Quantifying Canada's Clean Energy Economy

A forecast of clean energy investment, value-added and jobs

SUBMITTED TO

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About Us

Navius Research Inc. ("Navius") is a private consulting firm in Vancouver. Our consultants specialize in analysing government and corporate policies designed to meet environmental goals, with a focus on energy and greenhouse gas emission policy. They have been active in the energy and climate change field since 2004, and are recognized as some of Canada's leading experts in modeling the environmental and economic impacts of energy and climate policy initiatives. Navius is uniquely qualified to provide insightful and relevant analysis in this field because:

- We have a broad understanding of energy and environmental issues both within and outside of Canada.
- We use unique in-house models of the energy-economy system as principal analysis tools.
- We have a strong network of experts in related fields with whom we work to produce detailed and integrated climate and energy analyses.
- We have gained national and international credibility for producing sound, unbiased analyses for clients from every sector, including all levels of government, industry, labour, the non-profit sector, and academia.

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Summary

Clean Energy Canada engaged Navius Research to define the extent of the clean energy economy in Canada. This analysis is intended to (1) help Clean Energy Canada promote a broader dialogue about benefits of expanding clean energy and (2) contribute to the development of methodologies to refine future data collection efforts.

The objective of this project is to quantify, where possible, the GDP, investment and employment in each clean energy sector of Canada's economy. The first component of this work examined historical trends in clean energy and was released in May of 2019[1]. This second report provides a forecast of clean energy growth to 2030.

What is the clean energy economy?

This report defines the clean energy economy as:

> *"The technologies, services and resources that increase renewable energy supply, enhance energy productivity, improve the infrastructure and systems that transmit, store and use energy while reducing carbon pollution."*

A detailed taxonomy of clean energy sectors is provided in the previous report.

Please note that the modeling reflects a different methodology for estimating clean energy activity than was used for the historical analysis. The use of different methodologies helps to triangulate clean energy economy estimates. For a discussion about differences between the methodologies, please see Chapter 4.

[1] Clean Energy Canada. 2019. Missing the Bigger Picture: Tracking the Energy Revolution. Available from: https://cleanenergycanada.org/report/missing-the-bigger-picture

Our modeling toolkit

This report presents a forecast of clean energy economic activity to 2030. The forecast is developed in Navius' gTech model and accounts for the following factors:

- The competitiveness of energy technologies that are available and likely to become commercially available over the next decade (e.g. battery electric vehicles, high efficiency clothes washers and methane controls).
- Realistic firm and consumer decision-making regarding technology acquisition (e.g. aversion to large up-front capital costs).
- Energy and climate mitigation policies that are implemented or announced at the federal and provincial levels of government (a list of modeled policies is provided in Appendix B: "Clean energy policies in Canada").
- The multitude of economic interactions between provinces in Canada and with the US and rest of the world.

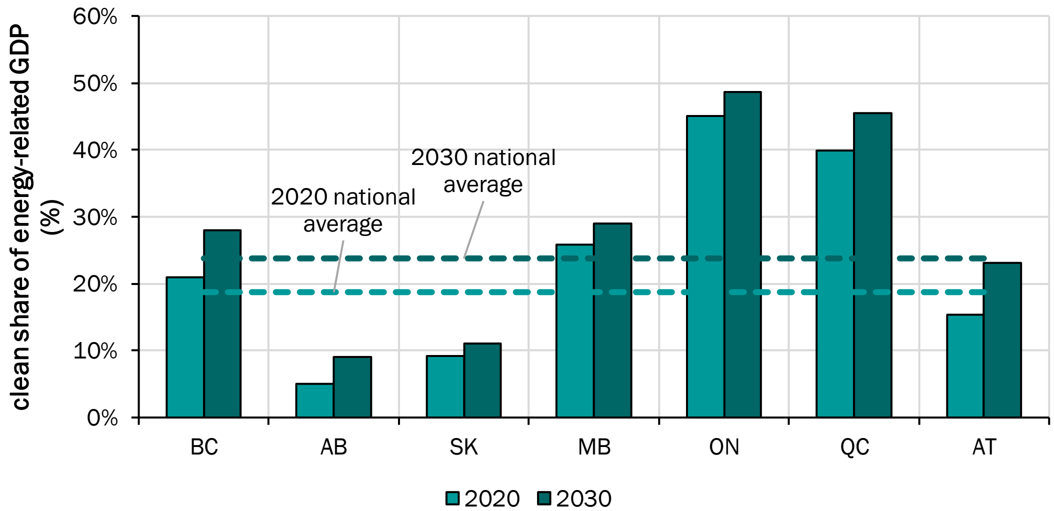
How is the clean energy economy likely to grow through 2030?

In sum:

- Clean energy GDP rises from $54.9 billion (2010$) in 2020 to $77.4 billion (2010$) in 2030, reflecting at an average annual growth rate of 3.4%. All clean energy sectors experience growth over this period except nuclear power.
- Clean energy investment and consumption increase from $28.6 billion (2018$) in 2020 to $38.2 billion (2018$) in 2030, reflecting an annual average of $32.6 billion.
- Clean energy jobs increase from 398 thousand full-time equivalent positions in 2020 to 559 thousand in 2030. Jobs related to clean buildings and transport increase the most, due to the growing share of the building stock and vehicles on the road considered to be clean.

Clean energy is likely to account for an increasing share of energy-related economic activity in the future. Clean energy growth outpaces that in the rest of energy through 2030 (and in the economy overall). Nationally, clean energy accounts for 19% of energy-related GDP in 2020. By 2030, it accounts for 24%. As shown in Figure 1, clean energy accounts for a greater share of energy-related GDP in 2030 relative to 2020 in all provinces.

Figure 1: Clean share of energy-related GDP in 2020 and 2030, by region



Source: Navius analysis using gTech.

Greater clean energy investments are likely needed to achieve Canada's 2030 greenhouse gas targets. In response to current and announced climate policies, emissions are forecast to decrease from 704 Mt CO_2e in 2016 to 673 Mt CO_2e in 2030. This forecast suggests that additional policies are required to further boost clean energy investments if Canada is to achieve its 2030 greenhouse gas reduction target.

Opportunities for future research

Expanding the clean energy economy is critical for mitigating climate change. Chapter 4 identifies several research opportunities for future efforts to track, refine and forecast clean energy activity in Canada, including:

- Working towards standardizing clean energy definitions and data tracking methods.
- Addressing data gaps for specific clean energy sectors for which data are lacking, such as industry, services and niche sectors (e.g. smart grid technology).
- Accounting for the impact of decarbonization policy on electricity transmission and distribution requirements.
- Considering the impact of uncertainty in clean energy forecasting.

Contents

1. Introduction

Clean Energy Canada engaged Navius Research to define the extent of the clean energy economy in Canada. This analysis is intended to (1) help Clean Energy Canada promote a broader dialogue about benefits of expanding clean energy and (2) contribute to the development of methodologies to refine future data collection efforts.

The objective of this project is to quantify, where possible, the GDP, investment and employment in each clean energy sector of Canada's economy. The first component of this work examined historical trends in clean energy and was released in May of 2019[2]. This second report provides a forecast of clean energy growth to 2030.

This report is structured as follows:

- Chapter 2 describes the approach.
- Chapter 3 provides a forecast of clean energy activity through 2030.
- Chapter 4 discusses opportunities for future research.

The appendices provide additional details about the methodology.

[2] Clean Energy Canada. 2019. Missing the Bigger Picture: Tracking the Energy Revolution. Available from: https://cleanenergycanada.org/report/missing-the-bigger-picture

2. Approach

We use Navius' gTech model to forecast the growth of the clean energy economy to 2030. This modeling helps fill in historical gaps and forecast future growth in response to Canadian climate policy.

gTech is designed to simulate the impacts of government policy and economic conditions on both technological adoption and the broader economy. It simultaneously combines an explicit representation of technologies (everything from vehicles to fridges to ways of getting oil out of the ground) with key economic transactions within the economy. As such, the model is designed to provide insight about policy impacts on broader economic indicators such as GDP, jobs, industrial competitiveness and household welfare.

gTech is unique among energy-economy models because it combines features that are typically only found in separate models:

- A realistic representation of how households and firms select technologies and processes that affect their energy consumption and greenhouse gas emissions.
- An exhaustive accounting of the economy at large, including how provinces interact with each other and the rest of the world.
- A detailed representation of liquid fuel (crude oil and biofuel) and gaseous fuel (natural gas and renewable natural gas) supply chains.

These features enable a comprehensive assessment of the impact that Canadian climate policy is likely to have on the energy economy.

Please see Appendix A: "Modeling methods" for more information about gTech.

Current policy forecast

The forecast shows how Canada's energy-economy may develop in response to federal and provincial climate policies. Given the scope of the modeling (covering all energy consumption, greenhouse gas emissions, and economic activity in Canada), many assumptions are required. These assumptions relate to:

- **Economic activity.** Canada's GDP is assumed to grow at a real average rate of about 2% annually through 2030. GDP by sector is largely determined by this rate of growth and the relative capital and labour productivity of that sector (i.e., the value of goods and services produced for a given amount of capital and labour inputs).

The activity of some sectors is calibrated to specific exogenous forecasts and assumptions. Of note, fossil energy extraction is based on the National Energy Board's 2018 reference case[3]. Please note that sector activity may vary from these assumptions with the introduction of new climate policies (see below).

- **Energy prices.** Oil and gas prices are calibrated to the National Energy Board's 2018 reference case forecast. The price for most energy commodities is determined by the model based on demand and the cost of production. For example, the price of electricity in a given province depends on a variety of factors that are accounted for by the modeling, such as the cost of generating electricity while meeting any constraints, the cost of maintaining the transmission and distribution network, the value of electricity exports and cost of imports and any taxes on or subsidies to the sector.
- **Policy.** The modeling accounts for most substantive energy and climate policies that are implemented or have been announced in Canada as of February 2019. The forecast assumes that implemented provincial and federal climate policies remain in place and that announced climate policies are implemented, as summarized in Appendix B: "Clean energy policies in Canada".
- **Opportunities to reduce emissions.** gTech represents multiple opportunities to reduce emissions across over 50 end-uses tracked by the model (e.g. high efficiency internal combustion engines, electric propulsion and biofuels for light-duty vehicle travel; condensing gas furnaces, electric baseboards, heat pumps and renewable natural gas for space heating, etc.). The technology archetypes in the model are informed by Navius' technology database that reflects a large number data sources that are regularly reviewed and updated. For a list of modeled sectors and end-uses, please see Appendix A: "Modeling methods".
- **Model structure.** gTech's structure (i.e., a technologically-detailed framework embedded in a computable general equilibrium model) and parameterization reflect assumptions about how the overall energy-economy operates. Appendix A: "Modeling methods" provides an overview of these assumptions.

Limits to forecasting

Despite using the best available forecasting methods and assumptions, the evolution of Canada's energy economy is uncertain. In particular, forecasting greenhouse gas emissions is subject to two main types of uncertainty.

