Technical note in net zero scenarios for New Brunswick

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1 Introduction

Achieving net zero emissions by 2050 will require electricity system operators to make large bets on how they will meet growing demand while decarbonizing their electricity mix. Choices about the supply mix to meet future demand requires a sound analytical foundation to understand relative costs to meet growing demand. In this note we present selected results from five electricity supply scenarios for New Brunswick under a net zero final demand constraint.

Consistent with our previous study, end-use demand is set to align with a high electrification net zero by 2050 scenario. However, generation and capacity investments respond to marginal changes in demand associated with differing cost and technology assumptions in the scenarios.

Two versions of the Navius IESD model are used to assess the scenarios. The first version used in the original modelling allowed for new interties to be developed and due to computational limitations, storage options were not available. In the second iteration of the modeling, the model accommodates utility-scale storage while new significant interties under an Atlantic Loop are precluded.

All policies are compared against this high electrification net zero reference case across several indicators including total system cost, electricity price, net imports, changes in capacity and generation with renewables paired with storage, and greenhouse gas emissions.

2 Scenarios assessed

Five scenarios and a reference case are assessed.

The **reference case promotes high electrification and net zero by 2050**. 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. Point Lepreau is not retired in 2040 and operates throughout the entire simulation. Small modular reactors are not available in the simulations as a policy choice and because this technology is not yet a technology option to compete. All other technologies compete on levelized cost basis subject to policies and technology constraints in each scenario.

This reference case, and therefore all following scenarios, is compliant with the developing federal Clean Electricity Regulations.

The three Atlantic Loop scenarios from the original modeling include:

1. **Atlantic Loop scenario: Net zero + NB retires Lepreau in 2040.** As requested in the first set of analysis one scenario assesses the planned phase-out of the Point Lepreau Nuclear Generating Station by 2040. Small modular reactors are not available in the simulations as a policy choice and because this technology is not yet a technology option to compete, but all other generating technology competes on a cost basis. In all other scenarios, Point Lepreau continues to operate through 2050.

2. **Atlantic Loop scenario: Net zero + QC large hydro intertie.** 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 a range of financing assumptions with 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.

3. **Atlantic Loop scenario: Net zero + Maritime Link 2 intertie.** 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 and a range of delivered energy costs of $50 to $80 per MWh.

Two new scenarios compare storage options and renewable generation costs. We examine the potential of storage, greater declining costs for renewables, and lack of intertie expansion to increase the adoption of wind and solar under two new scenarios. The updated analysis uses the region module of IESD, which does allow for storage. Specifically, this analysis considered the potential for utility-scale lithium-ion batteries based on optimistic assumptions from NREL as shown in

Table **1**:

4. **Utility-scale storage with current renewable costs (Storage + Current cost renewables).** Current cost renewables are paired with utility-scale storage. Innovations in renewable generation technology observed in today's marketplace become more widespread, and innovations that are nearly market-ready today come into the marketplace during the simulation. Table 2 provides the cost assumptions under the moderate scenario based on the National Renewable Energy Laboratory's (NREL's) Annual Technology Baseline report.

5. **Utility-scale storage with low renewable costs (Storage + Low-cost renewables)**. Low-cost renewables are paired with utility-scale storage. Innovations in renewable generation technology that are far from market-ready today are successful and become widespread in the marketplace. New technology architectures could look different from those observed today. Table 2 provides the cost assumptions under the advanced renewables scenario.

Table 1: Cost of lithium-ion batteries ($2021)

	2020	2030	2050
Storage CAPEX ($/kW)	316	146	66
Power CAPEX ($/kWh)	132	61	28

Source: National Renewable Energy Laboratory. 2020. *Cost Projections for Utility-Scale Battery Storage: 2020 Update.* https://www.nrel.gov/docs/fy20osti/75385.pdf

Note: Assumes a CAD-USD exchange rate of 1.3.

