Assessing Net-Zero Electricity Supply and Demand Models in the Atlantic Loop

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The work of moving forward with low-carbon solutions in Nova Scotia take place on unceded, unsurrendered Mi'kmaw territory that is governed by the "Treaties of Peace and Friendship". All work toward the transition to a net-zero future on this land must take place in the spirit of these treaties and in collaboration with the Mi'kmaq of Nova Scotia, and with the free, prior and informed consent of Mi'kmaw communities.

Summary and Conclusions

The phasing out of coal-fired generation is one of the few decarbonization opportunities that have already delivered significant reductions in greenhouse gas emissions across multiple jurisdictions. A portfolio of technically feasible and economically acceptable generation sources has made the transition away from high emitting coal-fired power easier. The ability of Alberta to rapidly reduce the amount of coal in its generation mix caught many by surprise starting in 2017, where carbon pricing and incentives for new renewables coupled with a long-term regulatory ban on coal-fired generation led to a rapid switch away from coal. The Ontario experience about a decade ago further highlights the feasibility of transitioning away from high emitting coal in the generation mix.

But there are technical and economic challenges with such energy transitions, with concerns over reliability and cost impacts front and centre for many utilities. But with the drive to net-zero, and signals from the federal government that uncontrolled fossil generation will not be permitted much past 2030, utilities clearly need to explore alternatives to fossil generation out to mid-century.

Given the reliance in both Nova Scotia and New Brunswick on coal-fired power, there is clearly a need to assess alternative options to reduce the grid intensity and drive emissions down to mere kilotonnes by mid-century. EnviroEconomics and Navius Research conducted new analysis and modelling of alternative electricity supply options for the Atlantic region within a broader context of a net-zero economy-wide energy transition. We use two models to first assess end-use energy demand across both economies as Canada transitions to net-zero, and then use the predicted end-use electricity demand in each province to run a regionally integrated dispatch model. Various technology, energy, emissions, and cost outcomes are predicted under alternative net-zero and Atlantic Loop scenarios out to 2050.

With coal-fired generation to be phased out before 2030 in New Brunswick and Nova Scotia, new supply will clearly be needed to meet that reduction in generation. Concurrently, a net-zero transition will require more fuel switching to electrification, increasing electricity's share of total energy significantly. Our simulations suggests that the combination of growing economies, the coal-phase out, and increased electrification under net-zero will mean a lot of new generation will be needed. But how to meet that demand?

While generation from new renewable sources within each of the provinces is important to meeting future generation mixes, the modelling suggests that Atlantic Loop scenarios that supply low emitting hydro from Newfoundland or Quebec are important to meeting future demand. Several uncertainties, however, suggest that a balanced approach to the supply mix is likely the prudent path forward.

First, the assumed costs in the model are uncertain, which would flip the results in favor of a more renewable intensive generation mix in each province. Notable cost uncertainties include the cost of Atlantic Loop scenarios, which could be underestimated as is typically the case, while renewable costs might continue a trend of falling faster than anticipated. Second, future supply out of Quebec and Newfoundland and Labrador to feed into the Atlantic Loop may be a question given competition for such low emitting generation in the United States and Ontario. Finally, our analysis suggests renewable generation paired with storage could be a total game changer, flipping the analysis on its head.

We conclude a portfolio approach that includes developing more domestic renewable generation while exploring Atlantic Loop opportunities is a prudent approach to meeting future electricity needs under a net-zero, and fossil free future.

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1 Report Overview

The Ecology Action Centre asked EnviroEconomics and Navius Research to assess 2050 net-zero electricity pathways for the Atlantic region, with a focus on Nova Scotia and New Brunswick. The project employed a mix of modelling and analysis to highlight how electricity demand and supply might evolve under alternative net-zero scenarios in the Atlantic region. The analysis provides a view on what decarbonized electrification looks like in Atlantic Canada, factoring in interconnected transmission systems and electricity trade. The report provides differing views of integrated planning opportunities for the region.

The project conducted detailed energy demand and electricity supply modelling of various net-zero and Atlantic Loop scenarios. On the energy demand side, a national energy and economic model assessed the impact on energy end-uses of a high electrification net-zero by 2050 scenario. This approach provided an integrated national view of how each Canadian province or territory might evolve its energy system in response to policy aligned with achieving net-zero emission by 2050. All major energy end-uses and energy carriers were assessed, including electrification. A key output from this scenario analysis was a projection of electricity load demand under net-zero in the Atlantic provinces, aggregated across end-use demand from the penetration of low carbon technology, including for example, heat pumps, electric vehicles, electrified process heat, and energy efficiency improvements.

To assess the generation mix that might emerge under net-zero, end-use load demand from the net-zero scenario was fed into a regionally disaggregated electricity supply model to assess alternative Atlantic Loop scenarios. The supply model has provincial resolution, including electricity trade within Canada and with the United States.

The report presents the results of the two separate but linked modelling exercises. Results explore emissions pathways, the generation mix, electricity trade, price impacts, and household energy costs from both the energy demand and electricity supply models with a focus on New Brunswick and Nova Scotia. In addition to this introductory section, the remainder of this report includes 5 sections:

- Section 2 discusses the two models used in the analysis.
- Section 3 discusses the Atlantic Loop scenarios assessed.
- Section 4 provides economy-wide results for a scenario that hits a greenhouse gas target of 42% below 2005 levels in 2030 and then net-zero emissions by 2050. The end-use electricity demand profile from the economy-wide energy and economic model is then loaded into a regionally explicit electricity model.
- Section 5 explores the electricity generation outcomes of the high electrification net-zero scenario as well as several Atlantic Loop scenarios.
- Section 6 explores the deployment of select end-use electrification technologies that emerge from the economy-wide net-zero scenario analysis.

2 Overview of the Modelling Approach

Two separate yet linked models were used to estimate net-zero electricity demand and supply balances for the Atlantic region under various Atlantic loop scenarios:

1. Simulate a high-electrification net-zero by 2050 energy pathway for Canada to estimate end-use electricity demand in the Atlantic Provinces.
2. Send end-use load demand to a regionally explicit dispatch model to determine supply that meets net-zero demand.

Each modelling element is discussed below.

1. **Simulate a high-electrification net-zero by 2050 energy pathway for Canada.** Economy-wide carbon mitigation policy is first simulated that achieves emission and energy pathways consistent with net-zero by 2050. The Navius research gTech model simulates the economy-wide evolution of economic, technology, energy, and emissions pathways under various market and policy assumptions. The gTech model provides a comprehensive representation of all economic activity, energy consumption, and greenhouse gas emissions in Canada. All the Atlantic provinces are represented as individual yet integrated economies, with the model data calibrated to historical trade, energy supply and demand, and macroeconomic structure.

   gTech provides insight into future electricity load demand in response to a broad combination of existing and/or new policies that directly or indirectly affect electricity supply and demand as well as cost and efficiency of electrification technologies relative to alternative options.

   After a model simulation in gTech is complete, and energy systems are realigned with the net-zero pathway, the resulting electricity consumption by end-use is compiled and used to "shape" an electricity consumption load curve. For example, if a policy increases the adoption of electric heat pumps, it will affect electricity consumption at specific times and days of the year.

   The gTech model is ideally suited for forecasting electricity demand because it represents:

   - **The competitiveness of electric technologies relative to conventional and low carbon alternatives.** This competitiveness depends not only on the attributes of end-use technologies themselves (such as their capital cost and operating performance), but also on the availability and price of electricity and other energy carriers (which will change based on the amount of electrification, the unique energy resources in each province, and energy trade among regions).
   - **Firm and consumer preferences**. Electric technologies may be perceived as an imperfect substitute for existing technologies. For example, a given household may prefer a conventional vehicle over an electric vehicle because of its lower upfront cost and greater model variety. In addition, some preferences may change as a technology gains market share. For example, if electric vehicles become widespread and fast charging stations are broadly deployed, concerns about running out of a battery charge would decline.
   - **The impact of existing federal and provincial climate policies on technology choice (including how they interact)**. Accounting for existing policies is important because

electrification is highly affected by their interactive and duplicative effects. For example, electric vehicle adoption is influenced by Zero-Emission Vehicles (ZEV) mandates, financial incentives, clean/low carbon fuel standards, fuel economy regulations, and carbon pricing.

- **Energy efficiency is an important decarbonization driver.** While demand side management programs are not explicitly modelled in the net-zero simulations, energy efficiency nevertheless is a big driver of emission reductions. In response to higher carbon costs under a net-zero emissions pathway to 2050, high efficiency equipment is widely deployed in the simulations.

2. **Send end-use load demand to a regionally explicit dispatch model to determine the generation mix and electricity trade to meet net-zero demand.** The second model used Navius's Integrated Electricity Supply and Demand (IESD) model, which is a regionally explicit electricity supply model that simulates electricity supply markets and how they respond to different demand scenarios. The model simulates capacity investment and hourly dispatch decisions in the electricity sector as well as the decisions by end-users that affect electricity demand.

   IESD is effectively two separate models – one that simulates capacity and hourly dispatch decisions in the electricity sector and another that simulates investment in electricity consuming technologies. For each simulated year, the supply and demand models run iteratively until they converge. This process is repeated over multiple years to show the long-term impact of capacity additions (supply model) and technology choices (demand model).

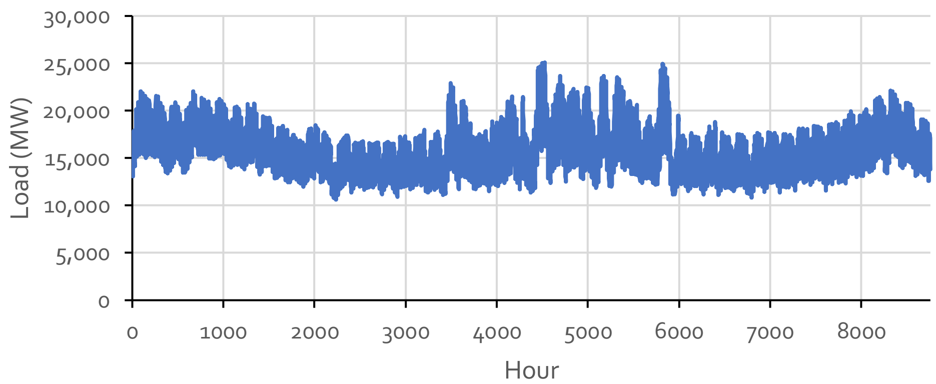
   Navius obtained hourly load data for all jurisdictions in North America (over 200 utilities). These data provide a starting point for understanding how load varies over the course of 2010, the model's base year. An example of Ontario's hourly load profile in 2010 is shown in Figure 1.

