

STATE OF
**ENERGY IN
NORTHEASTERN
NORTH AMERICA**

Chair in Energy Sector
Management
HEC MONTRÉAL

State of Energy in Northeastern North America

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The views presented in this document are those of the authors and do not necessarily represent the position of their organizations.

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Introduction

Northeastern North America

The Northeastern North America region spans over two countries, the United States and Canada. Each country has distinct, commonly understood regional groupings. In the United States, this includes New England and New York, but also New Jersey and Pennsylvania. In Canada Ontario and Quebec are considered “Central Canada”, while the “Atlantic Region” includes Newfoundland and Labrador, Prince Edward Island, Nova Scotia and New Brunswick.



Why have we chosen to develop an energy report on Northeastern North America?

- The energy markets of these provinces and states are already integrated and could be even more so in the future.
- A very limited understanding of the energy realities facing this region constrains the scope of solutions that can be envisioned, and does not foster an environment of cooperation,. We believe that energy planning could greatly benefit from improved regional collaboration.
- New York, all six New England states (Maine, Vermont, Massachusetts, Rhode Island, Connecticut, New Hampshire), Ontario, Quebec and the Atlantic provinces already belong to the same power coordinating Council: the Northeast Power Coordinating Council (NPCC). The NPCC promotes and enhances the reliability of the international, interconnected bulk power system. Given the critical role of electricity to reach societal decarbonization goals, we anticipate that the electricity system’s role will grow increasingly important in the coming years. Studying the NPCC region therefore appeared natural to us, as all members already collaborate on short and mid-term reliability issues. In the future, we believe that this cooperate could deepen and result in a more resilient and clean energy system.

Objective of this report

This report is the first of its kind and aims to provide key energy information required for a wide variety of energy project discussions. It draws on existing energy information sources and aims to offer a comprehensive and neutral overview of the energy system of Northeastern North America. Given the highly dynamic nature of the energy system, some information could be slightly out of date or incomplete. We will attempt to correct any omissions or errors in the future.

Key Takeaways

Each province and state has unique characteristics that must be carefully analyzed in context

- Nuclear energy and renewables dominate primary energy production in Ontario, New England and New York. Fossil fuels makes up 80% of the Atlantic provinces' energy production (mainly from Newfoundland & Labrador offshore oil and gas extraction).
- Energy production in Quebec is very distinct from the rest of the region, almost 100% comes from renewables (mainly hydroelectricity).
- Total energy consumption per capita varies significantly from 164 gigajoules (GJ) in New York up to 261 GJ in the Atlantic provinces.
- The industrial sector uses the most energy in Ontario, Quebec and the Atlantic provinces. Transportation accounts for the largest share of energy consumption in New York and New England.
- The main source for home heating in the region is natural gas and fuel oil except in Quebec and in two Atlantic provinces (New Brunswick and Newfoundland & Labrador) where electricity is the primary heating source.
- Energy prices and fuel taxes can vary by a factor of 2 from one province/state to another.

The region relies heavily on fossil fuel imports

- Fossil fuels usage represents between 70-80% of the total energy consumption in all provinces/states, except for Quebec where this number is lower (56%).
- The average energy self-sufficiency ratio (energy production over energy consumption) is around 0.35 for the region.

The region has very ambitious climate change targets that will require serious commitment and effort to realize

- GHG emissions reduction targets range from 35% to 45% for 2030, and 80% to net-zero for 2050.
- Historical GHG emissions trends in the region suggest that only Ontario, New England and New York are bending the curve downwards, which is mainly due to the decarbonization of electricity in these provinces / states with the elimination of coal-fired plants.

Fostering collaboration between provinces and states is key to achieving a cleaner and more efficient energy system

- At around 24 GWh of capacity, electricity storage in the region is still very limited. Most of this storage comes from pumped hydro sites in New York, New England and Ontario. However, there is opportunity to facilitate the integration of more intermittent renewable generation by accessing an estimated capacity of more than 200 TWh hydro reservoir storage which is mainly located in Quebec.
- The energy system in Northeastern North America is already interconnected through electric transmission lines and interties, and oil & gas pipelines, but could take advantage of further collaboration and coordination.

Energy Conversion and Definitions

Energy Conversion

- To present and compare energy production and consumption, we use the **joule (J)**, the unit of energy in the International System of Units.
- Energy quantities are expressed in megajoule (MJ), gigajoule (GJ), terajoule (TJ) and petajoule (PJ), where:

1 MJ = 1 million joules (10⁶ J)

1 GJ = 1 billion joules = 1,000 MJ (10⁹ J)

1 TJ = 1 trillion joules = 1,000 GJ (10¹² J)

1 PJ = 1 quadrillion joules = 1 million GJ (10¹⁵ J)

- Petroleum products, natural gas, electricity are all expressed in joule in this report to allow easier comparisons. Here are some **conversion examples**:

1 barrel of oil = 42 gallons ≈ 159 liters ≈ 6 GJ

1 gallon of gasoline = 3.785 liters ≈ 127 MJ ≈ 0.127 GJ

1,000 cubic feet of natural gas = 1,037,000 Btu = 1.094 GJ = 28.3 cubic meters

1 kilowatt-hour (kWh) of electricity = 3.6 MJ

1 MWh = 3.6 GJ

Definition

Primary energy is the energy embodied in natural resources prior to undergoing any human-made conversions. It appears on Earth as fossil fuels (crude oil, natural gas, coal), renewable energy (hydropower, wind, solar, geothermal) and nuclear energy. Nuclear energy is a primary energy source because it is usable only after the transformation of uranium in nuclear facilities. Electricity, all refined petroleum products, steam, and hydrogen are all secondary energy sources used by consumers. Natural gas and coal, requiring little conversion before being usable, are considered in primary energy sources and can also appear in final (secondary) energy consumption.

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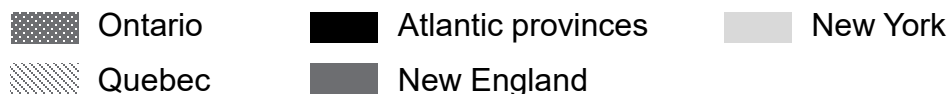
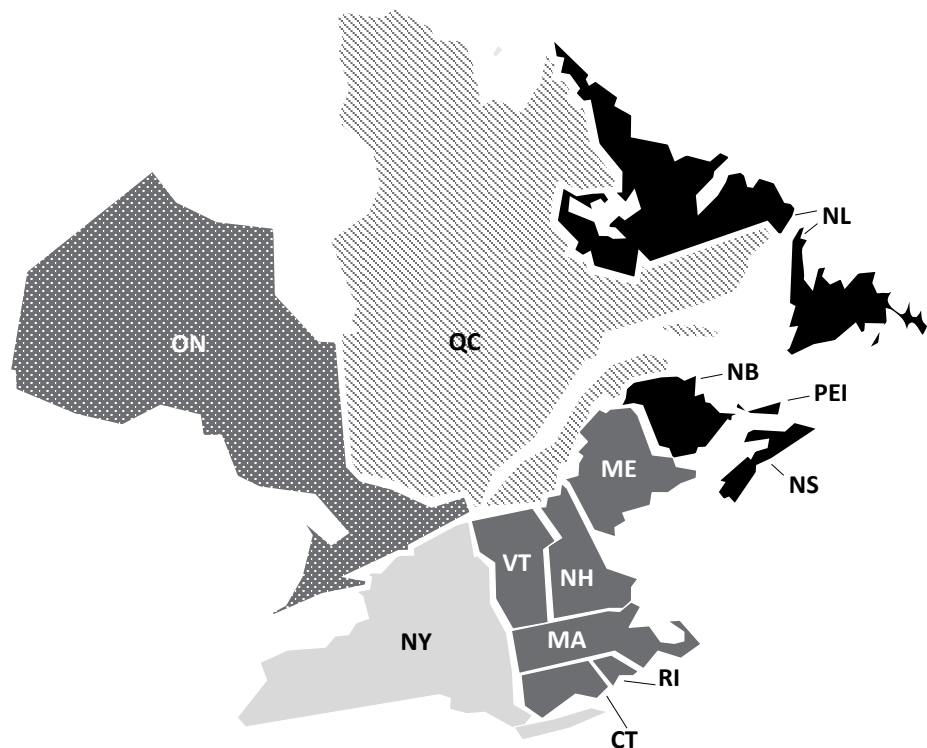
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1. REGIONAL OUTLOOK

Regional Overview and Macro Indicators

Northeastern North America Regional Map

Total population: 59.8 million



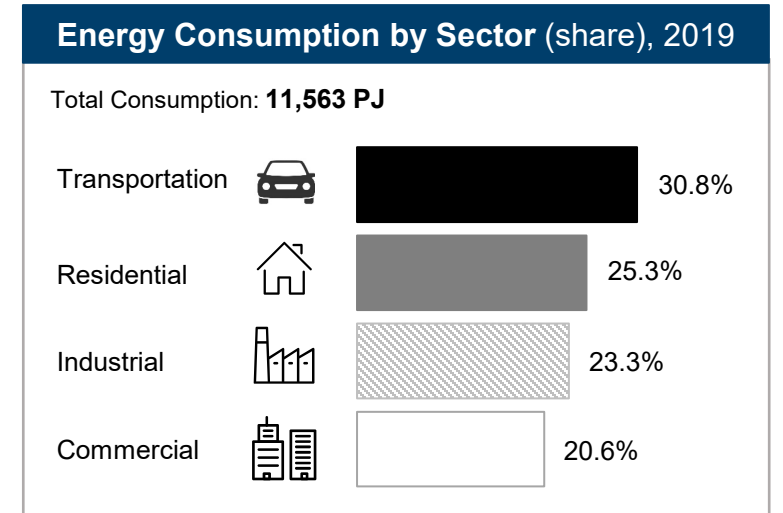
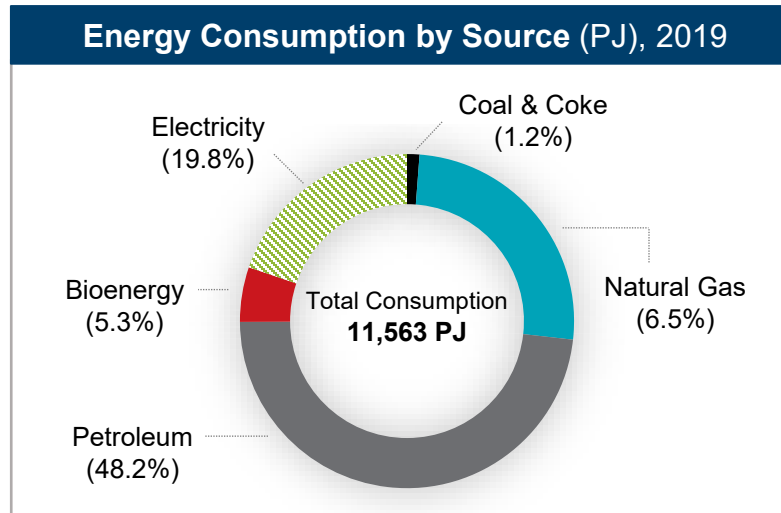
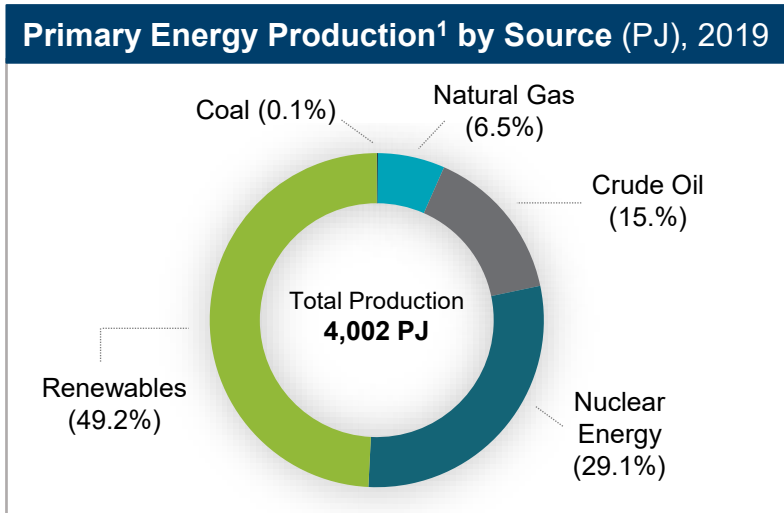
Macro Indicators for the Region, 2020

