicle	Category	Emissions (Mt)			Percent change
		2005	2019	Change	
Light-Duty Gasoline Trucks	LDGT	1.19	1.56	0.36	30.5%
Light-Duty Gasoline Vehicles	LDGV	1.35	1.12	-0.23	-17.1%
Heavy-Duty Diesel Vehicles	HDDV	1.26	1.05	-0.22	-17.0%
Heavy-Duty Gasoline Vehicles	HDGV	0.24	0.31	0.07	30.2%
Light-Duty Diesel Vehicles	LDDV	0.04	0.02	-0.02	-41.3%
Light-Duty Diesel Trucks	LDDT	0.01	0.02	0.02	175.4%
Motorcycles	Motorcycles	0.01	0.01	0.01	116.2%
	Totals	4.10	4.09		

[9] Categories: LDGT: Light-Duty Gasoline Truck (both passenger and freight); LDGV: Light-Duty Gasoline Vehicle (cars); HDDV: Heavy Duty Diesel Vehicle (medium and heavy trucks); HDGV: Heavy Duty Gasoline Vehicles; and Other: railways, LDDV (Light-Duty Diesel Vehicles), LDDT (Light-Duty Diesel Trucks), motorcycles, pipelines, and PNG (Pressurized Natural Gas) vehicles.

Restructuring transportation: Road vehicle emissions reduction to 2030

Restructuring transportation requires existing vehicles using internal combustion engines (ICEs) and gasoline be replaced with vehicles using other energy sources (typically electricity in electric vehicles and electric trucks; although a modal shift restructuring, for example, to an electric bus, bicycle, or even walking).

Unlike electricity (above) and buildings (below), the province has no legislation in place to explicitly lower vehicular emissions. Other than fuel taxes (both provincial and federal) and a federally approved provincial carbon-pricing system which is far less onerous than those found in most of the other provinces, the Nova Scotia government has few tools at its disposal other than federal funds for electric vehicle subsidies.

The effects of the Covid-19 pandemic are expected to have a multi-year impact on Canada's economy, including transportation. There is no reason to think that Nova Scotia will be any different. According to federal projections, overall transportation emissions are expected to decline by 17% between 2018 and 2020, and a further 2% between 2021 and 2030, although as Table 3 shows Nova Scotia's transportation energy demand only declined by an estimated 10% because of the pandemic. Global emissions, including those from transportation, are expected to rebound in 2021.

The two transport categories garnering the most interest in terms of their emissions are light duty gasoline trucks (LDGT) and light duty gasoline vehicles (LDGV). Many jurisdictions and automobile manufacturers are in the process of restructuring their transportation systems to support electric and hydrogen vehicles rather than liquid fuels or internal combustion engines.

Light Duty Gasoline Trucks

ECCC's emissions data does not distinguish between Passenger Light Duty Trucks (commonly referred to as SUVs) and Freight Light Duty Trucks, classifying them as "Light Duty Trucks". Although there are minor differences between the two in terms of fuel consumption, we examine both separately using data from NRCan.

Although average growth over the past decade in light trucks has averaged over 4%, we assume a growth rate between 2019 and 2030 of 2%. The average distance driven between 2015 and 2018 was 21,000 km, which we assume to be the average distance driven each year between 2019 and 2030. Finally, we assume an increase in fuel efficiency of 1% per year.

Table 6 shows the results of the analysis, starting in 2019 with 254,494 passenger light trucks and 70,602 freight light trucks. By 2030, the numbers increase to 316,431 passenger light trucks and 87,785 freight light trucks.

We apply the three adoption rates (5%, 10%, and 15%) to each. This means emissions decline slightly over time, offset by the increase in the number of non-electric light trucks. The results are summarized in Table 7. By 2030, at the 15% adoption rate, there are over 65,000 electric light trucks (LDET) on the road, but emissions only decline by 0.107 Mt.

Table 6: Total emissions LDGT to LDET (Passenger ■, Freight ■, and 2019 emissions ---)

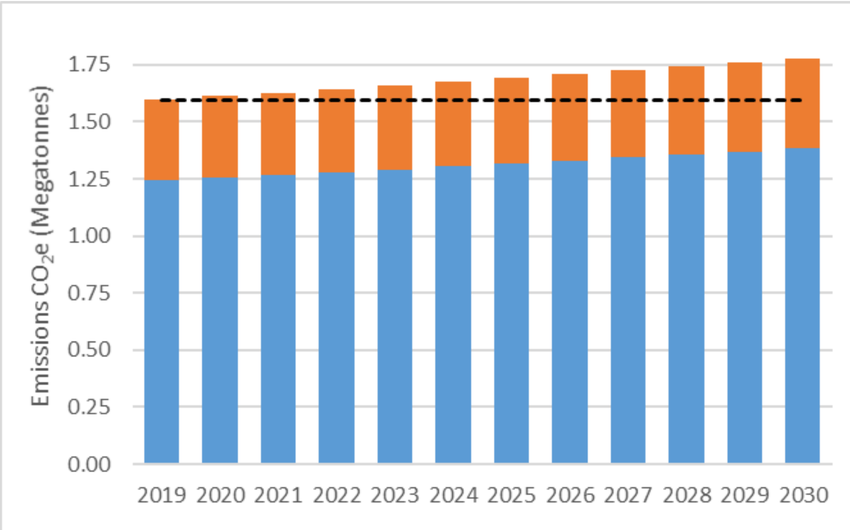


Table 6.1: LDGT only: BAU (Net change: +0.181 Mt)

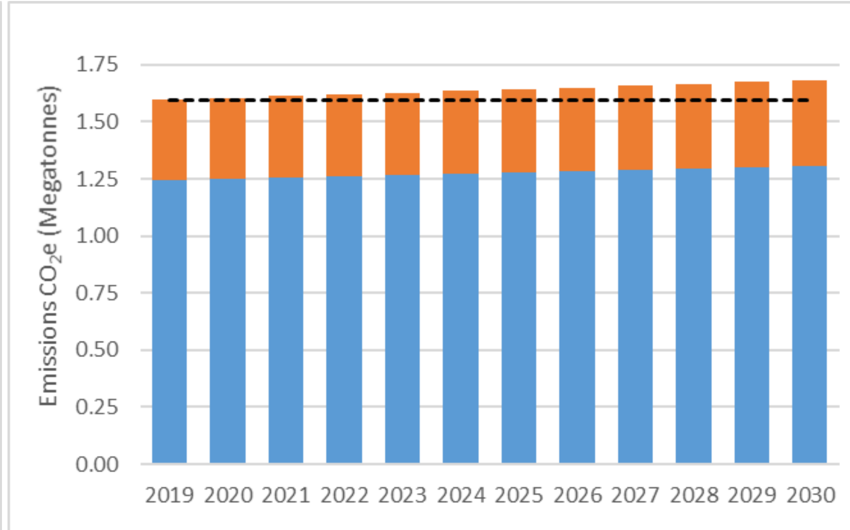


Table 6.2: LDGT to LDET 5% adoption (Net change: +0.085 Mt)

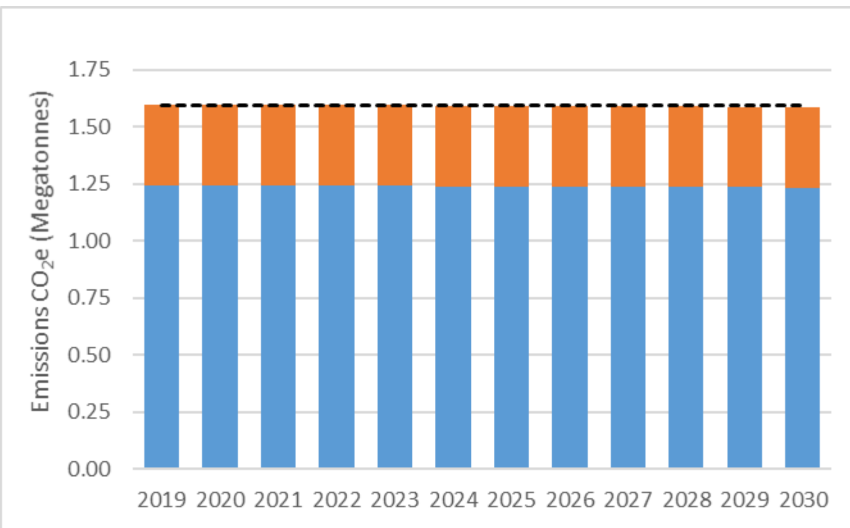


Table 6.3: LDGT to LDET 10% adoption (Net change: -0.011 Mt)

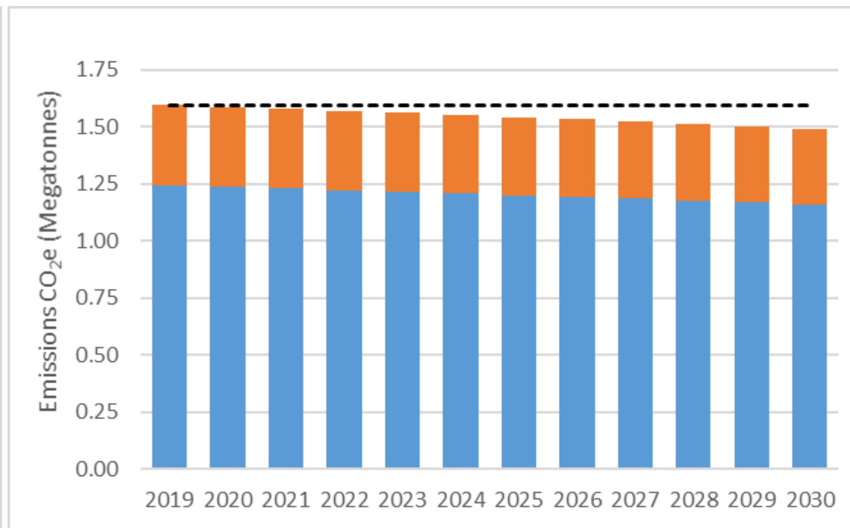


Table 6.4: LDGT to LDET 15% adoption (Net change: -0.107 Mt)

