# Canada's Clean Energy Economy to 2030

Final report prepared for Clean Energy Canada

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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# Executive Summary

This report builds on previous work that defined and quantified Canada's clean energy economy[1]. It provides an updated projection of how the clean energy economy may grow through 2030 in response to both existing policy and the federal government's new climate plan[2].

## What is the clean energy economy?

The clean energy economy is defined 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 more detailed explanation is available in this report.

## What are the key findings of this work?

**The clean energy economy will grow in response to current policies.** Without additional climate policy, clean energy economy GDP reaches $95 billion in 2030, growing by 3.4% per annum this decade. This pace of growth outpaces that in the "rest of energy" (i.e., energy-economy not classified as clean). Over this time-period, clean energy investment and consumption increase from $47 billion to $50 billion annually, while clean energy jobs increase from 431 to 554 thousand.

**Additional policies to help Canada achieve its 2030 target further boost the clean energy economy.** Additional policies increase GDP growth to 4.7% annually, meaning that the clean energy economy reaches $107 billion by 2030. Likewise, clean energy investment increases to $58 billion annually and jobs reach 639 thousand.

**Gains in the clean energy economy exceed reductions in the rest of energy under the new climate plan.** While the clean energy economy experiences growth under all scenarios examined, growth in the rest of energy depends on oil prices as well as policy. If oil prices are low, the rest of energy shrinks – but this reduction is exceeded by growth in the clean energy economy when strong climate policy is in place.

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[1] Navius Research. 2019. *Quantifying Canada's Clean Energy Economy: A forecast of clean energy investment, value-added and jobs.* https://cleanenergycanada.org/report/the-fast-lane-tracking-the-energy-revolution-2019/

[2] Environment and Climate Change Canada. 2020. *Healthy Environment and a Healthy Economy.* https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/climate-plan/healthy_environment_healthy_economy_plan.pdf

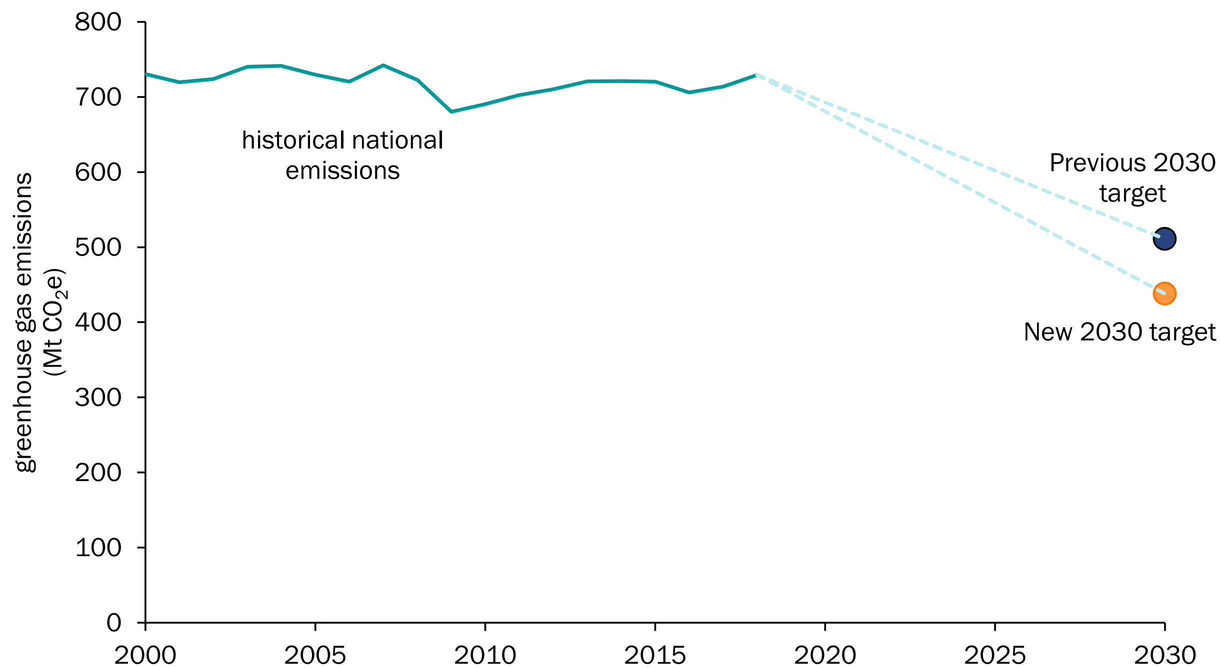
# Contents

# 1. Introduction

## 1.1. Background

Canada has committed to reduce emissions by 30% below 2005 by 2030[3], and has recently strengthened this target to at least 40%[4] (please see Figure 1). Achieving either of these targets requires a larger decrease in emissions than has ever been achieved nationally – and implies that strong policy is also required.

Figure 1: Canada's historical emissions and 2030 target




To help achieve Canada's target, the federal government announced a new climate plan in December of 2020, called "A Healthy Environment and a Healthy Economy". This plan identifies several new climate policies including and increase of the carbon

[3] Environment and Climate Change Canada. 2021. *Progress Towards Canada's Greenhouse Gas Emissions Reduction Target*. Available from: https://www.canada.ca/content/dam/eccc/documents/pdf/cesindicators/progress-towards-canada-greenhouse-gas-reduction-target/2021/progress-ghg-emissions-reduction-target.pdf

[4] Tasker, J.P, & Wherry, A. 2021. Treudeau pledges to slash greenhouse gas emissions by at least 40% by 2030. *CBC*. Available from: https://www.cbc.ca/news/politics/trudeau-climate-emissions-40-per-cent-1.5997613

price to $170/t $CO_2e$ by 2030 and providing $15 billion in multi-sectoral emission reduction funding[5].

It is against this background that Clean Energy Canada would like to understand the potential growth of the clean energy economy through 2030.

This report builds on previous work by Navius to quantify Canada's clean energy economy. It 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 explanation and taxonomy of clean energy sectors is available in the previous report[6]. More information can also be found in this report in Section 2.4.

## 1.2. Project objective

The objective of this report is to quantify the state of Canada's clean energy economy in 2030 under the proposed "A Healthy Environment and a Healthy Economy". In particular, it quantifies, where possible, the GDP, investment and employment in each clean energy sector of Canada's economy.

## 1.3. Report structure

The report is structured as follows:

- Section 2 outlines the approach to the analysis, covering an introduction to energy-economy modelling and to Navius' gTech model. This section also outlines scenarios modelled for this analysis, a definition of the clean energy economy, as well as the limitations to forecasting.
- Section 3 covers results from the analysis, including clean energy economy trends to 2030, the impact of "A Healthy Environment and a Healthy Economy" on the energy economy, and a sensitivity analysis.

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[5] Environment and Climate Change Canada. 2020. *Healthy Environment and a Healthy Economy.* https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/climate-plan/healthy_environment_healthy_economy_plan.pdf

[6] Navius Research. 2019. *Quantifying Canada's Clean Energy Economy: A forecast of clean energy investment, value-added and jobs.* https://cleanenergycanada.org/report/the-fast-lane-tracking-the-energy-revolution-2019/

- Appendix A covers assumptions, including a list of policies included in the current policy forecast, and Appendix B outlines covered sectors, fuels and end-uses in gTech.

# 2. Approach

This Chapter provides an overview of the approach used to simulate Canada's clean energy economy through 2030. It begins with an introduction to energy-economy modeling (Section 2.1), followed by a description of Navius' gTech model (Section 2.2), a discussion about the limits of forecasting (Section 2.3), and a definition of the clean energy economy (Section 2.4). It concludes with a description of the "A Healthy Environment and a Healthy Economy" policy package (Section 2.5).

## 2.1. Introduction to energy-economy modeling

Canada's energy-economy is complex. Energy consumption, which is the main driver of anthropogenic greenhouse gas emissions, results from the decisions made by tens of thousands of residents. For example, households must choose what type of vehicles they will buy and how to heat their homes; industry must decide whether to install technologies that might cost more but consume less energy; municipalities must determine whether to expand transit service; and investors need to decide whether to invest their money in Canada or somewhere else.

Existing policies and those required to achieve Canada's greenhouse gas reduction targets will have effects throughout the economy and interact with each other. For example, provincial policies (e.g., building codes, energy efficiency rebates) and federal policies (e.g., carbon pricing, energy efficiency regulations) influence greenhouse gas emissions from buildings. Likewise, multiple policies seek to influence emissions from passenger vehicles, such as federal vehicle emission standards, federal zero emission vehicle incentives and the federal carbon price. The interactive effects among such policies can be complex.

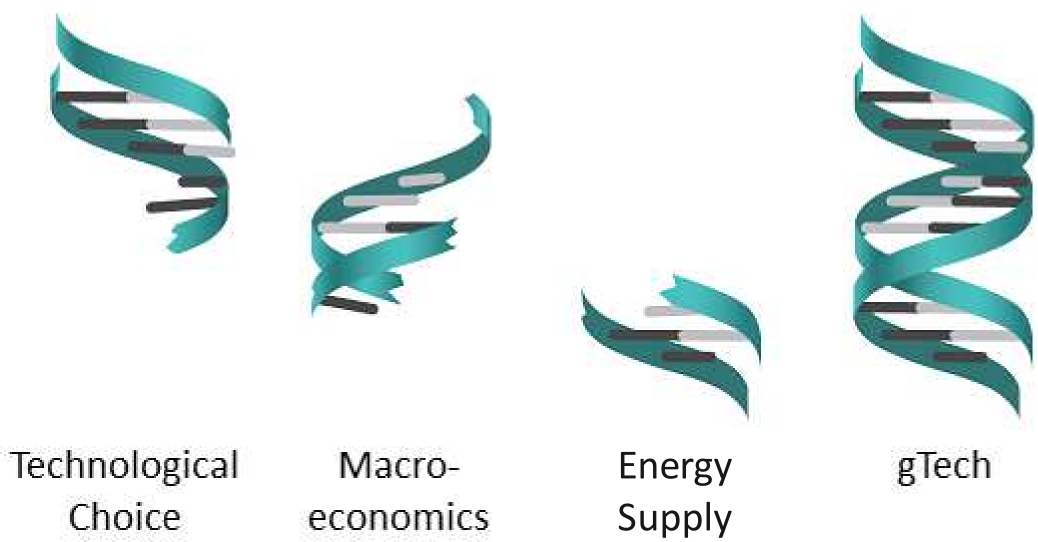
Estimating the greenhouse gas and economic impacts of climate policy therefore requires a modeling framework that captures much of the complexity of the energy-economic system as well as the range of policies implemented and proposed across multiple levels of government.

