Quantifying Canada's Clean Energy Economy

An assessment 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.

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. This exercise is conducted for both historical periods (since 2010) and forecasted (to 2030). The results of the forecast will be provided in a subsequent report.

What is the clean energy economy?

The short answer is it depends on who you ask! Unfortunately, the clean energy economy is generally under-defined in national statistics, posing a challenge for tracking the sector's growth over time and among regions of Canada. In addition, the clean energy economy means different things to different people.

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."*

Yet, more specific definitions are required to quantify clean energy activity. This report develops precise definitions for what constitutes clean energy economic activity, based on the following guiding principles:

- To be included as "clean energy", the expansion of this activity must be helpful for achieving Canada's 2030 greenhouse gas targets.
- Definitions must be workable. In other words, historical data must be available to allow estimates of clean energy activity to be made. Therefore, there is an element of practicality in the definitions.

Above all, this report tries to be transparent about what energy-related activities are included, and what aren't. Future researchers can adjust these definitions as they deem necessary in response to matters of judgement (e.g. is nuclear "clean"?), changing technology and standards, and data availability.

A clean energy taxonomy

This study builds on previous work in this field by starting with the sector classification scheme used by the Brookings Institution[1] for the United States and adopted by the Delphi Group's West Coast Clean Economy study[2].

Clean energy sectors are classified as follows:

- **Energy supply**
  - **Clean energy supply** includes sectors that provide us with energy produced from zero carbon sources (i.e., renewable and nuclear), as well as the sectors that directly contribute to this energy supply (e.g. manufacturing and construction). Efforts to reduce the emissions intensity of energy derived from fossil energy sources are also included (e.g. electrification of natural gas production and emissions control technologies).
  - **Grid infrastructure and energy storage** includes sectors that enable or optimize the delivery of clean energy supply to its customers, such as transmission lines and energy storage technologies that help match renewable energy output with when it is required.
- **Energy demand** includes energy-consuming sectors and activities related to (1) reducing energy consumption, (2) switching to low-carbon fuels and (3) implementing controls or process changes to reduce greenhouse gas emissions. These sectors are disaggregated into:
  - Buildings (green architecture and construction services, energy-saving building materials, HVAC, hot water and building control systems, high efficiency electrical appliances and lighting, professional services).
  - Transport (electric vehicles and infrastructure, hydrogen vehicles and infrastructure, public transit and rail, non-motorized transport).
  - Industry (energy-saving and low carbon machinery, industrial process change and emissions control).

Chapter 2 provides detailed definitions of each clean energy sector.

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[1] 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/

[2] 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

Indicators of clean energy activity

This report uses three methods (secondary data collection, a survey of clean energy companies and energy-economy modeling) to quantify the following indicators for the clean energy economy:

- **GDP ($).** Gross domestic product is an indicator of economic activity that can be defined in several ways. On a sectoral basis, it is most easily conceptualized as the value added of goods and services produced (e.g. the difference between sector output and intermediate inputs). The Box on the next page provides an overview of the different ways that GDP can be defined.
- **Investment ($).** Investment is an expenditure on goods that will be used to produce other goods and services in the future. Household consumption of clean energy technologies is also considered an investment (see Box below).
- **Employment (number of full-time equivalent positions).** Employment is defined as the number of paid workers, normalized to “full-time-equivalent positions” (i.e., 8 hours per working day).

Investment vs. consumption

In the economic sense, investment refers to the production of goods that will be used to produce other goods and services. For example, constructing a hydropower station is an investment because it will be used to produce electricity. In this way, investments today contribute to economic growth in the future.

The purchase of energy-related technologies by households is typically considered “consumption”. For example, a household purchasing an electric vehicle is consumption because the vehicle isn’t used to produce other goods (as opposed to say an Uber driver purchasing an electric vehicle that is used to provide transport services).

This report considers the consumption of energy technologies to be investment, because it provides a useful indicator of shifts toward a clean energy economy. The purchase of electric vehicles is therefore considered to be investment regardless of the purchaser, a break from traditional economic accounting.

Macroeconomics 101: What is GDP?

Gross domestic product, or GDP, is the value of goods and services produced in a given region over the course of the year. It can be measured in three ways as described below, with each approach yielding the same result[3].

1) GDP by production approach

The production approach consists of adding up the gross value added for all sectors of the economy. Using this approach, GDP for sector *j* (GDP_j) is determined by:

$$GDP_j = value\ of\ output_j - intermediate\ consumption_j$$

Where $value\ of\ output_j$ is the price paid on goods and services produced by sector *j* and $intermediate\ consumption_j$ is the cost of material, supplies and services used to produce sector *j*'s output.

2) GDP by income approach

The income approach consists of summing all sources of income across the economy. Using this approach, GDP for sector *j* (GDP_j) is determined by:

$$GDP_j = TAX_j - SUB_j + \ PI_j + CI_j$$

Where TAX_j is tax paid by sector *j*, SUB_j is subsidies received by sector *j*, PI_j is personal income (before tax) received by employees in sector *j* and CI_j is capital income (also before tax) received by sector *j*.

3) GDP by expenditure approach

The expenditure approach consists of summing the expenditures on final purchases of goods and services. Using this approach, GDP can be determined by:

$$GDP = C + I + G + X - M$$

Where C is consumption (i.e., household expenditures), I is investment, G is government spending, X is exports and M is imports.

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[3] Statistics Canada. National Economic Accounts: Gross Domestic Product. Available from: www150.statcan.gc.ca/n1/pub/13-607-x/2016001/174-eng.htm

How has Canada's clean energy economy changed since 2010?

Table 1 summarizes the clean energy economy estimates made based on a variety of historical data sources: an average of $30.8 billion of investment annually from 2010 to 2017, $56.3 billion of GDP in 2017 and 298 thousand jobs. These estimates suggest that the clean energy economy represents 3% of Canada's total GDP and 2% of jobs.

Table 1: Overview of Canada's clean energy economy

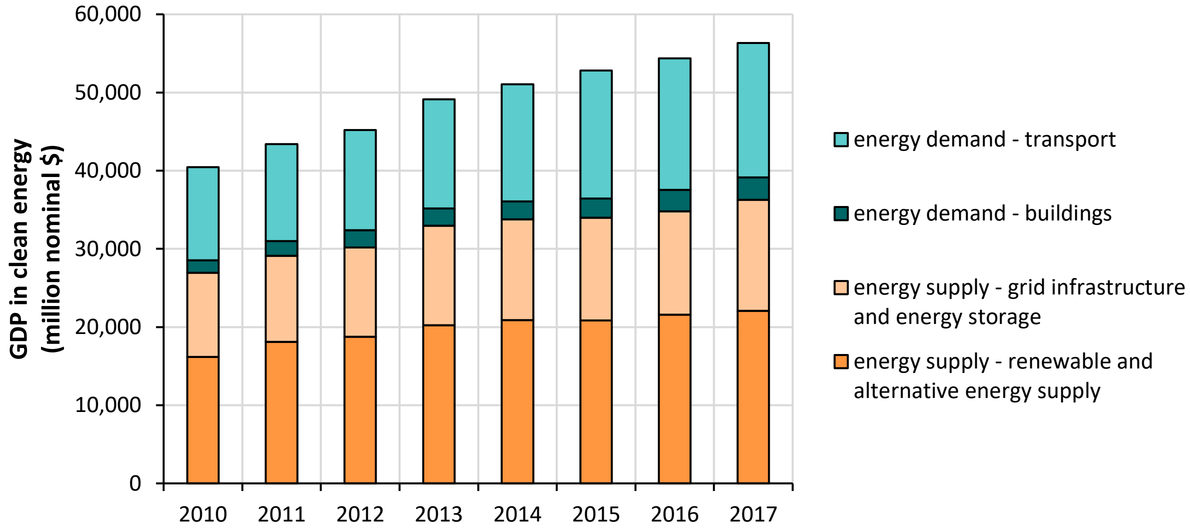
Sector	GDP in 2017 (nominal $)	Compound annual growth rate, 2010-2017	Average annual investment and consumption, 2010-2017	Jobs in 2017
Total clean energy economy (excluding industry)	**$56.3 billion**	**4.8%**	**$30.8 billion**	**298 thousand**
Energy supply				
Renewable and alternative energy supply	$22.1 billion	4.5%	$8.7 billion	60 thousand
Grid infrastructure and energy storage	$14.2 billion	4.0%	$6.6 billion	47 thousand
Energy demand				
Buildings	$2.9 billion	8.7%	$9.1 billion	20 thousand
Transport	$17.2 billion	5.4%	$6.5 billion	171 thousand

* An estimate for industry was developed using energy-economic modeling and has not been added to these historical estimates. The modeling suggests a 2015 GDP of $0.8 billion (2010$), annual investment of $0.2 billion (2018$) and 8.2 thousand jobs.

The contribution of clean energy to the Canadian economy, as measured by GDP, increased from $40.4 billion in 2010 to $56.3 billion in 2017. This increase reflects an average annual growth rate of 4.8%, higher than that of the overall Canadian economy during this time, which was 3.6% in nominal terms[4]. Clean energy GDP is concentrated in the following sectors, as shown in Figure 1:

- Renewable and alternative energy supply accounted for 39% of clean energy GDP in 2017. Energy supply sectors contribute to clean GDP in several ways: through the manufacturing of energy supply components (e.g. wind turbines), construction of new capacity and refurbishment of existing capacity (e.g. building wind farms, upgrading hydro facilities) and operation (i.e., the supply of electricity, or other energy carriers in the case of bioenergy). Hydro accounts for 58% of this sector's GDP because it is a mature technology that generated 60% of Canada's electricity needs in 2017[5]. It is followed by nuclear, with 29% of GDP. Other forms of energy account for a lower amount of GDP (e.g. wind, solar and bioenergy), although they have grown more quickly than hydro and nuclear.
- Grid infrastructure and energy storage accounted for 25% of clean energy GDP in 2017. This value-added is associated with the transmission and distribution of clean electricity.

Figure 1: GDP in the clean energy economy



Source: Numerous as described in Chapter 3 of this report.

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[4] Statistics Canada. Table 36-10-0104-01. Gross domestic product at market prices.

[5] National Energy Board. 2018. Canada's Energy Future 2018. Available from: www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/index-eng.html

- Clean buildings accounted for 5% of clean energy GDP in 2017. Value added from this sector is concentrated in architecture and construction services associated with buildings that registered or were certified to meet green building standards. The share of such buildings increased from 10% in 2010 to 14% in 2017 (please see Chapter 3 for more details). A smaller amount is associated with manufacturing of equipment used in buildings deemed to be clean, including HVAC and building control systems, high efficiency appliances and energy-saving building materials.

- Clean transport accounted for 30% of clean energy GDP in 2017. Value added from this sector is concentrated in rail and transit operation ($15.7 billion in 2017). Manufacturing accounts for a lower amount ($1.5 billion in 2017) and is concentrated in Manitoba, Ontario and Québec. Limited hybrid and plug-in electric vehicle manufacturing in Canada mean that electric vehicles and infrastructure currently contribute little to GDP.

Annual investment in clean energy sectors increased from $20.9 billion in 2010 to $35.3 billion in 2014, after which it stayed constant. The lack of growth in total clean energy investment since 2014 is due to falling investment in renewable and alternative energy supply. Clean energy investment and consumption are distributed across the following sectors, as shown in Figure 2:

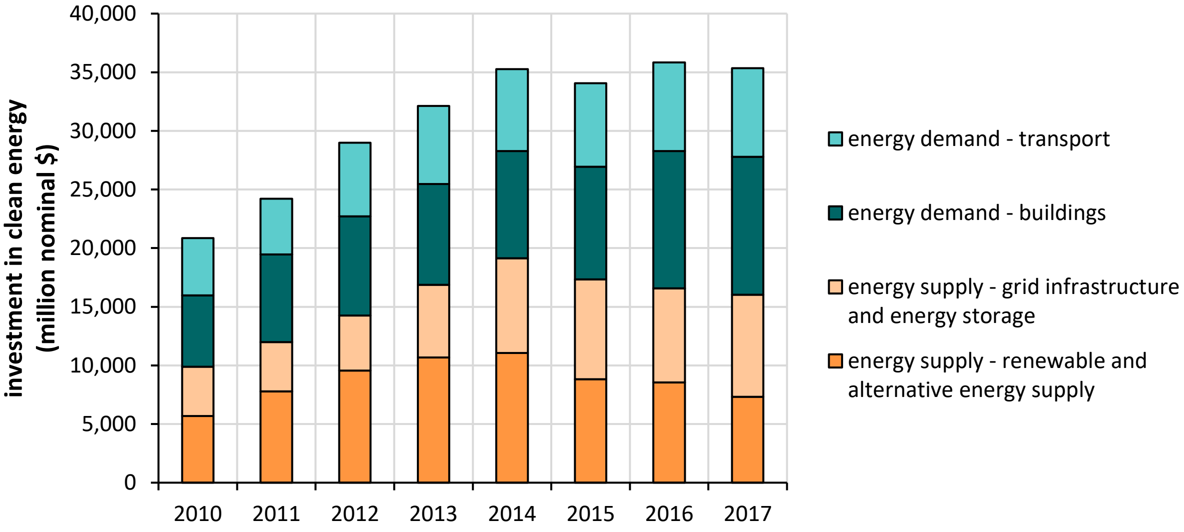
- Annual investment in renewable and alternative energy supply peaked in 2014 at $11.1 billion, after which it declined to $7.3 billion in 2017. This trend is primarily the result of procurement drives across many provinces. Investments were made in hydro ($25.9 billion cumulatively between 2010 and 2017), wind ($21.1 billion), nuclear ($6.7 billion), solar ($6.5 billion), bioenergy ($5.1 billion) and emission control technologies ($4.1 billion). These investments were generally distributed among provinces, except for solar (mostly in Ontario), nuclear (mostly in Ontario and New Brunswick) and emission control (mostly in Alberta and Saskatchewan).

- Annual investments in grid infrastructure and energy storage increased from $4.2 billion in 2010 to $8.7 billion in 2017. Most of these investments are associated with efforts to repair and modernize transmission and distribution infrastructure. Investments in batteries and energy storage peaked in 2015 at $168 million. The most substantial of these investments were made in electric battery technologies in Ontario, as part of energy storage procurement efforts in that province.

- Annual investment in clean buildings increased from $6.1 billion in 2010 to $11.8 billion in 2017. These investments include new construction and retrofits of buildings that registered or were certified to meet green building standards.

- Annual investment in clean transport increased from $4.9 billion in 2010 to $7.6 billion in 2017. Most of this investment occurred in transit and rail until it was overtaken by investments in hybrid and electric vehicles. Investment in electric vehicles increased particularly rapidly, from next to nothing in 2010 to over $1 billion in 2017. Investments in electric vehicles and infrastructure were concentrated in Ontario, Québec and British Columbia. Together, these provinces account for 95% of cumulative investment between 2010 and 2017 (compared with 75% of population).

Figure 2: Investment in the clean energy economy

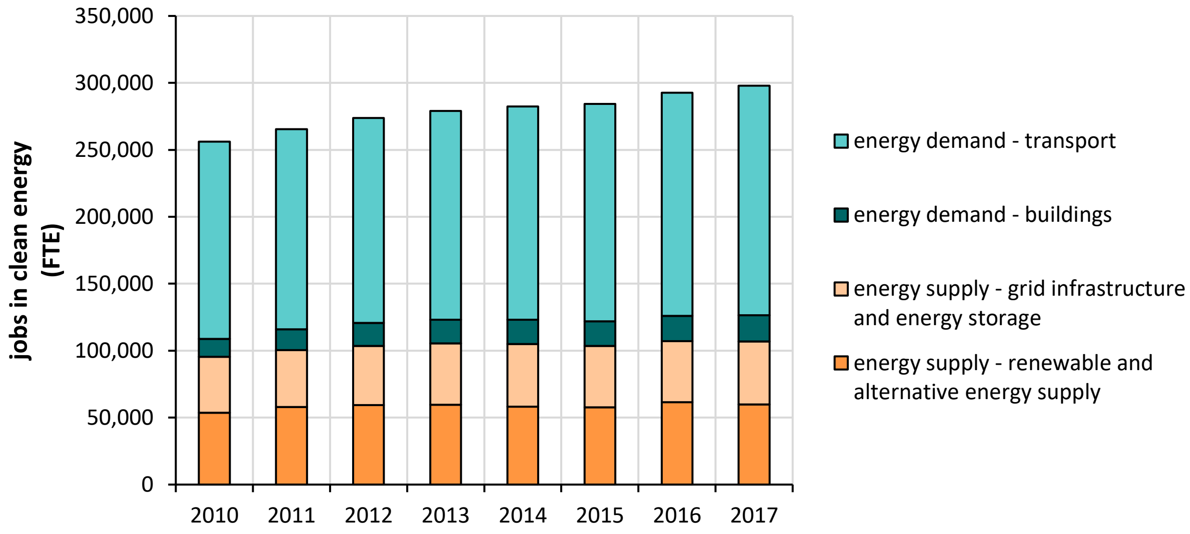


Source: Numerous as described in Chapter 3 of this report.

Clean energy jobs increased from 256 thousand in 2010 to 298 thousand in 2017, exceeding the rate of growth in overall jobs in Canada (2.2% vs. 1.4% on an annual basis[6]). In 2017, clean energy jobs accounted for 2% of all jobs in Canada. Clean energy jobs are distributed across the following sectors, as shown in Figure 3:

- Jobs in renewable and alternative energy supply grew from 54 thousand in 2010 to 60 thousand in 2017. Three quarters of these jobs are in electricity generation, with the remainder in construction, manufacturing and fuel production.
- Jobs in grid infrastructure grew steadily between 2010 and 2017, reaching 47 thousand in 2017.
- Clean transport is the largest employer (providing 171 thousand jobs in 2017) due in large part to transit, which is highly labour intensive. Employment in transit increased steadily between 2010 and 2017, reaching 111 thousand jobs in 2017.
- The clean buildings sector employed 19 thousand people in 2017. Most of these jobs are in green architecture and construction services.

Figure 3: Jobs in the clean energy economy



Source: Numerous as described in Chapter 3 of this report.
* FTE – full-time equivalent position

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[6] Statistics Canada. Table 14-10-0202-01. Employment by industry.

Acknowledgements

Navius would like to thank the following steering committee members who provided guidance and review of this work:

- Céline Bak, Analytica Advisors
- Conrad Barber-Dueck, Statistics Canada
- Glen Hodgson, Conference Board of Canada
- Dave Sawyer, EnviroEconomics
- Paul Shorthouse, The Delphi Group

We are also grateful to all of the clean energy companies that took the time to respond to our survey. We would like to highlight the contributions of the following respondent companies who elected to be identified:

- AdvEn Industries, Inc.
- ATHENA Technolo-G INC.
- BioPower Sustainable Energy Corporation
- CHAR Technologies Ltd.
- Clean Energy Consulting Inc.
- ClearLead Consulting
- Current Surveillance Inc. / CSI
- Dekany Consulting Inc.
- Echoflex Solutions Inc.
- Electrum Charging Solutions
- Etalim
- G4 Insights Inc.
- GHGSat Incorporated
- Hydrogen In Motion Inc. (H2M)
- Loop Energy Inc.
- Love Energy Consultants
- One Wind Services Inc.
- OverDrive Fuel Cell Engineering
- Panevo Services Limited
- Pinnacle Renewable Energy Inc.
- Process Ecology Inc.
- QSBR Innovations
- QuadroHawk Inc.
- Solcan
- Targray
- Will Solutions
- Your Solar Home Inc.

Contents

1. Introduction

1.1. Background

Mitigating climate change requires re-structuring Canada's economy and adopting low carbon technologies across most energy end-uses. While many studies focus on the economic cost of such a transition, Clean Energy Canada would like to promote a broader dialogue about the benefits of expanding clean energy activity.

Unfortunately, the clean energy economy is generally under-defined in national statistics, posing a challenge for tracking the sector's growth over time and among regions of Canada. Statistics Canada has begun quantifying the contribution of clean technology to the economy, although available data to date are summarized at a relatively high level (e.g. renewable energy production, nationally)[7].

A variety of studies have explored specific aspects of the "clean economy" in Canada. For example, a 2015 study by the Delphi Group quantified jobs and GDP in the clean economy in BC, along with California, Oregon and Washington[8]. Other Canadian studies have examined "clean tech" in BC[9] and green jobs in Vancouver[10]. One of the broader efforts in Canada is regularly conducted by Analytica Advisors, which describes business trends across many clean technology industries[11].

The study described in this report is both more ambitious and more focused than efforts to date for Canada. It is more ambitious because it seeks to quantify economic activity across all regions of Canada. It is more focused because it is only concerned with energy-related aspects of the clean economy, as opposed to environmental aspects more broadly.

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[7] Statistics Canada. Table 36-10-0366-01. Environmental and Clean Technology Products Economic Account.