	Population (million)	GDP (billion USD)	Temperature (annual average ¹)	
			°C	°F
Ontario (ON)	14.6	634	7.9	46.2
Quebec (QC)	8.5	324	6.5	43.7
Atlantic provinces	2.5	92	6.3	43.2
<i>New Brunswick (NB)</i>	<i>0.8</i>	<i>27</i>	<i>6.1</i>	<i>43.0</i>
<i>Newfoundland & Labrador (NL)</i>	<i>0.5</i>	<i>27</i>	<i>5.2</i>	<i>41.4</i>
<i>Nova Scotia (NS)</i>	<i>1.0</i>	<i>33</i>	<i>7.3</i>	<i>45.1</i>
<i>Prince Edward Island (PEI)</i>	<i>0.2</i>	<i>5</i>	<i>6.4</i>	<i>43.5</i>
New England	15.0	1,109	9.1	48.2
<i>Connecticut (CT)</i>	<i>3.6</i>	<i>276</i>	<i>10.9</i>	<i>51.8</i>
<i>Massachusetts (MA)</i>	<i>6.9</i>	<i>582</i>	<i>10.5</i>	<i>50.9</i>
<i>Maine (ME)</i>	<i>1.4</i>	<i>69</i>	<i>6.8</i>	<i>43.5</i>
<i>New Hampshire (NH)</i>	<i>1.4</i>	<i>88</i>	<i>7.9</i>	<i>45.8</i>
<i>Rhode Island (RI)</i>	<i>1.1</i>	<i>61</i>	<i>11.4</i>	<i>52.8</i>
<i>Vermont (VT)</i>	<i>0.6</i>	<i>33</i>	<i>7.4</i>	<i>44.8</i>
New York (NY)	19.3	1,699	8.9	47.8

¹ Based on average annual temperatures of major cities in each province/state.

Sources: Canada Energy Regulator - Canada's Energy Future (2020); U.S. EIA - State Energy Profiles (2020); U.S. Census Bureau - State Population Totals (2020); U.S. BEA - GDP by State (2020); NCEI - average temperatures (2020)

Aggregated Energy and Environmental Data



¹ See page 5 for definition

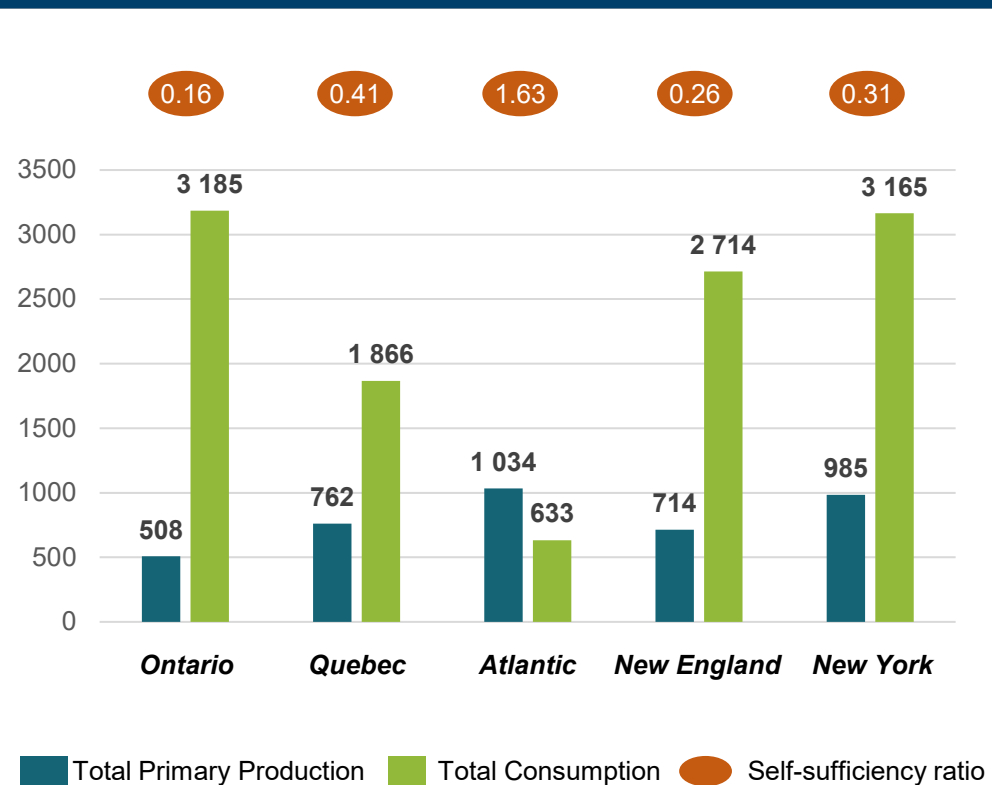
Sources: Statistics Canada - Supply and demand of primary and secondary energy in terajoules, annual (2019); Canada Energy Regulator - Provincial and Territorial Energy (2019); Canada Energy Regulator - Canada's Energy Future 2020; U.S. Energy Information Administration - State Energy Data System 2019 (data from 2019 or 2018 when not available).

<h4>Energy Self-Sufficiency Ratio</h4> <p>0.35</p> <p><i>Note: The Energy Self-Sufficiency Ratio is the energy production over the energy consumption. It provides an indication of how much a state, or a province, relies on trade to meet its energy needs.</i></p>	<h4>Greenhouse gas (GHG) emissions² (Mt of CO₂e), 2019</h4> <p>611</p> <p>Sources: U.S. Energy Information Administration - State CO₂ Emissions; Environment and Climate Change Canada - National Inventory Report Greenhouse Gas Sources and Sinks in Canada</p>	<h4>Average Retail Energy Prices, 2020</h4> <ul style="list-style-type: none"> ▶ Residential Natural Gas Price (USD per thousand cu ft) 12.71 ▶ Residential Electricity Price (USD per kWh) 0.13 ▶ Gasoline Retail Price (USD per litre) 1.00 <p>Sources: Canada Energy Regulator - Canada's Energy Future 2020; Energyhub - Electricity Prices in Canada 2021; Statistics Canada - Monthly average retail prices for gasoline (august 2021); U.S. Energy Information Administration - State Energy Data System 2019 and Gasoline and Diesel Fuel Update (August 2021)</p>
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² Canadian data includes all GHG emissions (both CO₂ and other greenhouse gases) whereas U.S. data only includes CO₂ emissions, due to the absence of state-level GHG inventory. Approximately 15-20% should be added to US emissions to account for non-CO₂ GHG emissions.

Primary Energy Production (excluding electricity generated from fossil fuels) and Energy Consumption by Region

Primary Energy Production¹ vs. Energy Consumption (PJ), 2019



Note: Total Energy Consumption does not include electrical system energy losses (i.e., losses incurred in the generation, transmission, and distribution of electricity plus plant use and unaccounted for).

¹ See page 5 for definition

Sources: Statistics Canada - Supply and demand of primary and secondary energy in terajoules, annual (2019) ; Canada Energy Regulator - Provincial and Territorial Energy (2019) ; Canada Energy Regulator - Canada's Energy Future 2020 ; U.S. Energy Information Administration - State Energy Data System 2019 (data from 2019 or 2018 when not available).

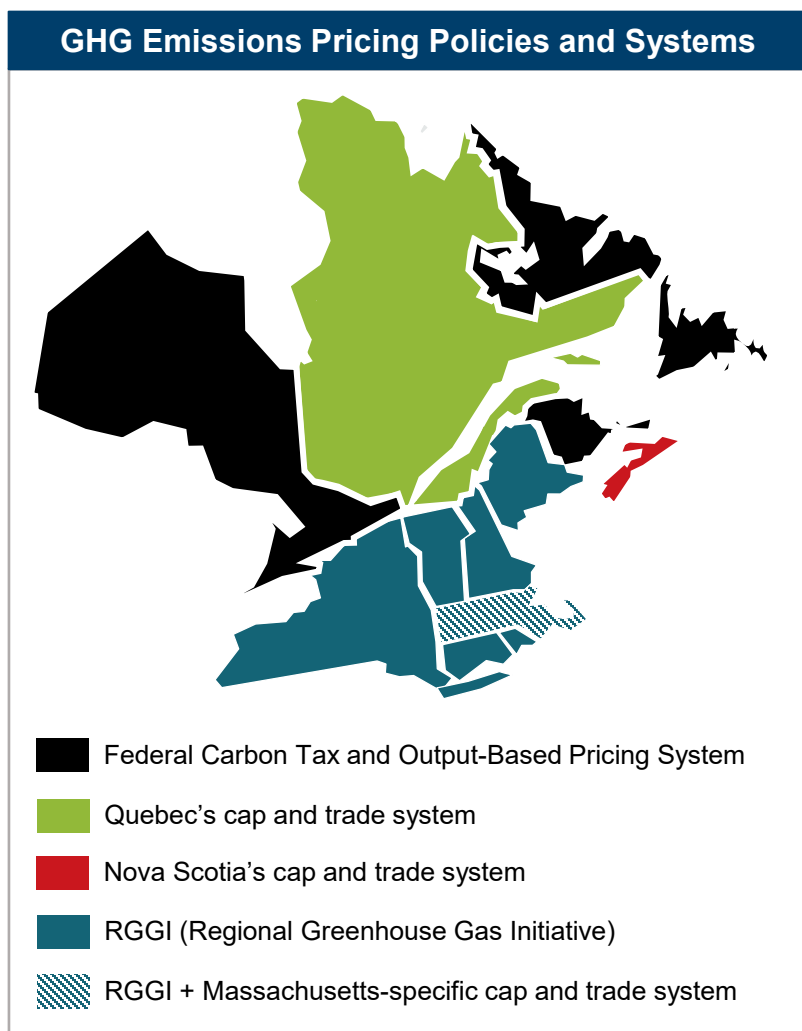
Main Source of Primary Energy Production¹ vs. Energy Consumption, 2019

	Main source - Production ¹	Main source - Consumption
Ontario	Nuclear & Renewables (99%)	Fossil Fuels (80%)
Quebec	Renewables (99%)	Fossil Fuels (56%)
Atlantic provinces	Fossil Fuels (81%)	Fossil Fuels (68%)
<i>New Brunswick</i>	<i>Nuclear</i>	<i>Fossil Fuels</i>
<i>Newfoundland & Labrador</i>	<i>Crude Oil</i>	<i>Fossil Fuels</i>
<i>Nova Scotia</i>	<i>Natural Gas</i>	<i>Fossil Fuels</i>
<i>Prince Edward Island</i>	<i>Renewables</i>	<i>Fossil Fuels</i>
New England	Renewables & Nuclear (100%)	Fossil Fuels (76%)
<i>Connecticut</i>	<i>Nuclear</i>	<i>Fossil Fuels</i>
<i>Massachusetts</i>	<i>Renewables</i>	<i>Fossil Fuels</i>
<i>Maine</i>	<i>Renewables</i>	<i>Fossil Fuels</i>
<i>New Hampshire</i>	<i>Nuclear</i>	<i>Fossil Fuels</i>
<i>Rhode Island</i>	<i>Renewables</i>	<i>Fossil Fuels</i>
<i>Vermont</i>	<i>Renewables</i>	<i>Fossil Fuels</i>
New York	Renewables & Nuclear (99%)	Fossil Fuels (78%)

Notes:

- Fossil Fuels include petroleum, natural gas, coal & coke.
- Renewables include Biofuels, biomass energy, hydroelectric power, geothermal, solar, and wind energy.