## 2.2. Introduction to gTech

gTech is unique among energy-economy models because it combines features that are typically only found in separate models (see Figure 2):

- 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 and territories interact with each other and the rest of the world.
- A detailed representation of energy supply, including liquid fuel (crude oil and biofuel), gaseous fuel (natural gas and renewable natural gas) and electricity.

Figure 2: The gTech model




### Simulating technological choice

Technological choice is one of the most critical decisions that influences greenhouse gas emissions in Canada. For example, if a household chooses to purchase an electric vehicle over a gasoline car, that decision will reduce their emissions. Similarly, if a manufacturing facility chooses to electrify its operations, that decision reduces its 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., light-duty vehicle travel, residential space heating, industrial process heat, management of agricultural manure). For a list of end-uses and fuels represented in the model, please see Appendix B: "Covered sectors, fuels and end-uses in gTech".

Naturally, technological choice is influenced by many factors. Table 1 summarizes key factors that influence technological choice and the extent to which these factors are included in gTech.

Table 1: 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.<br><br>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 climate 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] |

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

| Criteria | Description |
|---|---|
| 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, buyers of passenger vehicles can be concerned about the driving range and available charging infrastructure, some may worry about the risk of buying new technology, and some may see the vehicle as a "status symbol" that they value[8]. gTech quantifies these technology-specific preferences as "non-financial" costs, which are added to the technology choice algorithm. |
| 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 their neighbour purchases an SUV and another takes transit.<br><br>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 few years, and costs are expected to continue declining in the future. 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 and/or in response to cumulative production of that technology. |
| Policy | One of the most important drivers of technological choice is government policy. Current federal, provincial and territorial initiatives in Canada are already altering the technological choices households and firms make through various policies such as: (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; (4) variations in other tax policy (e.g., whether or not to charge GST on a given technology); and (5) flexible regulations, like the federal Clean Fuel Regulation, which will create a market for compliance credits.<br><br>gTech simulates the combined effects of all these policies implemented together. Policies included in the forecasting are described in Appendix A:. |

[8] Kormos, C., Axsen, J., Long, Z., Goldberg, S., 2019. Latent demand for zero-emissions vehicles in Canada (Part 2): Insights from a stated choice experiment. Transportation Research Part D: Transport and Environment 67, 685-702.

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

## 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 2.

Table 2: 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[10]. Specifically, it captures all sector activity, all gross domestic product, all trade of goods and services and the transactions that occur between households, firms and government. As such, the model provides a forecast of how government policy affects many different economic indicators, including gross domestic product, investment, household income and jobs. |
| 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 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 ultimately leading to higher wages.<br><br>The model also accounts for price effects. For example, the electricity sector can pass policy compliance costs on to households, who may alter their demand for electricity and other goods and services (e.g., by switching to technologies that consume other fuels and/or reducing consumption of other goods and services). |
| Sector detail | gTech provides a detailed accounting of sectors in Canada. In total, gTech simulates how policies affect over 80 sectors of the economy. Each of these sectors produces a unique good or service (e.g., the food manufacturing sector produces food, while the trucking sector produces transport services) and requires specific inputs into production. |
| 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 consumption level). If the real wage increases, the availability of labor increases. The model also accounts for "equilibrium unemployment".<br><br>Capital markets are introduced in more detail below. |

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

| Dynamic | Description |
| --- | --- |
| Interactions between regions | Economic activity in Canada is highly influenced by interactions among provinces/territories, with the United States and with countries outside of North America. Each province and territory in the model interacts with other regions 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 and territorial governments).<br><br>The version of gTech used for this project accounts for the 10 Canadian provinces, the territories as a region, 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 energy commodities 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 energy supply markets

gTech accounts for all major energy supply markets, such as electricity, refined petroleum products and natural gas. Each market is characterized by resource availability and production costs by province and territory, as well as costs and constraints (e.g., pipeline capacity) of transporting energy between regions.

Low carbon energy sources can be introduced within each fuel stream in response to policy, including renewable electricity and bioenergy. The model accounts for the availability and cost of bioenergy feedstocks, allowing it to provide insight about the economic effects of emission reduction and biofuels policy.

## 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 climate and energy policy.

First, gTech can provide insights related to technological change by answering questions such as:

- How do policies affect technological adoption (e.g., how many electric vehicles are likely to be on the road in 2030)?
- How does technological adoption affect greenhouse gas emissions and energy consumption?

Second, gTech can provide insights related to macroeconomics by answering questions such as:

- How do policies affect gross domestic product?
- How do policies affect individual sectors of the economy?
- How 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 energy supply modules:

- Will a policy result in more supply of renewable fuels?
- Does policy affect the cost of transporting refined petroleum products, and therefore the price of gasoline in Canada?

Finally, gTech provides insight 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 zero-emissions vehicle standard impact GDP)?
- Do biofuels focused policies affect (1) technological choice and (2) the macroeconomy?

This modeling toolkit allows for a comprehensive examination of Canada's clean energy economy through 2030 and beyond.

## 2.3. Limits to forecasting

Despite using the best available forecasting methods and assumptions, the evolution of our energy economy is uncertain. In particular, forecasting is subject to two main types of uncertainty.

First, all models are simplified representations of reality. Navius' gTech model is, 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 overlook important factors that may influence the future?"

The use of computable general equilibrium models (gTech) is well founded in the academic literature. In addition, Navius undertakes significant efforts to calibrate and back-cast the model to ensure that it captures key dynamics in the energy-economic system. However, the availability and quality of calibration data may be limited in some instances.

In addition, Navius' tools do not account for every dynamic that will influence technological change. 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-economic 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 subject to uncertainty. These assumptions include, but are not limited to, oil prices, improvements in labor productivity and a stable climate. If any of the assumptions used prove incorrect, the resulting forecast could be affected. Sensitivity analysis is useful for determining the impact of different assumptions on model results.

In sum, gTech is the most comprehensive model available for forecasting the techno-economic impacts of climate policy in Canada. Its representation of technological change, macroeconomic dynamics and fuels markets (as described above) mean that it is ideally positioned to forecast how the broad range of policies implemented in Canada will affect technological change, energy consumption, greenhouse gas emissions, the economy and a large array of other indicators.

## 2.4. Defining the clean energy economy

This report builds on previous work by Navius[11] that 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."*

To model the clean energy economy gTech, we assign GDP, investment, and jobs into one of three categories:

- **Clean energy** (i.e., generally as defined in the previous report, as noted in Section 2.4.1).
- **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 previous analyses, household consumption of clean technologies is reported as "investment". For example, a household purchasing a plug-in electric vehicle is added to investment, even though it would traditionally be considered consumption.

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, hydrogen production for transport, and transit) and (2) value-added associated with

[11] Navius Research. 2019. *Quantifying Canada's Clean Energy Economy: A forecast of clean energy investment, value-added and jobs.* https://cleanenergycanada.org/report/the-fast-lane-tracking-the-energy-revolution-2019/

the use of clean technologies in other sectors. For example, a plug-in 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 a plug-in 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, stationary batteries and energy storage, smart grid technology, energy-saving building materials 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, 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.

### 2.4.1. Summary of changes to methodology compared to previous 2030 forecast

This analysis relies on an updated version of gTech that has been updated since the previous clean energy economy projections were made in 2019. The most substantive updates include:

- Switching from a 2010 to 2015 model base year so that more recent Statistics Canada economic accounts data forms the basis for projections.
- Conducting a detailed calibration to the latest data sources, including the National Inventory Report and energy use trends.
- Incorporating the latest provincial and federal policies.
- Adding new clean technologies and fuels, most notably hydrogen fuel cell vehicles and hydrogen supply for transport.
- Revising the cost and performance of all emerging low carbon technologies, such as battery electric vehicles.
- Re-classifying hybrid-electric vehicles as part of "rest of energy" (plug-in hybrids remain classified as "clean energy").

The net effect of these changes is that the clean energy economy's GDP is anticipated to be roughly 10% larger in 2030 relative to previous current policy projections.

## 2.5. Scenarios

The list below provides a description of the two scenarios modeled for this analysis.

Table 3 outlines additional details on the "A Healthy Environment and a Healthy Economy" plan, and Appendix A covers details on policies included in the current policy forecast.

- Current policy with existing price schedule that reaches \$50/t $CO_2e$ and remains constant thereafter. Vehicle emission standards are assumed to be unchanged post-2021.
- New Climate Plan (NCP) includes (1) the newly announced carbon price schedule (\$170/t $CO_2e$ by 2030), assumed to apply to all provinces except Québec, (2) the

Clean Fuel Regulation as per the information available in the Gazette[12], and (3) $15 billion in multi-sectoral emission reduction funding[13].

Table 3: Summary of New Climate Plan

| Sector | Policy |
|---|---|
| **Multi-sectoral** | Increase carbon price to $170/t (nominal) by 2030 (does not apply to QC). |
| **Transport** | $300m in funding for ZEV transport.<br>CFS for liquid stream only.<br>Implement California VES post-2021. |
| **Buildings** | $4.1b in funding for building envelope improvements and heat pumps. |
| **Industry** | $5.3b in funding for low carbon industrial technologies. |
| **Electricity** | $1.3b in funding for clean electricity.<br>90% reduction in electricity generation emissions by 2030. |

Please note: Specific policy assumptions and scenario design determined in collaboration with Clean Energy Canada.

[12] Canada Gazette, Part 1, Volume 154, Number 51: Clean Fuel Regulations. 2020. https://gazette.gc.ca/rp-pr/p1/2020/2020-12-19/html/reg2-eng.html

[13] Environment and Climate Change Canada. 2020. A Healthy Environment and a Healthy Economy. https://www.canada.ca/en/environmentclimate-change/news/2020/12/a-healthy-environment-and-a-healthy-economy.html

# 3. Results

This chapter presents various projections for growth in the clean energy economy. Section 3.1 summarizes how Canada's clean energy economy – as measured by GDP, investment and jobs – is anticipated to grow in the absence of new policies. Section 3.2 explores how the clean energy economy may evolve in response to the Federal Government's new climate plan ("A Healthy Environment and a Healthy Economy). Finally, Section 3.3 discusses the impact of oil prices on the energy-economy.

## 3.1. How does Canada's clean energy economy grow in the absence of new policies?

This section outlines clean energy economy trends to 2030 under current policies, as described in Section 2.5 and Appendix A: "Assumptions".