   The electricity demand model in IESD disaggregates the hourly load curves into seven end-uses based on data from Natural Resources Canada's Comprehensive Energy End-Use Database. The end-uses for residential and commercial buildings include:

   - Space heating, air conditioning, and lighting.
   - Other multi-fuel end-uses (water heating, cooking, clothes dryers).
   - Other electric-only end-uses (refrigerators, freezers, dishwashers, clothes washers, computers, televisions, etc.).

   The model also represents industrial electric loads. However, they are represented in less detail. Industrial load is not broken down by end-use (e.g., compression, pumping, etc.) and we assume it is a base load that is relatively constant over every hour of the year.

Figure 1: Hourly load profile for Ontario in 2010



Source: Independent Electricity System Operator, 2017, Hourly Ontario and Market Demands, 2002-2016, available from: www.ieso.ca

3 The Atlantic Loop Scenarios

As discussed above, the economy-wide gTech model was used to simulate a national high electrification net-zero emissions pathway to 2050. Two scenarios were modelled using gTech: a **reference case and a high electrification net-zero scenario** (see table below). With the end-use electricity demand established from the economy-wide modelling, the electricity supply model was used to meet that demand. A reference case and six **net-zero plus Atlantic Loop** scenarios were modelled:

Scenario	Economy-wide (gTech)	Electricity Supply (IESD)
Reference Case	√	√
High electrification net-zero by 2050	√	√
Net-zero plus nuclear phase-out		√
Net-zero plus regional coordination under two financing options		√
Net-zero plus Maritime Link 2 under two financing options		√

Each scenario is discussed below.

Reference case. This case includes many of the current provincial and federal carbon mitigation policies already in place. Policies simulated in the Reference Case include low carbon fuel regulations, carbon pricing as implemented to 2022 (with the price held constant in nominal terms thereafter) through a fuel charge and large emitter output based pricing, and renewable fuel mandates. New GHG policy announced in the Strengthened Climate Plan (SPC) will amend what is outlined in the Greenhouse Gas Pollution Pricing Act (GGPPA) effective April 1, 2023. We do not include in the Reference Case, policies in the SPC as stated government policy, as many policies are not yet legislated, notably a carbon price above $50 per tonne.

Scenario 1: High electrification net-zero by 2050 (Hi-Elec-NZ). Canada implements sufficient policy to achieve a 40-45% reduction in GHGs in 2030 and net-zero by 2050. The modelled scenario achieves national emissions that are 42% below 2005 in 2030 while gross emissions in 2050 are 100 megatonnes (Mt), assuming these remnant net-zero emissions are reduced through carbon removal, inducing nature-based solutions and direct air capture.

Policies modelled that result in a high electrification net-zero energy system include:

- A carbon price that emerges from a hard cap on emissions aligned with the 2030 target and net-zero by 2050 with tradeable allowances.
- Large industrial emitters under an output-based pricing system where the average cost of the carbon price is a fraction of the marginal carbon price.
- Emissions cap on electricity production from emitting sources starting in 2030.
- A net-zero building standard for new buildings after 2030.
- A regulatory ban on fossil heat sources in new buildings starting in 2025.
- A strengthened renewable fuel standard starting in 2025.
- ZEV mandates for new light-duty, medium-duty, and heavy-duty vehicles starting in 2030.
- A ban on process heat from fossil fuel in industry starting in 2030.
- Carbon Capture & Storage (CCS) mandated wherever possible starting in 2030.
- Renewable Natural Gas mandate starting in 2030.
- Methane regulations with a 50% reduction against 2010.

Scenario 2: Net-zero plus nuclear phase-out (NZ + Retire Nukes). The planned phase-out of the Point Lepreau Nuclear Generating Station by 2040 is added to the policy package in Scenario 1.

Scenario 3a and b: Atlantic Loop 1 to New Brunswick: Net-zero plus regional coordination under two financing options (NZ + Large Hydro). A 1,000 MW line is built from Newfoundland and Labrador, wheeled through Quebec and entering New Brunswick. A 500 MW line is built for exchange between New Brunswick and Nova Scotia. Indicative costs include $1.6B in capital cost for transmission backbone upgrades between Nova Scotia and New Brunswick under two financing assumptions (low: 2% financed over 50 years; high: 7% financed over 30 years), and a range of delivered energy costs of $50 to $80 per MWh; any required transmission upgrades to the Quebec transmission system would either be incremental or would need to be included in the delivered energy cost.

Scenario 4: Atlantic Loop 2 to Nova Scotia: Net-zero plus Maritime Link 2 under two financing options (NZ + MLK 2). A 250 MW line, or Maritime Line 2, is built between Newfoundland and Labrador and Nova Scotia. Indicative costs include $1B in capital cost for 250MW undersea transmission cable between Nova Scotia and Newfoundland and Labrador under a range of financing assumptions (low: 2% financed over 50 years; high: 7% financed over 30 years), and a range of delivered energy costs of $50 to $80 per MWh.

The next section discusses the economy-wide modelling results for the high electrification scenario, compared against the reference case.

4 End-Use Electrification Results: Economy-wide Net-zero Outcomes

This section explores the results of the economy-wide modelling for the first two scenarios: the reference case, and the High electrification net-zero pathway. Five sets of indicators explore the emissions pathway to net-zero – impacts on GDP, the role of electricity in the economy, investment in low carbon technology, and household energy costs.

Section 6 provides details on the deployment of end-use technologies in the scenarios.

4.1 Emission Pathways to Net-zero

The net-zero emissions pathway shows a rapid decline in province-wide emissions starting almost immediately in the simulations. The provincial emission pathways fall out of the model reflecting the cost-effective contribution of each province to a national trajectory that hits the 2030 target of 42% below 2005 levels in 2030 and 100 megatonnes (Mt) of gross emissions in 2050. A notable feature of both provinces is that the reference case emissions rapidly decline at annual rates of 2 to 3%, which is well above historical levels and is related primarily to phasing out coal fired electricity in both provinces (Figure 4). Still, the net-zero pathway reinforces this trend significantly:

- In **Nova Scotia**, emissions reductions in the net-zero case before 2030 are 7% annually, or more than double the annual decline rate of 3% in the reference case (Figure 2 and Figure 4). The annual decline rate after 2030 is 7.5%, which is more than three times faster than the reference case projection. Emissions are about halved in 2030 from the reference level and down to about 1 Mt by 2050.
- In **New Brunswick**, the annual rate of emissions decline in net-zero more than doubles before 2030 from reference levels, rising to 6.3% from 2.5%. After 2030 on an annualized basis, the annual decline rate is 15% relative to the reference case of 0.25%. This drastic difference highlights a long term decarbonization possibility in the economy with emissions falling from current levels of about 12 Mt down to hundreds of kilotonnes (kt) by 2050 (Figure 3).

Figure 2: Nova Scotia Emissions Pathway

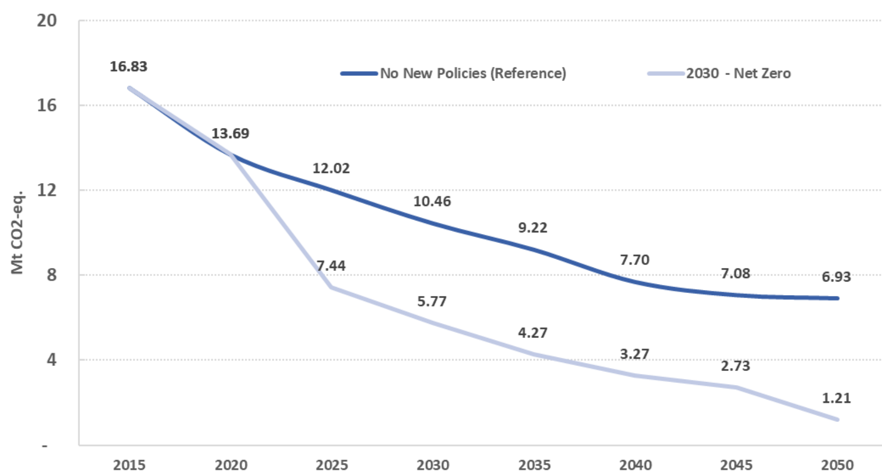


Figure 3: New Brunswick Emissions Pathway

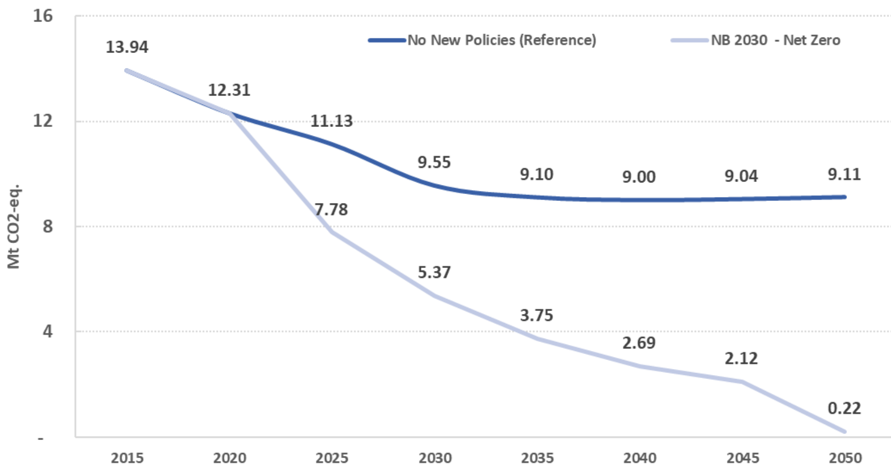
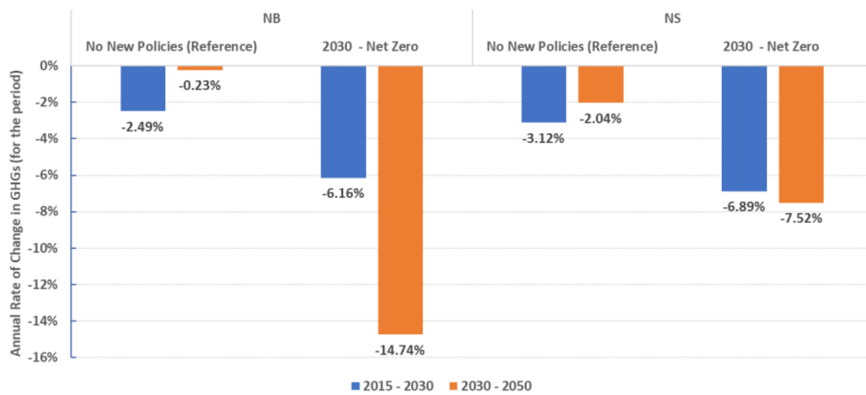