Table 2: Capital cost of solar and wind ($2021/kW)

	2020	2030	2050
Current costs scenario			
Solar	1,741	915	672
Wind	2,045	1,158	871
Low-costs scenario			
Solar	1,741	859	648
Wind	2,045	976	732

Source: National Renewable Energy Laboratory. 2022. *Annual Technology Baseline*. https://atb.nrel.gov/electricity/2022/technologies

Note: Assumes a CAD-USD exchange rate of 1.3. Current costs = moderate NREL scenario, low cost = NREL advanced scenario.

3 Insights

3.1 Total system cost

Annual system costs are summed, and a net present value is calculated for the scenarios between 2024 and 2050. We report on five groups of costs from the model:

- Capital expenditures or CapEx costs are calculated and analyzed using a capital recovery factor. New transmission costs under the Atlantic Loop scenarios are annualized using a capital recovery factor.
- Operating costs include fuel costs, fixed operating costs, and variable operating costs.
- Export sales and import costs are both included.
- Carbon payments under various provincial and federal programs are calculated.

All costs are streamed out over the 26-years from 2024 to 2050 and discounted back to 2021 dollars using a rate of 3%. Table 3 shows the percentage change in the net present value for the entire period relative to the reference case.

The scenario with the highest total cost is the retire nuclear in 2040 scenario. The lowest total cost scenario is the large hydro scenario importing a large share of total consumption from

Quebec. The addition of storage paired with renewable's shows a low total cost relative to all scenarios.

An upshot of storage, coupled with low-cost renewables, is a reduction in electricity system costs in most provinces in the Atlantic region. The greatest benefit is experienced in PEI, where electric batteries could reduce electricity costs by almost 17% in 2050 (from what they otherwise would have been). The benefit is largest in PEI due to the high share of generation from new renewables in that province. New Brunswick doesn't experience this magnitude of benefit because greater adoption of storage in other regions reduces demand for its electricity exports.

Regardless of the scenario, large capital expenditures are inevitable. This is particularly the case in the nuclear retirement scenario, where about 50% of total generation needs to be replaced when Point Lepreau is taken offline. The renewables with storage scenarios indicate that total system costs can be kept down with an approach that adds more renewables generation and storage starting as soon as possible.

Table 3: Total system costs (billion 2021)
Net Present Value @3%; 2024 to 2050

	CapEx	OpEx	Carbon	Exports	Imports	New Transmission	Total Cost
High electrification net zero case	$13,730	$5,369	$2,280	-$3,854	$4,609	$0	$20,904
Net zero + QC large hydro intertie	$12,289	$3,789	$995	-$6,107	$8,213	$1,119	$19,179
Net zero + Maritime Link 2 intertie	$11,854	$3,902	$1,020	-$4,082	$7,813	$231	$20,506
Net zero + NB retires Lepreau in 2040	$12,845	$3,563	$1,178	-$4,419	$9,557	$0	$22,724
Storage + Low-cost renewables	$13,857	$4,783	$1,586	-$3,724	$5,214	$0	$20,749
Storage + Current cost renewables	$13,849	$4,804	$1,721	-$4,244	$5,590	$0	$20,696

Note: Values shaded green are preferred. A three-colour stop light scheme where dark red is the highest value, yellow is the 50th percentile, and dark green is the lowest value

3.2 Electricity Price

The indicator is the wholesale price of electricity expressed as an index against the 2020 reference case. This indicator can be interpreted as a percentage increase in the electricity rate for households and businesses. Note that the modeling does not make any assumptions about the share of system costs that the federal government will contribute. Instead, the analysis assumes that the ratepayer will ultimately be responsible for all increases in system costs. To the extent the federal government subsidizes capital costs, the rate impacts identified below will be mitigated.