Table 7: Summary of LDGT to LDET in 2030 by adoption rate

	Passenger Light Trucks			Change in Emissions	Freight Light Trucks			Change in Emissions	Total Change
	Vehicles	LDGT	LDET		Vehicles	LDGT	LDET		
BAU	316,431	316,431	0	0.141	87,785	87,785	0	0.040	0.181
5%	316,431	299,369	17,062	0.066	87,785	83,052	4,734	0.019	0.085
10%	316,431	282,306	34,125	-0.008	87,785	78,318	9,467	-0.002	-0.011
15%	316,431	265,244	51,187	-0.083	87,785	73,585	14,201	-0.024	-0.107

Light Duty Gasoline Vehicles

Demand for Light Duty Gasoline Vehicles (LDGV) is falling as people abandon cars in favour of SUVs. This is true in Nova Scotia. We use data from NRCan to determine the characteristics of the LDGVs: fuel consumption was assumed to improve 1% per year, ownership declined at 0.5% a year (which is lower than listed by NRCan), and average distance driven between 2014 and 2018 was 21,000 km, which is used as the average distance driven between 2019 and 2030. The number of vehicles in 2019 was estimated to be 329,736.

The results of the analysis are shown in Table 9. With the decline in demand for LDGV, there is a decline in emissions between 2019 and 2030 of 0.155 Mt. This decline increases as the number of LDEVs increases.

Table 8 summaries the results for 2030 by adoption rate. At 15%, the number of LDEVs is over 51,000 with a decrease in emissions of 0.310 Mt, of which 0.170 Mt is from the decline in LDGV.

Table 8: Summary of LDGV to LDEV in 2030 by adoption rate

	Total Vehicles	LDGV	LDEV	Change in emissions (Mt)
BAU	311,372	311,372	0	-0.170
5%	311,372	294,157	17,215	-0.217
10%	311,372	276,942	34,430	-0.263
15%	311,372	259,727	51,645	-0.310

Premier Rankin's promise in February 2021 of $9 million for electric vehicles ($3,000 for new EVs, $2,000 for used EVs, and $500 for E-bikes) would subsidize a maximum of 3,000 new EVs, 4,500 used EVs, or 18,000 E-bikes.

At the 5% adoption by 2030, this would subsidize about three years of used EVs (about 1,500/year) or less than one year at 15% adoption (about 4,500/year). In other words, such sums may result in positive press coverage for the Premier, but do little to address the issue of vehicle electrification.

Table 9: Total emissions LDGV to LDEV (2019 emissions ---)

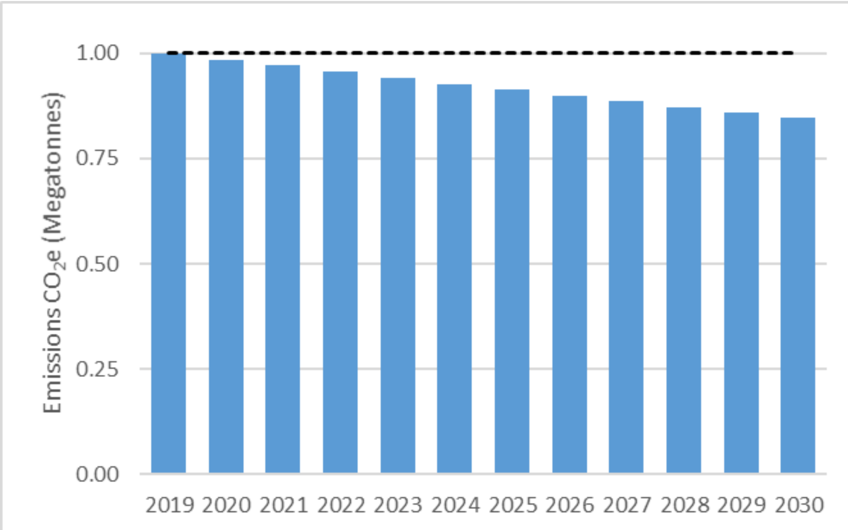


Table 9.1: LDGV only: BAU (Net change: -0.155 Mt)

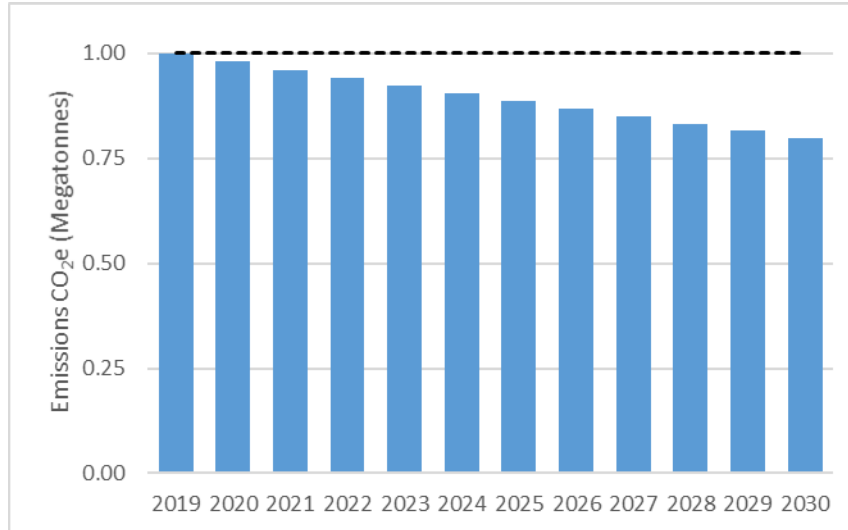


Table 9.2: LDGV to LDEV 5% adoption (Net change: -0.201 Mt)

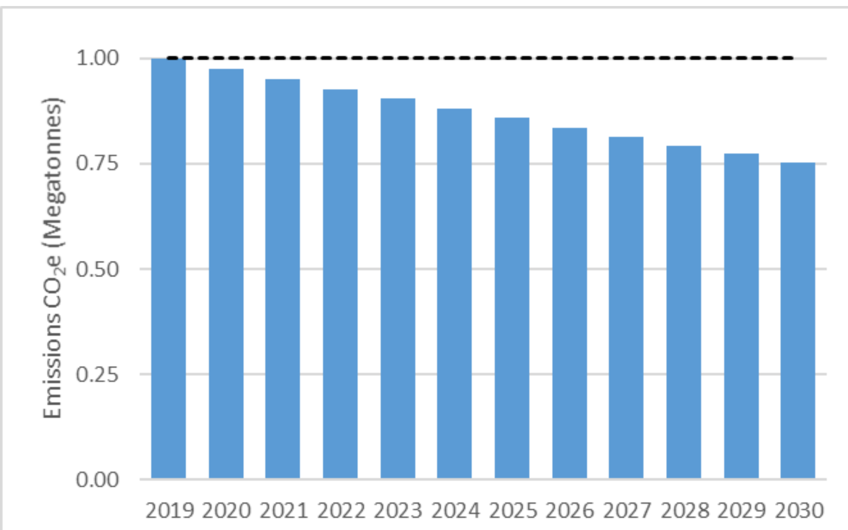


Table 9.3: LDGV to LDEV 10% adoption (Net change: -0.248 Mt)

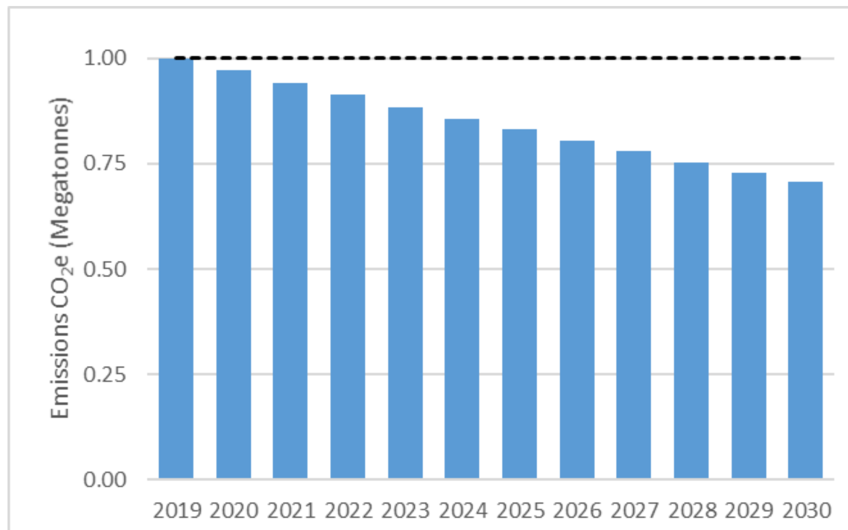


Table 9.4: LDGV to LDEV 15% adoption (Net change: -0.295 Mt)

Other road vehicles

Other road vehicles are Heavy-Duty Diesel Vehicles (HDDV) and the remaining vehicles categories with emissions under 1 Mt. The analysis results are summarized in Table 10. Since most of these are small to start with, their total reduction is small as well. By 2030, at 15% reduction, emissions would decline about 0.213 Mt.