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[3] National Energy Board (NEB). 2018. Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040. Available from: http://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/index-eng.html

First, all models are simplified representations of reality. Navius models are, effectively, a series of mathematical equations that are intended to forecast the future. This raises key questions: “are the equations selected a good representation of reality?” and “do the equations selected miss any important factors that may influence the future?”

The use of computable general equilibrium models is well founded in the academic literature.[4] Navius also undertakes significant efforts to calibrate and back-cast the model, which improves confidence in the model results.

However, Navius’ tools do not account for every factor that will influence the future. For example, household and firm decisions are influenced by many factors, which cannot be fully captured by even the most sophisticated model. The inherent limitation of energy forecasting is that virtually all projections of the future will differ, to some extent, from what ultimately transpires.

Second, the assumptions used to parameterize the models are uncertain. These assumptions include, but are not limited to, oil prices, improvements in labor productivity and the level of fossil energy extraction in Canada. If any of the assumptions used prove incorrect, the resulting forecast could be affected.

The uncertainties in modeling mean that all models will err in their forecasts of the future. But some models are more correct than others. The forecast prepared for this report employs a highly sophisticated model that provides powerful insights into the impact of climate policies in Canada. We also note that it would be possible to examine the impact of uncertainties inherent in the forecast through additional modeling (e.g. sensitivity analyses to determine the impact of alternative oil and gas developments or clean energy technology costs and the clean energy economy).

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[4] Rivers, N., & Jaccard, M. (2006). Useful models for simulating policies to induce technological change. *Energy policy*, *34*(15), 2038-2047.

gTech at a glance

- **Rich technological detail**
  - Over 50 unique energy end-uses and 200 technologies are available to meet end-use demand in all sectors of the economy.
  - Emerging technologies such as electric vehicles and biofuel production pathways are carefully parameterized using credible data sources.
  - Technology choice is behaviourally realistic, reflecting stated and revealed consumer preference data.
- **Comprehensive coverage**
  - gTech is a computable general equilibrium model that balances supply and demand for 86 commodities and services.
  - Up to 90 sectors are represented across each of the 12 regions in the model (including each Canadian province, the territories and the US).
  - Greenhouse gas emissions are calibrated on a line-by-line basis to Canada's National Inventory Report.
- **The ability to simulate the effects of virtually any policy**
  - gTech can examine the impact of almost any type of policy, from technology-specific regulations to market-based policies such as carbon pricing or hybrid flexible regulations.
  - It offers an integrated framework to examine combinations of policies and how they interact with each other.
- **Detailed reporting**
  - Provides insight into how policies and other factors influence technology adoption, energy consumption and expenditures, greenhouse gas emissions and the economy (e.g. GDP, investment, employment and trade).

3. Canada’s clean energy economy to 2030

This Chapter provides a forecast of how Canada’s clean energy economy may evolve to 2030 in response to implemented and announced climate policies. The modeling also provides a useful framework for comparing clean energy activities to the rest of the economy.

This Chapter is structured as follows:

- Section 3.1 reviews how clean energy activity is defined in the modeling.
- Section 3.2 provides context for the size of the clean energy economy in 2020.
- Section 3.3 describes the forecast of greenhouse gas emissions and clean energy GDP, investment and jobs to 2030.

3.1. Defining the clean energy economy in gTech

To identify clean energy GDP, investment and jobs, we first flagged clean technologies in gTech. Doing so allows the model to assign investment into one of three categories:

- **Clean energy** (i.e., generally as defined in the previous report, with exceptions noted in the following section).
- **Rest of energy** (i.e., most activities related to fossil energy supply and use, other than those considered clean such as emissions control efforts).
- **Non-energy** (e.g. insurance services, education).

Clean investment is defined as:

- Any investment into a sector that produces clean energy services. These sectors include renewable electricity generation, nuclear electricity generation, electricity transmission and distribution, bioenergy supply, transit and rail.
- Investment into a technology or process determined to be clean. These technologies can occur in any sector of the economy (e.g., electric trucks in the

trucking sector). Please note that in keeping with the convention of the historical analysis, household consumption of clean technologies is reported as "investment".

Clean gross domestic product and employment are attributed to one of three categories:

- **Direct.** This category includes GDP and employment of (1) sectors producing clean energy services (i.e., those defined above such as renewable electricity generation and transit) and (2) value-added associated with the use of clean technologies in other sectors. For example, an electric vehicle may be used to provide courier services. Likewise, a clean building may be used to provide real estate services.
- **Construction and services.** This category includes construction and services required to install a given clean energy technology.
- **Manufacturing.** This category includes any manufacturing value-added (e.g. manufacturing an electric vehicle, if it occurs in Canada).

As a technologically-detailed macroeconomic model, gTech excels at identifying economic activity associated with specific technologies as per the above categories. It is naturally unable to quantify economic activity associated with technologies that are not differentiated in the model. Technologies not differentiated in the model include geothermal and tidal electricity generation, batteries and energy storage, smart grid technology, energy-saving building materials, hydrogen vehicles and non-motorized transport.

gTech's representation of electricity transmission and distribution is also limited. With no explicit spatial component to the model, it is not presently well suited for forecasting transmission requirements for connecting new sources of electricity supply with areas of demand.

Despite these limitations, gTech is well suited to the task of forecasting the development of (most) clean energy sectors because it combines the following features:

- A realistic representation of how households and firms select technologies and processes that affect their energy consumption and greenhouse gas emissions.
- An exhaustive accounting of the economy at large, including how provinces interact with each other and the rest of the world.
- A detailed representation of liquid fuel (crude oil and biofuel) and gaseous fuel (natural gas and renewable natural gas) supply chains.

- Incorporation of the most substantive energy and climate mitigation policies in Canada (see Appendix B: "Clean energy policies in Canada").

Differences with the historical analysis

Modeling results differ from the historical estimates provided in the previous report for several reasons:

- The modeling defines some clean energy activities differently. We have aligned the definitions where possible, but some differences exist. As described in the previous section, the model identifies clean energy activity based on sectors (e.g. transit) and technologies (e.g. heat pumps). In the case of building construction, the historical review considered the share of buildings that registered or were certified to meet green building standards. By contrast, the modeling considers any building built above existing building codes to be clean (a broader definition).
- As a computable general equilibrium model, gTech provides a more systematic and comprehensive accounting of clean energy activity than was generally feasible through historical data collection efforts. In particular, gTech captures the value-added associated with the use of all clean energy technologies. For example, an electric vehicle may be used to provide courier services. Likewise, a clean building may be used to provide real estate services. The historical review did not consider these sources of clean energy activity.
- In its representation of technologies, gTech tries to capture those elements of capital costs that influence energy and/or emissions intensity. For example, most building construction costs are unrelated to the thermal efficiency (e.g. foundations, kitchen cabinets, hardwood floors). These costs (and any associated manufacturing and construction activity) are not considered part of the clean energy economy. We have worked to align such assumptions between the historical analysis and modeling, although some differences may remain.
- The model reports GDP in 2010$ while the historical analysis collected GDP in nominal $. This choice was made for the historical review so that it would be easier to update over time. The implication of this difference is that the historical and modeled GDP estimates are not directly comparable.

Both the historical and modeled estimates are uncertain and, in some cases, rely on different data sources. Confidence in the estimates should be higher when they are similar, while diverging estimates are an indication of greater uncertainty.

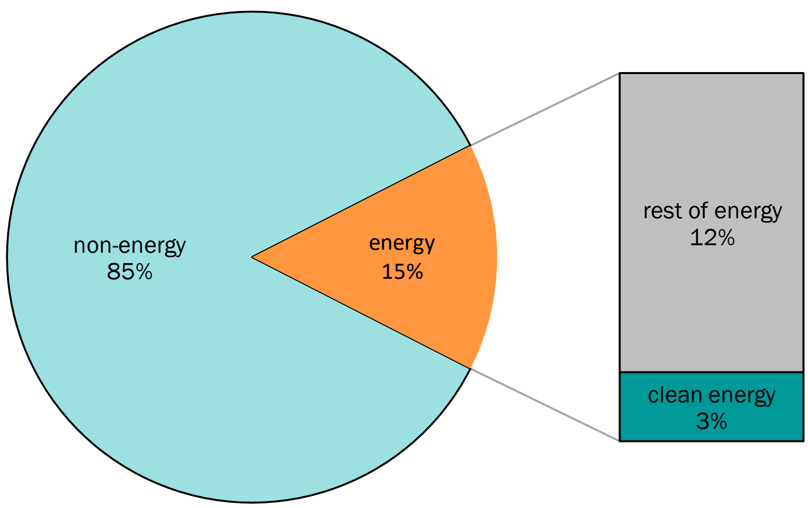
3.2. The clean energy economy in context

Categorizing all economic activity as clean, rest of energy and non-energy allows the modeling to provide context about the scale of the clean energy economy.

First, most economic activity in Canada is unrelated to the production and consumption of energy. As shown in Figure 2, 85% of GDP in 2020 is estimated to be unrelated to energy. This economic activity includes sectors such as insurance, education and IT services.

Second, most energy-related economic activity is not considered clean. The remaining 15% of GDP that is related to energy includes both clean energy and "rest of energy" sectors. Clean energy, as defined in this report, accounts for 3% of total GDP in 2020. By contrast, the rest of energy accounts for 12% of GDP. This "rest of energy" category includes activities related to fossil energy supply and use.

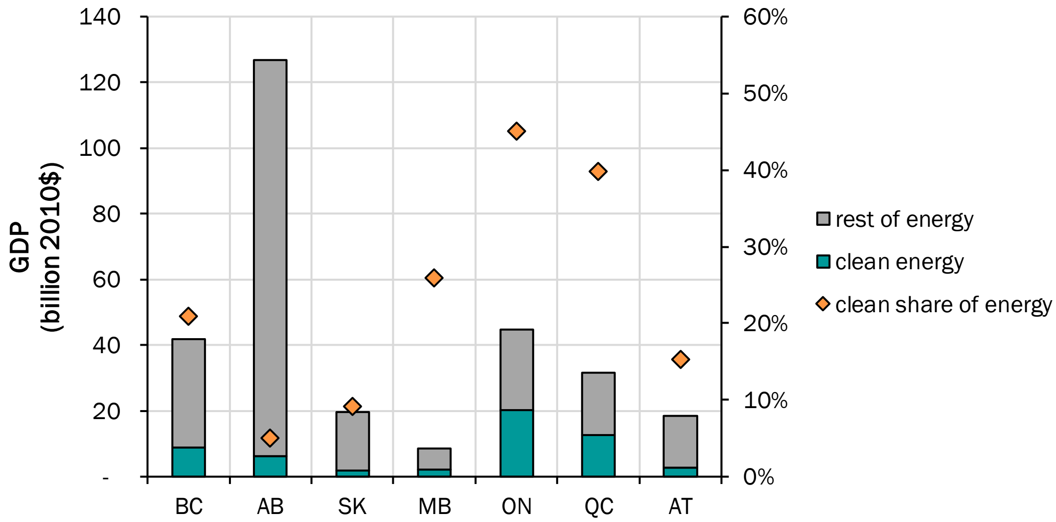
Figure 2: Energy's share of Canadian GDP in 2020



Source: Navius analysis using gTech.