[8] 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

[9] KPMG. 2017. British Columbia Cleantech 2016 Status Report. Available from: https://home.kpmg/ca/en/home/insights/2017/03/bc-cleantech-status-report.html

[10] Vancouver Economic Commission. 2014. Green and Local Food Jobs in the City of Vancouver. Available from: http://www.vancouvereconomic.com/wp-content/uploads/2015/04/VEC_GreenJobsReport_2014_web.pdf

[11] Analytica Advisors. Canadian Clean Technology Industry Report. Available from: http://analytica-advisors.com/

This study builds on previous work in this field, notably by starting with the sector classification scheme used by the Brookings Institution[12] and adopted by the Delphi Group's West Coast Clean Economy study. Yet it is worth pointing out that these studies benefited from the US Green Goods and Services Survey, which covered 120,000 business establishments[13].

Given the lack of a comparable dataset in Canada, this study is forced to be more creative. It has therefore employed a variety of methods to estimate clean energy activity, drawing from diverse datasets. This approach presents opportunities and challenges. On one hand, it allows us to estimate clean energy activity across a multitude of sectors and regions of Canada. On the other, it forces us to deal with oftentimes contradictory and inconsistent data.

Nevertheless, this effort enables us to provide preliminary answers to questions such as: How big is Canada's clean energy economy? How quickly has it grown and in which regions and sectors? It also helps develop a framework for thinking about clean energy activity by building on earlier classification schemes and developing working definitions and methodologies for quantifying this activity. Lastly, this work is carefully documented and identifies data gaps so that it can contribute to the development of future efforts to refine clean energy data collection efforts and estimates.

1.2. Study objectives

The objective of this project is to quantify, where possible, the direct GDP, investment and employment in each clean energy sector of Canada's economy. This exercise has been conducted for both historical periods (since 2010) and forecasted (to 2030).

The forecast accounts for the impacts of existing and announced climate policies in Canada as of February 2019. Results from this forecast will be provided in a subsequent report.

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[12] 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/

[13] US Bureau of Labor Statistics. Green Goods and Services. Available from: www.bls.gov/ggs/

1.3. Outline

This draft report is structured as follows:

- Chapter 2 describes the approach, including how sectors are defined and the various methodologies used to assess economic activity in different sectors.
- Chapter 3 provides estimates of clean energy investment, value-added and jobs in Canada between 2010 and 2017.

The appendices provide additional details about the methodology and data sources.

2. Approach

This Chapter describes the method by which we will attempt to quantify Canada's clean energy economy. It is structured as follows:

- Section 2.1 defines clean energy, the clean energy sectors of interest to this project and the economic indicators to be collected.
- Section 2.2 describes a three-pronged approach of data collection and modeling.

The appendices provide additional details about the methodology and data sources.

2.1. Definitions and scope

2.1.1. Defining the clean energy economy

Clean Energy Canada 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 and delivery of key energy services while reducing carbon pollution."

Table 2 builds on this definition of the clean energy economy, as well as work by the Brookings Institution[14], to provide a classification of clean energy sectors in Canada. Sectors are categorized as follows:

- **Energy supply**
  - **Renewable and alternative energy supply** includes sectors that provide us with energy carriers (i.e., electricity and liquid, solid and gaseous fuels) produced from renewable sources, as well as the sectors that directly contribute to this energy supply (e.g. wind turbine manufacturing, construction and supporting services). Also included under alternative energy supply are efforts to decarbonize energy derived from fossil energy sources (e.g. through carbon capture and storage or methane controls).
  - **Grid infrastructure and energy storage** includes sectors that enable or optimize the delivery of clean energy supply to its customers, such as transmission lines

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[14] 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/

and energy storage technologies that help match renewable energy output with when it is required.

- **Energy demand** includes energy-consuming sectors and activities related to (1) reducing energy consumption, (2) switching to zero carbon fuels and (3) implementing controls or process changes to reduce greenhouse gas emissions. These sectors are disaggregated into buildings, transport and industry.

Table 2 provides a working definition of each clean energy sector. The sector categories are intended to be “thematic” (e.g. wind) rather than focused on the type of economic activity (e.g. manufacturing wind turbines, constructing wind farms and generating electricity from wind). Where possible, definitions were articulated with data availability in mind so that the “clean energy” share of economic activity in each sector can be quantified.

Table 2: Clean energy sector classification

Sector	Working definition
Energy supply	
Renewable and alternative energy supply	
Hydropower	Manufacturing of supply technology components, construction of new capacity, alternative fuel production, and conversion of renewable energy to usable energy carriers (i.e., electricity and liquid, gaseous and solid fuels).
Wind	
Bioenergy	
Solar	
Waste-to-energy	
Geothermal	
Tidal	
Nuclear	
Low carbon machinery	Manufacturing and installation of industrial equipment that reduces the emissions intensity of fossil energy supply (e.g. electrification of natural gas transmission).
Emissions detection and control	Decarbonizing energy derived from fossil energy sources (e.g. capturing and sequestering carbon generated from coal-fired electricity, implementing practices to control methane leaks from upstream oil and gas production).

Sector	Working definition
Professional energy services	Services to support the development of renewable and alternative energy, including research and development and engineering consulting.
Grid infrastructure and energy storage	
Transmission infrastructure	Manufacturing, construction and operation of electrical transmission and distribution infrastructure used to carry clean electricity.
Batteries and energy storage technologies	Manufacturing, construction and operation of technologies that store electricity for later use to optimize grid operation.
Smart grid technology	Manufacturing and operation of hardware and software components that enable the decentralization of power supply, demand-response management, and bidirectionality of power flows.
Professional energy services	Services specializing in transmission, energy storage and grid decentralization consulting.
Energy demand	
Buildings	
Green architecture and construction services	Architectural and engineering services, building construction and contracting activities related to new buildings or retrofits seeking LEED, R-2000 or equivalent certifications.
Energy-saving building materials	Manufacturing and investment in energy-saving building materials such as insulation and multi-pane windows.
HVAC and building control systems	Manufacturing and investment in high efficiency equipment that exceeds federal energy efficiency regulations such as heat pumps and condensing boilers.
High efficiency appliances and lighting	Manufacturing and investment in appliances and lighting that exceed federal energy efficiency regulations.
Professional energy services	Services to support the adoption of clean energy technologies in buildings such as research and development and energy efficiency consulting.

Sector	Working definition
Transport	
Hybrids, electric vehicles and infrastructure	Manufacturing of hybrid and electric vehicles, manufacturing of electric vehicle chargers and research and development and investment in these technologies.
Hydrogen vehicles and infrastructure	Manufacturing of hydrogen vehicles and recharging infrastructure and research and development and investment in these technologies.
Public transit & rail	Manufacturing and operation of public transit vehicles and trains.
Non-motorized transport	Manufacturing, rental and investment in bicycles, rollerblades, etc.
Industry	
Energy-saving and low carbon machinery	Manufacturing and installation of industrial equipment that reduces energy consumption and/or emissions such as heat exchangers, industrial heat pumps and efficient motor systems.
Industrial process change and emissions control	Decarbonizing industrial processes by capturing CO_2 (e.g. in applications such as ammonia and hydrogen production) or changing processes (e.g. electrolysis of aluminum).

2.1.2. Indicators of economic activity

For each clean energy sector, this report identifies and/or estimates the following data using one of the three approaches described in the next section:

- **GDP ($).** Gross domestic product is the value added of goods and services produced by that sector. (e.g. the difference between sector output and intermediate inputs). It can be defined in various ways as summarized on page iv.
- **Investment ($).** Investment is an expenditure on goods that will be used to produce other goods in the future. Household consumption of clean energy technologies is also considered an investment[15].

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[15] Although we consider household expenditures on clean energy technologies as an investment, we note that Statistics Canada generally classifies these expenditures as consumption. One exception is residential construction, which Statistics Canada classifies as investment.

- **Employment (number of full-time equivalent positions).** Employment is defined as the number of paid workers, normalized to “full-time-equivalent positions” (i.e., 8 hours per working day). The estimates include direct jobs and indirect jobs (e.g. construction and manufacturing).

Data are collected and/or modeled for the period between 2010 and 2025, by province.

2.2. Data collection and modeling

This project relies on a three-pronged approach to quantify the contribution of clean energy to Canada’s economy:

- **Top-down data collection.** Where possible, we infer GDP, investment and employment based on secondary data sources such as government statistics, industry reports and NGO websites.
- **Primary data collection.** Second, we conduct a survey of clean energy firms in sectors for which top-down data are unavailable. To keep the survey tractable, only firms whose primary business line is in a relevant clean energy sector were targeted. Therefore, estimates made based on survey data provide a lower bound to clean energy activity.
- **Energy-economy modeling.** Lastly, we use Navius’ gTech and IESD energy-economy models to develop another estimate of historical clean energy GDP, investment and employment as well as a forecast through 2030. This forecast accounts for the impact of key Canadian energy and climate policies.

By using multiple data collection methods, we aim to increase the robustness of this analysis. Each of these methods is discussed below.

2.2.1. Top-down data collection

The first step was to identify what data are readily available that can be used to help inform GDP, investment and employment estimates for each clean energy sector. We then assigned each clean energy sector to one of the following “buckets” depending on the data sources identified:

- **Tier 1: Reliable top-down data exists.** Data exist that permit estimating investment, GDP and employment with a reasonable level of accuracy, at least at a national level. In addition, estimates may be cross-checked with other data to improve confidence. Estimates of the economic contribution of clean energy sectors in this Tier is rated as most certain.

- **Tier 2: Fragmented data are available.** Data may be available for some regions, but substantial effort is required to compile information and ensure that data are comparable across provinces and time. Estimates of the economic contribution of clean energy sectors in this Tier is rated as moderately certain.
- **Tier 3: Limited data are available.** Little or no data are readily available that would permit for estimates of GDP, investment and employment. Instead, primary data collection (Section 2.2.2) and/or economic modeling (Section 2.2.3) is required. Estimates of the economic contribution of clean energy sectors in this Tier are rated as least certain, if they can even be made.

Table 3 provides a high-level overview of data availability for each clean energy sector and assigns it to one of the three tiers. Overall, more comprehensive data are available for energy supply sectors than for energy demand sectors. Data availability is most sparse for supporting services which aren't clearly defined in national statistics nor associated with dedicated clean energy companies or industry groups. A complete list of data sources is provided in Appendix A: "Historical data collection methods".

Table 3: Method for historical data collection

Sector	Methodology for historical data collection
Energy supply	
Renewable and alternative energy supply	
Hydropower	Tier 2 (secondary data): Reasonably comprehensive data available for electric capacity, output and costs, but not disaggregated by source. Data are less comprehensive for the supply of solid, liquid and gaseous fuels. Tier 3 (survey): Data about manufacturing of energy supply system components is limited for certain types of renewable energy.
Wind	
Bioenergy	
Solar	
Waste-to-energy	
Geothermal	
Tidal	
Emissions detection and control	Tier 2 (secondary data): Manageable to collect data for carbon capture and storage projects given their limited number. Tier 3 (survey): Limited comprehensive data are available on methane detection and control systems.

Sector	Methodology for historical data collection
Professional energy services	Tier 3 (survey): Limited data are available with few dedicated clean energy companies in this category.
Grid infrastructure and energy storage	
Transmission infrastructure	Tier 2 (secondary data): Comprehensive data from Statistics Canada on electrical transmission infrastructure, but GDP and employment are aggregated with generation. Tier 3 (survey): Limited data are available for manufacturers of transmission towers.
Batteries and energy storage technologies	Tier 2 (secondary data): Manageable to collect data for specific energy storage projects given their limited number.
Smart grid technology	Tier 3 (survey): Data describing federal investments are available but hardware manufacturing and software development data are limited.
Professional energy services	Tier 3 (survey): Limited data are available.
Energy demand	
Buildings	
Green architecture and construction services	Tier 2 (secondary data): Reasonably comprehensive data about the number of applications for green certification as well as data about overall building construction from Statistics Canada.
Energy-saving building materials	Tier 3 (survey): Limited data about manufacturing of energy-saving building materials have been identified.
HVAC and building control systems	Tier 2 (secondary data): Mixed data depending on the type of equipment in question. Tier 3 (survey): Limited data available for building control systems
High efficiency appliances and lighting	Tier 2 (secondary data): Reasonably comprehensive data on manufacturing and use of lighting and major appliances.
Professional energy services	Tier 3 (survey): Limited data are available.
Transport	

Sector	Methodology for historical data collection
Hybrids, electric vehicles and infrastructure	Tier 2 (secondary data): Reasonably comprehensive information about the type of vehicles manufactured and purchased in Canada, as well as overall auto manufacturing. Investment in charging and refueling infrastructure can be inferred based on the number of stations.
Hydrogen vehicles and infrastructure	Tier 3 (survey): limited data is available on hydrogen vehicles and the associated infrastructure.
Public transit and rail	Tier 1 (secondary data): Comprehensive information is available for urban transit systems and rail from Statistics Canada. Tier 2 (secondary data): Less comprehensive data are available for bus manufacturing.
Non-motorized transport	Tier 3: Limited data are available. This sector was not included as part of survey efforts.
Industry	
Energy-saving and low carbon machinery	Tier 3 (survey): Limited data are available.
Industrial process change and emissions control	Tier 3 (survey): Limited data are available.

2.2.2. Primary data collection

We sent out a survey to 276 clean energy firms in sectors for which top-down data are unavailable (i.e., Tier 3 sectors as identified in the previous section). We identified firms and contact information in each sub-sector by consulting online directories from private, government and non-governmental organization sources. To keep the survey tractable, only firms whose primary business line is in a relevant clean energy sector were targeted. The implication of this approach is that estimates made based on survey data provide a lower bound to clean energy activity.

The survey was implemented via Google Survey. Its aim was to provide sufficient information to identify investment, value-added (i.e., GDP) and employment for each sector. The survey questionnaire is provided in Appendix B:. Respondents were contacted as follows:

1. By e-mail to announce the survey.
2. By e-mail approximately one week later as a reminder.

3. Phone calls were placed between three and four weeks after the initial e-mail was sent out.
4. A final e-mail was sent out a week before the survey was closed.

The survey resulted in an overall response rate of 13%. To supplement the survey, we consulted financial statements for publicly traded non-respondent firms.

2.2.3. Energy-economy modeling

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. Please note that the forecast results will be provided in a subsequent report.

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 C: “Modeling methods” for more information about gTech.

Current policy forecast

The forecast shows 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[16]. 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.
- **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 C: "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 C: "Modeling methods" provides an overview of these assumptions.

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[16] 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

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 emissions is subject to two main types of uncertainty.

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.[17] 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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[17] 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, 2010-2017

This Chapter contains estimates of the size of Canada’s clean energy economy in terms of GDP, investment and employment. The accompanying spreadsheet shows all GDP, investment and jobs estimates made at a provincial level. Please note that a complete list of sources and methods used to make these estimates is provided in Appendix A: “Historical data collection methods”.

3.1. Overview

Table 4 summarizes the clean energy economy estimates made to date: an average of $30.8 billion of investment annually from 2010 to 2017, $56.3 billion of GDP in 2017 and 298 thousand jobs. For context, these data suggest that the clean energy economy represents 3% of Canada’s total GDP and 2% of jobs.

Table 4: Overview of Canada's clean energy economy

Sector	GDP in 2017 (nominal $)	Compound annual growth rate, 2010-2017	Average annual investment and consumption, 2010-2017	Jobs in 2017
Total clean energy economy (excluding industry*)	$56.3 billion	4.8%	$30.8 billion	298 thousand
Energy supply				
Renewable and alternative energy supply	$22.1 billion	4.5%	$8.7 billion	60 thousand
Grid infrastructure and energy storage	$14.2 billion	4.0%	$6.6 billion	47 thousand
Energy demand				
Buildings	$2.9 billion	8.7%	$4.1 billion	20 thousand
Transport	$17.2 billion	5.4%	$6.5 billion	171 thousand

* An estimate for industry was developed using energy-economic modeling and has not been added to these historical estimates. The modeling suggests a 2015 GDP of $0.8 billion (2010$), annual investment of $0.2 billion (2018$) and 8.2 thousand jobs.

The contribution of clean energy to the Canadian economy, as measured by GDP, increased from $40.4 billion in 2010 to $56.3 billion in 2017. This increase reflects an average annual growth rate of 4.8%, higher than that of the overall Canadian economy during this time, which was 3.6% in nominal terms[18]. Clean energy GDP is concentrated in the following sectors, as shown in Figure 4:

- Renewable and alternative energy supply accounted for 39% of clean energy GDP in 2017. Energy supply sectors contribute to clean GDP in several ways: through the manufacturing of energy supply components (e.g. wind turbines), construction of new capacity and refurbishment of existing capacity (e.g. building wind farms, upgrading hydro facilities) and operation (i.e., the supply of electricity, or other energy carriers in the case of bioenergy). Hydro accounts for 58% of this sector's GDP because it is a mature technology that generated 60% of Canada's electricity

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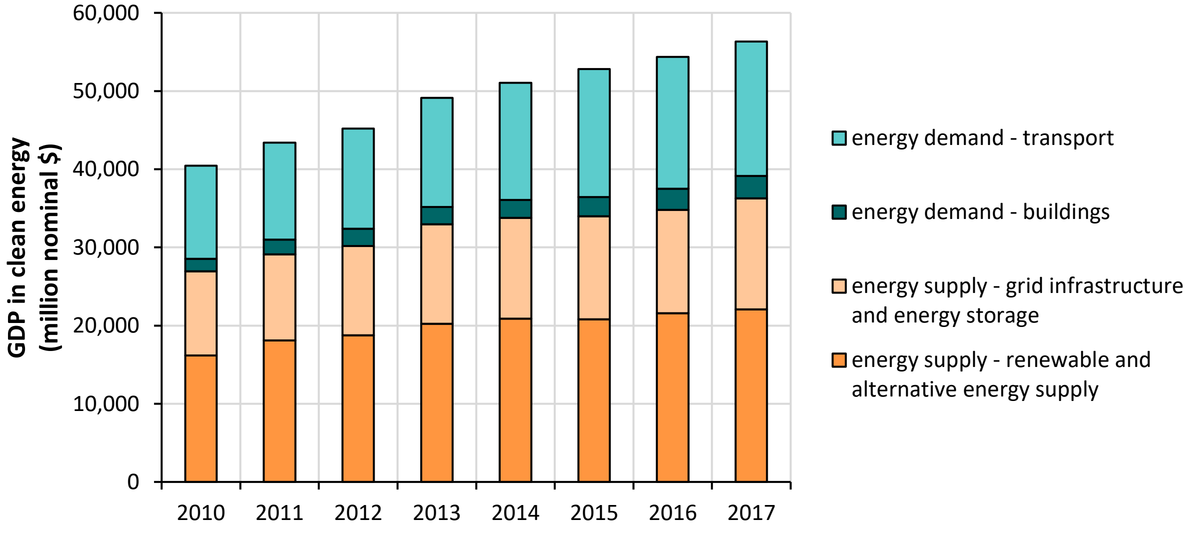
[18] Statistics Canada. Table 36-10-0104-01. Gross domestic product at market prices.

needs in 2017[19]. It is followed by nuclear, with 29% of GDP. Other forms of energy account for a lower amount of GDP (e.g. wind, solar and bioenergy), although they have grown more quickly than hydro and nuclear.

- Grid infrastructure and energy storage accounted for 25% of clean energy GDP in 2017. This value-added is associated with the transmission and distribution of clean electricity.
- Clean buildings accounted for 5% of clean energy GDP in 2017. Value added from this sector is concentrated in architecture and construction services associated with buildings that registered or were certified to meet green building standards. The share of such buildings increased from 10% in 2010 to 14% in 2017 (please see Chapter 3 for more details). A smaller amount is associated with manufacturing of equipment used in buildings deemed to be clean, including HVAC and building control systems, high efficiency appliances and energy-saving building materials.
- Clean transport accounted for 30% of clean energy GDP in 2017. Value added from this sector is concentrated in rail and transit operation ($15.7 billion in 2017). Manufacturing accounts for a lower amount ($1.4 billion in 2017) and is concentrated in Manitoba, Ontario and Québec. Limited hybrid and plug-in electric vehicle manufacturing in Canada mean that electric vehicles and infrastructure currently contribute little to GDP.

Figure 4: GDP in the clean energy economy



Source: Numerous as described in the following section.