Table 10: Emissions summary for other road vehicles in 2030 (Mt)

Category	Category	BAU	-5%	-10%	-15%
Heavy-Duty Diesel Vehicles	HDDV	1.048	0.996	0.944	0.891
Heavy-Duty Gasoline Vehicles	HDGV	0.309	0.293	0.278	0.263
Light-Duty Diesel Vehicles	LDDV	0.024	0.023	0.022	0.021
Light-Duty Diesel Trucks	LDDT	0.024	0.023	0.022	0.021
Motorcycles	Motorcycles	0.011	0.011	0.010	0.010
Totals		1.417	1.347	1.276	1.205
Change in emissions		0.000	-0.071	-0.142	-0.213

Non-road transportation emissions

Non-road transportation is dominated by Other Transportation which is off-road vehicles, such as ATVs. The remaining members of the category are air, sea, and rail (emissions from international air transport and international sea transport are not included in Canada's inventory of emissions).

The results of the analysis are shown in Table 11, with emissions decreasing from 1.545 Mt in 2019 to 1.314 Mt in 2030 or -0.232 Mt with a 15% decline.

Table 11: Emissions summary for non-road transportation emissions in 2030 (Mt)

Category	BAU	-5%	-10%	-15%
Domestic Aviation	0.294	0.279	0.264	0.249
Railways	0.158	0.150	0.142	0.135
Domestic Navigation	0.474	0.451	0.427	0.403
Other Transportation	0.619	0.588	0.557	0.526
Total	1.545	1.468	1.391	1.314
Change	0.000	-0.077	-0.155	-0.232

Summary

Table 12 summarizes the province's emissions reductions at various reduction rates. For example, in 2030, if 15% of all Light Duty Trucks and Light Duty Vehicles were electrified and the remaining sources of transport emissions were to reduce their emissions by 15%, transport emissions would fall an impressive 0.861 Mt.

Achieving such a reduction in such a short span of time is highly unlikely, given the lack of policies in place to cause such a transition.

Table 12: Transportation emission reductions (Mt)

Category	BAU	-5%	-10%	-15%
Light Duty Trucks	0.181	0.085	-0.011	-0.107
Light Duty Vehicles	-0.170	-0.217	-0.263	-0.310
Other road	0.000	-0.071	-0.142	-0.213
Non-road	0.000	-0.077	-0.155	-0.232
Total	0.011	-0.280	-0.571	-0.861

4.4.2 Buildings

Buildings (or the built environment) refer to residential and service industry (commercial and institutional) structures.[12] Emissions from buildings come from the combustion of fuels such as natural gas, home heating oil, and biomass fuels (unsustainably harvested),[13] primarily for space and domestic hot water (ECCC 2020, UNFCCC 2020). There are no residential emissions from the use of electricity; any emissions associated with the generation of electricity are indirect emissions and the responsibility of the electricity provider (Nova Scotia Power in this case).

Residential and service industry emissions in Nova Scotia's built environment between 2005 and 2019 are shown in Figure 9. In 2005, emissions were evenly split between service industry and residential buildings.[14] By 2019, emissions in the built environment had declined by about 0.66 megatonnes, with the residential sector responsible for about two-thirds of the total (1.3 megatonnes).

[12] According to Environment and Climate Change Canada, "The Commercial/Institutional subcategory also includes GHG emissions from the public administration subcategory (i.e., federal, provincial, and municipal establishments). GHG emissions for these subcategories are from fuel combustion, primarily related to space and water heating."

[13] According to the UNFCCC's Common Report Format, "*biomass… emissions should not be included in the national total emissions from the energy sector. Amounts of biomass used as fuel are included in the national energy consumption but the corresponding CO2 emissions are not included in the national total, as it is assumed that the biomass is produced in a sustainable manner. If the biomass is harvested at an unsustainable rate, net CO2 emissions are accounted for as a loss of biomass stocks in the land use, land-use change and forestry sector.*"

[14] This was due to an accounting practice used by Statistics Canada in the early 2000s, in which commercial fuel suppliers purchasing space heating fuel from a refinery were considered the end-user of the fuel, rather than the residential or industrial end-user. However, end-use customers purchasing fuel from a fuel supplier working for the refinery were considered the end-users. By 2007 the practice had ended, allocating the emissions to the end-user rather than the transporter of the fuel.

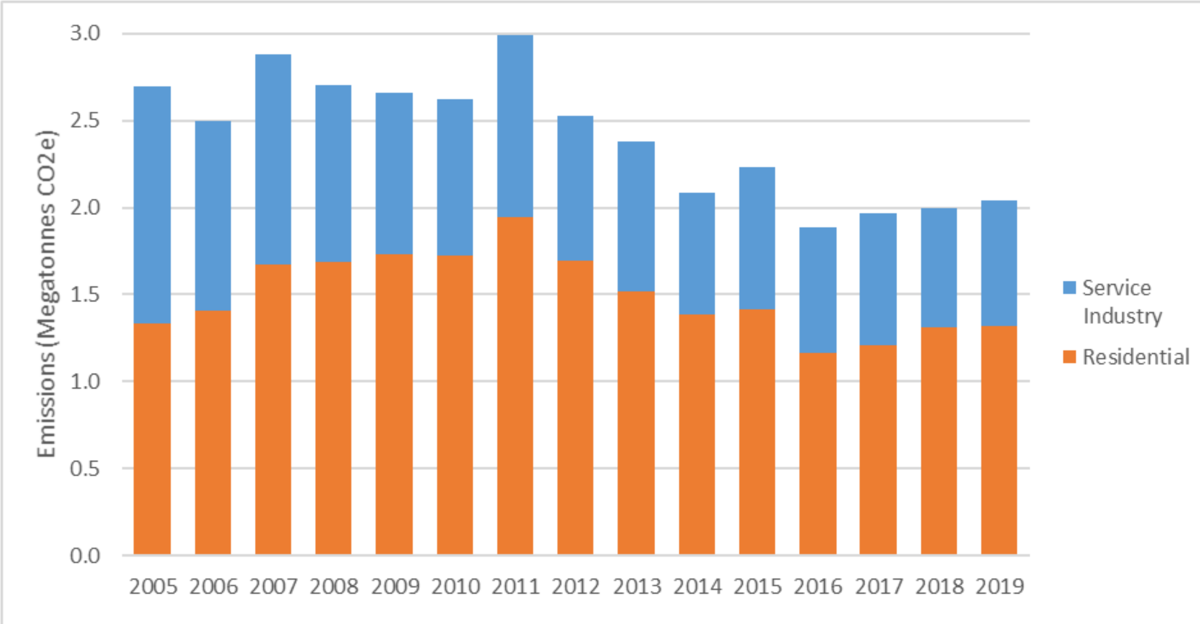


Figure 9: Emissions in Nova Scotia's built environment

Emissions reduction in the built environment can be done using any of the 3Rs in buildings that use a carbon intensive fuel (such as fuel oil, natural gas, biomass harvested unsustainably, propane, or coal):

Reduction: In a reduction, the same fuel and heating source are used for space or water heating, or both; however, the demand for the energy required is reduced, leading to a reduction in emissions if the fuel used was emissions intensive. Reduction is typically done by modifying the building envelope so that its heat loss (in winter) or heat gain (in summer) is reduced.

Replacement: Replacement (replacing one energy source with another and using the same process or replacing the process and using the same energy source) can lead to a reduction in energy demand and might reduce emissions. If the building replaces its lighting from incandescent bulbs to LEDs (light emitting diodes), it will probably reduce its electricity demand but not its emissions (any emissions reduction would be the result of the electricity supplier using less emissions-intensive fuels). If the building were to replace an existing low-efficiency oil furnace (60% efficient) with a high-efficiency furnace (85%), its demand for energy would probably decline as would the building's emissions.

Replacing electric baseboard heaters with a fuel pump (new process with the same fuel source) would reduce demand for electricity but it would have no impact on the building's emissions since the process and the energy used are non-emitting. As with replacing an incandescent bulb with a LED, any change in emissions will be the responsibility of the energy supplier, not the end-user.

Restructuring: Emissions in a building can be reduced to zero by replacing both the process and its energy source. Examples include replacing an oil furnace (using fuel oil) with a heat pump (using electricity), replacing a natural gas stove with an electric stove, and replacing an oil-fired water heater with an electric water heater.

Residential emissions

Residential emissions are due to two processes: space heating and water heating (for domestic hot water or DHW), and their energy sources: light fuel oil, wood, natural gas, and other carbon-intensive fuel sources such as propane and coal.