The share of energy-related GDP that is clean varies by province as shown in Figure 3. It is lowest in provinces with substantial fossil energy extraction industries such as Alberta and Saskatchewan, where clean energy accounts for less than 10% of energy-related GDP in 2020. Provinces with the highest share of energy-related GDP that is considered clean are Ontario (45%) and Québec (40%).

Figure 3: Clean share of energy-related GDP in 2020 by region



Source: Navius analysis using gTech.

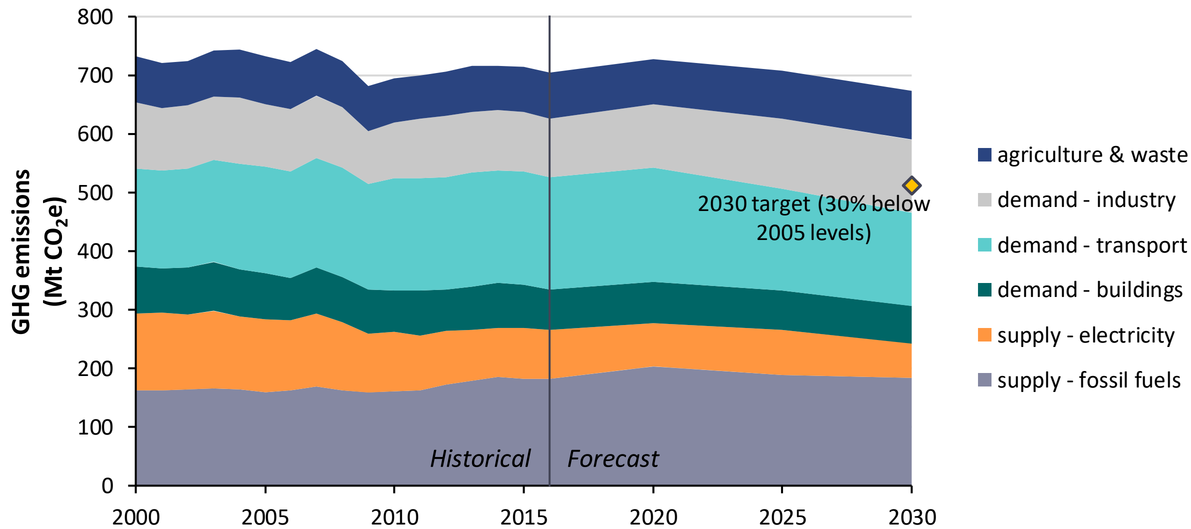
3.3. Forecast to 2030

3.3.1. Greenhouse gas emissions

In response to current and announced climate policies, emissions are forecast to decrease from 704 Mt CO_2e in 2016 to 673 Mt CO_2e in 2030 (please see Figure 4)[5]. This level of emissions is 161 CO_2e higher than Canada's 2030 target of 30% below 2005 levels (or 513 Mt CO_2e). This forecast suggests that additional policies are likely required (beyond those implemented and planned) for Canada to achieve its greenhouse gas reduction target.

[5] Please note: The federal government includes emissions reductions associated with (1) Land Use, Land Use Change and Forestry (LULUCF) and (2) Western Climate Initiative credit imports in its forecast. These sources would reduce emissions by 37 Mt CO_2e in 2030 relative to those shown here, based on: Environment and Climate Change Canada. 2018. Canada's Greenhouse Gas and Air Pollutant Emissions Projections. Available from: http://publications.gc.ca/collections/collection_2018/eccc/En1-78-2018-eng.pdf

Figure 4: Canada's GHG emissions to 2030



Sources: (1) Historical data: Environment and Climate Change Canada. 2018. National Inventory Report: 1990-2016. Canada's submission to the United Nations Framework Convention on Climate Change. Available from: https://unfccc.int/documents/65715 (2) Forecast data: Navius analysis using gTech.

While overall emissions decrease, trends are different among sectors. Between 2016 and 2030, emissions decrease from electricity, transport and buildings. The decrease is most substantial for transport (31 Mt CO_2e) and electricity (25 Mt CO_2e), which are both subject to relatively stringent policies. For example, the federal vehicle emission standards continue to require improvements in vehicle fuel economy, while Québec and BC's zero emission vehicle mandates require an increasing share of vehicles sold to be plug-in electric or hydrogen powered. On the electricity side, both federal and provincial efforts are expected to lead to the phase-out of coal-fired electricity generation by 2030 (other than that equipped with carbon capture and storage), while many provinces have requirements to generate an increasing share of electricity from renewable sources.

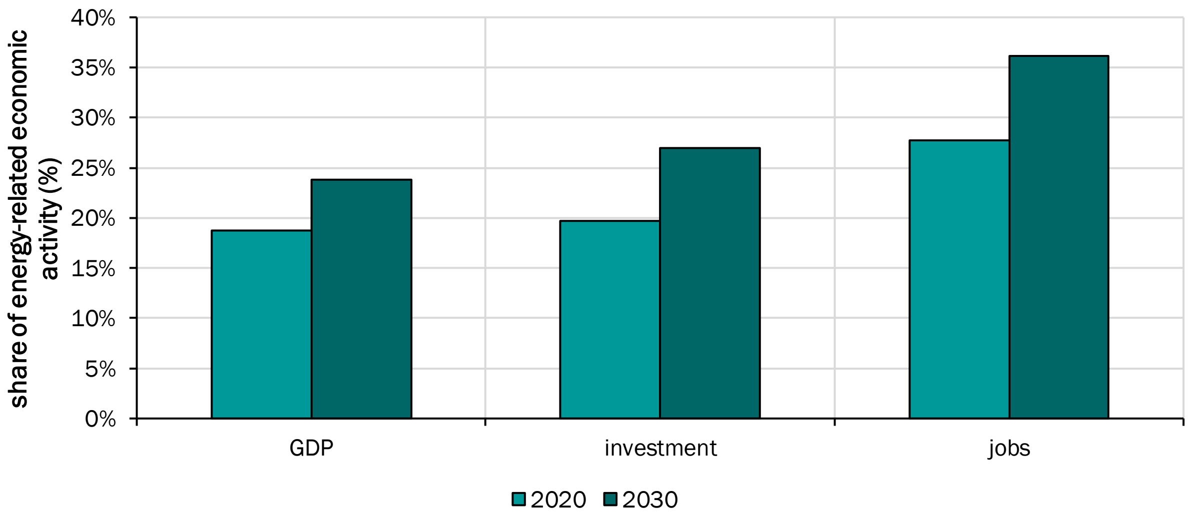
On the other hand, emissions increase from industry (24 Mt CO_2e between 2016 and 2030), agriculture (5 Mt CO_2e) and fossil energy extraction (2 Mt CO_2e). These sectors are subject to fewer and generally less stringent policies, including provincial carbon pricing and/or the federal backstop and methane regulations.

For a complete list of all policies included in the forecast, please see Appendix B: "Clean energy policies in Canada".

3.3.2. Clean energy growth in context

The forecast suggests that clean energy growth is likely to outpace that in the rest of energy through 2030 (and in the economy overall). As shown in Figure 5, the clean energy economy accounts for a greater share of energy-related GDP, investment and jobs in 2030 relative to 2020. This trend is evident across all provinces as shown in Figure 6.

Figure 5: Clean share of energy-related economic activity in 2020 and 2030



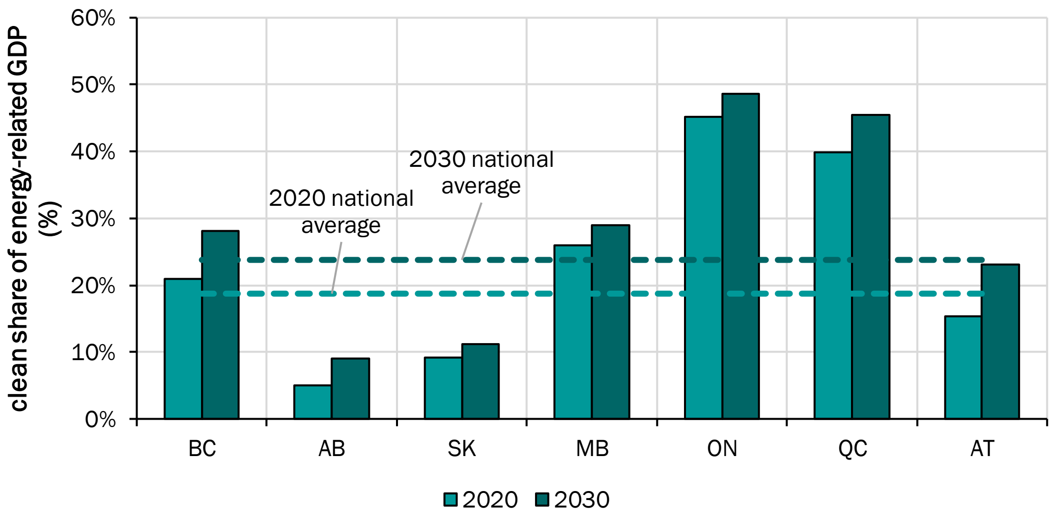
Source: Navius analysis using gTech.

In sum:

- Clean energy GDP rises from 19% of Canada's energy-related GDP in 2020 to 24% in 2030 (Figure 5). GDP from clean energy grows at an average annual rate of 3.4% through 2030, compared to 0.4% for the rest of energy.
- Clean energy investment and consumption increase from 20% of energy-related investments in 2020 to 27% in 2030. Annual investment in clean energy grows at an average annual rate of 2.9% through 2030, compared to decrease of 1.2% for the rest of energy.
- Clean energy jobs increase from 28% of energy-related jobs in 2020 to 36% in 2030. Jobs in clean energy grow at an average annual rate of 3.4% through 2030, compared to decrease of 0.5% for the rest of energy.

Clean energy growth is driven by many factors, including federal and provincial climate policies (for a list of policies included in the modeling, please see Appendix B: "Clean energy policies in Canada") and technology change (e.g. declining costs of battery-electric vehicles). The clean energy share of energy-related economic activity also depends on future oil and gas production levels. Growth in the rest of energy is due in large part to the expansion of oil and gas extraction in the three westernmost provinces (British Columbia, Alberta and Saskatchewan) as well as Newfoundland and Labrador.

Figure 6: Clean share of energy-related GDP in 2020 and 2030, by region



Source: Navius analysis using gTech.