Regulatory Frameworks to Reduce GHG Emissions

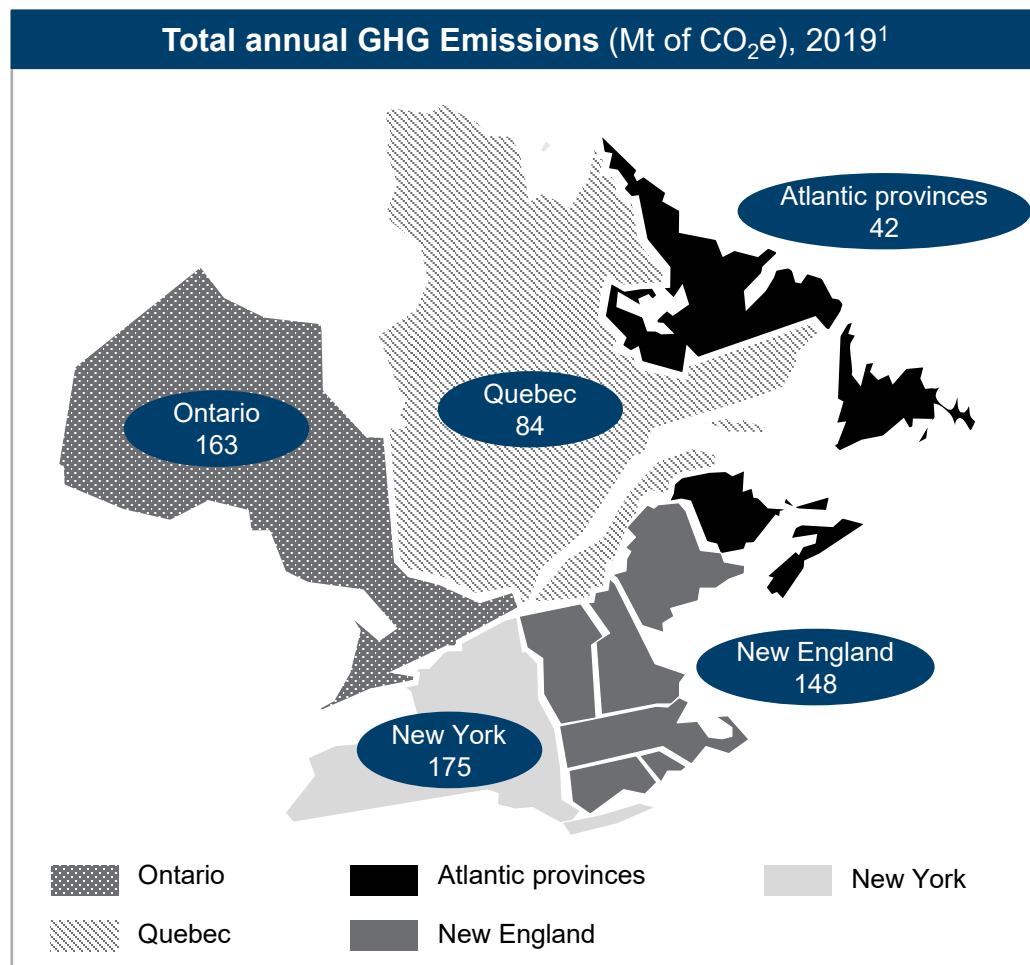


	Description	Covered sectors	Participants ¹
Federal Carbon Tax and Output-Based Pricing System (OBPS)	Established in 2019, this price-based carbon system acts as a federal backstop in Canadian jurisdictions that do not have a carbon pricing program that meets the benchmark.	Transport and buildings (Carbon Tax); Industries (OBPS). <i>Covering about 80% of GHG emissions.</i>	ON NB NL PEI
Quebec's cap and trade system	Established in 2013, this province-specific cap and trade program supports Quebec's 2030 target to reduce GHG emissions by 37.5% from 1990 levels. In 2014, Quebec linked its system with that of California through the WCI.	All businesses that emit 25,000 tons or more of CO ₂ e per year. <i>Covering about 80% of GHG emissions.</i>	QC
Nova Scotia's cap and trade system	Established in 2019, this province-specific cap and trade program sets a cap on the total amount of GHG emissions allowed in covered sectors in the province.	All businesses that emit 50,000 tons or more of CO ₂ e per year + Petroleum product suppliers, Natural gas distributors and Electricity importers. <i>Covering about 85% of GHG emissions.</i>	NS
RGGI (Regional Greenhouse Gas Initiative)	Established in 2005, RGGI is a regional cap and trade program to reduce CO ₂ emissions from power plants. All fossil fuel-fired power plants with a capacity of 25 MW or higher are required to comply with the regional cap. RGGI has set a goal of reducing emissions by an additional 30% compared to 2020 levels by 2030.	Power generation only. <i>Covering about 23% of GHG emissions.</i>	CT ME MA NH NY RI VT
Massachusetts' cap and trade system	Established in 2018, this state-specific cap and trade program runs in parallel to RGGI and establishes a declining limit on CO ₂ emissions from large power plants in Massachusetts. The program is expected to reduce aggregate CO ₂ emissions from these plants 80% below 2018 levels by 2050.	Power generation only. <i>Covering about 16% of GHG emissions.</i>	MA

Sources: C2ES - the Center for Climate and Energy Solutions; Environment and Climate Change Canada (2021); The World Bank - Carbon Pricing Dashboard (2021); The Canadian Institute for Climate Choices - The State of Carbon Pricing in Canada (2021)

¹ Participants in Northeastern Region only

Annual GHG Emissions, 2030 Targets and Carbon Prices



	Annual GHG Emissions ¹ (Mt of CO ₂ e), 2019	GHG Emissions Reduction 2030 Targets	Carbon Price (USD / tCO ₂ e), 2021
Ontario	163	37% below 1990 levels	32
Quebec	84	37.5% below 1990 levels	28
Atlantic provinces	42	N/A	N/A
<i>New Brunswick</i>	12	35% below 1990 levels	32
<i>Newfoundland & Labrador</i>	11	30% below 2005 levels	24
<i>Nova Scotia</i>	16	53% below 2005 levels	20
<i>Prince Edward Island</i>	2	40% below 2005 levels	24
New England	148	N/A	N/A
<i>Connecticut</i>	37	45% below 2001 levels	10
<i>Massachusetts</i>	64	At least 50% below 1990 levels	10
<i>Maine</i>	15	45% below 1990 levels	10
<i>New Hampshire</i>	14	20% below 1990 levels (by 2025)	10
<i>Rhode Island</i>	11	45% below 1990 levels (by 2035)	10
<i>Vermont</i>	6	40% below 1990 levels	10
New York	175	40% below 1990 levels	6

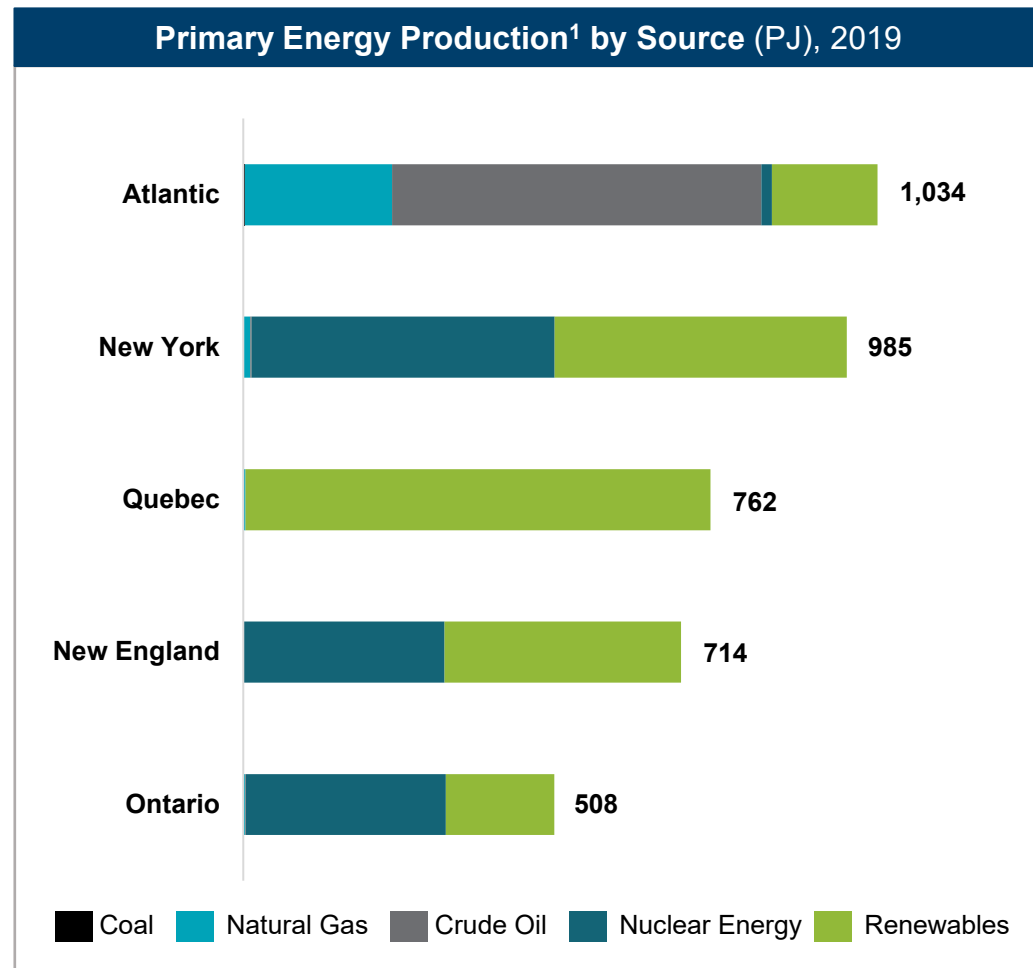
¹ Canadian data includes all GHG emissions (both CO₂ and other greenhouse gases) whereas U.S. data only includes CO₂ emissions, due to the absence of state-level GHG inventory. Approximately 15-20% should be added to US emissions to account for non-CO₂ GHG emissions. CO₂e is "CO₂ equivalent" and measures all GHG as a function of their global warming potential (over 100 years) as compared to CO₂.

Sources: U.S. Energy Information Administration - State Energy Data System (2019); Environment and Climate Change Canada - National Inventory Report Greenhouse Gas Sources and Sinks in Canada (2019); C2ES - the Center for Climate and Energy Solutions - for US and Canada GHG Emissions Targets (2021); The World Bank - Carbon Pricing Dashboard (2021), except for Quebec and New England for which we used the latest 2021 auctions.