Figure 4: Annual Change in Emissions to Net-zero Pathway



4.2 Economic Activity

This section provides estimates of the change in sectoral and provincial Gross Domestic Product (GDP), with the simulations suggesting that both provincial economies expand under the net-zero scenario above 2020 levels. In the simulations, the emissions reduction trajectory is quite aggressive, which does result in slowed growth relative to reference levels, especially before 2030 where stranded assets raise overall costs, yet the results are not uniform with some sectors showing strong growth:

- In **Nova Scotia**, economic growth essentially flat lines out to 2030 while the electricity sector more than doubles its contribution to GDP (Figure 5). Services remain mostly unaffected while the paper sector continues a downward trend that is accelerated in the net-zero scenario. Over the long-term under the net-zero scenario, the economy grows at an annualized rate that is about half that of the reference case.
- In **New Brunswick**, there is an ongoing decline in petroleum refining GDP, but this is a trend seen in the reference case, with net-zero accelerating the decline in value (Figure 6). Electricity generation GDP grows about 50% above 2020 levels by 2030 and more than doubles to 2050 in terms of its contribution to the total economy. Long-term economic growth continues at about 60% of the rate of the reference case, with the total economy 4% larger in 2030 relative to 2020 levels.

Figure 5: Nova Scotia: Change in the size of GDP from 2020

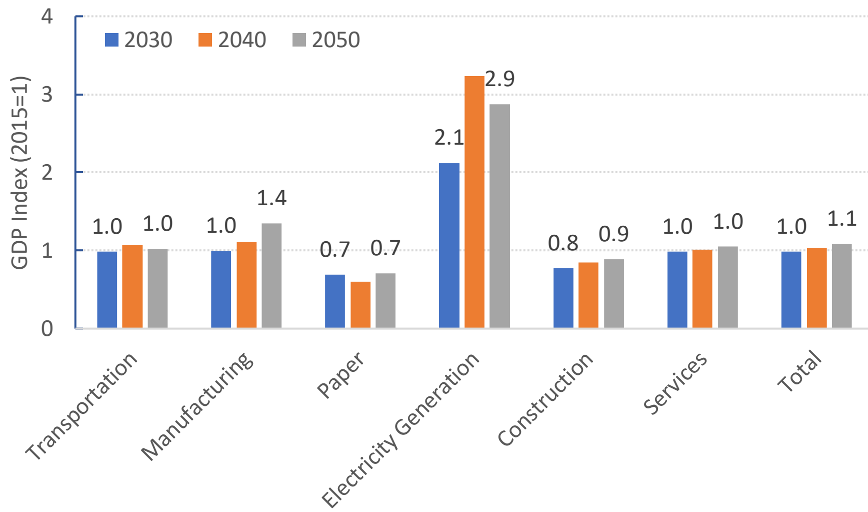
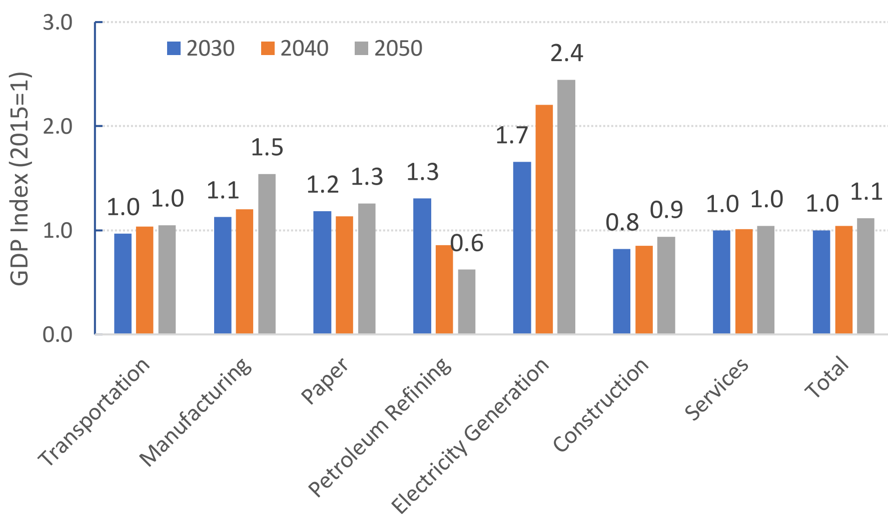


Figure 6: New Brunswick: Change in the size of GDP from 2020



4.3 Electricity in the Economy

Three indicators are presented that explore how electricity relates to total energy and GDP, all presented as an index relative to a base year of 2015 (Figure 7 and Figure 8):

- **Electricity's share of total energy** (Elec PetaJoules (PJ)/Total PJ) climbs significantly in both jurisdictions. In Nova Scotia, electricity's share of total energy nearly doubles by 2030, which corresponds to an expansion in generation of about four times the reference level. Whereas in New Brunswick, electricity's share of total energy climbs by about 60% to reach about one third of total energy. This trend continues through to 2050.
- In the latter part of the simulation, there is a drop in the intensity of electricity in total energy. In the simulations, renewable natural gas becomes economic at this point and the level of

electrification does not climb with the economy and instead renewable natural gas is used in more end-uses, including electricity generation, buildings, and industry. This finding implies that to the extent renewable natural gas can decarbonize the natural gas system and be cost-competitive with sufficient supply; it can compete in some end-uses with electrification.

- **The greenhouse gas (GHG) intensity of GDP** (GHGs/GDP) falls at about the same level in both jurisdictions. This trend reflects decarbonized electrification and fuel switching in end-uses as the economy expands. But given the trend to reduce electricity from fossil generation in the reference case, emissions per unit of GDP are not falling as rapidly as they would in some other jurisdictions like Alberta or Saskatchewan under a net-zero emissions pathway.
- **The energy intensity of GDP** (end-use energy/GDP) in both economies significantly improves over time with the move to electrification, and the associated efficiency gains of moving away from fossil generation and combustion engines. In both provinces, the economies are growing but are more productive with the energy used.

Figure 7: Nova Scotia: Electricity in the Economy

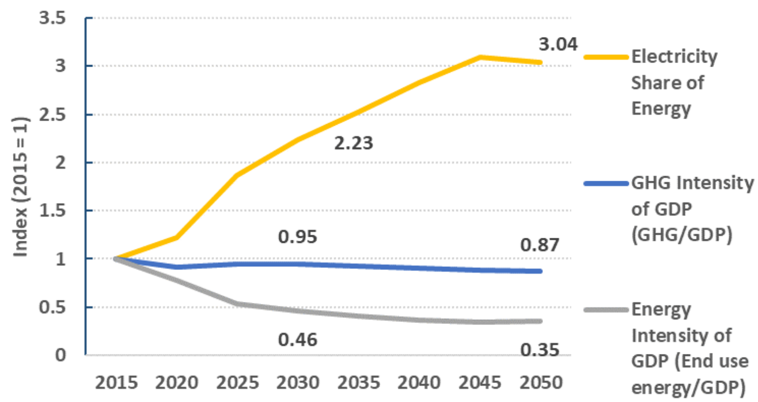
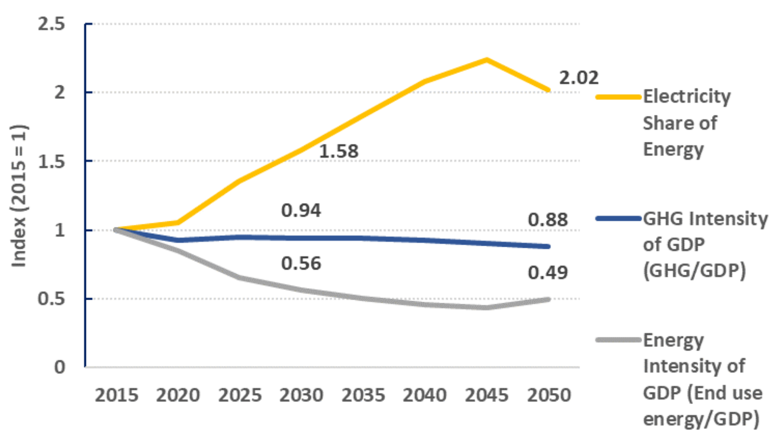


Figure 8: New Brunswick: Electricity in the Economy



4.4 Investment in Low Carbon Technology

This section explores business investment and household consumption across a number of investment categories, following a three-part taxonomy:

- Five categories of **low carbon technologies** are identified including decarbonizing fuels (energy carriers), decarbonized electricity, low carbon vehicles in businesses and households, efficiency and electrification in commercial and residential buildings, and industrial decarbonization.
- Investment and consumption for fossil energy technologies is termed **rest of energy investment.**
- **Investment unrelated to energy** is all other non-energy investment and consumption.

Two indicators are provided:

- **The total investment requirement** is the stream of total investment in the reference case and the net-zero scenarios. It is calculated as the discount sum of all expenditures in two periods, 2020 to 2030 and 2030 to 2050, calculated as the net present value assuming a discount rate of 3%.
- The **Annual increase in investment** from the reference case is also presented.

The investment levels are good indicators of where decarbonization happens in the economy and when. Given the high electrification scenario, we see decarbonized electrification investment grow significantly in both Nova Scotia and New Brunswick – more zero emitting generation and the deployment of electrified end-use technologies (Figure 9 and Figure 10). In end-uses, it is low carbon vehicles that expand the most in the period before 2030, suggesting a short-term decarbonization opportunity. Over the longer-term, renewable fuels and investments for industrial decarbonization become more important. But given the deep reductions to achieve net-zero, investment must scale up across the board.