### 3.1.1. GDP

Clean energy GDP increases from $68 billion (2015$) in 2020 to $95 billion in 2030 in the absence of new policies (please see Figure 3). The clean energy economy is projected to outpace the rest of energy through 2030, as the clean energy economy grows 3.4% annually between 2020 and 2030, while the rest of energy grows at 1.5% annually. By 2030, the clean energy economy accounts for 25% of total energy-related GDP (up from 22% in 2020).

Figure 3: Energy-related GDP under current policies

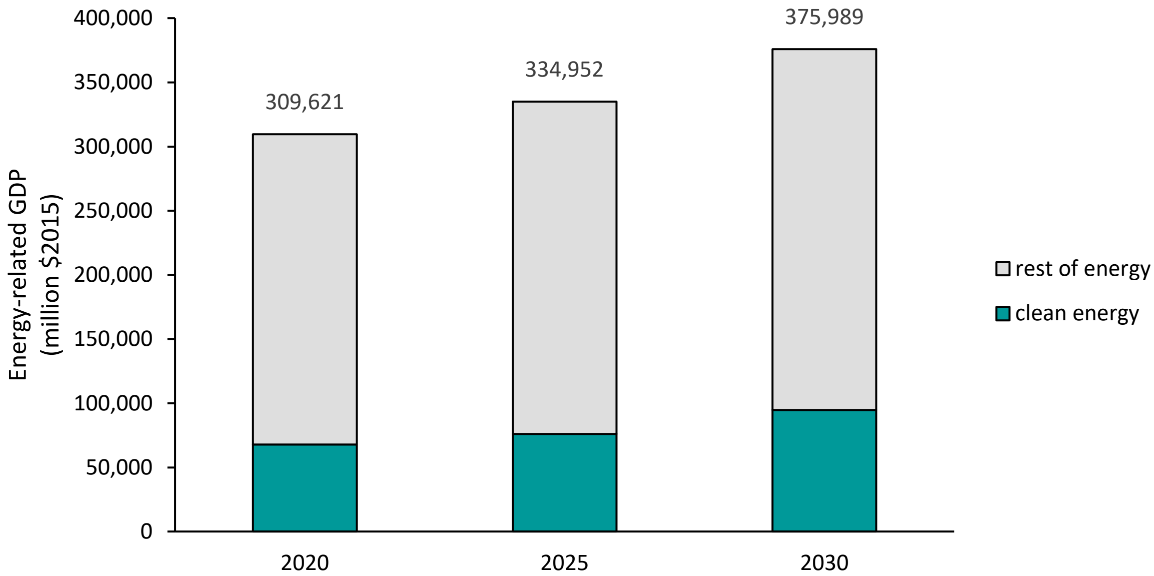
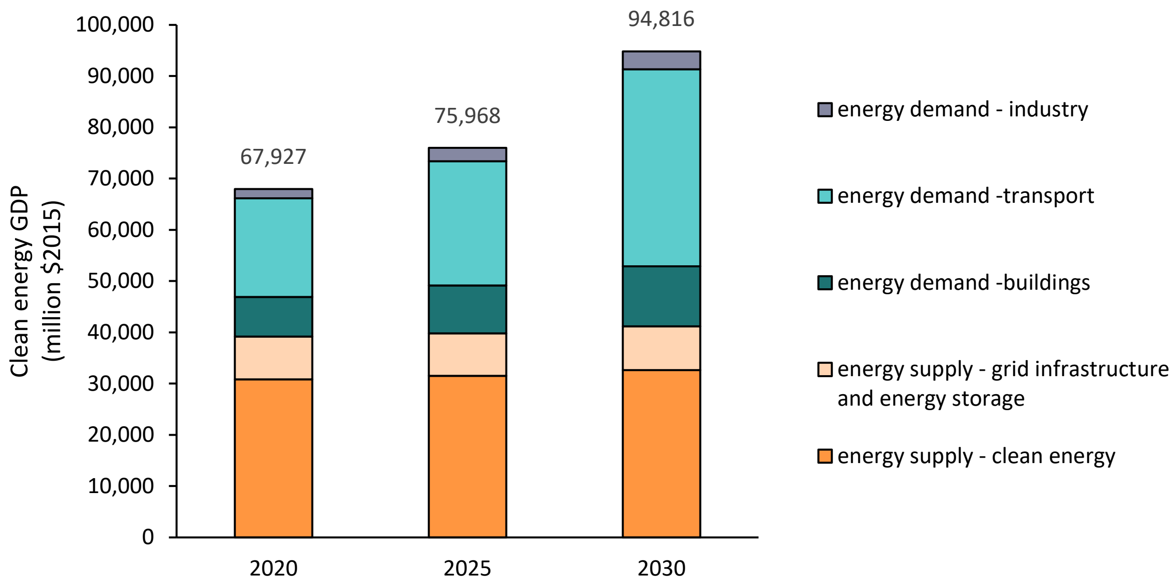



Figure 4 below shows clean energy GDP under current policies broken down by sector. All clean energy sectors experience growth between 2020 and 2030; clean energy supply increases, Canada's building stock becomes cleaner as new buildings are constructed to higher standards replacing older buildings, and industry becomes less carbon intensive (e.g., through adopting industrial heat pumps, methane controls and so on).

The largest increase in clean energy GDP comes from transport, which grows by 7.2% annually, contributing $19 billion to Canada's GDP in 2020 and $38 billion in 2030. This increase comes from adoption of zero-emission vehicles across all vehicle classes – including light, medium and heavy-duty vehicles. For example, plug-in electric vehicles (PEVs) account for 15% of light-duty vehicle sales in 2030. This increase in adoption is due to improved performance of the vehicles and falling costs of batteries, as well as policy. Key policies include the zero emission vehicle mandates in Québec and BC.

Figure 4: Clean energy GDP under current policies




## 3.1.2. Investment

Clean energy investment (and household consumption of clean energy technologies) is projected to grow by 0.7% annually, from $47 billion to $50 billion ($2015) between 2020 and 2030. If oil prices remain steady (in the $60/bbl range), investment in the rest of energy declines by 0.2% annually from $153 billion in 2020 to $149 billion in 2030. Under such a scenario, total energy-related investment is projected to stay relatively steady in the absence of new policies. With lower oil prices, both investment in rest of energy and total energy will decline (investment in clean energy is not impacted to a large extent). This is discussed in further detail in Section 3.3.

Figure 5 shows energy-related investment in Canada under current policies. As a reminder, consumption of technologies is included in this total (e.g., a household purchasing an electric vehicle is included in clean investment even though from a conventional economic perspective it is considered consumption).

Figure 5: Annual energy-related investment under current policies

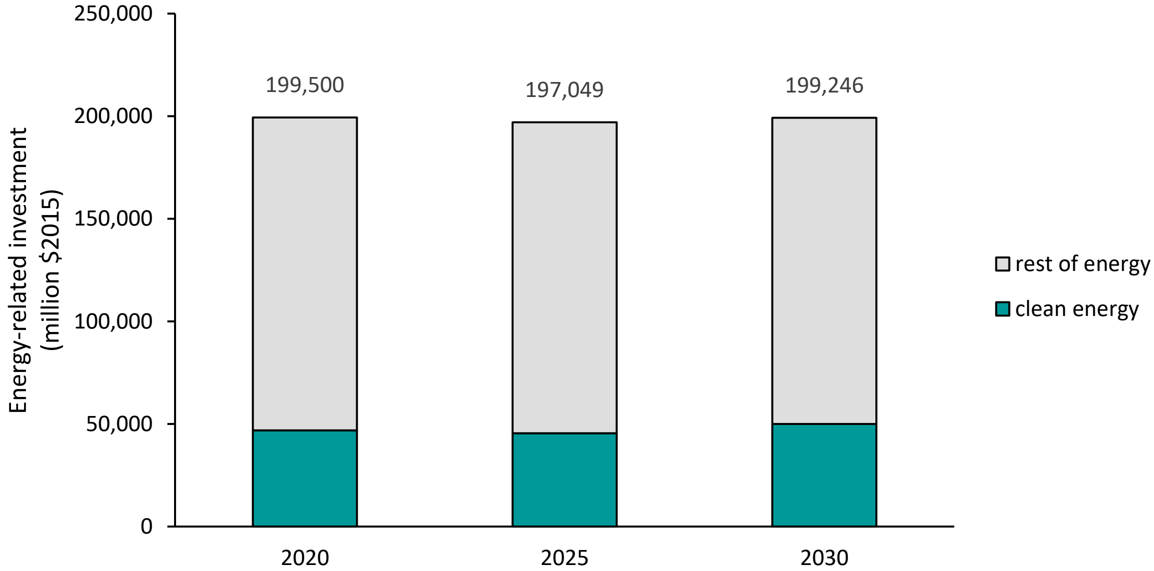
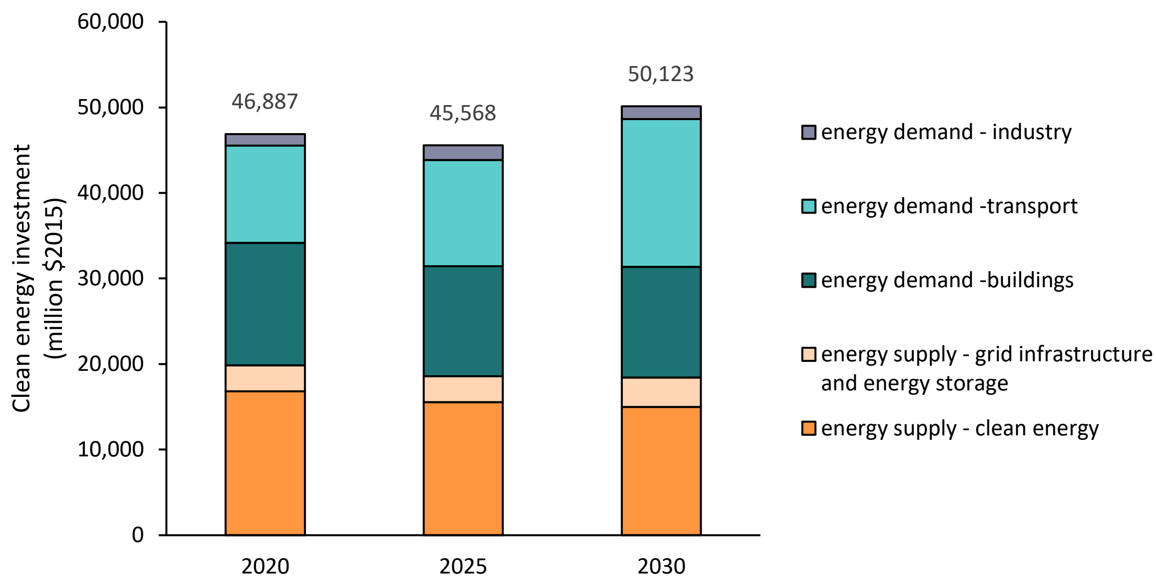



Figure 6 shows clean energy investment broken down by sector. Like with GDP, the increase in clean energy investment is largely due to clean transport investment. Investment in clean transportation increases from $11 billion in 2020 to $17 billion in 2030, an annual growth rate of 4.3%. As mentioned above, this investment is driven by a combination of factors, including policy (i.e., vehicle emission standards) and technological change (i.e., declining costs of batteries).