The 2018 emissions data for space and water (DHW) heating in Nova Scotia's Residential sector are shown in Figure 10. In both cases, heating oil is responsible for most residential emissions, with wood a distant second.[15]

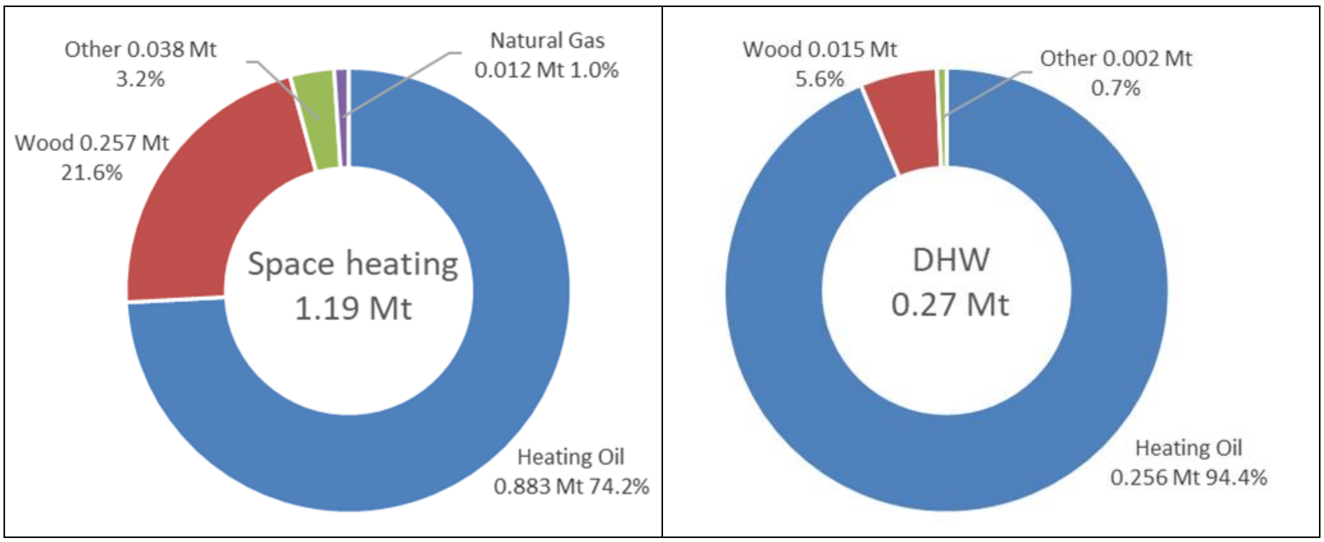


Figure 10: Nova Scotia's residential emissions sources in 2018.

There are three major challenges facing anyone designing an emissions reduction strategy for Nova Scotia's residential sector. First, about 40% of the secondary energy used in the residential sector is fuel oil; second, more than half of residential buildings are heated by oil; and third, Nova Scotia's population is growing. This means any reduction in emissions in existing buildings could be offset by new buildings designed to use an emissions-intensive energy source.

Residential emissions in 2019 were 1.3219 Mt. Table 13 shows four scenarios for emissions in 2030 (5% through 20% below the 2019 value), the 2030 reductions (for example, emissions declined to 1.1236 Mt if a 15% reduction was achieved), and the total reduction in megatonnes (for example, a 10% reduction would result in a decline of 0.1322 Mt).

[15] Although wood is considered a renewable source of energy by ECCC, NRCan includes its emissions in their residential calculations. For the remainder of this section, we will be using ECCC's data.

Table 13: Emissions reduction scenarios for residential sector

Reduction	Emissions (Mt)		Total reduction (Mt)
	2019	2030	
5%	1.3219	1.2558	-0.0661
10%	1.3219	1.1897	-0.1322
15%	1.3219	1.1236	-0.1983
20%	1.3219	1.0575	-0.2644

Table 14 shows how the four emissions reduction scenarios could be met through restructuring (replacing an oil furnace with a space heating system using a non-emitting source of energy). Five different efficiencies of furnace are used. In each reduction scenario, we determine the total number of furnaces to be removed between 2020 and 2030; for example, to achieve a 10% reduction, 17,464 furnaces emitting 7.57 t of CO_2e/year (Furnace 2) would need to be replaced. This would mean a total of 1,588 furnaces would need to be removed each year (30 per week) and replaced with a non-emitting energy source. Finally, the annual replacement cost (in millions), assuming each restructuring would cost $5000 each; in the example, it would cost about $7.94 million a year.

Table 14: Required restructuring in residential sector[16]

Total reduction		Furnace 1	Furnace 2	Furnace 3	Furnace 4	Furnace 5
	Furnace (t CO2e/yr)	9.19	7.57	6.76	4.73	4.22
5% 66,066 t	Total furnaces	7,189	8,729	9,775	13,965	15,641
	Replacements/year	654	794	889	1,270	1,422
	Cost M$/year	$3.27	$3.97	$4.44	$6.35	$7.11
10% 132,187 t	Total furnaces	14,384	17,464	19,559	27,941	31,294
	Replacements/year	1,308	1,588	1,778	2,540	2,845
	Cost M$/year	$6.54	$7.94	$8.89	$12.70	$14.22
15% 198,280 t	Total furnaces	21,576	26,196	29,338	41,911	46,941
	Replacements/year	1,961	2,381	2,667	3,810	4,267
	Cost M$/year	$9.81	$11.91	$13.34	$19.05	$21.34
20% 264,373 t	Total furnaces	28,767	34,928	39,117	55,881	62,588
	Replacements/year	2,615	3,175	3,556	5,080	5,690
	Cost M$/year	$13.08	$15.88	$17.78	$25.40	$28.45

Service Industry emissions

Service Industry emissions are from commercial and government institutional space and water heating applications. Since detailed data is not available from NRCan for commercial and institutional emissions in Nova Scotia (the sector's emissions are grouped with the other Atlantic Provinces), we will use ECCC's NIR data for Service Industry emissions.

[16] Furnace data from Efficiency Nova Scotia: Furnace 1, 80 MBTUs/yr "old"; Furnace 2, 80 MBTUs/yr "new"; Furnace 3, 80 MBTUs/yr "condensing"; Furnace 4, 50 MBTUs "new"; Furnace 5, 50 MBTUs, "condensing".

Service Industry emitters are typically large buildings or multi-building campuses (such as universities, colleges, hospitals, government complexes such as prisons, and shopping malls); most of their emissions are from space heating. Changing these systems can be a major restructuring requiring access to a new energy supply and possible new furnaces, such as replacing boilers using bunker C with more efficient natural gas boilers using natural gas. Moreover, once this restructuring has been done (from an emissions intensive source to one that is less emissions intensive, as was done by the hospitals and universities on the Halifax Peninsula in 2006 and is being done in other institutions across the province with trucked natural gas), potentially at a significant cost to the organization, there would be little enthusiasm to repeat the process to switch to some form of non-emitting heating.

With this in mind, we considered the impact of reducing Service Industry emissions from 2019 levels (0.7155 Mt) by 5%, 10%, 15%, and 20% by 2030. The results are shown in Table 15, with emissions declining by -0.0358 Mt (5%) and -0.1431 Mt (20%) by 2030.

Table 15: Reduction scenarios for Service Industries

Reduction	Emissions (Mt)		Total reduction (Mt)
	2019	2030	
5%	0.7155	0.6797	-0.0358
10%	0.7155	0.6439	-0.0715
15%	0.7155	0.6081	-0.1073
20%	0.7155	0.5724	-0.1431

Summary

The total decline in emissions for both Residential and Service Industry is shown in Table 16 for three different reduction scenarios. If emissions remained unchanged from 2019, they would be 2.037 Mt in 2030. However, if emissions were to decline by 15% in the entire Built environment, emissions would decline about 0.372 Mt

Table 16: Total reductions in Built environment (Mt)

	BAU	5%	10%	15%
Residential	1.322	-0.066	-0.132	-0.264
Service Industry	0.715	-0.036	-0.072	-0.107
Total	2.037	1.936	1.834	1.666
Reduction		-0.102	-0.204	-0.372

As with transportation, one of the major limiting factors in reducing emissions is the cost of a new heating system and the age of an existing heating system. Restructuring to achieve decarbonization in building is essential; however, a building owner might balk at making a change to a new heating system if the building's existing system has just been installed and is still being paid off. Again, this is an example of where policy reflecting the urgency of the climate emergency is essential, in this case, changing the building code to reflect this.

4.4.3 Oil, Gas & Coal

The Oil, Gas & Coal group includes energy emissions from upstream and downstream oil and natural gas operations (i.e., conventional oil production, natural gas production and processing, petroleum refining, and natural gas distribution). The change in emissions in this group are shown in Figure 11.