Figure 9: Nova Scotia: Low Carbon Investment/Consumption (Net present value: $2020 Millions @ 3%)

	Reference Case ($M NPV)		Net-zero ($M NPV)		Annual change from reference	
	2020 to 2030	**2030 to 2050**	**2020 to 2030**	**2030 to 2050**	**2020 to 2030**	**2030 to 2050**
Renewable Fuels	$155	$320	$196	$821	2.4%	9.9%
Decarbonized Electricity	$2,718	$5,131	$4,076	$7,643	4.1%	4.1%
Low Carbon Vehicles	$508	$2,377	$750	$3,786	4.0%	4.8%
Building Efficiency and Electrification	$926	$1,119	$1,131	$3,409	2.0%	11.8%
Industrial Decarbonization	$46	$63	$62	$407	3.2%	20.6%
Rest of energy investment	$23,610	$22,140	$19,700	$13,237	-1.8%	-5.0%
Investment Unrelated to Energy	$315,788	$390,378	$303,053	$356,853	-0.4%	-0.9%

Figure 10: New Brunswick: Low Carbon Investment/Consumption (Net present value: $2020 Millions @ 3%)

	Reference Case (NPV)		Net-zero (NPV)		Annual change from Reference	
	2020 to 2030	2030 to 2050	2020 to 2030	2030 to 2050	2020 to 2030	2030 to 2050
Renewable Fuels	$161	$317	$210	$1,013	2.7%	12.3%
Decarbonized Electricity	$2,785	$6,148	$4,895	$11,094	5.8%	6.1%
Low Carbon Vehicles	$649	$2,351	$901	$3,690	3.3%	4.6%
Building Efficiency and Electrification	$871	$681	$1,111	$1,275	2.5%	6.5%
Industrial Decarbonization	$147	$197	$236	$759	4.8%	14.4%
Rest of energy investment	$23,243	$19,496	$19,643	$12,484	-1.7%	-4.4%
Investment/consumption unrelated to energy	$234,868	$290,260	$227,626	$271,971	-0.3%	-0.6%

4.5 Household Energy Costs

In both provinces, total household energy costs fall due to significantly improved energy efficiency associated with fuel switching to electricity and other fuel saving technologies. When assessing household energy costs, it is the total energy expenditure for the household that matters. With net-zero driving more electrification at the same time it is reducing reliance on other fossil fuels in the household budget. While electricity prices can be expected to rise as higher cost renewables and imports increase electricity supply costs, energy efficiency and cost savings through building and transportation fuel switching can more than offset the cost increase.

The indicators in the figures below focus on household energy consumption, including operating and capital spending on buildings and transportation, as a share or total household expenditures. Three income groups are presented, including low, middle, and high-income households corresponding to the lowest and highest 20% of households and the average or 50th percentile:

- In **Nova Scotia**, short-term energy costs rise marginally for the lowest income group, primarily due to rising energy costs. But over the longer-term, and especially in 2030, total energy costs for households fall as efficiency and fuel savings take hold and offset capital spending (Figure 11).
- For **New Brunswick**, energy costs fall across all income levels in the gTech economy-wide simulations under the high electrification net-zero scenario. The rapid decrease in emissions under the net-zero scenario explains the small increase in energy costs in 2025 for the middle-income group, where low emitting capital is deployed in advance of offsetting longer-term fuel savings (Figure 12).

Figure 11: Nova Scotia: Total Energy as a Share of Household Expenditures (all fuels)

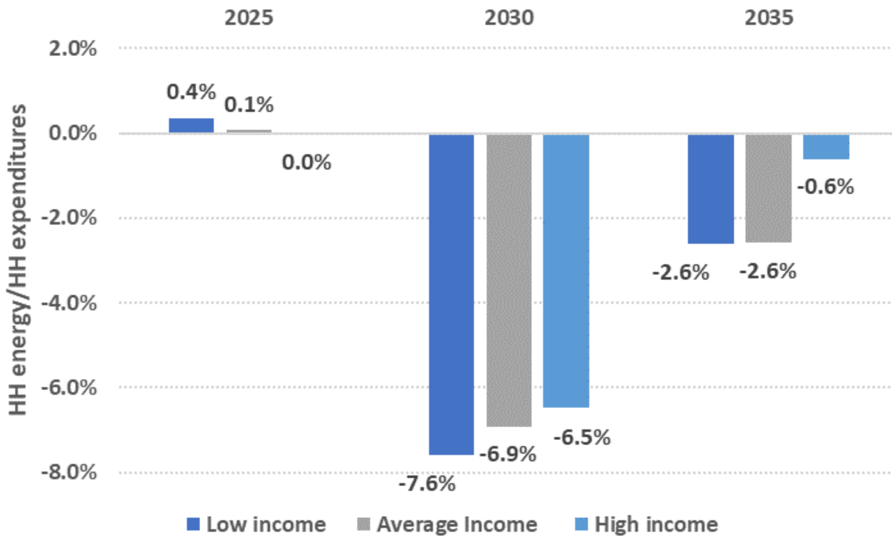
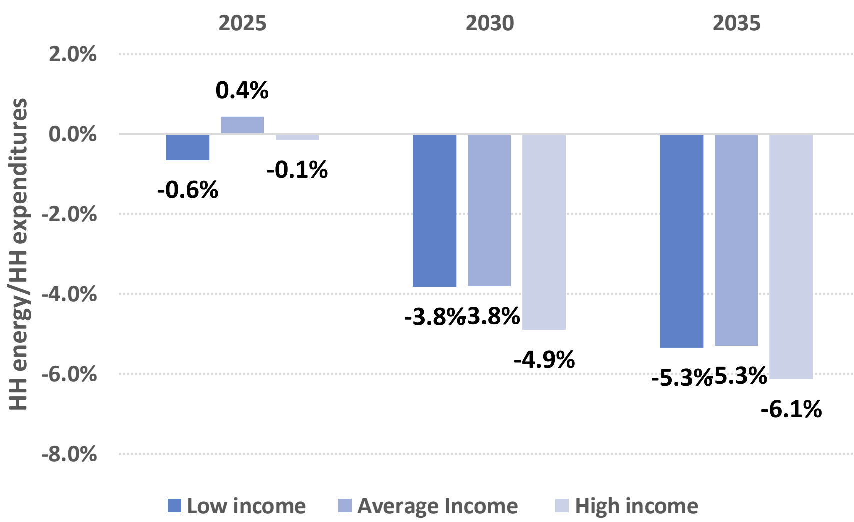


Figure 12: New Brunswick: Total Energy as a Share of Household Expenditures (all fuels)



5 Electricity Results: The Atlantic Loop and the Electricity Generation Mix

This section provides the results from the IESD dispatch model, where the load curve from the high electrification net-zero scenario is fed into IESD to determine electricity supply and demand balances. The Atlantic Loop scenarios are added to the high electrification net-zero scenario to compare electricity supply outcomes.

5.1 Nova Scotia

With the Nova Scotia government committed to achieving a coal phaseout by 2030 as well as an 80% renewable generation target, we look at the results from the perspective of the share of renewables and coal in generation.

Coal Falls of a cliff, with imports and renewables filling the supply gap. In all scenarios, the coal phaseout happens rapidly, with more stringent policy in the net-zero cases resulting in a more rapid decline in coal generation. In all scenarios, imports are an important factor for meeting domestic demand as coal is phased out, and in the scenarios where there are more interties, renewable generation is lower than the net-zero scenario without interties. Renewable generation can include a mix of domestic hydro, wind, PV, and biomass. Other fossil generation continues to supply small amounts of total demand but is important for reserve capacity.

Renewable penetration looks feasible in the range of 90% by 2030. The results indicate that there are two pathways for renewable generation to achieve the 80% target by 2030. First in the Reference case the coal phaseout is slower relative to the net-zero cases, with the acceleration towards renewable generation occurring closer to 2030 itself. Conversely in the Net-zero cases, more stringent policy in the short-term drives the rapid deployment of renewables leading to a renewable generation level exceeding the 80% target well before 2030 (Figure 14).

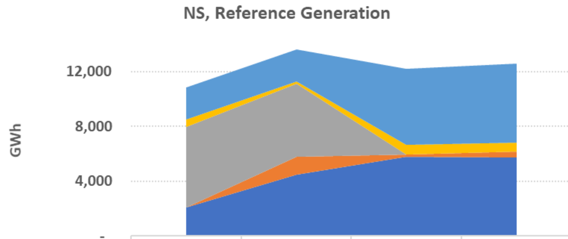
Both wind and solar compete to supply the generation with wind typically winning out most of the generation. However, sensitivity analysis indicates that the pairing of solar photovoltaics (PV) with storage can significantly increase the solar penetration. This is particularly the case in the scenarios with interties from large hydro in Quebec (NZ + large hydro) and phase 2 of the Maritime Link (NZ + MLK2).

Imports are a big part of achieving the 80% target. The coal phaseout necessitates a significant increase in firm imports (including from the Maritime Link) over historical levels, requiring almost a doubling by 2030 over 2020 levels. With the addition of the Atlantic Loop scenarios with more interties from either Quebec or Maritime Link 2, imports become even more important to supplying demand (Figure 15). Imports clearly act as a firm power back-up to the intermittent renewables that partially fill the gap left from the coal decrease.

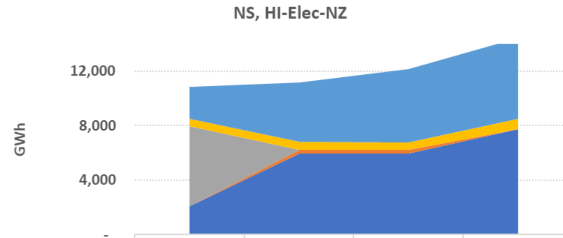
Electricity generation decarbonizes fast. If policy is implemented to phase out coal before 2030, all scenarios indicate that emissions drop very rapidly from about 6.3 megatonnes in 2020 down to just hundreds of kilotonnes by 2030 (Figure 16).

Wholesale prices rise with the coal phase-out. The net-zero case accelerates the cost increase associated with the coal phaseout and the expansion of renewables and the importation of electricity. But still, in the Reference case the price increases from the coal phaseout do catch up across the scenarios in 2030. In the longer term, the Atlantic Loop scenarios with more interties lower the overall wholesale price meaning that imports are cheaper than domestic generation at the margin. The longer assumed amortization periods and financing costs for the interties do not significantly impact the prices.