Both the Atlantic Loop intertie scenarios have similar costs to the storage plus renewable scenarios. In the shorter-term, with higher capital costs to deploy renewables, electricity prices would likely be higher under the with storage and renewables cases. Note the intertie scenarios have long construction lead times and costs are not experienced until at least 2030. The large hydro case with an intertie to Quebec has the lowest electricity prices followed by the two storage scenarios. Over the longer-term electricity prices are highest under the retiring nuclear scenario.

Table 4 provides an overview of the cumulative cost increases for each period by scenario. For example, 1.14 would indicate that between 2020 and 2025, the total rate increase would be 14%.

Table **5** provides the annualized rate increase for each scenario.

Based on the analysis, the lowest system costs over the simulation time period is for the intertie scenario with large hydro from Newfoundland through Quebec followed closely by the two renewables plus storage scenarios.

Table 4: Increase in the price of electricity (Net zero reference case 2020 = 1)

	2025	2030	2035	2040	2045	2050
Net zero + QC large hydro intertie	1.14	1.29	1.10	1.29	1.30	1.35
Net zero + Maritime Link 2 intertie	1.14	1.41	1.39	1.38	1.40	1.49
Net zero + NB retires Lepreau in 2040	1.14	1.33	1.33	1.90	1.87	1.95
Storage + Low-cost renewables	1.21	1.25	1.28	1.25	1.31	1.35
Storage + Current cost renewables	1.21	1.27	1.21	1.29	1.33	1.39

Note: Values shaded green are preferred. A three-colour stop light scheme where dark red is the highest value, yellow is the 50th percentile, and dark green is the lowest value

Table 5: Annual electricity rate change

	2021-25	2026-30	2031-35	2036-40	2041-45	2046-50	Average change 2020-50
Net zero + QC large hydro intertie	2.7%	2.4%	-3.0%	3.3%	0.1%	0.8%	**1.0%**
Net zero + Maritime Link 2 intertie	2.7%	4.4%	-0.3%	-0.2%	0.4%	1.2%	**1.3%**
Net zero + NB retires Lepreau in 2040	2.7%	3.1%	0.0%	7.4%	-0.3%	0.8%	**2.2%**
Storage + Low-cost renewables	3.9%	0.7%	0.4%	-0.5%	0.9%	0.6%	**1.0%**
Storage + Current cost renewables	3.8%	1.0%	-0.9%	1.2%	0.7%	0.9%	**1.1%**

Note: Values shaded green are preferred. A three-colour stop light scheme where dark red is the highest value, yellow is the 50th percentile, and dark green is the lowest value.

3.3 Net Imports

Wealth transfers to other jurisdictions. Each scenario is assessed based on the ratio of net imports over total domestic consumption. From the modeling, we subtract exports from imports to calculate net imports and then divide this by total consumption in five year increments to 2050. The higher the ratio, the greater the wealth transfer from ratepayers in New Brunswick to system operators in other jurisdictions.

Table 6: Net imports over total consumption

	2020	2025	2030	2035	2040	2045	2050
Net zero + QC large hydro intertie	9%	23%	25%	28%	32%	29%	29%
Net zero + Maritime Link 2 intertie	9%	23%	25%	28%	30%	26%	26%
Net zero + NB retires Lepreau in 2040	9%	23%	26%	30%	36%	32%	29%
Storage + Low-cost renewables	10%	24%	23%	21%	21%	20%	19%
Storage + Current cost renewables	10%	24%	23%	23%	23%	21%	20%

Note: Values shaded green are preferred. A three-colour stop light scheme where dark red is the highest value, yellow is the 50th percentile, and dark green is the lowest value

3.4 Change in capacity and generation with storage

Storage costs are coming down allowing renewable generation to take off. Technologies to store electricity are therefore important for integrating higher levels of renewables into New Brunswick's electricity system.

The addition of storage paired with renewables results in a reduction in the generation capacity needed in any given period. Table 7 shows how the adoption of storage (combined with lower cost assumptions for solar and wind as described above) influences generation capacity relative to the no storage scenario.