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[19] National Energy Board. 2018. Canada's Energy Future 2018. Available from: www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/index-eng.html

Annual investment in clean energy sectors increased rapidly from $20.9 billion in 2010 to $35.3 billion in 2014, after which it stayed constant. The lack of growth in total clean energy investment since 2014 is due to falling investment in renewable and alternative energy supply. Clean energy investment and consumption are distributed across the following sectors, as shown in Figure 5:

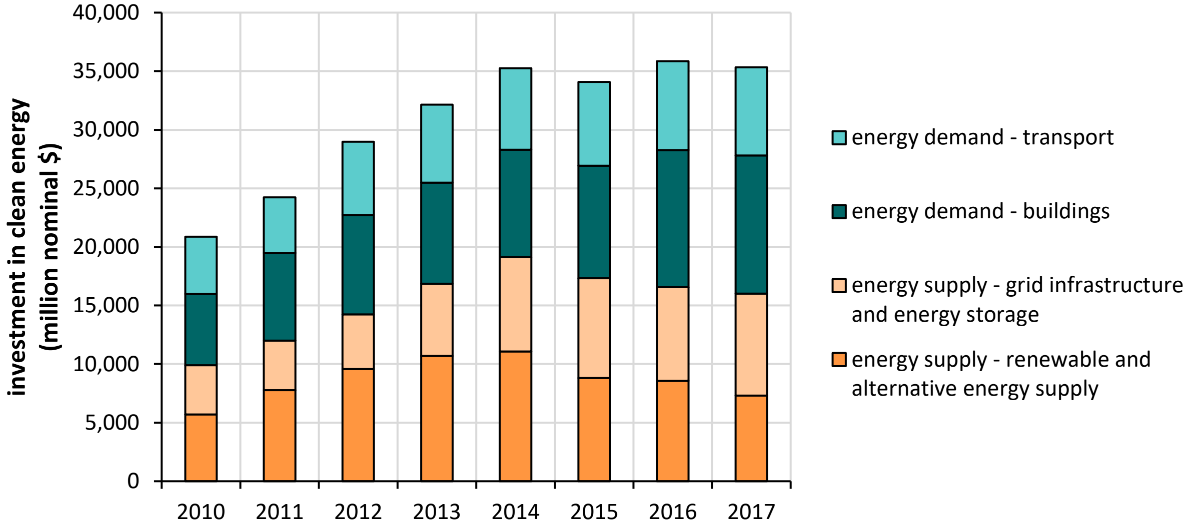
- Annual investment in renewable and alternative energy supply peaked in 2014 at $11.1 billion, after which it declined to $7.3 billion in 2017. This trend is primarily the result of procurement drives across many provinces. Investments were made in hydro ($25.9 billion cumulatively between 2010 and 2017), wind ($21.1 billion), nuclear ($6.7 billion), solar ($6.5 billion), bioenergy ($5.1 billion) and emission control technologies ($4.1 billion). These investments were generally distributed among provinces, with exceptions including solar (mostly in Ontario), nuclear (mostly in Ontario and New Brunswick) and emission control (mostly in Alberta and Saskatchewan).

- Annual investments in grid infrastructure and energy storage increased from $4.2 billion in 2010 to $8.7 billion in 2017. Most of these investments are associated with efforts to repair and modernize transmission and distribution infrastructure. Investments in batteries and energy storage peaked in 2015 at $168 million. The most substantial of these investments were made in electric battery technologies in Ontario, as part of energy storage procurement efforts in that province.

- Annual investment in clean buildings increased from $6.1 billion in 2010 to $11.8 billion in 2017 (when it accounted for 21% of all clean energy investment). These investments include new construction and retrofits of buildings that registered or were certified to meet green building standards.

- Annual investment in clean transport increased from $4.9 billion in 2010 to $7.6 billion in 2017. Most of this investment occurred in transit and rail until it was overtaken by investments in hybrid and electric vehicles. Investment in electric vehicles increased particularly rapidly, from next to nothing in 2010 to over $1 billion in 2017. Investments in electric vehicles and infrastructure were concentrated in Ontario, Québec and British Columbia. Together, these provinces account for 95% of cumulative investment between 2010 and 2017 (compared with 75% of population).

Figure 5: Investment in the clean energy economy



Source: Numerous as described in the following section.

Clean energy jobs increased from 256 thousand in 2010 to 298 thousand in 2017, exceeding the rate of growth in overall jobs in Canada (2.2% vs. 1.4% on an annual basis[20]). In 2017, clean energy jobs accounted for 2% of all jobs in Canada. Clean energy jobs are distributed across the following sectors, as shown in Figure 6:

- Jobs in renewable and alternative energy supply grew from 54 thousand in 2010 to 60 thousand in 2017. Three quarters of these jobs are in electricity generation, with the remainder in construction, manufacturing and fuel production.
- Jobs in grid infrastructure grew steadily between 2010 and 2017, reaching 47 thousand people in 2017.
- Clean transport is the largest employer (providing 171 thousand jobs in 2017) due in large part to transit, which is highly labour intensive. Employment in transit increased steadily between 2010 and 2017, reaching 111 thousand jobs in 2017.
- The clean buildings sector employed 19 thousand people in 2017. Most of these jobs are in green architecture and construction services.

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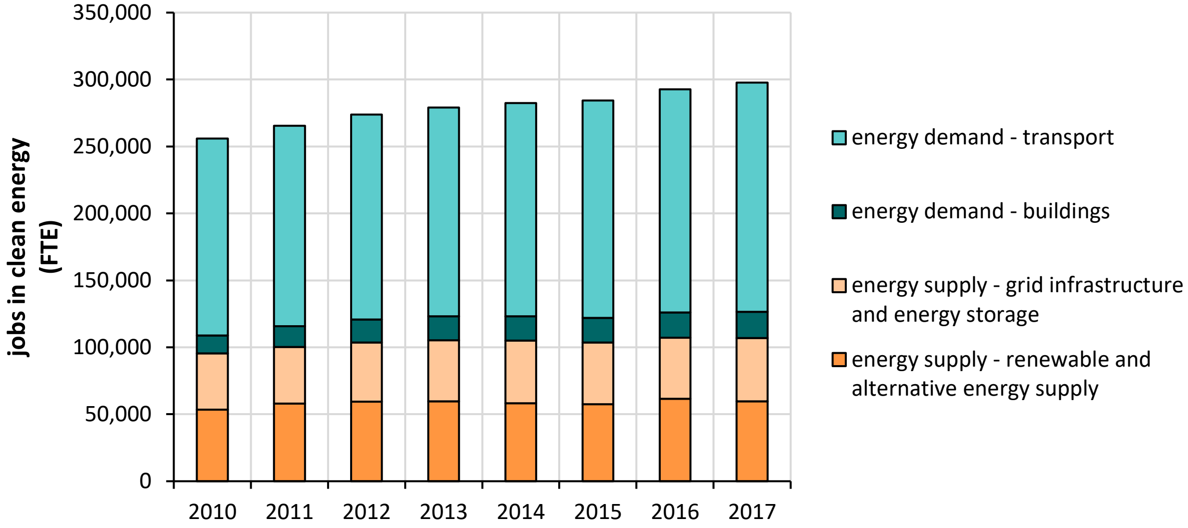
[20] Statistics Canada. Table 14-10-0202-01. Employment by industry.

Figure 6: Jobs in the clean energy economy



Source: Numerous as described in the following section.
* FTE – full-time equivalent position

The following sections review clean energy trends for each sector in greater detail.

3.2. Energy supply

3.2.1. Renewable and alternative energy supply

Renewable and alternative energy supply sectors are those that provide us with zero or low carbon energy. These sectors include:

- **Renewable energy supply.** Manufacturing of supply technology components, construction of new capacity, alternative fuel production, and conversion of renewable energy to usable energy carriers (i.e., electricity and liquid, gaseous and solid fuels).
- **Nuclear electricity supply.** Manufacturing of supply technology components, construction of new capacity, refurbishment of existing capacity and generation of electricity.
- **Emissions detection and control.** Decarbonizing energy derived from fossil energy sources (e.g. capturing and sequestering carbon generated from coal-fired electricity, implementing practices to control methane leaks from upstream oil and gas production).
- **Professional energy services.** Services to support the development of renewable and alternative energy, including research and development and engineering consulting. Please note that due to uncertainty in the underlying data, this sector is not disaggregated here.

Renewable and alternative energy supply: at a glance

$22.1 billion	4.5%	$8.7 billion	60 thousand
GDP in 2017 (nominal)	Average annual growth rate, 2010-2017	Average annual investment, 2010-2017	Jobs in 2017

GDP

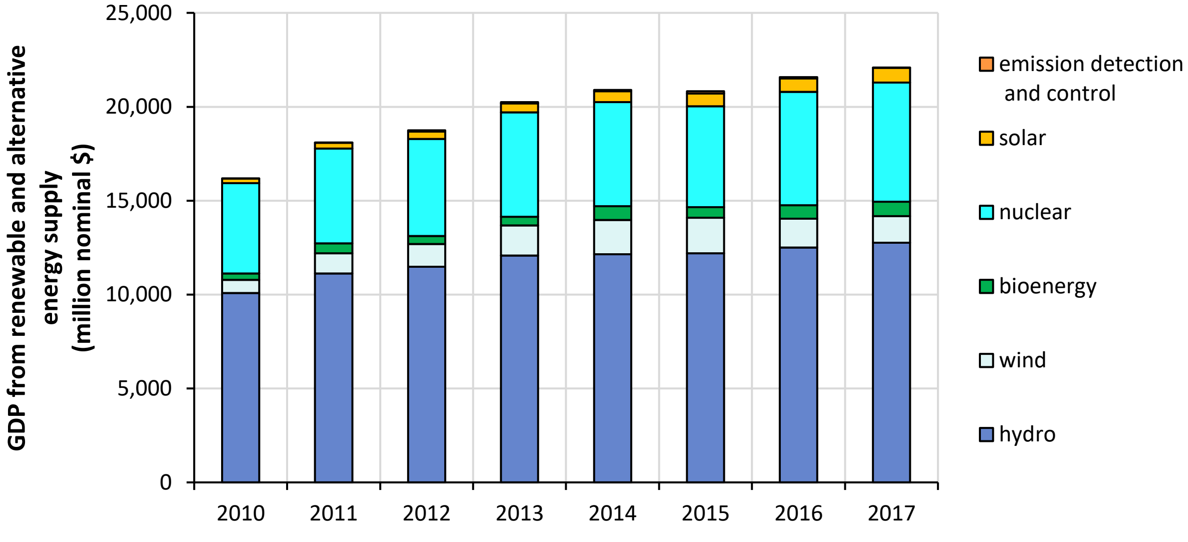
Energy supply sectors contribute to clean GDP in several ways: through the manufacturing of energy supply components (e.g. wind turbines), construction of new capacity and refurbishment of existing capacity (e.g. building wind farms, upgrading hydro facilities) and operation (i.e., the supply of electricity, or other energy carriers in the case of bioenergy).

GDP from renewable and alternative energy supply follows investment trends (discussed below), increasing from $16.2 billion in 2010 to $22.1 billion in 2017 as shown in Figure 7 (increasing at an average annual growth rate of 4.5%).

Hydro accounts for the majority of GDP from renewable and alternative energy supply ($13 billion in 2017, or 58% of total clean energy supply) because it is a mature technology that met 60% of Canada's electricity needs in 2017[21]. It is followed by nuclear, with 29% of GDP. Other forms of energy account for a lower amount of GDP (6% for wind and 4% each for biomass and solar), although they have grown more quickly than hydro. GDP from hydro grew at an average annual rate of 3% between 2010 and 2017, while wind grew at 10% and both solar and bioenergy exceeded 12%.

Figure 8 identifies the contribution of each type of activity to GDP by sector in 2017. For most types of renewable energy, the bulk of value-added is directly attributable to providing energy (i.e., the production of electricity or various forms of bioenergy). This is particularly true of hydro, which has a large existing capacity that contributes to GDP. In the case of wind and solar, manufacturing of wind turbines and solar panels account for a larger share of economic activity due to the presence of several key manufacturing firms. These firms include Senvion Canada Inc., Siemens Gamesa and General Electric for wind; Canadian Solar, GMA Solar and Morgan Solar for solar panel manufacturers; and Terragen Solar and Schletter for solar PV components.

Figure 7: GDP from renewable and alternative energy supply



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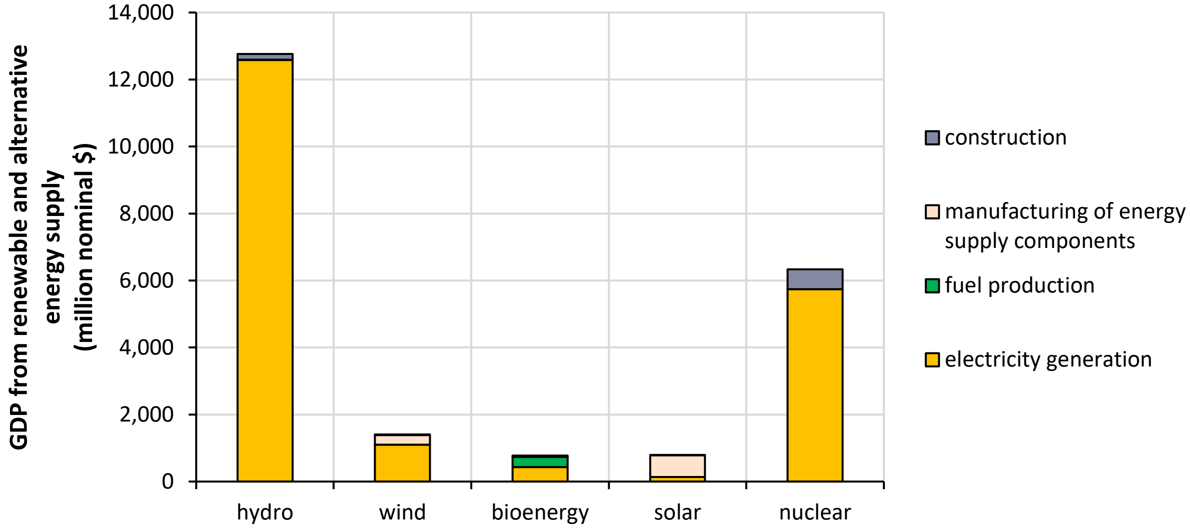
[21] National Energy Board. 2018. Canada's Energy Future 2018. Available from: www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/index-eng.html

Source: Calculations as described in Appendix A: "Historical data collection methods", with the following key sources: IBISWorld. 2018. Renewable Power in Canada. Industry Report 22111bCA; National Energy Board. 2018. Canada's Energy Future. Available from: www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/index-eng.html.

Figure 8: GDP from renewable energy supply by type of activity in 2017

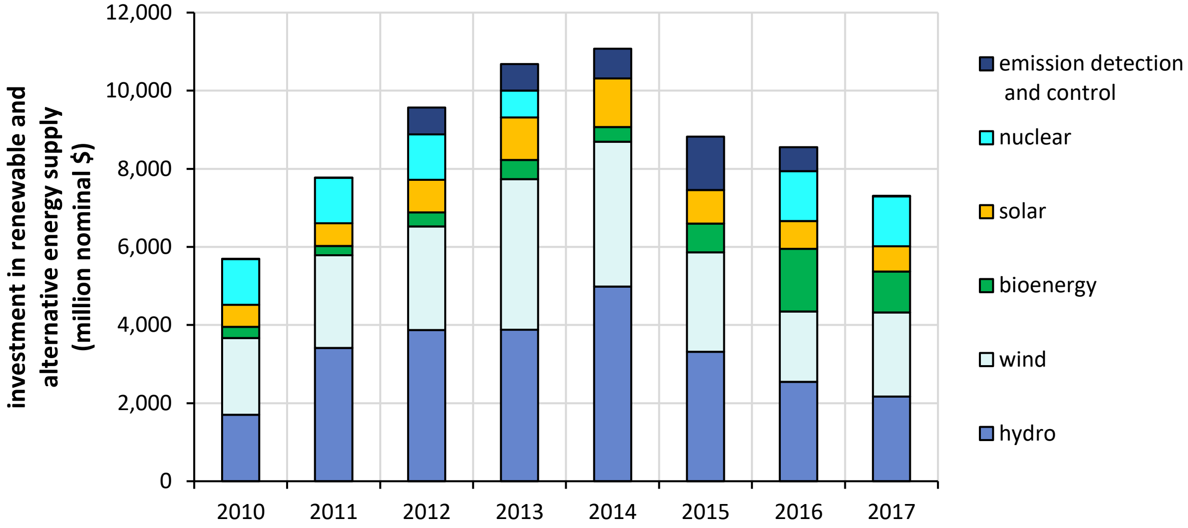


Source: Calculations as described in Appendix A: "Historical data collection methods", with the following key sources: IBISWorld. 2018. Renewable Power in Canada. Industry Report 22111bCA; National Energy Board. 2018. Canada's Energy Future. Available from: www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/index-eng.html.

Investment

Investment in renewable and alternative energy supply peaked in 2014 at $11 billion, after which it declined by 34% to $7 billion in 2017 (see Figure 9). This peak was caused by procurement drives across many provinces, but especially in Ontario, Québec and British Columbia. It also applies equally to most types of energy supply, with 2013-2015 being a period of peak investment for all types of clean energy supply other than bioenergy (which peaked in 2016) and nuclear. Investment in nuclear reflects refurbishment of existing capacity in Ontario and New Brunswick.

Figure 9: Investment in renewable and alternative energy supply



Source: Calculations as described in Appendix A: "Historical data collection methods", with the following key sources: National Energy Board. 2018. Canada's Energy Future. Available from: www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/index-eng.html; US Energy Information Administration. 2018. NEMS Documentation. Available from: www.eia.gov/outlooks/aeo/nems/documentation/; National Renewable Energy Laboratory. 2017 Annual Technology Baseline. Available from: https://atb.nrel.gov/; publicly available information for emission control projects.

Between 2010 and 2017, a cumulative total of $69.5 billion was invested in clean energy supply:

- Hydro ($25.9 billion, or 37% of cumulative investment in energy supply between 2010 and 2017). Hydro investments occurred in most provinces, although they were concentrated in Québec and British Columbia. Investments were made in both new facilities (e.g. la Romaine in Québec) as well as upgrades to existing dams (e.g. BC Hydro's upgrade of the Mica dam), both of which are capital intensive. Hydro investment peaked in 2014 nationally but has since picked up in some provinces, most notably due to the Muskrat Falls project in Newfoundland and Labrador and the Keeyask project in Manitoba.

- Wind ($21.1 billion, or 30% of cumulative investment in energy supply between 2010 and 2017). Investments in wind have been made in all provinces. Nearly three quarters of investment in wind have occurred in Ontario ($8 billion) and Québec ($7.6 billion). Cumulative investment over this period passed the billion-dollar threshold in both Alberta and British Columbia.

- Nuclear ($6.7 billion, or 10% of cumulative investment in energy supply between 2010 and 2017). This investment reflects refurbishments of nuclear reactors at Bruce Power and Darlington in Ontario and Point Lepreau in New Brunswick.

- Solar ($6.5 billion, or 9% of cumulative investment in energy supply between 2010 and 2017). Ontario dominated investment in solar energy, accounting for ninety-nine percent of investment between 2010 and 2017. This investment was driven by the province's feed-in-tariff (phased out at the end of 2016), which provided solar farm operators a higher price for their electricity relative to other generation sources[22]. Solar investment is estimated to have peaked at $1.2 billion dollars in 2014 and subsequently declined by 52% in 2017.

- Bioenergy ($5.1 billion, or 7% of cumulative investment in energy supply between 2010 and 2017). Bioenergy investments are less geographically dispersed than those in hydro or wind:

  - Most investment in biomass-fired electricity generation (a total of $4.6 billion) occurred in the three westernmost provinces (British Columbia, Alberta and Saskatchewan) and Ontario.

  - Investments in biodiesel and ethanol production (a total of $0.4 billion) were concentrated in Alberta and Ontario, with seven new facilities constructed between 2010 and 2017. Smaller investments were made in BC and Québec.

  - Please note that sufficient data have not been identified to determine investment in other forms of bioenergy supply (i.e., wood pellets, biogas).

Table 5: Cumulative investment by sector and region, 2010-2017 (billion $)

region	Hydro	Wind	Bioenergy	Solar	Nuclear	Emission control	Total
British Columbia	8.4	1.3	1.1	0.0	0.0	0.0	10.9
Alberta	0.0	2.1	1.1	0.0	0.0	2.6	5.8
Saskatchewan	0.1	0.5	0.9	0.0	0.0	1.5	3.0
Manitoba	1.3	0.3	0.0	0.0	0.0	0.0	1.6
Ontario	2.2	8.0	1.0	6.2	5.3	0.0	17.4
Québec	9.8	7.6	0.6	0.0	0.0	0.0	18.0
Atlantic	4.0	1.2	0.3	0.0	1.4	0.0	5.5
Territories	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Unspecified	0.0	0.0	0.1	0.2	0.0	0.0	0.4
Total	**25.9**	**21.1**	**5.1**	**6.5**	**6.7**	**4.1**	**69.5**

Sources are the same as those listed for Figure 9. Totals may not add up due to rounding.

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

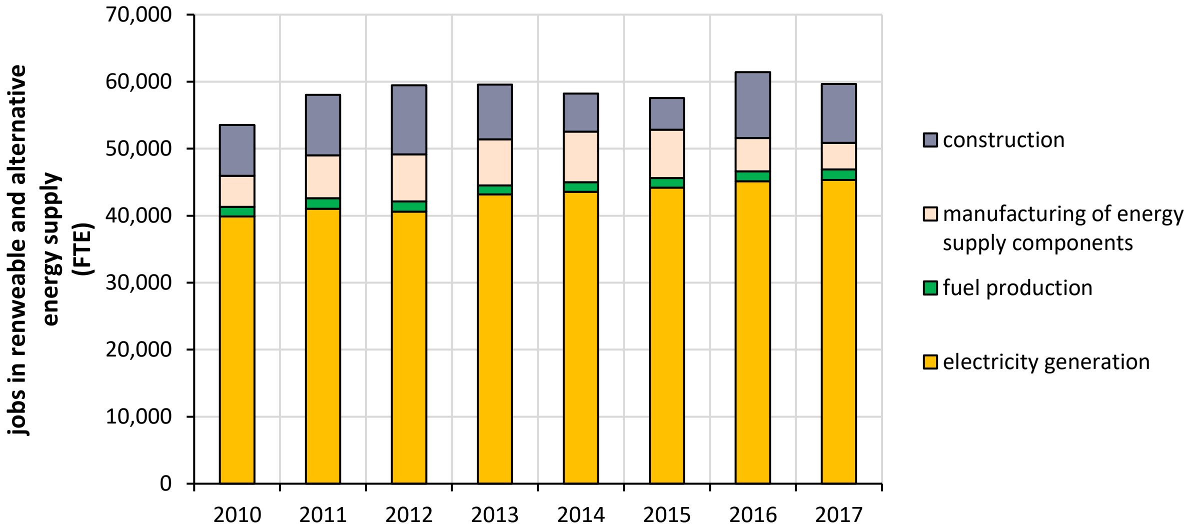
- Emissions control ($4.1 billion, or 6% of cumulative investment in energy supply between 2010 and 2017). Investment in emissions control technology is concentrated in several carbon capture and storage projects in Alberta (QUEST and the Alberta Carbon Trunk Line) and Saskatchewan (Boundary Dam). These projects all relate to energy supply, whether it is through the source of CO_2 (from the combustion of coal to produce electricity) or the use of CO_2 (for enhanced oil recovery in the case of the Alberta Carbon Trunk Line).