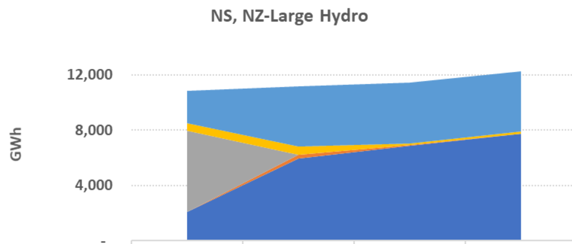
Figure 13: Generation Mix and Trade, Nova Scotia



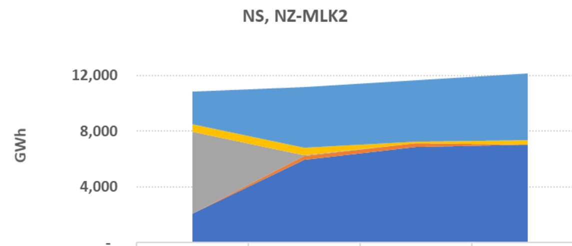
	2020	2025	2030	2035
Renewables	2,348	2,348	5,590	5,792
NG/Oil/Cogen	531	147	662	631
Coal	5,900	5,369	-	-
Exports	1	1,317	200	464
Imports	2,087	4,454	5,770	5,727



	2020	2025	2030	2035
Renewables	2,348	4,382	5,390	5,948
NG/Oil/Cogen	531	561	512	738
Coal	5,900	12	-	-
Exports	1	302	302	45
Imports	2,087	5,931	5,931	7,724



	2020	2025	2030	2035
Renewables	2,348	4,382	4,382	4,382
NG/Oil/Cogen	531	561	114	119
Coal	5,900	12	-	-
Exports	1	302	80	45
Imports	2,087	5,931	6,857	7,724



	2020	2025	2030	2035
Renewables	2,348	4,385	4,385	4,789
NG/Oil/Cogen	531	564	134	324
Coal	5,900	12	-	-
Exports	1	303	239	18
Imports	2,087	5,934	6,885	7,020

Figure 14: Share of Renewables in Nova Scotia Generation

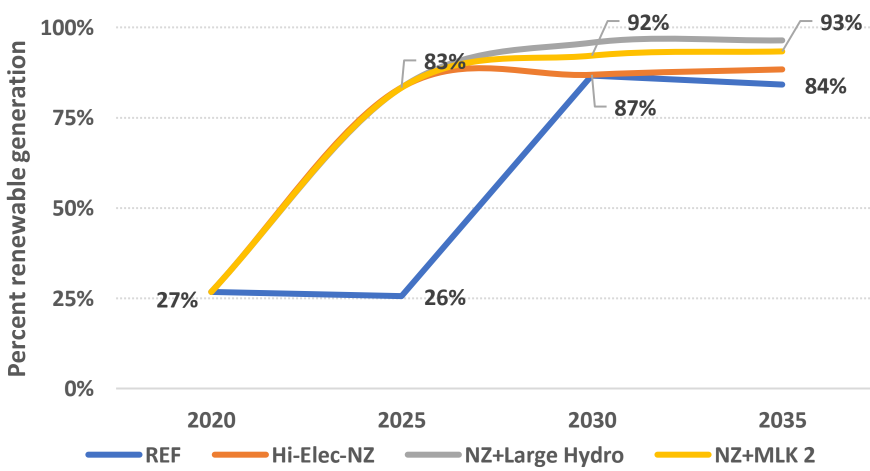


Figure 15: Share of Imports in Final Demand, Nova Scotia

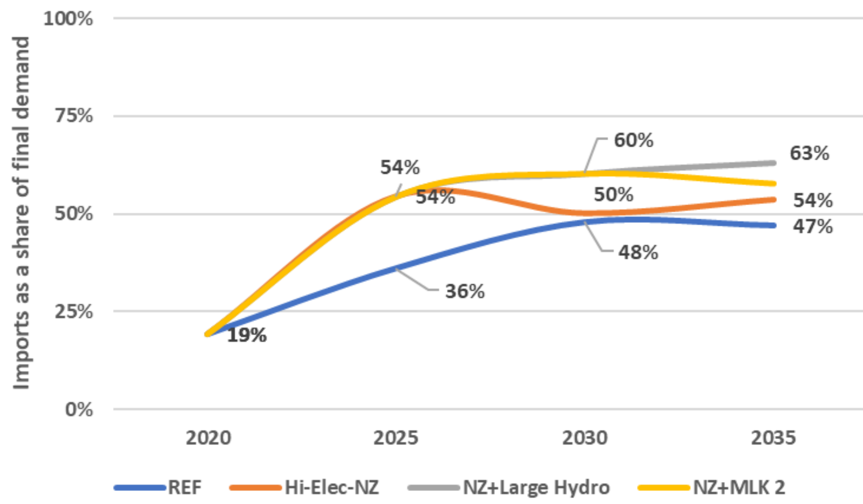


Figure 16: Electricity Sector GHGs, Nova Scotia

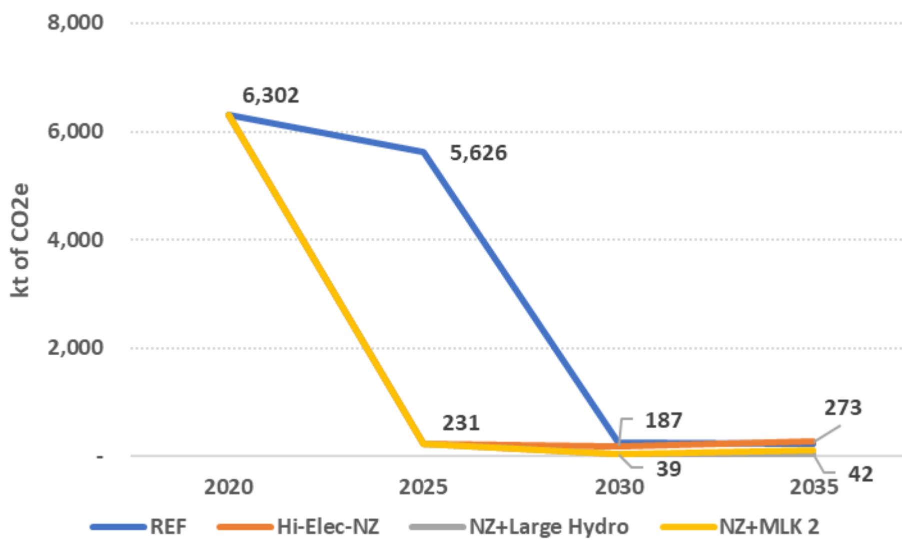
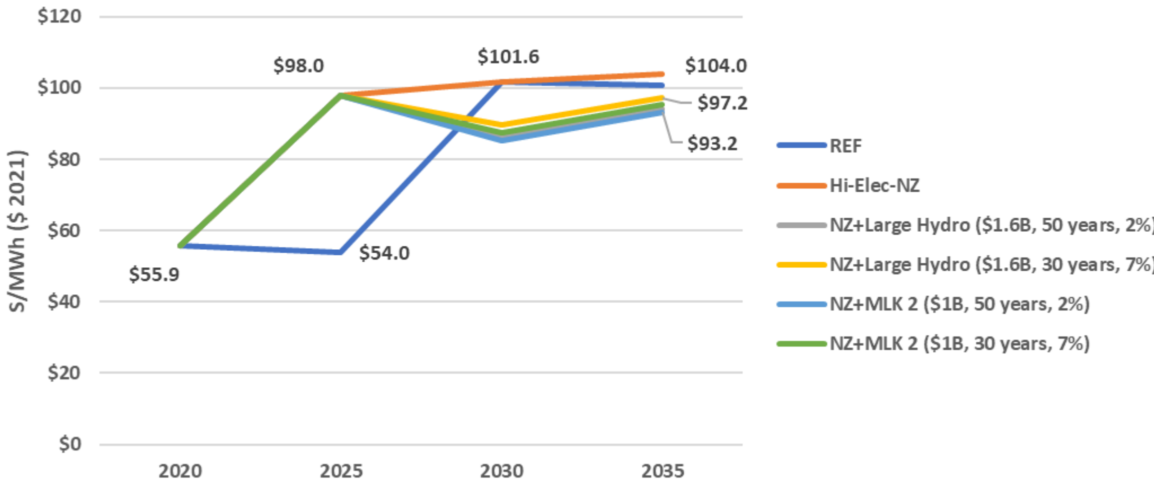


Figure 17: Wholesale Price Impact, Nova Scotia



5.2 New Brunswick

In the net-zero case, total energy falls almost 30% from the reference case while electricity's use in the economy rises slightly above reference levels. As discussed above, this downward trend in total energy use in New Brunswick implies that electricity's share of total energy rises significantly even though end use demand does not rise that much. This broader energy trend helps explain why total energy supply does not climb above reference levels. At the same time the Belledune generating station is to be phased out which then implies a significant level of supply must be met. This section uses several scenarios to explore how New Brunswick's electricity supply mix might evolve under net-zero. In most cases, it is electricity trade that makes up the difference, except in the case where the Point Lepreau Nuclear Generating Station is shuttered, and renewable generation fills the supply gap.

A final point to keep in mind is the net-zero economy-wide scenario is aggressive in terms of policy stringency to decarbonize fast. This fast net-zero transition has the impact of slowing demand for electricity and total energy across the economy. A more gradual transition with less aggressive decarbonization policy would not show such large short-term shifts in energy demand.

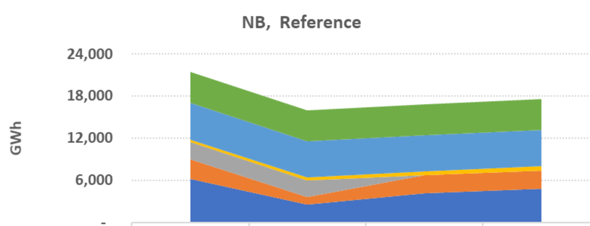
Coal's decline is import's gain. As with Nova Scotia, the coal phaseout happens in all scenarios, it is only a matter of policy stringency and timing. In the reference case, the coal phaseout takes a little longer than in the net-zero case. The simulations also suggest that decreased generation from the Belledune Generating Station is filled by imports. This happens in the reference case and the net-zero case. But the importance of trade to New Brunswick electricity supply becomes evident in the Atlantic Loop scenarios. In the scenario where New Brunswick directly imports large hydro either generated in Quebec or wheeled from Newfoundland and Labrador (NZ-Large Hydro), exports and imports are well above the reference case after 2030. In the Maritime Link 2 scenario, the quantity traded is much lower, presumably because Nova Scotia is the access point for imported hydro and wheels the power within the Atlantic Loop accordingly (Figure 19).