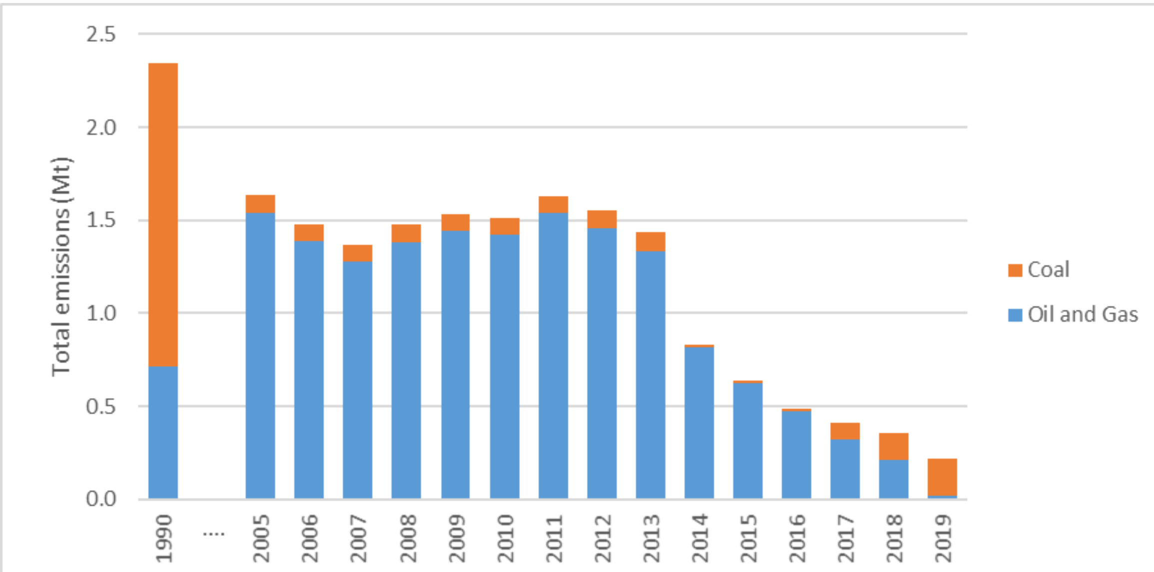


Figure 11: Oil, Gas, and Coal emissions 1990 and 2005-2019

In 1990, the major emissions source in this group were fugitive emissions from coal mining (1.6 Mt) and refining (0.7 Mt). By 2005, with limited coal production, the major emissions sources were the offshore natural gas plays (0.4 Mt) and the Dartmouth refinery (1.1 Mt). The closure of the refinery in 2013 caused emissions to drop by about 40% from 2013 to 2014. Emissions continued to decline with the shuttering of offshore natural gas production in 2018.

In 2012, Shell and BP were awarded offshore exploration licenses by CNSOPB. Despite the promises of offshore wealth, exploration has all but ceased with BP giving up half of its acreage and Shell surrendering its licenses in December 2017.[17] In January 2020, BP was granted a one-year extension to its license; this license was extended again until 2022, another firm deadline.

The reopening of the Donkin mine for the export of coking coal was responsible for the growing volume of emissions from coal production (0.2 Mt in 2019). However, repeated roof falls caused the mine to be shut in March 2020.[18] Although coal demand is projected to increase in many countries (not only in Asia, but the EU and the U.S., despite growing concerns over environmental, social, and governance issues), nothing has been said publicly to suggest the mine will reopen.

[17] Laura Wright, CNSOPB, Personal communication, 9 July 21. For map of current licenses, see here.

[18] According to Kameron, the owners of the mine, the roof falls meant mine was simply idling the project for an indeterminant period, in part because of the pandemic. However, news reports suggest that the closure is permanent.

Other than limited emissions from natural gas distribution (about 0.005 Mt in 2019), we assume that emissions will continue to decline in the Oil, Gas & Coal group over the next decade.

The projected 5%, 10%, and 15% declines for 2030 are summarized in Table 17. If emissions were to remain unchanged from 2019, they would be 0.222 Mt, although with a 15% decline, they would fall by 0.033 Mt to 0.189 Mt. These declines could be an underestimation if the all extractive energy industries in the province are shuttered by 2030; this would leave only emissions from natural gas pipelines (about 0.010 Mt) as the sole source of emissions in Oil, Gas & Coal.

Table 17: Summary of emissions decline in Oil, Gas & Coal by 2030

	BAU	5%	10%	15%
Total	0.222	0.211	0.200	0.189
Reduction		-0.011	-0.022	-0.033

This could change if Pieridae's long-promised liquefied natural gas (LNG) production train for Goldboro begins operation in the mid-2020s to produce LNG for Germany, as its projected emissions are about 3.7 Mt. In May 2021, Pieridae proposed setting up a carbon capture and storage facility in Alberta to offset these emissions, although questions remain as to the feasibility of these measures. At the end of June 2021, Pieridae put the project on hold pending a final investment decision.

4.4.4 Other

The "Other" group refers to the province's emissions sources with less than one megatonne of emissions in 2005: Heavy Industry; Waste; Agriculture; and Light Manufacturing, Construction and Forest Resources. Except for Agriculture on-farm fuel use, emissions in these sectors are from non-energy sources. As previously discussed, emissions from the consumption of electricity are the responsibility of Nova Scotia Power, not the end-user.

Between 2005 and 2019, all categories except Light Manufacturing, Construction and Forest Resources (LM, C & F) experienced a decline in emissions (see Figure 12). Some of the declines in Waste and Agriculture are due in part to changes in management practices, others reflect changes in the province's economy, with an ongoing decline in Heavy Industry.

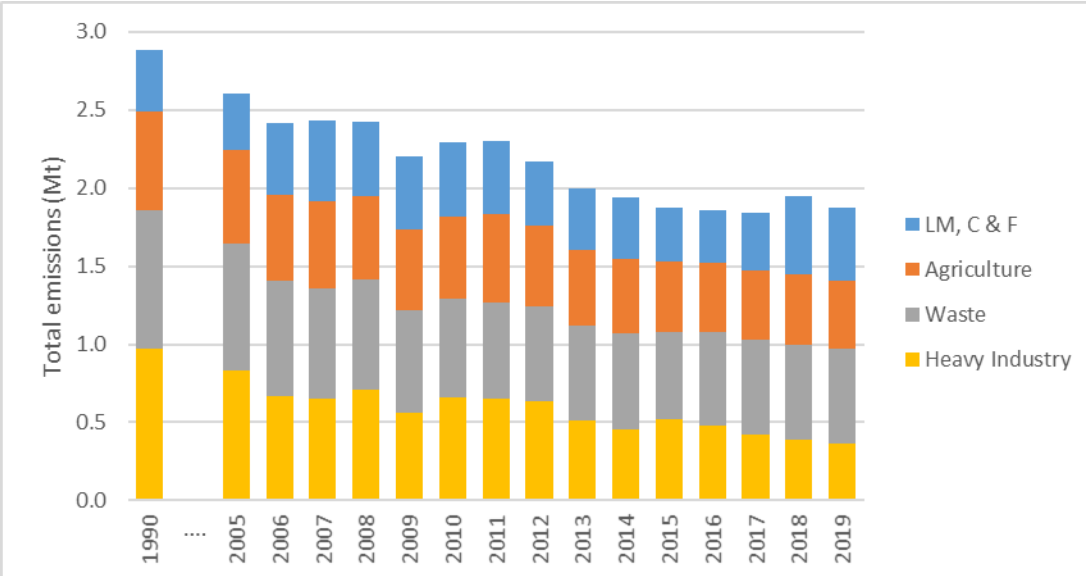


Figure 12: "Other" group emissions 1990 and 2005-2019

Between 2005 and 2019, we find:

Heavy Industry: Emissions in this sector fell by over 56% between 2005 and 2019, reflecting the changes in Nova Scotia's economy, with the decline in mining, pulp and paper, and chemicals and fertilizers. The decline in Heavy Industry emissions can be attributed to actions such as *replacing* carbon-intensive liquid fuels with natural gas and *restructuring* by using electricity rather than a carbon-intensive fuel for an industrial process), or simply the shuttering of some manufacturing facilities.

Waste: Emissions fell by 25% between 2005 and 2019, due in part to changes in how waste is handled. Zero emissions from waste seems unlikely as long as we have municipal solid waste landfills, wood waste landfills, sewage sludge, and municipal solid waste composting.

Agriculture: Agricultural emissions declined by 27% between 2005 and 2019 (0.597 Mt to 0.434 Mt). Farm fuel use (separate from Transportation) was responsible for about 0.1 Mt of the decline, with emissions from animals responsible for the remainder. Crop-related emissions were stable. During the same period, agricultural GDP increased by 20% in the province with crops, rather than animals, responsible for the increase.

The federal 2030 emissions plan expects agricultural emissions to remain constant between now and 2030, in part because of new measures to reduce methane (CH_4) from manure and nitrous oxide (N_2O) from fertilizers.

Light Manufacturing, Construction and Forest Resources (LM, C & F): Between 2005 and 2019, Light Manufacturing and Construction increased their emissions by about 0.11 Mt, reflecting the growth in post-industrial and service industries. Emissions from forest resources are related to the decomposition of woody biomass.

Summary

Possible changes in emissions in the Others category by 2030 are shown in Table 18. If emissions were to decline 15% by 2030, emissions would fall by 0.281 Mt, from 1.874 Mt in 2019 to 1.592 in 2030. Such a significant decline seems unlikely in some of these sources (such as Waste and Agriculture), while in others, such as Heavy Industry, it seems possible, given changes to Nova Scotia's economy.

Table 18: Summary of emissions decline by source in 2030

Source	BAU	5%	10%	15%
Heavy Industry	0.362	0.344	0.326	0.308
Agriculture	0.434	0.412	0.391	0.369
Waste	0.610	0.580	0.549	0.519
LM, C & F	0.468	0.444	0.421	0.398
Total	1.874	1.780	1.686	1.592
Change		-0.094	-0.187	-0.281

4.5 Discussion and Summary

In this section we examined possible changes in emissions between 2019 and 2030 in the five emissions category: Electricity; Transportation; Buildings; Oil, Gas, and Coal; and Other. We showed that to meet the province's 53% reduction target, either:

- The Atlantic Loop is completed by 2030, thereby allowing Nova Scotia Power to reduce its emissions from about 6.8 Mt in 2019 to about 0.5 Mt in 2030. By doing so, the province can achieve its 2030 emissions target of 53% below 2005 levels, provided all other emitting sectors increase their emissions by no more than 0.8 Mt.
- Non-NSP emitters reduce their emissions if the Atlantic Loop is not completed by 2030. We considered two cases, the required reductions if Nova Scotia Power could only meet its median reduction scenario and its high reduction scenario. In the median scenario, non-NSP emitters would need to reduce their emissions by 1.2 Mt, and in the high scenario, non-NSP emitters would need to reduce their emissions by 2.6 Mt.