Jobs

The renewable and alternative energy supply sector employed an estimated 59.8 thousand people in 2017, up from 53.6 thousand in 2010 (please see Figure 10). Jobs in electricity and fuel production increased steadily over this period, reaching 46.9 thousand in 2017.

Construction jobs were more variable, following the trends in investment reviewed earlier and finishing off the period with 8.7 thousand positions. Jobs in manufacturing fell from 7.5 thousand in 2014 to 4 thousand in 2017, largely due to a downturn in wind turbine manufacturing. This downturn was caused by lower demand for new wind turbines in Canada and in other jurisdictions as well as increased competition in the global industry[23].

Figure 10: Jobs in renewable and alternative energy supply, by type of work



Source: Calculations as described in Appendix A: “Historical data collection methods”, with the following key sources: IBISWorld. 2018. Renewable Power in Canada. Industry Report 22111bCA.; IBISWorld. 2018. Wind

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[23] IBISWorld. 2018. Wind Turbine Manufacturing in Canada. Industry Report 33361bCA.

Turbine Manufacturing in Canada. Industry Report 33361bCA.; Statistics Canada Supply-Use Tables.
*FTE – full-time equivalent positions

3.2.2. Grid infrastructure and energy storage

Grid infrastructure and energy storage includes sectors that enable or optimize the delivery of clean energy supply to its customers, including:

- **Transmission and distribution.** Manufacturing, construction and operation of electrical transmission and distribution infrastructure used to transport clean electricity.
- **Batteries and energy storage technologies.** Manufacturing, construction and operation of technologies that store electricity for later use to optimize grid operation.
- **Smart grid technology.** Hardware and software components that enable the decentralization of power supply, demand-response management, and bidirectionality of power flows. Please note that sufficient data have not been identified to quantify economic activity in this sector.
- **Professional energy services.** Services specializing in transmission, energy storage and grid decentralization consulting. Please note that due to uncertainty in the underlying data, this sector is not disaggregated here.

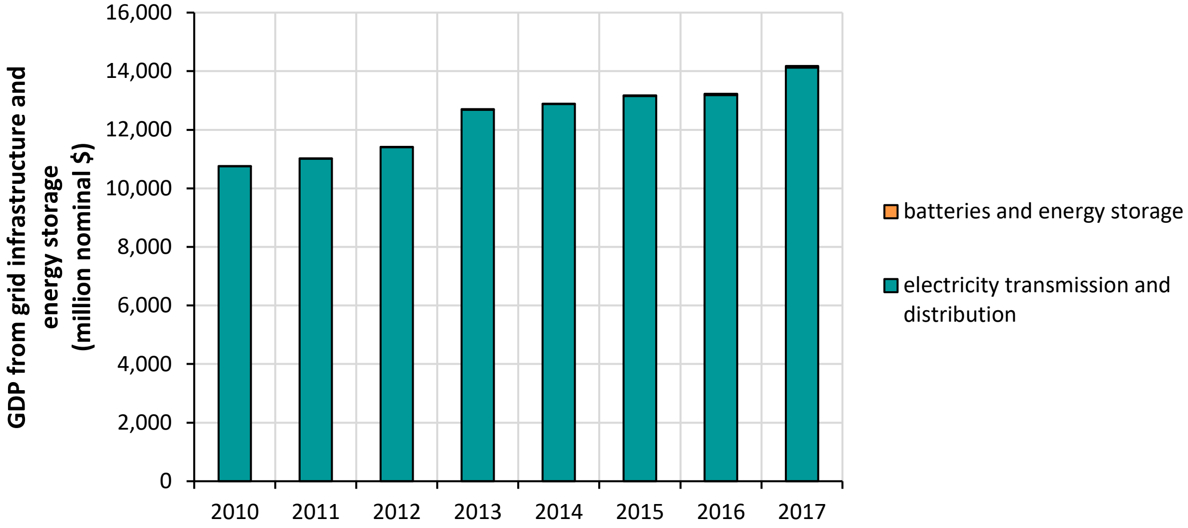
Grid infrastructure and energy storage: at a glance

$14.2 billion	**4.0%**	**$6.6 billion**	**47.2 thousand**
GDP in 2017 (nominal)	Average annual growth rate, 2010-2017	Average annual investment, 2010-2017	Jobs in 2017

GDP

GDP from electricity transmission and distribution reached $14.2 billion in 2017, up from $10.8 billion in 2010 as shown in Figure 11. This increase represents an average annual growth rate of 4%. Please note that sufficient data have not been identified to quantify GDP from energy storage. The value added from this sector is anticipated to be small relative to transmission and distribution.

Figure 11: GDP from grid infrastructure and energy storage



Source: Calculations as described in Appendix A: "Historical data collection methods", with the following key sources: IBISWorld. 2018. Electric Power Transmission in Canada. Industry Report 22112CA.

Investment

Investment in grid infrastructure and energy storage has been substantial, as shown in Figure 12. Between 2010 and 2012, investment averaged $6.6 billion annually, while since 2014 it has averaged $8.3 billion.

Most of these investments are associated with efforts to repair and modernize transmission and distribution infrastructure ($8.6 billion out of $8.7 billion in 2017). Investments in transmission help connect new sources of renewable energy supply to areas of electricity demand, while investments in distribution are necessary to keep up with population increases across the country.

Investments in batteries and energy storage peaked in 2015 at $168 million, as shown in Figure 13. The most substantial of these investments were made in electric battery technology in Ontario, as part of energy storage procurement efforts in that province[24]. Ontario has also invested in other technologies, including pumped hydro storage, flywheel, compressed air, thermal and hydrogen systems. Smaller

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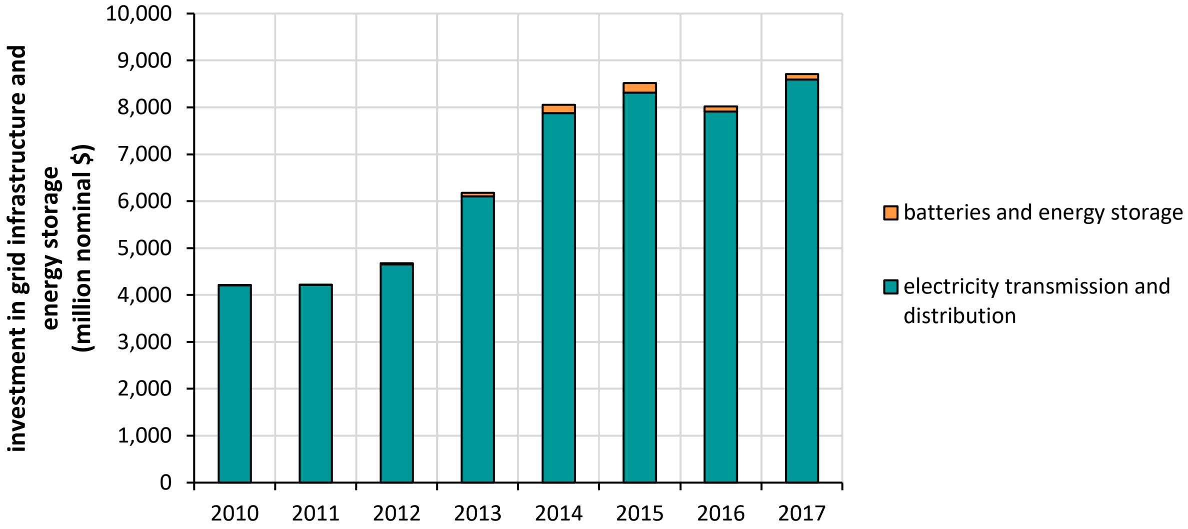
[24] Independent Electricity Systems Operator (IESO). Energy Storage Procurement at the IESO. Available at: www.ieso.ca/en/Sector-Participants/Energy-Procurement-Programs-and-Contracts/Energy-Storage

investments in batteries have been made in other provinces, often in remote communities and/or in conjunction with wind developments[25].

Figure 12: Investment in grid infrastructure and energy storage



Source: Calculations as described in Appendix A: “Historical data collection methods”, with the following key sources: Statistics Canada Table 34-10-0063-01 “Capital expenditures, non-residential tangible assets”; Independent Electricity System Operator (IESO). Energy Storage Procurement at the IESO. Available at: http://www.ieso.ca/en/Sector-Participants/Energy-Procurement-Programs-and-Contracts/Energy-Storage; Natural Resources Canada. Current Investments. Available at: www.nrcan.gc.ca/energy/funding/21146.

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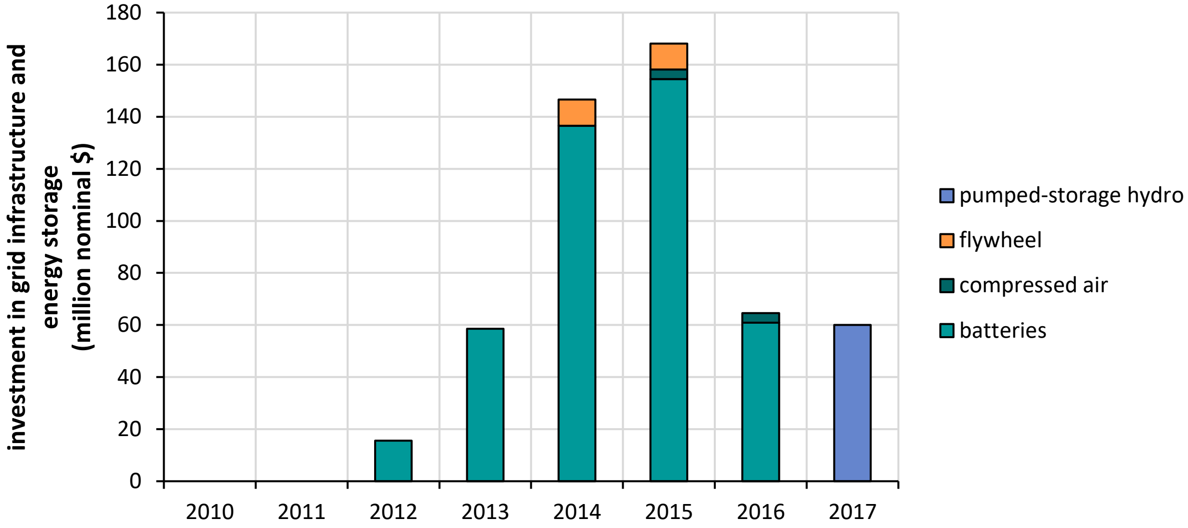
[25] For example, see list of projects here: Natural Resources Canada. Current investments in smart grid and energy storage. Available at: www.nrcan.gc.ca/energy/funding/21146

Figure 13: Investment in energy storage

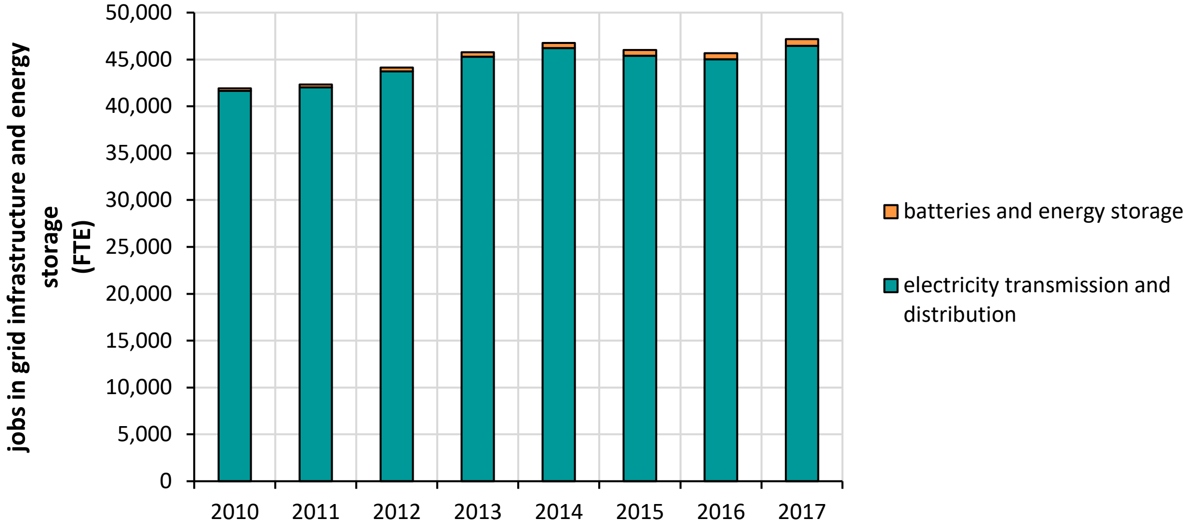


Source: Calculations as described in Appendix A: "Historical data collection methods", with the following key sources: Independent Electricity System Operator (IESO). Energy Storage Procurement at the IESO. Available at: http://www.ieso.ca/en/Sector-Participants/Energy-Procurement-Programs-and-Contracts/Energy-Storage; Natural Resources Canada. Current Investments. Available at: www.nrcan.gc.ca/energy/funding/21146.

Employment

Electricity transmission and distribution employed 47.2 thousand people in 2017, as shown in Figure 14. The number of jobs increased by 5 thousand since 2010. Please note that sufficient data have not been identified to quantify jobs in energy storage. Employment in this sector is anticipated to be small relative to transmission and distribution.

Figure 14: Jobs in grid infrastructure and energy storage



Source: Calculations as described in Appendix A: “Historical data collection methods”, with the following key sources: IBISWorld. 2018. Electric Power Transmission in Canada. Industry Report 22112CA.
*FTE – full-time equivalent positions

3.3. Energy demand

3.3.1. Buildings

This sector includes the following activities related to reducing energy consumption and switching to zero carbon fuels in residential, commercial and institutional buildings:

- **Green architecture and construction services.** Architectural and engineering services, building construction and contracting activities related to new buildings or retrofits seeking LEED, Energy Star or equivalent certifications.
- **Energy-saving building materials.** Manufacturing and investment in energy-saving building materials such as insulation and multi-pane windows. Please note that this estimate only captures manufacturing of doors and windows used in green construction (i.e., as defined above). It does not capture manufacturing of insulation or other materials due to a lack of data identified to date.
- **HVAC and building control systems.** Manufacturing and investment in high efficiency equipment that exceeds federal energy efficiency regulations[26] such as

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[26] Natural Resources Canada. Energy efficiency regulations. Available from: www.nrcan.gc.ca/energy/regulations-codes-standards/6845

heat pumps and condensing furnaces. Manufacturing of building control systems including control instruments (e.g. occupancy sensors, smart thermostats) and hardware and software developers (for building automation).

- **High efficiency appliances and lighting.** Manufacturing and investment in Energy Star appliances[27] and high efficiency lighting.
- **Professional energy services.** Services to support the adoption of clean energy technologies in buildings such as research and development and energy efficiency consulting. Please note that due to uncertainty in the underlying data, this sector is not disaggregated here.

Clean buildings: at a glance

$2.9 billion	**8.7%**	**$9.1 billion**	**20 thousand**
GDP in 2017 (nominal)	Average annual growth rate, 2010-2017	Average annual investment, 2010-2017	Jobs in 2017

GDP

GDP in the clean buildings sector increased from $1.6 billion in 2010 to $2.9 billion in 2017, as shown in Figure 15. Green architecture and construction services account for most of this economic activity ($2.2 billion in 2017, or 76% of total clean building GDP). This activity depends on the share of building construction and retrofits that registered or were certified to meet green building standards (including LEED in the case of large buildings and Energuide 80+ for houses). The share of such buildings increases between 2010 and 2017, from 10% to 14%.

The other clean building sectors contribute to GDP through the manufacturing of equipment and materials used in building construction:

- GDP from manufacturing HVAC and building control systems is estimated to have increased from $173 million in 2010 to $366 million in 2017. This increase was driven by a rising share of high efficiency equipment being manufactured in Canada, with 75% of new units being classified as Energy Star in 2017, up from 60% in 2010. Roughly half of the output from this sector is exported.

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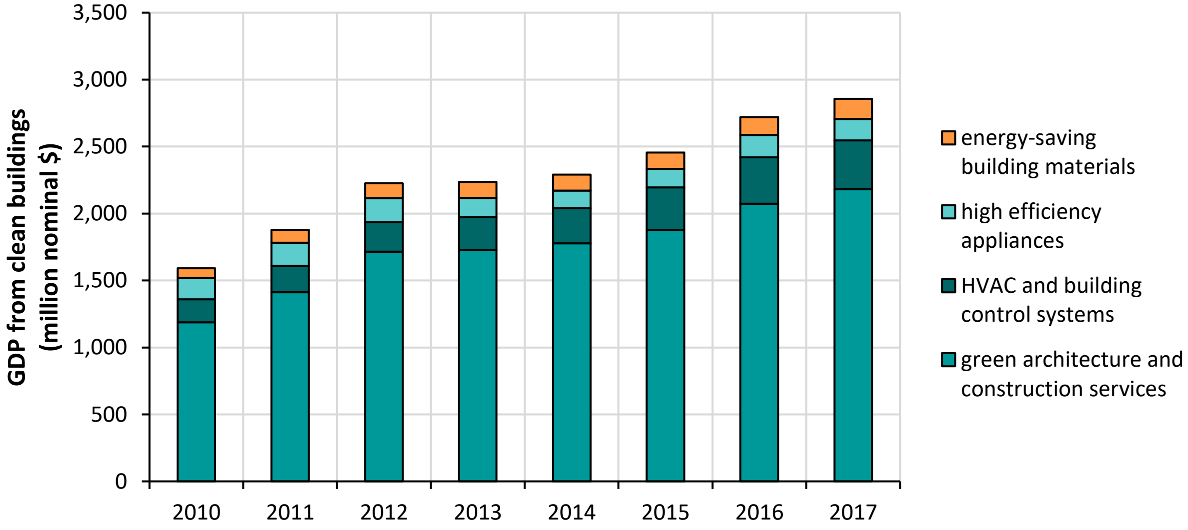
[27] Natural Resources Canada. ENERGY STAR Canada. Available from: www.nrcan.gc.ca/energy/products/energystar/12519

- GDP from manufacturing high efficiency appliances and lighting in 2017 was estimated at $160 million. However, there was a shift in economic activity between appliances and lighting manufacturing. GDP from appliance manufacturing decreased by $48.9 million between 2010 and 2017 (due partly to the closure of the Electrolux plant in Québec in 2014[28]). At the same time, GDP from lighting manufacturing increased in these two provinces.

- GDP from manufacturing energy-saving building materials was estimated at $150 million in 2017. However, this estimate only captures manufacturing of doors and windows used in clean construction (as defined above). It does not capture manufacturing of insulation or other materials due to a lack of data availability. With insulation included, GDP from this sector would increase.

Figure 15: GDP from clean buildings



Source: Calculations as described in Appendix A: "Historical data collection methods", with Figure 16's key sources in addition to: Statistics Canada Tables 36-10-0402-01 & Table 18-10-0005-01; IBISWorld. 2018. Electricians in Canada. Industry Reports 23821CA; IBISWorld. 2018. Heating & Air-Conditioning Contractors in Canada. Industry Reports 23822aCA; IBISWorld. 2017. Plumbing in Canada. Industry Report 23822bCA.