Renewable penetration is minimal until the nuclear phase-out in 2040. In all scenarios, the penetration of new renewables is low. On a cost basis, they simply don't compete with the price of imports in the various scenarios (Figure 20). In the longer term, out past 2035, we do however see significant renewables penetration as the policies get more stringent on the road to net-zero. This is particularly the case in the NZ-Retire Nukes scenario, where the phase-out of current nuclear generation in 2040 results in a six-to-eight-fold increase in renewable generation in the province (Figure 21).

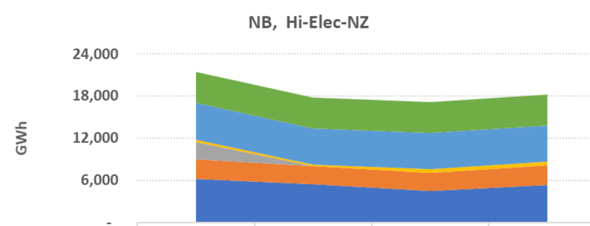
The Coal phase-out has a large and rapid impact to lower emissions. Regardless of the scenario, with policy to phase-out coal, the electricity sector GHG's are on a trajectory that is likely consistent with net-zero. Across all the scenarios, the combination of low emitting imports as well as more renewables penetration in later years in the simulation serve to keep emissions at net-zero levels. Even with the nuclear phaseout scenario, emissions don't climb significantly as renewables and more imports outcompete fossil generation to fill the supply gap (Figure 22).

Wholesale prices rise, but the nuclear phase-out has a large impact. Electricity prices in the net-zero case rise about 11% above the reference case in 2030 and stay at about that level throughout the simulation. With the addition of the large hydro scenario into New Brunswick, wholesale prices fall for a short period of time below the reference case level but then settle back into a trajectory over the longer term that is above the reference case. The assumed amortization for the cost of the Maritime Link 2 scenario is an important sensitivity on prices, with shorter amortization periods and higher prices driving up prices. Finally, the nuclear retirement scenario results in a material change in electricity prices as more renewable generation and some fossil generation is brought online within New Brunswick to meet growing supply. While we see electricity prices rise under the Atlantic Loop scenarios relative to the reference case, overall energy costs for households as a share of total expenditures fall under net-zero scenarios (See Figure 12).

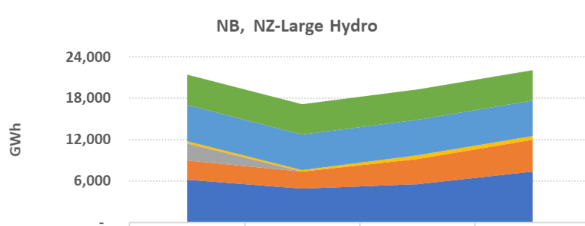
Figure 18: Generation Mix and Trade, New Brunswick



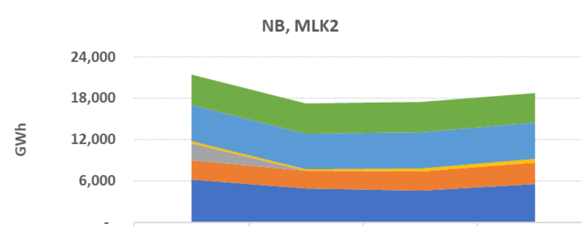
	2020	2025	2030	2035
Renewables	4,388	4,388	4,388	4,388
Nuclear	5,203	5,203	5,203	5,203
NG/Oil/Cogen	389	462	530	580
Coal	2,409	2,287	-	-
Exports	2,860	1,136	2,539	2,590
Imports	6,150	2,506	4,176	4,799



	2020	2025	2030	2035
Renewables	4,388	4,388	4,388	4,388
Nuclear	5,203	5,203	5,203	5,203
NG/Oil/Cogen	389	186	496	547
Coal	2,409	1	-	-
Exports	2,860	2,537	2,545	2,737
Imports	6,150	5,453	4,507	5,332



	2020	2025	2030	2035
Renewables	4,388	4,388	4,388	4,388
Nuclear	5,203	5,203	5,203	5,203
NG/Oil/Cogen	389	186	494	536
Coal	2,409	1	-	-
Exports	2,860	2,536	3,627	4,630
Imports	6,150	4,840	5,568	7,311



	2020	2025	2030	2035
Renewables	4,388	4,388	4,388	4,388
Nuclear	5,203	5,203	5,203	5,203
NG/Oil/Cogen	389	186	496	551
Coal	2,409	1	-	-
EX	2,860	2,582	2,782	3,106
IM	6,150	4,876	4,535	5,535

Figure 19: Change of Generation and Trade from Reference Case, New Brunswick

		Imports	Exports	NG/Oil/ Cogen	Nuclear	Coal	Renewable
Hi-Elec-NZ	2025	118%	123%	-60%			
	2030	8%	0%	-6%			
	2035	11%	6%	-6%			
NZ+Large Hydro	2025	93%	123%	-60%			
	2030	33%	43%	-7%	0%	-100%	0%
	2035	52%	79%	-8%			
NZ+MLK 2	2025	95%	127%	-60%			
	2030	9%	10%	-6%			
	2035	15%	20%	-5%			

Figure 20: Share of Renewables Generation, New Brunswick

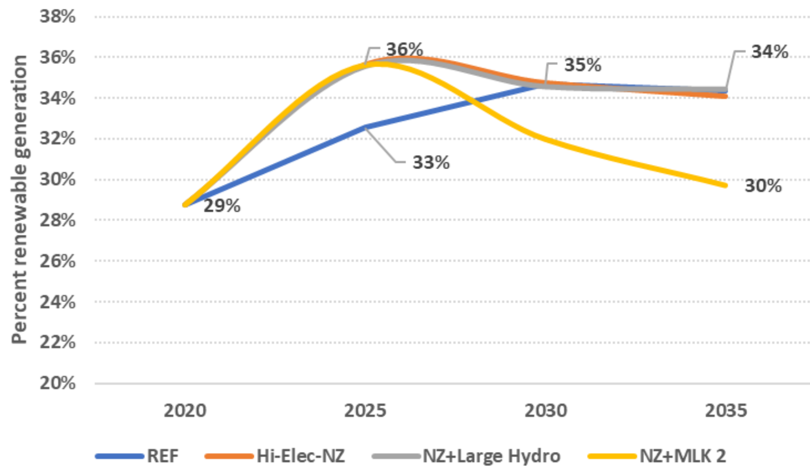


Figure 21: Impact of Nuclear Phase-out on Domestic Generation, New Brunswick

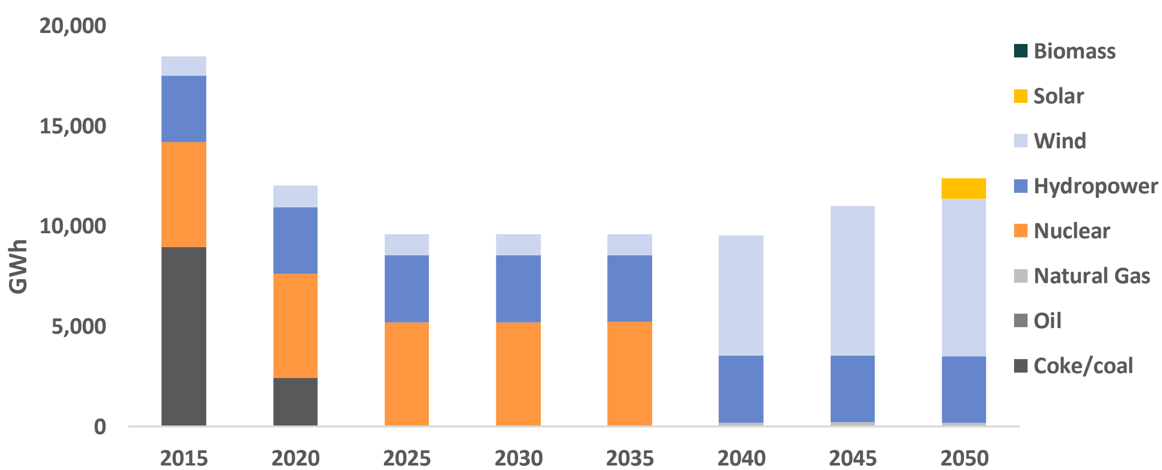


Figure 22: Electricity Sector GHGs, New Brunswick

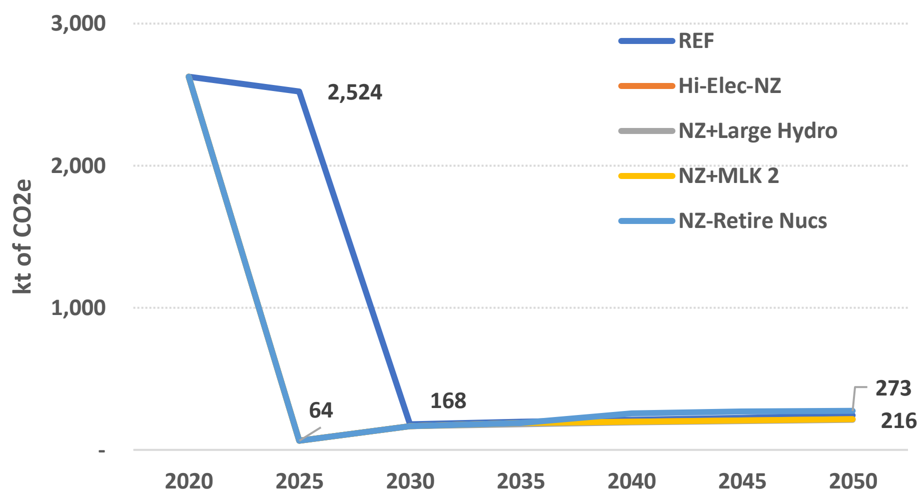
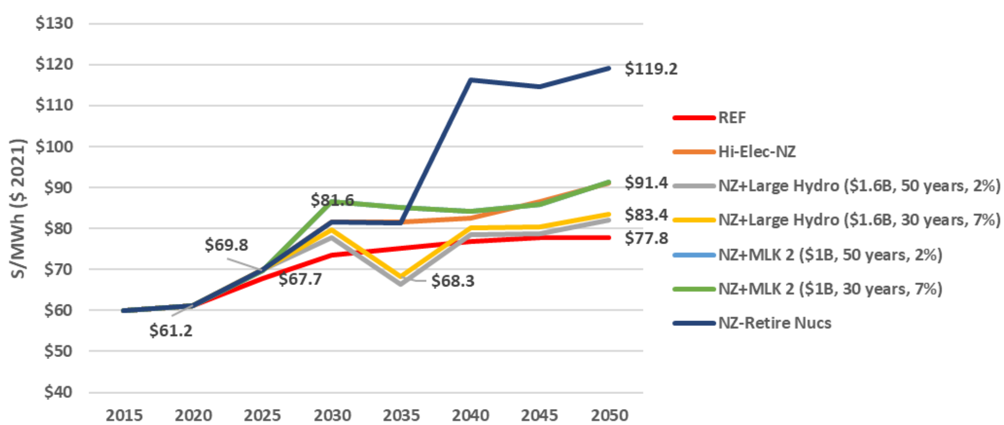


Figure 23: Wholesale Price Impact, New Brunswick



6 Atlantic Provinces: Net-zero High Electrification Pathway and End-use

To estimate the net-zero load demand used to assess the various Atlantic loop scenarios, the gTech model was first used. As presented above under Scenario 1 (high electrification net-zero by 2050), a series of net-zero policies were implemented that affect electricity demand and end-use technology choice in the simulation. Policies affect electrification in buildings, transportation, and process heat, which then determines the load forecast needed to be met in the IESD dispatch model. The section identifies changes in **end-use technology market shares** for the net-zero electrification pathway relative to the reference case for space heating, building shells, industrial process heat, and vehicles.