Table 19 is a summary of four emissions scenarios for emitters other than Nova Scotia Power in 2030. It shows results from Business As Usual (which assumes no change from 2019 levels in any source other than LDGT and LDGV, leading to a slight increase in emissions) to a 15% reduction by every source.

The reductions range from the possible (-5%) to the overly optimistic (-15%):

- The lack of a comprehensive transportation strategy means that most of the reductions in the Transportation category are due to a natural decline in LDGV ownership rather than policy. Decarbonizing programs (such as electrifying part of Halifax Transit's bus fleet and Nova Scotia Power's fast chargers) are dependent on federal funding.
- There is often confusion over the reduction of emissions in the Buildings category. Decarbonizing a building requires the building to restructure (i.e., oil furnace to electric heat

pump); decoupling through replacement (i.e., incandescent bulb to LED) reduces the building's electricity demand but it does not decarbonize the building.[19]

If restructuring leads to replacing a high emissions source such as oil with a low emissions source such as natural gas (or even natural gas mixed with hydrogen), emissions will decline, but not as much as had a non-emitting source been chosen. Moreover, it then locks the building into using that source for the life of the heating equipment.

- The outlook is somewhat mixed for Oil, Gas, & Coal. With the shuttering of offshore natural gas projects and exploration slowly drying up, emissions will continue to decline. However, emissions could increase if coal mining was to resume (an unlikely event), there was increased interest in natural gas leading to more fugitive emissions of methane, or Pieridae was to go ahead with its planned LNG export facility (the outcome of the provincial election will determine the likelihood of this event occurring).
- Emissions from the Other category will probably be dominated by declines in Heavy Industry and Forestry, depending on the demand for new infrastructure requiring products such as concrete and lumber, although as was discussed, there are ways to reduce emissions in these sectors. Methane escaping from the waste stream will remain an ongoing issue, although the federal government (in conjunction with the United States), is pushing to reduce these emissions.

Table 19: Summary of emissions reduction scenarios for non-NSP emitters by 2030

Source	Change in emissions (Mt)				Threats to reduction
	BAU	-5%	-10%	-15%	
Transportation	0.011	-0.280	-0.571	-0.861	Uptake of EVs and ETs is slower than needed
Buildings	0.000	-0.102	-0.204	-0.306	Slow uptake in changing from emissions-intensive fuels to non-emitting fuels
Oil, Gas, & Coal	0.000	-0.011	-0.022	-0.033	Offshore discovery, resumption of coal extraction, increase in demand for natural gas, or building of LNG plant
Other	0.000	-0.094	-0.187	-0.281	Increased building increases LM, C & F Methane and other gases increase Waste emissions
Total	0.011	-0.487	-0.984	-1.481	

If Nova Scotia Power fails to meet its 2030 low-emissions target, reductions will be required from the non-NSP emitters. If Nova Scotia Power meets its median-emissions target in 2030, a reduction of 15% by the non-NSP emitters would ensure the province's 53% reduction target.

However, if Nova Scotia Power can only achieve its high-emissions target, none of the scenarios discussed in this section offer any hope of the province reaching its 53% reduction target.

[19] Laying claim to any reduction in Nova Scotia Power's emissions will become increasingly difficult as Nova Scotia Power continues to decarbonize.

Whether or not you agree with the results shown in Table 19, the fact remains, basing an emissions target on hope rather than evidence-based policy makes little sense, especially given the need to make significant reductions in emissions.

5 2050 – Net zero[20]

The 2019 Environmental Goals and Sustainable Prosperity Act requires that Nova Scotia achieve net-zero emissions by 2050. Since there is no specific emissions target, the province faces the prospect of purchasing emissions sinks to achieve net-zero.

This section explains net zero, describes number of the types of emissions sinks, and the need for Nova Scotia to know its emissions sinks, institute protocols to maintain existing sinks, and develop new emissions sinks.

5.1 Net zero

A jurisdiction's total emissions are the sum of its actual emissions from all emissions sources and any emissions sinks it may claim (typically a combination of changes in land use or forestry, or both, technologies for carbon capture and storage or use, and emissions credits purchased in emissions trading systems):

$$Total\ Emissions = Emissions\ sources - Emissions\ sinks$$

When a jurisdiction reaches its net-zero target date, it will be in one of three states, determined by its total emissions:

$Total\ emissions\ = 0$: In this state, the jurisdiction's emissions sources are offset by its emissions sinks and the jurisdiction has achieved net-zero emissions.

$Total\ emissions\ < 0$: The jurisdiction is a net sink; after removing its own emissions, it still has "sink space" to remove additional emissions. The jurisdiction could, for example, use the space to attract industries from emissions intensive jurisdictions or sell the space as emissions credits to jurisdictions that are net emitters (see below). (As with the Covid-19 vaccines, there would always be the danger of jurisdictions hoarding emissions credits to force up the market price.)

$Total\ emissions > 0$: The jurisdiction's emissions sources exceed its sinks, making it a net source. If a jurisdiction in this state is required to achieve net zero, it should aim to maximize its decoupling and decarbonizing efforts before the net-zero target date. Since the total emissions exceed zero, it will be necessary to obtain emissions credits from jurisdictions that are net sinks. Such purchases will need to be made until the jurisdiction finds other, lower-cost sinks.

Achieving zero-emissions this way could be a costly exercise if there is a significant global demand for the carbon-removal process, as there may well be, given the number of regions and countries pledging to attain net-zero by 2050.

[20] This section was written by Mark McCoy and Larry Hughes.

5.2 Emissions sinks

Emissions sinks can be divided into biological and technological.[21] In either case, the sink is required to remove heat trapping gases (primarily carbon dioxide) from the atmosphere and store or sequester it for an indefinite period.

Biological sinks are those activities that use or enhance biological processes to sequester carbon. Examples include the management and preservation of grasslands, wetlands, and forestland. Activities such as restoring wetlands, reforesting existing forestland, and afforesting long-term non-forested land can also contribute to the removal of carbon from the atmosphere. Carbon removal is not limited to terrestrial sinks; coastal blue carbon approaches refer to land-use and management practices that increase the carbon stored in certain marine and coastal ecosystems.

Climate change is a threat to biological sinks. For example, forest fires and extreme weather events, such as hurricanes, can affect forests, while prolonged drought can affect grasslands, wetlands, and forestlands.

Technological sinks are intended to capture and remove carbon, either before or after it has been emitted and then store it on or under land or in the ocean.

Some examples of technological sinks are biomass energy with carbon capture and sequestration (BECCS) and direct air capture (DAC) in conjunction with carbon sequestration in geological formations (CSGF).

BECCS operates as both a biological sink and a technological sink. The general process of BECCS is that carbon is first captured from the atmosphere into growing plants, the plant matter is used in bioenergy power plants, and resulting CO_2 is captured and stored in geological formations.

DAC is a purely technological sink which only captures CO_2 and does not store it; that job is given to CSGF. There are two methods of capturing CO_2 with DAC (both of which require air to be pulled into a DAC system): using chemical reactions to capture CO_2 from pulled in air and then release it for storage; and using CO_2-adsorbing material to capture CO_2 from pulled in air and then releasing it using heat or a vacuum for storage.

CSGF is a component of the carbon capture and sequestration (CCS) process for both DAC and BECCS. Captured CO_2 must be prepared for storage by being compressed. It will then be ready to be pumped into a suitable geological formation. A crucial component of CSGF is finding the right characteristics of a geological formation that allows for the safe and secure sequestration of CO_2, such as type of rocks, their locations, and depth. Examples of potential storage sites are

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[21] The UNFCCC Common Reporting Format (CRF) divides a jurisdiction's emissions inventories (both sources and sinks) into Total Energy, Total Industrial Processes, Total Solvent and Other Product Use, Total Agriculture, Total Land-Use Categories, Total Waste (UNFCCC 2006, 74). While most of the categories are sources, Total Land-Use Categories can be referred to as LULUCF (Land Use, Land-Use Change, and Forestry) and refer to practices that can change forest land, cropland, grassland, wetlands, settlements, and harvested wood products from a source to a sink or vice versa.

depleted oil or natural gas reservoirs and deep saline aquifers, either onshore or offshore. CSGF is used in enhanced oil/gas recovery projects to increase oil or natural gas extraction while also sequestering CO_2.

Another sink option is carbon capture, utilization, and storage (CCUS). CCUS technologies are those which are involved in the CCS process with the option to use the captured CO_2 for various applications where it can be stored. Two examples of CCUS technologies are CSGF for enhanced oil/gas recovery, which was mentioned previously, and the storage of CO_2 in concrete.

Jurisdictions without access to either biological or technological sinks which intend to achieve net zero by a specific date will need to purchase sinks (that is, pay for someone else's sink). It behoves them to get their emissions as low as possible.