Figure 6: Annual clean energy investment under current policies



### 3.1.3. Jobs

Clean energy jobs grow by 2.6% annually from 431,000 in 2020 to 554,000 in 2030. On the other hand, jobs in the rest of energy are simulated to decline by 0.4% annually from 1,342,000 to 1,284,000 in the same period. However, total energy-related jobs still increase from 1,772,000 to 1,838,000, with the share of clean energy jobs increasing from 24% of energy-related jobs in 2020 to 30% in 2030. Figure 7 shows energy-related jobs under current policies.

Figure 7: Energy-related jobs under current policies

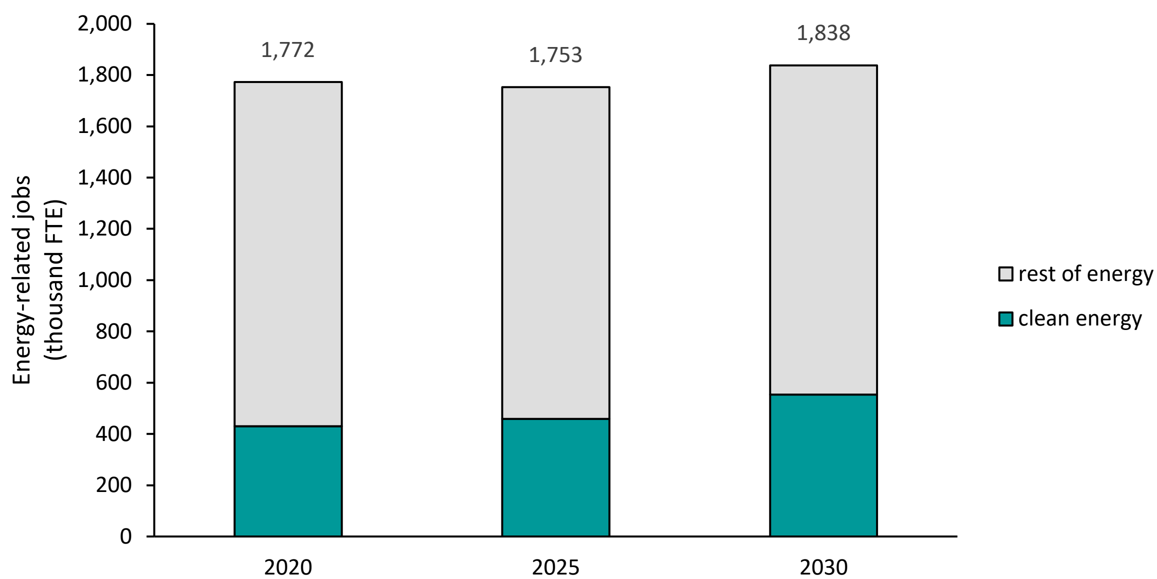
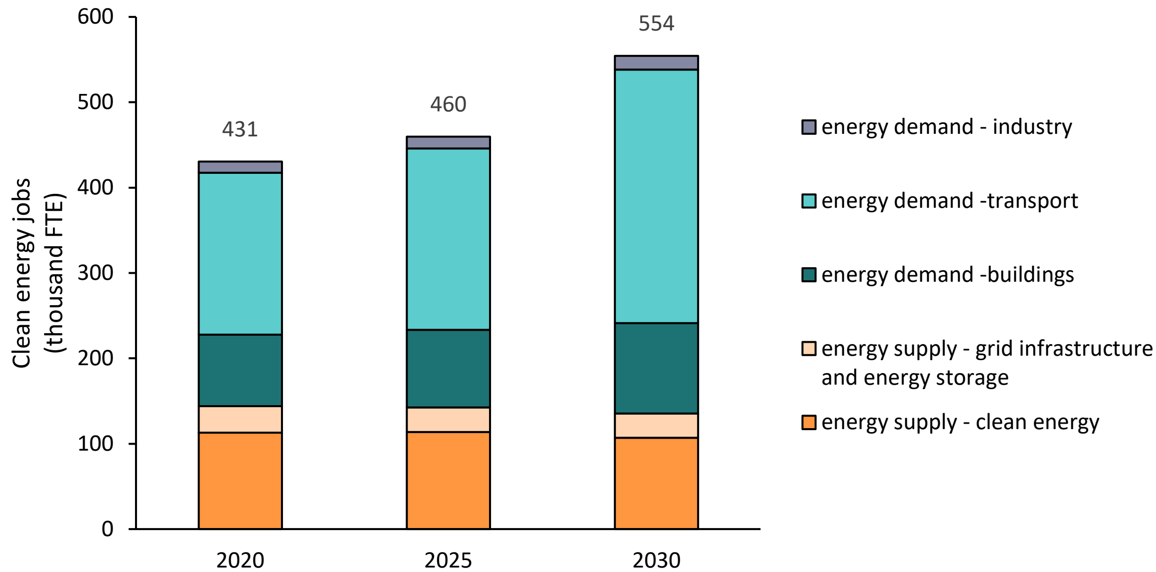



Figure 8 shows clean energy jobs broken down by sector. Most clean energy sectors experience growth in jobs between 2020 and 2030. Transport jobs account for the largest increase, growing by 4.6% annually. This is due to an increase in plug-in electric vehicles (PEVs) and fuel cell electric vehicles (FCEVs) providing transport services. As ZEV adoption grows, the share of drivers operating them increases. Jobs related to PEVs grow from 7,000 to 114,000 between 2020 and 2030, and jobs related to FCEVs more than triple between 2025 and 2030, growing from 5,000 to 16,000.

Figure 8: Clean energy jobs under current policies




# 3.2. How is the clean energy economy impacted by new policies?

This section explores the impact of the new climate plan (NCP), called “A Healthy Environment and a Healthy Economy”, on the clean energy economy. More information about the policy package is available in Section 2.5.

## 3.2.1. GDP

The clean energy economy grows more quickly in response to the new climate plan, at 4.7% annually between 2020 and 2030 relative to 3.4% under current policies. Under the new climate plan, the clean energy economy reaches $107 billion in 2030. At the same time, GDP from the rest of energy grows, though at a slower rate than under current policies (0.9% annually between 2020 and 2030). However, total energy-related GDP still grows between 2020 to 2030 under the new climate plan to reach $371 billion in 2030.

Figure 9: Energy-related GDP to 2030

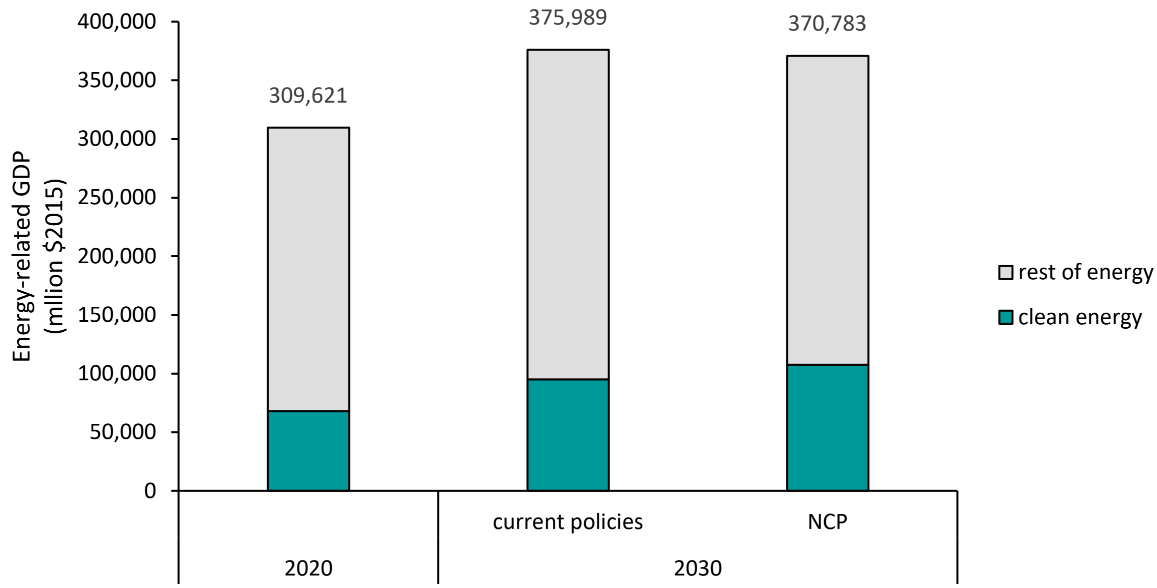



Figure 10 and Figure 11 show a breakdown of the clean energy economy by sector and region, respectively. The difference between the policies is in large part due to transportation. In 2030, GDP from clean energy transportation is 23% greater under the new climate plan relative to current policies, reaching $47 billion in 2030. Greater adoption of PEVs and FCEVs result in a growing share of transport activity being clean.

Under current polices, PEVs account for 15% of new light-duty vehicle sales and FCEVs account for 4% of new heavy-duty vehicle sales in 2030. However, under the new climate plan, PEVs account for 18% of new light-duty vehicle sales and FCEVs account for 7% of new heavy-duty vehicle sales.

Another difference between current policies and the new climate plan is GDP from clean energy in industry. GDP from greenhouse gas control in industry (e.g., carbon capture and storage, landfill gas flaring, and inert anodes in aluminium production) is 60% greater under the new climate plan relative to current policies in 2030, and low carbon machinery GDP (i.e., adoption of electric motors and compressors, industrial heat pumps, biomass, and high efficiency natural gas-fired boilers) is 51% greater.