Total electricity generation does not change up very much but with the addition of storage, natural gas generation falls off significantly while wind expands. The model indicates that when paired with storage, wind out competes solar paired with storage (Table 8).

A few observations from the analysis:

- Coal-fired power at Belledune is phased out prior to 2030 in all scenarios, dropping its share of total generation from ~50% in 2015 to zero by 2030.
- Biomass is not adopted on a cost-effective basis in any scenario.
- In the absence of electricity storage, thermal capacity grows to meet reserve requirements. This is true even under a scenario in which New Brunswick achieves net zero (in which case thermal plants are operated at very low-capacity factors, e.g., <5%). Electricity storage provides an opportunity to contribute to reserve margins and better utilize renewable resources.

Table 7: Change in generating capacity with storage (MW)

	2030	2035	2040	2045	2050
Oil/Diesel	-70	-70	-70	-70	-70
Natural Gas	-299	-431	-665	-893	-1,103
Cogeneration					
Nuclear			71	91	
Hydropower					
Wind	-62	-39	-87	-89	43
Solar			-35	-123	-229
Biomass					
Total	**-431**	**-540**	**-787**	**-1,084**	**-1,360**

Table 8: Change in electricity generation with storage (GWh)

	2030	2035	2040	2045	2050
Oil/Diesel	0	0	0	0	0
Natural Gas	-165	-365	-405	-476	-588
Cogeneration					
Nuclear					
Hydropower					
Wind	-83	293	529	886	1,371
Solar			-47	-206	-297
Biomass					
Total	**-248**	**-72**	**76**	**204**	**486**

3.5 Greenhouse gas emissions

All scenarios result in a significant decline in emissions from current levels.

Table 9: GHG emissions (kilotonnes CO2e)

	2020	2030	2040	2050
Net zero + QC large hydro intertie	**~2,900**	**168**	**193**	**214**
Net zero + Maritime Link 2 intertie		**169**	**200**	**216**
Net zero + NB retires Lepreau in 2040		**168**	**259**	**273**
Storage + Low-cost renewables		**257**	**274**	**3**
Storage + Current cost renewables		**278**	**296**	**4**

Note: Values shaded green are preferred. A three-colour stop light scheme where dark red is the highest value, yellow is the 50th percentile, and dark green is the lowest value

Appendix

User selections

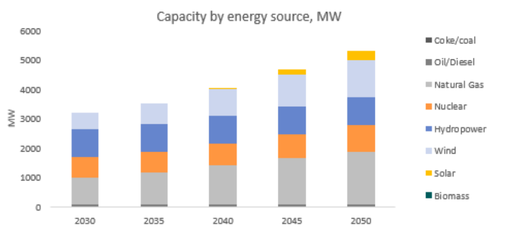
Province/Region	New Brunswick
Policy	p4-netzero-freeal-pol
Policy Description	net zero scenario
Sensitivity	baseline costs no storage

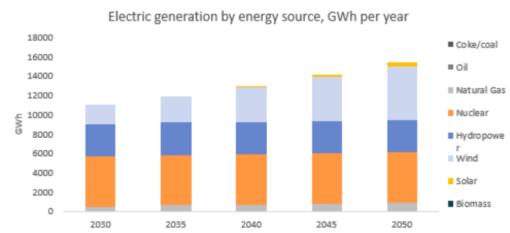
New Brunswick Generation Capacity by Energy Source

Technology	Unit	2030	2035	2040	2045	2050
Coke/coal	MW					
Oil/Diesel	MW	70	70	70	70	70
Natural Gas	MW	935	1111	1345	1573	1784
Cogeneration	MW	66	72	76	80	85
Nuclear	MW	705	705	736	824	916
Hydropower	MW	947	947	947	947	947
Wind	MW	538	691	912	1093	1282
Solar	MW			35	154	301
Biomass	MW					
Total	MW	3262	3597	4122	4741	5385
	check					