2. PRODUCTION & CONSUMPTION

Primary Energy Production by Source

(excluding electricity generated from fossil fuels)

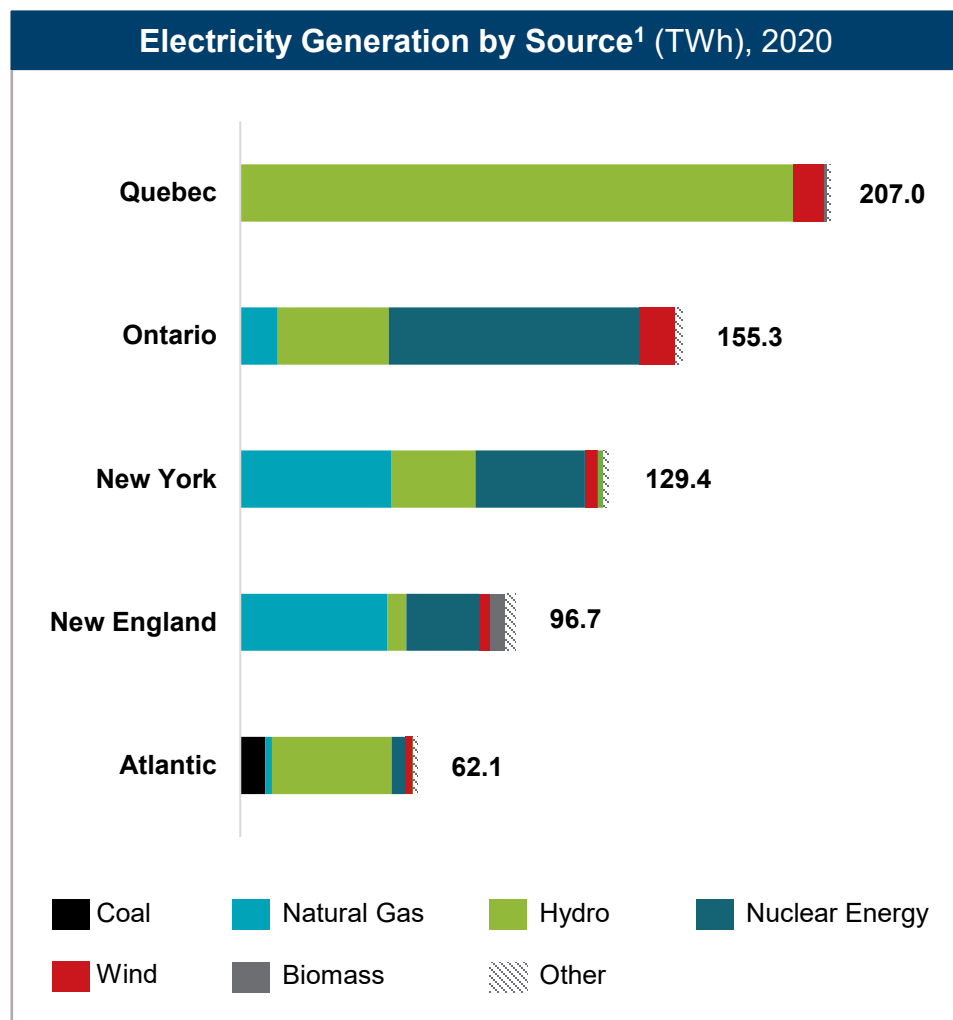


Primary Energy Production ¹ (PJ), 2019	Coal	Natural Gas	Crude Oil	Nuclear Energy	Renewables	Total
Ontario	0	3	1	326	177	508
Quebec	0	4	0	0	758	762
Atlantic provinces	3	240	602	17	172	1,034
<i>New Brunswick</i>	0	2	0	17	15	34
<i>Newfoundland & Labrador</i>	0	211	599	0	148	958
<i>Nova Scotia</i>	3	27	3	0	8	40
<i>Prince Edward Island</i>	0	0	0	0	2	2
New England	0	0	0	328	386	714
<i>Connecticut</i>	0	0	0	184	39	224
<i>Massachusetts</i>	0	0	0	24	78	102
<i>Maine</i>	0	0	0	0	157	157
<i>New Hampshire</i>	0	0	0	120	59	179
<i>Rhode Island</i>	0	0	0	0	9	9
<i>Vermont</i>	0	0	0	0	43	43
New York	0	12	2	494	477	985

¹ See page 5 for definition

Sources: Statistics Canada - Supply and demand of primary and secondary energy in terajoules, annual (2019); Canada Energy Regulator - Provincial and Territorial Energy (2019); Canada Energy Regulator - Canada's Energy Future 2020 ; U.S. Energy Information Administration - State Energy Data System 2019 (data from 2019 or 2018 when not available).

Transformation of Energy - Electricity Generation by Source



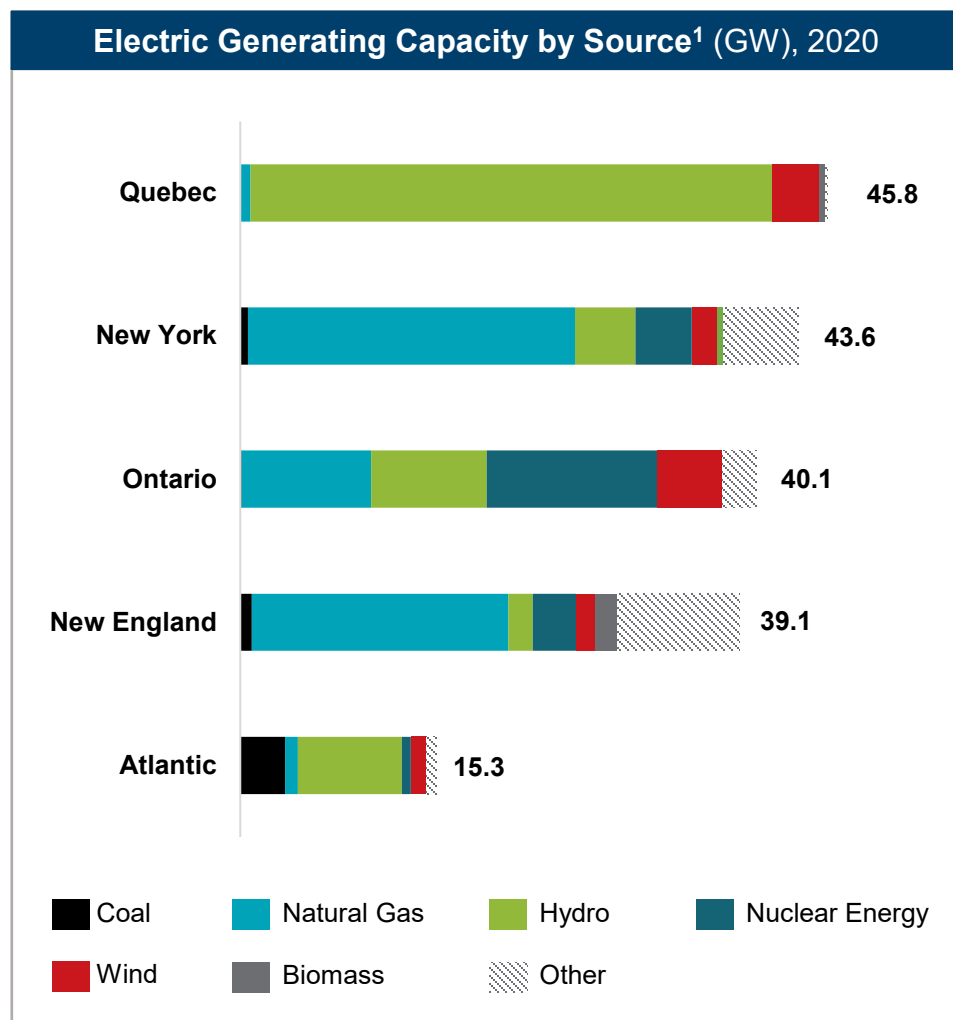
Electricity Generation ¹ (TWh), 2020	Coal	Natural Gas	Hydro	Nuclear Energy	Wind	Bio-mass	Other ²	TOTAL
Ontario	0	13.2	39.0	87.9	12.7	0	2.5	155.3
Quebec	0	0	194.2	0	10.8	1.2	0.8	207.0
Atlantic provinces	8.8	2.4	41.9	4.8	2.6	0	1.6	62.1
<i>New Brunswick</i>	2.9	0.9	2.8	4.8	0.9	0	0	12.3
<i>Newfoundland & Labrador</i>	0	0	38.3	0	0.2	0	1.5	40.0
<i>Nova Scotia</i>	5.9	1.5	0.8	0	0.9	0	0	9.1
<i>Prince Edward Island</i>	0	0	0	0	0.6	0	0.1	0.7
New England	0.1	51.5	6.7	25.6	3.8	5.4	3.6	96.7
<i>Connecticut</i>	0	23.5	0.3	15.7	0	0.8	0.8	41.2
<i>Massachusetts</i>	0	14.2	0.8	0	0.2	1.0	1.9	18.1
<i>Maine</i>	0	1.9	3.2	0	2.4	2.1	0.4	10.0
<i>New Hampshire</i>	0.1	3.6	1.2	9.9	0.5	0.9	0	16.2
<i>Rhode Island</i>	0	8.3	0	0	0.2	0.2	0.2	8.9
<i>Vermont</i>	0	0	1.1	0	0.4	0.5	0.2	2.2
New York	0.1	53.0	29.5	38.4	4.5	2.0	1.9	129.4
TOTAL	9.1	120.1	311.3	156.7	34.5	8.6	10.3	650.5

¹ Electricity generated by Electric Utilities, Independent Power Producers (IPPs) and Industries (i.e., self-generation)

² Other includes Solar, Geothermal, Oil / Petroleum

Sources: Statistics Canada, Electric power generation, monthly generation by type of electricity: Table: 25-10-0015-01 (2021); Statistics Canada, Electric power generating stations, (2020); U.S. Energy Information Administration - Detailed State Data, Electric Power Monthly (2021);

Transformation of Energy - Electric Generating Capacity by Source



Electric Generating Capacity¹ (GW) and Capacity Factors [%], 2020

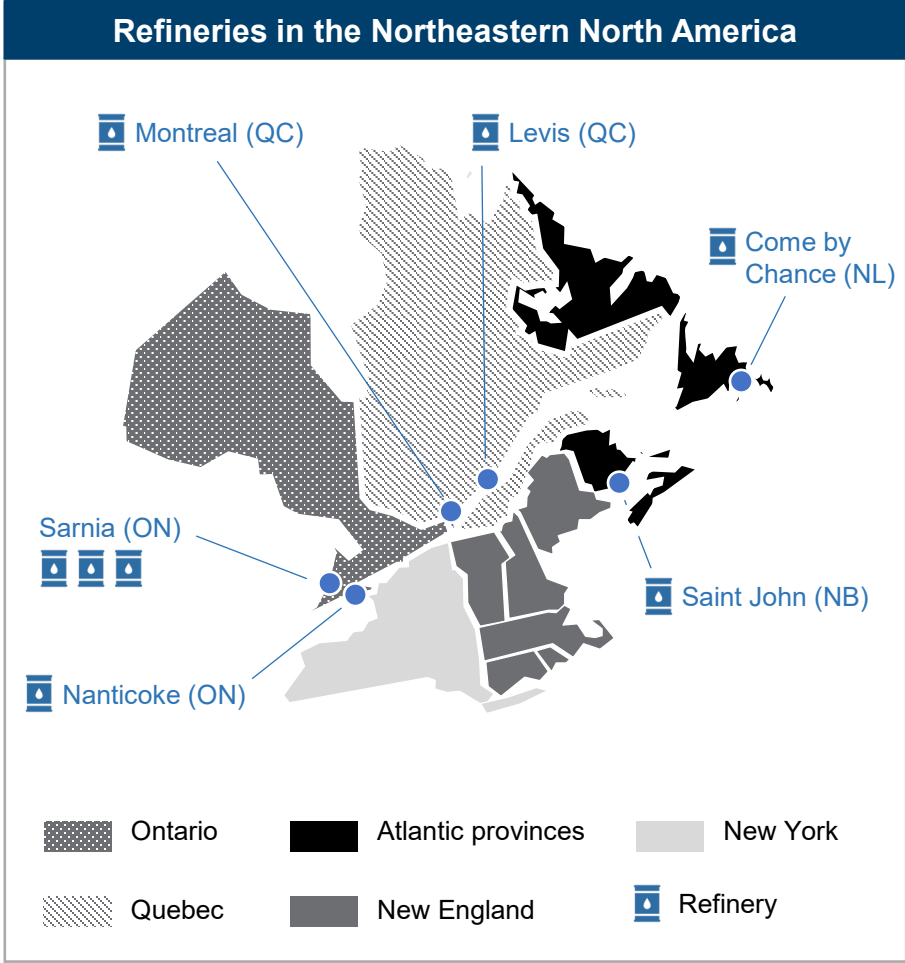
	Coal	Natural Gas	Hydro	Nuclear Energy	Wind	Bio-mass	Other ²	TOTAL
Ontario	0 [N/A]	10.1 [15%]	9.0 [49%]	13.3 [75%]	5.1 [29%]	0 [N/A]	2.6 [11%]	40.1
Quebec	0 [N/A]	0.8 [0%]	40.7 [54%]	0 [N/A]	3.6 [34%]	0.5 [26%]	0.2 [48%]	45.8
Atlantic provinces	3.5 [29%]	1.0 [27%]	8.1 [59%]	0.7 [78%]	1.2 [25%]	0 [N/A]	0.8 [22%]	15.3
<i>New Brunswick</i>	1.8	0.7	1.0	0.7	0.3	0	0	4.5
<i>Newfoundland & Labrador</i>	0	0	6.8	0	0	0	0.6	7.4
<i>Nova Scotia</i>	1.7	0.3	0.4	0	0.6	0	0	3.0
<i>Prince Edward Island</i>	0	0	0	0	0.2	0	0.1	0.3
New England	0.9 [2%]	20.0 [29%]	1.9 [39%]	3.4 [86%]	1.5 [28%]	1.7 [37%]	9.5 [4%]	39.1
<i>Connecticut</i>	0.4	5.9	0.1	2.1	0	0.3	2.5	11.3
<i>Massachusetts</i>	0	8.6	0.3	0	0.1	0.4	5.5	14.7
<i>Maine</i>	0	1.8	0.7	0	1.0	0.6	1.0	5.1
<i>New Hampshire</i>	0.6	1.8	0.5	1.2	0.2	0.3	0.1	4.7
<i>Rhode Island</i>	0	2.0	0	0	0	0	0.2	2.3
<i>Vermont</i>	0	0	0.3	0	0.2	0.1	0.3	0.9
New York	0.6 [3%]	25.5 [24%]	4.7 [72%]	4.4 [99%]	2.0 [26%]	0.5 [43%]	5.8 [4%]	43.6
TOTAL	5.1	57.4	64.5	21.8	13.4	2.7	19.0	184.0