Figure 10: Clean energy GDP to 2030

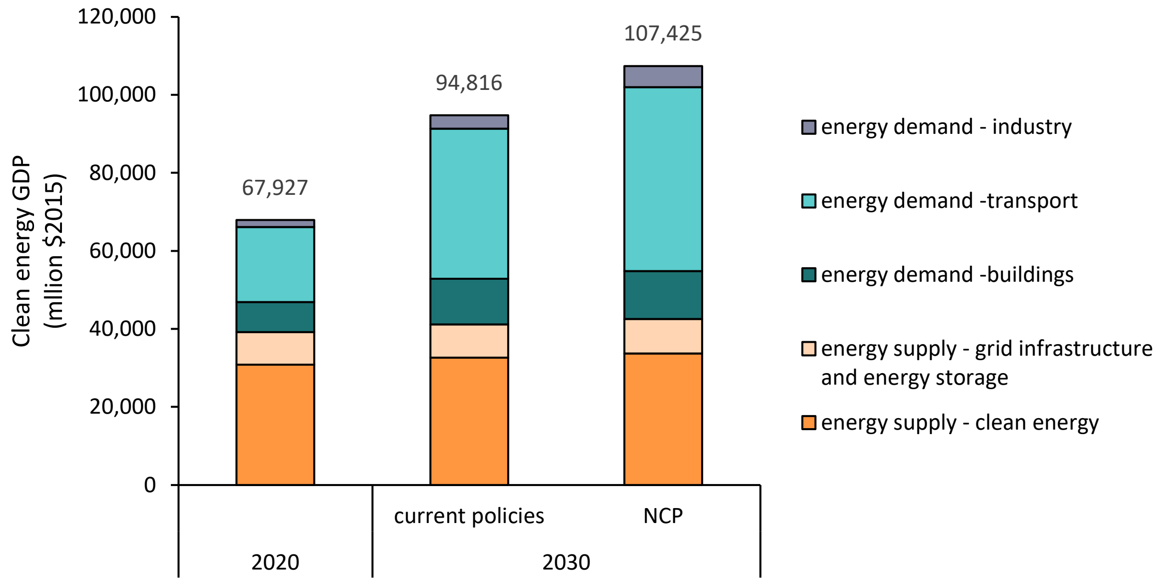
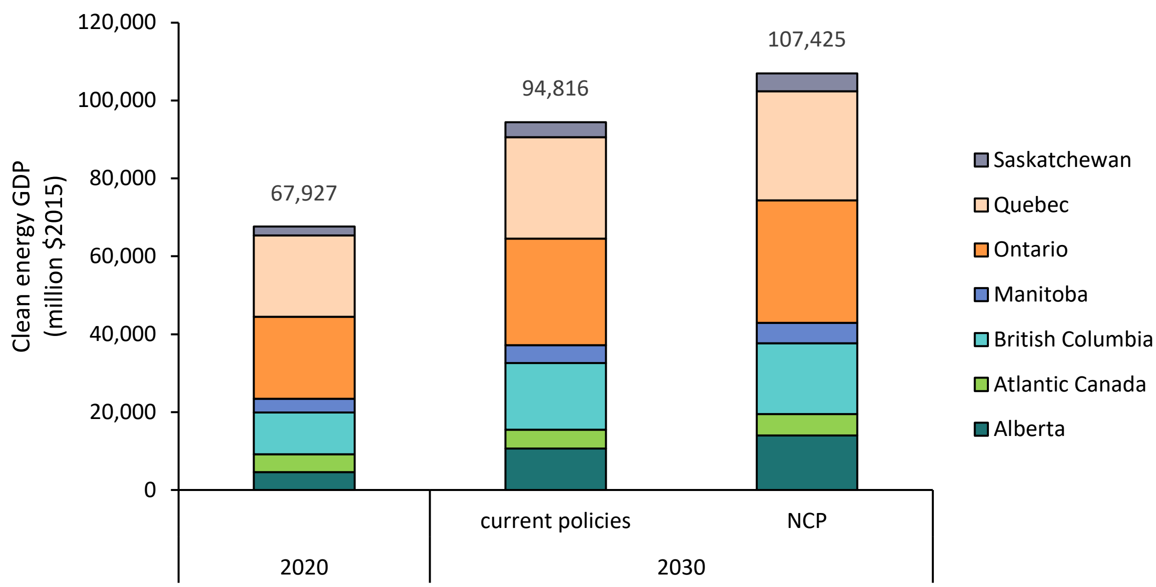



Figure 11: Clean Energy GDP by region



### 3.2.2. Investment

Clean energy investment grows by 2.2% annually under the new climate plan, reaching $58 billion in 2030. However, investment in the rest of energy declines in this scenario by 1.1% annually, compared to a 0.2% annual decline under current polices.

Due to the decline in rest of energy investment, total energy-related investments shrink between 2020 and 2030 under both the current policies and the new climate plan. Under the new climate plan, total energy-related investments decline to $195 billion in 2030, relative to $200 billion in 2020. Under the new climate plan, clean energy investments account for 30% of total energy-related investments in 2030, relative to 24% in 2020.

Figure 12: Annual energy-related investment to 2030

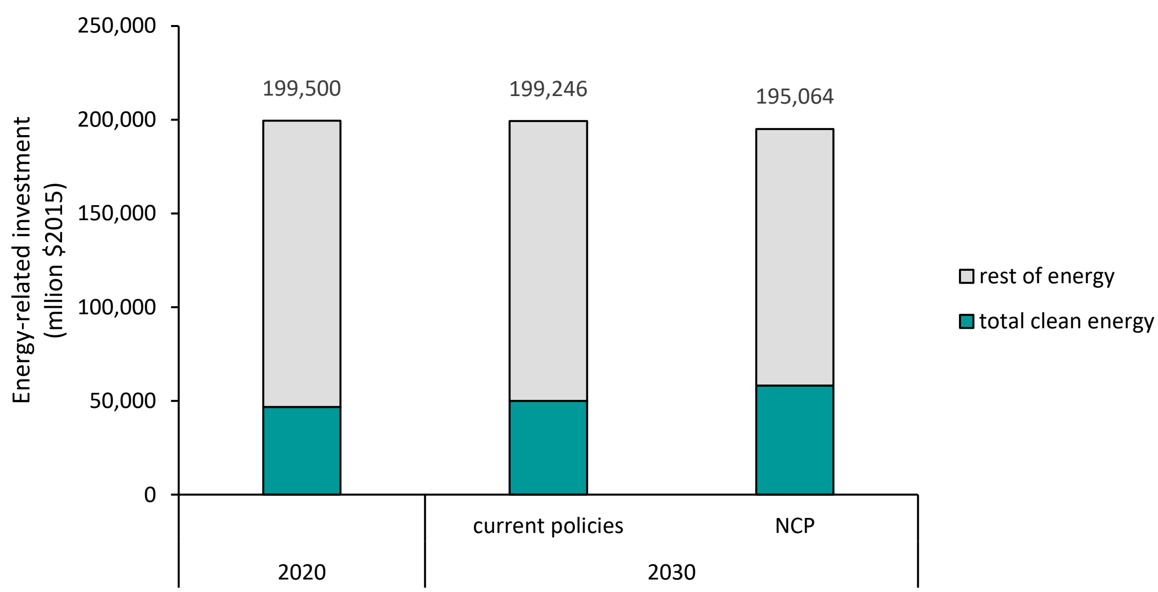
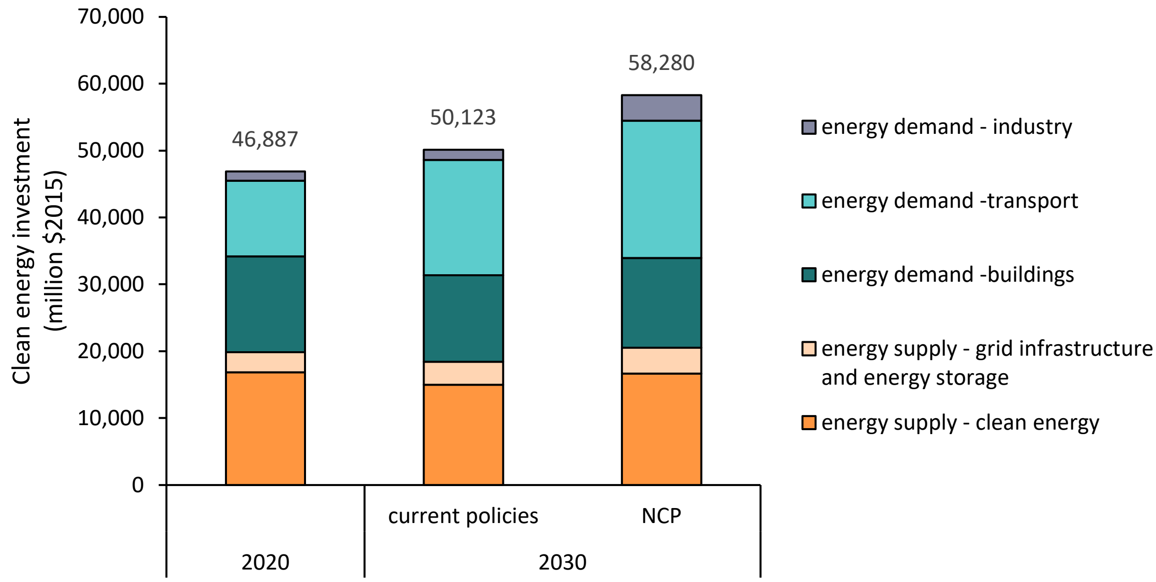



Figure 13 shows clean energy investment in Canada broken down by sector. Under the new climate plan, clean energy investment is higher across all sectors, but especially so in transport and industry. Clean energy investment in industry reaches $3.8 billion in 2030, growing by 10.7% annually between 2020 and 2030, relative to a 0.9% annual growth rate under current policies.

The largest clean investment increase in absolute terms occurs in transportation activities. Investment in this sector grows from $11 billion in 2020 to $21 billion in 2030, growing at 6.1% annually between 2020 and 2030, relative to 4.3% under current policies. This is largely due to an increase in adoption of PEVs.

Figure 13: Annual clean energy investment to 2030




## 3.2.3. Jobs

Clean energy jobs grow at a higher rate under the new climate plan relative to current policies. Under the new climate plan, jobs in clean energy reach 639,000 in 2030, with an annual growth rate of 4.0% between 2020 and 2030.

Jobs in the rest of energy decline more under the new climate plan relative to current policies. Under the new climate plan, jobs in the rest of energy decline by 1.0% annually, relative to a 0.4% annual decline under current policies between 2020 and 2030.

Despite this, total energy-related jobs are simulated to increase between 2020 and 2030 by 0.4% for current policies and 0.5% for the new climate plan. Under the new climate plan, clean energy jobs make up 35% of total energy-related jobs in 2030, relative to just 24% in 2020. Figure 14 shows energy-related jobs to 2030.