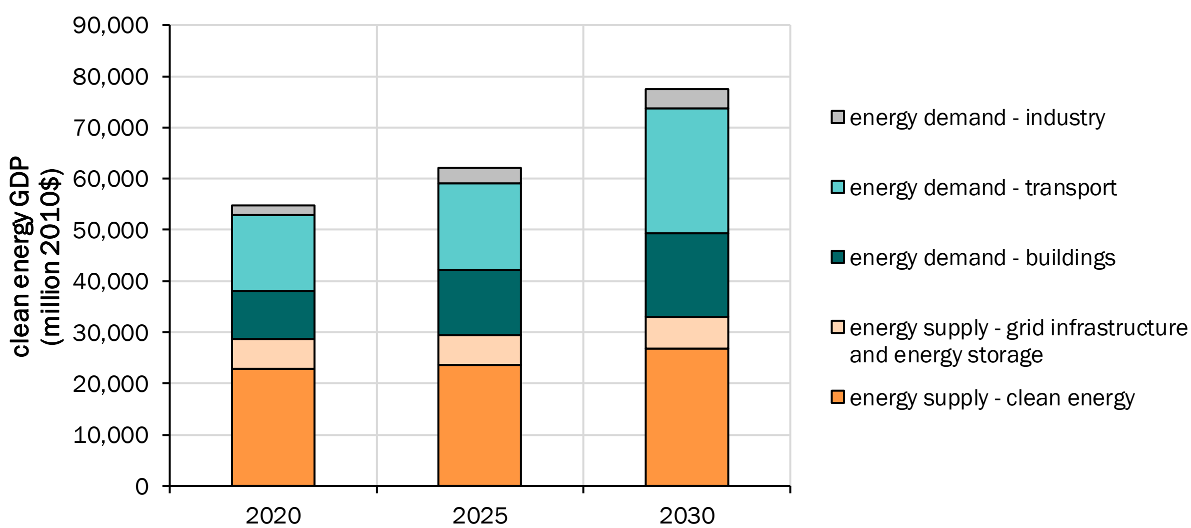
3.3.3. GDP to 2030

Clean energy GDP increases from $54.9 billion (2010$) in 2020 to $77.4 billion in 2030, growing at an average annual rate of 3.4% (see Figure 7). All clean energy sectors experience growth over this period except nuclear power, as shown in Table 1:

- GDP from clean energy supply increases from $22.9 billion in 2020 to $26.8 billion in 2030. The areas of highest growth include several types of renewables (wind, bioenergy and waste-to energy) as well as efforts to decarbonize fossil energy supply (e.g. methane controls on oil and gas operations and electrification of natural gas transmission). GDP from nuclear energy fluctuates over the forecast due to planned refurbishments but is lower in 2030 than 2020.

- GDP from electricity transmission and distribution increases from $5.7 billion in 2020 to $6.3 billion in 2030. As noted in Section 3.1, the version of gTech used for this study is somewhat limited in its ability to forecast transmission requirements for connecting new sources of electricity supply with areas of demand. The implication is that this forecast may underestimate transmission and distribution requirements.

Figure 7: Clean energy GDP to 2030



Source: Navius analysis using gTech.

- GDP from clean buildings increases from $9.5 billion in 2020 to $16.3 billion in 2030. Over time, a greater share of Canada's building stock becomes clean as new buildings are constructed to higher standards and old buildings are demolished or retrofit. This means that the value-added from economic activity occurring in green buildings increases over time (e.g. leasing office space in a green building). It is this dynamic that contributes most to the increase in clean building GDP. By contrast, value-added from construction and engineering services remains relatively flat.

- GDP from clean transport increases from $14.8 billion in 2020 to $24.3 billion in 2030. Most of the increase in GDP is associated with hybrid and electric vehicles, which account for 48% of new light-duty vehicle sales in 2030. The adoption of these vehicles is driven by improved performance and falling costs of batteries, as well as policy. Key policies include the zero emission vehicle mandates in Québec and BC, as well as the federal vehicle emissions standard. The bulk of the contribution of this sector to GDP is by businesses that use these vehicles to provide transport services (e.g. taxis and delivery services). A smaller share is associated with vehicle manufacturing.
- GDP from clean industry sectors increases from $1.9 billion in 2020 to $3.8 billion in 2030. This sector includes low carbon machinery (e.g. the adoption of technologies such as electric motors and compressors, industrial heat pumps and biomass and high efficiency natural gas-fired boilers) and emission control (e.g. landfill gas flaring, inert anodes in aluminum production, and carbon capture unrelated to energy supply).

Table 1: Clean energy GDP to 2030 (billion 2010$)

	2020	2025	2030	Change, 2020-2030	
				Absolute change	*CAGR[a]*
Clean energy supply					
Hydro	12.3	12.5	12.4	*0.0*	*0.0%*
Wind	2.2	2.5	3.5	*1.3*	*4.7%*
Solar	0.2	0.2	0.2	*0.0*	*0.0%*
Bioenergy	0.2	0.3	0.4	*0.2*	*5.1%*
Waste to energy	0.1	0.3	0.4	*0.2*	*10.4%*
Nuclear	5.7	4.8	5.6	*-0.1*	*-0.3%*
Low carbon machinery	1.7	2.0	2.9	*1.2*	*5.1%*
Emission detection & control	0.4	1.1	1.5	*1.1*	*13.0%*
Total clean energy supply	**22.9**	**23.6**	**26.8**	*3.9*	*1.6%*
Grid infrastructure & energy storage					
Electricity transmission & distribution	5.7	5.9	6.3	*0.6*	*1.0%*
Total grid infr. & energy storage	**5.7**	**5.9**	**6.3**	*0.6*	*1.0%*
Buildings					
Shells	7.1	9.6	12.6	*5.5*	*5.7%*
HVAC & building control systems	0.5	0.7	0.8	*0.4*	*5.7%*
High efficiency appliances & lighting	1.9	2.4	2.8	*0.9*	*3.8%*
Total buildings	**9.5**	**12.7**	**16.3**	*6.8*	*5.4%*
Transport					
Hybrid & electric vehicles	0.5	2.6	8.5	*8.0*	*28.1%*
Public transit	4.3	4.6	5.6	*1.4*	*2.8%*
Rail	10.0	9.6	10.2	*0.1*	*0.1%*
Total transport	**14.8**	**16.8**	**24.3**	*9.5*	*5.0%*
Industry					
Low carbon machinery	1.4	2.0	2.7	*1.3*	*6.5%*
Emission detection & control	0.5	1.1	1.1	*0.6*	*7.3%*
Total industry	**1.9**	**3.1**	**3.8**	*1.9*	*6.7%*
Total clean energy	54.9	62.1	77.4	*22.6*	*3.4%*
Rest of energy	238.0	240.5	248.3	*10.3*	*0.4%*

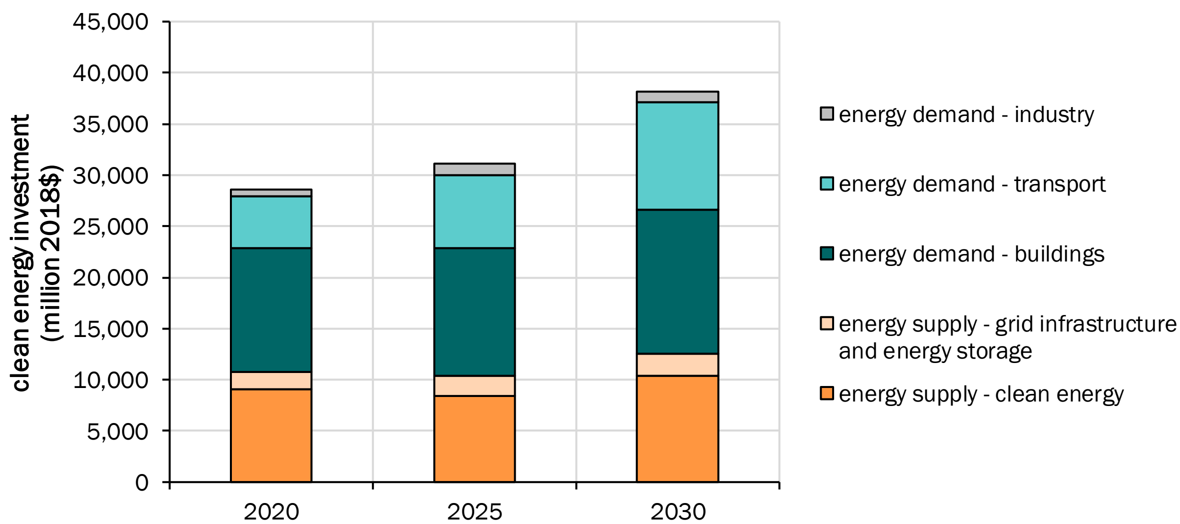
Source: Navius analysis using gTech. Note: (a) compound annual growth rate.

3.3.4. Investment to 2030

Clean energy investment increases from $28.6 billion (2018$) in 2020 to $38.2 billion in 2030 on an annual basis (see Figure 8). In keeping with convention from the previous report, consumption of clean technologies is included (e.g. a household purchasing an electric vehicle is included even though from a conventional economic perspective it is considered consumption).

Investment in clean energy is stable or growing across most sectors except rail and low carbon machinery in energy supply sectors, as shown in Table 2. The greatest absolute increase in annual investment occurs in hybrid and electric vehicles, which rises by $5.3 billion between 2020 and 2030. As mentioned above, this investment is driven by a combination of factors, including policy (federal vehicle emission standard, ZEV mandates in BC and Québec) and technological change (i.e., declining costs of batteries).

Figure 8: Clean energy investment to 2030



Source: Navius analysis using gTech. Includes household consumption of clean energy technologies.

Table 2: Clean energy annual investment to 2030 (billion 2018$)

	2020	2025	2030	Change, 2020-2030	
				Absolute change	*CAGR[a]*
Clean energy supply					
Hydro	3.6	3.6	3.6	*0.0*	*0.0%*
Wind	1.8	1.1	2.5	*0.7*	*3.0%*
Solar	0.0	0.0	0.0	*0.0*	*0.0%*
Bioenergy	0.1	0.6	0.7	*0.5*	*15.0%*
Waste to energy	0.1	0.1	0.1	*0.0*	*3.8%*
Nuclear	1.4	1.2	1.8	*0.4*	*2.6%*
Low carbon machinery	1.4	0.3	0.9	*-0.5*	*-4.4%*
Emission detection and control	0.5	1.5	0.7	*0.2*	*3.1%*
Total clean energy supply	**9.0**	**8.4**	**10.4**	*1.3*	*1.4%*
Grid infrastructure & energy storage					
Electricity transmission & distribution	1.7	1.9	2.2	*0.5*	*2.4%*
Total grid infr. & energy storage	**1.7**	**1.9**	**2.2**	*0.5*	*2.4%*
Buildings					
Shells	6.9	6.7	7.5	*0.6*	*0.9%*
HVAC & building control systems	1.0	1.2	1.4	*0.3*	*2.7%*
High efficiency appliances & lighting	4.2	4.5	5.2	*1.1*	*2.3%*
Total buildings	**12.1**	**12.5**	**14.1**	*2.0*	*1.5%*
Transport					
Hybrid & electric vehicles	1.7	4.7	7.0	*5.3*	*14.4%*
Public transit	0.7	0.8	1.2	*0.5*	*5.1%*
Rail	2.7	1.6	2.3	*-0.4*	*-1.4%*
Total transport	**5.0**	**7.1**	**10.5**	*5.5*	*7.3%*
Industry					
Low carbon machinery	0.5	0.9	0.8	*0.3*	*4.1%*
Emission detection & control	0.2	0.2	0.2	*0.1*	*2.9%*
Total industry	**0.7**	**1.2**	**1.0**	*0.3*	*3.8%*
Total clean energy	**28.6**	**31.1**	**38.2**	*9.6*	*2.9%*
Rest of energy	116.8	100.6	103.6	*-13.2*	*-1.2%*