Net-zero policies favor technological substitution at end-uses between technologies that use carbon intensive energy and technologies that use low carbon energy such as electricity generated from nuclear electric power and hydroelectric power. New technologies such as electric vehicles and LED lightbulbs not only result in **lower greenhouse gas emissions but will lower energy output** across Atlantic Canada through electrification.

Modelling indicates an increasingly stringent net-zero policy suite rolled out to 2050 will facilitate a rapid decrease in energy consumption in Atlantic Canadian households and end-use sectors such as construction and manufacturing as electricity becomes a more economically attractive energy source for businesses and households. As demand for low carbon electricity rises, a subsequent decline in greenhouse gas emissions from electricity generation is forecast in Atlantic Canada from fossil fuel generating assets.

Space Heating in Buildings

We see significant declines in existing heating equipment types in both the reference and net-zero scenarios:

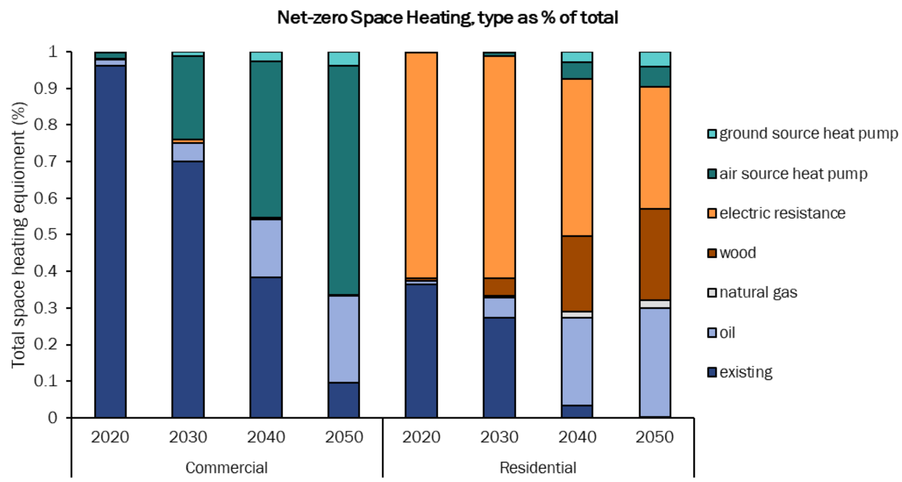
- Air source heat pumps become much more popular, and we see high penetration in the commercial sector.
- Net-zero promotes Atlantic households to switch away from oil-based space heating towards wood, electric resistance, and air source heat pumps for space heating.
- Commercial building switch away from fossil fuel-based space heating to air source heat pumps.

In **commercial buildings**, there is a shift by 2030 away from existing heating equipment to air source heat pumps. The rise in use of air source heat pumps can be attributed to declines in light fuel oil, heavy fuel, and heavy fuel oil. Shifts away from existing heating equipment in commercial buildings occurs in both the reference and net-zero scenarios.

In **residential buildings**, declines occur in existing space heating equipment fuel types such as light fuel oil. The simulation indicates more demand for electric resistance and heating equipment that uses electricity such as air source heat pumps. Shifts away from existing heating equipment in Atlantic Canada is observed in both reference and net-zero cases.

Figure 24: Change in Space Heating, Atlantic Region (Net-zero market share - Reference case share)

	Commercial				Residential			
heating equipment type	2020	2030	2040	2050	2020	2030	2040	2050
existing	0%	0.7%	1.6%	0.8%	0%	0.8%	-0.7%	0.0%
oil (more efficient)	0%	-2.6%	-6.3%	-8.5%	0%	-3.2%	-11.1%	-15.2%
natural gas (more efficient)	0%	-1.4%	-3.2%	-4.5%	0%	0.4%	1.5%	2.1%
wood	0%	0.0%	0.0%	0.0%	0%	0.8%	2.8%	0.9%
electric resistance	0%	-0.1%	-0.1%	-0.1%	0%	-0.1%	2.5%	5.4%
air source heat pump	0%	2.9%	6.8%	10.4%	0%	1.1%	3.5%	4.8%
ground source heat pump	0%	0.5%	1.2%	1.8%	0%	0.2%	1.4%	2.0%



Building Shells

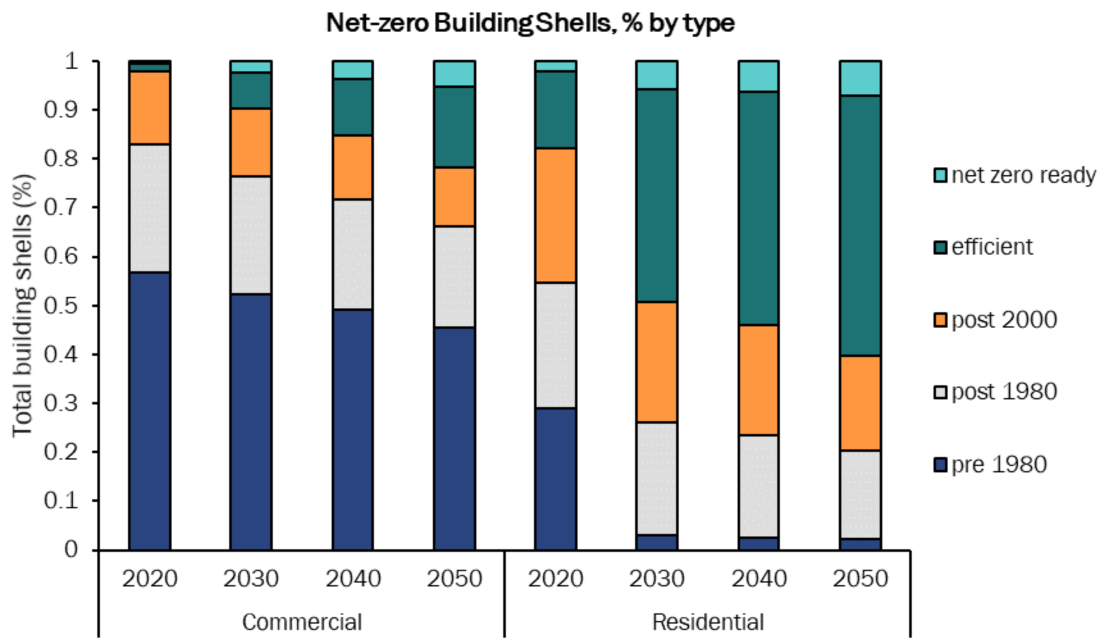
The net-zero scenario includes a zero-emission building code starting in the model year 2030, which drives a trend towards an increased proportion of highly efficient net-zero ready buildings. At the same time, older vintages of buildings are upgraded to be more efficient (Figure 25).

In the **residential sector**, net-zero residential shells start to penetrate more after 2040. Due to various other net-zero policies like carbon pricing, there is also significant upgrading of older buildings. The scenarios suggest households with pre-1980 shell types will have a higher propensity to retrofit in the net-zero scenario, whereas it is compulsory that new buildings be net-zero ready. Retrofits includes projects such as installing better insulation, energy star appliances/equipment/windows, and LED's.

A similar pattern is observed in the **commercial sector**, but with a slightly higher penetration of new net-zero ready buildings.

Figure 25: Change in Building Shells, Atlantic Region (Net-zero market share - Reference case share)

	Commercial				Residential			
Shell Type	**2020**	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**	**2050**
Pre 1980	0%	2%	2%	2%	0%	2%	13%	13%
Post 1980	0%	1%	1%	1%	0%	2%	2%	2%
Post 2000	0%	0%	1%	1%	0%	2%	2%	2%
Efficient	0%	-4%	-14%	-24%	0%	-6%	-22%	-29%
Net-zero Ready	0%	1%	9%	19%	0%	1%	5%	12%



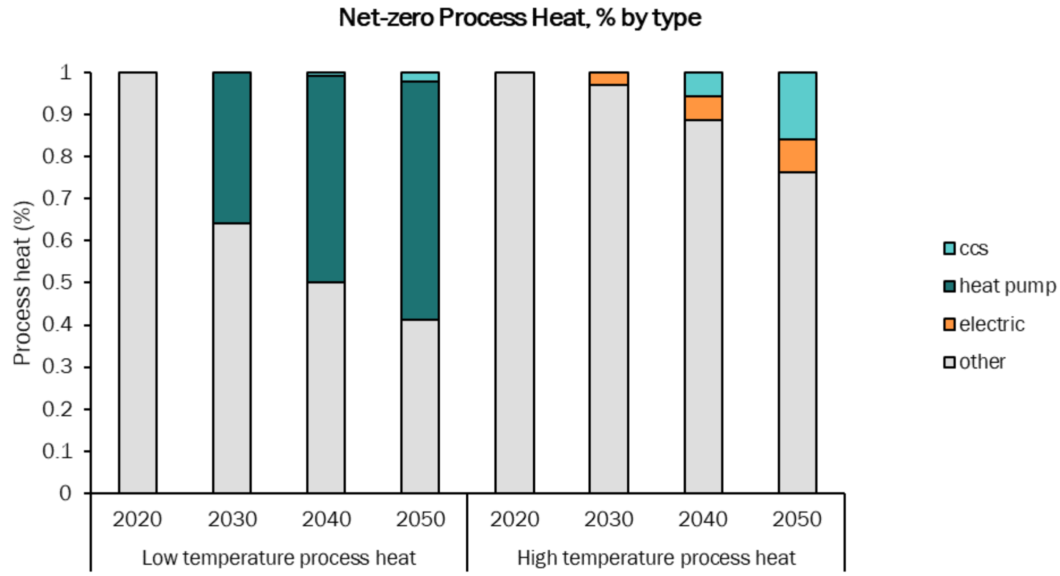
Process Heat

The model simulates technology choice in both low and high temperature process heat. Technologies in the model include various approaches to the electrification of industrial processes, heat pumps and heat recovery, and carbon capture utilization and storage (Figure 26). Main takeaways include:

- There is a large decline in fossil fuel-based process heating in low process heat temperature with significant switching to heat pumps or electric heating equipment.
- The composition of high temperature process heating applications does not change significantly even in a high carbon pricing setting. Challenges with electrifying high temperature process heat are borne out in the model with CCUS as the main decarbonization driver. There is some electrification potential in high temperature process heat.