## Figure 14: Energy-related jobs to 2030

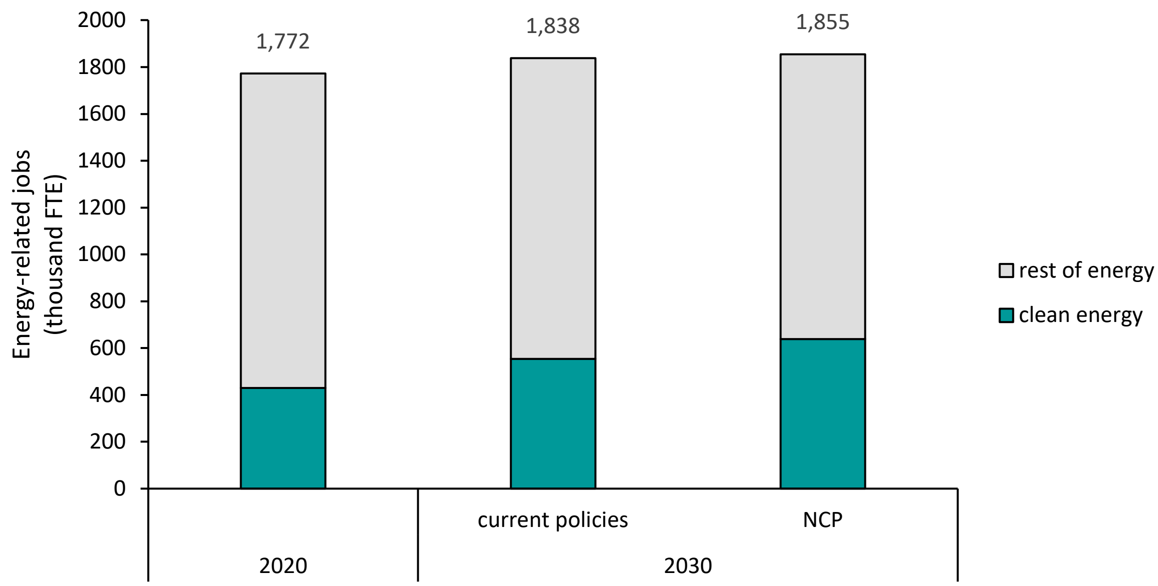



Figure 15 and Figure 16 show a breakdown of clean energy jobs by sector and region, respectively. The largest increase in clean energy jobs comes from the transport sector. Total clean energy jobs in transportation reach 364,000 in 2030 under the new climate policy (growing at an average annual rate of 6.7%). This is due to an increase of jobs related to PEVs; an annual increase of 39% between 2020 and 2030, relative to 32% under current policies.

## Figure 15: Clean energy jobs to 2030

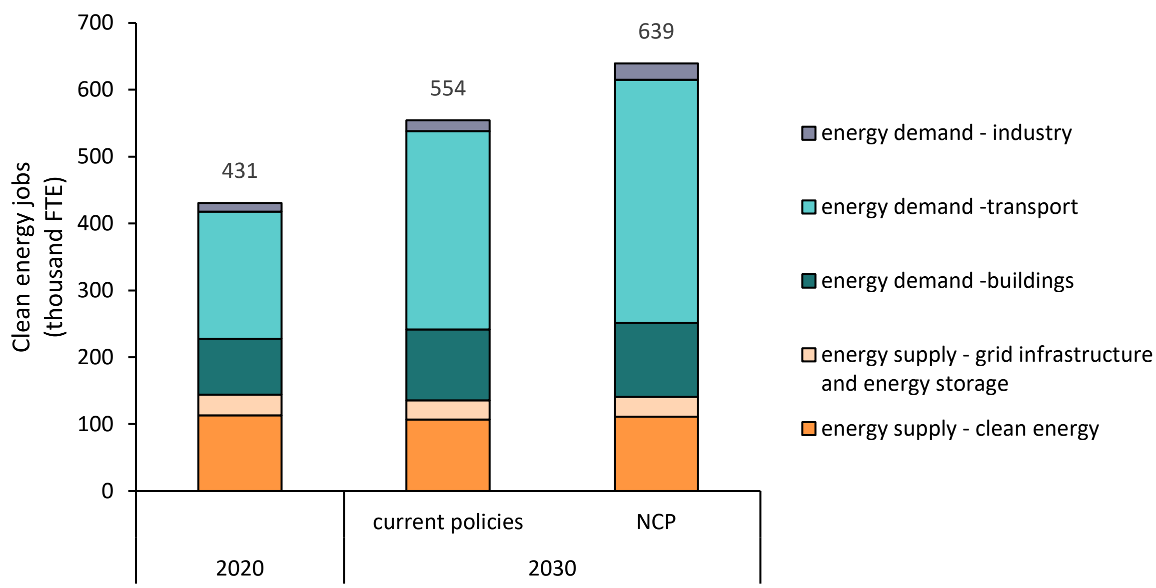
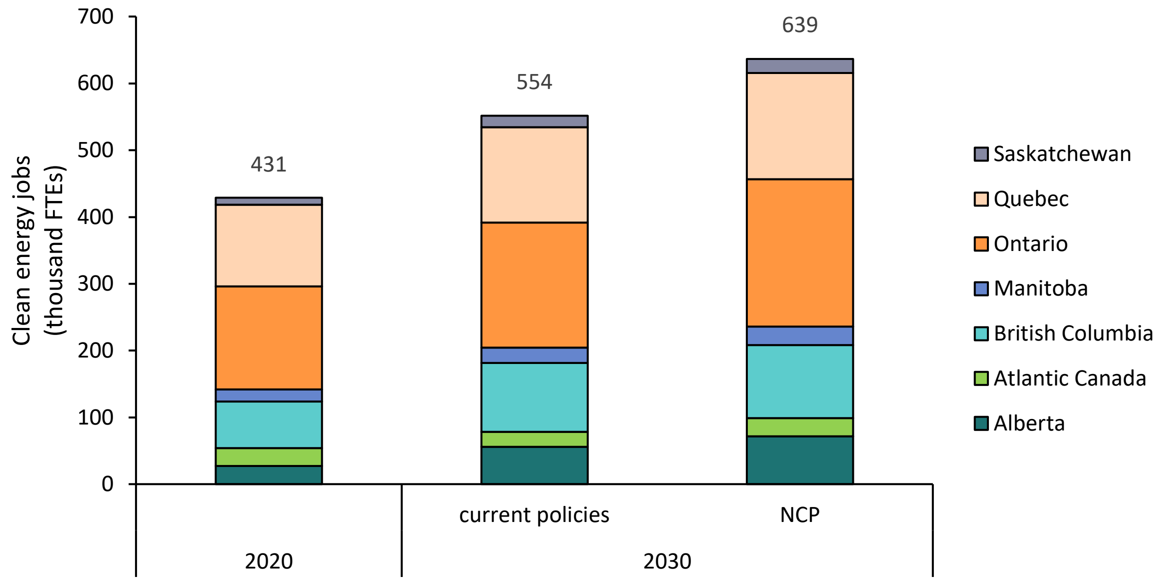


Figure 16: Clean energy jobs to 2030 by region




## 3.3. What are the impacts of oil prices on the energy-economy?

A sensitivity analysis was conducted with a lower oil price, staying constant at around 34 USD per barrel in 2030. See Appendix A for details. The most important findings are as follows:

- Oil price is important for determining demand for Canada's oil and investments in the oil sands. Lower oil prices mean lower GDP from "rest of energy" due to a decrease in investment and output. Under current policies with a lower oil price, the "rest of energy" economy is $39 billion smaller (at $243 billion) relative to a scenario with a higher oil price.

- Oil prices have a less clear impact on the clean energy economy. On the one hand, lower oil prices may favour investment in clean energy production. On the other hand, low oil prices make fossil fuel consumptive technologies (e.g. conventional vehicles) more attractive. The net effect of these factors depends on policy. With stronger levels of greenhouse gas abatement policy in place, lower oil prices are more likely to lead to greater growth in the clean energy economy.

# Appendix A: Assumptions

## Calibration sources

To characterize Canada's energy-economy, and that of the United States, gTech is calibrated to a large variety of historical data sources. Key calibration data sources are listed below, in order of priority:

- Environment and Climate Change Canada's National Inventory Report[14].
- Statistics Canada's Supply-Use Tables[15].
- Natural Resources Canada's Comprehensive Energy Use Database[16].
- Statistics Canada's Annual Industrial Consumption of Energy Survey[17].
- Statistics Canada's Report on Energy Supply and Demand[18].
- Navius' technology database.

Each of these data sources is generated using different methods and are therefore not necessarily consistent with one another. For example, expenditures on gasoline by households in Statistics Canada's Supply-Use tables may not be consistent with natural gas consumption reported by Natural Resources Canada's Comprehensive Energy Use Database. Further, energy expenditures are a function of consumption and prices, so if prices vary over the course of the year, it is difficult to perfectly align consumption and expenditures.

gTech's calibration routine places greater emphasis on some data sources relative to others. This approach means that gTech achieves near perfect alignment with data

14 Environment and Climate Change Canada. National Inventory Report. Available from: www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/inventory.html

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

16 Natural Resources Canada. Comprehensive Energy Use Database. Available from: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm

17 Statistics Canada. Annual Industrial Consumption of Energy Survey. Available from: www.statcan.gc.ca

18 Statistics Canada. Report on Energy Supply and Demand in Canada. Available from: https://www150.statcan.gc.ca/n1/en/catalogue/57-003-X

sources receiving the highest priority weight, but alignment starts to diverge from data sources that receive a lower weight.

# Economic activity

Canada's economy is calibrated to grow at an average annual growth rate of 1.9% between 2016 and 2030.

# Energy prices

The price for oil is an exogenous input to the model (i.e., based on an assumed global price). This price reflects Canada Energy Regulator projections as shown in Table 4. The reference projection is steady at 34 USD per barrel, while the high sensitivity reaches $64 per barrel in 2030.

Table 4: Oil price forecast (2015 USD per barrel)

| | 2025 | 2030 |
|---|---|---|
| Low | 34 | 34 |
| Reference | 61 | 64 |

Source: Canada Energy Regulator. Canada's Energy Future 2018 & 2019. Available from: www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/index.html

The price for other energy commodities (e.g. natural gas, electricity, biofuels) is determined by the model based on demand and the cost of production. For example, the price of electricity depends on a variety of factors that are accounted for by the modeling, such as:

- The cost of generating electricity while meeting any policy constraints.
- The cost of maintaining the transmission and distribution network.
- Any taxes on or subsidies to the sector.