¹ Electric capacity owned by Electric Utilities, Independent Power Producers (IPPs) and Industries (i.e., self-generation)

² Other includes Solar, Geothermal, Oil / Petroleum

Sources: Statistics Canada, Electric power generation, monthly generation by type of electricity: Table: 25-10-0015-01 (2021); Statistics Canada, Electric power generating stations, (2020); U.S. Energy Information Administration - Detailed State Data, Electric Power Monthly (2021);

Transformation of Energy - Oil Refineries



	Number of refineries	Capacity of production (1,000 barrels/day), 2018	Owner (location)
Ontario	4	393	Imperial Oil (Sarnia and Nanticoke) Suncor (Sarnia) Shell (Sarnia)
Quebec	2	372	Suncor (Montreal) Valero (Levis)
Atlantic provinces	2	450	North Atlantic Refinery (Come by Chance, NL) Irving Oil (St John, NB)
New England	0	0	N/A
New York	0	0	N/A

Sources: U.S. Energy Information Administration - State Profile and Energy Estimates (2020); Canada Energy Regulator - Provincial and Territorial Energy Profiles 2020

Estimated Capacity of Electricity Storage

Electricity Storage Capacity by type - Excluding Hydro Reservoir Storage (MWh), 2020

	Pumped Hydro	Batteries	Other Storage Technologies ¹	Total
Ontario	1,044	106	7	1,157
Quebec	0	21	0	21
Atlantic provinces	0	2	0	2
New England	11,482	252	6	11,740
New York	12,000	153	30	12,183

¹ Other storage technologies included are Compressed air, Flywheels and Thermal energy storage
Sources: U.S. DOE Global Energy Storage Database - Sandia (only operational projects included here)

Pumped Hydro: Electricity is used to pump water up to a reservoir. When water is released from the reservoir, it flows down through a turbine to generate electricity.

Batteries: Like common rechargeable batteries, very large batteries can store electricity until it is needed. Battery systems can use lithium ion, lead acid, lithium iron or other technologies.

Other Storage Technologies:

- **Compressed air:** Electricity is used to compress air at up to 1,000 pounds per square inch and store it, often in underground caverns. When electricity demand is high, the pressurized air is released to generate electricity through an expansion turbine generator
- **Flywheels:** Electricity is used to accelerate a rotor through which the energy is conserved as kinetic rotational energy. When needed, the spinning force is used to turn a generator.
- **Thermal energy storage:** Electricity can be used to produce thermal energy which can be stored until it is needed. For example, electricity can be used to produce chilled water or ice during times of low demand and later used for cooling during periods of peak electricity consumption.

Estimated Hydro Reservoir Storage Capacity (TWh), 2020

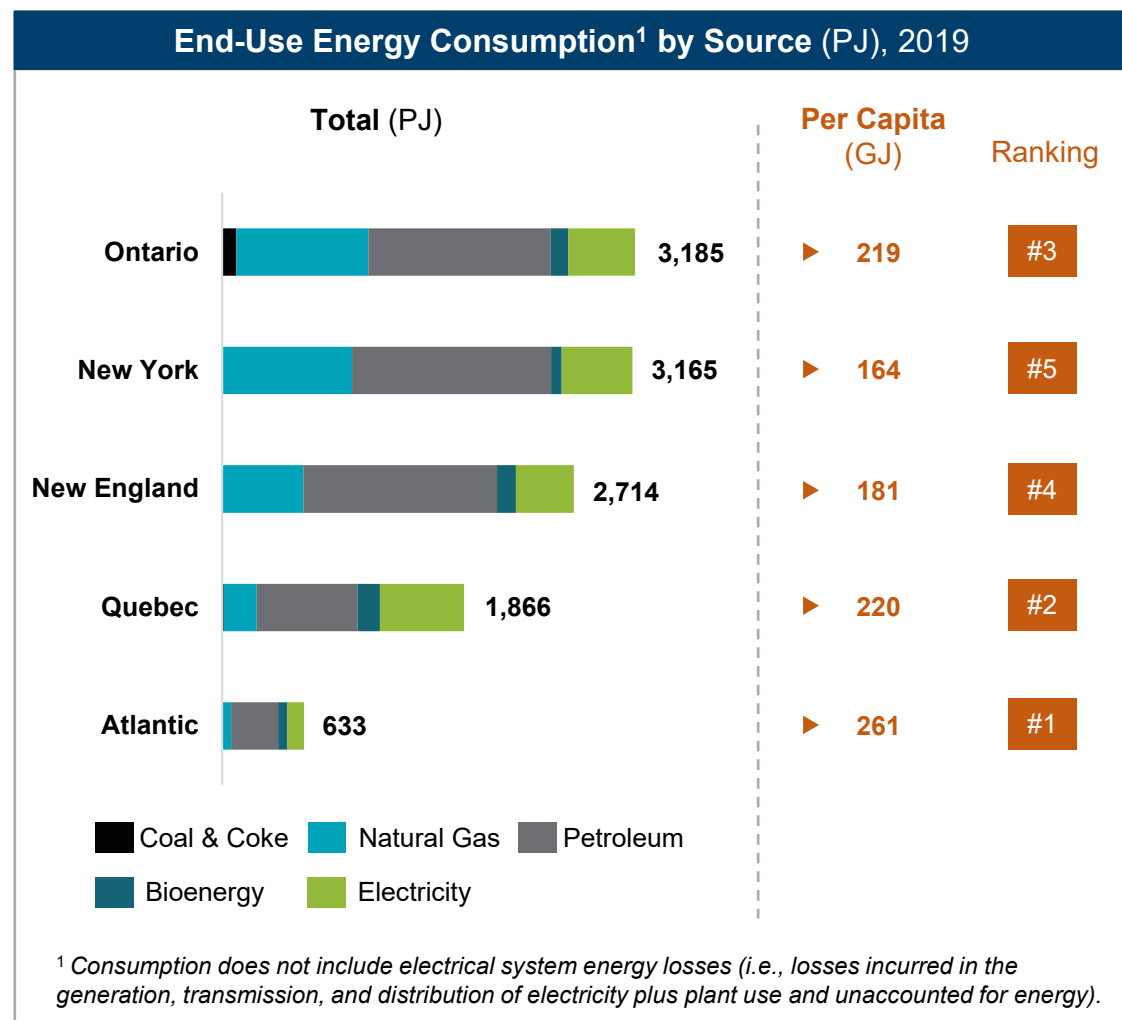
	Hydro Reservoir Storage ²
Ontario	2.2
Quebec	228.0
Atlantic provinces	28.3
New England	Not available (but very limited)
New York	Not available (but very limited)

² The maximum capacity of energy storage hydro reservoirs has been estimated using calculation from Study Report No.1 (2017) of the HEC Montreal's Chair of Energy Sector Management.
Sources: Global Reservoir and Dam Database (GRanD); Hydropower, The Engineering Toolbox (2016)

Hydro Reservoir Storage:

- Some hydropower plants include a dam and a reservoir to impound water. Reservoirs act like giant batteries that provide energy when needed. Hydropower operators use the stored water in the reservoirs behind the dam to adjust the amount of water flowing through the turbines to match electricity use.
- Water stored in reservoirs provides flexibility to generate electricity on demand and reduces dependence on the variability of inflow. The consistent availability of hydropower helps support other more variable types of renewable energy sources such as wind. Dams can quickly ramp up to provide more electricity when the wind drops and can scale back generation when the wind picks up again.
- Very large reservoirs can store inflow for months or even years.
- Different constraints exist on how reservoirs can be used, notably the requirement to maintain minimum water flows in rivers.