5.3 Nova Scotia and its sinks

In November 2020, the federal government brought forward legislation for achieving its 2030 and 2050 targets, 30% below 2005 levels and net-zero, respectively. About half of Canada's 2030 target is projected to be met because of Covid-19 and by the federal government redefining LULUCF (Land Use, Land Use Change, and Forestry) to include it in the total national emissions.[22]

At present, Canada's National Inventory Reports do not include LULUCF in national, provincial, or territorial summaries. However, British Columbia has its own LULUCF inventory, independent of the federal government for its internal emissions inventory.

Three potential sinks included in LULUCF accounting are forests, croplands, and wetlands. Nova Scotia's forests, croplands, and wetlands will be examined below. Additionally, Nova Scotia's carbon storage potential will be discussed.

5.3.1 Forests

According to the 2019 update of the provincial ecological landscape analysis (ELA) reports for Nova Scotia's eco districts, the total area of Nova Scotia's forests is roughly 4.3 Mha (found by summing each ecoregion's forest area provided in the ELA report). Using the ELA data, it was determined that forests constituted approximately 78.3% of Nova Scotia's land area in 2019, thus making forests Nova Scotia's largest carbon sink by land area.

The average CO_2 flux (i.e., change in CO_2 emissions) of Nova Scotia's forests was approximately -9.38 MtCO2/y between 2013 and 2017.[23] The data used to determine this value were collected from permanent forest sample plots (PSPs) in the province. The PSP-based estimations show only change in carbon stocks between measurement periods. Therefore, if a given plot is harvested, it is assumed that all emissions associated with the harvested wood products are emitted entirely at harvest, which will lead to an overestimation of emissions from harvested wood products that store carbon for a longer period as they decompose.

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[22] Prior to this, Canada has, like other countries, omitted LULUCF from its national totals. However, to achieve the 2030 and 2050 targets, the federal government has

[23] J. Steenberg (NS Department of Lands and Forestry), personal communications, 26 July 2021.

Additionally, forests and PSPs were stratified by eco region and it is therefore assumed that the sample plots share the same carbon capture characteristics of a given ecoregion. Moreover, emissions from dead organic matter only include coarse woody debris and standing dead trees (i.e., snags) and not litter, fine woody debris, dead tree roots, or soils, which will lead to an underestimation of emissions from forests due to the decomposition of these dead organic matter pools. The total net removal of carbon from forests and harvested wood products is likely overestimated by the PSP-based data.

5.3.2 Croplands

In 2011, the area of cropland in Nova Scotia was 280,889 acres (or 113,674 ha), and the area decreased by 4.8% to approximately 267,406 acres (or 108,218 ha) in 2016. When comparing this value to the total area of Nova Scotia calculated from the data in the ELA reports, cropland constituted approximately 1.96% of Nova Scotia's land area in 2016.

Due to insufficient data available about the ability of Nova Scotia's croplands to absorb or emit carbon, a coarse estimate was made. The most specific data provided regarding the carbon capture ability for cropland is the LULUCF data for the Atlantic Maritime Ecozone (AME), which is that the cropland for this region released approximately 541 ktCO_2e in 2019. This value was scaled down linearly from the cropland data of the AME to the cropland data for Nova Scotia by using the ratio of the area of Nova Scotia to the area of the AME.[24]

The result of this calculation is that Nova Scotia's croplands were a source of approximately 145 ktCO_2e/y rather than a sink in 2019. Due to the coarseness of this estimate, it does not provide an accurate indication of Nova Scotia's croplands sink; therefore, work must be done to produce an accurate estimate. Since it is relatively small in comparison to other sinks and sources, this inaccuracy does not have a significant impact on Nova Scotia's total carbon sinks. Currently, there is no incentive for cropland owners to focus on carbon sequestration on their cropland.[25]

5.3.3 Wetlands

According to the 2019 update of the provincial ELA reports for Nova Scotia's eco districts, the total area of Nova Scotia's wetlands is roughly 383 kha (found by summing the wetland areas provided in the ELA report for each ecoregion). Using the ELA data, it was determined that wetlands constituted approximately 6.9% of the land area of Nova Scotia in 2019; this makes the wetlands Nova Scotia's second largest carbon sink by land area.

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[24] Source: ESTR Secretariat. 2014. Atlantic Maritime Ecozone+ evidence for key findings summary. Canadian Biodiversity: Ecosystem Status and Trends 2010, Evidence for Key Findings Summary Report No. 3. Canadian Councils of Resource Ministers. Ottawa, ON. ix + 100 p. https://biodivcanada.chm-cbd.net/sites/ca/files/2018-02/EN_AtlanticMaritime_EKFS_FINAL_2014-05-07.pdf. The area information reproduced in the calculations is a copy of an official work that is published by the Government of Canada and the reproduction has not been produced in affiliation with or with the endorsement of the Government of Canada.

[25] Derek Lynch (Dalhousie University), personal communication, June 30, 2021

A study of Nova Scotia wetlands examined 55 wetlands consisting of five kinds of wetland across the province during summer of 2017. One portion of the study was to determine the GHG flux from Nova Scotia's wetlands and it was determined that the wetlands emit an average of 1.46 tCO_2e/ha/y as methane and capture 6.45 tCO_2e/ha/y, resulting in an average net capture of 4.99 tCO_2e/ha/y. Assuming that the net capture rate per hectare in 2019 was the same as in 2017, the area of wetlands and this rate were used to determine that the wetlands were a sink of approximately 1.91 $MtCO_2e$/y for 2019.

5.3.4 Geological Sequestration of Carbon

While geological sequestration does not include the capture of CO_2 and as such is not technically a sink, it is important to discuss it as the sequestration sites make up Nova Scotia's "natural" carbon storage capacity for captured anthropogenic carbon.

Nova Scotia has the potential to be an important location for CO_2 sequestration due to the geology of the region.[26] While work is being done to estimate the CO_2 sequestration potential in and around Nova Scotia,[27] an estimate can be made for the potential sites that are known, namely the depleted offshore oil and gas fields, if some assumptions are made.

The volumes of oil or gas that were extracted from the Sable Offshore Energy Project, the Deep Panuke Offshore Gas Development Project, and the Cohaset-Panuke Project were approximately 60 billion m^3, 4.2 billion m^3, and 7.1 million m^3,[28] each. Assuming that the volume that can be injected into the depleted reservoirs is equivalent to the volume that was extracted, that the density of supercritical CO_2 being injected into the reservoirs is 600 kg/m^3, and that the reservoirs can retain supercritical CO_2, the potential CO_2 storage capacity of Nova Scotia's depleted offshore oil/gas fields is approximately 38.5 $GtCO_2$. Given that Canada's total anthropogenic GHG emissions were 730 Mt in 2019, Nova Scotia could theoretically store 50 years of Canada's emissions.

One concern for direct air capture (DAC) in conjunction with carbon sequestration in geological formations (CSGF) is the potential for carbon leakage. Carbon leakage may happen anywhere in the CCS process, such as in the capture, transportation, and storage of CO_2. Reasonable questions can be asked like "Does a DAC system capture 100% of the CO_2 fed into it?", "Could pipelines or other methods carrying CO_2 leak?", and "Are the storage sites secure enough to contain CO_2 for potentially thousands of years?". These leakages could have severe environmental impacts if not considered and accounted for in the development of CCS technologies. Any leakage would undo the efforts taken to sequester the carbon, so long-term monitoring of potential leaks is necessary.

[26] Grant Wach (Dalhousie University), personal communication, June 23, 2021

[27] Grant Wach (Dalhousie University), personal communication, July 5, 2021

[28] Source: https://www.cnsopb.ns.ca/offshore-activity//legacy-production-projects/cohasset-panuke

5.4 Summary

While Nova Scotia appears to have significant sink capabilities in relation to its emissions, it is important to remember that today's biological emissions sinks are at risk from tomorrow's worsening climate.

Ideally, Nova Scotia will be an emissions-sink as opposed to an emissions-source, as this could allow it to profit from the sales of its "negative emissions". Given the potential storage capacity for CO_2 in Nova Scotia, storage space could also be sold to other regions. However, without a long term, net-zero policy based on a detailed inventory of the province's existing and potential future carbon sinks, as is being done in other jurisdictions, achieving net-zero could potentially be an expensive endeavour and a missed opportunity.

6 Analysis and Discussion

This report examined the three emissions goals specified in Nova Scotia's *Environmental Goals and Sustainable Prosperity Act* of 2019 for 2020, 2030, and 2050. The findings are summarized as follows:

- It is extremely likely that the province's 2020 target (10% below 1990 levels) will be met because Nova Scotia Power reduced its reliance on coal for the first three quarters of 2020 due to delays in the completion of the Muskrat Falls project and Covid-19, which affected electricity demand and likely the demand for liquid fuels for transportation. Had these events not occurred, the likelihood of achieving the target would still have been high as power from Muskrat Falls would have resulted in a decline in coal consumption. Since Nova Scotia Power's emissions declined in 2019, it is unlikely that the province's emissions will exceed the 2020 target in 2019.
- The 2030 target (53% below 2005 levels) relies on the completion of the Atlantic Loop making power from Hydro Quebec available to the Maritime Provinces. If this occurs, it is highly likely that Nova Scotia Power's emissions will meet one of its best-case scenarios with emissions declining to well below a megatonne.