# Low carbon technology costs

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

The sections below summarize low carbon technology assumptions related to plug-in electric vehicles, hydrogen fuel cell vehicles and carbon capture and storage. Reference, low and high cost assumptions are provided.

## Transport technologies

Table 5 summarizes the assumptions for battery and fuel cell electric technologies. The cost of battery electric and hydrogen fuel cell vehicle components declines endogenously in the model (i.e., the decline is calculated as a function of adoption as opposed to being a fixed input). To simulate the impact of lower vehicle costs, we vary the trajectory and minimum values of the declining capital and intangible cost functions.

Table 5: Summary of low emission vehicle capital costs (2019 CAD)

| Uncertainty | Assumption<br>Reference | Low | High | Sources |
|---|---|---|---|---|
| Cost of battery electric vehicles | Battery pack costs decline from $492/kWh in 2015 to a minimum of $82/kWh. | Battery pack costs decline to a minimum of $74/kWh. | Battery pack costs decline to a minimum of $102/kWh. | Bloomberg New Energy Finance. (2017, 2019, 2020). Electric vehicle outlook.<br><br>ICCT. (2019). Update on electric vehicle costs in the United States through 2030.<br><br>Nykvist, B., F. Sprei, et al. (2019). "Assessing the progress toward lower priced long range battery electric vehicles." Energy Policy 124: 144-155. |
| Cost of hydrogen electric vehicles | Fuel cell stack system costs decline from $300/kW in 2015 to a minimum of $73/kW.<br><br>Fuel tanks decline from $30/kWh in 2015 to a minimum of $11/kWh. | Fuel cell stack system costs decline to a minimum of $38/kW and fuel tanks decline to a minimum of $10/kWh. | Fuel cell stack system and hydrogen tank costs decline to a minimum of $120/kW and fuel tanks decline to a minimum of $26/kWh. | SA Consultants. (2016). Final report: Hydrogen storage system cost analysis.<br><br>SA Consultants. (2017). Mass production cost estimation of direct H2 PEM fuel cell systems for transportation applications.<br><br>IEA. (2020). Breakdown of cost-reduction potential for electrochemical devices by component category. |

## Carbon capture and storage

CCS technology costs decline from a 1st-of-a-kind (FOAK) to an nth-of-a-kind (NOAK) plant as a function of adoption. Table 6 below lists the end-uses that can adopt CCS technology and the associated capture costs (i.e., transport and storage are extra).

Table 6: CCS capture costs by end-use in gTech (2019 CAD/t $CO_2$)

| Carbon capture for | Reference | | Low | | High | | Source |
|---|---|---|---|---|---|---|---|
| | FOAK | NOAK | FOAK | NOAK | FOAK | NOAK | |
| Natural gas formation | 64 | 61 | 26 | 25 | 102 | 97 | Global CCS Institute (2017). |
| Cement production | 180 | 135 | 86 | 57 | 242 | 180 | Global CCS Institute (2017). |
| SMR hydrogen production (also applies to fertilizer) | 78 | 75 | 46 | 45 | 110 | 106 | International Energy Agency (2011). |
| Pulverized coal, electricity | 106 | 79 | 70 | 52 | 122 | 92 | International Energy Agency (2011). |
| Combined cycle natural gas | 162 | 118 | 104 | 75 | 188 | 137 | International Energy Agency (2011). |
| Coal for process heat (also applies to iron and steel) | 106 | 71 | 70 | 52 | 122 | 92 | International Energy Agency (2011). |
| Natural gas for process heat | 162 | 110 | 104 | 75 | 190 | 130 | International Energy Agency (2011). |

Values in 2019 CAD/t $CO_2$ captured. Sources: Global CCS Institute. (2017). *Global Costs of Carbon Capture and Storage: 2017 Update*; International Energy Agency. (2011). *Cost and Performance of Carbon Dioxide Capture from Power Generation.* Capture costs were recalculated using common discounting and energy price parameters. A discount rate of 10% and 30-year project life was assumed. The energy prices assumed are $2.15/GJ for coal and $2.8/GJ for natural gas. A 2% inflation rate is assumed.

# Current policies

Table 7 below describes the policies included in the current policy forecast.

Table 7: List of all policies included in the current policy forecast.

| Region/Sector | Policy | Description | Status |
|---|---|---|---|
| Federal | | | |
| Multi-sector | | | |
| | Federal Carbon Pricing Backstop[19] | 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.<br>Revenue raised by this policy is returned to households in each respective province/territory. | Implemented |
| Electricity | | | |
| | Regulations Amending the Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations[20] | 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[21] | This policy limits the emissions intensity of natural-gas fired electricity generation to 420 tonnes $CO_2e$/GWh. | Implemented |
| Transport | | | |
| | Renewable Fuels Regulation[22] | 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[23] | 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. | Implemented |

[19] 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.

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

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

[22] Government of Canada (2013). Renewable Fuels Regulations: SOR/2010-189. Available from: https://laws-lois.justice.gc.ca/eng/regulations/SOR-2010-189/index.html.

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

| Region/Sector | Policy | Description | Status |
|---|---|---|---|
| | Federal Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations[24] | 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[25] | 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 |
| | Light-Duty ZEV Subsidy[26] | Light-duty vehicle subsidy available at $2,500 for short-range plug-in hybrids and $5,000 for long-range plug-in hybrids, hydrogen vehicles, and battery electric vehicles. | Implemented |
| Industry | | | |
| | Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds[27] | Oil and gas facilities must adopt methane control technologies and practices. | Implemented |
| British Columbia | | | |
| Multi-sector | | | |
| | Carbon Tax[28] | 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[29] | Require that 15% of natural gas consumption be provided by renewable sources by 2030. | Announced |
| Electricity | | | |
| | Clean Energy Act[30] | A minimum of 93% of provincial electricity generation must be provided by clean or renewable sources. | Implemented |
| | PST Exemption[31] | Use of electricity in residential and industrial buildings is exempt from provincial sales tax. | Implemented |

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

[25] 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. Available from: http://gazette.gc.ca/rp-pr/p2/2018/2018-05-30/html/sor-dors98-eng.html.

[26] Government of Canada. (2020). Zero Emission Vehicles. Tax Write-Off. Available from: https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles.

[27] Government of Canada. (2020). Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector): SOR/2018-66. Available from: https://laws-lois.justice.gc.ca/eng/regulations/SOR-2018-66/index.html.

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

[29] Government of British Columbia. (2019). CleanBC. Available from: https://cleanbc.gov.bc.ca/.

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

| Region/Sector | Policy | Description | Status |
|---|---|---|---|
| Transportation | | | |
| | Low Carbon Fuel Requirement Regulation (part of the Low Carbon Fuel Standard)[32] | British Columbia introduced this policy in 2008. This regulation requires a decrease in average carbon intensity of transportation fuels by 10% by 2020 and by 20% by 2030 relative to 2010. Fuel suppliers can meet the second requirement by acquiring credits generated from fueling electric vehicles. | Implemented |
| | Zero Emission Vehicle Standard[33]. | Requires 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. | Implemented |
| | Light-Duty ZEV subsidies[34] | Provides incentives at $1,500 for short-range plug-in hybrids and $3,000 for long-range plug-in hybrids, battery electric vehicles, and hydrogen vehicles. It is unclear how long the incentives will be available for, the province has extended the policy multiple times since funding ran out since its introduction. | Implemented |
| Industry | | | |
| | Clean Industry Fund[35] | A portion of revenue collected from the carbon tax is used to fund additional industrial emission reductions. | Implemented |
| | Industrial Electrification[36] | Supply electricity to power natural gas extraction in the Peace region, and other large industrial operations. | Announced |
| Buildings | | | |
| | Strengthened BC Building Code[37] | New buildings must be "net zero energy ready" by 2032. | Announced |
| Waste | | | |
| | Organic Waste Diversion[38] | Divert 95% of organic waste from landfills. | Announced |
| | Landfill Gas Management Regulation[39] | Capture 75% of landfill gas. | Announced |

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[31] Government of British Columbia. 2017. Provincial Sales Tax (PST). Tax Rate. Available from: https://www2.gov.bc.ca/gov/content/taxes/sales-taxes/pst.

[32] Government of British Columbia. (2020). Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act, SBC 2008, c. 16. Available from: https://www.bclaws.ca/civix/document/id/complete/statreg/08016_01.

[33] Government of British Columbia. (2019). Zero-Emission Vehicle Act. SBC 2019, Chapter 29. Available from: https://www.bclaws.ca/civix/document/id/complete/statreg/19029.

[34] Government of British Columbia. (2020). Go Electric Passenger Vehicle Rebates. Available from: https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/clean-transportation-policies-programs/clean-energy-vehicle-program/passenger-vehicles.

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

[36] Ibid

[37] Ibid.

[38] Ibid.

[39] Ibid.

| Region/Sector | Policy | Description | Status |
|---|---|---|---|
| Alberta | | | |
| Multi-Sector | | | |
| | Technology Innovation and Emissions Reduction (TIER) Regulation[40] | The Technology Innovation and Emissions Reduction (TIER) Regulation applies to facilities with more than 100,000 tonnes of annual greenhouse gas emissions.<br>This policy replaces the Carbon Competitiveness Incentive Regulation[41] on large final emitters in Alberta. Facilities receive free emission credits based on the emissions intensity of high performing facilities producing similar products. Compliance pathways are CO2e reductions, purchasing credits from other facilities under the TIER, and offsets. | Implemented |
| Electricity | | | |
| | Phasing out coal pollution[42] | This policy closes coal-fired electricity by 2030. | Implemented |
| | Renewable Electricity Act[43] | Requires that 30% of electricity produced in the province come from renewable sources by 2030. | Implemented |
| Industry | | | |
| | Methane Emissions reduction[44] | Reduce methane emissions from oil and gas operations by 45% by 2025. | Implemented |
| | Capping oil sands emissions[45] | Limits emissions from the oil sands to 100 Mt $CO_2e$ annually. | Implemented |
| | Carbon capture and storage investments | Alberta has contributed funding to several CCS projects, including the Shell Canada Energy Quest Project[46] and the Alberta Carbon Trunk Line[47]. Modelled as CCS projects that use the Trunk Line. | Implemented |
| Saskatchewan | | | |
| Electricity | | | |
| | Boundary Dam Carbon Capture Project[48] | This project stores and captures $CO_2$ emissions from a 115 MW coal plant. | Implemented |

40 Government of Alberta. (2020). Technology Innovation and Emissions Reduction Regulation. Available from: https://www.alberta.ca/technology-innovation-and-emissions-reduction-regulation.aspx.