Figure 26: Change in Process Heat, Atlantic Region (Net-zero market share - Reference case share)

Process Heat Technology	unit	Low temperature process heat 2020	2030	2040	2050	High temperature process heat 2020	2030	2040	2050
Other	%	0%	-32%	-45%	-54%	0%	-3%	-11%	-24%
Electric	%	0%	0%	0%	0%	0%	3%	6%	8%
Heat Pump	%	0%	32%	44%	52%	0%	0%	0%	0%
CCS	%	0%	0%	1%	2%	0%	0%	6%	16%



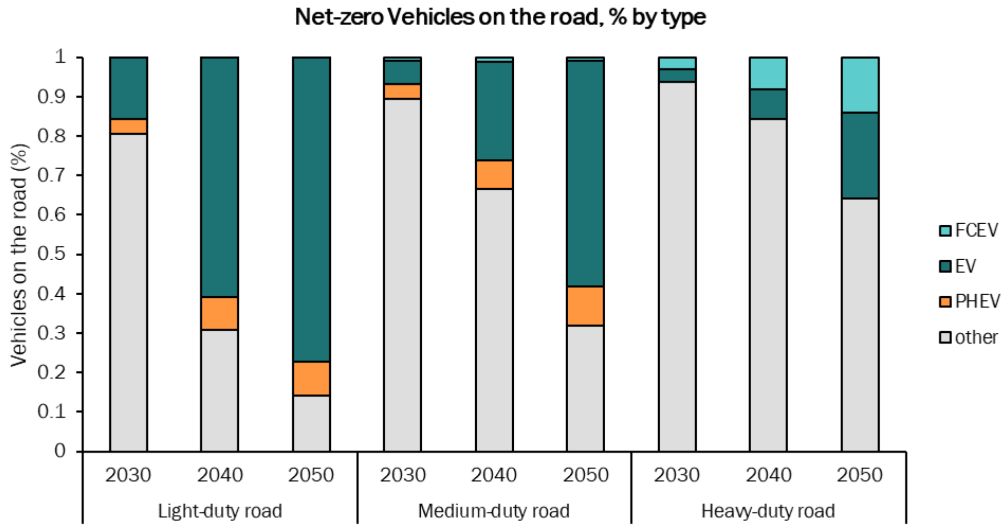
Vehicles on the Road

The net-zero simulation suggests significantly more electric vehicles are deployed due to vehicle standards, fuel charges, and EV mandates. The large shifts in the Atlantic vehicle composition happen between 2030 and 2040, which encompasses lower demand for fossil fuels and higher demand for electric vehicles:

- By 2040, 32% more light-duty electric vehicles are deployed relative to the reference case.
- Both medium and heavy-duty vehicles electrify much slower than light-duty vehicles and accelerate more towards 2040.

Figure 27: Change in Vehicles, Atlantic Region (Net-zero market share - Reference case share)
***PHEV – Plug-in Hybrid Vehicles, FCEV – Fuel Cell Electric Vehicles**

Vehicle Technology	unit	Light-duty road 2030	2040	2050	Medium-duty road 2030	2040	2050	Heavy-duty road 2030	2040	2050
Other	%	-14.4%	-35.9%	-31.2%	-4.2%	-16.6%	-25.5%	-3.0%	-9.5%	-27.8%
PHEV	%	2.2%	3.8%	2.3%	1.2%	2.6%	2.2%	0.0%	0.0%	0.0%
EV	%	12.2%	32.0%	28.8%	2.7%	13.7%	23.2%	1.6%	4.6%	18.1%
FCEV	%	0.0%	0.0%	0.0%	0.3%	0.3%	0.1%	1.4%	4.9%	9.7%



Electricity's Share of Total Energy

The simulation suggests that net-zero policies stimulate increased electrification across all Atlantic provinces, however specific economic sectors are expected to go through this shift faster than others (Figure 28). Declines in total end-use energy consumption takes place as Atlantic economies start to demand more electricity and less energy from coal, natural gas, and petroleum.

In **New Brunswick**, the federal government has not agreed to extend the life of the Belledune Generating Station beyond 2030, resulting in significant emissions reductions in the reference case. Other policies such as federal carbon pricing on fuels and a provincial large emitter program also contribute to a downward trend in GHGs in the reference case.

The net-zero policies facilitate a rise in electricity consumption and a decline in fossil fuel use. Energy use from coal, coke, and coal products, natural gas, and natural gas liquids is forecast to decline by 2035. A shift away from natural gas consumption in the manufacturing sector is expected by 2035. Electricity, biomass, and renewable natural gas in the simulations become the dominant energy sources in the province by 2035 representing almost 60% of total energy, up from 40% in the reference case. Under a net-zero scenario, refined petroleum is still a major component of New Brunswick's energy use, however consumption is forecast to decline by 28.7% by 2035.

The drop in electricity's share of total energy in latter parts of the situation is attributed to more renewable natural gas, which is used, at least in the simulation, across a number of sectors including, to generate electricity.

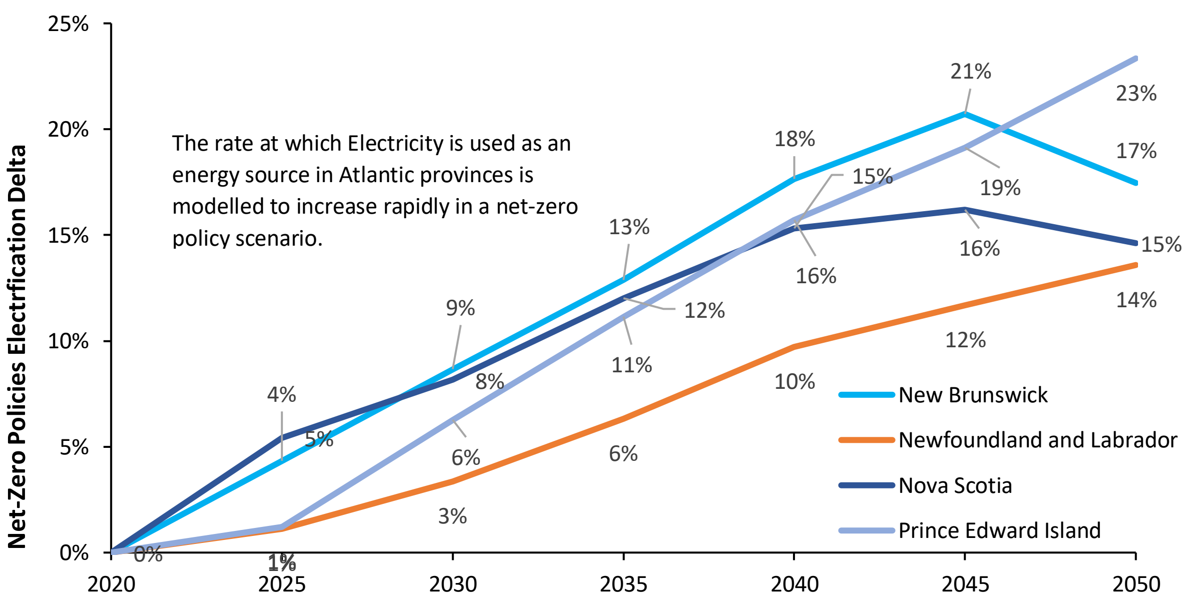
In Newfoundland and Labrador, significant drops in refined petroleum consumption are anticipated by 2030 along with a coal, coke, and coal products phase out. Households will be responsible for much of the decline in petroleum consumption as petroleum products become costly due to carbon pricing. Electricity consumption is forecast to be relatively constant between 2020 and 2050 in the province as a cause of increasing energy efficiencies and rising demand. In 2030, electricity will account for 3.3 % more of the province's energy use in a net-zero policy scenario than in a baseline policy scenario, and 13.5 % more in 2050.

Nova Scotia is largely dependent on coal-fired electricity generation, with four coal and petroleum coke generation plants in operation. Nova Scotia Power (NSPI) owns and operates the largest of the four plants located in Lingan, Nova Scotia which was built in 1979 and has a 620 MW capacity. The provincial government has set targets to shut down all the plants by 2030 to meet Federal greenhouse gas emission reduction targets. Despite favorable economic pressures emanating from current regulations to run the coal plants till their end of life, complete phase out is a feasible outcome as the four plants have an end of life between 2024 and 2029.

Net-zero runs in Nova Scotia depict shifts away from energy generated from coal, natural gas, and refined petroleum products by 2030 and a steady rise in electricity consumption. Declines in natural gas consumption in net-zero runs arise mostly in the manufacturing and service sectors. Near constant electricity consumption in the manufacturing and service sectors can be attributed to continuous improvements in energy efficiencies. Examples of these efficiency gains can be depicted in building's energy consumption, as the proportion of building shells characterized as "efficient" is forecast to rise from 10% of commercial building shells in 2020 to 18% by 2030 along with a 39% decrease in residential space heating consumption.

Net-zero policies have a large impact on the rate of electrification in **Prince Edward Island**. In 2030, net-zero policies induce a 6.3% increase in electricity's share of provincial energy consumption. By 2035, energy consumption will have largely shifted away from natural gas liquids and refined petroleum and electricity consumption will rise. Households will consume less energy from biomass and refined petroleum products.

Figure 28: Net-zero Electrification Relative to Baseline Provincial Policies



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