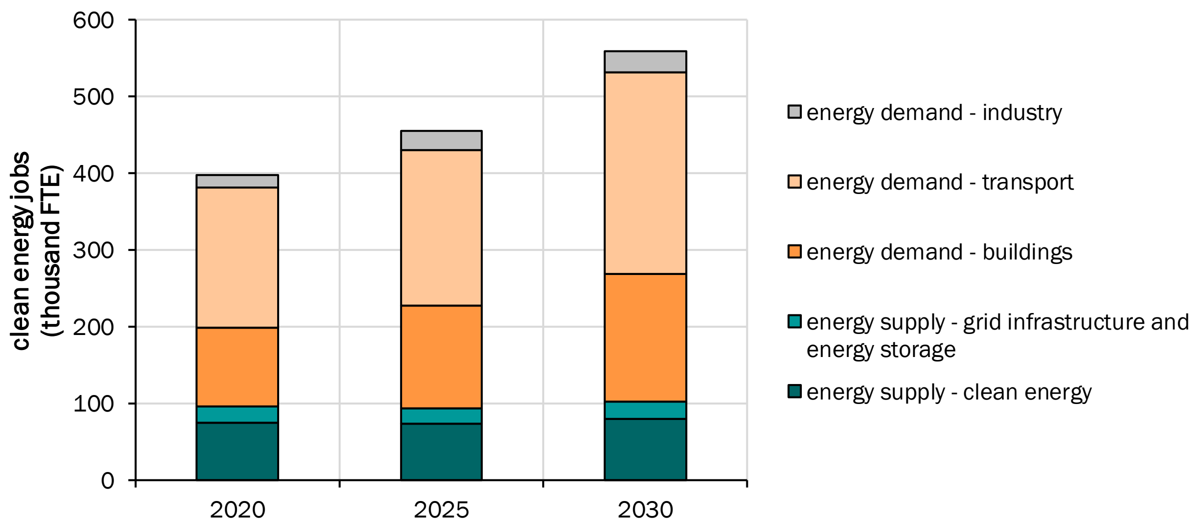
Source: Navius analysis using gTech. Includes household consumption of clean energy technologies. Note: (a) compound annual growth rate.

3.3.5. Jobs to 2030

Clean energy jobs increase from 398 thousand in 2020 to 559 thousand in 2030 (see Figure 9 and Table 3). This increase represents an average annual growth rate of 3.4%, above both that of the rest of energy (-0.5%) and the overall economy (0.9%). In 2020, clean energy jobs account for 28% of all energy-related jobs. By 2030, the clean energy share increases to 36%.

Jobs related to electric and hybrid vehicles increase the most (67 thousand) due to the growing fleet of such vehicles used for transport services. Likewise, jobs related to clean buildings experience strong growth (65 thousand) due to the growing share of the building stock that is considered clean. Other sectors experiencing particularly large job growth include transit, wind and low carbon machinery.

Figure 9: Clean energy jobs to 2030



Source: Navius analysis using gTech.

Table 3: Clean energy jobs to 2030 (thousand FTE)

	2020	2025	2030	Change, 2020-2030	
				Absolute change	*CAGR[a]*
Clean energy supply					
Hydro	41.5	41.5	39.4	*-2.1*	*-0.5%*
Wind	7.9	8.0	11.9	*4.0*	*4.1%*
Solar	0.5	0.5	0.5	*0.0*	*0.0%*
Bioenergy	1.0	1.4	1.7	*0.7*	*4.9%*
Waste to energy	0.3	0.5	0.7	*0.4*	*7.6%*
Nuclear	22.4	18.3	21.7	*-0.6*	*-0.3%*
Low carbon machinery	1.1	1.4	2.3	*1.2*	*7.5%*
Emission detection & control	0.5	1.5	1.9	*1.4*	*13.3%*
Total clean energy supply	**75.2**	**73.2**	**80.2**	*5.0*	*0.6%*
Grid infrastructure & energy storage					
Electricity transmission & distribution	20.7	20.8	21.6	*0.9*	*0.4%*
Total grid infr. & energy storage	**20.7**	**20.8**	**21.6**	*0.9*	*0.4%*
Buildings					
Shells	77.1	101.9	130.5	*53.4*	*5.3%*
HVAC & building control systems	5.2	7.2	8.8	*3.6*	*5.3%*
High efficiency appliances & lighting	19.9	24.1	27.7	*7.8*	*3.3%*
Total buildings	**102.2**	**133.2**	**167.0**	*64.8*	*4.9%*
Transport					
Hybrid & electric vehicles	5.2	24.5	72.0	*66.8*	*26.3%*
Public transit	121.6	127.1	136.6	*15.0*	*1.2%*
Rail	56.4	51.5	54.0	*-2.4*	*-0.4%*
Total transport	**183.2**	**203.1**	**262.6**	*79.4*	*3.6%*
Industry					
Low carbon machinery	13.4	17.5	22.2	*8.8*	*5.0%*
Emission detection & control	3.3	7.2	5.7	*2.4*	*5.5%*
Total industry	**16.7**	**24.7**	**28.0**	*11.2*	*5.1%*
Total clean energy	**398.0**	**455.0**	**559.4**	*161.4*	*3.4%*
Rest of energy	1039.6	994.5	989.7	*-49.9*	*-0.5%*

Source: Navius analysis using gTech. Includes household consumption of clean energy technologies. Note: (a) compound annual growth rate.

4. Opportunities for future research

Expanding the clean energy economy is critical for mitigating climate change. This project used a variety of data sources and methodologies to quantify clean energy activity in Canada, both historically and in response to federal and provincial climate policy moving forward. In the process of conducting this work, we identified several research opportunities for future efforts to track, refine and forecast clean energy activity in Canada. These areas are discussed below.

Work towards standardizing clean energy definitions and methods

This study builds on previous work in this field, notably by starting with the sector classification scheme used by the Brookings Institution[6] and adopted by the Delphi Group's West Coast Clean Economy study. Our efforts then diverged because (1) the scope of this study was concerned with energy-related aspects of the clean economy rather than environmental aspects more broadly and (2) definitions had to be workable based on available data sources (i.e., there was little point in defining a sector a certain way if it couldn't then be quantified).

Comparing the findings of this study with results available from other Canadian studies reveals substantial differences in definitions and estimates (see Table 4). First, Statistics Canada suggests that jobs related to environmental and clean technology were 273.2 thousand in 2015, less than the clean energy jobs estimates made in this project (which were 284.4 thousand based on historical data collection and 344.6 thousand based on the modeling, the latter which included various broader definitions and more comprehensive accounting as discussed in Section 3.1). While there is some overlap between this study's clean energy sector analysis and Statistics Canada's Environmental and Clean Technology Products Economic Account, the two studies consider different data sets (e.g. Statistics Canada includes data related to environmental sectors such as waste management and excludes data related to clean transportation) and are not directly comparable. Statistics Canada uses a conventional economic sector disaggregation (i.e., in line with the supply use tables) which makes more detailed comparisons challenging.

Second, two other studies have been conducted by Delphi related to (1) the clean economy in BC and (2) green buildings in Canada. Their estimates for both areas are higher than those in this report for two reasons. First, the focus of the Delphi studies is

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[6] The Brookings Institution. 2011. Sizing the Clean Economy. A National and Regional Green Jobs Assessment. Available from: www.brookings.edu/research/sizing-the-clean-economy-a-national-and-regional-green-jobs-assessment/

broader than clean energy, including activities related to other environmental attributes such as waste management. Second, The Delphi studies tend to cast a wider net in terms of the types of economic activity that it considers to be related to clean activity.

Definitions chosen by future researchers in this field will likely depend on various factors, including their objectives and perspectives, available data sources and choice of methods. It is therefore unlikely to expect differences in definitions and clean energy economy estimates to disappear. At a minimum, being aware of different approaches and documenting assumptions will help others interpret and compare studies.

Table 4: Comparison of clean economy estimates

Measurement	Source	Comparison study estimate	Estimates from this study	
			Historical analysis	Modeling
Environmental and clean technology related in Canada, 2015	STC (2018)	273.2	284.4	344.6
Clean economy in BC 2014	Delphi (2015)	68.2	31.2	42.5
Green buildings in Canada, 2014	Delphi/CGBC (2016)	297.9	18.3	70.8

Sources: Statistics Canada. Table 36-10-0366-01. Environmental and Clean Technology Products Economic Account; The Delphi Group. 2015. West Coast Clean Economy: 2010-2014 Jobs Update. Available from: http://delphi.ca/wp-content/uploads/2015/12/PCC-Clean-Economy-Report-FINAL.pdf; The Delphi Group/Canada Green Building Council. 2016. Green building in Canada: Assessing the market impacts and opportunities. Available from: www.cagbc.org/CAGBC/Advocacy/Green_Building_in_Canada_Assessing_the_Market_Impacts_Opportunities.aspx

Address data gaps for clean energy sectors

Implementing the survey of clean energy firms accounted for a large share of the effort put into this project, but ultimately yielded a small fraction of the results that were compiled. Improvements to data collection and dissemination by government (e.g. Statistics Canada), industry associations and other organizations well positioned to do so would be helpful for future efforts to quantify the clean energy economy.

This project found limited or insufficient data in a variety of areas which could be addressed by future efforts:

- Industrial clean energy sectors, including low carbon machinery and emissions detection and control.

- Production of several types of renewable energy: wood pellets, biogas, waste-to-energy, tidal and geothermal.
- Distinguishing economic activity related to electricity transmission and distribution from generation.
- Development and deployment of smart grid technology. While we identified some investment/R&D data, it is not comprehensive. Some activities related to smart grid may be embedded in overall transmission and distribution statistics.
- Manufacturing of insulation (within the energy-saving building materials sector).
- The provision of many types of “energy services”. Often, these services are one among multiple offerings of a given firm and are thus difficult to isolate.
- Hydrogen vehicles and related infrastructure.
- Non-motorized transport (e.g. bikes and bike infrastructure).

Account for the impact of policy on all clean energy sectors

The clean energy forecasting undertaken for this project provided a reasonably comprehensive assessment of the impact that Canadian climate policy is likely to have on the economy. Yet, not all clean energy sectors are disaggregated in the modeling and some dynamics were omitted. Future research could further consider the impact of policy on:

- Electricity transmission and distribution requirements.
- Batteries and energy storage technologies.
- Many of the sectors and activities listed above for which data are lacking.

Quantify uncertainty

This study developed a single forecast of clean energy economic activity through 2030. Yet the growth of the clean energy economy depends on many developments that are ultimately uncertain. Future research could examine the extent to which different assumptions and developments may impact clean economy growth, such as:

- The cost of clean energy technologies (e.g. plug-in electric vehicles, carbon capture and storage, solar PV).
- Oil and gas production in Canada, which depend on international demand, Canadian policy and other constraints such as pipelines.