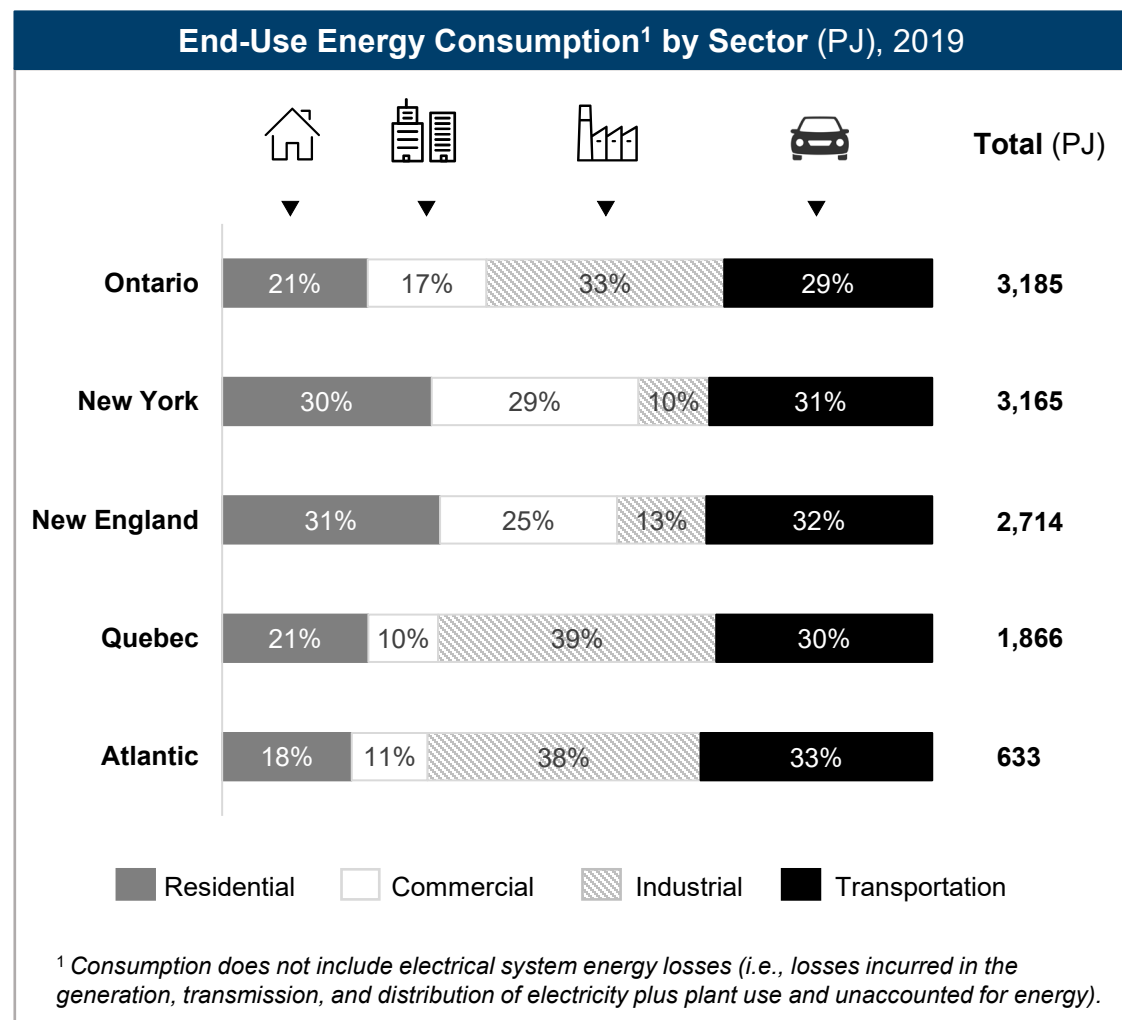
End-Use Energy Consumption by Source







Energy Consumption ¹ (PJ), 2019	Coal & Coke	Natural Gas	Petroleum	Bioenergy	Electricity	Total
Ontario	110	1,018	1,405	139	514	3,185
Quebec	13	254	778	172	650	1,866
Atlantic provinces	5	65	362	69	132	633
<i>New Brunswick</i>	1	26	134	35	49	246
<i>Newfoundland & Labrador</i>	3	27	100	11	38	179
<i>Nova Scotia</i>	1	11	111	21	39	183
<i>Prince Edward Island</i>	0	1	17	2	6	26
New England	1	628	1,429	209	447	2,714
<i>Connecticut</i>	0	153	317	12	107	610
<i>Massachusetts</i>	0	343	615	27	206	1,201
<i>Maine</i>	1	39	172	98	44	343
<i>New Hampshire</i>	0	31	158	30	40	259
<i>Rhode Island</i>	0	47	84	4	28	163
<i>Vermont</i>	0	15	84	28	21	139
New York	9	994	1,474	143	545	3,165

Sources: Statistics Canada - Supply and demand of primary and secondary energy in terajoules, annual (2019); Canada Energy Regulator - Provincial and Territorial Energy (2019); Canada Energy Regulator - Canada's Energy Future 2020; U.S. Energy Information Administration - State Energy Data System 2019 (data from 2019 or 2018 when not available).

End-Use Energy Consumption by Sector



Energy Consumption ¹ (PJ), 2019					Total
	Residential	Commercial	Industrial	Transportation	
Ontario	654	533	1,065	933	3,185
Quebec	384	184	731	567	1,866
Atlantic provinces	116	68	243	207	633
<i>New Brunswick</i>	36	29	127	54	246
<i>Newfoundland & Labrador</i>	27	12	80	61	179
<i>Nova Scotia</i>	47	24	32	80	183
<i>Prince Edward Island</i>	6	3	5	12	26
New England	833	676	341	864	2,714
<i>Connecticut</i>	199	155	62	194	610
<i>Massachusetts</i>	354	335	118	394	1,201
<i>Maine</i>	95	60	92	95	343
<i>New Hampshire</i>	85	57	33	84	259
<i>Rhode Island</i>	52	41	19	51	163
<i>Vermont</i>	48	26	17	47	139
New York	935	921	315	994	3,165

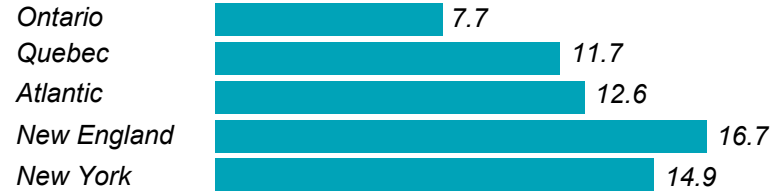
Sources: Statistics Canada - Supply and demand of primary and secondary energy in terajoules, annual (2019); Canada Energy Regulator - Provincial and Territorial Energy (2019); Canada Energy Regulator - Canada's Energy Future 2020 ; U.S. Energy Information Administration - State Energy Data System 2019 (data from 2019 or 2018 when not available).

3. PRICES & TRADING

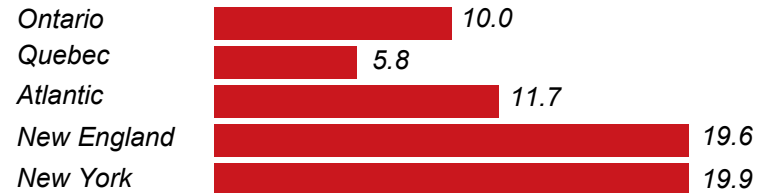
Energy Prices and Tax Comparison

Energy Prices Comparison

Residential Gas Price (USD, \$ per thousand cu ft)



Residential Electricity Price (USD, cents per kWh)



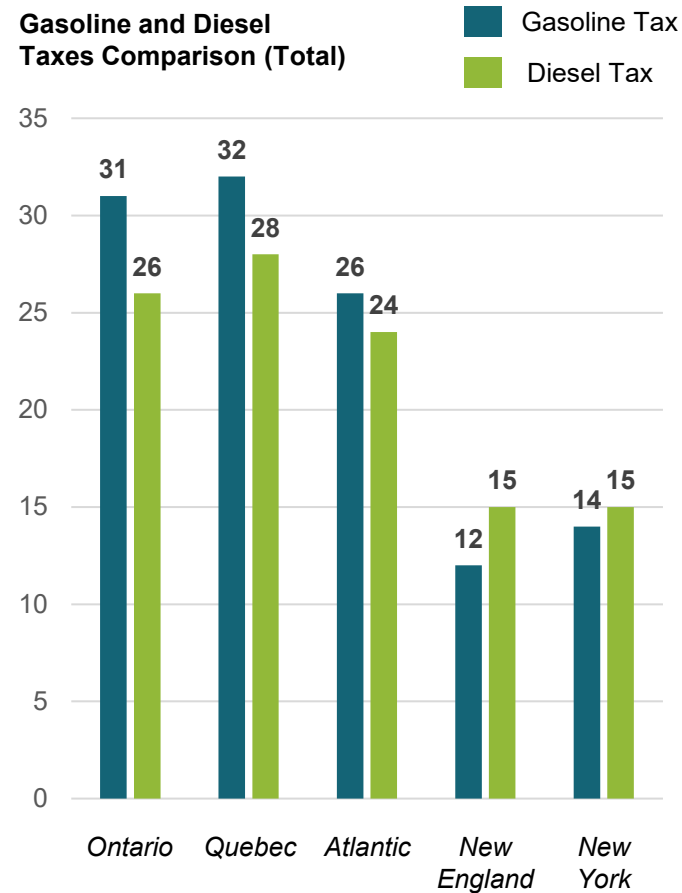
Gasoline Retail Price (USD, \$ per liter)



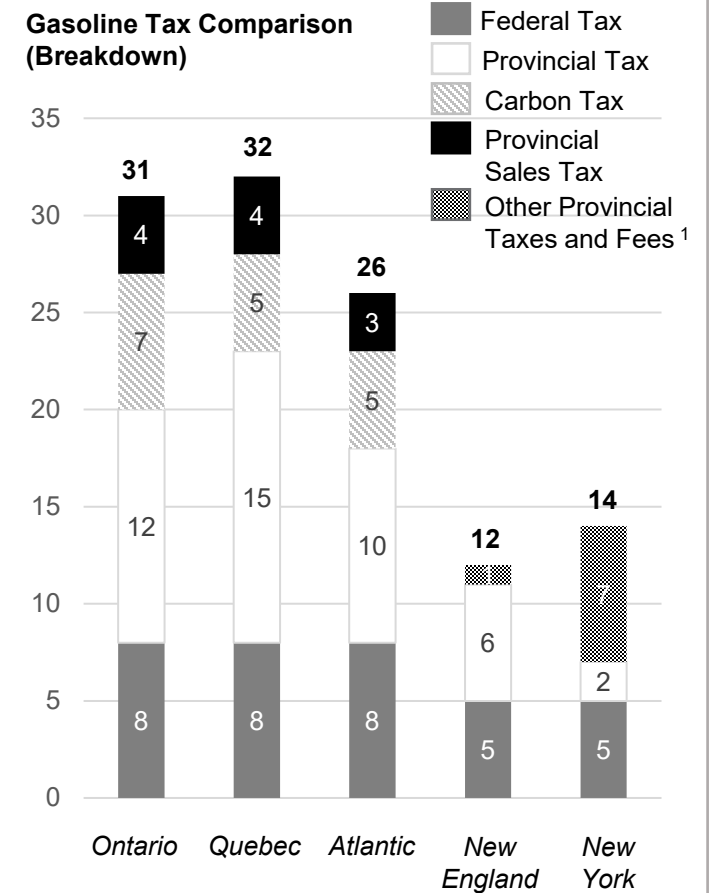
Sources: Canada Energy Regulator - Canada's Energy Future 2020; Energyhub - Electricity Prices in Canada (2021); Statistics Canada - Monthly average retail prices for gasoline (august 2021); U.S. EIA - State Energy Data System 2019 and Gasoline and Diesel Fuel Update (august 2021).

Fuel Tax Comparison (USD, cents per liter) 2021

Gasoline and Diesel Taxes Comparison (Total)



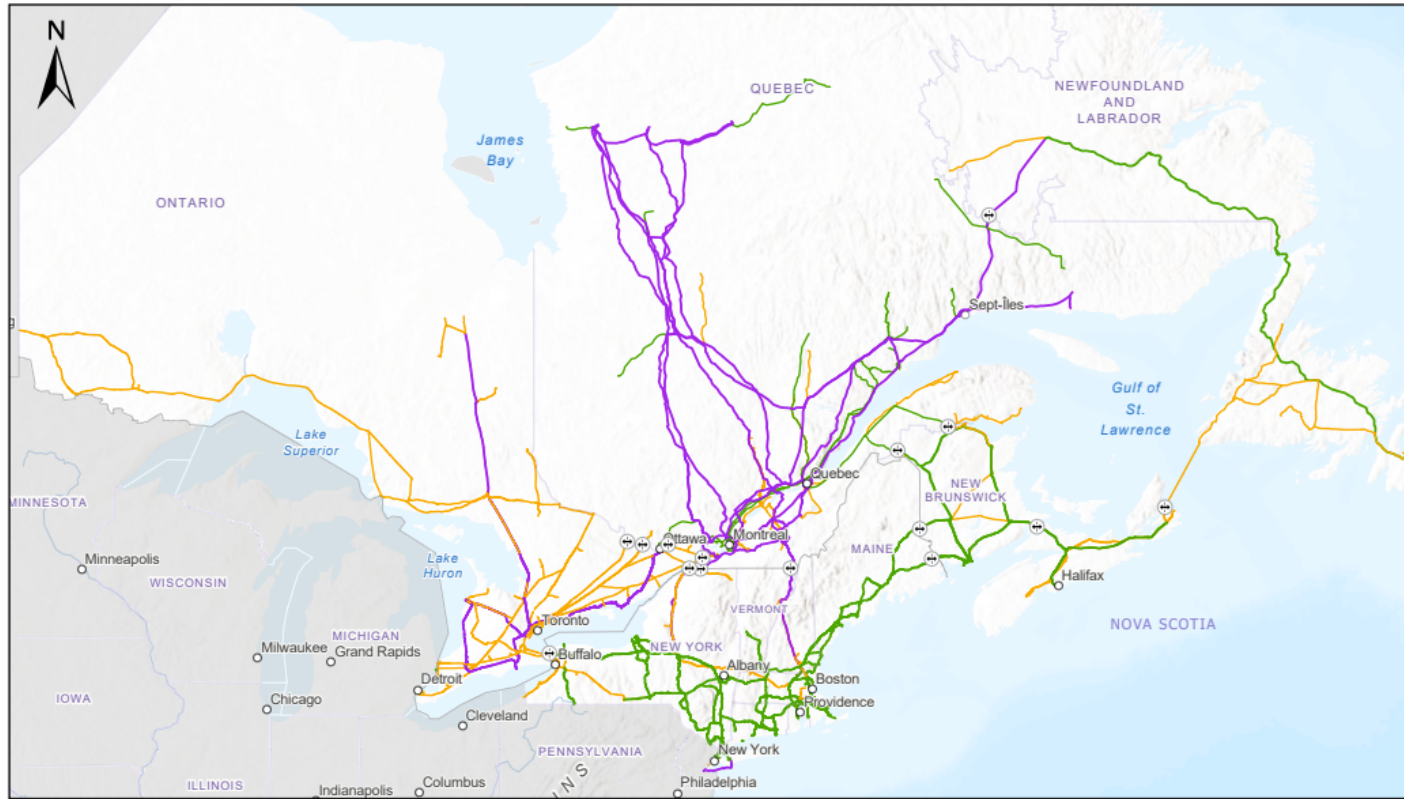
Gasoline Tax Comparison (Breakdown)



¹ May include sales and/or use taxes, inspection fees, environmental fees, or other charges

Sources: U.S. EIA - Federal and state motor fuels taxes (2021); NR Canada - Fuel Consumption Levies in Canada (2021)

Energy Infrastructure - Electric Transmission Lines and Interties



Map of Transmission Lines
Carte des lignes de transmission
Northeast Region - Région du Nord-Est

Background Map Data Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCAN, Parks Canada, Esri, USGS.
Pipeline Data Source: Energin (2020), Canada Energy Regulator (2020), U.S. Energy Information Administration (2020), Ontario Ministry of Natural Resources and Forestry (2020).