Investment

Investment in the clean building sector increased from $6.1 billion in 2010 to $11.8 billion in 2017, as shown in Figure 16. This investment includes several components:

- Investment in building construction ($5.2 billion in 2017). As mentioned above, building construction includes both new construction and retrofits of buildings that

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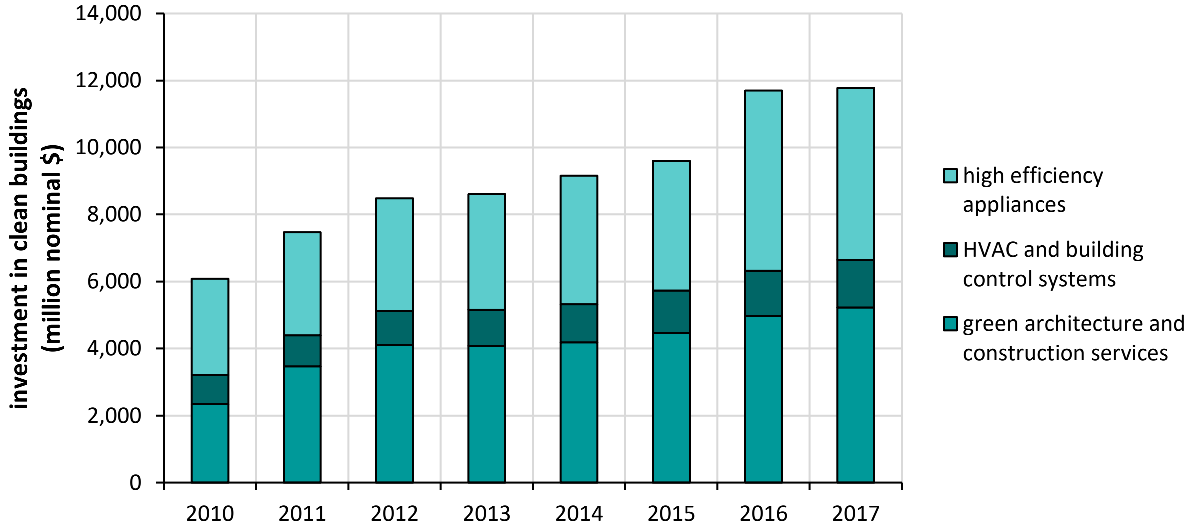
[28] CTV News Montreal. 2014, July 17. Electrolux closes Montreal area plant, leaving thousands unemployed. Available from: https://montreal.ctvnews.ca/electrolux-closes-montreal-area-plant-leaving-thousands-unemployed-1.1919052

registered or were certified to meet green building standards (including LEED in the case of large buildings and Energuide 80+ for houses).

- Investment in HVAC and building control systems ($1.4 billion in 2017). This amount represents the purchase of such systems for installation in new and existing buildings. The share of HVAC systems that exceed federal energy efficiency standards increased from 62% in 2010 to 76% in 2017 (based on number of units). Almost all new construction of large buildings involves the use of building control systems.
- Investment in high efficiency appliances and lighting ($5.1 billion in 2017). These investments include purchases in refrigerators, ranges, clothes washers, hot water heaters, dryers, dishwashers, freezers and lighting systems that exceed federal efficiency regulations. From 2010 to 2017 the share of equipment meeting this standard fluctuated between 65% and 78%.

As mentioned in Section 2.1.2, Statistics Canada considers the purchase of most energy-consuming technologies to be "consumption" rather than investment. Please note that for the purposes of the clean energy accounting, all purchases of clean energy technologies are considered to be investment.

Figure 16: Investment in clean buildings



Source: Calculations as described in Appendix A: "Historical data collection methods", with the following key sources: Statistics Canada Tables Supply Use Tables from 2010 to 2015, Tables 34-10-0010-01, 34-10-0011-01, 34-10-0066-01, 34-10-0003-01, & 34-10-0135-01; IBISWorld. 2018. Architects in Canada. Industry Report 54131CA; IBISWorld. 2018. Engineering Services in Canada; Canadian Green Building Council. 2019. LEED certification data received via email; Natural Resources Canada. 2019. EnerGuide evaluation, Energy Star certifications, and R-2000 certifications data received via email; CHBA. 2019. Net Zero/Net Zero Ready certified buildings data received via email; Natural Resources Canada. 2018. Comprehensive End-Use Database. Available at http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm; IBISWorld.

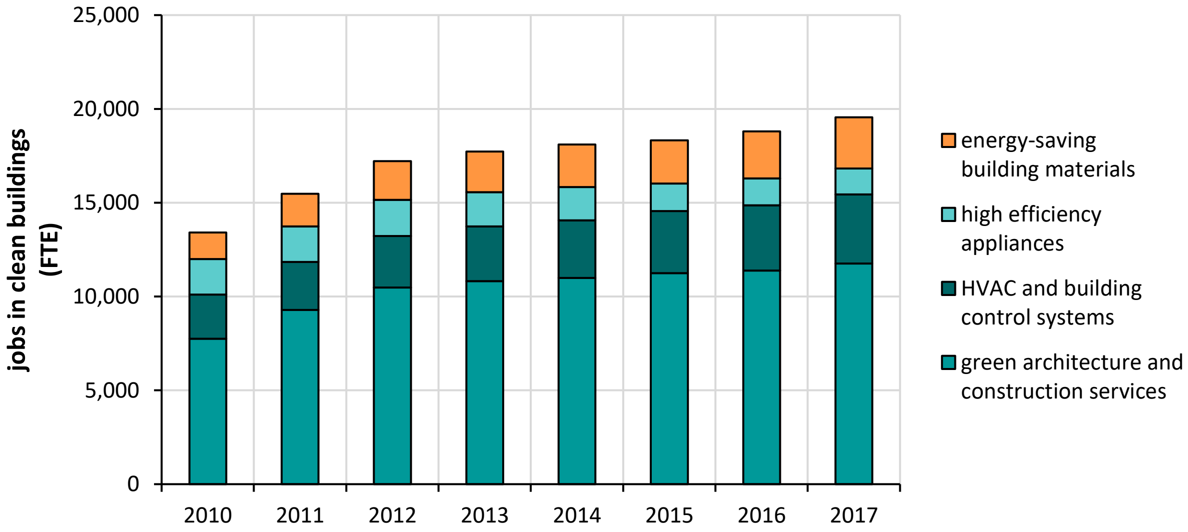
2017. Heating & Air-Conditioning Equipment Manufacturing in Canada. Industry Report 33341CA; IBISWorld. 2018. Major Household Appliance Manufacturing in Canada. Industry Report 33522CA; IBISWorld. 2017. Lighting & Bulb Manufacturing in Canada. Industry Report 33511CA; IBISWorld. 2018. Lighting Fixtures Manufacturing in Canada. Industry Reports 33512CA; National Electricity Manufacturers Association. 2018. Lamp Indices. Available at: https://www.nema.org/Intelligence/Pages/Lamp-Indices.aspx

Jobs

The clean buildings sector employed 19.6 thousand people in 2017, as shown in Figure 17. Most jobs are in green architecture and construction services (11.8 thousand in 2017). Of these, about 93.8% are in construction, 4.3% are in engineering and 1.9% are in architecture. Trends in green building investment, as described above, drive change in employment in this sector.

Manufacturing of doors and windows used in green construction (the only energy saving building material identified based on available data) is estimated at 2.7 thousand. HVAC and building control systems manufacturing employed 3.7 thousand people in 2017 (up from 2.4 thousand in 2010), while manufacturing of high efficiency electrical appliances employed 1.4 thousand in 2017 (down from 1.9 thousand in 2010).

Figure 17: Employment in clean buildings



Source: Calculations as described in Appendix A: “Historical data collection methods”, with Figure 16’s key sources in addition to: Statistics Canada Table 14-10-0202-01.
* FTE – full-time equivalent positions

3.3.2. Transport

This sector includes the following activities related to reducing energy consumption and switching to zero carbon fuels in transport:

- **Hybrids, electric vehicles and infrastructure.** Manufacturing of hybrid and plug-in electric vehicles and chargers, research and development related to hybrid and electric vehicles and investment in these technologies.
- **Hydrogen vehicles and infrastructure.** Manufacturing of hydrogen vehicles and refueling infrastructure, research and development related to hydrogen vehicles and investment in these technologies. Please note that sufficient data have not been identified to quantify economic activity in this sector.
- **Public transit and rail.** Manufacturing and operation of public transit vehicles, passenger trains and railway lines
- **Non-motorized transport.** Manufacturing, rental and investment in bicycles and other types of non-motorized transport. Please note that sufficient data have not been identified to quantify economic activity in this sector.

Clean transport: at a glance

$17.2 billion	5.4%	$6.5 billion	171 thousand
GDP in 2017 (nominal)	Average annual growth rate, 2010-2017	Average annual investment, 2010-2017	Jobs in 2017

GDP

GDP from clean transport was $17.2 billion in 2017, up from $11.8 billion in 2010. Economic activity in clean transport is generated through the following activities:

- Rail operation ($9.6 billion in 2017), which includes both freight and passenger travel. GDP from rail is distributed across most provinces (with the exception of PEI). As a matter of comparison, rail freight is estimated to be 81% less emissions intensive than road freight[29].

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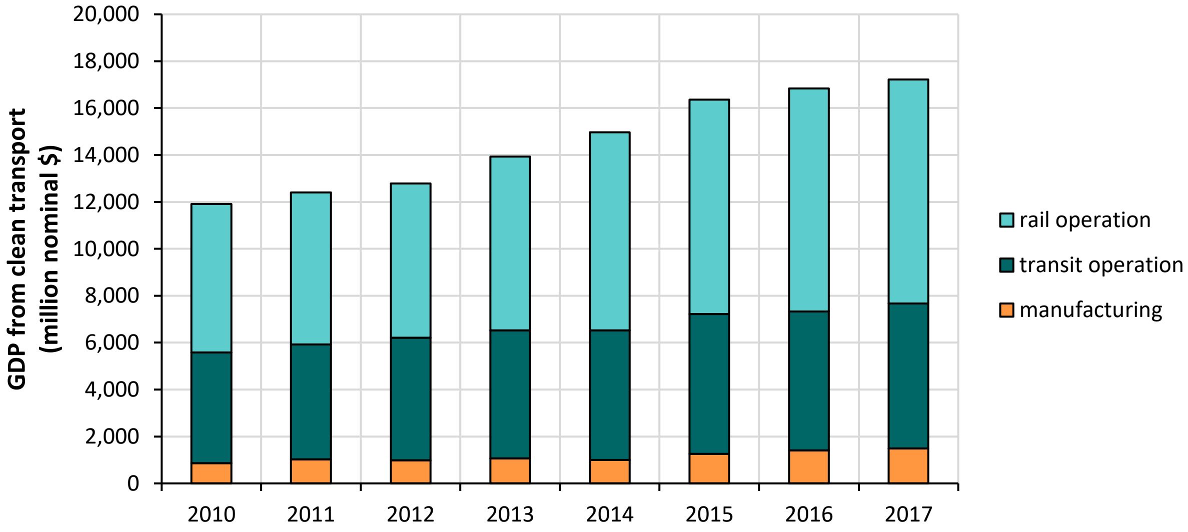
[29] Natural Resources Canada. Comprehensive Energy Use Database. Available from: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm

- Transit operation ($6.2 billion in 2017), which includes travel by bus, street car and rapid transit. 96% of transit GDP is generated in Ontario, Québec, British Columbia and Alberta.
- Manufacturing of hybrids, electric vehicles, buses, transit equipment and trains ($1.5 billion in 2017). Manufacturing activity is concentrated in Ontario (Bombardier and Toyota), Québec (Bombardier, Railpower Technologies, the Lion Electric Co.) and Manitoba (Novabus, New Flyer Group). GDP from this sector experienced an upsurge between 2014 and 2017, spurred in part by a relatively weak Canadian dollar which made imports less attractive (and exports more attractive)[30].

While purchases of electric vehicles have increased sharply in recent years (see previous section), they contribute little in terms of value-added to Canada. Some economic activity is generated through retailing and the development of charging infrastructure but that has not been estimated here. There are currently limited electric vehicle manufacturers in Canada, although it is worth noting Canadian manufacturers focused on electric light-duty vehicles (Chrysler), buses (Novabus), neighbourhood electric vehicles (Canadian Electric Vehicles Ltd) and single passenger vehicles (Meccanica).

Figure 18: GDP from clean transport



Source: Calculations as described in Appendix A: “Historical data collection methods”, with the following key sources: Figure 19 sources in addition to: Statistics Canada Supply Use Tables 2010 to 2015; IBISWorld. 2017. Truck & Bus Manufacturing in Canada. Industry Reports 33612CA; IBISWorld. 2017. Train, Subway & Transit Car

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[30] IBISWorld. 2017. Train, Subway and Transit Car Manufacturing In Canada. Industry Report 33651CA.

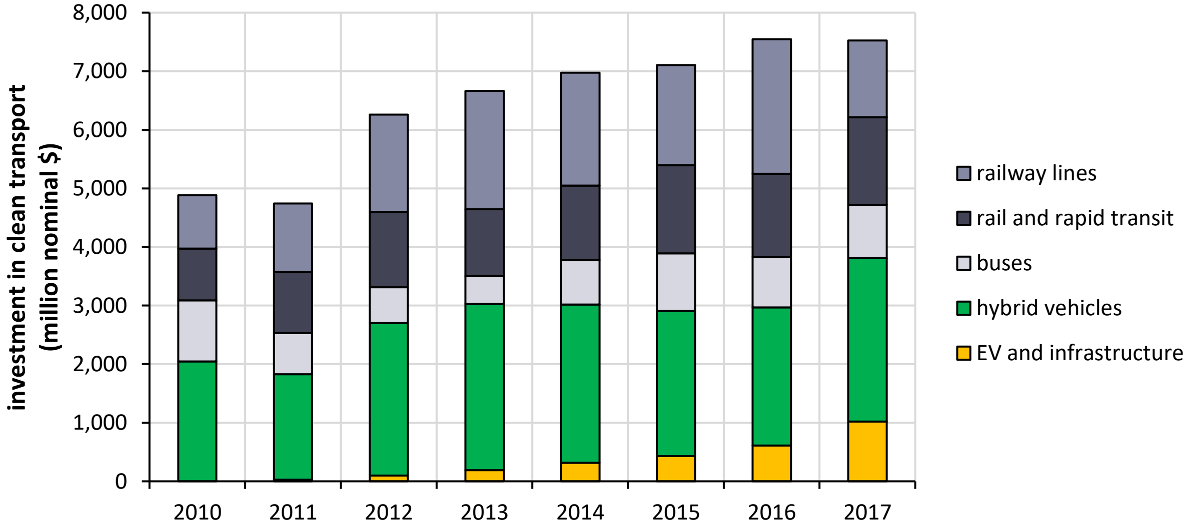
Manufacturing in Canada. Industry Reports 33651CA; IBISWorld. 2018. Rail Transportation in Canada. Industry Report 48211CA; IBISWorld. 2018. Public Transportation in Canada. Industry Report 48511CA.

Investment

Annual investment in clean transport increased from $4.9 billion in 2010 to $7.6 billion in 2017, as shown in Figure 19. This investment includes hybrid and electric vehicles ($3.8 billion in 2017), rail and rapid transit ($1.5 billion in 2017), railway lines ($1.3 billion in 2017), and buses ($0.9 billion in 2017).

Investments in plug-in electric vehicles and infrastructure grew particularly quickly over this period, from next to nothing in 2010 to over $1 billion in 2017. These investments were concentrated in Ontario, Québec and British Columbia (see Table 6). Together, these provinces account for 95% of cumulative investment between 2010 and 2017 (compared with 75% of population[31]). These provinces also implemented the most substantial electric vehicle-supportive policies during this time, which consisted of incentives for the purchase of both electric vehicles and chargers[32]. In 2017, electric vehicles accounted for between 0.9% and 1.6% of new light duty vehicle sales in these three provinces. By contrast, the market share was below 0.2% in the rest of Canada.

Figure 19: Investment in clean transport



Source: Calculations as described in Appendix A: "Historical data collection methods", with the following key sources: Statistics Canada. Table 36-26-0002. Infrastructure Economic Account. FleetCarma. 2018. Electric

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[31] Statistics Canada. Table 17-10-0005-01. Population estimates.

[32] Melton, N., Axsen, J., & Goldberg, S. (2017). Evaluating plug-in electric vehicle policies in the context of long-term greenhouse gas reduction goals: Comparing 10 Canadian provinces using the "PEV policy report card". *Energy Policy, 107*, 381-393.

vehicles sales updates. Available at: https://www.fleetcarma.com/blog/; Natural Resources Canada. 2019. Electric Charging and Alternative Fuelling Stations Locator. Available at: https://www.nrcan.gc.ca/energy/transportation/personal/20487#/find/nearest; Rocky Mountain Institute. 2014. Pulling Back the Veil on EV Charging Station Costs. Available at: https://rmi.org/pulling-back-veil-ev-charging-station-costs/; Statistics Canada. 2018. Infrastructure Economic Account, 2017. Available at: https://www150.statcan.gc.ca/n1/daily-quotidien/180913/dq180913b-eng.htm.

Table 6: Cumulative investment in plug-electric vehicles and charging infrastructure by province, 2010-2017 (million $)

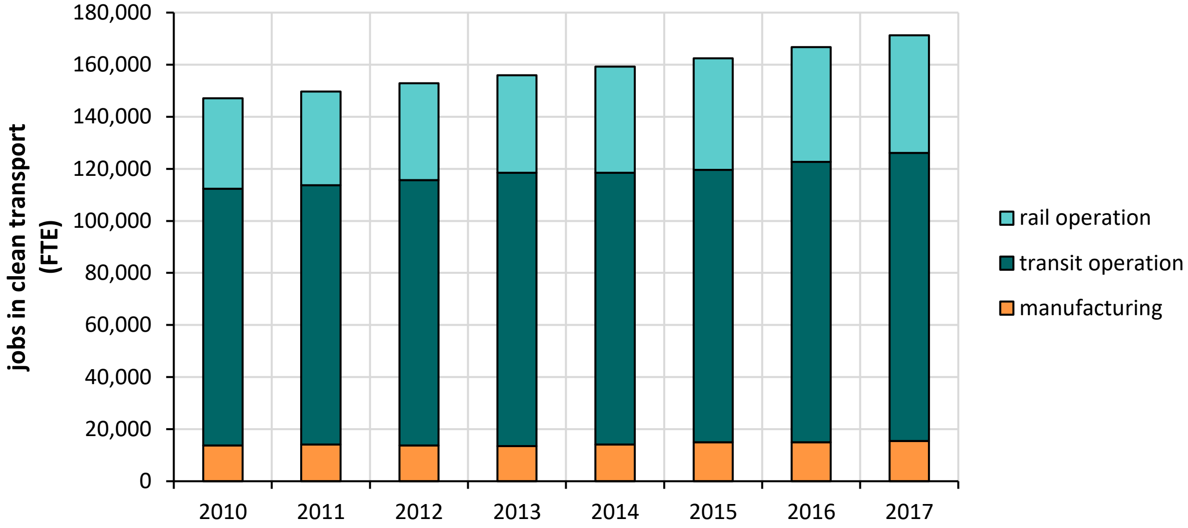
region	Plug-in electric vehicles	Electric vehicle infrastructure	Total
British Columbia	557.6	18.0	575.7
Alberta	95.5	3.8	99.3
Saskatchewan	4.0	0.4	4.4
Manitoba	15.5	0.6	16.1
Ontario	1,068	31.8	1,100
Québec	939.8	29.9	969.6
Atlantic	12.4	4.2	16.6
Total	**2,693**	**88.7**	**2,781**

Notes: Only light-duty passenger vehicles are included. Infrastructure is defined as publicly accessible chargers.
Source: Calculations as described in Appendix A: “Historical data collection methods”, with Figure 19 key sources.

Jobs

The clean transport sector provided 171 thousand jobs in 2017, up from 146 thousand in 2010 as shown in Figure 20. As with economic activity, most clean transport jobs are associated with transit and rail rather than vehicle manufacturing. Transit is the largest employer, and larger than its GDP might suggest, because it is quite labour intensive. In 2017, transit employed 111 thousand people. Rail operations accounted for 45 thousand jobs and manufacturing accounted for 14.5 thousand jobs.

Figure 20: Clean transport jobs



Source: Calculations as described in Appendix A: "Historical data collection methods", with the following key sources: Statistics Canada Table 14-10-0202-01
* FTE – full-time equivalent positions

3.3.3. Industry

This sector includes the following activities related to reducing energy consumption, switching to zero carbon fuels and implementing controls or process changes to reduce emissions in industry:

- **Energy-saving and low carbon machinery.** Manufacturing and installation of industrial equipment that reduces energy consumption and/or emissions such as heat exchangers, industrial heat pumps and efficient motor systems.
- **Industrial process change and emissions control.** Decarbonizing industrial processes by capturing CO_2 (e.g. in applications such as ammonia and hydrogen production) or changing processes (e.g. electrolysis of aluminum).

Given the lack of suitable data sources, the estimate for industry was developed using energy-economic modeling and is included in the modeling results (which will be provided in a subsequent report).

Appendix A: Historical data collection methods

This Appendix describes the methods and data sources used to estimate historical economic activity in Canada's clean energy sectors.

For each clean energy sector, this report identifies and/or estimates the following data to the extent possible:

- **GDP ($).** Gross domestic product is the value added of goods and services produced by that sector.
- **Investment ($).** Investment is an expenditure on goods and services that are not consumed at the present time, such as machinery, factories, inventory and workforce education. For example, a heat pump manufacturer may invest in a new factory for producing heat pumps. Households may also install a heat pump in their home, which can be considered an investment[33].
- **Employment (number of full-time equivalent positions).** Employment is defined as the number of paid workers, normalized to "full-time-equivalent positions" (i.e., 8 hours per working day).

Please note that this Appendix is organized by method rather than by thematic sector as described in Chapter 2. For example, we employ a similar method for estimating investment in all renewable electricity generation, so this grouping has its own section in this Appendix. Likewise, we use a similar method for estimating economic activity for all surveyed sectors.