  However, if the Atlantic Loop is not completed by 2030, sectors other than Electricity, notably Transportation and Buildings, will also need to make reductions. As the report showed, even in the unlikely event that 15% of light duty vehicles and light duty trucks are electrified by 2030, meeting the 2030 could be a challenge if Nova Scotia Power does not meet its best-case scenario.

  Additional reductions in Buildings through decoupling (reducing electricity use by replacing baseboard heaters with heat pumps) could help reduce Nova Scotia Power's emissions, and decarbonizing (changing from an emissions-intensive heating fuel to electricity) would reduce the building's emissions, although it would increase Nova Scotia Power's emissions.

  This will require reductions in the remaining two sectors, Oil & Gas and Other, neither of which are major emissions sources.

  Since we do not know whether the Atlantic Loop will be completed by 2030, the province should develop policies that prepare for the eventuality that it will not be completed on time.
- Declaring that the province will achieve net-zero by 2050 is a convenient way of "kicking the can down the road" while appearing to do something. The challenge facing Nova Scotia will be finding possible net sinks and using these to determine its maximum emissions sources for 2050. Failure to identify, and possibly develop, sinks could prove costly to the province if it must purchase technology or emissions credits, or both. Nova Scotia stands to gain if it can develop its sinks for storing emissions from other jurisdictions.

Of the three sectors with more than one megatonne of emissions in 2018 (Electricity, Transportation, and Buildings), only Electricity has specific targets (Nova Scotia Power's emissions cap and renewables requirements), while Buildings and Transportation are subject to a minimal carbon price on emissions intensive fuels (based on the province's weak, although federally approved, cap-and-trade system).

In the Buildings sector, there are incentives to reduce emissions through decoupling and decarbonizing. Grants are available for low-income households to decouple by improving the building envelope and to decarbonize by restructuring their heating system, moving from oil to electric heating. Rebates on energy efficient appliances are also available; however, since these are decoupling measures, they reduce energy demand but do not reduce emissions in the Building sector, any reduction takes place in the Electricity sector.

Emissions reduction policies targeting Nova Scotia's transportation sector appear to be intended to minimize the impact on the driving public. This might be a deliberate policy decision, recognizing Nova Scotia's weak economy, the considerable number of non-urban dwellers, low household incomes, and the limited availability of low-cost electric vehicles. However, the province has funded the installation of a limited number of Electric Vehicle Charging Stations (or EVCS), while the federal government, through Nova Scotia Power, has funded both publicly accessible EVCS and a limited number of EVCS for individual homeowners.

Finally, the *Environmental Goals and Sustainable Prosperity Act*, describes two goals, one for 2030 (emissions are to be at least 53% below the levels that were emitted in 2005) and the other for 2050 (emissions will be at net zero, by balancing greenhouse gas emissions with greenhouse gas removals and other offsetting measures).

If these goals are not met, who is responsible?

7 Recommendations

From the analysis and discussion of Nova Scotia's emissions goals for 2020, 2030, and 2050, we make the following recommendations for the province to follow to meet its emissions goals:

1. *Conduct a biannual inventory of the province's quantifiable and verifiable biological carbon sinks and continue to search for potential geological carbon storage sites that are quantifiable and verifiable.*
   - Identify each sink's threats and vulnerabilities, and the likelihood of the threat events occurring.
   - Develop protocols to reduce each sink's vulnerability and, if possible, its threats over both the short and long term.
   - These sinks would be used to set the limits on the province's 2050 emissions sources.
   - Locate potential geological storage sites and quantify their potential storage capacity for carbon.
2. *Monitor the progress of the Atlantic Loop (for the 2030 goal).*
   - Failure to complete the Atlantic Loop by 2030 will require other sectors to make significant cuts in their emissions. By monitoring the progress of the Atlantic Loop, the province will know whether it will be completed on time and what other actions are required in other sectors.
3. *Focus on electric vehicle infrastructure rather than subsidizing electric vehicles.*
   - One of the limiting factors of electric vehicle uptake is the availability of EVCS. Subsidizing a few electric vehicles will help a few people, whereas increasing the number of EVCS has the potential to help large numbers of people.
   - If electric vehicles must be subsidized, then the target audience should be those on low-income rather than high-income earners.
4. *Introduce emissions targets for 2035, 2040, 2045, and 2050 (for the 2050 goal).*
   - These should be sector-specific and adjusted over time as knowledge of the province's emissions sinks becomes better understood and the existing and potential causes of changes to a sector's emissions are identified.
   - Given the need to reduce emissions, a four-year emissions-target interval could be introduced to adjust the targets more frequently than in the five-year interval as new information come to light.
5. *Adopt the recently modified federal carbon-pricing system or develop a provincial carbon-pricing system based on the federal backstop for emitters under 50,000 tonnes per year.*
   - The price of carbon would be adjusted over time, reflecting the changes required to meet the province's emission targets in the short-term and the province's 2050 target in the long term.

- As with the federal backstop, rebates would be income adjusted (for low- and middle-income households and small businesses) and paid quarterly.
- The quarterly payments would be adjusted for season, with larger payments during the heating season, and location, with higher payments to households and businesses in rural communities to address transportation costs.

6. *Apply an Output-Based Pricing System to industries emitting over 50,000 tonnes of CO2e per year.*

- Participants in the cap-and-trade program will include all entities that were previously regulated under the province's Quantification, Reporting and Verification regulations.
- A biannual annual cap should be designed to let industrial emitters adjust their emissions over time.

7. *Unallocated revenues collected from the carbon levy (emitters < 50,000 t) and the OBPS (emitters > 50,000 t) should fund programs to maintain and enhance the province's carbon sinks.*

- Maintaining and enhancing emissions sinks should not be supported from general revenues; instead, the cost of the sinks should be covered by the revenues generated from the emissions sources.

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Ms. Laura Wright, CNSOPB

1 November 2021

The Honourable Brad Johns
Chair, Law Amendments
Province House
1726 Hollis Street
Halifax

Dear Mr. Johns,

I would like to have the following considered as part of my submission to today's Law Amendments hearings regarding Bill 57 - Environmental Goals and Climate Change Reduction Act:

Clause 7:

(a) to complete and release a Province-wide climate change risk assessment by December 31, 2022, an update by December 31, 2025, and an update every five years thereafter.

The Act should specify what is to be addressed in the *climate change risk assessment*, is it to focus on adaptation (for example, sea level rise or building retrofits) or mitigation (for example, the status of the Atlantic Loop or the state of the province's natural emissions sinks).

Clause 7:

(f) to require any new build or major retrofit in government buildings, including schools and hospitals, that enters the planning stage after 2022, to be *net-zero energy performance* and *climate resilient*;

(g) to encourage landlords who currently lease office space to Government to transition existing office space to meet *net-zero energy performance*;

(h) to prioritize leased office accommodations in buildings that are *climate resilient* and meet *net-zero energy performance* starting in 2030;

The Act should specify in Clause 2 what the government means by *net-zero energy performance* and *climate resilient*, as is done with other terms used in the Act.

Clause 7:

(j) to develop and implement a zero-emission vehicle mandate that ensures, at a minimum, that 30% of new vehicle sales of all light duty and personal vehicles in the Province will be zero-emission vehicles by 2030;

(k) to develop and implement supporting initiatives for the goal in clause (j);

The Act should include provisions that specify a percentage of all zero-emissions vehicles will be made available to low-income Nova Scotians (7j).

It should also specify that the province will increase the number of public Level 3 charging stations across the province (7k).

Clause 7:

(l) to have 80% of electricity in the Province supplied by renewable energy by 2030.

(m) to phase out coal-fired electricity generation in the Province by the year 2030.

These two sections require the completion of the Atlantic Loop. The Act should direct the government to lobby the federal government and get other provinces on-side for the estimated $5 billion it will take to complete the project.

Clause 6:

(b) by 2050, to be net zero, by balancing greenhouse gas emissions with greenhouse gas removals and other offsetting measures.

The province's net-zero plans as outlined in the Act are woefully inadequate. Quite simply, without sufficient natural sinks, the province will be forced to purchase emissions credits from other jurisdictions, a potentially costly exercise. The Act should include a new clause specific to 2050, keeping in mind that we must continue reducing emissions after 2050 (net zero or better) and if we do not achieve net zero by 2050, the province could be required to purchase (expensive) emissions credits and be prepared for the loss of its biological sinks that are at risk from extreme climate events. To this end the province must:

a) *Conduct a complete and accurate publicly accessible biannual assessment of the province's greenhouse gas (GHG) fluxes of the biological sinks (such as forests, croplands, wetlands, and seagrass meadows)*.
b) *Publish a publicly-accessible biannual report which measures, reports, and verifies the carbon-related impacts of the threats to Nova Scotia's biological sinks and conduct an economic and carbon flux assessment of the potential solutions to reducing the threats and vulnerabilities of the sinks*.
c) *Establish interim emissions reduction targets between 2030 and 2050*.
d) *Ensure that emissions are reduced beyond 2050*.
e) *Introduce tax incentives for carbon captured in natural sinks to promote the maintenance of our efforts to increase their carbon capture ability*.
f) *Support the research and development of its geological storage capacity for carbon-sequestration*.

If you or committee have any questions regarding the above, please feel free to contact me at larry.hughes@dal.ca.

Sincerely,

Larry Hughes, PhD