- The extent to which governments (1) maintain existing climate policies and (2) implement announced policies. For example, any backtracking of the federal backstop would reduce clean economy activity in the forecast presented here.

Appendix A: Modeling methods

4.1. Introduction to gTech

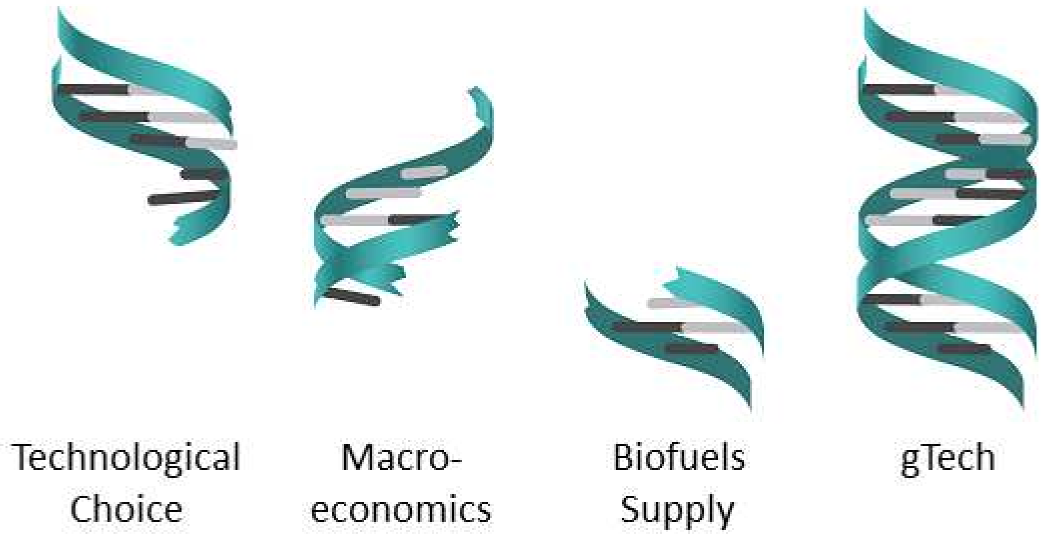
The gTech model is designed to simulate the impacts of government policy and economic conditions on both technological adoption and the broader economy. It simultaneously combines an explicit representation of technologies (everything from vehicles to fridges to ways of getting oil out of the ground) with key economic transactions within an economy. As such, the model is designed to provide insight about policy impacts on broader economic indicators such as GDP, industrial competitiveness and household welfare.

gTech is unique among energy-economy models because it combines features that are typically only found in separate models:

- A realistic representation of how households and firms select technologies and processes that affect their energy consumption and greenhouse gas emissions.
- An exhaustive accounting of the economy at large, including how provinces interact with each other and the rest of the world.
- A detailed representation of liquid fuel (crude oil and biofuel) and gaseous fuel (natural gas and renewable natural gas) supply chains.

These features are discussed below.

Figure 10: The gTech model



gTech builds on three of Navius' previous models (CIMS, GEEM and OILTRANS), combining their best elements into a comprehensive integrated framework.

Simulating technological choice

Technological choice is one of the most critical decisions that influence energy consumption and greenhouse gas emissions in Canada. For example, if a household chooses to purchase an electric heat pump over a natural gas-fired furnace, that decision will reduce their direct emissions (while potentially increasing upstream electricity emissions).

gTech provides a detailed accounting of the types of energy-related technologies available to households and businesses. In total, gTech includes 200 technologies across more than 50 end-uses (e.g., residential space heating, industrial process heat, management of agricultural manure).

Naturally, technological choice is influenced by many factors. Table 5 summarizes key factors that influence technological choice and the extent to which these factors are included in gTech.

Table 5: Technological choice dynamics captured by gTech

Criteria	Description
Purchasing (capital) costs	Purchasing costs are simply the upfront cost of purchasing a technology. Every technology in gTech has a unique capital cost that is based on research conducted by Navius. Everything else being equal (which is rarely the case), households and firms prefer technologies with a lower purchasing cost.
Energy costs	Energy costs are a function of two factors: (1) the price for energy (e.g., cents per litre of gasoline) and (2) the energy requirements of an individual technology (e.g., a vehicle's fuel economy, measured in litres per 100 km). In gTech, the energy requirements for a given technology are fixed, but the price for energy is determined by the model. The method of "solving" for energy prices is discussed in more detail below.
Time preference of capital	Most technologies have both a purchasing cost as well as an energy cost. Households and businesses must generally incur a technology's purchasing cost before they incur the energy costs. In other words, a household will buy a vehicle before it needs to be fueled. As such, there is a tradeoff between near-term capital costs and long-term energy costs. gTech represents this tradeoff using a "discount rate". Discount rates are analogous to the interest rate used for a loan. The question then becomes: is a household willing to incur greater upfront costs to enable energy or emissions savings in the future? Many energy modelers use a "financial" discount rate (commonly between 5% and 10%). However, given the objective of forecasting how households and firms are likely to respond to energy policy, gTech employs "behaviourally" realistic discount rates of between 8% and 25% to simulate technological choice. Research consistently shows that households and firms do not make decisions using a financial discount rate, but rather use significantly higher rates.[7] The implication is that using a financial discount rate would overvalue future savings relative to revealed behavior and provide a poor forecast of household and firm decisions.
Technology specific preferences	In addition to preferences around near-term and long-term costs, households (and even firms) exhibit "preferences" towards certain types of technologies. These preferences are often so strong that they can overwhelm most other factors (including financial ones). For example, research on electric vehicles indicates that Canadians often have very strong preferences (positive or negative) towards electric vehicles. One segment of the population prefers electric vehicles to such an extent that capital and energy costs are almost irrelevant. Another segment dislikes electric vehicles to such an extent that there are relatively few circumstances in which they will be willing to purchase such a vehicle. And then there are many other groups in between.[8] gTech quantifies these technology-specific preferences as "non-financial" costs, which are added to the technology choice algorithm.

[7] Rivers, N., & Jaccard, M. (2006). Useful models for simulating policies to induce technological change. *Energy policy*, *34*(15), 2038-2047.

[8] Axsen, J., Cairns, J., Dusyk, N., & Goldberg, S. (2018). What drives the Pioneers? Applying lifestyle theory to early electric vehicle buyers in Canada. *Energy Research & Social Science*, *44*, 17-30.

Criteria	Description
The diverse nature of Canadians	Canadians are not a homogenous group. Individuals are unique and will weigh factors differently when choosing what type of technology to purchase. For example, one household may purchase a Toyota Prius while one neighbour purchases an SUV and another takes transit. gTech uses a “market share” equation in which technologies with the lowest net costs (including all the cost dynamics described above) achieve the greatest market share, but technologies with higher net costs may still capture some market share[9]. As a technology becomes increasingly costly relative to its alternatives, that technology earns less market share.
Changing costs over time	Costs for technologies are not fixed over time. For example, the cost of electric vehicles has come down significantly over the past couple of years, and they are expected to continue their decline into the future[10]. Similarly, costs for many other energy efficient devices and emissions-reducing technologies have declined and are expected to continue declining. gTech accounts for whether and how costs for technologies are projected to decline over time.
Policy	One of the most important drivers of technological choice is government policy. gTech can model virtually any energy or climate policy, including: (1) incentive programs, which pay for a portion of the purchasing cost of a given technology; (2) regulations, which either require a group of technologies to be purchased or prevent another group of technologies from being purchased; (3) carbon pricing, which increases fuel costs in proportion to their carbon content (and uses revenue for some purpose, such as reducing other taxes, investing in energy efficient technologies); (4) variations in other tax policy (e.g., whether or not to charge GST on a given technology); and (5) flexible regulations, like BC’s low-carbon fuel standard which creates a market for compliance credits. gTech simulates the combined effects of all policies implemented together (e.g. a current policy forecast, or a forecast in which new policies are added). It provides a comprehensive framework for considering the combined impact of all policies in a given package and how they will interact.

[9] Rivers, N., & Jaccard, M. (2006). Useful models for simulating policies to induce technological change. *Energy policy*, *34*(15), 2038-2047.

[10] Nykvist, B., Sprei, F., & Nilsson, M. (2019). Assessing the progress toward lower priced long range battery electric vehicles. *Energy Policy*, 124, 144-155.

Understanding the macroeconomic impacts of policy

As a full macroeconomic model (specifically, a "general equilibrium model"), gTech provides insight about how policies affect the economy at large. The key macroeconomic dynamics captured by gTech are summarised in Table 6.

Table 6: Macroeconomic dynamics captured by gTech

Dynamic	Description
Comprehensive coverage of economic activity	gTech accounts for all economic activity in Canada as measured by Statistics Canada national accounts[11]. Specifically, it captures all sector activity, all gross domestic product, all trade of goods and services and a large number of transactions that occur between households, firms, government and people/firms between provinces. As such, the model provides a forecast of how government policy affects many different economic indicators, including gross domestic product, investment, household income, jobs, etc.
Full equilibrium dynamics	gTech ensures that all markets in the model return to equilibrium (i.e., that the supply for a good or service is equal to its demand). This means that a decision made in one sector is likely to have ripple effects throughout the entire economy. For example, greater demand for electricity in Canada requires greater electricity production. In turn, greater production necessitates greater investment and demand for goods and services from the electricity sector, increasing demand for labor in construction services and finally leading to higher wages.
Sector detail	gTech provides a detailed accounting of sectors in Canada. In total, gTech simulates how policies affect 90 sectors of the economy. Each of these sectors produces a unique good or service (e.g., the natural gas sector produces natural gas, while the services sector produces services) and requires specific inputs into production. Of these inputs, some are not directly related to energy consumption or greenhouse gas emissions (e.g., the demand by the natural gas sector for services or labor requirements). But other inputs are classified as "energy end-uses". Covered energy end-uses (along with sectors and fuels) are listed in 4.2 "List of sectors, fuels and end-uses in gTech".
Labor and capital markets	Labor and capital markets must also achieve equilibrium in the model. The availability of labor can change with the "real" wage rate (i.e., the wage rate relative to the price for consumption). If the real wage increases, the availability of labor increases. The model also accounts for "equilibrium unemployment". Capital markets are introduced in more detail below.

[11] Statistics Canada. Supply and Use Tables. Available from: www150.statcan.gc.ca/n1/en/catalogue/15-602-X

Dynamic	Description
Interactions between provinces and other regions	Economic activity in a given province is highly influenced by interactions with other provinces, the United States and countries outside of North America. Regions interact via (1) the trade of goods and services, (2) capital movements, (3) government taxation and (4) various types of "transfers" between regions (e.g., the federal government provides transfers to provincial governments). gTech accounts for 11 regions in Canada (10 provinces and an aggregated region representing the three territories) and the United States. The model simulates each of the interactions described above, and how interactions may change in response to policy. In other words, the model can forecast how a policy may affect the trade of natural gas between Canada and the United States; or whether a policy would affect how corporations invest in Canada.
Households	On one hand, households earn income from the economy at large. On the other, households use this income to consume different goods and services. gTech accounts for each of these dynamics, and how either changes with policy.