Surveyed sectors

The survey directly solicited investment and employment information. It also solicited the components needed to estimate GDP by the following two methods, in order to help validate the responses. Using the first method, GDP is estimated by comparing outputs and inputs in the economy. With this approach, the GDP for sector j (GDP_j) can be determined by:

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[33] Although we consider household expenditures on clean energy technologies as an investment, we note that Statistics Canada generally classifies these expenditures as consumption. One exception is residential construction, which Statistics Canada classifies as investment.

$$GDP_j = value\ of\ output_j - intermediate\ consumption_j$$

Where $value\ of\ output_j$ is the price paid on goods and services produced by sector *j* and $intermediate\ consumption_j$ is the cost of material, supplies and services used to produce sector *j*’s output.

Using the second method, GDP is calculated by summing up sources of income in the economy. Using this approach, the GDP for sector *j* (GDP_j) can be determined by:

$$GDP_j = TAX_j - SUB_j + PI_j + CI_j$$

Where TAX_j is tax paid by sector *j*, SUB_j is subsidies received by sector *j*, PI_j is personal income (before tax) received by employees in sector *j* and CI_j is capital income (also before tax) received by sector *j*.

To calculate the economic contribution of a surveyed sector *j* in year *t* toward investment, employment or GDP, we use the following calculation:

$$Contribution_{j,t,r} = \sum_{i=1}^{n} contribution_i\ x\ \frac{total\ firms_{j,t,r}}{respondent\ firms_{j,t,r}}$$

Several notes about the approach are warranted:

- The survey ignores firms whose primary business line is not clean energy. Thus, the estimates provide a floor for clean energy activity.
- The survey was supplemented by information from financial statements of publicly traded non-respondent firms.
- The estimates assume that respondent firms are representative of non-respondent firms, although we did scale responses where we believed respondents to be particularly large or small relative to the industry average.
- Estimates are suppressed where they may allow individual company responses to be estimated (i.e., if there are fewer than 3 firms in a sector).

Renewable and alternative energy supply

Table 7: Electricity generation methods and data sources

Electricity generation

Overview

Data quality assessment: Tier 2	Covered NAICS codes: 221111 – Hydro-electric power generation 221113 – Nuclear power generation 221119 – Other electric power generation

Method for estimating GDP by source *j*, region r and year *t*

$$GDP_{j,r,t} = generation_{j,r,t} \times (wholesale\ price_{r,t} - levelized\ cost\ of\ production_{j,r,t})$$

Parameter	Unit	Description	Source
$generation_{j,r,t}$	MWh	Generation of electricity by source (e.g. wind, solar PV), region and year	National Energy Board. Canada's Energy Future 2018. Available from: www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/index-eng.html
$wholesale\ price_{r,t}$	\$/MWh	Average price for electricity by region and year	Navius' IESD model
$levelized\ cost\ of\ production_{j,r,t}$	\$/MWh	Levelized cost of producing electricity by source, region and year	US Energy Information Administration, 2018, NEMS Documentation National Renewable Energy Laboratory. 2017 Annual Technology Baseline. Available from: https://atb.nrel.gov/ Inferred capacity factors from: National Energy Board, Canada's Energy Future 2018.

Method for estimating investment by source *j*, region *r* and year *t*

$$investment_{j,r,t} = capacity\ additions_{j,r,t} \times capital\ cost_{j,t}$$

Parameter	Unit	Description	Source
$capacity\ additions_{j,r,t}$	GW	Capacity additions by source, region and year	National Energy Board. Canada's Energy Future 2018.

Electricity generation			
$capital\ cost_{j,t}$	$/kW	Average capacity costs by source and year	US Energy Information Administration, 2018, NEMS Documentation National Renewable Energy Laboratory, 2017 Annual Technology Baseline US Energy Information Administration, 2015, Photovoltaic System Pricing Trends
Method for estimating employment by source *j*, region r year *t* and region *r*			
$employment_{j,r,t} = employment_t \times renewable\ share_{j,r,t}$			
Parameter	Unit	Description	Source
$employment_t$	FTE	Employment in renewable power generation by year	IBISWorld Industry Report 22111bCA, Renewable Power in Canada.
$renewable\ share_{j,r,t}$	%	Share of renewable generation by source, region and year	National Energy Board. Canada’s Energy Future 2018.
Validation			
Compare investment with Statistics Canada Table 34-10-0063-01 “Capital expenditures, non-residential tangible assets”.			
Ensure proportion of total electricity generation, transmission and distribution GDP, investment and employment as reported by Statistics Canada is reasonable for each province.			
Check against cost of large projects based on project-specific info from energy utilities and regulators.			
Notes			
Although data about generation, capacity and cost/price trends are generally good, the disaggregation by sector and source remains uncertain (particularly for value-added).			
The employment estimate assumes similar labour intensity (i.e., FTE/GWh) across all generation sources.			

Table 8: Biofuel production methods and data sources

Biofuel production

Overview

Data quality assessment:	Covered NAICS codes:
Tier 2	325190 – Other basic organic chemical manufacturing

Method for estimating GDP by fuel type *j*, year *t* and region *r*

$$GDP_{j,r,t} = production_{j,t} \times capacity\ share_{j,r,t} \times \left(biofuel\ price_{j,t} - production\ cost_{j}\right)$$

Parameter	Unit	Description	Source
$production_{j,t}$	Million liters	National biofuel production by type (biodiesel, ethanol) and year	Global Agricultural Information Network Report, USDA Foreign Agricultural Service
$capacity\ share_{j,r,t}$	%	Share of biofuel production capacity by type by province by year	Canadian Renewable Fuels Association, Ethanol and Biodiesel facilities
$biofuel\ price_{j,t}$	$/liter	Price of biodiesel and ethanol by year	Chicago Mercantile Exchange futures price
$production\ cost_{j}$	$/liter	Cost of producing ethanol and biodiesel	GHGenius 4.03a model (feedstock quantity, energy input, co-product output) International Renewable Energy Association (IRENA), 2013, road transport: the cost of renewable solutions. (capex) APEC, 2010, Biofuel Costs, Technologies and Economics in APEC Economies (opex)

Method for estimating investment by fuel type *j*, year *t* and region *r*

$$investment_{j,r,t} = capacity\ additions_{j,r,t} \times capital\ cost_{j,t}$$

Parameter	Unit	Description	Source
$capacity\ additions_{j,r,t}$	Million liters per year	Capacity additions by source, region and year	Canadian Renewable Fuels Association, Ethanol and Biodiesel facilities
$capital\ cost_{j,t}$	$/million-liter capacity	Average capacity costs by source and year	International Renewable Energy Association (IRENA), 2013, road transport: the cost of renewable solutions.

Method for estimating employment by fuel type *j*, year *t* and region *r*

$$employment_{j,r,t} = \frac{wages_{j,r,t}}{average\ salary_{t}}$$

Biofuel production			
Parameter	Unit	Description	Source
$wages_{j,r,t}$	$	Employment expenses for a given amount of biofuel production by fuel type by province by year	GHGenius 4.03a model (feedstock quantity, energy input, co-product output) International Renewable Energy Association (IRENA), 2013, road transport: the cost of renewable solutions. (capex) APEC, 2010, Biofuel Costs, Technologies and Economics in APEC Economies (opex)
$average\ salary_t$	$	Average annual salary in basic chemical manufacturing	Statistics Canada Table 36-10-0489-01 “Employee wages by industry”
Notes			
Few data sources are available for validating the estimates.			

Table 9: Gaseous bioenergy supply methods and data sources

Solid bioenergy supply	
Overview	
Data quality assessment:	Covered NAICS codes:
Tier 3	325190 – Other basic organic chemical manufacturing
Data sources	
Natural Resources Canada. Investing in Renewable Natural Gas. Available from: www.nrcan.gc.ca/19445	
Canadian Biogas Association. Biogas projects in Canada. Available from: https://biogasassociation.ca/about_biogas/projects_canada	
Notes	
Sufficient data was not identified to make estimates for this sector within the timeframe of this project.	

Table 10: Solid bioenergy supply methods and data sources

Solid bioenergy supply	
Overview	
Data quality assessment:	Covered NAICS codes:
Tier 3	321999 – All other miscellaneous wood product manufacturing
Method for estimating GDP, investment and employment	

<table>
<tr><th>Solid bioenergy supply</th></tr>
<tr><td>Survey of dedicated clean energy companies.</td></tr>
<tr><td>Notes</td></tr>
<tr><td>Excludes other solid fuels (e.g. cord wood) or use of wood waste in industry.</td></tr>
</table>

Table 11: Manufacturing of energy supply components methods and data sources

<table>
<tr><th colspan="2">Manufacturing of energy supply components</th></tr>
<tr><td colspan="2">Overview</td></tr>
<tr><td>Data quality assessment:
Tier 3</td><td>Covered NAICS codes:
333611 – Turbine and turbine generator set manufacturing
332410 – Power boiler and heat exchanger manufacturing
334410 – Semiconductor and other electronic components manufacturing</td></tr>
<tr><td colspan="2">Method for estimating GDP, investment and employment</td></tr>
<tr><td colspan="2">Survey of dedicated clean energy companies.</td></tr>
<tr><td colspan="2">Supplemented with IBISWorld Report: Wind Turbine Manufacturing in Canada</td></tr>
<tr><td colspan="2">Notes</td></tr>
<tr><td colspan="2">This includes all energy supply technologies (electricity, heat, liquid fuels, etc.)</td></tr>
</table>

Table 12: Construction of energy supply infrastructure

<table>
<tr><th colspan="4">Construction of energy supply infrastructure</th></tr>
<tr><td colspan="4">Overview</td></tr>
<tr><td>Data quality assessment:
Tier 2</td><td colspan="3">Covered NAICS codes:
237130 – Power and communication line and related structures construction
237990 – Other heavy and civil engineering construction</td></tr>
<tr><td colspan="4">Method for estimating GDP by sector <i>j</i>, year <i>t</i> and region <i>r</i></td></tr>
<tr><td colspan="4">$GDP_{j,r,t} = investment_{j,t,r} \times multiplier_{j,t,r}$</td></tr>
<tr><td>Parameter</td><td>Unit</td><td>Description</td><td>Source</td></tr>
<tr><td>$investment_{j,t,r}\,_{j,t}$</td><td>$</td><td>Investment in energy supply infrastructure</td><td>Calculated value for each energy supply sector as described in Table 7</td></tr>
<tr><td>$multiplier_{j,t,r}$</td><td>N/A</td><td>Ratio of construction GDP per investment</td><td>Statistics Canada Supply-Use Tables</td></tr>
</table>

Construction of energy supply infrastructure

Method for estimating employment by sector *j*, year *t* and region *r*

$$Employment_{j,r,t} = \frac{GDP_{j,t,r} \times wage\ share_{j,t,r}}{average\ salary_{j,t,r}}$$

Parameter	Unit	Description	Source
$GDP_{j,t,r}$	$	Construction GDP	Calculation as per above
$wage\ share_{j,t,r}$	%	Share of construction GDP attributable to wages	Statistics Canada Supply-Use Tables
$average\ salary_{j,t,r}$	$	Average salary in the construction industry	Statistics Canada Table 14-10-0204-01 “Average weekly earnings by industry”

Notes

This approach was taken for all energy supply technologies as well as transmission infrastructure.

Table 13: Professional energy services methods and data sources

Professional energy services

Overview

Data quality assessment:	Covered NAICS codes:
Tier 3	541330 – Engineering services 541690 – Other scientific and technical consulting services 541710 – Research and development in the physical, engineering and life sciences 541990 – All other professional, scientific and technical services

Method for estimating GDP, investment and employment

Survey of dedicated clean energy companies

Supplemented with:

Statistics Canada Table 27-10-0347-01 “Industrial energy research and development expenditures by area of technology”

List of feasibility projects from Natural Resources Canada, “Carbon capture and storage: Canada’s Technology Demonstration Leadership”, available from: www.nrcan.gc.ca/energy/publications/16226

Notes

Professional services for both grid infrastructure and energy storage and renewable and alternative energy supply have been merged due to insufficient data to separate the two.

Table 14: Methane reduction methods and data sources

Methane reduction	
Overview	
Data quality assessment: Tier 3	Covered NAICS codes: 334512 – Measuring, medical and controlling devices manufacturing
Method for estimating GDP, investment and employment	
Survey of dedicated clean energy companies	

Table 15: Carbon capture and storage methods and data sources

Carbon capture and storage	
Overview	
Data quality assessment: Tier 2	Covered NAICS codes: 21111 – Oil and gas extraction 221112 – Fossil-fuel electric power generation 334512 – Measuring, medical and controlling devices manufacturing
Method for estimating investment by region r and year *t*, and CCS project *i*	

$$Investment_{r,t} = \sum_{i=1}^{\#\ of\ projects\ _{r,t}} \left(Project\ Cost_{i,r}\ \div\ Funding\ Time\ Frame_{i,r}\right)$$

Parameter	Unit	Description	Source
$Project\ Cost_{i,r}$	$	Total cost by ccs project by region	MIT Carbon Capture and Sequestration Technologies program Government of Alberta news releases NRCAN Energy Publications
$\#\ of\ projects\ _{r,t}$	stock	# of operational energy projects by region by year	NRCAN Carbon Capture and Storage: Canada's Technology Demonstration Leadership
$Funding\ Time\ Frame$	years	# years active by project by region	MIT Carbon Capture and Sequestration Technologies program Government of Alberta news release NRCAN Energy Publications

Carbon capture and storage
Notes
Employment and GDP information has not been identified other than for construction.

Grid infrastructure and energy storage

Table 16: Transmission infrastructure methods and data sources

Transmission infrastructure			
Overview			
Data quality assessment: Tier 2		Covered NAICS codes: 22112 – Electric power transmission, control and distribution	
Method for estimating GDP by year *t* and region *r*			
$GDP_{t,r} = Tranmission\ Infrastructure\ Value\ Added_t \times Electricity\ Share_{r,t}$			
Parameter	Unit	Description	Source
$Electricity\ Share_{r,t}$	%	% of value-added from the electricity sector relative to Canadian total by region and year	Statistics Canada 34-10-0434-02
$Tranmission\ Infrastructure\ Value\ Added_t$	$	Canadian value-added from electricity transmission and distribution by year	IBISWorld report 22112CA "Electric power transmission in Canada"
Method for estimating investment by sector *j*, year *t* and region *r*			
As reported by Statistics Canada Table 36-10-0096-01 "Investment in fixed non-residential capital, by industry and type of asset"			
Method for estimating employment by sector *j*, year *t* and region *r*			
$Employment_{t,r} = Tranmission\ Employment_t \times Utility\ Share_{t,r}$			
Parameter	Unit	Description	Source
$Utility\ Share_{t,r}$	%	% of employment from the electricity sector relative to Canadian total by region and year	Statistics Canada Table 14-10-0023-01 "Employment by industry"

Transmission infrastructure

$Tranmission\ Employment_t$	FTE	Canadian employment in electricity transmission and distribution by year	IBISWorld report 22112CA "Electric power transmission in Canada"

Notes

Electricity transmission was further pro-rated based on the share of electricity generation considered clean in each province.

Table 17: Batteries and energy storage technologies methods and data sources

Batteries and energy storage technologies

Overview

Data quality assessment: Tier 2	Covered NAICS codes: 221111 – Hydro-electric power generation 221119 – Other electric power generation

Method for estimating investment by year *t* region *r, and energy storage project i*

$$Investment_{r,t} = \sum_{i=1}^{\#\ of\ projects\ _r} \left(Project\ Cost_{i,r}\ \div\ Funding\ Time\ Frame_{i,r}\right)$$

Parameter	Unit	Description	Source
$Project\ Cost_{i,r}$	$	Total cost by energy storage project by region	U.S. Department of Energy Global Energy Storage Database Natural Resources Canada Current Investments Ontario Independent Electricity System Operator. Energy Storage Procurement at the IESO. Available at: www.ieso.ca
$\#\ of\ projects\ _r$	stock	# of operational energy projects by region	U.S. Department of Energy Global Energy Storage Database
$Funding\ Time\ Frame_{i,r}$	years	# years funding is provided by project by region	U.S. Department of Energy Global Energy Storage Database NRCAN Current Investments

Notes

No GDP or employment information could be identified for this sector.

Table 18: Smart grid technology methods and data sources

Smart grid technology	
Overview	
Data quality assessment: Tier 3	Covered NAICS codes: 221122 – Electric power distribution 23713 – Power and communication line and related structures construction 334410 – Semiconductor and other electronic component manufacturing 334512 – Measuring, medical and controlling devices manufacturing 335311 – Power, distribution and specialty transformers manufacturing 335920 – Communication and energy wire and cable manufacturing 335990 – All other electrical equipment and component manufacturing 541710 – Research and development in the physical, engineering and life sciences 541330 – Engineering services
Method for estimating GDP, investment and employment	
Survey of dedicated clean energy companies.	
Notes	
The survey did not yield sufficient information to make estimates for this sector.	

Table 19: Professional energy services methods and data sources

Professional energy services	
Overview	
Data quality assessment: Tier 3	Covered NAICS codes: 541690 – Other scientific and technical consulting services; 541330 – Engineering services
Method for estimating GDP, investment and employment	
Survey of dedicated clean energy companies.	
Notes	
Professional services for both grid infrastructure and energy storage and renewable and alternative energy supply have been merged due to insufficient data to separate the two.	

Buildings

Table 20: Green architecture and construction services methods and data sources

Green architecture and construction services

Overview

Data quality assessment: Tier 2	Covered NAICS codes: 236 – Construction of buildings 238X – Building construction-related contractors 541310 – Architectural services 541330 – Engineering services

Method for estimating GDP by region *r* and year *t*, where *j* is the activity (construction, architectural services, or engineering) *i* is the building type (residential or non-residential)

$$GDP_{r,t} = \sum_{j=1}^{3}\sum_{i=1}^{2}\frac{\#\ certification\ applications_{i,r,t}}{\#\ buildings\ constructed_{i,t}} \times \left(GDP_{j,i,r,t}\right) \times share_{building\ j,i} \times share_{energy}$$

Parameter	Unit	Description	Source
$\#\ certification\ applications_{i,r,t}$	flow	Number of buildings seeking certification by type of building by region by year	CaGBC and NRCan
$\#\ buildings\ constructed_{i,t}$	flow	Number of buildings under construction by type of building by year	Statistics Canada 34-10-0066-01, 34-10-0003, & 34-10-0135
$GDP_{j,i,r,t}$	$	Construction GDP by activity by type of building by region by year	Statistics Canada Supply Use Table
$share_{building}$	%	Share of buildings by activity by building type (relevant for architect and engineering activities only)	IBISWorld 54131CA & IBISWorld 54133CA
$share_{energy}$	%	Share of buildings value related to energy system, held constant at 24%	gTech modelling results

Method for estimating investment by region *r* and year *t*, where *i* is the building type (residential or non-residential)

$$investment_{r,t} = \sum_{i=1}^{2}\frac{\#\ certification\ applications_{i,r,t}}{\#\ buildings\ constructed_{i,r,t}} \times \left(investment_{j,i,r,t}\right) \times share_{building\ j,i} \times share_{energy}$$

Parameter	Unit	Description	Source

Green architecture and construction services

$\#\ certification\ applications_{i,t,r}$	flow	Number of buildings seeking certification by type of building by region by year	CaGBC LEED certifications and NRCan Energuide 80+ evaluations, and Energy Star and R-2000 certifications
$\#\ buildings\ constructed_{i,r,t}$	flow	Number of buildings under construction by type of building by region by year	Statistics Canada 34-10-0066-01, 34-10-0003, & 34-10-0135
$investment_{j,i,r,t}$	\$	Construction investment by activity by type of building by region by year	Statistics Canada 34-10-0010-01, 34-10-0011-01, Supply Use Tables 2010 to 2015, IBISWorld 23811CA, 23816CA, 23821CA, 23821CA, 54131CA, & 54133CA
$share_{building}$	%	Share of buildings by activity by building type (relevant for architect and engineering activities only)	IBISWorld 54131CA & IBISWorld 54133CA
$share_{energy}$	%	Share of buildings value related to energy system, held constant at 24%	gTech modelling results

Method for estimating employment by region *r* and year *t*, where *i* is the building type (residential or non-residential)

$$employment_{r,t} = \sum_{i=1}^{2} \frac{\#\ certification\ applications_{i,r,t}}{\#\ buildings\ constructed_{i,t}} \times \left(employment_{j,i,r,t}\right) \times share_{building\ j,i} \times share_{energy} \times \frac{GDP_{j,i,r,t}}{GDP_{j,i,t}}$$

Parameter	Unit	Description	Source
$\#\ certification\ applications_{i,r,t}$	flow	Number of buildings seeking certification by type of building by region by year	CaGBC LEED certifications and NRCan Energuide 80+ evaluations, and Energy Star and R-2000 certifications
$\#\ buildings\ constructed_{i,t}$	flow	Number of buildings under construction by type of building by region by year	Statistics Canada 34-10-0066-01, 34-10-0003, & 34-10-0135
$employment_{j,i,r,t}$	FTE	Construction employment by type of building by year	Statistics Canada 14-10-0202-01, IBISWorld reports 23811CA, 23816CA, 23821CA, 23821CA, 54131CA, & 54133CA
$share_{building}$	%	Share of buildings by activity by building type (relevant for architect, engineering, and contractor activities only)	IBISWorld reports 23811CA, 23816CA, 23821CA, 23821CA, 54131CA, & 54133CA
$share_{energy}$	%	Share of buildings value related to energy system, held constant at 24%	gTech modelling results

Green architecture and construction services

$GDP_{j,i,r,t}$	$	Construction GDP by activity by type of building by region by year	Statistics Canada Table 36-10-0402-01 & Table 18-10-0005-01
$GDP_{j,i,t}$	$	Construction GDP by activity by type of building by year	Statistics Canada Table 36-10-0402-01 & Table 18-10-0005-01

Validation

Ensure that the GDP and investment are below total GDP for construction after accounting for the cost premium factor.