New Brunswick Electricity Generation by Energy Source

Technology	Unit	2030	2035	2040	2045	2050
Coke/coal	GWh					
Oil	GWh	0	0	0	0	0
Natural Gas	GWh	430	618	642	745	882
Cogeneratio	GWh	494	536	567	596	629
Nuclear	GWh	5203	5203	5203	5203	5203
Hydropower	GWh	3325	3325	3325	3325	3325
Wind	GWh	2063	2681	3646	4596	5590
Solar	GWh			47	206	403
Biomass	GWh					
Total	GWh	11516	12363	13430	14672	16034
	check					





User selections

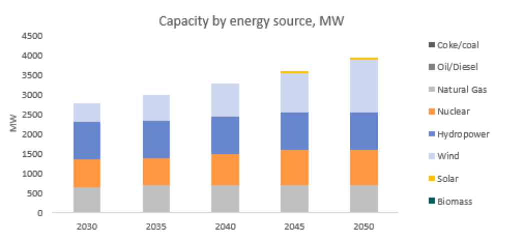
Province/Region	New Brunswick
Policy	p4-netzero-freeal-pol
Policy Description	net zero scenario
Sensitivity	baseline costs storage

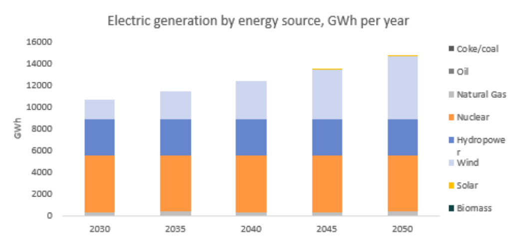
New Brunswick Generation Capacity by Energy Source

Technology	Unit	2030	2035	2040	2045	2050
Coke/coal	MW					
Oil/Diesel	MW					
Natural Gas	MW	635	680	680	680	680
Cogeneration	MW	66	72	76	80	85
Nuclear	MW	705	705	807	915	916
Hydropower	MW	947	947	947	947	947
Wind	MW	476	652	825	1004	1325
Solar	MW				31	73
Biomass	MW					
Total	MW	2830	3056	3335	3658	4025
	check					

New Brunswick Electricity Generation by Energy Source

Technology	Unit	2030	2035	2040	2045	2050
Coke/coal	GWh					
Oil	GWh					
Natural Gas	GWh	323	347	299	323	353
Cogeneratio	GWh	494	536	567	596	629
Nuclear	GWh	5203	5203	5203	5203	5203
Hydropower	GWh	3325	3325	3325	3325	3325
Wind	GWh	1818	2522	3563	4575	5743
Solar	GWh				41	97
Biomass	GWh					
Total	GWh	11163	11934	12957	14065	15352
	check					





User selections

Province/Region	New Brunswick
Policy	p4-netzero-freeal-pol
Policy Description	net zero scenario
Sensitivity	optimistic costs storage

New Brunswick Generation Capacity by Energy Source

Technology	Unit	2030	2035	2040	2045	2050
Coke/coal	MW					
Oil/Diesel	MW					
Natural Gas	MW	615	615	615	615	615
Cogeneration	MW	66	72	76	80	85
Nuclear	MW	705	706	810	882	916
Hydropower	MW	947	947	947	947	947
Wind	MW	518	762	990	1284	1676
Solar	MW					79
Biomass	MW					
Total	MW	2851	3102	3438	3807	4318
	check					

New Brunswick Electricity Generation by Energy Source

Technology	Unit	2030	2035	2040	2045	2050
Coke/coal	GWh					
Oil	GWh					
Natural Gas	GWh	265	252	237	269	294
Cogeneratio	GWh	494	536	567	596	629
Nuclear	GWh	5203	5203	5203	5203	5203
Hydropower	GWh	3325	3325	3325	3325	3325
Wind	GWh	1980	2974	4174	5482	6962
Solar	GWh					106
Biomass	GWh					
Total	GWh	11268	12291	13507	14876	16520
	check