Understanding petroleum, natural gas and biofuels markets

gTech accounts for biofuel feedstock availability and the costs of transporting liquid and gaseous fuels between regions. This allows the model to provide insight about the economic effects of biofuels policy and the approval of pipelines.

gTech: The benefits of merging macroeconomics with technological detail

By merging the three features described above (technological detail, macroeconomic dynamics, and energy supply dynamics), gTech can provide extensive insight into the effect of energy policy.

First, gTech can provide insights that would typically be provided by a technologically explicit model. These include answering questions such as:

- How do policies affect technological adoption (e.g. how many heat pumps are likely to be installed in 2030)?
- How does technological adoption affect greenhouse gas emissions and energy consumption?

Second, gTech can further provide insights associated with macroeconomic models (in this case "computable general equilibrium" models) by answering questions such as:

- How do policies affect gross domestic product?
- How do policies affect individual sectors of the economy?

- Are households affected by the policy?
- Does the policy affect energy prices or any other price in the model (e.g., food prices)?

Third, gTech answers questions related to its biofuels and natural gas module:

- Will a policy generate more supply of renewable fuels?
- Does policy affect the cost of transporting natural gas, and therefore the price for natural gas?

Finally, gTech expands our insights into areas where there is overlap between its various features:

- What is the effect of investing carbon revenue into low- and zero-carbon technologies? This answer can only be answered with a model such as gTech.
- What are the macroeconomic impacts of technology-focused policies (e.g. how might a net zero energy-ready building code impact GDP)?
- Do biofuels focused policies affect (1) technological choice and (2) the macroeconomy?

4.2. List of sectors, fuels and end-uses in gTech

4.2.1. Sectors

Sector name	NAICS code
Soybean farming	11111
Oilseed (except soybean) farming	11112
Wheat farming	11114
Corn farming	11115
Other farming	Rest of 1111
Animal production and aquaculture	112
Forestry and logging	113
Fishing, hunting and trapping	114
Agriculture services	115
Natural gas extraction (conventional)	211113
Natural gas extraction (tight)	
Natural gas extraction (shale)	

Sector name	NAICS code
Light oil extraction	211114
Heavy oil extraction	
Oil sands in-situ	
Oil sands mining	
Bitumen upgrading (integrated)	
Bitumen upgrading (merchant)	
Coal mining	2121
Metal mining	2122
Non-metallic mineral mining and quarrying	2123
Oil and gas services	213111 to 213118
Mining services	213119
Fossil-fuel electric power generation	221111
Hydro-electric and other renewable electric power generation	221112 and 221119
Nuclear electric power generation	221113
Electric power transmission, control and distribution	22112
Natural gas distribution	222
Construction	23
Food manufacturing	311
Beverage and tobacco manufacturing	312
Textile and product mills, clothing manufacturing and leather and allied product manufacturing	313-316
Wood product manufacturing	321
Paper manufacturing	322
Petroleum refining	32411
Coal products manufacturing	Rest of 324
Petrochemical manufacturing	32511
Industrial gas manufacturing	32512
Other basic inorganic chemicals manufacturing	32518
Other basic organic chemicals manufacturing	32519
Biodiesel production from canola seed feedstock	
Biodiesel production from soybean feedstock	
Ethanol production from corn feedstock	
Ethanol production from wheat feedstock	
HDRD (or HRD) production from canola seed feedstock	
Renewable gasoline and diesel production	
Cellulosic ethanol production	
Resin and synthetic rubber manufacturing	3252
Fertilizer manufacturing	32531

Sector name	NAICS code
Other chemicals manufacturing	Rest of 325
Plastics manufacturing	326
Cement manufacturing	32731
Lime and gypsum manufacturing	3274
Other non-metallic mineral products	Rest of 327
Iron and steel mills and ferro-alloy manufacturing	3311
Electric-arc steel manufacturing	
Steel product manufacturing from purchased steel	3312
Alumina and aluminum production and processing	3313
Other primary metals manufacturing	3314
Foundries	3315
Fabricated metal product manufacturing	332
Machinery manufacturing	333
Computer, electronic product and equipment, appliance and component manufacturing	334 and 335
Transportation equipment manufacturing	336
Other manufacturing	Rest of 31-33
Wholesale and retail trade	41-45
Air transportation	481
Rail transportation	482
Water transportation	483
Truck transportation	484
Transit and ground passenger transportation	485
Pipeline transportation of crude oil	4861 and 4869
Pipeline transportation of natural gas	4862
Other transportation, excluding warehousing and storage	4867-492
Landfills	Part of 562
Services	Rest of 51-91

4.2.2. Fuels

Fuel
Fossil fuels
Coal
Coke oven gas
Coke
Natural gas
Natural gas liquids
Gasoline and diesel
Heavy fuel oil
Still gas
Electricity
Electricity
Renewable fuels (non-transportation)
Spent pulping liquor
Wood
Wood waste (in industry)
Renewable natural gas
Renewable fuels (transportation)
Ethanol produced from corn
Ethanol produced from wheat
Cellulosic ethanol
Biodiesel produced from canola
Biodiesel produced from soy
Hydrogenated renewable diesel (“hdrd”)
Renewable gasoline and diesel from pyrolysis of biomass
Renewable natural gas

4.2.3. End-uses

End use
Stationary industrial energy/emissions sources
Fossil-fuel electricity generation
Process heat for industry
Process heat for cement and lime manufacturing
Heat (in remote areas without access to natural gas)
Cogeneration
Compression for natural gas production and pipelines
Large compression for LNG production
Electric motors (in industry)
Other electricity consumption
Transportation
Air travel
Buses
Rail transport
Light rail for personal transport
Marine transport
Light-duty vehicles
Trucking freight
Diesel services (for simulating biodiesel and other renewable diesel options)
Gasoline services (for simulating ethanol options)
Oil and gas fugitives
Formation co2 removal from natural gas processing
Flaring in areas close to natural gas pipelines
Flaring in areas far from natural gas pipelines
Venting and leaks of methane (oil and gas sector)
Industrial process
Mineral product GHG emissions
Aluminum electrolysis
Metallurgical coke consumption in steel production
Hydrogen production for petroleum refining and chemicals manufacturing
Non-fuel consumption of energy in chemicals manufacturing
Nitric acid production
Agriculture
Process CH4 for which no know abatement option is available (enteric fermentation)
Manure management
Agricultural soils
Waste

End use
Landfill gas management
Residential buildings
Single family detached shells
Single family attached shells
Apartment shells
Heat load
Furnaces
Air conditioning
Lighting
Dishwashers
Clothes washers
Clothes dryers
Ranges
Faucet use of hot water
Refrigerators
Freezers
Hot water
Other appliances
Commercial buildings
Food retail shells
Office building shells
Non-food retail shells
Educational shells
Warehouses (shells)
Other commercial shells
Commercial heat load
Commercial hot water
Commercial lighting
Commercial air conditioning
Auxiliary equipment
Auxiliary motors (in commercial buildings)

Appendix B: Clean energy policies in Canada

Table 7 summarizes policies included in the forecast. Policies are categorized as (1) implemented (e.g. legislated) and (2) announced (e.g. government has announced a policy but not yet implemented/legislated it).

Table 7: Summary of policies

Region	Policy	Description	Status
Federal			
	Federal Carbon Pricing Backstop[12]	This policy includes two components: (1) a carbon levy applied to fossil fuels that reaches $50/t CO_2e by 2022 and is constant thereafter in nominal terms and (2) an output-based pricing system for industrial facilities emitting more than 50 kt CO_2e annually. This policy applies to Saskatchewan, Manitoba, Ontario, New Brunswick, Prince Edward Island, Newfoundland and Labrador, the Yukon and Nunavut. Revenue raised by this policy is returned to households in each respective province/territory.	Announced
	Clean Fuel Standard[13]	The federal government has proposed introducing a performance-based fuel supply standard requiring liquid, solid and gaseous fuel suppliers to reduce the lifecycle GHG intensity of their fuels. The government is considering reductions of approximately 10 to 15% by 2030.	Announced
	Regulations Amending the Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations[14]	This policy closes coal-fired power plants by 2030 unless they emit less than 420 tonnes CO_2e/GWh (effectively requiring carbon capture and storage technology).	Implemented
	Regulations Limiting Carbon Dioxide Emissions from Natural Gas-fired Generation of Electricity[15]	This policy limits the emissions intensity of natural-gas fired electricity generation to 420 tonnes CO_2e/GWh.	Implemented

[12] Government of Canada. (2019). Pricing pollution: how it will work. www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work.html

[13] Government of Canada. (2018). Clean Fuel Standard: timelines, approach and next steps. www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-standard/timelines-approach-next-steps.html

[14] Government of Canada. (2018). Regulations Amending the Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations: SOR/2018-263. https://laws-lois.justice.gc.ca/eng/regulations/SOR-2012-167/page-2.html#h-4

[15] Government of Canada. (2018). Regulations Limiting Carbon Dioxide Emissions from Natural Gas-fired Generation of Electricity: SOR/2018-261. https://laws-lois.justice.gc.ca/eng/regulations/SOR-2018-261/index.html

Region	Policy	Description	Status
	Hydrofluorocarbon Controls[16]	The Canadian government was one of the signatories of the 2016 Montreal Protocol-amending Kigali Agreement on ozone-depleting substances. Canada has pledged to reduce its HFC-related GHG emissions by 15% by 2036 relative to 2011 to 2013 levels by amending the Regulations Amending the Ozone-depleting Substances and Halocarbon Alternatives Regulations.	Implemented
	Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds[17]	Oil and gas facilities must adopt methane control technologies and practices.	Implemented
	Renewable Fuels Regulation[18]	Specifies a minimum renewable content of 5% for gasoline and 2% for diesel, by volume.	Implemented
	Regulations Amending the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations[19]	New passenger vehicles and light-commercial vehicles/light trucks sold in Canada must meet fleet-wide GHG emission standards between 2012 and 2016, and between 2017 and 2025. Fleet targets for passenger cars are 135g/km in 2016 and 98 g/km in 2025.	Implemented
	Federal Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations[20]	New heavy-duty vehicles sold in Canada must meet GHG emissions standards between 2014 and 2018. These regulations require that GHG emissions from 2018 model-year heavy-duty vehicles will be reduced by 23%.	Implemented
	Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations[21]	The national government has proposed amending the Heavy-Duty Vehicle Emissions Standard to increase the vehicle emission stringency for vehicles manufactured in model years 2018 to 2027. The overall decrease in emissions intensity is expected to be around 20% for vehicles manufactured in the 2027 model year relative to 2015 model year.	Implemented

[16] Government of Canada. (2018). Canada agrees to control hydrofluorocarbons under the Montreal Protocol. www.canada.ca/en/environment-climate-change/services/sustainable-development/strategic-environmental-assessment/public-statements/canada-agree-control-hydrofluorocarbons.html