Notes

Building construction contractors include electricians, plumbers, HVAC installation professionals, and drywall and insulation specialists.

The building types considered under residential are single-family homes (singled detached, double, and row) and multi-unit buildings (apartments and condominiums). Non-residential buildings include commercial and institutional but exclude industrial buildings.

We were unable to find data for multi-unit residential, commercial and institutional building completions. Statistics Canada only reports total building permit value for all new buildings from 2010 to 2017 (in Table 34-10-0003). We extrapolate individual new building permits using the 2018 average permit value per unit (from Table 34-10-0066-01).

The data includes both new and retrofit constructions. The share of green buildings for new construction was also applied to retrofits since we were unable to find detailed data on green retrofits.

We apply the 2010-2017 average to the green portion of total building construction from 2012 to 2017 to adjust for irregular trends. (e.g., 2011 green building portion reflects actual data, whereas 2012 and 2015 values are equal to the 2010-2017 average).

We used IBISWorld's products and services segmentation breakdowns to estimate the share of contractor employment related to building construction (new and retrofit). Equipment repair, industrial, and other unrelated activities were excluded.

Table 21: Energy-saving building materials methods and data sources

Energy-saving building materials

Overview

Data quality assessment: Tier 3	Covered NAICS codes: 325220 – Artificial and synthetic fibres and filaments manufacturing 326140 – Polystyrene foam product manufacturing 326150 – Urethane and other foam product (except polystyrene) manufacturing 326190 – Other plastic product manufacturing 332321 – Metal window and door manufacturing

Method for estimating GDP by region *r* and year *t*, where *j* is the material (doors and windows, or insulation)

Energy-saving building materials

$$GDP_{r,t} = \frac{\#\ certification\ applications_{r,t}}{\#\ buildings\ constructed_{r,t}} \times \left(GDP_{r,t}\right) \times share_{energy}$$

$\#\ certification\ applications_{i,r,t}$	flow	Number of buildings seeking certification by type of building by region by year	CaGBC LEED certifications and NRCan Energuide 80+ evaluations, and Energy Star and R-2000 certifications
$\#\ buildings\ constructed_{i,t}$	flow	Number of buildings under construction by type of building by region by year	Statistics Canada 34-10-0066-01, 34-10-0003, & 34-10-0135
$GDP_{r,t}$	$	GDP by region by year	Statistics Canada Supply and Use Tables 2010 to 2015, IBISWorld report 33232CA, Statistics Canada, NAICS 326196 Plastic windows and doors
$share_{energy}$	%	Share of building material value related to clean energy system, held constant at 67%	Judgmentally decided

Method for estimating investment by region *r* and year *t*, where *j* is the material (doors and windows, or insulation)

$$investment_{r,t} = \frac{\#\ certification\ applications_{r,t}}{\#\ buildings\ constructed_{r,t}} \times \left(investment_{r,t}\right) \times share_{energy}$$

$\#\ certification\ applications_{i,r,t}$	flow	Number of buildings seeking certification by type of building by region by year	CaGBC LEED certifications and NRCan Energuide 80+ evaluations, and Energy Star and R-2000 certifications
$\#\ buildings\ constructed_{i,t}$	flow	Number of buildings under construction by type of building by region by year	Statistics Canada 34-10-0066-01, 34-10-0003, & 34-10-0135
$investment_{r,t}$	$	investment by region by year	Statistics Canada Supply and Use Tables 2010 to 2015, IBISWorld report 33232CA, Statistics Canada, NAICS 326196 Plastic windows and doors
$share_{energy}$	%	Share of building material value related to clean energy system, held constant at 67%	Judgmentally decided

Method for estimating employment by region *r* and year *t*, where *j* is the material (doors and windows, or insulation)

$$employment_{r,t} = \frac{\#\ certification\ applications_{r,t}}{\#\ buildings\ constructed_{r,t}} \times \left(employment_{r,t}\right) \times share_{energy\ t}$$

$\#\ certification\ applications_{i,r,t}$	flow	Number of buildings seeking certification by type of building by region by year	CaGBC LEED certifications and NRCan Energuide 80+ evaluations, and Energy Star and R-2000 certifications

Energy-saving building materials			
$\#\ buildings\ constructed_{i,t}$	flow	Number of buildings under construction by type of building by region by year	Statistics Canada 34-10-0066-01, 34-10-0003, & 34-10-0135
$employment_{r,t}$	FTE	investment by region by year	Statistics Canada 14-10-0202-01, IBISWorld report 33232CA, Statistics Canada, NAICS 326196 Plastic windows and doors
$share_{energy}$	%	Share of building material value related to clean energy system, held constant at 67%	Judgmentally decided

Notes
We are assuming a one-to-one ratio between the share of buildings that are green and the share of energy-saving building material that counts as “clean”. This approach is imperfect since some non-green buildings could use energy-saving building materials.
We use shipments data, interpreted as revenue, from Statistics Canada, NAICS 326196 Plastic windows and doors to isolate economic contribution of plastic windows and doors from total data found in IBISWorld NAICS 326190 Other plastics product manufacturing in Canada.
We were unable to isolate insulation from the aggregated chemicals (e.g., polysterene foam, synthetic and artificial fibres) sections in Statistics Canada’s reporting.

Table 22: Heating, ventilation and air conditioning systems methods and data sources

Heating, ventilation and air conditioning systems

Overview

Data quality assessment: Tier 2	Covered NAICS codes: 33341 – Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing

Method for estimating manufacturing GDP by region *r* and year *t*

$$GDP_{r,t} = \frac{\#\, new\, efficient\, HVAC_t}{\#\, new\, total\, HVAC_t} \times \frac{GDP_{3334\, r,t}}{GDP_{3334\, t}} \times GDP_{33341\, t} \times share_{energy}$$

Parameter	Unit	Description	Source
$\#\, new\, efficient\, HVAC_t$	flow	Number of new efficient HVAC units purchased by year	Natural Resources Canada Comprehensive End-Use Data Tables
$\#\, new\, total\, HVAC_t$	flow	Total number of HVAC units purchased by year	Natural Resources Canada Comprehensive End-Use Data Tables
$GDP_{3334\, r,t}$	$	GDP for ventilation, heating, air-conditioning and commercial refrigeration systems by region by year	Supply and Use Tables 2010 to 2015
$GDP_{3334\, t}$	$	GDP for ventilation, heating, air-conditioning and commercial refrigeration systems in Canada by year	Supply and Use Tables 2010 to 2015
$GDP_{33341\, t}$	$	Total Canadian GDP for heating, ventilating, and air conditioning manufacturing in Canada	Supply and Use Tables 2010 to 2015, IBISWorld report 33341CA
$share_{energy}$	%	Share of HVAC value related to clean energy system, held constant at 50%	gTech modelling results

Method for estimating investment (i.e., including household consumption) by region *r* and year *t*

$$investment_{t,r} = \frac{\#\, new\, efficient\, HVAC_t}{\#\, new\, total\, HVAC_t} \times investment_{t,r} \times share_{energy}$$

Parameter	Unit	Description	Source
$\#\, new\, efficient\, HVAC_t$	flow	Number of new efficient HVAC units purchased by year	Natural Resources Canada Comprehensive End-Use Data Tables
$\#\, new\, total\, HVAC_t$	flow	Total number of HVAC units purchased by year	Natural Resources Canada Comprehensive End-Use Data Tables

Heating, ventilation and air conditioning systems

$investment_{t,r}$	$	Total Canadian purchase investment in heating, ventilating, and air conditioning in Canada by year by region	Supply and Use Tables 2010 to 2015, IBISWorld report 33341CA
$share_{energy}$	%	Share of HVAC value related to clean energy system, held constant at 50%	gTech modelling results

Method for estimating employment by region *r* and year *t*

$$employment_{t,r} = \frac{\#\ new\ efficient\ HVAC_t}{\#\ new\ total\ HVAC_t} \times \frac{wages\ and\ salaries_{3334\ t,r}}{wages\ and\ salaries_{3334\ t}} \times share_{energy} \times employment_t$$

Parameter	Unit	Description	Source
$\#\ new\ efficient\ HVAC_{t,r}$	flow	Number of new efficient HVAC units purchased by region by year	Natural Resources Canada Comprehensive End-Use Data Tables
$\#\ new\ total\ HVAC_{t,r}$	flow	Total number of HVAC units purchased by region by year	Natural Resources Canada Comprehensive End-Use Data Tables
$wages\ and\ salaries_{3334\ r,t}$	$	Wages and salaries for ventilation, heating, air-conditioning and commercial refrigeration systems by region by year	Supply and Use Tables 2010 to 2015
$wages\ and\ salaries_{3334\ t}$	$	Wages and salaries for ventilation, heating, air-conditioning and commercial refrigeration systems in Canada by year	Supply and Use Tables 2010 to 2015
$share_{energy}$	%	Share of HVAC value related to clean energy system, held constant at 50%	gTech modelling results
$employment_t$	FTE	Total employment in heating, ventilating, and air conditioning manufacturing in Canada by year	Statistics Canada 14-10-0202, Supply and Use Tables 2010 to 2015, IBISWorld report 33341CA

Validation

Ensure that calculated consumption does not exceed total investment made into HVAC systems.

Notes

We estimate the number of new HVAC equipment by building a stock turnover model using NRCan's data. Since the technologies stock is only available for heating equipment in the residential sector, we assume that the ratio of efficient to total space heating equipment is the same for residential and commercial. We also apply that ratio to space cooling equipment for both sectors. While we assume that all Canadian buildings are equipped with space heating, we use NRCan's survey data to determine what portion of buildings are fitted with space cooling systems.

We assume that there are four technologies considered to be efficient: heat pumps, electric baseboards, high efficiency natural gas boilers/furnaces, and high efficiency air conditioners. We assume two archetypes for each of the technologies, one for single-family homes and one for larger buildings including multi-unit residential, commercial and institutional.

Table 23: Building control systems methods and data sources

Building control systems	
Overview	
Data quality assessment:	Covered NAICS codes:
Tier 3	334512 – Measuring medical and controlling devices
Method for estimating GDP, investment and employment	
Survey of building control systems companies (e.g. Delta Controls, Reliable Controls etc.)	
Notes	
The survey did not yield sufficient information to make estimates for this sector.	

Table 24: High efficiency appliances methods and data sources

High efficiency appliances and auxiliary systems

Overview

Data quality assessment:	Covered NAICS codes:
Tier 2	3352 – Household appliance manufacturing

Method for estimating manufacturing GDP by region *r* and year *t*, where *i* is the appliance type

$$GDP_{t,r} = \left(\sum_{i=1}^{3} \frac{stock_{i,t}}{\sum_{i=1}^{3} stock_i} \times efficient\ portion_{i,t} \right) \times share_{energy} \times GDP_t$$

Parameter	Unit	Description	Source
$stock_{i,t}$	flow	Stock by appliance type by year	Natural Resources Canada Comprehensive End-use Database
$stock_t$	flow	Total stock of appliances by year	Natural Resources Canada Comprehensive End-use Database
$efficient\ portion_{i,t}$	%	Portion of efficient equipment by appliance by year	Natural Resources Canada Energy Consumption of Major Household Appliances Shipped in Canada Data
$share_{energy}$	%	Share of appliances value related to clean energy system, held constant at 50%	gTech modelling results
GDP_t	$	Manufacturing GDP for major household appliances by year	Supply and Use Tables 2010 to 2015, IBISWorld report 33522CA

Method for estimating investment (i.e., including household consumption) by region *r* and year *t*, where *i* is the appliance type

$$investment_{t,r} = \left(\sum_{i=1}^{3} \frac{stock_{i,t}}{\sum_{i=1}^{3} stock_i} \times efficient\ portion_{i,t} \right) \times share_{energy} \times investment_{t,r}$$

Parameter	Unit	Description	Source
$stock_{i,t}$	flow	Stock by appliance type by year	Natural Resources Canada Comprehensive End-use Database
$stock_t$	flow	Total stock of appliances by year	Natural Resources Canada Comprehensive End-use Database
$efficient\ portion_{i,t}$	%	Portion of efficient equipment by appliance by year	Natural Resources Canada Energy Consumption of Major Household Appliances Shipped in Canada Data
$share_{energy}$	%	Share of appliances value related to clean energy system, held constant at 50%	gTech modelling results

High efficiency appliances and auxiliary systems

$investment_{t,r}$	$	Purchase investment for major household appliances by region by year	Supply and Use Tables 2010 to 2015, IBISWorld report 33522CA

Method for estimating employment by region *r* and year *t*, where *i* is the appliance type

$$employment_{t,r} = \left(\sum_{i=1}^{3} \frac{stock_{i,t}}{\sum_{i=1}^{3} stock_i} \times efficient\ portion_{i,t}\right) \times \frac{wages\ and\ salaries_{3352\ t,r}}{wages\ and\ salaries_{3352\ t}} \times share_{energy} \times employment_t$$

Parameter	Unit	Description	Source
$stock_{i,t}$	flow	Stock by appliance type by year	Natural Resources Canada Comprehensive End-use Database
$stock_t$	flow	Total stock of appliances by year	Natural Resources Canada Comprehensive End-use Database
$efficient\ portion_{i,t}$	%	Portion of efficient equipment by appliance by year	Natural Resources Canada Energy Consumption of Major Household Appliances Shipped in Canada Data
$wages\ and\ salaries_{3352\ t,r}$	$	Wages and salaries for major household appliances by region by year	Statistics Canada Supply Use Table 2010 to 2015
$wages\ and\ salaries_{3352\ t}$	$	Wages and salaries for major appliances by year in Canada	Statistics Canada Supply Use Table 2010 to 2015
$share_{energy}$	%	Share of appliances value related to clean energy system, held constant at 50%	gTech modelling results
$employment_t$	FTE	Manufacturing employment for major household appliances by year	Statistics Canada 14-10-0202, IBISWorld report 33522CA

Notes

We were able to find reliable Energy Star data for refrigerators, dishwashers, and clothes washers. We assume that the weighted average portion applies to the other four major appliances including hot water heaters, clothes dryers, freezers, and cooking ranges.

We assume that the appliance market share is mature and saturated, therefore the breakdown of new sales by appliance is similar to the stock breakdown by appliance.

We assume that the share of energy efficient stock is the same whether produced in Canada or imported.

Table 25: Lighting systems methods and data sources

Lighting

Lighting

Overview

Data quality assessment:	Covered NAICS codes:
Tier 2	3351 – Electric lighting equipment manufacturing

Method for estimating manufacturing GDP by region *r* and year *t*

$$GDP_{r,t} = share\ efficient_{lighting\ t} \times share_{energy} \times GDP_t$$

Parameter	Unit	Description	Source
$share\ efficient_{lighting\ t}$	%	Efficient lights portion of total new market share by year	U.S. National Electrical Manufacturers Association
$share_{energy}$	%	Share of appliances value related to clean energy system, held constant at 50%	gTech modelling results
GDP_t	$	Canadian lighting manufacturing GDP by year	IBISWorld reports 33511CA and 33522CA

Method for estimating investment (i.e., including household consumption) by region *r* and year *t*

$$investment_{r,t} = share\ efficient_{lighting\ t} \times share_{energy} \times investment_{r,t}$$

Parameter	Unit	Description	Source
$share\ efficient_{lighting\ t}$	%	Efficient lights portion of total new market share by year	U.S. National Electrical Manufacturers Association
$share_{energy}$	%	Share of appliances value related to clean energy system, held constant at 50%	gTech modelling results
$investment_{r,t}$	$	Investment in lighting systems purchases by region by year	Statistics Canada Supply Use Tables 2010 to 2015

Method for estimating employment by region *r* and year *t*

$$employment_{r,t} = share\ efficient_{lighting\ t} \times \frac{wages\ and\ salaries_{3351\ r,t}}{wages\ and\ salaries_{3351\ t}} \times employment_t$$

Parameter	Unit	Description	Source
$share\ efficient_{lighting\ t}$	%	Efficient lights portion of total new market share by year	U.S. National Electrical Manufacturers Association
$wages\ and\ salaries_{3351\ r,t}$	$	Manufacturing wages and salaries of lighting systems by region by year	Statistics Canada Supply Use Tables 2010 to 2015
$wages\ and\ salaries_{3351\ t}$	$	Manufacturing wages and salaries of lighting systems by year	Statistics Canada Supply Use Tables 2010 to 2015

Lighting			
$share_{energy}$	%	Share of appliances value related to clean energy system, held constant at 50%	gTech modelling results
$employment_t$	FTE	Canadian lighting manufacturing employment by year	Statistics Canada 14-10-0202, IBISWorld reports 33511CA and 33522CA
Notes			
Includes light bulbs and lamp fixtures.			
We are assuming that U.S. efficient lighting data applies directly to Canada.			
The 2 types of lamps that are included as energy efficient are compact fluorescent lamps and LED lamps.			

Table 26: Professional energy services methods and data sources

Professional energy services	
Overview	
Data quality assessment: Tier 3	Covered NAICS codes: 541330 – Engineering Services; 541514 – Computer systems design and related services; 541690 – Other scientific and technical
Method for estimating GDP, investment and employment	
Survey of dedicated clean energy companies	
Notes	
The survey did not yield sufficient data for estimates to be made.	

Transport

Table 27: Electric vehicles methods and data sources

Electric vehicles and infrastructure

Overview

Data quality assessment: Tier 2	Covered NAICS codes: 336110 – Automobile and light-duty motor vehicle manufacturing 336120 – Heavy duty truck manufacturing 336990 – Other transportation equipment manufacturing

Method for estimating GDP by region *r* and year *t*, where *i* is the type of vehicle

$$GDP_{r,t} = \sum_{i=1}^{3} portion_{hybrid\ and\ electric\ i,t} \times GDP_{i,r,t}$$

Parameter	Unit	Description	Source
$portion_{hybrid\ and\ electric\ i,t}$	%	Portion of hybrid and electric vehicles sold by type of vehicle in year t in Canada	US AFDC hybrid vehicle sales, Statistics Canada Table 20-10-0002-01
$GDP_{i,r,t}$	$	GDP of vehicle manufacturing by type by region by year	IBISWorld 33611aCA with assumption that manufacturing only occurs in ON

Method for estimating investment (i.e., including household consumption) by region *r* and year *t*, where *i* is the type of vehicle

$$investment_{r,t} = \sum_{i=1}^{n} \#\ PEV\ sold_{i,r,t} \times MSRP_{i,t} + portion_{hybrid\ i,t} \times investment_{i,r,t}$$

Parameter	Unit	Description	Source
$\#\ PEV\ sold_{i,r,t}$	flow	Number of plug-in electric vehicles sold by model type by region by year	FleetCarma
$MSRP_{i,t}$	$/unit	Plug-in electric manufacturer suggested retail price by model type by year	Various websites
$portion_{hybrid\ i,t}$	%	Portion of hybrid vehicles sold by type of vehicle in year t in Canada	US AFDC hybrid vehicle sales, Statistics Canada Table 20-10-0002-01
$investment_{i,r,t}$	$	Investment in vehicle purchases by type by region by year	Supply and Use Tables 2010 to 2015

Method for estimating employment (i.e., including household consumption) by region *r* and year *t*, where *i* is the type of vehicle

Electric vehicles and infrastructure

$$employment_{r,t} = \sum_{i=1}^{3} portion_{hybrid\ and\ electric\ i,t} \times employment_{i,r,t}$$

Parameter	Unit	Description	Source
$portion_{hybrid\ and\ electric\ i,t}$	%	Portion of hybrid and electric vehicles sold by type of vehicle in year t in Canada	US AFDC hybrid vehicle sales, Statistics Canada Table 20-10-0002-01
$employment_{i,r,t}$	$	Employment in vehicle manufacturing by type by region by year	IBISWorld 33611aCA with assumption that manufacturing only occurs in ON

Validation

Ensure that residential consumption is reasonable when compared to household consumption of automobiles.

Notes

The three vehicle types are: light duty cars, light duty trucks, and medium/heavy-duty trucks.

Electric and hybrid bus manufacturing is captured under public transit and rail section vehicle manufacturing.

Tesla Model 3, Chrysler Pacifica PHEV are examples of plug-in electric vehicle model types.

The manufacturing GDP and employment associated with the Chyrsler Pacifica PHEV is not included since the vehicle’s sales are negligible compared to the total number of vehicles sold that are manufactured in Canada.

We assume that the portion of hybrid vehicles sold in the United States is the same in Canada.

We apply the portion of hybrid vehicles sold in the United States and Canada to estimate the portion of GDP, employment, and investment associated with the manufacture of hybrid vehicles.