Homeland Infrastructure Foundation Level Database (2020), Open Street Map (2020), IESO (2020), New Brunswick (2020), Nova Scotia Power (2020), Hydro-Quebec (Multiple documents)

Coordinate System / Projection: WGS 1984 World Mercator

Chair in Energy Sector
Management
HEC MONTRÉAL

Prepared by /
Préparé par: **PEG Strategy**

Date: 10 décembre 2020

Legend / Légende

- ⊕ Interconnection - Interconnexion
- Transmission Line - Ligne de transmission
- 450 kV, DC or - ou 500/735/765 kV
- 345 kV
- 230 kV

0 345 690 Mi
0 500 1,000 Km

Electricity Exports and Interties, 2020

Actual Energy Exports in 2020 (TWh)

Max. Export Capacity (MW)

FROM \ TO	Ontario	Quebec	Atlantic	New England	New York
Ontario		1.9 1,970	0 0	0 0	7.4 1,950
Quebec	5.4 2,705		3.7 1,200	15.3 2,355	9.1 1,999
Atlantic provinces	0 0	30 5,925		3 700 *	0 0
New England	0 0	0 2,170	0.1 400		5.5 1,400
New York	0 1,800	0 1,100	0 0	11.1 1,400	

* The transfer capability is 1,000 MW but modeled as 700 MW to reflect NE constraints.

Sources: Canada Energy Regulator Annual Electricity Export Flows to the US (2020); IESO Imports and Exports (2020); Hydro-Quebec Exports (2020); NYISO Real-Time Transactions by Control Area and Proxy Bus (2020); ISO-NE Net Energy and Peak Load by Source (2020); NPCC Long Range Adequacy Overview (2020); OATI - OASIS Website (2021)

Energy Infrastructure - Oil & Gas Transmission Pipelines



Map of Pipelines
Carte des pipelines
Northeast Region - Région du Nord-Est

Background Map Data Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCAN, Parks Canada, Esri, USGS.
Pipeline Data Source: Energinr (2020), Canada Energy Regulator (2020), U.S. Energy Information Administration (2020), Ontario Ministry of Natural Resources and Forestry (2020).

Coordinate System / Projection: WGS 1984 World Mercator

Chair in Energy Sector
Management
HEC MONTRÉAL

Prepared by /
Préparé par: **PEG Strategy**

Date: 10 décembre 2020

Legend / Légende

- + Border Crossing (Natural Gas) / Interconnexion (Gaz naturel)
- + Border Crossing (Liquid) / Interconnexion (Liquide)
- Petroleum Product Terminal / Terminal de produits pétroliers
- Crude Oil Pipeline / Oléoduc de pétrole brut
- Petroleum Product Pipeline / Pipeline de produits pétroliers
- Natural Gas Pipeline / Gazoduc
- Hydrocarbon Gas Liquid / Liquides de gaz d'hydrocarbures

0 280 560 Mi
0 500 1,000 Km

Petroleum and crude oil terminal in the Northeast region

	# Petroleum Ports	City
Ontario	0	N/A
Quebec	3	Quebec Montreal Sainte Victoire
Atlantic provinces	2	Come by Chance (NL) St John (NB)
New England	7	New Haven (CT) Bridgeport (CT) Boston (MA) Portland (ME) Searsport (ME) Portsmouth (NH) Providence (RI)
New York	4	New York Glen Cove Port Jefferson Albany

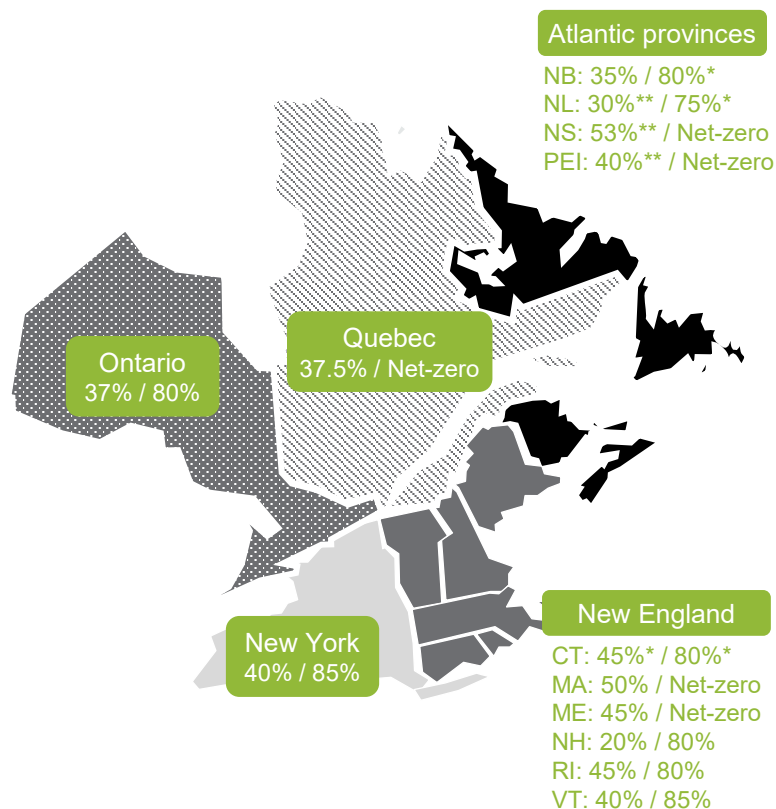
	# Crude oil terminals	City
Ontario	0	N/A
Quebec	0	N/A
Atlantic provinces	0	N/A
New England	1	Portland
New York	1	Albany

Sources: U.S. Energy Information Administration - U.S. Energy Mapping System 2018; Oils and Sands Magazine - Oil Transport Marine Terminals

4. CLEAN ENERGY TARGETS & POLICIES

GHG Emissions and Renewable Electricity Targets

GHG Emissions Reduction Targets (2030 / 2050)

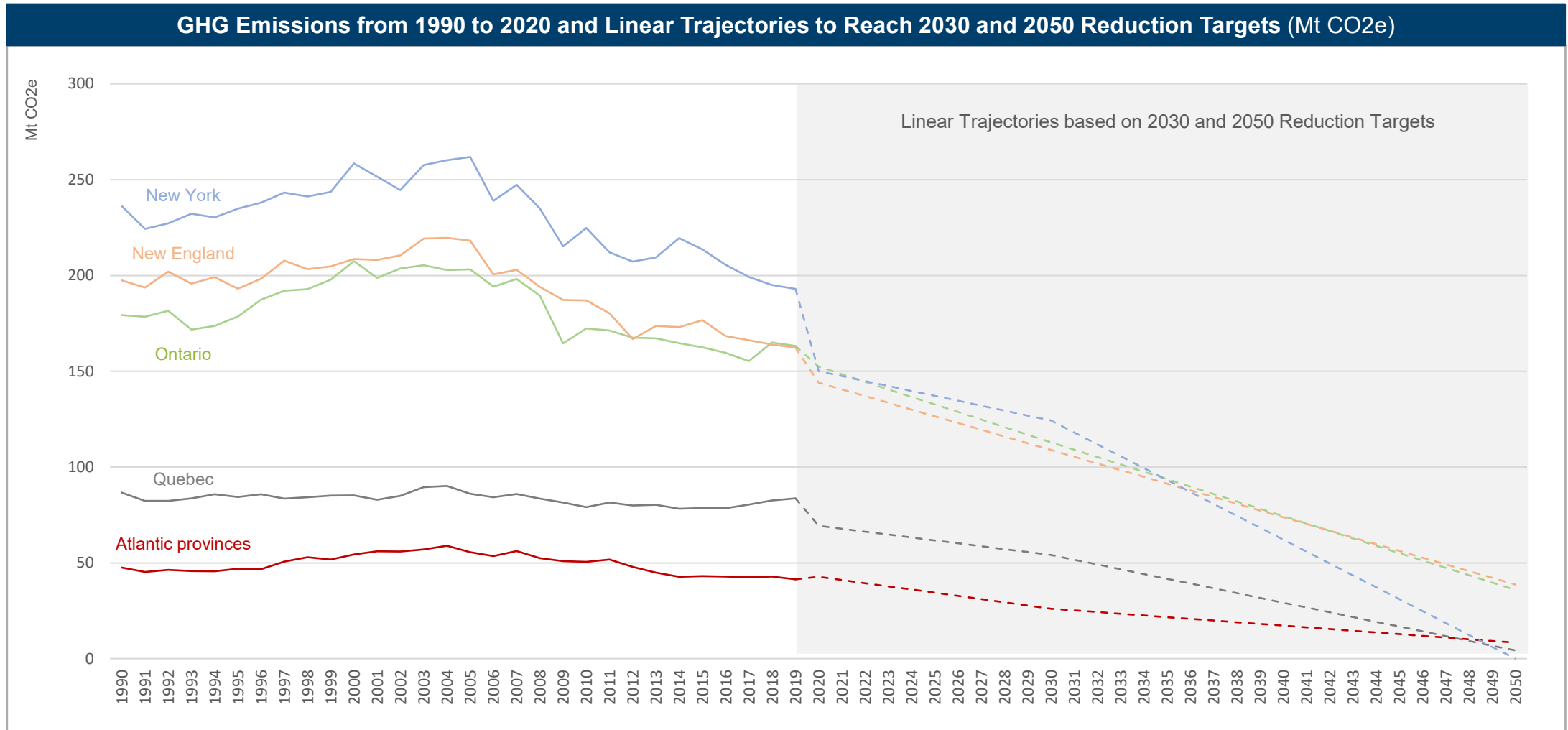


Note: GHG emissions targets are measured below 1990 levels except for * (below 2002 levels) and ** (below 2005 levels)

	GHG Emissions Reduction Targets		Renewable Electricity Targets
	2030	2050	
Ontario	37% below 1990 levels	80% below 1990 levels	Already at 96% (incl. nuclear)
Quebec	37.5% below 1990 levels	Net-zero	Already at 99%
Atlantic provinces	N/A	N/A	N/A
<i>New Brunswick</i>	<i>35% below 1990 levels</i>	<i>80% below 2001 levels</i>	<i>40% by 2020; new target TBA</i>
<i>Newfoundland & Labrador</i>	<i>30% below 2005 levels</i>	<i>75-85% below 2001 levels</i>	<i>Already at 94%</i>
<i>Nova Scotia</i>	<i>53% below 2005 levels</i>	<i>Net-zero</i>	<i>40% by 2022</i>
<i>Prince Edward Island</i>	<i>40% below 2005 levels</i>	<i>Net-zero (by 2040)</i>	<i>Already at 99%</i>
New England	N/A	N/A	N/A
<i>Connecticut</i>	<i>45% below 2001 levels</i>	<i>80% below 2001 levels</i>	<i>44% by 2030 and 100% by 2040</i>
<i>Massachusetts</i>	<i>At least 50% below 1990 levels</i>	<i>Net-zero</i>	<i>35% by 2030</i>
<i>Maine</i>	<i>45% below 1990 levels</i>	<i>Net-zero</i>	<i>80% by 2030 and 100% by 2050</i>
<i>New Hampshire</i>	<i>20% below 1990 levels (by 2025)</i>	<i>80% below 1990 levels</i>	<i>25% by 2025</i>
<i>Rhode Island</i>	<i>45% below 1990 levels (by 2035)</i>	<i>80% below 1990 levels</i>	<i>38.5% by 2035</i>
<i>Vermont</i>	<i>40% below 1990 levels</i>	<i>80% below 1990 levels</i>	<i>75% by 2032</i>
New York	40% below 1990 levels	At least 85% below 1990 levels	70% by 2030 and 100% by 2040