[17] Government of Canada. (2018). Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector): SOR/2018-66. https://laws-lois.justice.gc.ca/eng/regulations/SOR-2018-66/index.html

[18] Government of Canada (2010). Renewable Fuels Regulations: SOR/2010-189. https://laws-lois.justice.gc.ca/eng/regulations/SOR-2010-189/index.html

[19] Government of Canada. (2018). Regulations Amending the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. http://www.gazette.gc.ca/rp-pr/p2/2014/2014-10-08/html/sor-dors207-eng.html

[20] Government of Canada. (2018). Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations: SOR/2013-24. https://laws-lois.justice.gc.ca/eng/regulations/SOR-2013-24/

[21] Government of Canada. (2018). Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and Other Regulations Made Under the Canadian Environmental Protection Act, 1999: SOR/2018-98. http://gazette.gc.ca/rp-pr/p2/2018/2018-05-30/html/sor-dors98-eng.html

Region	Policy	Description	Status
	Energy efficiency regulations[22]	Federal standards exist for space conditioning equipment, water heaters, household appliances, and lighting products. Major standards include a minimum annual fuel utilization efficiency of 90% for natural gas furnaces, a minimum energy factor of 0.61 for gas water heaters and ban of incandescent light bulbs.	Implemented
British Columbia			
	Carbon Tax[23]	Continue increasing the carbon tax by $5 per tonne of carbon dioxide equivalent annually, until it reaches $50 per tonne in 2021.	Implemented
	Renewable natural gas regulation[24]	Require that 15% of natural gas consumption be provided by renewable sources by 2030.	Announced
	Clean Energy Act[25]	A minimum of 93% of provincial electricity generation must be provided by clean or renewable sources.	Implemented
	PST Exemption[26]	Use of electricity in residential and industrial buildings is exempt from provincial sales tax.	Implemented
	Clean Industry Fund[27]	A portion of revenue collected from the carbon tax is used to fund additional industrial emission reductions.	Announced
	Industrial Electrification[28]	Supply electricity to power natural gas extraction in the Peace region, and other large industrial operations.	Announced
	Renewable and Low Carbon Fuel Requirements Regulation[29]	This policy includes two components: 1) a minimum renewable fuel content for gasoline (5% by volume) and diesel (4% by volume); and 2) a decrease in average carbon intensity of fuels by 10% by 2020 relative to 2010.	Implemented
	Strengthened Low Carbon Fuel Standard[30]	Require fuel suppliers to reduce the carbon intensity of diesel and gasoline pools by 20% by 2030 from 2010 levels, while expanding coverage to domestic aviation and navigation fuels.	Announced

22 Natural Resources Canada. (2017). Canada's Energy Efficiency Act and Energy Efficiency Regulations. www.nrcan.gc.ca/energy/regulations-codes-standards/6861

23 Government of British Columbia. (2019). BC's Carbon Tax. https://www2.gov.bc.ca/gov/content/environment/climate-change/planning-and-action/carbon-tax

24 Government of British Columbia. (2019). CleanBC. https://cleanbc.gov.bc.ca/

25 Government of British Columbia. (2010). Clean Energy Act. SBC 2010, Chapter 22. http://www.bclaws.ca/civix/document/id/lc/statreg/10022_01

26 Government of British Columbia. 2017. Provincial Sales Tax (PST) Bulletin: Energy, Energy Conservation and the ICE Fund Tax. https://www2.gov.bc.ca/gov/content/taxes/sales-taxes/pst

27 Government of British Columbia. (2019). CleanBC. https://cleanbc.gov.bc.ca/

28 Ibid

29 Government of British Columbia. (2016). Renewable and Low Carbon Fuel Requirements Regulation: B.C. Reg. 287/2016. http://www.bclaws.ca/civix/document/id/lc/statreg/394_2008

30 Government of British Columbia. (2019). CleanBC. https://cleanbc.gov.bc.ca/

Region	Policy	Description	Status
	Zero-emission vehicle mandate[31]	Require a minimum share of light-duty vehicles sold in BC to be zero-emission. This mandate achieves 10% electric vehicles sales by 2025, 30% by 2030 and 100% by 2040.	Announced
	Strengthened BC Building Code[32]	New buildings must be "net zero energy ready" by 2032.	Announced
	Organic Waste Diversion[33]	Divert 95% of organic waste from landfills.	Announced
	Landfill Gas Management Regulation[34]	Capture 75% of landfill gas.	Announced
Alberta			
	Carbon levy[35]	Applies a tax of $30/t CO2e on fossil fuels. Revenue from the tax is used to pay for initiatives that reduce emissions and support adaptation and transition to a lower carbon economy.	Implemented
	Carbon Competitiveness Incentive Regulation[36]	This policy replaces the Specified Gas Emitters Regulation on large final emitters in Alberta. Facilities receive free emission credits based on the emissions intensity of high performing facilities producing similar products.	Implemented
	Phasing out coal pollution[37]	This policy closes coal-fired electricity by 2030.	Implemented
	Renewable Electricity Program[38]	Target of generating 30% of electricity from renewable sources by 2030.	Announced
	Methane Emissions reduction[39]	Reduce methane emissions from oil and gas operations by 45% by 2025.	Implemented
	Capping oil sands emissions[40]	Limits emissions from the oil sands to 100 Mt CO_2e annually.	Implemented

31 Ibid

32 Ibid

33 Ibid

34 B.C. Reg. 391/2008. Environmental Management Act: Landfill Gas Management Regulation. Available from: http://www.bclaws.ca

35 Government of Alberta. (2019). Carbon levy and rebates. www.alberta.ca/climate-carbon-pricing.aspx

36 Government of Alberta. (2019). Carbon Competitiveness Incentive Regulation. Accessed from: www.alberta.ca/carbon-competitiveness-incentive-regulation.aspx

37 Government of Alberta. (2019). Phasing out coal pollution. www.alberta.ca/climate-coal-electricity.aspx

38 Alberta Electric System Operator. (2016). Renewable Electricity Program. Accessed from: www.aeso.ca/market/renewable-electricity-program/

39 Government of Alberta. (2019). Reducing methane emissions. Accessed from: www.alberta.ca/climate-methane-emissions.aspx

Region	Policy	Description	Status
	Carbon capture and storage investments	Alberta has contributed funding to several CCS projects, including the Shell Canada Energy Quest Project[41] and the Alberta Carbon Trunk Line[42].	Implemented
Saskatchewan			
	Boundary Dam Carbon Capture Project[43]	This project stores and captures CO_2 emissions from a 115 MW coal plant.	Implemented
	Methane reduction[44]	Reduce methane emissions by 40 to 45% of 2015 levels.	Announced
Manitoba			
	Emissions tax on coal[45]	Tax rate based on the emissions intensity of a specific type of coal, ranging from $14.27 per tonne (Lignite) to $31.90 per tonne (Petroleum Coke).	Implemented
	Biodiesel mandate[46]	Require a minimum renewable fuel content of 5% for diesel.	Announced
Ontario			
	Ethanol mandate[47]	Increase the renewable content of gasoline to 15% as early as 2025.	Announced
	Ontario Building Code[48]	New houses must achieve an EnerGuide rating of 80. Large buildings must meet ASHRAE standards.	Implemented
Québec			
	Cap and Trade System for Greenhouse Gas Emissions Allowances[49]	Cap and trade for industrial and electricity sectors as well as fossil fuel distributors. Revenue raised by the policy is invested in low carbon technologies.	Implemented

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[40] Government of Alberta. (2019). Capping oil sands emissions. Accessed from: www.alberta.ca/climate-oilsands-emissions.aspx

[41] Natural Resources Canada. (2018). Shell Canada Energy Quest Project. Accessed from: www.nrcan.gc.ca/energy/funding/cef/18168

[42] Natural Resources Canada. (2016). Alberta Carbon Trunk Line (ACTL). Accessed from: www.nrcan.gc.ca/energy/publications/16233

[43] SaskPower. (2019). Boundary Dam Carbon Capture Project. www.saskpower.com/our-power-future/infrastructure-projects/carbon-capture-and-storage/boundary-dam-carbon-capture-project

[44] Ibid

[45] Government of Manitoba. (2019). The Emissions Tax on Coal and Petroleum Coke Act: C.C.S.M. c. E90. https://web2.gov.mb.ca/laws/statutes/ccsm/e090e.php

[46] Government of Manitoba. (2017). A Made-in-Manitoba Climate and Green Plan. Available from: www.gov.mb.ca/asset_library/en/climatechange/climategreenplandiscussionpaper.pdf

[47] Government of Ontario. (2019). Increasing renewable content in fuels. Available from: https://ero.ontario.ca/notice/013-4598

[48] Government of Ontario. (2019). Building code: O. Reg. 332/112. www.ontario.ca/laws/regulation/120332

Region	Policy	Description	Status
	ZEV Mandate[50]	Requires automakers to sell a minimum of zero emission vehicles.	Implemented
Nova Scotia			
	Cap-and-Trade Program[51]	Annual caps on certain activities in Nova Scotia, including fuel suppliers, electricity importers and large final emitters.	Implemented
	Cap on GHG emissions from electricity generation[52]	This policy requires emissions from the electricity sector to decline to 4.5 Mt by 2030.	Implemented
	Renewable portfolio standard[53]	This renewable portfolio standard requires that 25% of electricity consumption be provided from renewable resources in 2015, increasing to 40% by 2020.	Implemented
	Maritime Link[54]	This transmission line will connect Nova Scotia to hydroelectric generation from Newfoundland Labrador (and in particular, to the Muskrat Falls hydroelectric project).	Implemented
New Brunswick			
	Renewable Portfolio Standard[55]	The renewable portfolio standard requires NB Power to ensure that 40% of in-province electricity sales are provided from renewable energy by 2020. Imports of renewable energy from other jurisdictions qualify for compliance, as do energy efficiency improvements.	Implemented

49 Gouvernement du Québec. (2019). The Carbon Market. www.environnement.gouv.qc.ca/changements/carbone/Systeme-plafonnement-droits-GES-en.htm

50 Gouvernement du Québec. (2018). The zero-emission vehicle (ZEV) standard. www.environnement.gouv.qc.ca/changementsclimatiques/vze/index-en.htm

51 Government of Nova Scotia. (2019). Nova Scotia's Cap-and-Trade Program. https://climatechange.novascotia.ca/nova-scotias-cap-trade-program

52 Government of Nova Scotia. Greenhouse Gas Emissions Regulations made under subsection 28(6) and Section 112 of the Environment Act. www.novascotia.ca/JUST/REGULATIONS/regs/envgreenhouse.htm

53 Government of Nova Scotia. Renewable Electricity Regulations made under Section 5 of the Electricity Act. https://novascotia.ca/just/regulations/regs/elecrenew.htm

54 Emera Newfoundland & Labrador. (2014). Maritime Link. http://www.emeranl.com/en/home/themaritimelink/overview.aspx

55 Government of New Brunswick. 2015. New Brunswick Regulation 2015-60 under the Electricity Act (O.C. 2015-263). www.gnb.ca/0062/acts/BBR-2015/2015-60.pdf

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