Table 28: Electric vehicle infrastructure methods and data sources

Electric vehicle infrastructure

Overview

Data quality assessment:	Covered NAICS codes:
Tier 3	335990 – All other electrical equipment and component manufacturing

Method for estimating manufacturing GDP by region *r* and year *t*

Survey results.

Method for estimating investments by region *r* and year *t*, where *i* is the charger type

$$investment_{r,t} = survey\ results_{manufacturing} + \sum_{i=1}^{n} \#\ outlets_{i,r,t} \times estimated\ cost_i$$

Parameter	Unit	Description	Source
$survey\ results_{manufacturing\ i,t}$	$	Manufacturing portion of investment captured with survey	Canadian Clean Energy Economy Survey
$\#\ outlets_{i,r,t}$	flow	Number of outlets by type by region by year	Natural Resources Canada Electric Charging and Alternative Fuelling Stations Locator tool
$estimated\ cost_i$	$/unit	Estimated cost by type	Rocky Mountain Institute 2014 EV charging costs study

Method for estimating employment by region *r* and year *t*

Survey of dedicated clean energy companies.

Validation

Compare to the amount of investment made by governments dedicated to electric vehicle infrastructure.

Notes

The three charger types are level 1 (~1.4 kW charging), level 2 (~ 6.2 – 7.6 kW charging), and level 3 (~ 13.8 – 450 kW charging).

The survey did not yield sufficient information to make GDP and employment estimates.

Table 29: Hydrogen vehicles and infrastructure methods and data sources

<table>
<tr><th colspan="2">Hydrogen vehicles and infrastructure</th></tr>
<tr><td colspan="2">Overview</td></tr>
<tr><td>Data quality assessment:
Tier 3</td><td>Covered NAICS codes:
335990 – All other electrical equipment and component manufacturing
336110 – Automobile and light-duty motor vehicle manufacturing
336120 – Heavy-duty manufacturing
541710 – Research and development in the physical, engineering and life sciences</td></tr>
<tr><td colspan="2">Method for estimating GDP, investment and employment</td></tr>
<tr><td colspan="2">Survey of dedicated clean energy companies
Statistics Canada Table 27-10-0347-01 “Industrial energy research and development expenditures by area of technology, by industry group”</td></tr>
<tr><td colspan="2">Notes</td></tr>
<tr><td colspan="2">Research and development investment data is redacted for hydrogen transport due to confidentiality.</td></tr>
<tr><td colspan="2">The survey did not yield sufficient data to make estimates for this sector.</td></tr>
</table>

Table 30: Public transit and rail manufacturing methods and data sources

Public transit and rail manufacturing

Overview

Data quality assessment: Tier 1/2	Covered NAICS codes: 336120 – Heavy duty truck manufacturing 336211 – Motor vehicle body manufacturing 336510 – Railroad and rolling stock manufacturing

Method for estimating manufacturing GDP by region *r* and year *t*

$$GDP_{r,t} = GDP_{336510\ r,t} + (GDP_{336120\ r,t} + GDP_{336211\ r,t}) \times share_{buses}$$

Parameter	Unit	Description	Source
$GDP_{336510\ r,t}$	$	Railroad and rolling stock manufacturing GDP by region by year	Statistics Canada Supply Use Tables 2010 to 2015
$GDP_{336120\ r,t}$	$	Heavy-duty truck manufacturing GDP by region by year	Statistics Canada Supply Use Tables 2010 to 2015
$GDP_{336200\ r,t}$	$	Vehicle body manufacturing GDP by region by year	Statistics Canada Supply Use Tables 2010 to 2015
$share_{buses}$	%	Share of heavy-duty truck manufacturing and body manufacturing that is for buses	Statistics Canada Supply Use Tables 2010 to 2015, IBISWorld Report 33612CA

Method for estimating employment by region *r* and year *t*, where *i* is manufacturing type (heavy duty manufacturing, body manufacturing, and rail and rolling stock manufacturing)

$$employment_{r,t} = \sum_{i=1}^{3} employment_{NAICS\ i,t} \times \frac{wages\ and\ salaries_{NAICS\ i,r,t}}{wages\ and\ salaries_{NAICS\ i,t}} \times share_{transit\ i}$$

Parameter	Unit	Description	Source
$wages\ and\ salaries_{NAICS\ r,t}$	$	NAICS 336510, 336120, 336211 wages and salaries by region by year	Statistics Canada Supply Use Tables 2010 to 2015
$wages\ and\ salaries_{NAICS\ r,t}$	$	NAICS 336510, 336120, 336211 wages and salaries by year	Statistics Canada Supply Use Tables 2010 to 2015
$employment_{NAICS\ i,t}$	FTE	NAICS 336510, 336120, 336211 employment by activity by year	Statistics Canada Table 14-10-0202
$share_{transit\ i}$	%	share of vehicles manufactured that are transit or rail related by year	Statistics Canada Supply Use Tables 2010 to 2015, IBISWorld Report 33612CA

Notes

Assumes that buses account for a constant share of heavy-duty vehicle manufacturing from 2010 to 2018.

Public transit and rail manufacturing
Assumes that the ratio of products and services segmentation applies to GDP, investment, and employment.
No data could be found for manufacturing investments.

Table 31: Public transit and rail operation methods and data sources

Public transit and rail operation			
Overview			
Data quality assessment: Tier 2	Covered NAICS codes: 482113 – Mainline freight rail transportation 482114 – Passenger rail transportation 485110 – Urban transit systems		
Method for estimating GDP by region *r* and year *t*			
$GDP_{r,t} = GDP_{48211\ r,t} + GDP_{48511\ r,t}$			
Parameter	Unit	Description	Source
$GDP_{48211\ r,t}$	$	Rail transportation GDP by region by year	Statistics Canada Supply Use Tables 2010 to 2015, IBISWorld 48211CA
$GDP_{48511\ r,t}$	$	Urban transit systems GDP by region by year	Statistics Canada Supply Use Tables 2010 to 2015, IBISWorld 48511CA
Method for estimating manufacturing investment by region *r* and year *t*			
$investment_{r,t} = investment_{buses} + investment_{locomotives\ \&\ rolling\ stock} + investment_{rail\ lines}$			
Parameter	Unit	Description	Source
$investment_{buses}$	$	Investments in buses by region by year	Statistics Canada Infrastructure Economic Account, 2017
$investment_{locomotives\ \&\ rolling\ stock}$	$	Investments in locomotives and rolling stock	Statistics Canada Infrastructure Economic Account, 2017
$investment_{rail\ lines}$	$	Urban transit systems investment by region by year	Statistics Canada Infrastructure Economic Account, 2017
Method for estimating employment by region *r* and year *t*			
$employment_{r,t} = employment_{48211\ r,t} + employment_{48511\ r,t}$			
Parameter	Unit	Description	Source
$employment_{48211\ r,t}$	FTE	Rail transportation employment by region by year	Statistics Canada Table 36-10-0489-01
$employment_{48511\ r,t}$	FTE	Urban transit systems employment by region by year	Statistics Canada Table 36-10-0489-01
Notes			
Does not capture construction employment.			

Table 32: Non-motorized transport methods and data sources

Non-motorized transport	
Overview	
Data quality assessment: Tier 3	Covered NAICS codes: 336990 – Other transportation equipment manufacturing 339920 – Sporting and athletic goods manufacturing 532280 – All other consumer goods rental
Method for estimating GDP, investment and employment	
Survey of dedicated clean energy companies	
Validation	
Ensure that clean portion of non-motorized transport does not exceed overall non-motorized transport.	
Notes	
The survey did not yield sufficient information to make estimates for this sector.	

Industry

Table 33: Energy-saving and low carbon machinery methods and data sources

Energy-saving and low carbon machinery	
Overview	
Data quality assessment: Tier 3	Covered NAICS codes: 333130 – Mining and oil and gas field machinery manufacturing 332410 – Power boiler and heat exchanger manufacturing 333416 – Heating equipment and commercial refrigeration equipment manufacturing; 334512 – Measuring, medical and controlling devices manufacturing
Method for estimating GDP, investment and employment	
Survey of dedicated clean energy companies Statistics Canada Table 27-10-0347-01 “Industrial energy research and development expenditures by area of technology, by industry group”	
Notes	
The survey did not result in sufficient information to make estimates for this sector.	

Table 34: Industrial process change and emissions control methods and data sources

Industrial process change and emissions control

Industrial process change and emissions control	
Overview	
Data quality assessment: Tier 3	Covered NAICS codes: 334512 – Measuring, medical and controlling devices manufacturing
Method for estimating GDP, investment and employment	
Survey of dedicated clean energy companies Statistics Canada Table 27-10-0347-01 “Industrial energy research and development expenditures by area of technology, by industry group”	
Notes	
The survey did not result in sufficient information to make estimates for this sector.	
All CCS projects have been included in energy supply (leaving none for industry).	

Appendix B: Survey

Canadian Clean Energy Economy Survey

Welcome to the Canadian Clean Energy Economy Survey!

The survey should take 15 to 20 minutes to complete and is available until Wednesday, January 16 2019.

Please complete what you can and ensure to click submit on page 7. The more information we have, the better we are able to estimate the contribution of clean energy to Canada's economy.

For more information including response confidentiality and data privacy, please visit https://www.naviusresearch.com/ccee-survey.

For more information about Clean Energy Canada and Navius Research, please visit http://www.cleanenergycanada.org and https://www.naviusresearch.com

Contact information

1. Contact Name:

2. Email address:

3. Phone number:

4. I consent to being contacted by Navius regarding potential follow-up questions:

Mark only one oval.

○ Yes

○ No

Company Information

Please provide the following information about your company:

5. Company Name:

☐ Alberta
☐ British Columbia
☐ Manitoba
☐ New Brunswick
☐ Newfoundland and Labrador
☐ Northwest Territories
☐ Nova Scotia
☐ Nunavut
☐ Ontario
☐ Prince Edward Island
☐ Québec
☐ Saskatchewan
☐ Yukon

Optional additional comments

7. Please share any additional comments you have regarding information about your company:

Sector classification

The following information will help us attribute your company to the appropriate clean energy economy sector.

Manufacturers - If you are a manufacturer producing goods in Canada, please check all that apply.

8. Renewable energy equipment and fuel:

Check all that apply.

☐ Hydroelectric/tidal generation equipment
☐ Biomass/biogas power equipment
☐ Biomass fuel (e.g., pellets)
☐ Solar photovoltaic/thermal equipment
☐ Geothermal power generation equipment (excluding GSHP)
☐ Other:

9. **Grid infrastructure equipment:**

☐ Smart grid components

☐ Energy storage (including battery, fuel cells, compressed air, pumped hydro etc.)

☐ Transmission towers and components

☐ Other: ____________________

10. **Energy efficiency equipment for the built environment:**

Check all that apply.

☐ Building energy management controls, sensors, software and peripheral equipment

☐ Industrial energy management controls, sensors, software and peripheral equipment

☐ Insulated doors and windows

☐ Shell and wall insulation material

☐ Architectural metal sun shades (i.e., passive energy management)

☐ Other: ____________________

11. **Other clean energy equipment:**

Check all that apply.

☐ Methane leak detection and/or prevention equipment

☐ Electric vehicle supply equipment (EVSE)

☐ Electric vehicles or electric vehicle components

☐ Fuel cell vehicles or fuel cell vehicle components

☐ Other: ____________________

Service providers - If you are a service provider in Canada, check all that apply.

12. **Clean energy-related services:**

Check all that apply.

☐ Renewable energy services (excluding construction-related activities)

☐ Smart grid services

☐ Energy storage services

☐ Energy efficiency services for buildings (excluding design and construction-related activities)

☐ Energy efficiency services for industry

☐ Transport including electric charging network, bikeshare service provision, non-motorized and/or public transit consulting

☐ Methane leak detection and/or prevention services

☐ Other: ____________________

Multiple activities - If you are engaged in multiple activities, please tell us what share of your company's overall activity these represent.

13. Please be as specific as you can (e.g. smart grid components manufacturing - 30% of revenue, energy storage equipment manufacturing - 20% of revenue, and 50% unrelated):

Optional additional comments

14. Please share any additional comments you have regarding sector classification:

Employment

The following information will help us determine the number of people employed by the Canadian clean energy economy.

How many people did you employ in Canada:

15. in the most recent year to date?

16. in 2015?

17. in 2010?

Optional additional comments

18. Please share any additional comments you have regarding employment:

Investment

The following information will help us assess the amount of investment made in the Canadian clean energy economy.

If you would like to provide precise numbers please check the "Other" option and enter them there.

What is the value of investment made by your company (e.g., in expanding production capacity, physical or digital infrastructure, educating your workforce, etc.):

19. in the most recent year to date?

Check all that apply.

☐ $0 to $50k
☐ $50k to $100k
☐ $100k to $500k
☐ $500k to $1m
☐ $1m to $5m
☐ $5m +
☐ Other: ____________________

20. in 2015?

Check all that apply.

☐ $0 to $50k
☐ $50k to $100k
☐ $100k to $500k
☐ $500k to $1m
☐ $1m to $5m
☐ $5m +
☐ Other: ____________________

21. in 2010?

☐ $0 to $50k
☐ $50k to $100k
☐ $100k to $500k
☐ $500k to $1m
☐ $1m to $5m
☐ $5m
☐ Other: ____________________

Optional additional comments

22. Please share any additional comments you have regarding investment:

____
____
____
____
____

Gross domestic product

This information is to help us estimate total Canadian economic activity for the clean energy sector in which you operate.

If you would like to provide precise numbers please check the "Other" option and enter them there.

Please state your company's annual income (gross revenue):

23. in the most recent year to date?

Check all that apply.

☐ $0 to $100k
☐ $100k to $500k
☐ $500k to $1m
☐ $1m to $5m
☐ $5m to $10m
☐ $10m +
☐ Other: ____________________

24. **in 2015?**

24. in 2015?

- ☐ $0 to $100k
- ☐ $100k to $500k
- ☐ $500k to $1m
- ☐ $1m to $5m
- ☐ $5m to $10m
- ☐ $10m +
- ☐ Other: ____________________

25. in 2010?

Check all that apply.

- ☐ $0 to $100k
- ☐ $100k to $500k
- ☐ $500k to $1m
- ☐ $1m to $5m
- ☐ $5m to $10m
- ☐ $10m +
- ☐ Other: ____________________

Please state total subsidies received from government:

26. in the most recent year to date?

Check all that apply.

- ☐ None
- ☐ $0 to $50k
- ☐ $50k to $100k
- ☐ $100k to $250k
- ☐ $250k to $500k
- ☐ $500k to $1m
- ☐ $1m +
- ☐ Other: ____________________

27. in 2015?

- ☐ None
- ☐ $0 to $50k
- ☐ $50k to $100k
- ☐ $100k to $250k
- ☐ $250k to $500k
- ☐ $500k to $1m
- ☐ $1m +
- ☐ Other: ____________________

28. in 2010?
Check all that apply.

- ☐ None
- ☐ $0 to $50k
- ☐ $50k to $100k
- ☐ $100k to $250k
- ☐ $250k to $500k
- ☐ $500k to $1m
- ☐ $1m +
- ☐ Other: ____________________

Please state your company's expenditures on intermediate goods and services (i.e., cost of goods and services required to generate revenue, not including employment or taxes):

29. in the most recent year to date?
Check all that apply.

- ☐ $0 to $100k
- ☐ $100k to $500k
- ☐ $500k to $1m
- ☐ $1m to $5m
- ☐ $5m to $10m
- ☐ $10m +
- ☐ Other: ____________________

30. **in 2015?**

30. in 2015?

- ☐ $0 to $100k
- ☐ $100k to $500k
- ☐ $500k to $1m
- ☐ $1m to $5m
- ☐ $5m to $10m
- ☐ $10m +
- ☐ Other: ______________________

31. in 2010?

Check all that apply.

- ☐ $0 to $100k
- ☐ $100k to $500k
- ☐ $500k to $1m
- ☐ $1m to $5m
- ☐ $5m to $10m
- ☐ $10m +
- ☐ Other: ______________________

Please state your company's expenditures on employment costs including wages, salaries and benefit contributions:

32. in the most recent year to date?

Check all that apply.

- ☐ $0 to $100k
- ☐ $100k to $500k
- ☐ $500k to $1m
- ☐ $1m to $5m
- ☐ $5m to $10m
- ☐ $10m +
- ☐ Other: ______________________

33. in 2015?

☐ $0 to $100k
☐ $100k to $500k
☐ $500k to $1m
☐ $1m to $5m
☐ $5m to $10m
☐ $10m +
☐ Other: ____________________

34. in 2010?

Check all that apply.

☐ $0 to $100k
☐ $100k to $500k
☐ $500k to $1m
☐ $1m to $5m
☐ $5m to $10m
☐ $10m +
☐ Other: ____________________

Please state the total taxes paid to government:

35. in the most recent year to date?

Check all that apply.

☐ $0 to $50k
☐ $50k to $100k
☐ $100k to $250k
☐ $250k to $500k
☐ $500k to $1m
☐ $1m +
☐ Other: ____________________

36. **in 2015?**

36. in 2015?

- ☐ $0 to $50k
- ☐ $50k to $100k
- ☐ $100k to $250k
- ☐ $250k to $500k
- ☐ $500k to $1m
- ☐ $1m +
- ☐ Other: ____________________

37. in 2010?

Check all that apply.

- ☐ $0 to $50k
- ☐ $50k to $100k
- ☐ $100k to $250k
- ☐ $250k to $500k
- ☐ $500k to $1m
- ☐ $1m +
- ☐ Other: ____________________

Please state your company's profits before tax:

38. in the most recent year to date?

Check all that apply.

- ☐ No profits
- ☐ $0 to $50k
- ☐ $50k to $100k
- ☐ $100k to $250k
- ☐ $250k to $500k
- ☐ $500k to $1m
- ☐ $1m +
- ☐ Other: ____________________

☐ No profits
☐ $0 to $50k
☐ $50k to $100k
☐ $100k to $250k
☐ $250k to $500k
☐ $500k to $1m
☐ $1m +
☐ Other: ____________________

40. in 2010?
Check all that apply.

☐ No profits
☐ $0 to $50k
☐ $50k to $100k
☐ $100k to $250k
☐ $250k to $500k
☐ $500k to $1m
☐ $1m +
☐ Other: ____________________

Optional additional comments

41. Please share any additional comments you have regarding your contribution to the gross domestic product:

____
____
____
____
____

Acknowledgement consent and submission page

42. We will be recognizing your contribution by adding your company to a list of acknowledged entities in the report. Should you choose to opt out, please check the box below.
Check all that apply.

☐ Opt out.

43. Please share any other comments you have below and click submit to complete the survey:

Appendix C: Modeling methods

3.4. Introduction to gTech

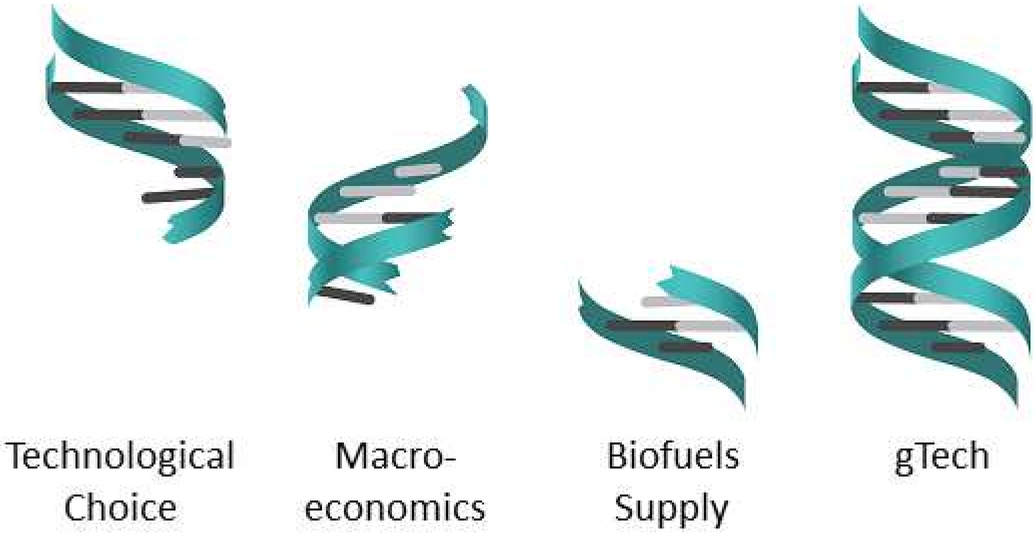
The gTech model is designed to simulate the impacts of government policy and economic conditions on both technological adoption and the broader economy. It simultaneously combines an explicit representation of technologies (everything from vehicles to fridges to ways of getting oil out of the ground) 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 21: 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 35 summarizes key factors that influence technological choice and the extent to which these factors are included in gTech.

Table 35: 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.[34] 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.[35] gTech quantifies these technology-specific preferences as "non-financial" costs, which are added to the technology choice algorithm.

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

[35] 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[36]. 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[37]. 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.

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

[37] 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 36.

Table 36: 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[38]. 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 3.5 “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.

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[38] 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?

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

3.5.1. 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

3.5.2. 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

3.5.3. 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)

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