Sources: C2ES - the Center for Climate and Energy Solutions - for US and Canada GHG Emissions Targets (2021); Energyhub - Clean Energy Targets Canada (2021); National Conference of State Legislatures (NCSL) - State Renewable Portfolio Standards and Goals (2021)

Historical GHG Emissions and Linear Trajectories to Reach Targets



Sources: U.S. Energy Information Administration - State Energy Data System (2019); Environment and Climate Change Canada - National Inventory Report Greenhouse Gas Sources and Sinks in Canada (2019); C2ES - the Center for Climate and Energy Solutions (2021) for US and Canada GHG Emissions Targets

5. KEY INSTITUTIONS & COMPANIES

Electric Sector | Canada

	REGULATOR	SYSTEM PLANNING ¹	SYSTEM OPERATION ²	GENERATION	TRANSMISSION	DISTRIBUTION	RETAIL	Sources
Ontario	Ontario Energy Board (OEB)	Independent Electricity System Operator (IESO)	Independent Electricity System Operator (IESO)	Ontario Power Generation Bruce Power + a total of 228 licensed electricity generators	Hydro One + 9 licensed electricity transmitters	Hydro One + 68 licensed electricity distributors	7 Retailers	OEB (2021)
Quebec	Régie de l'énergie du Québec	<i>Integrated with the vertically-integrated generation and transmission company</i>	<i>Integrated with the vertically-integrated generation and transmission company</i>	Hydro-Quebec + Purchase Agreements: 39 wind, 23 biomass, 46 hydro	Hydro-Quebec TransEnergie	Hydro-Quebec + Municipally owned electric utilities (9) Cooperative (1)	N/A	Hydro-Quebec (2020) MERN (2019)
New Brunswick	New Brunswick Energy and Utilities Board			NB Power + Purchase Agreements: 4 wind, 4 biomass, 2 hydro, 1 natural gas	NB Power	NB Power	N/A	NB Power (2020)
Newfoundland & Labrador	Newfoundland & Labrador Board of Commissioners of Public Utilities			NL Hydro (Nalcor) Newfoundland Power + 3 IPPs	NL Hydro + Newfoundland Power	NL Hydro + Newfoundland Power	N/A	NL Hydro (2021) Government of Newfoundland and Labrador (2021)
Nova Scotia	Nova Scotia Utility and Review Board			Nova Scotia Power + 2 IPPs	Nova Scotia Power	Nova Scotia Power	N/A	Emera (2021)
Prince Edward Island	Island Regulatory and Appeals Commission			PEI Energy Corporation + Engie + City of Summerside	Maritime Electric + PEI Energy Corporation	Maritime Electric	N/A	Gvt. of PEI (2021) Maritime Electric (2021) PEI Energy Corp. (2021)

¹ In charge of the Integrated Bulk System Planning Process (note: distribution system planning is led by the Local Distribution Companies)

² In charge of managing the Bulk Power System in real-time

Electric Sector | United States

	REGULATOR	SYSTEM PLANNING ¹	SYSTEM OPERATION ²	GENERATION	TRANSMISSION	DISTRIBUTION	RETAIL	Sources
Connecticut	CT Public Utilities Regulatory Authority	ISO New England (ISO-NE) <i>with the support of transmission companies and dedicated state-level planning entities (e.g., CT Dpt. of Energy & Environmental Protection, MA Department of Energy Resources)</i>	ISO New England (ISO-NE)	Dominion Energy + PSEG + multiple IPPs	Eversource + Avangrid	Eversource + Avangrid + Municipally owned electric utilities (5)	7 Retailers	U.S. EIA State Electricity Profiles (2021) Regulator websites (2021)
Massachusetts	MA Department of Public Utilities			Entergy + multiple IPPs	National Grid + Eversource + Unitil	Eversource + Unitil + National Grid + Municipally owned electric utilities (41)	11 Retailers	
Maine	ME Public Utilities Commission			Multiple IPPs (e.g. Calpine, Great Lakes Hydro)	Avangrid + Versant Power + EMEC (coop)	Avangrid + Emera Maine + Municipally owned electric utilities (9)	12 Retailers	
New Hampshire	NH Public Utilities Commission			NextEra + multiple IPPs	National Grid + Eversource	Eversource + Liberty Utilities + Unitil + NHEC	16 Retailers	
Rhode Island	RI Public Utilities Commission			Dominion Energy + multiple IPPs	National Grid	National Grid + Municipally owned electric utilities (2)	6 Retailers	
Vermont	VT Public Utility Commission			Great River Hydro + Green Mountain Power + City of Burlington Elec.	VELCO + National Grid	Green Mountain Power + Municipally owned electric utilities (14), Cooperatives (2)	N/A	
New York	NY Department of Public Service	New York ISO (NYISO) <i>with the support of New York State Energy R&D Authority (NYSERDA)</i>	New York ISO (NYISO)	New York Power Authority (NYPA) + Exelon + Entergy + PSEG + multiple IPPs	National Grid	Consolidated Edison + LIPA, Eversource, National Grid CHG&E, NYSEG + Municipally owned electric utilities (26)	~ 100 retailers	

¹ In charge of the Integrated Bulk System Planning Process (note: distribution system planning is led by the Local Distribution Companies)

² In charge of managing the Bulk Power System in real-time

Natural Gas Sector

	REGULATOR	PRODUCTION ¹	TRANSMISSION	DISTRIBUTION	RETAIL	Sources
Ontario	Ontario Energy Board	N/A (very limited production)	TC Energy (Canadian Mainline)	Enbridge Gas, EPCOR Natural Gas	8 Retailers	Regulator websites (2021) Utilities websites (2021)
Quebec	Régie de l'énergie du Québec	N/A	TC Energy (TQM)	Energir, Gazifère	N/A	
New Brunswick	New Brunswick Energy and Utilities Board	N/A (very limited production)	M&NP (JV of Enbridge, Emera and ExxonMobil)	Enbridge Gas New Brunswick, Liberty Utilities	N/A	
Newfoundland & Labrador	N/A	4 offshore operators ² (Hibernia, Suncor, Husky, ExxonMobil)	N/A	N/A	N/A	
Nova Scotia	Nova Scotia Utility and Review Board	N/A (very limited production)	M&NP	Heritage Gas	N/A	
Prince Edward Island	N/A	N/A	N/A	N/A	N/A	
Connecticut	CT Public Utilities Regulatory Authority	N/A	Tennessee gas (Kinder Morgan) Algonquin Gas	Eversource, Avangrid	13 Retailers	
Massachusetts	MA Department of Public Utilities	N/A	Tennessee gas Algonquin Gas	Eversource, Liberty Utilities, National Grid, Unitil + Municipally owned gas utilities (4)	17 Retailers	
Maine	Maine Public Utilities Commission	N/A	M&NP TC Energy	Avangrid, Unitil, Bangor Gas Company, Summit Natural Gas of Maine	N/A	
New Hampshire	New Hampshire Public Utilities Commission	N/A	M&NP, Tennessee gas TC Energy	Unitil, Liberty Utilities	5 Retailers	
Rhode Island	RI Public Utilities Commission	N/A	Algonquin Gas	National Grid	N/A	
Vermont	VT Public Utility Commission	N/A	Vermont Gas	Vermont Gas	N/A	
New York	NY Department of Public Service	N/A (very limited production)	Tennessee gas	Consolidated Edison, CHG&E, NYSEG + 15 other licensed distributors	15 retailers	

¹ Excluding the marginal production of biogas and renewable natural gas

² Natural gas used for power at the offshore crude oil facilities, reinjected into the ground to maintain reservoir pressure, or flared

6. APPENDIX

List of Natural Gas Pipelines

Name	Start	End	Provinces/States served	Companies
Réseau principal de TransCanada	AB	QC	Ontario, Quebec	Energy TC
Réseau du Gazoduc Trans Quebec et Maritimes	Saint-Lazare, QC	Levis, QC East Hereford, QC	Quebec	Energy TC Energir
Gazoduc Brunswick	Saint John, NB	St. Stephen, NB	New Brunswick	Emera Brunswick Pipeline Company Ltd.
Texas Eastern Transmission	Texas	State of New York	New York	Enbridge
Algonquin Gas Transmission	State of New York	MA near Beverly	New York Connecticut Rhode Island Massachusetts	Enbridge
Maritimes & Northeast Pipeline	Goldboro, NS	MA near Beverly	Nova Scotia New Brunswick Maine New Hampshire Massachusetts	Enbridge
Iroquois Gas Transmission	Canadian border at Waddington, NY	Bronx, New York	New York Connecticut	TC PipeLines, LP TransCanada PipeLines USA Ltd. Dominion Energy, Inc.
Portland Natural Gas Transmission System	Pittsburg, NH	Westbrook, ME	New Hampshire Maine Massachusetts	Enbridge
Tennessee Gas Pipeline	Louisiana	NH	New York Connecticut Rhode Island New Hampshire Massachusetts	Kinder Morgan
Granite State Gas	MA-NH border	Portland, ME	New Hampshire Maine Massachusetts	Unitil (transport gas for other pipeline companies)
Millennium Pipeline Co.	New York State	New York State	New York (intrastate)	TC Energy National Grid DTE Energy
Columbia Gas Trans Co.	New York State	Virginia Ohio	New York	TC Energy
National Fuel Gas Supply Co.	Pennsylvania State	NY-Ontario border	Ontario New York	National Fuel Gas Supply Corporation (transport gas for other pipeline companies)

Sources: Natural Resources Canada - Natural Gas Facts (2020); Canada Energy Regulator - Pipelines profiles; U.S. Energy Information Administration - Energy Mapping System; Enbridge – Infrastructures Map; Kinder Morgan - Eastern Gas Pipeline; Northeast Gas - Description of Pipelines/LNG Import Facilities Serving the Northeast Market; TC Energy - Millennium Pipeline, Columbia Gas Transmission, Iroquois Gas Transmission System

List of Petroleum Product Pipelines

Name	Start	End	Provinces/States served	Companies
Pipeline Portland - Montreal	Portland, ME	Montreal, QC	Quebec Maine	Montreal Pipeline Ltd. (Canada) Portland Pipeline (US)
Réseau principal Trans-Nord	Montreal, QC	Nanticoke, ON	Quebec Ontario	Trans Northern Pipeline Inc.
Line 9	Sarnia, ON	Montreal, QC	Quebec Ontario	Enbridge
Portland-Bangor	Portland, ME	Bangor, ME	Maine	BuckeyePartner
Connecticut	New Haven, CT	Westover AFB Terminal, MA	Connecticut Massachusetts	BuckeyePartner
Buckeye Pipeline	Pennsylvania	Northwest of New York State (Rochester & Utica) LaGuardia Airport (NY)	New York	BuckeyePartner
Buffalo Pipeline	Pennsylvania	Buffalo, NY	New York	Sunoco

Sources: Natural Resources Canada - Crude Oil Facts (2020); Canada Energy Regulator - Pipelines profiles Montreal, Trans-Northern; U.S. Energy Information Administration - Energy Mapping System; Buckeye Partner – System Map