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

42 Government of Alberta. (2019). Phasing out coal pollution. Available from: www.alberta.ca/climate-coal-electricity.aspx .

43 Government of Alberta. (2020). Renewable Electricity Act. Statutes of Alberta, 2016 Chapter R-16.5. Available from: https://www.qp.alberta.ca/1266.cfm?page=r16p5.cfm&leg_type=Acts&isbncln=9780779814060.

44 Government of Alberta. (2020). Reducing methane emissions. Available from: www.alberta.ca/climate-methane-emissions.aspx

45 Government of Alberta. (2020). Capping oil sands emissions. Available from: www.alberta.ca/climate-oilsands-emissions.aspx

46 Natural Resources Canada. (2018). Shell Canada Energy Quest Project. Available from: www.nrcan.gc.ca/energy/funding/cef/18168

47 Natural Resources Canada. (2016). Alberta Carbon Trunk Line (ACTL). Available from: www.nrcan.gc.ca/energy/publications/16233

48 SaskPower. (2019). Boundary Dam Carbon Capture Project. Available from: www.saskpower.com/our-power-future/infrastructure-projects/carbon-capture-and-storage/boundary-dam-carbon-capture-project

| Region/Sector | Policy | Description | Status |
|---|---|---|---|
| Industry | | | |
| | Methane reduction[49] | Reduce methane emissions by over 40% of 2015 levels. | Implemented |
| Manitoba | | | |
| Electricity | | | |
| | Manitoba coal phase-out[50] | Manitoba Hydro phased out its last coal-fired generating unit in 2018. | Implemented |
| | Manitoba Keeyask Hydro-electricity Project[51] | Ongoing construction of the 695-megawatt (MW) hydro generating station with expected completion in 2021, modelled as generating 4.4 TWh of electricity annually. | Construction Ongoing |
| Transport | | | |
| | Biofuels Mandate[52]. | Requires a minimum renewable fuel content of 8.5% for gasoline and 2% for diesel by volume. | Implemented |
| | Biofuels Mandate Amendment[53]. | Increase in minimum renewable fuel content requirement to 10% for gasoline and 5% for diesel by volume announced. | Announced |
| Ontario | | | |
| Transportation | | | |
| | Greener Diesel Regulation[54]. | Specifies a minimum renewable fuel content of 4% for diesel, by volume. Renewable diesel life cycle GHG emissions are required to be at least 70% lower than standard petroleum diesel. | Implemented |
| | Greener Gasoline Regulation[55]. | Specifies a minimum renewable fuel content of 10% for gasoline, by volume. Renewable gasoline must have an average of 45% less life cycle GHG emissions than standard petroleum gasoline. | Implemented |
| | Greener Gasoline Regulation Amendment[56]. | The bio-based content for gasoline was proposed to be raised to 15% by 2025. The proposal is currently under review. | Announced |

[49] Government of Saskatchewan. (2019). Methane Action Plan. Available from: https://publications.saskatchewan.ca/#/products/92902.

[50] Manitoba Hydro (n.d.). Generating Stations. Available from: https://www.hydro.mb.ca/corporate/facilities/generating_stations/.

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[53] Government of Manitoba. (2020). News Release – Manitoba. Manitoba will have cleanest fuel standard in Canada. Available from: https://news.gov.mb.ca/news/index.html?item=46739.

[54] Government of Ontario. (2020). Greener Diesel. Available from: https://www.ontario.ca/page/greener-diesel-regulation

[55] Government of Ontario. (2020). Greener Gasoline. Available from: https://www.ontario.ca/page/greener-gasoline,

[56] Government of Ontario. (2020). Increasing renewable content in fuels. Available from: https://ero.ontario.ca/notice/013-4598#:~:text=Regulatory%20impact%20statement,of%20greenhouse%20gas%20emission%20reductions.

| Region/Sector | Policy | Description | Status |
|---|---|---|---|
| Electricity | | | |
| | Feed-in tariff program[57] | Long-term contracts guaranteeing a price for renewable electricity generation. Part of an initiative to help meet Ontario's renewable energy capacity of 10,700 MW by 2021 and 20,000 MW by 2025. | Implemented |
| | Nuclear power-plant refurbishment[58]. | Ontario will refurbish 10 nuclear power plants which together will provide more than 9,800 MW emissions-free capacity. Nuclear generation aligns with IESO projections. | Implemented |
| Québec | | | |
| Multi-sector | | | |
| | Cap and Trade System for Greenhouse Gas Emissions Allowances[59] | 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 |
| | Renewable Natural Gas Regulation[60]. | This regulation requires a minimum renewable fuel content of 1% in distributed natural gas in Québec as of 2020, rising to 2% in 2023, and 5% in 2025. | Implemented |
| Transport | | | |
| | Biofuels mandate[61]. | Québec is planning to require a minimum blend of 10% renewable fuel in gasoline and 2% in diesel by volume starting in 2021 and rising to 15% for gasoline and 4% for diesel by 2025. | Announced |
| | Zero Emission Vehicle Standard[62] | Automakers that sell over 4,500 vehicles in the province are required to meet a minimum zero-emission vehicle credit quota. The credit requirement is set to rise from 3.5% in 2018 to 22% of non-ZEV sales by 2025. The government's own impact assessment estimates that the policy will result in zero-emission vehicles accounting for 9.9% of new sales in 2025. | Implemented |
| | Electric vehicle incentives[63] | Incentives of between $4,000 and $8,000 for the purchase of a zero-emission vehicle ending in 2020. | Implemented |

[57] Independent Electricity System Operator (IESO). (2019). Feed-in Tariff Program. www.ieso.ca/sector-participants/feed-in-tariff-program/overview

[58] Government of Ontario. (2018). Chapter 2. Ensuring a Flexible Energy System. Available from: https://www.ontario.ca/document/ontarios-long-term-energy-plan-2017-order-council-21202017/chapter-2-ensuring-flexible-energy-system#section-8.

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

[60] Gouvernement du Québec. (2019). Québec encadre la quantité minimale de gaz naturel renouvelable et met en place un comité de suivi. Available from: https://mern.gouv.qc.ca/quebec-encadre-quantite-gaz-naturel-2019-03-26/.

[61] Gouvernement du Québec. (2019). Analyse d'Impact règlementaire. Projet de règlement concernant le volume minimal de carburant renouvelable dans l'essence et le carburant diesel. Available from: https://cdn-contenu.quebec.ca/cdn-contenu/adm/min/energie-ressources-naturelles/publications-adm/lois-reglements/allegement/AIR_Projet__reglement_volume_carburant_MERN.pdf?1570737693.

[62] Gouvernement du Québec. (2018). The zero-emission vehicle (ZEV) standard. Available from: http://www.environnement.gouv.qc.ca/changementsclimatiques/vze/index-en.htm.

[63] Gouvernement du Québec. (2019). Discover electric vehicles. Available from: http://vehiculeselectriques.gouv.qc.ca/english/

| Region/Sector | Policy | Description | Status |
|---|---|---|---|
| Nova Scotia | | | |
| Multi-sector | | | |
| | Cap-and-Trade Program[64] | Annual caps on certain activities in Nova Scotia, including fuel suppliers, electricity importers and large final emitters. | Implemented |
| Electricity | | | |
| | Cap on GHG emissions from electricity generation[65] | This policy requires emissions from the electricity sector to decline to 4.5 Mt by 2030. | Implemented |
| | Renewable portfolio standard[66] | 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[67] | This transmission line will connect Nova Scotia to hydroelectric generation from Newfoundland Labrador (and in particular, to the Muskrat Falls hydroelectric project). | Implemented |
| Waste | | | |
| | Solid Waste-Resource Management Regulations[68] | Regulation outlining the management of solid waste as well as the establishment of a Resource Recovery Fund. | Implemented |
| New Brunswick | | | |
| Electricity | | | |
| | Renewable Portfolio Standard[69] | 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 |
| Newfoundland and Labrador | | | |
| Electricity | | | |
| | Muskrat Falls hydro project[70] | A hydro project with a capacity of 824 MW, modelled as generating 4.9 TWh of electricity annually. | Implemented |

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

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

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

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

[68] Government of Nova Scotia. Solid Waste-Resource Management Regulations made under Section 102 of the Environment Act S.N.S 1994-95, c.1. https://novascotia.ca/just/regulations/regs/envsolid.htm

[69] 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

[70] Nalcor Energy. (2019). Muskrat Falls Project: Project Overview. https://muskratfalls.nalcorenergy.com/project-overview/

# Appendix B: Covered sectors, fuels and end-uses in gTech

Table 8: Covered 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) | |
| Light oil extraction | |
| Heavy oil extraction | |
| Oil sands in-situ | 211114 |
| 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 |

| Sector name | NAICS code |
|---|---|
| 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 |
| 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 |

| Sector name | NAICS code |
| --- | --- |
| 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 |

Table 9: Covered fuels

| Fuel |
| --- |
| Fossil fuels |
| Coal |
| Coke oven gas |
| Refinery petroleum coke |
| Delayed coker petroleum coke |
| Natural gas |
| Natural gas liquids |
| Gasoline |
| Diesel |
| Heavy fuel oil |
| Still gas |
| Electricity |
| Electricity |
| Hydrogen |
| Hydrogen |
| Hydrogen for NG pipeline blending |
| Biomass gasification |
| 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 |

Table 10: Covered end-uses

| End use |
| --- |
| **Stationary industrial energy/emissions sources** |
| Fossil-fuel electricity generation |
| Process heat for industry |
| Low temperature industrial heat |
| Heat (in remote areas without access to natural gas) |
| Cement heat |
| 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 |
| Medium-duty diesel vehicles |
| Medium-duty gasoline vehicles |
| Trucking freight |
| Vehicle size choice |
| Diesel services (for simulating biodiesel and other renewable diesel options) |
| Gasoline services (for simulating ethanol options) |
| Natural gas services (for simulating RNG 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 |
| Leaks |
| Venting |
| Surface casing vent flows |
| **Industrial process** |
| Mineral product GHG emissions |
| Aluminum electrolysis |
| Cement $CO_2$ |
| Metallurgical coke consumption in steel production |
| Hydrogen production for petroleum refining and chemicals manufacturing |

| End use |
| --- |
| Non-fuel consumption of energy in chemicals manufacturing |
| Nitric acid production |
| Direct air capture |
| **Agriculture** |
| Process CH4 for which no know abatement option is available (enteric fermentation) |
| Manure management |
| Agricultural soils |
| **Waste** |
| 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) |

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